USING INFORMATION PROCESSING THEORY TO DESIGN AN UNDERGRADUATE PRACTICAL COURSE IN CHEMISTRY

BY

JOSE FRANCISCO VIANNA

A thesis submitted in part fulfilment of the requirements for the degree of Doctor of Philosophy of the University of Glasgow.

CENTRE FOR SCIENCE EDUCATION, November 1991

ABSTRACT

This thesis describes a study of practical work in a first year undergraduate laboratory. In a conventional laboratory course, there are many variables that influence the students' learning. These include the recall of theoretical concepts and acquired skills, learning of new concepts and skills, following and interpreting the experimental procedures, making observations, and the organisation of the laboratory. To all this is added the data and information generated by the experiment.

Under these conditions there is a possibility of overloading students' working memory leading them to follow the experimental procedures with little or no understanding of what they are doing or why.

This survey, spread over a period of three years (1988-90) and five different laboratory courses, was formulated and developed within the context of Information Processing Theory.

In the FIRST YEAR (1988) a diagnostic study was done with the purpose of identifying the various factors which lead students to a state of working memory overload affecting the efficiency of learning.

In the SECOND YEAR (1989) four versions of laboratory course were designed with one change of variable in each. The variables selected for control were: the nature of the written instructions, the method of teaching manipulative skills, the use of a Prelab exercise, and the use of Mini-Projects.

Written Instruction and Laboratory Techniques Session were designed to reduce the number of information to be processed by the students at once. This was intended to allow the students to use their potential working memory space for processing the information gathered from the experiments.

The Prelab Work was introduced to improve the students' perception of the tasks by building upon existing understanding and making it ready available for recall (meaningful learning). Once the techniques and experimental content are mastered, students are free to use all their working memory space to solve practical problems (Mini-Projects). The students are not given a "recipe" or instruction to follow - and so they must think for themselves within the context of knowledge and understanding they have already mastered.

In the THIRD YEAR (1990) the fifth version of the laboratory course was designed with four stages which gradually introduced to the students in the following sequence: Firstly the laboratory techniques training; secondly the pre-laboratory exercise; thirdly close-ended experiments; and finally the Mini-Projects.

Recommendations and suggestions for further work have been proposed to extend this piece of research in order to improve practical work in chemistry in general.

CONTENTS

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to Dr. R.J. Sleet for his encouragement and indispensable critical insights in the design and or planning of the surveys used in this thesis. Professor A.H. Johnstone for his supervision and advice during the research period. I would also like to thank Dr. K.C. Campbell for his support and participation in the laboratory and discussion of the materials we introduced.

I am also grateful for the cooperation of the demonstrators and technicians who guaranteed the smooth running of the laboratory over the study period. Finally I thank the first year students without who this study would have been impossible.

I am grateful to the Coordenadoria de Aperfeicoamento de Pessoal de Nivel Superior - CAPES - BRAZILIAN EDUCATION MINISTRY and UNIVERSIDADE FEDERAL DE MATO GROSSO DO SUL- UFMS (BRAZIL) for their financial support.

Finally , I would like to thank my colleagues at the Centre for Science, Glasgow University , for their friendship and support and , last but not least, my family (here and in Brazil) for their patience and support over the past years.

INTRODUCTION

The importance of practical work in chemistry courses is generally agreed upon by chemistry teachers and field researchers despite some disagreement concerning the role of the laboratory course, its objectives and effectiveness.

Mainly due to the many different factors which affect the students in practical work situations, this area is viewed as one of great difficulty by researchers. The students have to cope with many types of learning stimuli that may lead to a state of "working memory" overload. So, it is not surprising that many of the attempts made to measure the learning outcomes from practical work have produced disappointing results.

Many researchers have recorded that students perceive practical work as boring and a waste of time - students following experimental procedures like a recipe without thinking about what they are doing and why they are doing it.

At the Centre for Science Education, Glasgow University, two surveys have been carried out, prior to this work, to attempt to improve this particular area of chemistry teaching.

In 1977, Alasdair J. B. Wham[1] developed and tested a two-stage model of laboratory instruction for the undergraduate laboratory. In the first stage, called the "Learning" stage, the emphasis was placed on learning and practice of techniques. The second stage, called the "experience" stage, the emphasis was on giving the students a chance to work on their own. Wham also devised a teaching package for lab techniques and theoretical pre-laboratory exercises to increase the effectiveness of the learning stage.

In 1987, Kirsty M. Letton[2] carried out a study with the objective of finding the factors which affect the efficiency of learning in a second year undergraduate laboratory. Letton suggested that the written instructions should be redesigned in an attempt to reduce the distractions ("noise") which have the effect of obscuring the purpose of the laboratory. She also recommended that the management of the laboratory should be efficient and a map indicating the location of chemicals, equipment and apparatus should be included in the manual, with the most relevant skills being taught separately - before the students attempt to do the actual experiments.

Our survey was carried out with five classes of first year undergraduates in practical inorganic chemistry and it was spread over a period of three years (1988, 1989, and 1990).

The psychological background guiding our thinking throughout has been derived from Information Processing Theory. This theory divides the cognitive system into components and the model it provides attempts to identify what happens during the acquisition, storage, and retrieval stages of learning.

Special consideration was given to student perception, the ever present possibility of working memory overload and the necessity for students to construct for themselves sound and branched mental structures to help them to approach practical bench problems by lateral thinking.

In the FIRST YEAR (1988) a diagnostic survey was carried out in an attempt to find the problems of the first year practical course. In this preliminary survey, four points were under scrutiny: (i) organisation of the lab; (ii) laboratory manual; (iii) the use of practical problem; and (iv) student attitude to practical work.

In the SECOND YEAR (1989), results of the preliminary survey were used to redesign the first year laboratory course and sought to deal with the Working Memory Overload.

First the lab manual was written to improve the layout, remove distracting and irritating "noise" (unimportant information) and allow the students to focus on the "signal"(essential information) that the laboratory was intended to convey. Illustrated instructions for laboratory techniques were introduced to support the training session at the beginning of the lab course.

The Written Instruction was redesigned as an attempt to filter out the "signal" from "noise" and allow the students to use all potential Working Memory space for processing experimental information.

A Laboratory Techniques Session, supported by illustrated written instructions, was introduced to allow students to gain the experience necessary in the laboratory's techniques involved in the experiment. Students were encouraged to practise the techniques until they had mastered them, i.e., doing them automatically, without thinking about the next step.

Secondly, four versions of the laboratory course were designed in which one factor at a time was changed. The variables selected to be controlled were: the nature of the laboratory manual, the introduction of lab techniques, the use of a Prelab exercise, and the introduction of Mini-Projects. All four laboratory courses had from the outset a training session in basic laboratory techniques.

COURSE ONE (CONTROL) used the Improved Lab Manual which had been written to avoid "overload" in its layout and language. This course was run in two phases: (i) training in lab techniques; and (ii) experiments taken directly from the manual "learning stage". COURSE ONE was the CONTROL group of our research being the course with lowest number of stages.

COURSE TWO (PLW) used the Improved Lab Manual with Prelab exercises designed to familiarise students with the theoretical background and to involve them in necessary pre-requisite calculations and decisions. This version had three stages: (i) Prelab Work to be done before the lab session; (ii) laboratory techniques training; and (iii) experiments from the manual (learning stage).

The Prelab Work was introduced to improve the students' perception of the tasks - the theory being that the information is filtered in the sensory stage, processed and linked to existing understanding in the Working Memory before being stored in the Long Term Memory (LTM) and made available for recall.

COURSE THREE (MP) used the Improved Lab Manual but it introduced Mini-Projects at the end of each experiment to give the students a chance to design their own experiment and apply the skills of the "learning stage." This version had three stages: (i) laboratory techniques training; (ii) experiment from the manual; and (iii) practical problem at the end of the experiment.

Once the techniques and the experimental content is well mastered, the Mini-Project is introduced to put the students in the position of having to select for themselves relevant from irrelevant information utilising the information stored elsewhere in the Long Term Memory in order to decide what is relevant or not.

COURSE FOUR (P&P) used the Improved Lab Manual with Prelab Work, so it involved both the PRELAB WORK of COURSE TWO and the Mini-Projects from COURSE THREE. In this version all the factors were put together and the course had four stages: (i) Prelab work; (ii) lab techniques training; (iii) experiments from the manual; and (iv) Mini-Projects.

COURSE FIVE (PMP) was introduced in the THIRD and LAST YEAR of the survey. Some changes in COURSE FOUR had been made to take into account the results obtained in the previous survey: (i) Mini-Projects were introduced at the end of the course instead of at the end of each experiment; and (ii) the Mini-Projects replaced two experiments from the learning stage.

Each version was tried on 100 students and several types of measurement were carried out to evaluate and compare the efficacy of course design. Instruments were devised to find out the opinion of students and demonstrators as well as changes in students' attitudes.

CHAPTER 1

LITERATURE SURVEY

1 - ORIGINS AND DEVELOPMENT OF LABORATORY INSTRUCTION

From the beginning of the formal teaching of chemistry there were only lectures by the teachers and it was only during the eighteenth century that some practical chemistry was introduced to lectures as demonstration.

The teaching of chemistry with laboratory practise by the students began at the turn of the nineteenth-century. In Paris (France), the Ecole Polytechnique, offered laboratory instruction from 1795[3]. In Germany, at the University of Gottingen, a practical course was introduced in 1806 by Friedrich Stromeyer who believed that chemistry could only really be learned through laboratory practise and that the students must be given an opportunity to carry out analyses on their own[4].

In 1808 Berzelius had opened a teaching laboratory for a few students at the Collegium Medicum in Stockholm, though it was his own private laboratory, first situated in Hisinger's house and then in the Swedish Academy of Sciences, which his more famous pupils attended[3].

Liebig's chemistry laboratory, opened in 1824 at the University of Giessen, was a crucial event in the history of nineteenth-century science. It was the first institutional laboratory in which students experienced systematic preparation for chemical research, and in which they were deliberately trained for membership of a highly effective research school[3].

The success of Liebig's laboratory may be better judged by looking to the number of well-known students who worked and got their doctoral qualification there. According to Morrell[3] by the 1850's 11 out of 30 of Liebig's British former pupils occupied most of the important chairs and posts available in British University chemistry.

Liebig's guiding principle was that: "Experiment is only an aid to thought ... which ... must always and necessarily precede it if it is to have any meaning. An empirical mode of research, in the usual sense of the term does not exist. <u>An experiment not preceded by theory</u>, i.e., <u>by an idea, bears the same relation to scientific research as a child's rattle does to music</u>."[5]

In the United State the first laboratory instruction in chemistry is credited to Willian James MacNeven who was professor of chemistry in the College of

Physicians and Surgeons of New York during the period 1810 to 1826. It is, perhaps, the first laboratory in which students had an opportunity to practise the techniques, processes and procedures of chemistry[6].

In Britain the first laboratory is credited to Thomas Thomson who introduced it to Edinburgh University in 1807 and then to Glasgow University in 1819[4]. At Glasgow University, Thomson took up a university teaching post and tried to create a research school based on his teaching laboratory[3].

However, credit for the growth of practical work is accorded to Edward Frankland, a graduate of Liebig's laboratory, who, throughout his life did much to encourage the introduction of laboratory instruction. Largely due to his efforts, by 1876 there were one hundred and fifteen laboratories in operation in Britain, most giving very elementary instruction[4].

It was at the turn of the nineteenth-century that laboratory-based methods of teaching achieved its most rapid growth associated with the growth of research schools in chemistry. So it was that, individual practical work was accepted as an essential part of University Chemistry courses. Until then, Laboratory Instruction had been an isolated activity with little support: some of it private instead of institutional and outwith the curriculum, i.e., it was not compulsory.

Practical work at this time filled a largely supportive role, that of confirming the theory which had already been taught in lectures. The experimental procedures were printed along with details in the text book, and any help required during this period was given by fully-trained staff[3]. It was during this period too, however, that doubts started to arise about the efficacy of teaching through individual practical work in chemistry - doubts which grew from then until the Second World War[7].

In the first three decades of this century several investigations comparing individual laboratory instruction with the demonstration method were published. Adams[8] reported that during this period the literature recorded some 50 studies related to individual versus demonstration laboratories. Of these, 45 were applied to high school and five to college classes; 23 dealt with chemistry instruction; 7 investigations of the debate were conducted by means of questionnaires, and 13 were reviews of findings of previous investigations. Fourteen papers expressed the opinions of the authors on the relative merits of the individual laboratory versus the demonstration method.

The consequence of the debate into aims and styles of laboratory instructions was a production of a large list of advantages and disadvantages of both methods.

Those who were against the individual method of laboratory instruction, argued that it was a waste of time and money and concluded that they were used inefficiently in the laboratory. Hunt[9] argued that demonstrations could be done in 5-40% of the time required for individual labs and students would be less likely to be victims of overzealous instructors who required them to stay after hours and do extra experiment. Demonstration methods would also make more efficient use of faculty time, not only because they required more concentrated effort but also because the teacher who tended to neglect laboratory supervision would be forced to take on a more active role.

The demonstration method, Hunt maintained, offered the advantages of keeping the entire class together and preventing poor students from becoming discouraged. It also offered students a greater opportunity to think because instructors could call attention to every point and ensure that certain principles would not be overlooked. Demonstrations thus exposed students to a broader experience of chemistry by introducing them to methods, apparatus, compounds, and uses of chemistry which could only be accomplished by spending long hours in the laboratory over one experiment[9].

Supporters of the demonstrations' method also contended that most laboratory manuals of the day were quite useless as far as the scientific method was concerned; yet many students gave evidence of their genuine interest in science through their thoughtfully and independently written notebooks[9].

The arguments used by those who supported individual laboratory instruction were that it facilitated the learning and retention of chemical facts and principles discussed in the classroom by providing contact with actual materials[10]. It was further suggested that individual practical work gave the students some basic insight into elementary laboratory method and left them with a feeling of the reality of science thus increasing their interest and enthusiasm, resulting in increased enrollment for chemistry courses.

All sorts of arguments, including economic, educational and philosophical ones, have been used for or against both methods[11]. These arguments tend to favour demonstrations over individual methods. Garret and Roberts[12] argued that most of the studies done in this period failed to report vital information, such as, sample size, sampling techniques employed, and suffered from the researchers inability to recognise the need to subject their findings to any statistical treatment. In the 1930's and 40's there was a marked improvement in the use of statistics, with standard tests to pre-test students then used for group comparison etc. In this period the number of studies that show the superiority of demonstration over small group work is less clear than in the former one.

After the Second World War a movement to reexamine laboratory work objectives was started. Before the war, chemistry had been taught with primary emphasis on knowledge objectives which gradually shifted to a greater concern for process, attitude and interest, and cultural awareness objectives[13].

The physicist, Owen[14], stated that the normal experiment provided too much information for the students and was too abstract, i.e., beyond the students' normal experience. He proposed that not all experiments should be designed to develop scientific method but those which were should give the minimum of information and let the students find out for themselves. The experiments, he said, should allow the students to formulate questions, recognise assumptions, apply general principles, interpret data, and make and test hypotheses. Mallison and Buck[15] further argued that there was no critical thinking done in the laboratory, merely "cookbook" manipulations where students followed a printed list of instructions.

And so it was that, in this post war period the discussion moved from the two forms of practical work to a greater concern for the objectives of laboratory instruction.

However in the 1960's there occurred a major shift in the emphasis of educational research towards problems associated with curriculum development. The CBA and CHEM Study in the USA, the Scottish Alternative Syllabus and the Nuffield and School Council courses in the U.K., as well as the ASEP in Australia, signalled the end of a long period of stability in the school chemistry curriculum.

The "new" science curriculum of the 60's resulted in several changes in the role of traditional laboratory work. The curriculum stressed the processes of science and place emphasis upon the development of higher cognitive skills. Laboratory work acquired a central role as the core of the science learning process, not just a place for demonstration or confirmation. It was thought that the laboratory ought to provide students with opportunities to engage in the processes of investigation and enquiry[16].

For instance, Young[17] proposed that laboratory work should be more than manipulation of apparatus. He argued that there was a failure to find out what students were getting from practical work. He thought it valid to present the students with a detailed experimental plan to work through, to teach principles and techniques. However, he maintained, from the first year onwards this method should be supplemented by an approach that allowed students to make their own investigations.

Over the years many researchers who recognised the existence of problems in laboratory teaching had attempted to redesign their courses; putting forward hybrid schemes involving various degrees of student participation and concentrating on one particular aspect of this. For example, the "Art of Observation" was emphasised by Swinehart[18]; "Chemical Measurement" by Atkinson[19]. Methods of class participation - where the students were more actively involved by being asked to do things for themselves. From then on students would be encouraged to acquire specific skills in order to answer questions which they posed in the laboratory[17].

The literature reported a number of courses where the students were given greater freedom after initial instruction in basic techniques[20,21,22]. Therefore, these courses ran with fairly low student numbers and involved standard experiments and experimental procedures in the introduction to the course.

A less structured course was reported by Newman and Gassman[22]. They devised it for chemistry majors and allowed students to plan their own experiments based on objectives which were discussed in laboratory lectures - in an attempt to develop a research atmosphere. The laboratory techniques were taught as required. Their evaluation of the courses with open-ended experiments showed that students expressed positive enjoyment and exhibited a truer reflection of their ability and potential. The students were able to undertake original research successfully and also developed the qualities of independence and motivation. However, their enjoyment was closely related to their interest in the subject, independence, and need for guidance.

The influence of open-ended experiments led to the development of more integrated courses based on modules which consisted of techniques grouped on a natural or essentially non-classical basis, e.g., the syntheses of an inorganic compound would be followed with characterisation by appropriate physical method and by measurement of its reactivity[23].

The integrated programme consisted of several laboratory courses following the freshman year. In order to assist students to carry out their laboratory work, each laboratory session began with a discussion of techniques, and an elaboration of the principles involved in the experiment. This approach was intended to help students to realise that chemistry was a single discipline in which organic, inorganic, etc., are interrelated and interlocking parts.

Cochran et al.[24] asserted that the experiments should be organised by level of sophistication and include various topics and techniques in chemistry. Initially students were not completely free to choose their experiments and had to take certain basic experiments, but beyond that they could choose any of the listed experiments. Research problems could also be integrated in the scheme, and in these experiments, students could participate in ongoing research projects conducted by a faculty member. Supporters of this approach claim that enthusiasm was generated among the students and staff because of the individuality of each programme and the research nature of the high-level experiments which imparted a degree of realism.

However by the 1970's the laboratory teaching was beset by "inquiry-discovery" methods and "problem-solving" approaches, in the belief that students could discover for themselves much of what was previously given in lectures.

Laboratory courses in this period emphasised that students should learn how to deal with systems as they actually behave in the real world, in contrast to the 'ideal' behaviour normally portrayed in lectures. Aikens[25] suggested a unified laboratory programme where the students received instructions about experimental techniques, experimental procedures, evaluation of results; planning, design and executing laboratory projects that required a significant degree of judgement.

Hodson[26] argued that students needed a prior conceptual framework to be able to discovery anything. He propounded that discovery methods could legitimately investigate the relationships between concepts, but they cannot lead to the formation of new concepts.

There was also an increasing number of researchers applying computers in laboratory simulations and audio-visual technologies as an alternative method of laboratory instructions in the seventies[27].

Wade[28] argued that for students, the goal of practical work with detailed experimental procedures was to follow the prescribed procedure as carefully and as closely as possible to achieve the optimum result. So he suggested a practical course without a "cookbook": instead students were provided with background material on the techniques and synthetic methods that might be useful.

Venkatachelam and Rudolph[29] proposed a learning/challenge cycle of laboratory work in which the learning stage was followed by a challenge stage. In the learning stage the students were given background reading material in the manual, and a bibliography for the more motivated students, which familiarised them with techniques and equipment. After completing the learning cycle the students were given the challenge cycle mainly comprising of variations of the "cookbook" laboratory experiment, phrased in terms of open-ended questions.

Following on from this work, Johnstone and Wham[30] argued that it is necessary to practise in a systematic manner, the skills of personal decision, experiment planning, self criticism, evaluation of errors and overcoming practical problems. To achieve this they suggested the use of Mini-Projects, i.e., small open-ended exercises at any level with the minimum of instruction and the maximum of freedom within the limitations of the present state of the student's knowledge with the objective of reinforcing the learnt skills.

In addition, Pickering[31] argued that puzzle labs of project-type could provide much more opportunity for creativity and therefore were likely to be more successful in the task of laboratory teaching.

Today there is a trend towards education about science, its relevance to society and to the environment and away from education in science. It is advocated that the idea of the pursuit of science for the sake of knowledge be abandoned to give way to growing concerns about social, political and technological issues[26].

2 - PRACTICAL WORK OBJECTIVES

The important aims and objectives of practical work had been stressed from as far back as the early nineteenth century and special attention to this has been given in the post war period by teachers and researchers. The need is recognised for a list of practical objectives to help laboratory teachers to think clearly about their intentions and to ensure that all important goals of the course have been pursued. Also there is a consensus about the need for a list of aims or objectives in order to be able to assess practical work.

Kempa[32] argued that if the components of experimental work in science are to be satisfactorily assessed, it is necessary to evolve at least some broad qualities with reference to which students' performance can be judged.

Mainly due to the many different ways in which the aims and objectives of practical work can be formulated, there exists a substantial lack of clarity of purpose in this area. The literature shows a wide number of attempts to specify the desirable outcomes of practical work[33,34,35,36,32].

Swain[33], in a review of the literature on practical objectives in school chemistry, pointed out that:

i the authors differ on what they think to be "desirable" practical objectives;

ii there is often no detailed breakdown of objectives and vague titles are predominant;

iii pupils' attitudes to practical work are neglected.

He attempted to produce a list of objectives desired directly from the practical situation and analysis of the experiment itself. The resulting objectives were, however, based upon those given by previous authors and sometimes modified to produce a new list. Moreover, he proposed three main areas for consideration:

i The road to the experiment - consisting of comprehension of purpose, planning and set-up of the experiment;

ii The experiment - consisting of performing manipulation, observation and recording.

iii The conclusions of the experiment - consisting of analysis, interpretation, organisation and evaluation of results, and presentation of report.

Johnstone and Wood[27] examined practical work in secondary schools from the view of teachers and of pupils and showed that practical work should not only be used for theory illustration but should stand on its own as part of the chemistry course, with its own objectives.

Shulman and Tamir[34] proposed a classification of goals for laboratory instruction in science education as follows:

i To arouse and maintain interest, attitude, satisfaction, open mindedness and curiosity in science;

ii To develop creative thinking and problem solving ability;

iii To promote aspects of scientific thinking and the scientific method

iv To develop conceptual understanding and intellectual ability; and

v To develop practical abilities

More detailed list of objectives for biology, chemistry and physics were elaborated by Hellingman (1982)[35]. He hoped that the list of objectives would be used as a comprehensive list from which items would be chosen in accordance with the particular requirements of each course and situation. The objectives were described as 'abilities' required for practical work in chemistry as follows:

i Preparation for an experiment - which consisted of formulating a research question, planning and handling sources of information;

ii Performing the experiment - which consisted of performing manipulations, observation, making notes and repeat or supplementary activities;

iii Elaboration of the observations - which consisted of working out measurement and interpreting data;

iv Accounting for activities and results - which consisted of investigating reliability and validity of conclusions, offering explanations and suggestions and repeating the experiment if necessary.

Kempa[32] described the process of practical work in five stages which are now widely recognised as forming a valid and satisfactory framework within which practical skills are to be developed and assessed. The five stages are:

i recognition and formulation of the problem;

ii planning and design of an investigation in which the student predicts the results, formulates hypotheses and designs procedures;

iii carrying out the experiments in which the student make decisions about investigative techniques and manipulates materials and equipment;

iv observational and measuring skills; and

v analysis, application and explanation in which the student processes data, discusses results, explores relationships, and formulates new questions and problems.

The objectives of practical work are almost synonymous with those defined for science courses in general and there is a need to define goals for the areas in which laboratory work makes a significant contribution and to capitalize on the uniqueness of this mode of instruction[16].

Kempa[32] pointed out that only two out of five stages, setting-up the experiment and conducting of measurements and observations, are genuinely practical in nature, in that they involve handling of chemicals and apparatus. The other activities have a strong theoretical orientation and although they form an integral part of experimental work, they do not involve or depend upon the exercise of manipulative and observational skills.

Whittaker[37] explains, that "The integration of practical work with the factual and theoretical basis of a subject and the development of courses involving open-ended practical investigations rather than routine practical operations, results in a blurring of the distinctions between practical and theoretical work."

Much criticism had arisen for neglecting the "affective" domain in most of the aims and objectives lists focusing exclusively on practical work. For example, in the aims and objectives discussed above, most of them did not include attitude, interest, curiosity or motivation as a desirable outcome of laboratory instructions. Lunetta and Tamir[16] suggested that the affective outcomes of practical work should certainly be given more emphasis in research studies and that the development of favourable attitudes towards science could be achieved through laboratory instruction.

It has been reported by several authors that the pupil's attitude to practical work should be part of the objective of laboratory instruction. There are of course certain attitudes which are more applicable to practical work, such as regard to safety, faith and reliance in observations made and orderliness, than attitudes such as persistence, enthusiasm, interest and enjoyment[33].

The question which arises is how we can teach a feeling of enjoyment or a sense of curiosity and how such qualities can be assessed. Hellingman[35] recognised the problem and explained that he had chosen to focus attention merely on cognitive and psycho-motor aspects and to consider attitudes as a by-product of practical work, at least for the purpose of assessment.

Another criticism which has arisen is the evident lack of clarity of purpose in laboratory teaching and the students complain that laboratory work is not related to the theoretical course. Boud and Thorley[36] investigated the perception of laboratory work amongst practising scientists, recent graduates and undergraduates. They found a high degree of concordance between practising scientists and recent graduates, who regard laboratory experiences as important to the acquisition of practical skills, equipment familiarity, observational skills, interpretations of data and a critical approach to experimentation. On the other hand, undergraduate students have a different perception of laboratory aims, tending to rate highly those activities associated with educational processes, for example the linking of theoretical material and laboratory work.

Gunning and Johnstone[38] also noticed that a gap between teachers' objectives and their achievement by pupils. There was a lack of correlation between teachers' and pupils' rankings of the importance of objectives. There was evidence that pupils gave most importance to psychomotor skills, while teachers felt that these skills were less important than objectives in the affective domain.

There is a consensus amongst the researchers in Science Education about the difficulty in designing a comprehensive list of objectives but there is also a consensus that objectives should be meaningful and helpful to learners and teachers.

Much practical work involves the application of knowledge, the use of theoretical concepts and the theoretical evaluation of the results obtained by the practical experience. All such interrelationships between practice and theory will continue to raise problems for effective assessment. Another ongoing concern is how to achieve the desired and more or less constant level of generality in the formulation of these objectives.

3 - PSYCHOLOGICAL THEORIES

3.1 - INFORMATION PROCESSING THEORY

The information processing approach has its roots in disciplines that were concerned with the study of information since the Second World War. To study cognition researchers borrowed ideas from communications theory, the theory of computation, artificial intelligence and linguistics.

The information processing approach, viewed by some researchers as a framework, provides the general principles within which particular theories are constructed. For example, cognitive psychology is often called Human Information Processing to reflect the predominance of the subject in the field.

Information processing theories divide the cognitive system into components and explore the way in which these components encode, transform and manipulate information. For example, the acquisition, storage, retrieval and use of information all involve a number of separate stages, and the information processing approach attempts to identify what happens during each of these stages.

The information processing theories have also been concerned with studying the differences between a skilled expert and a novice performing some task. There is a considerable difference in the knowledge and strategies that an expert and a novice possess and this difference will affect such factors as how a task is approached and what information is sought. The expert usually has available a variety of problem-solving strategies not available to the novice.

Figure 1.1 identifies the stages most commonly included in information processing models based on a model provided by Atkinson and Shiffrin[39]. Their model consists of three memory stores: a sensory register; a short-term store; and a long-term store - and a control process that operate on the short-term and long-term stores.

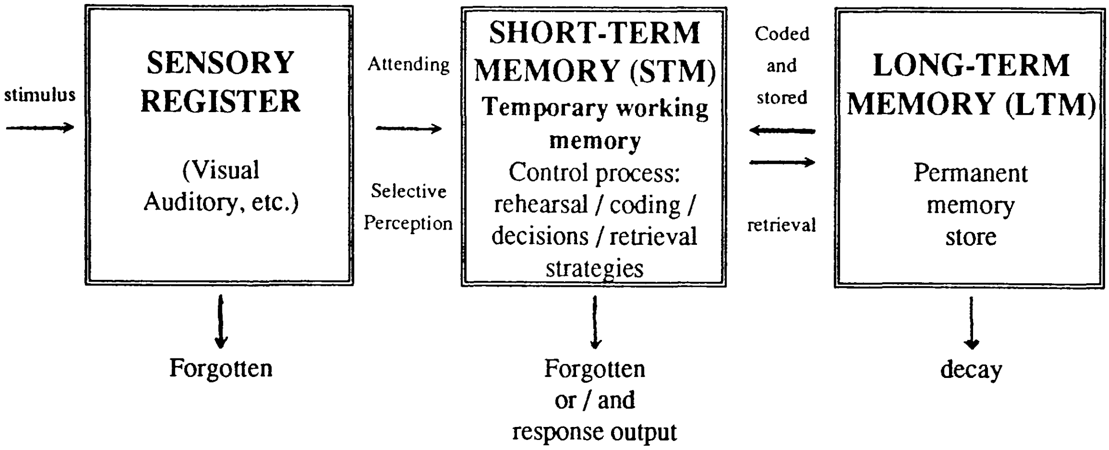


Figure 1.1 - Hypothetical Structure of the Information Processing Model of Memory

A brief consideration of the Information processing stages is presented below:

3.1.1 - SENSORY STORE (MEMORY)

The sensory store (memory) provides the information storage for a very short period of time in its original sensory form. The sensory memory is defined as a continuation or persistence of the process involved in perceiving a stimulus when that stimulus is no longer physically present. It is believed that a sensory store is associated with each of our senses, although the visual and auditory stores have been the most widely studied. The sensory store has the feature of retaining the information for a period estimated to be about 1 to 5 milliseconds and it is lost at the end of this time. It is considered a transient information store as it operates for a very short time and operates to process perceptions. Therefore, it stores the information with much more detail than the short and long term memory.

3.1.2 - SHORT TERM MEMORY (STM)

The short term memory is limited in both the amount of information it can hold (capacity) and the length of time it can hold the information (duration). These limitations make the distinction between the Short-Term Memory (STM) and Long-Term Memory (LTM).

The information which is held in the short term memory is usually the information which we are paying attention to. Items that are not actively rehearsed can be lost in 20 to 30 seconds. The short term memory allows an easy recall of small amounts of information over a short time. Evidence suggests that interference, rather than decay, is the primary cause of forgetting. Interference can result from items presented either before (proactive interference) or after (retroactive interference) the tested item. The reduction of interference improves the memory capacity of remembering.

The limitation of STM capacity was researched by Miller[40]. He found that, after reviewing a large number of findings on absolute judgement and memory span, the capacity of STM as consisted of about seven chunks, i.e., the capacity of STM lies between five and nine chunks of information. A chunk is a group of items that is stored as a unit in LTM. We use the short term memory, for example, to remember a telephone number as we are dialling it. We may quickly forget the number if we don't store in the long term memory by rehearsal.

De Groot[41] argued that the superior ability of a master player to reproduce a chessboard is a result of his ability to group the pieces into familiar configurations. Chase and Simon[42] argued that master chess players have both more chunks and larger chunks stored in LTM than less experienced players. Success in reproducing other configurations, such as circuit diagrams, chemical formulae, etc. also depends on the availability of chunks[43].

Most of these hypotheses suggest that the time required, in a recognition task, for one to decide whether an item had been stored in the short term memory increases as a linear function of the number of items stored. This suggests that people search the items one at a time.

Other important factor which the search time seems to depend on are whether the items are simple, such as letters or digits, or more complex, such as random forms or nonsense syllables, and the clarity of the item to be remembered. There appears to be an inverse relationship between search rate and memory span: by definition the faster the search rate, the greater the number of items that can be stored in STM. A possible explanation is that both are influenced by the number of features composing each item.

3.1.3 - LONG TERM MEMORY (LTM)

The long term memory has no limitations on the amount of information it can hold, and forgetting occurs relatively slowly, if at all. This type of memory requires more conscious effort for encoding the information and it always encodes the information which is in its lasting form, i.e., after being processed in the short term memory.

Most of the hypotheses suggest that the information which enters the long term memory does not decay but tends to be kept permanently. It is believed that the storage of a chunk of information in the long term memory takes longer than the retrieval of it, which means that we may retrieve more quickly many chunks from long-term while our memory capacity to store it is much less.

Our capability to retrieve information previously stored, and the search procedures for retrieval are the main differences between the long term memory and other memories

Learning can be represented as the transfer of information from STM to LTM. The decay rate for information in LTM is slow compared with the rapid decay rate from STM. In order to retrieve information from LTM, we must initially decide whether the information is stored in LTM. The "tip of the tongue" phenomenon occurs when a person knows information is stored in LTM but cannot immediately retrieve it. Strategies for searching LTM include using partial information such as word length or sounds, generating plausible names, and using contextual information associated with a name.

It is important at this point to differentiate between recall and recognition. A model of recognition memory derived from signal detection theory assumes that items vary in familiarity along a continuum. Items that were presented before (old items) generally have higher familiarity values than items that were not presented before(new items) but the two distributions overlap. A person must select a criterion value along the continuum in order to decide whether an item is old or new.

A recognition task differs from a recall task in that it tests judgment of whether an item was previously presented, usually within a specified context.

3.1.4 - INFORMATION FLOW

The Multi-Store approach assumes that the information is initially received by the sensory register through one of our five senses: sight; hearing; touch; taste; and smell. The information is held in a relatively uninterpreted form for a very short period of time. From the sensory stores a small fraction is attended to and selected for further processing in the short-term store (STM) and interacts with the existing information (LTM). Information in the Short-Term Store is actively processed and may be transferred into the Long-Term Store.

3.1.5 - WORKING MEMORY

Since Atkinson and Shiffrin's[39] first presentation of their model there have been many revisions and alternatives suggested. Among the most important is the suggestion by Baddeley and Hitch[44]. They proposed that the idea of short-term memory with a single unitary store should be substituted by a number of sub-systems controlled by a limited capacity executive system. In place of a unitary short-term memory there thus emerges four separate components of the working memory system: a modality-free Central Executive, an articulatory loop; a visual spatial sketchpad; and a primary acoustic store.

The central executive is used to deal with task of a cognitively demanding nature. Since it allocates attention to inputs and directs the operation of the other components. It is the most important of the four components. The central executive has strictly limited capacity being a very flexible system that can process information in any sensory modality in a variety of ways. It can also store information over brief periods of time.

The Articulatory loop can be regard as a verbal rehearsal loop. It organises information in a temporal and serial fashion, and it deals with verbal information in terms of its articulation. It has a time based capacity.

The Visuo-Spatial Sketch Pad is in some way similar to the articulatory loop being able to handle more than one stimulus at a time and has the ability to rehearse information. It deals with visual and/or spatial information rather than the phonemic information used by the articulatory loop.

The Primary acoustic Store receives direct auditory input. Visual input can only enter it indirectly after being converted to phonological form.

So, working memory fulfils the same function as short-term memory in the Atkinson and Shiffrin model. Both views agree in that the system has limited capacity, whether this limit is set by number of items, amount of information, or time.

There is now almost universal agreement that it is much more realistic to assume that working memory consist of several relatively independent processing mechanisms rather than a single unitary short-term store. It also seems useful to treat attentional processes and short-term storage as part of the same system, primarily because they are probably used together much of the time in everyday life.

The nature of the information stored in long-term memory must be affected by the precise use of perceptual and attentional resources at the time of learning. Craik and Lockhart[45] suggested that there is an attentional system which can process any given stimulus in a number of different ways. The process varies in terms of its depth which is defined in terms of meaningfulness extracted from the stimulus rather than in terms of the number of analyses performed upon it. So, the memory is a by-product of the depth of processing inputs, the deeper the processing the better the retention. The analysis of meaning is also an important factor for long-term retention. Research in both Perception and Attention have also emphasized the importance of knowledge in determining what we perceive and attend to.

4 - LEARNING IMPLICATIONS

Learning theories are concerned with how we learn from experience to produce an appropriate response to deal with the environment. From the Information Processing Framework it is possible to identify the phases of processing that take place from the beginning to the end of an act of learning. The results of research into how our memory encodes, stores and retrieves informations has provided valuable indicators of what is needed to complete each phase and the conditions required to improve learning. The Working Memory model provides some insight into the active processes which are used in our everyday interactions with the environment.

According to Miller[40] the human ability to process information depends upon the span of absolute judgement which is apparently limited by the amount of information, and the span of immediate memory which seems to be limited by the numbers of items to be remembered. There is evidence that what determines the individual differences in memory is how effectively one can group material into familiar chunks.

One example, applied to chemistry, is given by Johnstone and Kellett[46]. They argue that the ability of "chemistry masters" and "chemistry novices" to recognise structural chemical formulae depends on their ability to "chunk" the information.

Mainly due to the large number of variables by which influence laboratory instruction - practical work is described as an area of educational difficulty one where the working memory capacity can be easily overloaded.

Johnstone and Wham[47] argue that learning in a laboratory situation may result in a state of working memory overload because of the large amount of information given at once. The overload also occurs when the learner is incapable of discriminating between the "noise" (unimportant information) and the "signal" (important information) in laboratory instruction. Also overload arises due to the incidental information given by teachers and demonstrators which contributes to an increase "noise" and become difficult for the students to recognise the "signal". Further some laboratory manuals introduce unnecessary amounts of information for the student to cope with, thus adding to "noise."

It has been shown earlier in this chapter (in the objectives of practical work section) that what the students perceive to be the requirements of practical work was not what the teachers believe them to be. The content which the teacher is trying to teach is well understood and well organised in his mind. However to the learner, who does not yet have a grasp on the ideas, the position may look very different[47].

Boud[48] argued for identification of learning experience as a separate reality, to emphasise the potential significance of the gap between intentions and experiences. This draws attention to any hidden messages in course plans which are conteracting teaching intentions: For example when an activity requires students to make frequent repetitive measurements which occupy a large proportion of the time available in the laboratory. The resultant boredom can lead students to the conclusion that experimental science is characterized by tedium.

Moreira[49] contended that often students did not have a clear idea of what they were doing during the laboratory period. They were unable to answer questions correctly on the basic concepts involved in the experiment, which he took to illustrate an overload situation.

On the other hand, Warren and Pickering[50] argued that the students appeared to cope with the constraints of their own working memory and they would often include a few theoretical ideas when they were allowed to write their own procedures.

Johnstone and Kellett[46] recommended that it is good practice in teaching to operate in low-information situations while a concept is being developed. Where a high-information situation is inevitable because of the nature of the science, teachers ought to either postpone the introduction of new concepts or provide students with efficient strategies to allow for "chunking" and the development of confidence at the temporary expense of understanding. Finally, they advise that teachers keep redundant information well out of the way during the development of concepts. Pupils at a low development stage may see redundant material as essential and overload their capacity.

Johnstone and Wham[47] further suggested that the load could be reduced and the signal-noise ratio enhanced by:

i giving a clear statement of the point of the experiment;

ii making clear what is preliminary, peripheral and preparatory in an experiment;

iii redesigning experiments; and

iv avoiding the teaching of manipulative or interpretative skill at the same time as data is being sought.

According to Case[51] the designing of effective instruction with a minimum load on working memory must do the following three things:

i reduce to a bare minimum the number of items of information that require the student's attention. By definition, the fewer the number of items of information with which the student must deal at anyone time, the smaller the load on working memory[52].

ii make familiar all cues to which the student must attend and all responses he or she must exhibit. The more familiar a cue, the less working memory is need for the task of extracting it from the context. Similarly, the more familiar a response, the less working memory is need for its execution[53].

iii highlight all stimuli to which the subject must attend, making them salient, either because their physical characteristics make them stand out from their context, or because they are pointed out verbally by the instructor. Once again, the more salient a stimulus, the less working memory is need to be devoted the task of extracting it[54].

Letton[2] suggested that for reducing the "noise" in the existing laboratories one should identify and attend to all areas of possible overload by:

i giving a clear statement of objectives;

ii giving clear instructions on the requirements for the lab report;

iii identifying which instruction matter and which is peripheral and make this apparent in the material;

iv redesigning the experiment with regard to the content;

v dividing the written material into sections which are easily managed by the students;

vi making the management of the lab efficient and giving a map of the layout of the lab with the location of all equipment and material; and

vi ensuring that relevant skills are taught separately from the actual experiment in order that the students should gain confidence.

5 - LABORATORY COURSE DESIGN

5.1 - DESIGN AND TYPES OF LABORATORY INSTRUCTIONS

Laboratory instructions for undergraduate students can be organised in many different ways. A broad classification can range from the traditional type in which a series of guided experiments are supervised by staff and post-graduate demonstrators, to research projects that last for weeks, a term, a semester or even one year of an undergraduate course. Between these two extremes the literature on the subject reports courses with varying degrees of freedom in their instruction.

Dunn[48] classified the types of laboratory instruction into three groups depending on their purpose and the degree of detailed control exercised by the staff over students' activities:

i Controlled exercises: which are devised by the staff and can be completed by the students in one or two laboratory periods;

ii Experimental investigations: which are normally longer term activities set by the class supervisor with the procedure and methods of data analysis chosen by the students; and

iii Research projects: which are significant pieces of work that may occupy the practical session for a term, semester or even one or two years of an undergraduate course.

There are many aspects of practical work which are present in the laboratory situation under the control of the staff, these include:

i The decision on content of experiments;

ii The organisation of the laboratory;

iii The choice of apparatus, chemicals, and equipment; and

iv The content of the written instruction.

With regard to the students the aspects of concern can be grouped as follows:

i Cognitive aspects, i.e. recall and new learning of concepts and ideas;

ii Psychomotor aspects, i.e. old and new manipulative skills;

iii Affective aspects, i.e. enjoyment, satisfaction and interest in the subject; and

iv Management aspects:, i.e. time, lab report, new equipment, and written instructions.

Boud[48] argued that all course design methods have their particular strengths or limitations. The course designers need to take the desirable elements from each and balance them in a programme which pursues all major objectives and provides a coherent experience for students.

5.2 - WRITTEN INSTRUCTIONS - LAB MANUALS

The examination of laboratory instruction over the years has shown that students do a considerable amount of the activity involved in practical work by themselves. The first year practical chemistry course, which is the target of this survey, is a good example. In the laboratory the students are asked to do the experiments following the manual's procedures and they get help from members of staff or demonstrators when necessary.

So, it is essential to provide a good written instructions which give information not only about the experimental procedures, but also about the basic organisation of the laboratory and laboratory techniques involved in the experiments.

Most of the time little attention is given to the design of instructional material. The courses are designed to fulfil their objectives with long procedures that are very likely to frustrate the attainment of some of these objectives. A lot of time has been spent on improving the content of the practical course but little to how to convey this information effectively to students.

Segerblom[55] reported that 30 out of 100 teachers surveyed preferred to use their own notes in preference to choosing from over a dozen printed laboratory manual available. It was evident that many teachers were dissatisfied with the manuals on the market and were trying to adapt their work to the needs of their students. The commercial manuals had taken on the characteristics of a workbook. They were combinations of directions for laboratory experiments, questions and problems usually found at the end of the chapters in the text, drill exercises, and devices for helping students correlate their ideas.

Most of laboratory instruction is routine, laborious and uninteresting and the practical work done in our present system is open to serious criticism because in many cases it consists of little more than a pupil going through a set of motions following directions of a "cookbook" of recipe.

Silberman[21] in planning a procedureless organic chemistry course argued that, since there was no laboratory manual for the course, the students were forced to go to the library to find an experiment. He found that it generated tremendous interest and enthusiasm among the better students, and all students began realising that Organic Chemistry is very often not what a cookbook lab manual leads one to believe. They discovered that reactions did not always work smoothly, yields were not always good, experiments often took longer than three hours, and what works on the paper may not work in a flask - indeed the lab does not have to be dull and repetitive.

Mallison[15] reported that students frequently do the experiments mechanically to get the result expected as a consequence of the laboratory manual. There is an emphasis on an imitative deductive approach rather then an inductive approach that requires the students to draw conclusions.

Young[17] argued that the practice of presenting the student with an experimental plan designed by someone else is a valid means for teaching principles and techniques, and for showing by example how lab procedures is designed to fit an investigation, while helping the student to gain confidence in this own handling of the apparatus.

There are in the literature many reports of information processing research which have direct implications for the design of instructional written materials. These researches, besides helping us to find out how the information is processed in our cognitive system, also indicate what ought to be avoided, or what could be used to improve the process of encoding, decoding, and retrieval.

The information we receive from the environment is perceived through one of our five senses. When a situation is presented to us first we pay attention to the stimulus and process it before encoding it into our own terms. To do this the ideas, concepts, skills, etc., from the long term memory are brought from the long term memory to the working memory and allowed to interplay with the new information before formulating any response or storing the new information. This flow of information is called bottom-up (perception through our senses) and top-down (retrieve from LTM) processes.

The process of giving attention is characterised by its Selectivity, a capacity which is necessary to avoid overload with too much information, and Mental Effort which is required to perform the task concerned with different activities.

Capacity theories emphasize the amount of mental effort that is required to perform tasks and are concerned with how effort is allocated to different activities. Capacity theory suggests that the ability to perform simultaneous activities is limited when the activities require more mental effort than is available.

Our capacity to perceive and attend to letters, words and phrases have been used in a large number of research activities to try to understand how information is processed, encoded, and retrieved in our cognitive system.

Letters, words, and phrases, with differing degrees of complexity have been used to try to find out the time and accuracy of recalling and understanding them. The findings show a marked degree of difficulty in recalling letters, words, and phrases with varying degrees of complexity. For example, a letter can be recognised more easily when it is part of a word than when it is part of a non-word or is presented by itself. This is known as the "Word Superiority Effect."

The fact that so many words exist and can be combined in so many ways means that one would have to learn an infinite number of associations in order to form sentences. The alternative is to learn systems of rules (grammar) capable of producing sentences.

Hitch and Baddeley[44] measured the speed of verbal reasoning tasks using sentences of varied complexity. They found that the reasoning time increased with the complexity of the sentence. It was observed that the subjects' reasoning time was slowed down by the introduction of a concurrent digit task. Subjects were also significantly slower when a random digit task was introduced. These results illustrate the Working Memory's limited capacity and the difficulty of remembering more complex phrases.

Johnstone and Cassel[56] argued that removing the negative forms of a question improved the students' score because the negative has the effect of a "double think" and if by chance two negatives are included in a question, even the strongest candidate quails.

Hartley[57] thereafter suggested guidelines for writing an instructional text. He recommended that:

i The paragraph length should be short and well-spaced in order to make it easier to read;

ii The sentence length should also be short. Long sentences tend to overload the working memory and are more difficult to understand;

iii The word length should be short and familiar to the students because it is easy to understand; and

iv Texts are easier to understand when sentences with subordinate clauses, the passive voice; negative forms; and passive negative forms are avoided.

Johnstone and Cassel[56] found, however, that the words which are normal in English usage give more trouble than those which have specific meaning in Science (e.g., technical terms such as 'isotope').

It would then appear that the comprehension of both written and spoken language depends on some form of working memory and that the limited capacity of the Working Memory system influences learning, comprehension and reasoning.

Another area of research useful in designing instructions that is done to establish how images are recognised and stored in our memory. That visual imagery improves memory has been recognised for centuries and has resulted in the use of imagery in many mnemonic strategies. This is supported by a variety of evidence which suggests that visual images are important to our ability to perform many cognitive tasks. The usefulness of visual images in memory is further supported by research showing that people usually remember pictures better than concrete words and concrete words better than abstracts words. These results correspond to the fact that images are easiest to form from pictures and hardest to form from abstract words.

Lutz and Lutz[58] found that people are better able to recognise pictures combined with words than words only. Learning pairs of items are facilitated by forming an interactive image that combines the members of the pair. Also, a person has two chances to recall the item rather than only one.

A study that compared four strategies, verbal rehearsal, sentence reading, sentence generation, and imagery; found that people who used the imagery recalled the most words. However, the two sentence elaboration strategies produced much better recall than simple rehearsal, suggesting that the former strategies could facilitate learning abstract words.

Hartley[57] has argued that the "layout" of the educational instruction plays an important role in the learning process and the designing should take into account the following:

i The page size and overall width of the information area: to provide a reliable frame of reference within which the readers can move about, leave and return without confusions.

ii The decisions about the type sizes, type faces, spacing, line-length: which are affected by practical matters, such as what is available and what should be avoided.

iii Space and structure: the organisation of text can be enhanced by its spatial layout, i.e., units of line-feed can be used consistently throughout a text to separate and group related part of the text; and consistent word-spacing can be used as a device for better displaying the structure of text.

In addition, Hartley suggested that, the use of illustration can serve a variety of overlapping functions which aid the motivation, attention, and retention. Illustrations help to improve the recall of information of a text which is illustrated, but they do not help the recall of related, but unillustrated, information.

The organisation of ideas in the written instructions should be also taken into account when considering the comprehension process which depends on how people's prior knowledge interacts with the organisation of ideas in a text according to Information Processing Theories.

The organisation of the knowledge in our cognitive system seems to be organised by "category" and hierarchies made up of categories. These "categories" seem to exist to reduce the complexity of the environment and the need for constant learning and to enable us to recognise objects, respond appropriately, order, relate and classify events.

Experiments have shown that people can learn hierarchical information quickly, but they have considerable difficulty in learning the same information when it is presented randomly.

5.3 - MANIPULATIVE SKILL

There is general agreement amongst science education researchers that practical work improves students' manipulative skills.

Most of the research studies conducted to compare the effects of instructional methods of practical work have shown no significant difference (as measured by standard paper-and-pencil tests) in students' achievement, attitude, critical thinking, and in their knowledge of the processes of science. The only area where laboratory work showed a marked improvement over alternative methods was in the development of manipulative skills, as would be expected[16].

Kempa and Palmer[59], looking at the effectiveness of video-tape demonstrations in the learning of manipulative skill in practical chemistry in university undergraduate course, have shown that whilst there was little difference between students performance in relation to the cognitive aspects of the skills being taught, there were marked differences in the performance of manipulative skills - a not altogether unexpected result. However, they also showed that those who had seen the video film were more competent in manipulative skills than those who had only been given written instruction. Similar results were found by Johnstone and Wham[60]. They reported that despite the low number of students involved in the experiment, the group which had been taught using a film had better performance than the control group. Johnstone and Wham[47], suggested that the simultaneous introduction of laboratory techniques and experimental measurements can cause interference to the detriment of the attainment of the experimental objectives.

According to Information Processing Theory, any attempt to comprehend two messages at the same time results in a decline in accuracy on the primary message and slower responses to a subsidiary task designed to measure capacity.

This new manipulative skill contributed to the students' working memory overload when taught at the same time as data collection. The students should first become competent in their manipulative skill, i.e., taught to do it automatically, before trying to do the experiments itself. So, they are able to use most of their working memory capacity to think about the experiment with very little being used on manipulative skills. In other words, when they have to be concerned about the details of pipetting, titrating, etc., less working memory space will be available for application of thinking skills. Automatic processing occurs when a task requires very little working memory capacity to perform. Posner and Snyder[61] proposed three criteria to determine whether a use of skill is "automatic": (i) it occurs without intention; (ii) it does not give rise to conscious awareness, and (iii) it does not interfere with other mental activities.

5.4 - PRELAB WORK

The idea of pre laboratory work is not new. It is generally accepted that students' engagement in laboratory work without prior consideration of the concepts, calculations and techniques involved in the experiment militate against clear understanding of what they are doing. However, these engagements can be achieved by developing forms of pre-laboratory activity to highlight the essential ideas of the work and introduce new principles, concepts, and lab techniques.

The literature reported several kinds of prelab work, such as, "reading the laboratory manual before starting the experimental work"; "solving theoretical problems related to the experiment before coming to the lab course"; "doing computer simulations of experiments"; "listening to a short talk about the most important point of experiment in the first half hour of the lab session"; "undertaking audio-visual preparation"; etc.

Pickering[62] adopted a prelab preparation in which the students were not allowed to bring the manual into the laboratory. This was supposed to force the students to develop their own experimental procedure, in a self-reliant way.

The importance of previous knowledge in the learning process has been stressed by psychologists and educators and has been subject to several investigations in both fields.

Psychological investigation of text comprehension involves trying to find out how people's prior knowledge and information-processing characteristics interact with the organisation of ideas in a text. The model of text comprehension takes account of how the reader relates the ideas in the text to ideas already read. Comprehension seems to be easier when the ideas can be related to ideas that are still available in STM. If no related ideas are found, the reader can search LTM. If still no related concepts are found in LTM, the new material must be stored separately rather than integrated with the old material. Related ideas can sometimes be found by inference, but this slows down comprehension compared with direct repetition of the same concepts.

So it appears that prior knowledge can make abstract ideas seem less abstract and easier to comprehend. It can also determine what teachers emphasise in a text and provide by way of a framework for recalling ideas.

Students' preparation before starting practical work thus increases the chances of their understanding what they are doing in the lab. This is intended to avoid "cookbook" scenario.

Pickering and Crabtree[63] argued that the majority of conceptual learning in laboratory courses probably occurred outwith the lab, either during report writing or prelab preparation.

5.5 - PRACTICAL PROBLEMS SOLVING

The terms "investigation"; "open-ended" experiment; and "problem-solving" are used to describe practical activities in which the students are expected to plan, design, set-up apparatus, choose the appropriate techniques, and draw conclusions.

Lock[64] defined "Investigation" as an experimental study that requires first-hand student participation, provides evidence that permits questions, posed at the outset, to be answered.

"Problem-Solving" relates to the nature and style of the question posed at the outset of an investigation. However such an approach tends to narrow the investigative possibilities. "Open-ended" exercise clearly allows more than one solution, design or answer. Independent of the type of practical work adopted, the role of teachers in practical work crucially affects students' learning experience.

The term experimental investigation is used to indicate any laboratory teaching method which allows the students to display some personal initiative in the performance of the task and aims to develop students ability in scientific enquiry[48].

Practical activities can be more open-ended and student centred depending on the level of student or teacher control over specific elements involved in the practical work, i.e., choice of subject; formulation of problem, planning, choice of strategies, etc.

Laboratory work has been strongly criticised over the years for neglecting important components, such as, formulation, planning and designing of experiments.

There are two major aims in using practical problems in undergraduate laboratories: The first is to give students an opportunity to practise various inquiry skills, plan and devise an experimental programme to solve a problem. This is frequently omitted. Secondly, it has long been realised that investigational work which involves individualised problem solving is highly motivational, especially if the student develops a sense of ownership for the problem.

Identifying and stating a problem, however, is a very difficult task, especially for first year students, particularly if it has to be solved within the constraint of time and available equipment.

Johnstone and Wham[47] suggested that once the student has become competent in manipulative skill and has grasped theoretical ideas which underlie the work, the student can be placed in an investigative situation in which there is considerable "noise."

In order to solve problems, students need both general strategies and domain specific knowledge to enable them to categorize the information given and plan the solution. Performance on problem solving is influenced by the storage capacity, and the retrieval time of short term and long term memory. It is also influenced by the "search space," i.e. the number of legal moves available at each point in solving the problem.

There are several ways that the cognitive system affects success in solving a problem. Short term memory is used to evaluate the alternative choices at each point when searching for a solution. Long term memory is also used to store information about previously visited problem states, evaluated hypotheses, and selected operators.

Therefore the selection of practical problems ought to be done observing the following criteria[29]:

i The scope of the experiment should be sufficiently broad to give the students a variety of way to approach them.

ii The experiments should deal with subjects that are of interest to the students and yet sufficiently accessible so that a hard-working student has a reasonable chance of making some progress within the allotted period of time.

iii Since most laboratory courses involve large numbers of students, and resources are limited, the experiments should be feasible without extensive instrumentation.

iv The experiment should encourage the students to make accurate measurements. There should be sources of error that are not trivial, yet which can be appreciated and controlled by an alert student.

5.6 - STAFF, ORGANISATION AND COST

The cost of staffing with lecturers has become prohibitive and unrealistic for several institutions around the world. The teaching economy has been achieved by having advanced pupils offset the cost of their continuing education by assisting the teaching of younger ones (the "demonstrator" system). The use of post-graduate demonstrators in laboratories is viewed by some institutions as a way of helping them through the lean years, and by critics as the exploitation of cheap labour, under-writing demands for more staff or calls on staff time[65].

Apart from the economic factors, there are doubts about the effectiveness of post-graduate demonstration. However, from the staff point of view, since the demonstrators are much of an age with the students this may enable them to understand the students better. Students also may tend to see the demonstrator as less "threatening" than staff.

However, some argue that it is necessary to give proper training to demonstrators, though this has been rejected by some staff members and even by demonstrators due to temporary nature of the activity. As a result the effectiveness of a demonstrator is often a matter of luck. However as untrained demonstrators have to think on their feet, it is argued they better demonstrate how to approach an experiment. Moreover many research students are presumed to be experienced because they have been through the same. Indeed some research students are ex-students of the University, so probably demonstrate the same experiments they did in their undergraduate course[65].

Thus there is a tendency for large teaching laboratories to remain unchanged over long periods of time, evolving but rarely undergoing any radical change.

The degree of involvement by staff and demonstrators in the laboratory sessions varies from course to course and from university to university. In some, staff reserve for themselves tasks like marking reports, leaving demonstrators to assist mainly with the "nuts and bolts." In others, staff does little and exercise only a general supervisory role with the demonstrators filling the gap. In a few, both the staff and demonstrators get involved at the same level.

Certainly many post graduate demonstrators do a good job, even when they feel unsure about it. A fuller dialogue between staff and post graduate demonstrators could perhaps be useful to minimise problems in laboratory teaching.

Though students present some initial anxiety when they arrive in the first year of University. A problem which requires further attention is the higher level of anxiety among women students who feel more acutely the fear of helplessness at the start.

The requirements of a practical course compared with those for lectures have always been higher. For example: space occupied per student, ratio staff/student, need for technician back up, chemicals used and use of specialist rooms, and equipment are higher for lab than for lectures. And so departmental decisions on finance will obviously have a major effect on any revision of laboratory courses.

In order to overcome the cost barrier substantive research is required to show that, despite the higher cost, the laboratory can offer good value for money.

6 - ATTITUDE AND ATTITUDE CHANGE

The place of attitudes, beliefs and values in the educational process have in recent years assumed an increasing importance. The number of attitude studies published have grown every year, as is shown by reviews of the subject[66,67]. Despite the large number of studies in the area, there is still a lack of agreement about the definition for the term "Attitude."

The term "Attitude" is a very broad one and has been the subject of extended debate. Researchers have used it in many different contexts without reaching a consensus.

A pioneer definition of Attitude was offered by Thurstone[68] who described it as: "the degree of positive or negative effects associated with some psychological object". This definition revealed an affective basis denoted by the predisposition to react negatively or positively in some degree toward an object.

Other authors define attitude as a product of the cognitive process. Bloom, Krothwohl and Masia[69] characterised the thought, feeling, and action dimensions of human development into the cognitive, affective, and psychomotor domains as a way of describing the process of internalisation.

Krech and Cruthfield[70] suggest that "an attitude can be defined as an enduring organisation of motivational, emotional, perceptual, and cognitive processes with respect to some aspect of the individual's world." Their definition emphasising the aspects of learning and problem solving.

Many social psychologists have proposed definitions but one that has survived the test of time, was formulated by Allport[71]. His definition was an attempt to put together the different contemporary notions. "An attitude is a mental and neural state of readiness, organised through experience, exerting a directive and/or dynamic influence upon the individual's response to all objects and situations with which it is related." His definition closely allies attitude to a variable which predisposes behaviour. Adding to this Cook and Sellitz[72] concluded that attitudes, on their own, do not control behaviour but enter into the determination of a variety of behaviours along with other influences.

Katz and Stotland[73] analyse attitudes into three dimensions: affective, cognitive, and behavioural components. Whereas, the affective component consists primarily of negative and positive feelings which have been learnt, the cognitive component is the knowledge base of the intellectual process. The Behavioural (Action) component is defined as a measure of the physical response associated with attitudes.

The definitions seem to mirror the differing psychological orientation of the researchers, viz, Attitude as affective outcome (Affective); Attitude as a product of cognition (Cognitive); and Attitudes as behaviour determinants (Conative). However, most agree that the three components are strongly interconnected.

There is a great proliferation of instruments concerning attitude measurements which have been criticised because new instruments enclose new variables or introduce new definitions of established ones. Despite these criticisms there are a number of well established methods of attitude measurement available, e.g., the Likert scale, Semantic Differential Scales, etc.

Another, concern is the weakness of the relationship of attitude to cognitive variables as shown by correlation coefficients. Schibeci[67] in his review of the literature argued that it is possible that there is a two-way rather than a one-way relationship between the attitude and achievement. It is, therefore, likely that the association between cognitive domain and attitudes is a complex one which is not apparent from the results of bivariate studies.

Gardner[66] subdivided science-related attitudes into two major categories: Attitudes to Science, (e.g., enjoyment, interest, etc.) for which there is always some distinct attitude object; and scientific attitudes (e.g., "openmindness," "honesty," "scepticism," etc.), i.e., styles which the scientist is presumed to display.

What we are interested in are the attitudes to Science, more specifically, attitudes to practical work.

Teachers play a very important role in students' attitude to practical work in science since they decide what and how to teach. Gardner[66] reported that science teachers give more importance to knowledge of basic facts than to attitude objectives. Laboratory work is often said to lead to many desirable outcomes in the cognitive, and psychomotor domain and to influence a variety of affective domains, such us scientific attitude, motivation, and interest in science etc. Supporters of practical work claim that it provides opportunities for enhancing the students' scientific attitudes and their enjoyment as well as their knowledge of science.

However students' reaction to practical work seems at variance with the teachers' view even though many students enjoy and prefer it to other modes of learning. Guy[74] reported that students recall more "bad" memories than "good" memories of lectures, laboratories and tutorials but more "good" than "bad" of individual work and projects.

The physical conditions on offer for lab work have a direct effect on students attitudes to science. The time allowed for labs varies (from ample to insufficient); differing goals are given different levels of emphasis (from open to close-ended experimental work); the degree of intellectual challenge on offer varies (from easy to difficult) as does the degree of integration with theoretical work, and the professional competence of the staff which reflects in the organisation of the practical work[48].

Devenport et al.[75], compared students' attitudes to practical work at secondary school and university and found their enjoyment declined in the university practical course. They suggested that whilst the students should become more independent at university, the change is too sudden and that practical work organisers should take these factors into account when designing a course. They also suggested a movement away from "cookbook" routine to more project work, allowing students to think for themselves and to appreciate more what a chemist actually does.

CHAPTER 2

METHODOLOGY

1 - RESEARCH DESIGN

The literature presents a wide range of different experimental designs. Below are listed descriptions of the approaches that most suit the testing of the main hypotheses of this survey. The designs differ from each other to the extent to which they exert control over the variables which might invalidate the research findings[66].

i - ONE SHOT CASE STUDIES employing the following model

Experimental Group → **TREATMENT** → **POST-OBSERVATION**

Where the POST OBSERVATION is an attitude scale.

This is the least sophisticated of all designs and simply deals with a group of students who are tested only after the learning experience takes place to find what effect, if any, the experience has had on them. It has the disadvantage that the initial condition of the pupils was unknown leaving it open to criticism because it lacked the essential elements of research. It can be a useful tool if one has an external standard of reference or other test as a basis for comparison or if used by an experienced teacher who knows the class well.

ii - ONE-GROUP PRE-TEST and POST-TEST DESIGN employing the design:

Experimental Group → **PRE OBSERVATION** → **TREATMENT** → **POST OBSERVATION**

The introduction of a pre-test enables a comparison to be made by measurement "before" and "after" the learning experience. The gain which each student derives from the learning experience is measured by the difference between post and pre. Clearly, however, other influences could also be acting to promote or hinder the intended change.

iii - TWO-GROUP POST-TEST-ONLY employing the following design:

Experimental group → TREATMENT → POST OBSERVATION

Control Group → NO TREATMENT → POST OBSERVATION

This design tries to make good the shortcomings of models 1 and 2 by introducing an external standard of reference as a basis for comparison. An experimental group is exposed to the learning experience while a control group is not and there is no pre-test to know the initial condition of the pupils. Any difference between the two Post observations can be attributed to the treatment. This assumption is reasonable if all conditions are equal. The weakness of design 1 still exists mainly because of the absence of a pre-test and the conditions in the experimental and control groups may be different.

iv - TWO GROUPS PRE-TEST and POST-TEST DESIGN employing the following model:

Experimental Group → PRE OBSERVATION → TREATMENT → POST OBSERVATION

Control Group → PRE OBSERVATION → NO TREATMENT → POST OBSERVATION

This model could be seen as being a merger of designs 2 and 3, i.e., incorporating a control group into design 2 and introducing a pre test into design 3.

The pre test and the post test can be the same or the parallel forms of one another. The pre test enables the researcher to compare the experimental with the control group and so this represents an advance on design 3. There ought to be a high correlation between pre-observations in the experimental and control group to ensure that as far as can be discerned, all conditions are equal.

2 - ATTITUDE MEASUREMENT

2.1 - SCALES

The data collected by a survey or experiment are often of different types. Some are wholly qualitative, other wholly quantitative. Between these two extremes the levels of quantitativity vary. The number of cases is important because the statistical techniques that can be applied to variables which depends on how quantitative they are. Four scales of measurement can be distinguished, referred to as nominal, ordinal, interval and ratio scales. Each scale is hierarchical in that next higher scale incorporates the properties of the lower one.

1. The Nominal Scale is the most basic form of measurement. On this scale the measurements are essentially classifications or labels suited to a given purpose. Examples of nominal scales are sex, marital status and religion. They have no numerical meaning and no objective value to make one measurement preferable to another. The nominal scale has no sense of order or progression and it is not concerned with continuous variables - they count but do not order or measure with discrete variables. This sort of scale is used to measure non-quantitative variables so they cannot be added, subtracted, multiplied or divided. Statistical treatment of nominal measures is very limited.
2. The Ordinal Scale incorporates the discrete nature of the nominal scale and introduces a sense of order or progression. The categories have a natural order, but the intervals between the points on the scale are not necessarily constant; for instance the difference between points 1 and 2 may be very different from the difference between point 2 and 3. Items can be ordered, but the size of the jumps between values may be uneven. The ordinal scale is used to arrange individuals/objects in a series ranging from the highest to the lowest according to the particular characteristic being measured. It expresses more quantitative information than a nominal scales and is used to measure variables which are partly quantitative. Here, limitations are also imposed on the statistical treatment of measures taken by this scale, e.g., mean and standard deviation have no meaning.
3. The Interval Scale has all the properties of the ordinal and the nominal scales and also has the property of equal intervals. Scales of this type take a continuous range of values. They count, order and measure intervals. It is the form of scale most used by physical scientists but it is not always applicable to Social Science. Measures on the interval scale however do lend themselves to statistical treatment, e.g., calculations of

mean, standard deviation and other measures derivable from the normal distribution curve etc.

4. The Ratio Scale is the most comprehensive form of measurement and subsumes all that the three previous scales. This scale entails the absolute zero. Very few educational research studies utilise the ratio scale. Despite staff-room rumours, no pupil has zero intelligence. Without a zero measurement there can be no ratio rating scale. It is the essential prerogative of the physical scientists concerned with mass, time, length, etc.

In this survey, most of the variables were measured at the nominal and ordinal level: consequently some limitations on statistical treatment were imposed and respected.

2.2 - ATTITUDE SCALE

An attitude scale is designed to give some indication of an individual's (or group of individuals') position along an unidimensional attitude continuum. The scale allows comparisons of the attitudes of different groups, or comparison of an individual's attitude with that of a group. It must be noted, however, that an attitude scale has limitations; it cannot grade individuals in rank order, nor measure attitudes absolutely. Its function is to place individuals on a scale relative to others. It should be made clear for the purpose of this survey, that absolute measurement of attitude is not necessary, since it seeks to measure relative shifts.

There are several well established techniques that could have been adopted in order to obtain data on respondents' attitudes and opinions. These include:

i Differential (Thurstone) scale;
ii Rating scales;
iii Summated rating scales, of which Likert-type scales are the most common type;
iv Semantic differential scales;
v Interest inventories;
vi Preference ranking;
vii Projective techniques;
viii Enrolment data.

In this survey it was decided to use two of these techniques: Semantic Differential and Likert Scales.

The reasons for choosing Semantic Differential and Likert Scale were:

i they are very easy and quick to construct and administer;

ii they allow comparison of various attitude objects along standard dimension;

iii they facilitate good sampling and are not time consuming; and

iv they are highly reliable and valid - as reported by several eminent research studies when compared with other methods.

The Semantic Differential Scale - was developed by Osgood, Suci and Tannenbaum[76] in 1957. The technique consists of asking the student to rate an attitude object by placing their opinion on a five or seven point scale between a pair of bipolar adjectives. For example: 'What is your opinion about any previous laboratory work you have experienced' EASY/DIFFICULT, INTERESTING/BORING, etc. These separate ratings can then serve as measures of the respondent's attitude towards the attitude object.

On the other hand there are two negative aspects associated with these scales, namely:

i the meaning of a word may vary from subject to subject, the interpretation is not the same to all people;

ii the interval on a five point scale is not necessarily the same for all subjects. So, the scores are only ordinal scales which only provide an indication of the relative strengths of attitude between different people.

The Summated Rating Scales - gives each item a set of responses with an associated weighing. The respondent's score is the sum of the weightings for all items.

The most commonly used form of summated rating scale is the Likert-type[77] scale developed in 1932. This consisted of a number of opinion statements beside which there is a scale, varying from 2 to 7 points, the rating ranging from "strong agreement" to "strong disagreement" on which a subject can indicate his reaction to the attitude object being studied. Usually the scale has an odd number of points so that the subject need not commit himself if he is undecided. Examples of the scales are: (i) YES / NO; (ii) APPROVE / NEUTRAL / DISAPPROVE; ALWAYS / FREQUENTLY / SOMETIMES / NEVER; and so on. The five choice STRONGLY AGREE / AGREE / NEUTRAL / DISAGREE / STRONGLY DISAGREE string is commonly used.

Originally points on this scale were given a value and then added up to give an overall attitude scale. However, the validity of this procedure is questionable as it assumes that:

i the statements are measure in the same dimension;

ii the frequency of responses from "agree" to "disagree" form a normal distribution;

iii the intervals on the scales are equal.

It is nonetheless possible by using this technique, to determine changes in attitudes and opinions. The advantage of this method is that it gives the student three or more choices and the objectives which specify the required standard can be used in their original form.

Questionnaire approaches have the added advantage that they are easy to administer. It is not difficult to obtain good sampling and it is not a time consuming method. However, there is a risk that not all students will give the questions the same consideration.

Questionnaire responses can be affected by the "Halo Effect" - where respondent is influenced by an overall feeling of enjoyment or boredom instead of giving attention separately to each item. So, when having decided to 'enjoy' doing a particular activity, the student gives high marks for all variables being assessed therein; but if the student does not 'enjoy' the activity its shortcomings will be stressed.

The halo effect also occurs when a respondent decides to take a favourable or unfavourable stance and always ticks in the same position on the left or right without actually reading the items or giving each of them separate thought. This effect may be exacerbated when the rating scales are arranged one under the other, with the "good" or "bad" end on the same side for all variables. In order to avoid this, it is always advisable randomize the direction of the rating scales, or even introduce some statement with a different direction, so that the desirable response falls sometimes on the left and sometimes on the right.

In constructing an attitude scale it is necessary to:

i define the dimension that is being tested;

ii assure that all variables will have approximately the same meaning to all the respondents involved in the survey; and

iii define the number of points on the scale (these tend to vary from two to ten points).

However, researchers have pointed out that respondents are often unable to discriminate when using scales containing a large number of points. While for scales with fewer than five points, respondents are a little afraid of using the extreme categories. This is known as "the error of the central tendency."

3 - STATISTICAL TREATMENT

3.1 - COMPUTER SOFTWARE - SPSS/PC+

The analysis of data provided by attitude instruments had to be carefully considered so that important information from the Semantic Differential or Likert scales was not lost. Numbers were used instead of letters in the scales to denote a position on an attitude continuum and to facilitate subsequent computer processing. Five subprograms of the Statistical Package for the Social Sciences version 3.1 for Personal Computers (SPSS/PC+) and their options were used for carrying out the analysis of the data collected in this survey.

i. Subprogram FREQUENCIES

This subprogram computes and presents one-way frequency distribution tables for discrete or categorical variables and is operated by the integer mode. The options PERCENTAGE and MODE from the descriptive statistics were employed. The PERCENTAGE for each category enabled us to compare samples and sub-samples with different numbers of cases. The MODE was used to estimate the central tendency of response indicating the category which occurred most often.

ii. Subprogram CROSSTAB

The CROSSTAB subprogram produces a joint frequency distribution of cases according to two or more variables. A contingency analysis table displayed the distribution of cases by their position on the two variables. So, a series of 5 x 5 tables were produced where X, Y, and Z were integers as shown in the Figure 2.1. The frequencies of PRE and POST tests were recorded together, as follows:

		P	O	S	T	
		1	2	3	4	5
P	1	Z	Y	Y	Y	Y
	2	X	Z	Y	Y	Y
R	3	X	X	Z	Y	Y
	4	X	X	X	Z	Y
E	5	X	X	X	X	Z

Figure 2.1 - Crosstab table of PRE versus POST Questionnaires

Where 1=very negative; 5=very positive

The "X" indicated that the student's attitude change negatively;

The "Z" indicated that the student's response is the same in the PRE and POST test (no attitude change) and

The "Y" indicated that the student's attitude changed positively.

The CROSSTAB subprogram reduced the PRE and POST tests' results by the same individual to one set of frequencies that indicated the frequency of students who expressed a positive, negative or unchanged attitude.

iii. Subprogram CORRELATION coefficient

Although examination of the various row and column percentages in a cross-tabulation is a useful step in studying the relationship between two variables, row and column percentages do not allow for quantification or testing of that relationship. For this purpose the Pearson Product-Moment correlation coefficients, optionally available in the CROSSTAB sub program, was computed for each pair of variables in order to estimate the extent of association.

A test of significance was provided to be reported as a percentage within the accepted 1% criteria as in the subprogram cross-tabulation above.

iv. Subprogram FACTOR

The most distinctive characteristic of Factor Analysis is its data-reduction capability. An array of correlation coefficients can be examined to reveal underlying patterns or relationships and the data can be reduced to a smaller set of components which account for the observed interrelations.

The procedure which were used in the present survey involved: (i) preparation of a correlation matrix; (ii) extraction of initial factors; and (iii) rotation to a terminal solution.

The correlation coefficients were calculated using the subprogram CORRELATION and arrayed as a matrix.

v. Subprogram RELIABILITY

The subprogram RELIABILITY offered several different ways of estimating the reliability of an instrument or scale. One of the most commonly used reliability coefficient is Cronbach's Alpha which is based on the internal consistency of a test.

"BASIC" PROGRAM

A Computer program written in "Basic" language has been used to calculate the Chi-Square for **k** x **n** tables provided by Cohen & Holliday in "Statistics for Social Scientists"[78].

3.2 - CHI-SQUARE

When measurements are made on a nominal scale it is not possible to compare the performance of two groups in terms of their average or mean score, since this is clearly meaningless. All we can say about the groups is whether they differ in the proportion of subjects who come into one category rather than another.

Whenever our data consisted of frequency counts of the number of times different events occurred, the chi-square test could be used to compare the proportions of these events in two independent samples.

The chi-square is a very useful statistic in a variety of problems involving frequencies. Even if the data was truly quantitative, it is possible to convert the scores into frequencies. The quantity of chi-square being defined as:

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

Where χ^2 = Chi-Square

O = Observed frequencies

E= Expected frequencies

It is also necessary to determine the degrees of freedom **(df)** of the contingency table. The general rule-of-thumb for ascertaining the **(df)** for all contingency-type tables of rows (**k**) and columns (**l**) is:

$$df = (k-1)\ (l-1)$$

When the total number of categories or cells in the contingency table is only 4 (i.e., a table 2 x 2) then there is only one degree of freedom. The Chi-Square calculated from such data is likely to be an overestimate, and may wrongly suggest that the data is significant, unless an adjustment is made to the formula for calculating Chi-Square.

Yates' correction for lack of continuity is frequently employed to effect such an adjustment. It involves subtracting 0.5 from the numerical value of each

(O - E) quantity in the Chi-Square calculation. The corrected quantity Chi-Square is defined as:

$$\chi^2 = \sum \frac{(|O - E| - 0.5)^2}{E}$$

Three things are readily apparent from this formula:

i The greater the discrepancy relative to E, the greater the contribution to Chi-Square.

ii The parts being summated to obtain chi-square are not independent, (i.e., when the absolute discrepancy for heads is known, that for tails can be inferred to be the same); and

iii The squaring process means that chi-square is always a positive quantity regardless of the direction of the discrepancies.

When the sample size is very small, the value of chi-square cannot be meaningfully interpreted, even after Yates' correction has been made. As a rough guide, the chi-square test should not be used when one or more of the expected frequencies falls below five.

3.3 - McNEMAR CHI-SQUARE[79]

One-to-one matching is frequently used by research workers to increase the precision of a comparison. Two samples matched in a one-to-one way must be thought of as correlated rather than independent; consequently the usual Chi-Square test is not strictly applicable for assessing the differences between frequencies obtained with reference to such samples.

The appropriate test for comparing frequencies in matched samples is one derived by McNemar and the formula for testing for an association in a 2 x 2 table is:

		BEFORE +	BEFORE -
AFTER	+	A	B
AFTER	-	C	D

$$\chi^2 = \frac{(A - D)^2}{(A + D)}$$

if a correction for continuity is applied, this expression becomes:

$$\chi^2 = \frac{(|A - D| - 1)^2}{(A + D)}$$

When 1/2 of (A + D) is less than five then the McNemar test cannot be employed.

The assumptions for using the McNemar test are that the pairs of scores or observations are randomly drawn from a population and that the data are either nominal or ordinal levels of measurement.

3.4 - ZUBIN'S NOMOGRAPHS[80]

Percentages are one of the most used form for presenting survey results because they facilitate a variety of comparison. However, the statistical significance of the differences between percentages must be done using the raw frequencies and calculating the respective Chi-Square.

In 1939 Joseph Zubin developed a Nomograph for the Testing of Statistical Significance of Differences between Percentages which has the great advantage that we do not have to go back to the raw frequencies. Thus the significance of different proportions can be estimated directly from the percentage figures.

The method consists of two charts: The first chart enables us to find the "standard error" or "level of significance" which depends on the sizes of the two sample. Another chart, enables us to find whether the difference between the two percentages is significant at a certain level. The chart has, on its centre line, significance values for 1 and 5 percent levels. Thus, if we find that the difference between two percentages is significant at the 5 per cent level, it may be worthwhile checking the significance for the 1% or even for the 0.1% level.

This method is particularly helpful in survey work, in which the number of percentages to be tested for statistical significance is large. Also, where the percentages are based on sample sizes that remain stable throughout the questionnaire. After having looked up the significance value on the first chart, it is only necessary to use the second chart, unless dealing with a different set of sub-samples.

However, nomographs are somewhat lacking in precision. So that for the more important differences, where the significance levels border on the limits, further calculations ought to be carried out by another method. The same applies to instances where the sample sizes are very low.

The most helpful way to use the nomograph is to think of it as an aid to inspection, a simple device that will enables us to focus attention on the more important differences and sort the grain from the chaff.

3.5 - FACTOR ANALYSIS

Factor Analysis is a method that can be used to confirm what content a test measures and enables us to describe or predict the variables being manipulated.

This procedure, generally based on patterns of test intercorrelation, is designed to identify the traits being measured by the tests in the matrix. High intercorrelation indicates that tests converge or share in the measurements of some common trait or traits, while low intercorrelation indicates divergence or absence of some common trait.

Many of the fundamental ideas in factor analysis derive from the concept of variance. Variance is the index of dispersion of scores in a test. There are two important components of variance which account for the total variance of a test. These are Common variance and Unique Variance.

When a factor contains two or more tests with significant loadings it is referred to as a common factor and the variance of the test in that factor is know as common variance. So, common variance is the variance of two or more test that load significantly on the same factor.

Unique variance is the remaining part of the total variance of a test resulting from unique properties possessed by the test and as such would be entirely uncorrelated with the other tests in a particular analysis.

Unique variance can be broken down into two further elements of specific and error variance. Each test possesses some particular qualities which are not shared with any other test under consideration, and the variation in scores arising from these qualities will produce specific variance.

Error variance results from the imperfections of test measurement. The difference between this and the total test variance gives a measure of the reliability of the test. Unfortunately, factor analysis does not discriminate between specific and error variance, so we cannot put this knowledge to use.

In summary, the total variance(V_t) of a test made up from common variance(V_c) and unique variance(V_u) which can be broken down into specific variance(V_s) and error variance(V_e). As the variance is additive, the relationship can be expressed in its simplest form as

$$V_t = V_c + V_s + V_e$$

Communality is the sum of all common factor variance of a test, that is the variance shared in common with other tests. So, communality is the proportion of the variance of a test due to all of the factors. The communality problem in factor analysis is associated with the number of factor problems. As the communalities are adjusted, the number of factors necessary to reproduce the correlation coefficients in the off-diagonal cells can vary.

The communality of a test, h^2, is the proportion of variance shared by that test and all of the factors. In the equation above the communality would be V_c.

A loading is a product moment correlation between a test and a perfectly reliable measure of a given factor. Since a loading is a validity coefficient, the squared product-moment correlation indicates the proportion of test variance due to that particular factor.

The primary aim of factor analysis is the discovery of the common factors. The techniques for extracting the factors generally endeavour to take out as much common variance as possible in the first factor. Subsequent factors are, in turn, intended to account for the maximum amount of the remaining common variance until, hopefully, no common variance remains.

The first factor is calculated using the centroid method. Loadings are correlation coefficients between the tests and the first centroid factor. They can also be thought of as validity coefficients, i.e., correlating a test with the first factor. The principle of squaring the validity coefficient can be used to indicate the proportion of test variance predictable from or due to each factor.

Often an additional transformation of the centroid factor matrix is undertaken and it is referred to as "rotation" in factor analysis.

After the centroid factoring has been completed, this centroid factor matrix can be transformed and rotated into a new factor matrix capable of reproducing the off-diagonal elements of the correlation matrix.

Indeed, an infinite number of factor matrices could be generated that would reproduce off-diagonal elements of the correlation matrix. However, only a few of these many matrices would be psychologically meaningful.

Considerable controversy has arisen over the rotation problem in factor analysis. Those psychologists who rotate the centroid factor matrix suggest that the procedure clarifies the meaning of the factors. While those who do not rotate (or rotate only while maintaining the first factor) point to the meaningfulness of the unrotated factors. It seems that the decision to rotate or not to rotate is highly related to the question of test validity.

Generally speaking, non-rotational procedures are followed in situations in which the research hypotheses focuses on the psychological meaning of the first centroid factor.

In contrast, rotational procedures are associated with research hypotheses that focus on the psychological meaning of the grouping of tests embedded in the matrix of test intercorrelations.

For the purpose of this survey rotation procedures were adopted using the Varimax, which is one of the options on the Subprogram FACTOR - SPSS/PC+. with the main objective of validating the proposed scales.

From each of the unrotated (centroid) and rotated factor matrix related to factoring procedures, two sizes of common factors are derived; General, Bipolar, Group, and Specific factors.

The General Factor has moderate to high loadings for all tests by definition. The squared loadings for each test indicates the substantial involvement of that factor in all tests. The general factor is usually found as the first factor in the unrotated centroid factor matrix, and can be used to identify the common element involved in all of the test.

The Bipolar Factor has a different pattern; it has both high positive and high negative loading. It can be thought of as representing a psychological continuum with tests of high positive loadings on one end of the continuum and high negative loadings on the other. The second factor in an unrotated centroid of a bipolar factor matrix is usually a bipolar factor.

The Group Factor is the one in which a group of tests has high loadings, but at least one test has a near-zero or zero loading, that is, a group of tests, but not all tests, has substantial variance accounted for by that factor. Group factors often emerge from the transformation of the centroid factor matrix into the rotated factor matrix. Often several group factors occur in the analysis.

The Specific Factor is one where only one test has high loading on a particular factor

In summary, a general factor has substantial loading on all tests. A bipolar factor has both high positive and high negative loadings. A group factor has high loadings on two or more tests, and has at least one zero loading and the Specific Factor has only one test with high loading.

The criteria for the number of factors to be extracted was guided chiefly by experience in adopting particular criteria, although some methods depended for their justification on mathematical interpretation. A technique in considerable use at present is Kaiser's criterion where only the factors with a latent root greater than one are considered as common factors.

Cattell[81] has suggested that Kaiser's criterion is probably most reliable when the number of variables is between 20 and 50. Where the number of variables is less than 20, there is a tendency for this method to extract a conservative number of factors. When the number of factors is more than 50 too many are taken out. He described a method whereby a graph is plotted of latent roots against the factor numbers in the order of extraction and the shape of the resulting curve was then employed to decided the cut-off point.

The Significance level of factor loadings can be calculated using the Burt and Banks'[82] formula. This gives an idea of the changes in loading values when corrections are applied to the standard error of a correlation coefficient. The formula is:

$$r = r_0 \sqrt{\frac{N}{(N + 1 + f)}}$$

Where: **r** = Standard error of a loading factor
$\mathbf{r_0}$ = Standard error of a correlation
N = the number of variables(items) in the analysis; and
f = the factor number, that is the position of the factor during extraction

The standard error of a correlation is the significance level for Pearson Product-Moment Correlation Coefficients.

3.6 - PEARSON CORRELATION COEFFICIENT

Correlation is a study of similarity or agreement. The correlation between two sets of marks, for instance, is simply the extent which they are similar in the extent to which they agree. Coefficients of correlation are such that they can range in value from -1 to +1. The extreme of +1 represents perfect agreement, while the extreme -1 represents the opposite, perfect disagreement. Intermediate values represent imperfect agreement or disagreement, except for the 'half-way' value of zero, which would represent the complete absence of both agreement and disagreement.

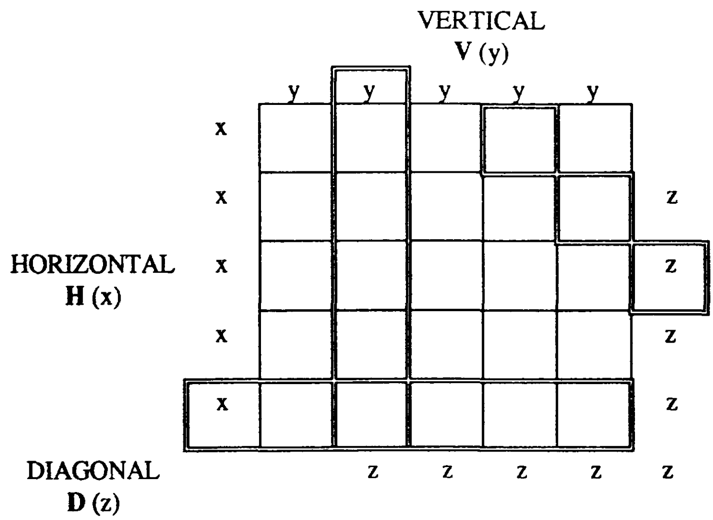
To calculate the correlation coefficient the differences in means are irrelevant in assessing the extent of agreement and the differences in dispersion are irrelevant in correlation. The formula for calculating the product moment correlation directly from scores is:

$$r_{xy} = \frac{S'_{xy}}{\sqrt{S'^2_x \cdot S'^2_y}}$$

where r_{xy} = Pearson product moment correlation of x and y sets of marks; and

S' = Corrected sum of products of square of variables (x, y and xy)

Procedure with grouped data[83] - for a large list of marks, the calculation of **r** could prove very laborious, even if full use were made of coding, unless one had access to a computer. The calculation could be made considerably easier, however, by grouping the marks in a scattergram or correlation grid. The scattergram gives the grouped frequencies for the sets of marks. It is these frequencies which provide the corrected sums of squares. The Pearson coefficient of correlation, r, can be calculated as follows:



$$r = \frac{\mathbf{H} + \mathbf{V} + \mathbf{D}}{2 \,.\, \sqrt{\mathbf{H} \,.\, \mathbf{V}}}$$

where **H** = $S'_x 2$ - horizontal frequency of score

V = $S'_y 2$ - vertical frequency of score

D = S'_z - diagonal frequency of score

It is as well to realize, however, that a correlation calculated correctly from a scattergram can still be slightly inaccurate as a value for the correlation between the original scores. This is because the scattergram is formed from grouping scores, and the actual value of the scores is thus replaced by the group mid-points.

If the total number of scores is large and the grouping is not too coarse, i.e., the group intervals are small in relation to the complete range of scores, the inaccuracy is only slight.

4 - RELIABILITY

The reliability of a Test or instrument is the extent to which it gives consistent results when applied by different persons on different occasions. In other words, it is the extent to which test scores are free from chance errors. As a consequence of the different ways of distinguishing between a true score and an error there is more than one way of measuring the reliability. The four main methods of estimating reliability of tests are:

1. Test - re-test reliability - A group of students is given a test and after a set time interval they take the same test again. The correlation coefficient between the two sets of scores are determined. This coefficient could also be described as a coefficient of stability, measuring stability over time. The time interval should be sufficiently long to reduce, if not eliminate, memory effects and yet not so long that the interest or abilities of the group change through intermediate learning.
2. Parallel form reliability (or equivalent) involves a group of students taking a test. The same group takes another test after an interval of time which is designed to sample the same behaviour as the first test. The correlation between the two sets of test results is then determined. This is the equivalent form method of determining reliability. It could be used either with or without a time interval between administering the two forms.
3. Internal consistency reliability - A group of students is given a test once. The items which make up the test are divided into two equal sets say odd and even numbered items. This is similar to the equivalent method without a time interval, in that all the testing takes place on one occasion. If only one form of the test exists, then this can be split into two halves - the halves being, if possible, equivalent 'half-test' and the scores on each half computed separately. The correlation between the half-tests then provides a measure of the reliability of the whole test.
4. Kuder-Richardson method is based on the consistency method of performance on the separate items. For non dichotomous items the calculation is done using the variance for each item. Generally, the Kuder-Richardson coefficient may regarded as the average of the split-half coefficients obtained by splitting the test in all possible ways. The more homogeneous the test content, or the more the items correlate with each other, the higher will be the coefficient.

Error variance, which detracts from reliability, is usually present in instruments and may result from the measuring procedure used, the variable condition of the student, the circumstances, seldom identical, under which the instruments were applied and finally the difference which may arise due to different judgements. An attempt has been made to reduce the effect of error variance here by using a large sample of students in the experimental group and by including a control group.

The present survey was developed in a six week period with several variables being controlled at once. So, due to the large number of instruments applied the first two method described above were not used because this would have involved increasing the number of instruments answered by each student.

The internal consistency method seemed to us the most appropriate for this survey. Also the SPSS/PC+ software offered several subprogram to calculate the coefficient.

5 - VALIDITY

The validity of an instrument is regarded as the extent to which it measures what it is intended to measure. In other words, it tells us whether the question or item really measures what it is supposed to measure. Validity is a wider and more general concept than reliability. It is not as straightforward as it appears to be. An instrument cannot have a high validity without a corresponding high reliability. On the other hand, a high reliability is not in itself a guarantee of high validity.

There are two main categories into which validity measurements can be broadly grouped:

i Procedures which involve the direct scrutiny and analysis of test and examinations by experts; and

ii Procedures which depend upon the statistical comparison of tests and examination results with scores obtained from an independent test.

Validity can be broken down further into five different types:

1. Content validity is displayed when the test administered consists of a suitable sample of the course covered by the students. Our questions dealt with work which was representative of the syllabus or lesson recognising that content validity required careful sampling to be acceptable.
2. Predictive validity, as the name implies, is the means whereby the examination provides a clear pointer to the student's future success. Scottish '"Higher" qualifications have had this predictive validity imposed on them and are used to sift applicants for employment, further, and higher education. The correlation between examination performance and later performance, say at university, is one measure of predictive validity.
3. Concurrent validity sometimes it is useful to have the results of two tests correlated to find out how they compare, say one is an established test and the other a trial

test. If the correlation coefficient is high then the trial test may take its place alongside the established one.

4. Construct validity - A "construct" is a personal quality associated with a certain aspect of behaviour, e.g., a construct could be intelligence, sensitivity, a particular attitude. These constructs cannot be directly observed; their existence is inferred from the behaviour of the pupil. There are tests which are intended to measure such construct, not directly, but indirectly. Factor Analysis is a systematic method of studying test intercorrelations.

5. Face validity results from a superficial evaluation of a test, and credibility is given to a test which may, indeed, be suspect. With attitude scales there may be important differences between what a test appears to be measuring (face validity) and what it is, in fact, measuring as established by comparison with other tests which are known to display concurrent and construct validity. To accept face validity of an attitude test is however told to be an unwarranted practice.

CHAPTER 3

THE PRELIMINARY SURVEY

The purpose of this preliminary survey was to identify key problems in the first year inorganic chemistry practical course at Glasgow University - our eventual aim being to resolve these by restructuring the course. This required prior study of the existing six week course making observations, gathering relevant information and discussing any problem with the technical and academic staff, who gave their full co-operation and support. It was thought to be advisable to find out the problems of the course through the eyes of students, demonstrators and staff, recording their opinions and suggestions on perceived deficiencies.

At Glasgow University there was no possibility of ever planning the practical course without considering the existing framework involving technical and academic staff.

We focussed upon two main areas in these preliminary survey, i.e.

i The organisation of the Laboratory - e.g. chemicals, apparatus, equipment and their location in the laboratory; and

ii The written Instructions (Manual) - e.g. the vocabulary used, the amount of information, its clarity, and helpfulness.

1 - FIRST YEAR LABORATORY COURSE

The first year inorganic practical course at Glasgow University is attended each year by approximately four hundred undergraduate students from a variety of different degree courses in which chemistry is a course component. These students come from various secondary schools, and therefore have differing experience and knowledge of chemistry.

1.1 - LABORATORY'S ORGANISATION

The inorganic practical course was held in the Chemistry Department in a laboratory with a capacity of 110 students per class. The four hundred enrolled students were scheduled to attend in five class from Monday to Friday of approximately 80 students per class of 3 hours duration - each student has 3 hours of lab work per week.

The lab sessions were supervised by 2 members of the academic staff, 5 demonstrators (post-graduate students) and 1 technician.

Each student was given a station at the bench equipped with an apparatus kit containing personal and communal items. The communal items was shared with 4 other students.

The chemicals needed for the experiments were placed on the benches A and B and in the FUME CUPBOARDS as indicated in the lab map (see Appendix A-1 - page 248). The rough balances were placed beside the chemicals on benches A and B and the analytical balances in a special room at one end of the lab. Other apparatus such as filter paper, litmus paper etc. were placed on bench C.

On the first lab day, the staff explained the safety precautions which have to be observed in the lab, stressing the need to keep the equipment and the lab in good order. The students were then asked to do experiments 1; 2; 3 or 4, i.e. only twenty students would do the same experiment simultaneously in any session. Once the experiment was finished and lab reports marked by the demonstrator, a staff member would allocate the next experiment with regard to the lab's physical capacity.

1.2 - MANUAL

The student's manual on the Inorganic Chemistry practical course had two main parts: the INTRODUCTION and the EXPERIMENTAL PROCEDURES sections.

The Introduction contained instruction on safety and laboratory practice, how to keep laboratory notebooks, what lab techniques were in use, e.g. use of rough and analytical balances, volumetric techniques, the procedure for balancing redox equations, water-solubility of some inorganic compounds, the colours of some inorganic ions and qualitative tests for oxygen and chlorine.

The second part contained the following EXPERIMENTAL PROCEDURES:

Experiment 1 - INORGANIC PYROTECHNICS - illustrating two solid state redox reactions and how to calculate their percentage yield.

Experiment 2 - CHEMISTRY OF THE HALOGENS - illustrating five series of reactions on halogen compounds comparing the reactions within each series.

Experiment 3 - IODIMETRY - The preparation of a standard solution of sodium thiosulphate by titration with iodine.

Experiment 4 - ACID-BASE TITRATIONS - The preparation of standard solutions of Sodium Hydroxide and Hydrochloric Acid.

Experiment 5 - PREPARATION AND ANALYSIS OF A THIOUREA COPPER(I) COMPLEX - The preparation of a copper(I) complex and its analysis by iodimetry titration. It is an application of the techniques learned in experiment 3.

Experiment 6 - PREPARATION AND ANALYSIS OF $K_3[Cr(C_2O_4)_3].3H_2O$ - The preparation of a chromium(III) complex and its analysis by titration - a quantitative experiment that has titration as its basis.

Two versions of written instructions were utilised by the students. VERSION 1 (or OLD VERSION) that had been used till the first term of 1986 and VERSION 2 (or NEW VERSION) that had been designed according to Letton's[2] findings in a survey done in the second year course and used in 1987. The content of these versions was however the same.

A full set of both manuals is included in the Appendices A-2 (from pages 240 to 69) and A-3 (from pages 270 to 287)

Table - 3.1 shows how the versions of written instructions were used (alternating between OLD and NEW) by the students. On Monday and Wednesday experiments 1, 3 and 5 were done with the OLD versions of the Manual and experiments 2, 4 and 6 with the NEW one. On Tuesday and Thursday this was reversed.

On Friday only the NEW version was used but students were asked to solve a practical problem at the end of each experiment.

	SESSIONS				
EXPERI-MENTS	**MONDAY**	**TUESDAY**	**WEDNESDAY**	**THURSDAY**	**FRIDAY**
	Version	version	version	version	version
EXPER.1	OLD (1)	NEW (2)	OLD (1)	NEW (2)	NEW (2)
EXPER.2	NEW (2)	OLD (1)	NEW (2)	OLD (1)	NEW (2)
EXPER.3	OLD (1)	NEW (2)	OLD (1)	NEW (2)	NEW (2)
EXPER.4	NEW (2)	OLD (1)	NEW (2)	OLD (1)	NEW (2)
EXPER.5	OLD (1)	NEW (2)	OLD (1)	NEW (2)	NEW (2)
EXPER.6	NEW (2)	OLD (1)	NEW (2)	OLD (1)	NEW (2)

Table 3.1- Experiments and Manual Versions used by the students

The aim in alternating experiments between OLD and NEW written instruction was to allow students to use and to compare them by the end of the course.

To avoid any bias students were simply told that the two kind of written instructions were being compared. They were given no indication as to which was the "OLD" one and which was the "NEW" one. The sheets were referred to as the "Manual" or "Worksheet" throughout the course.

2 - ASSESSMENT

The students were asked to respond to a set of questionnaires as shown in the Table 3.2. A Demonstrators' Diary, as the name suggests, was completed by the Demonstrators.

The questionnaires were printed using different colours for each session to facilitate administration and to avoid mixing anonymous responses - students having been given the option of not identifying themselves.

The number of questionnaires answered by each student during the six week course was the same in each lab session. Diary-ONE was applied on Mondays and Tuesdays sessions and diary-TWO was applied on Wednesdays and Thursdays in order to avoid overloading students.

	SESSION				
	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
Instrument's colour	white	blue	yellow	pink	green
PRE QUESTIONNAIRE	YES	YES	YES	YES	YES
DIARY-1 / LAB ORGANISATION	YES	YES	-	-	-
DIARY-2 /WRITTEN INSTRUCTION	-	-	YES	YES	-
PRACTICAL PROBLEM-SOLVING QUESTIONNAIRE	-	-	-	-	YES
POST QUESTIONNAIRE	YES	YES	YES	YES	YES
DEMONSTRATOR'S DIARIES	YES	YES	YES	YES	YES

Table 3.2 - Instruments used in the assessment

The Instruments mentioned in the Table 3.2 will be discussed later in this chapter. See sections 2.2, 2.3, 2.4 and 3.

2.1 - DATA ANALYSIS

The data gathered by this survey was classified as non-quantitative or partly quantitative. For example, the non-quantitative (nominal scales) included data on the OLD and NEW versions of the written instructions; the sub-samples HGRD; SYS and OTHER.

The partly quantitative (ordinal scales) included the Semantic Differential or Likert scale questions by which frequencies were used to compare the responses to the questionnaires.

We compared the PRE and POST questionnaires in two ways:

i Response frequencies and percentages for each question were used to compare the samples and sub-samples and to calculate Chi-Square to determine whether the difference between them was statistically significant. The raw frequencies were also used to estimate a Level of Agreement (%DIFF) used to draw a bar chart and facilitate comparisons of the variables.

The level of agreement was based on the difference of positive and negative response percentages (ignoring the neutral ones). The positive group combined categories 1 and 2, the negative combined of categories 4 and 5, with the category 3 being the neutral one.

ii Using the computer software, Statistical Package for Social Science (SPSS/PC+), cross-tabulations were produced for the PRE and POST questionnaires' questions to determine the frequency of students who either changed their opinion positively or changed negatively or had not changed.

The frequency of positive change was equal to the number of student who had changed their opinion positively by at least one level from PRE to POST. The frequency of negative change was the opposite, and no change was when the student in the PRE and POST questionnaire answered in the same categories.

The Level of Attitude change used to draw charts was the difference of percentages between positive and negative change.

2.2 - PRE and POST QUESTIONNAIRE

The PRE questionnaire objective was to find out what the students thought about their previous laboratory experience, and if they had any experience of practical work at secondary school. Hence, in the first part the student answered the following questions:

1. What is your HIGHEST qualification in chemistry?
2. How many years of secondary schooling did you complete?
3. In your previous laboratory work have you experienced practical work which was done (tick more than one if required) INDIVIDUALLY; IN SMALL GROUPS; OR BY TEACHER DEMONSTRATION?

SEMANTIC DIFFERENTIAL QUESTIONNAIRE

In the second part a five point scale between opposite adjective pairs was offered to the students to state their opinion about any previous practical work they had experienced. For example:

1.	MEANINGFUL	_ _ _ _ _	MEANINGLESS
2.	DIFFICULT	_ _ _ _ _	EASY
3.	WASTE OF TIME	_ _ _ _ _	USEFUL
4.	ENJOYABLE	_ _ _ _ _	UNENJOYABLE
5.	FRUSTRATING	_ _ _ _ _	SATISFYING
6.	INTERESTING	_ _ _ _ _	BORING
7.	CONFUSING	_ _ _ _ _	UNDERSTANDABLE
8.	VARIED	_ _ _ _ _	REPETITIVE
9	ADEQUATE WRITTEN INSTRUCTIONS	_ _ _ _ _	INADEQUATE WRITTEN INSTRUCTIONS
10.	RUSHED	_ _ _ _ _	LEISURELY
11.	WELL-ORGANISED	_ _ _ _ _	DISORGANISED

The Post questionnaire objective was to find out whether the students opinion changed after the six week course. It contained the second part of the PRE questionnaire, i.e. the semantic differential questions and the students answered it during the last week of the course.

The PRE and POST Questionnaire are included in Appendices A-4 (page 288) and A-5 (page 289) respectively.

2.2.1 - PRE and POST QUESTIONNAIRES RESULTS

The five sessions of the practical course had a total of 403 students. According with question-1, 55% had completed the Higher Grade examination (HGRD) and 33% had gone on to complete their Sixth Year Studies (SYS). Any different qualification from these was classified as OTHER (12%).

The same analysis was done grouping together Monday and Tuesday session; Wednesday and Thursday session; Friday session was taken independently. Laboratory sessions were grouped according to the instruments applied and the activity developed (See Table 3.2). The proportion of students in HGRD, SYS and OTHER sub-samples were approximately the same - indicating that the samples were equivalent as shown in Table 3.3.

1.WHAT IS YOUR HIGHEST QUALIFICATION IN CHEMISTRY?				
Instrument	DIARY-1	DIARY-2	PPS(*)	
sessions	MON+TUE	WED+THU	FRI	GLOBAL
HGRD(**)	86 (54%)	94 (58%)	40 (50%)	220 (55%)
SYS(***)	56 (35%)	52 (32%)	24 (30%)	132 (33%)
OTHER	18 (11%)	17 (10%)	16 (20%)	51 (12%)
TOTAL	160	163	80	403

(*)PPS=Practical Problem-solving (**)HGRD=Higher Grade (***)SYS=Sixth Year Studies

Table - 3.3 - PRE QUESTIONNAIRE - PART I - QUESTION 1

The Post questionnaire was answered by 75% of the population as shown in Table 3.4. The proportion of students in each sample and sub-samples was approximately the same as that for the PRE questionnaire. In this survey only the students who had answered both PRE and POST questionnaires were computed in the analysis to allow examination of Attitude Changes over the period of the course.

SESSIONS				
	MON+TUE	WED+THU	FRIDAY	GLOBAL
HGRD	68 (54%)	74 (62%)	26 (46%)	168 (56%)
SYS	48 (38%)	35 (29%)	18 (32%)	101 (34%)
OTHER	10 (8%)	10 (9%)	12 (21%)	32 (10%)
TOTAL	126	119	56	301

Table - 3.4 - Number of students who answered the POST-QUESTIONNAIRE

Question two asked how many years of secondary schooling the student had completed. We found that 69% had completed six years; 22% five years and 9% were classified as OTHER because they did not fit the first two categories.

Table 3.5 shows the results of question two for the three sample Monday plus Tuesday sessions; Wednesday plus Thursday sessions and Friday sessions and their sub-sample HGRD (Higher); SYS; and OTHER.

As might have been expected 98% of the SYS sub-group had completed six years of secondary school. Interestingly 58% of the HGRD sub-group had completed six years; 34% five years and 8% fell into the OTHER category.

Thus we found that a considerable number of students had completed the Higher Grade (HGRD) in six years of secondary schooling, over half our sample. However, their background knowledge in chemistry cannot be compared with the SYS students. Most if not all students presented for Sixth Year Studies in Scottish Schools have successfully completed the Higher Grade. Then the SYS students have both qualifications. Another difference between them is concerned to the curriculum, while the SYS curriculum is project based with students working independently and in depth on a particular topic, the sixth year HGRD group follow the same traditional curriculum of the secondary school fifth year. Rather than preparing for university these students are usually seeking to improve grades to secure a place in university. Ironically SYS grades rarely have the same weight as good higher grades in entry competition.

2.HOW MANY YEARS AT SECONDARY SCHOOLING DID YOU COMPLETED?

MON+TUE / DIARY-1				
	HGRD	SYS	OTHER	GLOBAL
SIX YEARS	58 (67%)	55 (98%)	6 (33%)	119 (74%)
FIVE YEARS	22 (26%)	0 (0)	4 (22%)	29 (18%)
OTHER	6 (7%)	1 (2%)	8 (44%)	12 (8%)
TOTAL	86	56	18	160

WED+THU / DIARY-2				
	HGRD	SYS	OTHER	GLOBAL
SIX YEARS	43 (46%)	52 (100%)	9 (53%)	104 (64%)
FIVE YEARS	42 (45%)	0 (0)	2 (12%)	44 (27%)
OTHER	9 (9%)	0 (0)	6 (35%)	15 (9%)
TOTAL	94	52	17	163

FRIDAY / PRACTICAL PROBLEM SOLVING (PPS)				
	HGRD	SYS	OTHER	GLOBAL
SIX YEARS	26 (65%)	23 (96%)	7 (44%)	56 (70%)
FIVE YEARS	11 (28%)	0 (0)	4 (25%)	15 (19%)
OTHER	3 (7%)	1 (4%)	5 (31%)	9 (11%)
TOTAL	40	24	16	80

GLOBAL RESULTS				
	HGRD	SYS	OTHER	GLOBAL
SIX YEARS	127 (58%)	130 (98%)	22 (43%)	279 (69%)
FIVE YEARS	75 (34%)	0 (0)	10 (20%)	88 (22%)
OTHER	18 (8%)	2 (2%)	19 (37%)	36 (9%)
GLOBAL	220	132	51	403

Table - 3.5 - Pre-Questionnaire - Part I - QUESTION 2

Responses to question three provided some evidence of the students experience of practical work at secondary school (the results are summarised in the Table 3.6).

The comparison between our samples(Mon+Tue; Wed+Thu; and Fri) revealed that there was no significant difference. However, significant differences were found between the sub-samples HGRD and SYS with the latter having experienced practical work in a more individual mode than the HGRD students.

3.IN YOUR PREVIOUS LABORATORY WORK HAVE YOU EXPERIENCED PRACTICAL WORK WHICH WAS DONE:- (tick more than one if required)

MON+TUE / DIARY-1				
	HGRD	SYS	OTHER	GLOBAL
INDIVIDUALLY	28 (32%)	48 (54%)	12 (14%)	88
IN SMALL GROUPS	79 (58%)	45 (33%)	13 (9%)	137
BY TEACHER DEMONSTRATIONS	59 (58%)	31 (31%)	11 (11%)	101

WED+THU / DIARY-2				
	HGRD	SYS	OTHER	GLOBAL
INDIVIDUALLY	31 (34%)	47 (52%)	13 (14%)	91
IN SMALL GROUPS	79 (60%)	40 (31%)	12 (9%)	131
BY TEACHER DEMONSTRATIONS	68 (60%)	34 (30%)	12 (10%)	114

FRIDAY / PRACTICAL PROBLEM				
	HGRD	SYS	OTHER	GLOBAL
INDIVIDUALLY	11 (26%)	21 (48%)	11 (26%)	43
IN SMALL GROUPS	37 (54%)	20 (29%)	12 (17%)	69
BY TEACHER DEMONSTRATIONS	28 (57%)	13 (27%)	8 (16%)	49

Table - 3.6 - PRE-Questionnaire - Part I - Question 3

Given these differences in our samples characteristics it is possible to compare PRE and POST Questionnaires responses.

The raw frequencies of recorded responses for the PRE and POST questionnaires are presented in Table 3.7, the frequencies of attitude change obtained by cross-tabulation are shown in Table 3.8. To facilitate a comparison between the questions employed in the PRE and POST questionnaires, the positive adjectives will be presented all on the same side, i.e., left hand column as follows.

However in the questionnaire the polarity of these adjectives was changed to encourage the students to respond in a more thoughtful way.

1-MEANINGFUL
2-EASY
3-USEFUL
4-ENJOYABLE
5-SATISFYING
6-INTERESTING
7-UNDERSTANDABLE
8-VARIED
9-ADEQUATE WRITTEN INSTRUCTIONS
10-LEISURELY
11-WELL-ORGANISED

PRE versus POST QUESTIONNAIRES

Q - 1	MEANINGFUL	UNDECIDED	MEANINGLESS	% DIFF	HG vsSYS	
HGRD	98 (69)	31 (22)	13 (9)	60		PRE
	88 (62)	43 (30)	11 (8)	54		POST
SYS	66 (80)	12 (15)	5 (6)	73	5%	PRE
	52 (63)	25 (30)	6 (7)	55		POST
GLBL	178 (73)	47 (19)	20 (8)	65	1%	PRE
	149 (61)	76 (31)	20 (8)	53		POST

Q - 2	EASY	UNDECIDED	DIFFICULT	% DIFF	HGvsSYS	
HGRD	46 (32)	65 (46)	31 (22)	10	5%	PRE
	26 (18)	75 (53)	41 (29)	-11		POST
SYS	22 (27)	44 (53)	17 (20)	6		PRE
	28 (34)	34 (41)	21 (25)	8		POST
GLBL	74 (30)	120 (49)	51 (21)	9		PRE
	61 (25)	117 (48)	67 (27)	-2		POST

Q - 3	USEFUL	UNDECIDED	WASTE OF TIME	% DIFF	HGvsSYS	
HGRD	105 (74)	26 (18)	11 (8)	66		PRE
	96 (68)	30 (21)	16 (11)	56		POST
SYS	70 (84)	11 (13)	2 (2)	82	1%	PRE
	49 (59)	21 (25)	13 (16)	43		POST
GLBL	192 (78)	39 (16)	14 (6)	73	1%	PRE
	157 (64)	58 (24)	30 (12)	52		POST

Q - 4	ENJOYABLE	UNDECIDED	UNENJOYABLE	% DIFF	HGvsSYS	
HGRD	93 (65)	29 (20)	20 (14)	51		PRE
	82 (58)	32 (23)	28 (20)	38		POST
SYS	61 (73)	13 (16)	9 (11)	63	1%	PRE
	41 (49)	30 (36)	12 (14)	35		POST
GLBL	167 (68)	44 (18)	34 (14)	54	1%	PRE
	134 (55)	68 (28)	43 (18)	37		POST

Q - 5	SATISFYING	UNDECIDED	FRUSTRATING	% DIFF	HGvsSYS	
HGRD	60 (42)	52 (44)	20 (14)	28	1%	PRE
	40 (28)	57 (40)	45 (32)	-4		POST
SYS	39 (47)	27 (33)	17 (20)	27	1%	PRE
	19 (23)	42 (51)	21 (25)	-2		POST
GLBL	106 (43)	100(41)	39 (16)	27	1%	PRE
	65 (27)	108(44)	71 (29)	-2		POST

Q - 6	INTERESTING	UNDECIDED	BORING	% DIFF	HGvsSYS	
HGRD	102 (72)	25 (18)	15 (11)	61		PRE
	93 (65)	38 (27)	11 (8)	58		POST
SYS	66 (80)	12 (14)	5 (6)	73	1%	PRE
	48 (58)	20 (24)	15 (18)	40		POST
GLBL	181 (74)	43 (18)	21 (9)	65	1%	PRE
	151 (62)	63 (26)	31 (13)	49		POST

Table 3.7 (A) - Frequencies of responses of PRE and POST Questionnaires Monday to Thursday

Q - 7	UNDERSTAND-ABLE	UNDECIDED	CONFUSING	% DIFF	HG vs SYS	
HGRD	76 (54)	44 (31)	22 (15)	38	5%	PRE
	58 (41)	50 (35)	34 (24)	17		POST
SYS	45 (54)	20 (24)	17 (20)	34		PRE
	41 (49)	32 (39)	10 (12)	37		POST
GLBL	134 (55)	69 (28)	41 (17)	38	5%	PRE
	110 (45)	90 (37)	45 (18)	27		POST

Q - 8	VARIED	UNDECIDED	REPETITIVE	% DIFF	HGvsSYS	
HGRD	81 (57)	36 (25)	25 (18)	39		PRE
	67 (47)	38 (27)	37 (26)	21		POST
SYS	53 (64)	22 (27)	8 (10)	54		PRE
	52 (63)	16 (19)	15 (18)	45		POST
GLBL	141 (58)	64 (26)	40 (16)	41		PRE
	128 (52)	60 (24)	57 (23)	29		POST

Q - 9	ADEQUATE WRITTEN INSTRUCTION.	UNDECIDED	INADEQUATE WRITTEN INSTRUCTION.	% DIFF	HG vs SYS	
HGRD	65 (46)	36 (25)	41 (29)	17	1%	PRE
	93 (65)	25 (18)	24 (17)	49		POST
SYS	55 (66)	18 (22)	10 (12)	54		PRE
	51 (61)	23 (28)	9 (11)	51		POST
GLBL	130 (53)	60 (24)	55 (22)	31	5%	PRE
	156 (64)	53 (22)	36 (15)	49		POST

Q - 10	LEISURELY	UNDECIDED	RUSHED	% DIFF	HGvsSYS	
HGRD	30 (21)	38 (27)	74 (52)	-31		PRE
	36 (25)	52 (37)	54 (38)	-13		POST
SYS	27 (33)	32 (39)	24 (29)	4		PRE
	24 (29)	35 (42)	24 (29)	0		POST
GLBL	62 (25)	77 (31)	106 (43)	-18		PRE
	65 (270	98 (40)	82 (33)	-7		POST

Q - 11	WELL-ORGANISED	UNDECIDED	DIS-ORGANISED	% DIFF	HG vs SYS	
HGRD	63 (44)	47 (33)	32 (23)	22		PRE
	74 (52)	45 (32)	23 (16)	36		POST
SYS	47 (57)	19 (23)	17 (20)	36		PRE
	44 (53)	24 (29)	15 (18)	35		POST
GLBL	120 (49)	75 (31)	50 (20)	29		PRE
	128 (52)	77 (31)	40 (16)	36		POST

Table 3.7 (B) - Frequencies of responses of PRE and POST-Questionnaires Monday to Thursday

CROSS TABULATION OF PRE versus POST QUESTIONNAIRES

		MON+TUE+WED+THU - DIARIES				FRIDAY - MP			
	DEG	POSITIVE CHANGE	NO CHANGE	NEGATIVE CHANGE	% DIFF	POSITIVE CHANGE	NO CHANGE	NEGATIVE CHANGE	% DIFF
1	HGRD	35 (25)	60 (42)	47 (33)	-8.5	4 (15)	18 (69)	4 (15)	0
	SYS	13 (16)	25 (30)	46 (55)	-39.3	4 (22)	11 (61)	2 (11)	11
	GLBL	52 (21)	107 (44)	85 (35)	-13.5	9 (16)	36 (64)	10 (18)	-1.7
2	HGRD	26 (18)	62 (44)	54 (38)	-19.7	3 (12)	11 (42)	12 (46)	-34.6
	SYS	24 (29)	38 (45)	21 (25)	3.6	4 (22)	8 (44)	6 (33)	-11.1
	GLBL	55 (22)	108 (44)	81 (33)	-10.7	10 (18)	24 (43)	22 (39)	-21.5
3	HGRD	32 (23)	59 (42)	50 (35)	-12.7	5 (19)	15 (58)	6 (23)	-3.8
	SYS	9 (11)	38 (45)	35 (42)	-31.0	3 (17)	8 (44)	7 (39)	-22.2
	GLBL	41 (17)	106 (43)	94 (38)	-21.7	10 (18)	26 (46)	20 (36)	-17.9
4	HGRD	31 (22)	52 (37)	59 (42)	-19.7	6 (23)	8 (31)	12 (46)	-23.1
	SYS	14 (17)	34 (41)	35 (42)	-25.0	1 (6)	6 (33)	11 (61)	-55.6
	GLBL	49 (20)	96 (39)	99 (40)	-20.5	7 (13)	18 (32)	31 (55)	-42.9
5	HGRD	27 (19)	48 (34)	67 (47)	-28.2	5 (19)	9 (35)	12 (46)	-26.9
	SYS	17 (20)	30 (36)	36 (43)	-22.6	5 (28)	6 (33)	6 (33)	-5.6
	GLBL	47 (19)	87 (36)	110 (45)	-25.8	11 (20)	20 (36)	24 (43)	-23.2
6	HGRD	40 (28)	55 (39)	47 (33)	-4.9	5 (19)	14 (54)	7 (27)	-7.7
	SYS	10 (12)	36 (43)	38 (45)	-33.3	2 (11)	8 (44)	7 (39)	-27.8
	GLBL	52 (21)	101 (41)	92 (38)	-16.4	8 (14)	28 (50)	19 (34)	-20.9
7	HGRD	27 (19)	50 (35)	65 (46)	-26.8	3 (12)	11 (42)	12 (46)	-34.6
	SYS	26 (31)	32 (38)	25 (30)	1.2	2 (11)	10 (56)	6 (33)	-22.2
	GLBL	60 (25)	86 (35)	98 (40)	-15.6	7 (13)	27 (48)	22 (39)	-26.8
8	HGRD	23 (16)	51 (36)	58 (41)	-24.6	4 (15)	9 (35)	13 (50)	-34.6
	SYS	23 (27)	36 (43)	25 (30)	-2.4	5 (28)	6 (33)	6 (33)	-5.6
	GLBL	63 (26)	93 (38)	88 (36)	-10.2	9 (16)	21 (38)	25 (45)	-28.5
9	HGRD	71 (50)	39 (28)	32 (23)	28	11 (42)	11 (42)	4 (15)	26.9
	SYS	28 (33)	24 (29)	30 (36)	-2.4	2 (11)	11 (61)	5 (28)	-16.7
	GLBL	106 (43)	69 (28)	68 (28)	16	18 (32)	25 (46)	13 (23)	8.9
10	HGRD	59 (42)	43 (30)	40 (28)	13	10 (39)	7 (27)	9 (35)	3.8
	SYS	26 (31)	25 (30)	32 (38)	-7.1	5 (28)	10 (56)	3 (17)	11.0
	GLBL	91 (37)	76 (31)	77 (31)	5.7	20 (36)	18 (32)	18 (32)	3.6
11	HGRD	57 (40)	48 (34)	37 (26)	14	8 (31)	7 (27)	11 (42)	-11.5
	SYS	25 (30)	30 (36)	28 (33)	-3.6	5 (28)	7 (39)	5 (28)	0
	GLBL	89 (36)	81 (33)	74 (30)	6.1	13 (23)	17 (30)	25 (45)	-21.4

Table 3.6 - Cross-tabulation of PRE versus POST - Questionnaires

Three charts were drawn comparing the Level of Agreement of the PRE and POST questionnaire (i.e. shown in Figure 3.1, Chart (A) Global sample; chart (B) HGRD sub-sample; and chart (C) SYS sub-sample). It is clearly indicated that the students' opinions about the six week practical course were very negative. The Global analysis indicates that the practical inorganic course was **LESS**: MEANINGFUL; EASY, USEFUL; ENJOYABLE; SATISFYING; INTERESTING; and UNDERSTANDABLE than their previous experience at secondary school. Only in two aspects were the students' opinion positive compared with their previous experience: ADEQUATELY WRITTEN INSTRUCTION (results were statistically significant) and WELL-ORGANISED (not statistically significant). From questions 1 to 7 the levels of agreement were negative and the difference between PRE and POST were all statistically significant at either the 1% or 5% level.

2.2.2 - COMPARISON BETWEEN HGRD and SYS

Figure 3.1 (B) and (C) compares the level of agreement for the HGRD and SYS sub-samples for the PRE and POST questionnaires. It is evident that the difference between PRE and POST results is more significant in the SYS sub-sample than in the HGRD one.

It shows that the HGRD students considered the practical inorganic chemistry course **LESS:** 2. EASY; 5. SATISFYING; and 7. UNDERSTANDABLE than their previous secondary school experience. ADEQUATELY WRITTEN INSTRUCTION was the only statistically significantly positive finding with regard to students' opinions of the first year practical course.

The SYS students considered the course **LESS:** 3. USEFUL; 4. ENJOYABLE, 5. SATISFYING, and 6. INTERESTING than their secondary school course. Other questions were not statistically significant but most translate a preference in favour of students pre university experience.

The significant difference between the HGRD and SYS sub samples indicates clearly that the SYS students were more disappointed with the practical course than their HGRD counterparts. The coherence of the responses can be seen by comparing questions 2 and 7. The SYS students found the course EASIER and MORE UNDERSTANDABLE while the HGRD students found it more DIFFICULT and CONFUSING. This evidences the main difference between the two groups.

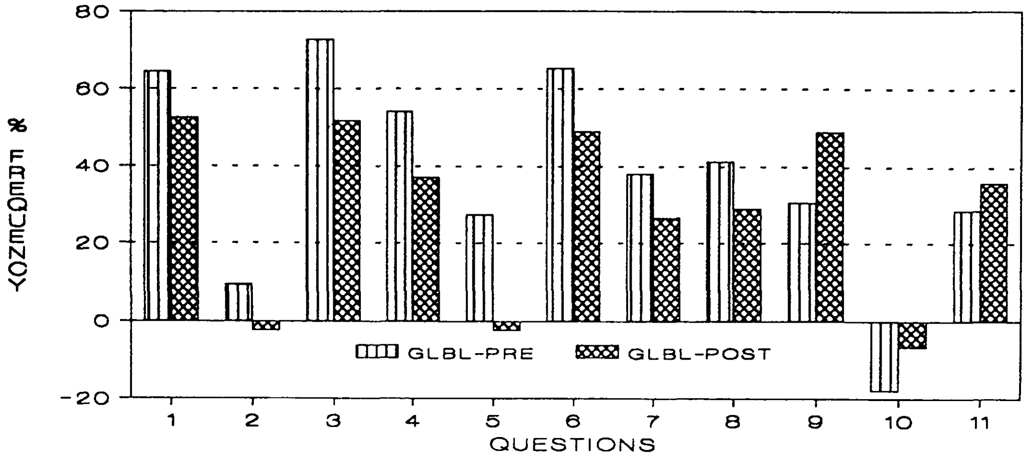


FIG. 3.1 (A) - PRE vs POST - GLOBAL

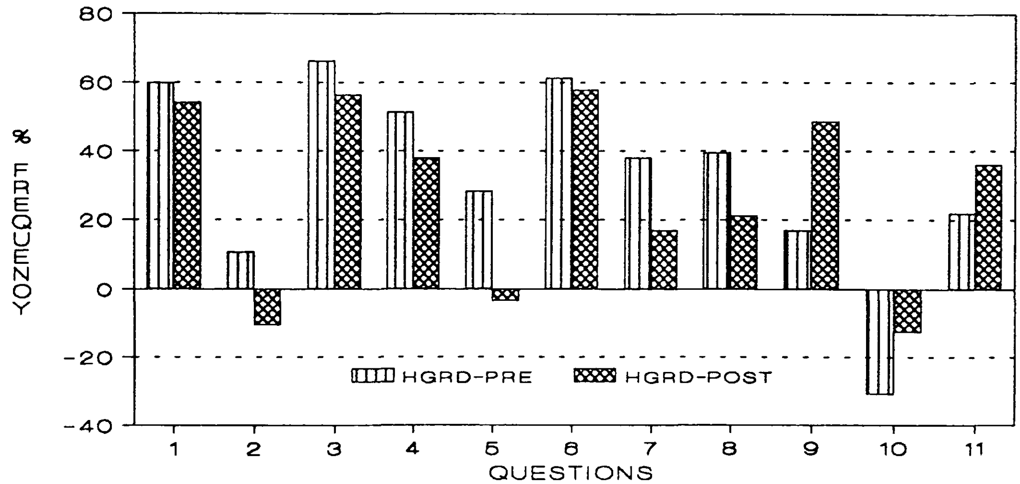


FIG. 3.1 (B) - PRE vs POST - HGRD

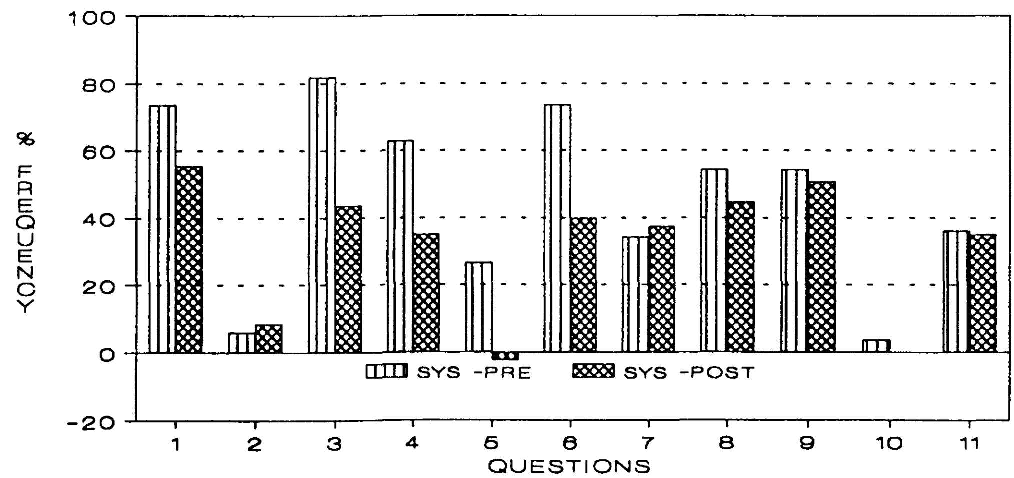


FIG. 3.1 (C) - PRE vs POST - S Y S

The SYS students' disappointment with the first year practical course was greater than that of the HGRD students. This result would appear to confirm that, considering that the project based SYS secondary school curriculum increase the students independence and self confidence in grasping basic laboratory instruction.

2.2.3 - CONCLUSION

The three questions in the PRE-Questionnaire usefully characterised our samples and sub-samples. Question one minimised the problem of heterogeneity, by indicating the existence of two major sub-groups (HGRD and SYS). While the other two provided evidence of how HGRD and SYS students differed.

The comparison between the raw frequencies for the PRE (second part) and POST questionnaires demonstrate that the respondent developed very negative opinion about the first year practical course. This negative change in attitude was more obvious in the cross-tabulation of the PRE and POST question results.

Thus our comparison of the SYS and HGRD sub samples seems to support the view that SYS students are more disappointed with the course on offer from Glasgow University than are the HGRD students in the first year undergraduate intake.

2.3 - DIARIES

The Diaries were introduced in an attempt to find out in detail students' opinions about the first year laboratory course with regard to the organisation of the laboratory, the quality of the written instructions for each experiment and students' attitudes to these.

To complete their diary students were required to rate statements - a format which offered the advantage of being very quick and easy to be answered by students. The vantages and disadvantages of the method were described earlier in the Chapter 2. Students were simply asked to state whether they agreed (YES) or disagreed (NO) with a set of statements.

Diary-ONE (used in the MONDAY and TUESDAY sessions -see Table 3.2) was designed to highlight any problems in the written instructions and differences between the two versions used.

The questions asked about the written instructions could be grouped under following headings:

1. layout / organisation of the information

2. language / vocabulary
3. amount of information
4. time demand
5. knowledge acquired

The test hypothesis for Diary being:

"There is no difference of opinion about the written instructions between first year students who had used different written instructions (OLD/NEW) in the Inorganic practical course (independent of their previous experiences and the experimental content)."

Diary-TWO (applied on WEDNESDAY and THURSDAY sessions), was designed to reveal any organisational problems in the laboratory and students' attitudes to the experiments. The Diary was basically the same as that used by Letton[2] in a previous survey of a second year laboratory in Chemistry Department of Glasgow University.

The questions asked in Diary-TWO were grouped under the following headings:

1. attitude to each experiment
2. lab organisation
3. new things learned
4. time
5. help available

The test hypothesis for Diary-TWO being:

"There is no difference of opinion about practical work between first year students who had used different versions of written instructions (OLD/NEW) in the inorganic practical course (independent of their previous chemical knowledge and content of the experiment)."

Appendices A-6 (page 290) and A-7 (page 291) show Diary-ONE and Diary TWO.

2.3.1 - DIARY-ONE'S RESULTS

The responses from all DIARIES were collected for each lab day. A table of frequencies and percentages for each statement is shown in the Appendix A-8 (page 292). The rows indicate the experiments (1 to 6) and which version (OLD/NEW) the students had been using. At the end of each row there is an estimate Level of

Agreement (calculated by subtracting the value of "NO" from "YES") which were used to compare samples and sub-samples.

We tested the hypothesis initially using Zubin's Nomographs for percentages differences, to find out roughly whether the differences were significant or not. Chi-Square values were also calculated where expected frequencies were greater than or equal to five.

The hypotheses were also tested by comparing the frequencies of response as follows:

i A comparison of the experiments performed under the OLD written instructions and the same experiment done with the NEW instructions recording global and sub-samples (HGRD and SYS) results.

ii A comparison of the experiments performed with the OLD written instructions again for Global and sub-samples results.

iii The same comparison for item b of the NEW written instructions; and

iv A comparison of the sub-samples HGRD and SYS for both sets of written instructions (OLD/NEW).

Table 3.9 shows a summary of the DIARY-ONE questions for each sample and sub-samples. The experiment indicated in the table are those which had the smallest frequencies of positive responses and where the differences were statistically significant at the level indicated. The comments which follow each question are based on the summary of Table 3.9 and the frequencies and charts included in the Appendix A-8 (page 292).

Question 1 - What experiment did you do to-day? Were you starting it to-day? or finishing it from the previous day?

The response to this question was intended to give us an estimate of the time expended by the students on doing each experiment, however, few students answered this rendering the results redundant,

Question 2 - Which kind of Written Instruction did you use? Manual? or worksheet?

This question was intended to ascertain if the students' comments were about the OLD or NEW written instructions.

Question 3 - Were the Written Instructions well-organised? (POSITIVE RESPONSE = YES)

There was no significant difference in students' response regarding the organisation of the NEW and OLD version of Written Instructions; the level of agreement was higher than 80%.

DIARY - ONE											
	NEW v OLD version			OLD version / E1vE2vE3vE4			NEW version / E1vE2vE3vE4			HGRD v SYS	
QT	GLBL	HGRD	SYS	GLBL	HGRD	SYS	GLBL	HGRD	SYS	OLD	NEW
1											
2											
3	-	-	-	-	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-	-	-	-	-
5	-	-	-	-	-	-	-	-	-	-	-
6	-	-	-	E2 5%	E2 5%	E2 5%	-	-	-	-	-
7	E2/O 1%	E2/O 5%	E2/O 1%	E2 1%	E2 1%	E2 5%	-	-	-	E2/SYS 1%	-
8	E2/O 5% E3/N 5%	E2/O 5% E3/N 5%	E2/O 5% E3/N 5%	E2 5%	E2 5%	E2 5%	E3 5%	E3 5%	E3 5%	-	-
9	E/2O 5% E3/N 5%	E2/O 5% E3/N 5%	-	E2 1%	E2 1%	E2 1%	-	E3 5%	E2 1%	-	E2/SYS 5% E3/HG 5%
10	E2/O 5%	-	E2/O 5%	E2 5%	-	E2 5%	-	-	-	E2/SYS 5%	E2/HG 5% E1/HG 5%
11	E1/O 5%	-	E1/O 5%	E1 5%	-	E1 5%	-	-	-	E1/SYS 1% E2/SYS 5% E4/SYS 5%	E3/SYS 5%
12	E2/O 5%	-	-	-	E2 5%	E3 5%	E2 5%	E2 5%	E3 5%	E3/SYS 5% E4/HG 5%	E3/HG 5%

E/x = Experiment Number with the lowest frequency of positive response $y\%$ = Significance Level

N = New version **O** = Old version **HG** = HGRD sub-sample **SYS** = SYS sub-sample

Table 3.9 - Summary of DIARY ONE

Question 4 - Were the Written Instructions easy to follow? (POSITIVE RESPONSE = YES)

Once again there was no significant difference of opinion about how easy the OLD and NEW version of Written Instructions were to follow; the level of agreement was again higher than 80%.

Question 5 - Did you find any word, sentence or paragraph that you didn't understand? If so, please specify. (POSITIVE RESPONSE = NO)

Differences in students' responses were not statistically significant. The responses for the second part of the question is shown in the Table 3.10.

EXP	OLD VERSION	NEW VERSION
1		**SYS** -Pg23/ln1-3 -Why add HCl,How long do you let the reaction run for
2	**HGRD** -Pg27/Ln-28 -Ignition tube -Pg-26/ln-29-34	**HGRD** -Pg28/ln8 -'Prepare 10ml of a chlorine water solution by ... dilute sulphuric acid'
3	**HGRD** -Pg29/ln3-8 -First paragraph unspecific -Pg29/ln26 -Analar KIO_3 -Pg30/ln8 -Add 1 g KI (does this mean exactly of roughly) -Pg29/ln33-6 -Preparation of Standard $Na_2S_2O_3$ solution **SYS** -Pg30/ln7 -No mention of using a conical flask	**HGRD** -Pg31/ln6-20 -'Basic ideas behind the experiment' **SYS** -Pg32/ln7 -Weighing bottle
4	**HGRD** -Pg31/ln17 -Hygroscopic -Pg34/ln22 -Aliquot -Pg33/ln8 -The equation of equilibrium of indicator **SYS** -Pg31/ln17 -Hygroscopic	**HGRD** -Pg2/ln2 and 10 -I have not seen 0.1M expressed as M/10 before
5	**HGRD** -Pg37/ln18 -Paragraph-'Dissolve ...70oC' Not clear if you heat solution first then add solid or add the solid then heat. **SYS** -Pg38/ln6-7 -Said to put solution in a beaker instead of a conical flask	**HGRD** -Pg39/ln14/25 -Paragraph about analysis
6		**SYS** -Pg42/ln15 -How long do you treat the blue-green precipitate solution?

Pg = Manual's Page ln = page's line

Table 3.10 - Summary of responses of question 5 - Diary - ONE

Question 6 - Were the objectives of the experiment clear to you? (POSITIVE RESPONSE = YES)

Experiment 2 exhibited a smaller level of positive response compared with the others in the OLD version of written instruction. There was a significant difference in <u>favour</u> of the NEW version. (Figure 3.2)

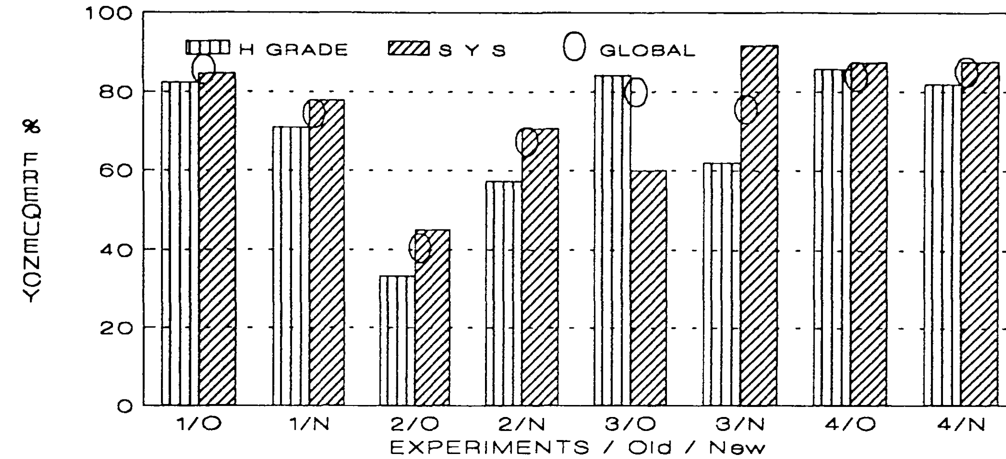


FIG. 3.2 - DIARY 1 / QUEST. 6
(ANSWER YES - NO)

Question 7 - Did the Written Instructions have all the information necessary for understanding the experiment? (POSITIVE RESPONSE = YES)

There was a significant difference in favour of the NEW version of written instruction for experiment 2, i.e. experiment 2, independent of the version of written instruction (OLD or NEW) used, achieved a positive response significantly smaller than any other experiment.(Figure 3.3)

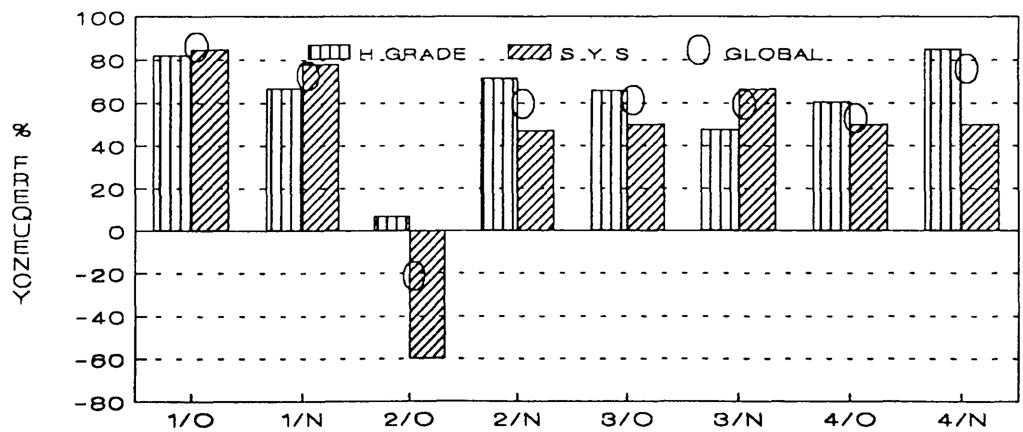


FIG. 3-3 - DIARY 1 / QUEST. 7
(ANSWER YES - NO)

Question 8 - Did you have to ask for any help to interpret the instructions? (POSITIVE RESPONSE = NO)

Once again experiment 2, when the OLD version was used, exhibited a significantly smaller positive response compared with the NEW version. Also a comparison of this with other experiments (1,3,4) within the same version of the written instructions (OLD or NEW) proved to be significantly smaller. (Figure 3.4)

Experiment 3, performed by the NEW version of written instructions, also exhibited a low frequency of positive response compared with the OLD version.

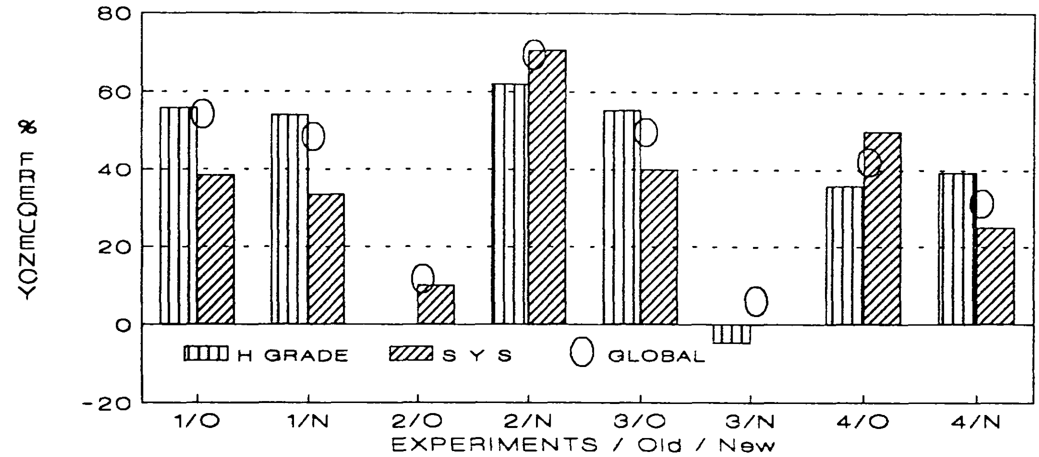


FIG. 3-4 - DIARY 1 / QUEST. 8
(ANSWER NO - YES)

Question 9 - Did you have enough time to do the experiment? (POSITIVE RESPONSE = YES)

The students were clearly told at the beginning of the course that they were not asked to do one whole experiment per day, rather they should do as much as they could then repeat it if necessary. Despite this advice, students considered that there was insufficient time to do the experiments. Because they were not able to finish in one lab period, it appears they believed they had to rush. (Figure 3.5)

Question 10 - Were the Written Instructions helpful for completing your report? (POSITIVE RESPONSE = YES)

Experiment 2, OLD version, had a notably low frequency of positive response compared with other experiments performed with the same written instructions. (Figure 3.6)

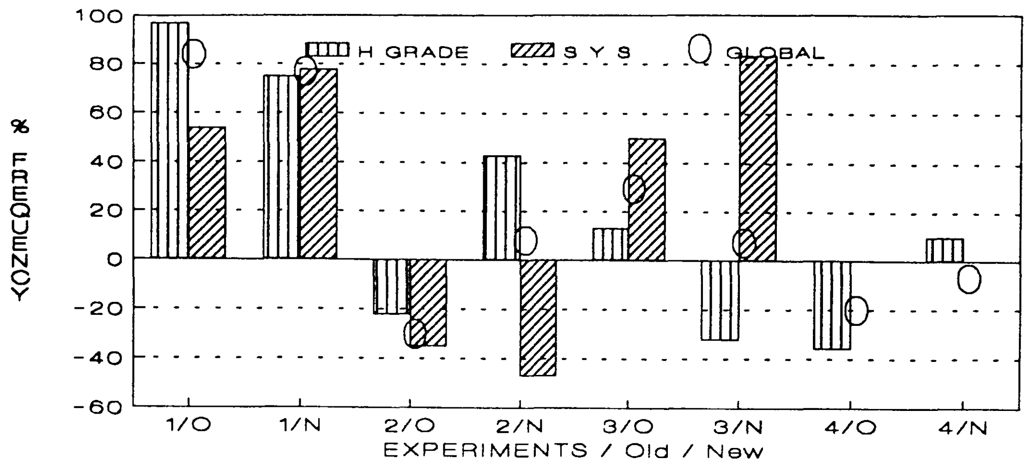


FIG. 3-5 - DIARY 1 / QUEST. 9
ANSWER YES - NO

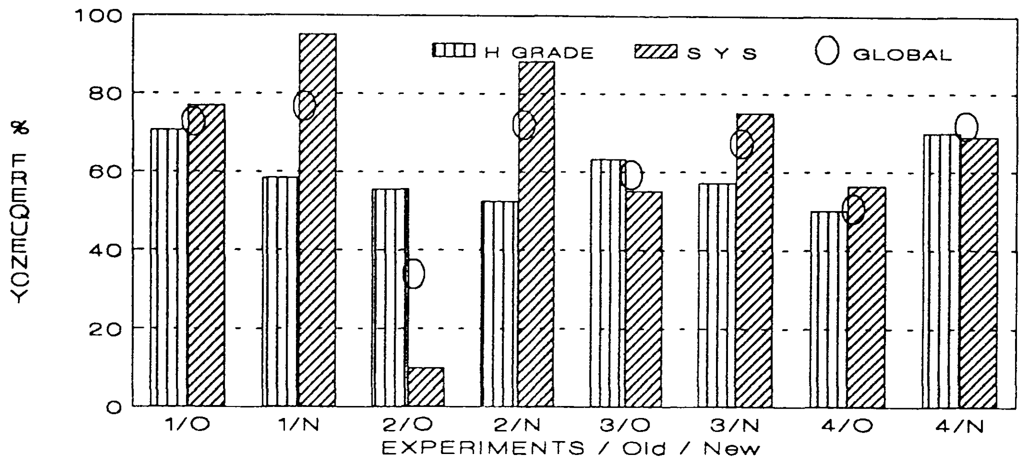


FIG. 3-6 - DIARY 1 / QUEST. 10
ANSWER YES - NO

Question 11 - Did the theoretical lectures help you to understand this experiment? (POSITIVE RESPONSE = YES)

It would have been surprising if the students had answered YES in this question since the theoretical lectures and practical work were out of sequence. The frequency of the YES response in the SYS group was higher than that for the HGRD. It may therefore be the case that those who answered YES were referring to lectures they had had at secondary school.

Question 12 - When you finished the laboratory to-day had you learned anything in particular? If so, please specify. (POSITIVE RESPONSE = YES)

There was a significant difference recorded in favour of experiment 2 of the NEW version of the written instructions when compared with the OLD one. Students' comments for this question are shown in Table 3.11.

QUESTION-12/DIARY-ONE - When you finished the laboratory to-day had you learned anything in particular? If so, please specify		
EXP	OLD VERSION	NEW VERSION
1	**HGRD** -Experimental techniques -Method of producing Cr -Oxi-reduction reaction **SYS** -Calculation of % yield -Safety precautions -Calculation -Redox reactions	**HGRD** -Method of producing Cr -How to test for chromium **SYS** -Solid state redox reactions; -That the reaction to produce Cr is highly exothermic; -Combustion of Ammonium dichromate produce N_2;Cr_2O_3;O_2 -Safety precautions -Volcano and Thermite reaction
2	**HGRD** -Fluorine reacts with glass / -Ions prefer to be in CCl_4 / -Comparative reactivity of halogens **SYS** -Fluorine reacts with glass -Function of different pH paper -More about halide reaction -Different products depends on reactions condition /solution/ heat etc. -Better understanding of gases evolved -Vigorous reaction with halide -Test for halides	**HGRD** -Properties of halogens -Sulphuric acid reacts with HBr, HI -Reactions of halogens -About oxidising agents -To use lab equipment **SYS** -About the Halides -Gases evolved from reaction -How to test halogens in compounds -Reactions of halogens
3	**HGRD** -Practical use of Unit Cancellation Method -Revision of Redox reaction -Calculation of Concentrations -That IO_3 is titrated with S_2O_3 -Method for weighing / -Method for titrate -Proper method of filtration -How to standardise solutions -How to produce iodine solution **SYS** -To write down all measurements / -To calculate molarity / -Redox equation of IO_3^- with $S_2O_3^-$	**HGRD** -How to use balances -Calculate molarity -How to do titrations -How to prepare solutions **SYS** -How to use balances -How to do Redox equations -Iodimetry -How to use equipment -Redox equation of Iodine
4	**HGRD** -Calculate molarity -How to use balances -How to do a titration **SYS** -How to do a titration -lab techniques -How to use balances -How to standardise solutions -Colour change of phenolphtalein	**HGRD** -How to do titrations / -How to use balances -Use of Unit Cancellation method -To use some equipments /-Calculate molarities **SYS** -How to use balances -How to titrate accurate -Calculate molarities -Nothing - work covered in CSYS -How to carry out a titration
5 and 6	**HGRD** -How to use buchner funnel -The experiment helped visualise what is written in the equation -Can get an equilibrium with Cu(I) and its complex and about crystal formation.	**SYS** -How to calculate %Cu in Thiourea copper(I) complex which I had prepared earlier -NO_2 is a brown gas -Nothing - This work was covered in CYS -How to work out molarities

Table 3.11 - Students' comment - Question 12 - DIARY ONE

Students' comments - Could you give us any suggestion or comments about the laboratory worksheet or manual(written instruction) for to-day's experiment.		
EXP	OLD VERSION	NEW VERSION
1	**HGRD** -I thought the lab was overcrowded. I spent much more time in queries than in working -The ratio of demonstrators to students was hopelessly inadequate -Though I used the worksheet, I had read the manual instructions beforehand and found their step by step approach much easier to follow.	
2	**HGRD** -Make objectives clearer. It was not always apparent what I was meant to look out for -More technical instructions required . -Demonstrator are subject to availability -Looking at the manual sheet at the end of the lab, I think I would have found it easier to follow -I would have found it helpful to have some explanation (not necessarily an equation) for the reaction of the gases evolved in item 2 and 3 with NH_3 and water as I had no idea whatsoever of what the tests did or did not indicate otherwise I did not understand the significance of the presence of MnO_2 in **SYS** -For this series of experiment which require use of fume cupboard a method of rotating the experiment so that less time is spent waiting to use a fume cupboard is indeed because there are so many people waiting to use them	**HGRD** -Do not assume that intimate knowledge of halogens and their chemistry has already been gained (i.e. in secondary school) **SYS** -In the preparation of a chlorine water solution, could be a good idea to specify how much dilute sulphuric acid you need, because it could take you a long time depending in the molarity that you use.
3 AND 4	**HGRD** -Since it was my first time in the lab I feel it would have helped if the equipment had been labelled or we had been instructed it.Some of it was new to me i.e.Labelled diagram in how to use it. -The redox reaction involved is related only to the problem session and as such were difficult to complete with knowledge on how to balance redox equations only with the form of the products being given in each case. -The written instructions gave no idea as how to set out your report. -Could give a list of apparatus so frequent trips to the cupboard are avoided	**HGRD** -Write instruction on single lines so one gain the information at a quicker and easier pace with minimum loss of time -These instructions were more helpful in carrying out titrations -I think in the second week instead of doing maths there should be demonstrations of titrations and weighing **SYS** -A more detailed account of how to calculate the molarity in exp-3 is needed,i.e., A step by step method showing how the molarity is calculated would be more helpful
5 AND 6	**SYS** -The worksheet could also explain the reason behind the procedure in the experiment as this would help explain the experiment	**HGRD** -It would have been really helpful to have done exp-3 before exp-5 because you can get experience of titration and in exp-3 to do exp-5 **SYS** -More instructions on the actual methods needed to do the calculations

Table 3.12 - Students' comments about written instruction - DIARY-ONE

The students had been asked to comment and give suggestions about the experimental procedures and the lab manual (See Table 3.12). Students were not restricted to the written instructions in this exercise but could comment on any aspect of the lab instructions. In general we found that there were more negative comments for the OLD manual than for the NEW one.

2.3.2 - DIARY TWO'S RESULTS

The response from all Diary TWO responses were collected for each lab day and the frequencies for each statement displayed as for Diary ONE responses.

The hypotheses were also tested by comparing the frequencies of response as follow:

i A comparison of the experiments performed under the OLD written instructions and the same experiment done with the NEW instructions recording global and sub-samples (HGRD and SYS) results.

ii A comparison of the experiments performed with the OLD written instructions again for Global and sub-samples results.

iii The same comparison for item b of the NEW written instructions; and

iv A comparison of the sub-samples HGRD and SYS for both sets of written instructions (OLD/NEW).

We tested the hypotheses initially using the Zubin's Nomographs for percentage differences, to find out whether the differences were significant or not. Chi-Square values were also calculated where the expected frequencies were greater than or equal to five. Tables of Frequencies and percentages with their respective bar charts is in Appendix A-9 (page 295).

Table 3.13 shows a summary of the responses for the Diary-TWO - each cell indicating the experiment with the lowest positive response frequency, version of written instruction, and the level of significance of the difference between them.

QUESTION 1 - What experiment did you do to-day? Were you starting it to-day? or finishing it from the previous day?

This questions was an attempt to determine the time expended by the student in doing the experiment again a few students answered this rendering the results redundant.

QUESTION 2 - When did the point of to-day's experiment become clear to you? at the beginning? part way through? at the end? or not at all?

Again only a few students answered this.

QUESTION 3 - Did you find the experiment interesting? (POSITIVE RESPONSE = YES).

Experiment 2 of the OLD version was found to be the least interesting one exhibiting a significant difference when compared with experiment 2 of the NEW version. (Figure 3.7)

The experiments done with the OLD version of the written instructions exhibited significant differences in the frequencies recorded for each experiment with experiment 2 registering the lowest level of positive response. Of those done with the NEW version only experiment 2 had a significant low frequency of positive response, while the others had approximately the same level of response.

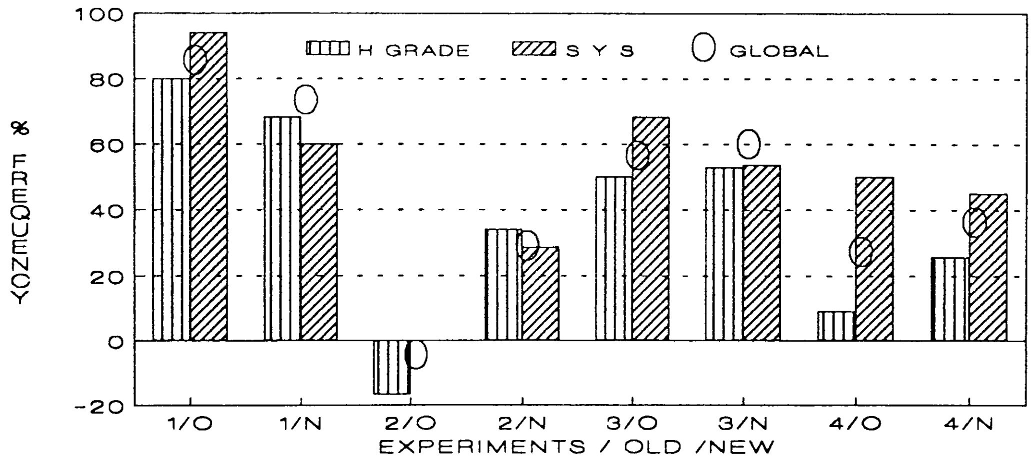


FIG. 3.7 - DIARY 2 / QUEST. 3
ANSWER YES - NO

QUESTION 4 - Did you find the experiment difficult? (POSITIVE RESPONSE = NO)

The students opinion about the degree of difficulty were not significantly different when the NEW and OLD version were compared or among the experiments in each version.

QUESTION 5 - Was the laboratory session well-organised? (POSITIVE RESPONSE = YES).

Experiment 3 of the NEW version exhibited the lowest response frequency and was significantly different when compared with experiment 3 of the OLD version. This, we would agree demonstrates that the students found the laboratory less organised when they had to do the experiment 3 of the NEW version. (Figure 3.8)

DIARY - TWO											
	NEW v OLD version			OLD version / E1vE2vE3vE4			NEW version / E1vE2vE3vE4			HGRD v SYS	
QT	GLBL	HGRD	SYS	GLBL	HGRD	SYS	GLBL	HGRD	SYS	OLD	NEW
1											
2											
3	E2 /O 1%	E2/O 1%	E2/O 1%	E2<4<3<1 E2 1%	E2<4<3<1 E2 1%	E2<4<3<1 E2 1%	E1/3/4 nsd E2 1%	-	E1/3/4 nsd E2 1%	-	-
4	-	-	-	-	-	-	-	-	-	-	-
5	E3/N 5%	E3/N 5%	E3/N 5%	E2 5%	E2 5%	E2/4 5%	-	E3 5%	-	E4/SYS 5%	E1/SYS 5%
6	-	E2/4/O 1%	E4/N 1%	E2/4 1%	E2/4 1%	-	-	-	-	E-2/HGRD E-4/SYS	-
7	-	-	-	-	-	-	-	-	-	-	-
8	E2/O 5%	E2/O 5%	E2/O 5%	E2 1%	E2/4 5%	E2 1%	-	-	-	E4/HG 1%	-
9	E2/O 5% E4/N 5%	E2/O 5% E4/N 5%	E2/O 5% E4/N 5%	E2 1%	E2 1%	E2 5%	E2/4 1%	E2/4 1%	E2 1% E4 5%	-	-
10	E3/O 5%	E3/O 5%	-	E2 5%	E3 5%	-	-	-	E1 5%	E3/HG 5%	E3/4/H5%
11	-	-	-	-	-	-	-	-	-	-	-
12	-	-	-	E1	E1	E1	E1	E1	E1	-	-
13	E1/N 5% E2/O 5%	E1/N 5% E2/O 5%	E1/N 5% E2/O 5%	E2 5%	E2 5%	E2 5%	-	-	-	-	-
13A	-	-	-	E2 5%	E2 5%	E2 1%	E2 1%	E2 1%	E2 1%	E1/HG 5%	E1/HG 5%
14	-	-	-	-	-	-	-	-	-	-	-
15	-	-	-	E2 5%	E2 5%	E2	E2	E2	E2	-	-
16	E3/N 5%	-	E1/O 5% E2/O 1%	-	E3 5%	-	-	-	E3/4 5%	E1/2/4HG 5%	E1/2 HGR 5%
17	-	-	-	-	-	-	-	-	-	-	-

E/x = Experiment number with the lowest frequency of positive response **y%** = Significance level
N = New version **O** = Old version **HG** = HGRD sub-sample **SYS** = SYS sub-sample

Table 3.13 - Summary of DIARY TWO

Experiment 2 had the lowest frequency of positive response and the difference when compared with other experiments in the same version, was found to be statistically significant.

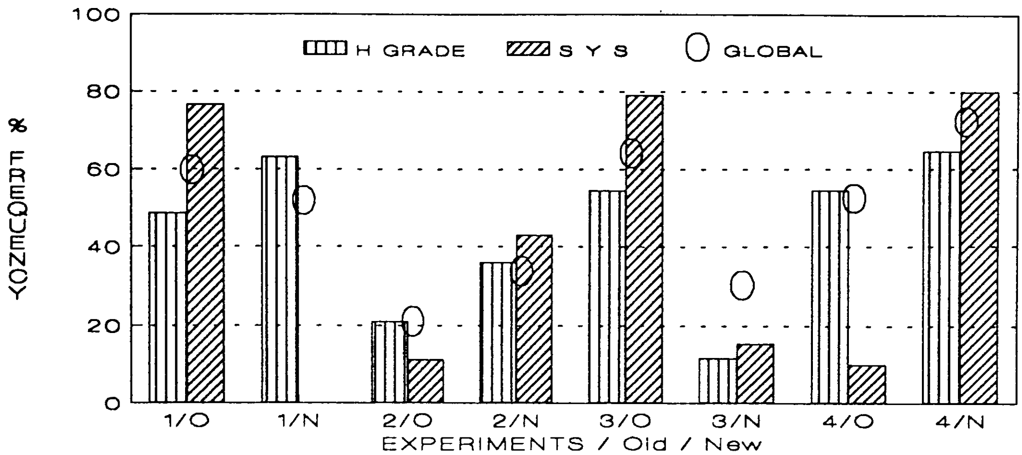


FIG. 3.8 - DIARY 2 / QUEST. 5
ANSWER YES - NO

QUESTION 6 - Did you enjoy doing this experiment? (POSITIVE RESPONSE = YES)

Experiments 2 and 4 were found to be the least enjoyable ones for both versions and a significant difference was found in favour of the NEW version in experiment 2, and in favour of the OLD version in experiment 4.

Experiments 2 and 4 of the OLD version, showed the lowest frequency of positive response when compared with others done with the OLD version.

QUESTION 7 - Did you think it was a waste of time? (POSITIVE RESPONSE = NO)

The results for this question were very positive though no significant difference was found between the OLD and the NEW versions or among the experiments themselves.

QUESTION 8 - Did you gain some satisfaction from this laboratory's work? (POSITIVE RESPONSE = YES)

Experiment 2 of the OLD version was found to exhibit a significant difference in response frequency with students favouring the NEW version. When compared with other experiments in the OLD version it was also significantly lower. No significant differences were found among experiments in the NEW version of the written instructions. (Figure 3.9)

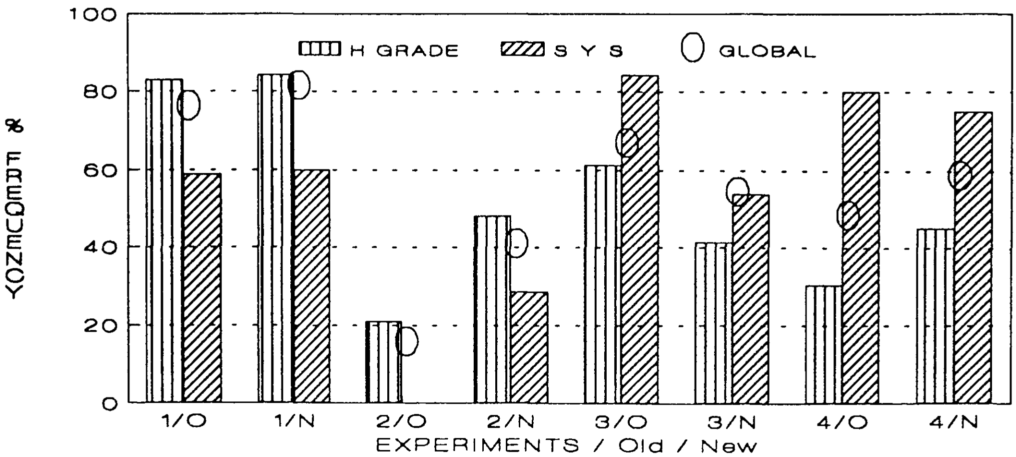


FIG. 3.9 - DIARY 2 - QUEST. 8
ANSWER YES - NO

QUESTION 9 - Did you have enough time to complete the experiment? (POSITIVE RESPONSE = YES).

Experiment 2 of the OLD version and experiment 4 of the NEW version appear to have been rushed and required more time. That is students felt unable to complete the experiment in one lab period (3 hours). (Figure 3.10)

Experiment 2 of the OLD version exhibited the lowest frequencies of positive response when compared with the others in the same version. The difference was also significantly lower when compared to the NEW version.

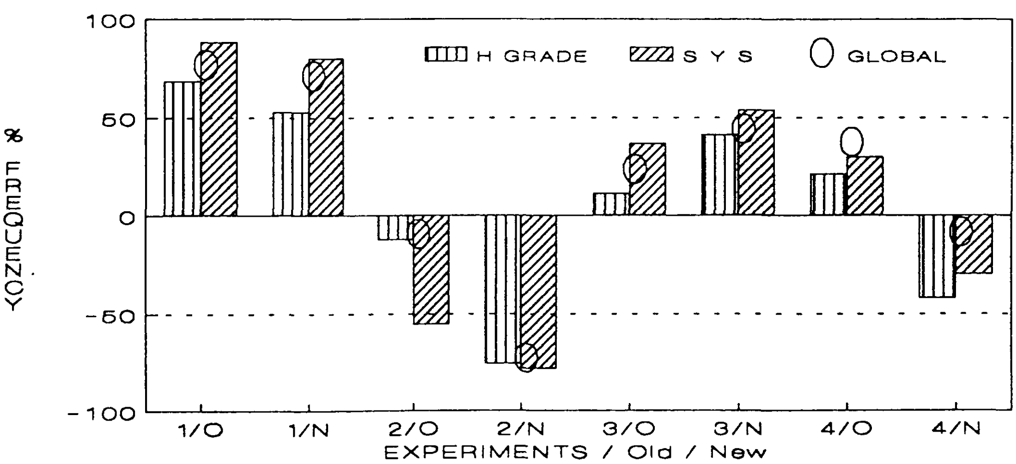


FIG. 3.10 - DIARY 2 / QUEST. 9
ANSWER YES - NO

QUESTION 10 - Did you find the experiment itself, confusing in any way? (POSITIVE RESPONSE = NO)

A significant difference was found in favour of the NEW Version for both experiments 2 and 3. This has been taken to indicate that the OLD version was found to be more confusing than the NEW version by the respondents.

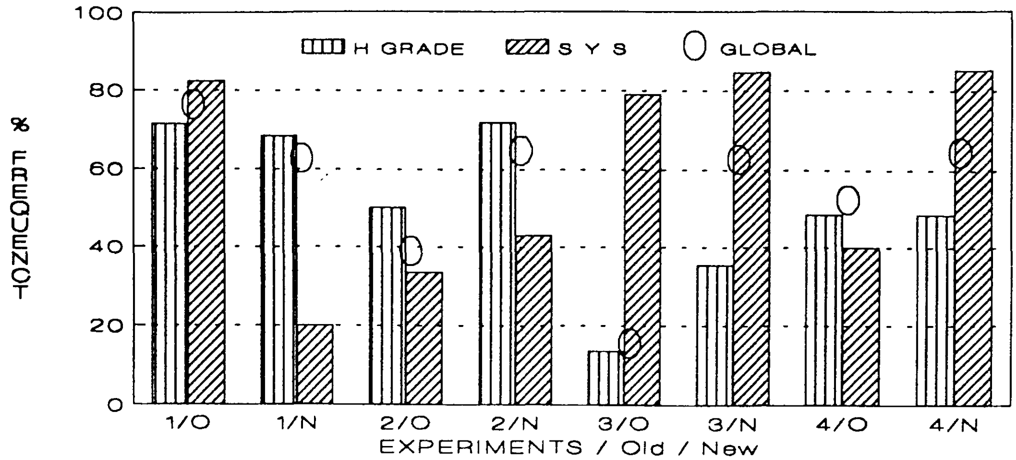


FIG. 3.11 - DIARY 2 / QUEST. 10
ANSWER NO - YES

QUESTION 11 - Did you get all the help you needed from the staff and demonstrators available? (POSITIVE RESPONSE = YES)

The frequency of response for this question was very positive. No significant difference were found between the two versions or among the experiments within each version.

QUESTIONS 12 - Have you already had a lecture covering the topic of to-day's experiment? (POSITIVE RESPONSE = YES)

The response was markedly very positive with no significant differences among experiments in each version found. However the positive response to this questions can only be credited to students' previous knowledge and lectures at the secondary school - University lectures were still three months off.

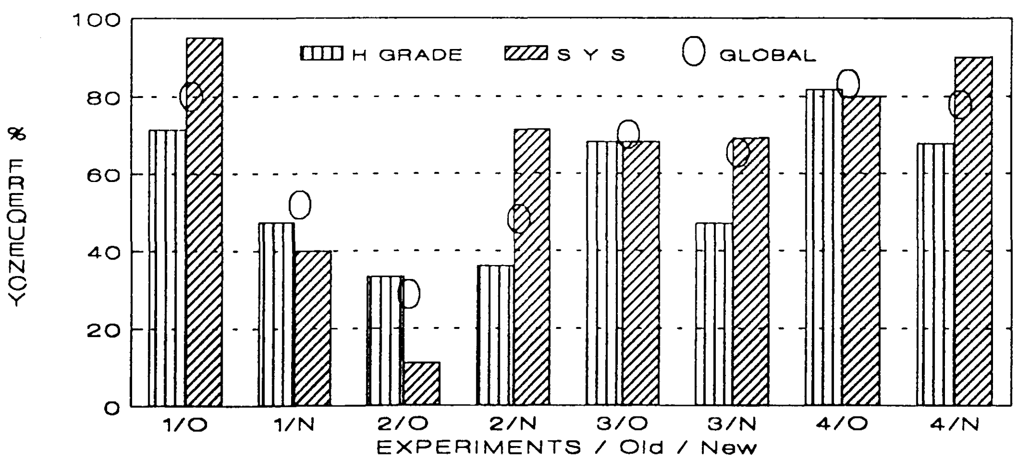


FIG. 3.12 - DIARY 2 / QUEST. 13
ANSWER YES - NO

QUESTION 13 - Were all the chemicals and equipment that you needed to-day, easily located? If not, please specify - (POSITIVE RESPONSE = YES)

The responses for this question were very positive except for experiment 2 of the OLD version which exhibited the lowest statistically significant frequency in favour of the NEW VERSION. Experiment 2 was also significantly different when compared in the other experiments done with the OLD version. A summary of students' comments is shown in Table 3.14.

EXP	OLD VERSION	NEW VERSION
1	It was hard to find chemicals and apparatus	It was hard to find chemicals and apparatus -Long queue too much time to wait
2	It was hard to find chemicals -It was not clear whether a lot of things were solutions or solids	It was hard to find Chemicals
3	It was hard to find chemicals and apparatus -Things too far away	It was hard to find chemicals and apparatus
4	It was hard to find chemicals and apparatus	It was hard to find chemicals -It had long queues at the balance
5		It was hard to find apparatus
6	It was hard to find apparatus	It was hard to find chemicals and apparatus

Table 3.14 - Summary of students comments for Question 13 - DIARY-TWO

QUESTION 13A - Did you encounter any new equipment to-day? (POSITIVE RESPONSE = YES)

No significant differences were found between OLD and NEW versions. The negative response was very high for the experiments 1 and 2 and slightly over 50% for the experiments 3 and4.

QUESTION 14 - If you did, were you taught how to use it? (POSITIVE RESPONSE = YES)

Majority of the students didn't answer this questions leaving a blank.

QUESTION 15 - Are you CONFIDENT that you will BE ABLE to use it again next time? (POSITIVE RESPONSE = YES)

About fifty percent of the students didn't answer this question. No significant difference was found between OLD and NEW Versions of the Written Instructions.

QUESTION 16 - Were you in ANY DOUBT about what was expected of you in your laboratory report? (POSITIVE RESPONSE = NO)

A significant difference was found favourable to the OLD Version of experiment 2 and favourable to the NEW Version of experiment 3.

QUESTION 17 - Have you learned anything in particular from this experiment to-day? If so, please specify. (POSITIVE RESPONSE = YES)

A very negative response was found for this question with a significant difference noted for experiments 1 and 2 favourable to the OLD version of the Written Instructions. The students' comments are displayed in Table 3.15.

Students' comments about what they had learned did not differ from those given in Diary-ONE as can be seen by comparing Tables 3.11 and 3.15

Students' suggestions about changes in the experiments are displayed in Table 3.16.

2.3.3 - CONCLUSION

The Diaries had a number of question that were not useful, i.e. they did not discriminate, namely, questions 1, 2, 3, 4, and 5 of Diary-ONE and questions1, 2, 4, 7, 11, 12, 14, and 17 of Diary-TWO. Students' responses were very positive in questions 3, 4 and 5 of DIARY-ONE; and questions 7, 11, and 12 of Diary-TWO.

Question 5 of Diary-ONE and 13 of Diary-TWO are noteworthy since the students' comments indicate problems in the written instructions and organisation of the lab. These comments help identify some of the 'Noise' that contributes to students' working memory overload.

According to Johnstone and Wham[30], "noise" in the learning process is any unclear information that forces students to interrupt their experiment in order to get this information from somebody else. For example, if no instructions are given as to where the chemicals and apparatus are situated in the lab students may have to walk around the lab looking for them and wasting their time.

The diaries show, that regardless of which written instructions were used, experiments 2 and 3 had more negative response than the rest. It would appear that objectives of their written instructions were unclear; that there was not enough time allowed; and that student found them less interesting and more difficult than the other experiments.

Since the DIARIES for experiments 5 and 6 were answered by a very small number of students we have restricted our analyses to experiments 1 to 4.

QUESTION-17/DIARY-TWO - Have you learned anything in particular from this experiment to-day? If so, please specify		
EXP	**OLD VERSION**	**NEW VERSION**
1	**HGRD** -Lab techniques -How to produce Cr metal -How to calculate % yield -Redox and exothermic reactions -Experiments don't always work -Volcano reaction -reduction of Cr is very exothermic -Inorganic chemistry is not all pipettes and solutions -That the lab does not have to be as frustrating as the previous two sessions (maths skills) **SYS** -Method of calculation -How powerful some experiment are! -Safety precautions	**HGRD** -Products of thermite reactions -Safety precautions-wear glasses **SYS** -Decomposition of Ammonium dichromate gives N_2 not NH_3 -Safety precautions - handle chemicals -Reminded of some Cr chemistry -How to calculate %yield
2	**HGRD** -How to use balances -variation in halogens reactions -Properties of halogens -Halogens reactions -Patience **SYS** -Halogens reactions -The products of halogens with sulphuric acid. -Difference between CCl_4 and $SiCl_4$ -Nothing - I've done a lot of it before.	**HGRD** -Learned about properties of halides -To distinguish between halides -reaction of halogens **SYS** -How to identify halides -Reactions of halide
3	**HGRD** -How to do titrations -How to calculate molarities (3) -How accuracy can affect yours results -How to use balances -Calculations could have explained a bit better -How to use Unit cancellation method **SYS** -Time passes quicker when you work -How to use balance -How to do a titration -Balance redox equations	**HGRD** -How to use balances -How to titrate with confidence **SYS** -The accuracy needed in titration -Calculations of molarities -A more correct procedure for titration -How to use balances -Nothing - I had done titration and standard solutions before.
4	**HGRD** -Lab techniques -How to do a titration -To get accurate measurements (-The fact that adding water did not alter molarity of HCl -The reason for doing titration **SYS** -Accurate weighing by difference -How to do a titration	**HGRD** -Techniques of titration /-Calculations -Importance of accurate measures -Safety precautions -To cope with experiment as a single person **SYS** -How to use a pipette properly / -Method of calculations / -How to perform an acid-base titration

Table 3.15 - Summary of Question 17 - DIARY TWO

Summary of students' comments - Could you give us any suggestion or comments about this experiment.		
EXP		
1 NEW VERSION	**SYS** -Got the impression form certain demonstrators their attitude was basically " you don't know?... Why not? You should know" -I thought this experiment was real good because of the sparks and little explosions etc.	
2	**HGRD / OLD VERSION** -More explanation of reason for experiment -I thought that there would be far less confusion if the chemicals necessary for each reaction were grouped together. i.e. an area for exp-1; an area for exp-2 etc. Instead time being wasted looking for each chemical needed. -text books' references did not seem relevant. Perhaps they are from a different edition. e.g. Chemistry the Central Science pp 633-43, in the 4th edition is about chemical thermodynamics and not about halogens(sheet slightly ambiguous) -The lab staff were moderately helpful but few tend to be sarcastic if I did not know something	**HGRD / NEW VERSION** -Experiment took a long time to complete and involve many different reactions. It was far too long and boring. **OTHER / NEW VERSION** -The instructions were far, far better than the handouts. I used the last two experiments (this week I was working from the folder). They were very clear, leaving no doubts as to what was expected and the idea behind the experiment (I know we are supposed to think for ourselves but I found it confusing in the first fortnight not knowing what type of write-up-report was expected).
3 OLD VERSION	**HGRD** -I felt that the instructions was very poor and confusing. e.g. Part I - which equation and to what? Other than that I enjoyed it. **SYS** -Students should be able to use their own method of calculations if they so wish, and should not have to do the unit cancellation if they do not wish so. **OTHER** -I hate titrations. I know they are necessary and an important technique etc. but they are repetitive and hence boring.	
4 OLD VER-SION	**HGRD** -The main problem is too many students and too little equipment - this creates a bad working atmosphere. -There was no indication that in measuring the $KHC_8H_4O_4$ the "accurate" balance should be used. This was only discovered half way through the experiment! -For students who have done CSYS chemistry the experiments could be more interesting perhaps with a greater degree of difficulty. Also, the fact that the accurate balance had to be used (near the glass bin) should have been made clear at the beginning of the lab and not when students had almost completed the experiment.	
5 OLD VERSION	**OTHER** -The lab was well organised considering the size of the class. Since today was the last practical before Christmas everyone needed to be tested at weighing and titrating thus there were quite a few people waiting to be tested. Although I had to wait nearly 45 minutes for this. I feel the wait was understandable. A few more people should be authorised to test on titration - two for a class of our size is	

Table 3.16 - Students comments about the experiment - DIARY TWO

2.4 - THE DEMONSTRATOR'S DIARY

The purpose of the Demonstrators' Diary was to identify the problems in the practical inorganic chemistry course from the viewpoint of the demonstrators.

The DEMONSTRATOR'S DIARY was structured as follows:

1.COMMENTS, QUERIES FROM STUDENTS ABOUT:

1.1 - Written Instructions

1.2 - Experiments

1.3 - Laboratory's organisation

1.4 - Practical Problem

2.DEMONSTRATOR'S OWN OBSERVATIONS

For each item of this DIARY the demonstrator recorded any student's reported problem - any problem the demonstrator might have observed during the lab sessions. In the second part of the Diary the demonstrators were asked to state their own opinions and suggestions or any other problem that did not fit into the diary's headings. A copy of the DEMONSTRATOR'S DIARY can be found in Appendix A-10 (page 299).

2.4.1 - RESULTS OF THE DEMONSTRATORS' DIARY

The Demonstrators helpfully provided a detailed account of their own opinions and observations at the end of each laboratory session. Table 3.17 shows a summary of these comments.

1.1 - WRITTEN INSTRUCTIONS

Instructions on how to weigh seem to have been a particular problem in both versions of the manual. The OLD version had no instructions regarding the kind of balance students should use. While the NEW version introduced a new symbol for weighing which students were unable to identify i.e. no key for this symbol had been included in the manual.

Demonstrator's comments about the new version of Written Instruction in Friday session were the same as for the other sessions. (See Table 3.17).

1.1 - WRITTEN INSTRUCTIONS		
EXP	OLD VERSION	OLD VERSION
1	-pg21/ln18 -'about 3 g' Does it mean roughly or accurately weighing? -pg23/ln5/7/10-'weigh up to 7g'/'add 5.5g Al' and '3g of chromium(VI)' -pg23/ln33- 'Weigh the chromium and calculate...' -Reference to wrong edition	-pg21/ln24-'weigh about 3 g' roughly or accurately? -pg22/3/4 -'weigh up to 7g' / 'add 5.5g Al and 3 g chromium (VI)' -pg22/ln24- 'Weigh the metal' -The students did not see symbol of rough balance at side. -References but no edition stated
2	-References with wrong editions -pg26/ln18-'...small sample of Al...' How much is this small? -pg27/ln3/9/14-'warm a little...' How much is this little? -pg27/ln21- 'Prepare a solution of...' How much? -pg27/ln28-'Heat strongly some potassium...' How much is this some?	-Reference to wrong edition -pg28/ln9-'Prepare 10ml of a chlorine solution...' How much of sulphuric acid? -pg28/ln31-'...add few drops of CONC. AMMONIA to...' What does it means? and Where is it placed?
3	-Reference to wrong book edition -pg29/ln26- 'Weigh accurately about 0.9g of...' -pg30/ln7- 'Transfer...to a clean beaker...' Should be conical flask.	-References to wrong book edition -pg32/ln7- 'Weigh accurately about 0.9g of...' -pg32/ln18- 'Weigh out approximately 1 g...' -Due the absence of explanation for symbols used. -The symbols were not clear
4	-pg34/ln6-'Weigh accurately 0.6-0.7g of...' -pg34/ln7-'...into a 250ml beaker...' Should be a conical flask. -pg34/ln18-'...of the SPECIAL HYDROCHLORIC ACID solution...' Why is it SPECIAL? -pg34/ln19-'...into a beaker..' Should be a conical flask. -pg34/ln9-'pKa=9.6, colour change colourless-red'	-pg34/ln2/10/12- 'Preparation of an M/10 solution...' What does M/10 mean? (0.1M or 10M). -pg34/ln18-'Weigh a sample between 0.6 and 0.7 g of...' -pg34/ln38/40-'until you see a pink colour at the point of entry'
5	-Reference to wrong book edition -pg38/ln6- 'Weigh accurately 0.5-1.0g of...' -pg38/ln10-'...has evaporate almost to dryness' How dry is almost?	-pg37/ln32- 'Cool and divide this solution into...' Should the solution be cooled in an ice or water bath? -pg39/ln3-'Weigh accurately a sample of...' -pg39/ln12-'...has evaporated almost to dryness'
6	-pg43/ln7-'Cool the mixture...' -pg43/ln10- '... by filtration (Buchner funnel)'	-pg42/ln15-'Cool the solution.'

Table 3.17 (A) - Comments of Demonstrators' Diary

1.2 - EXPERIMENTS	
-Calculations skills:	
-Molarity	-Work out the molarity from titrations results
-Percentage of Cu in Thiourea Complex	-Theoretical yield
-Chemical Equations	
-Prediction of reaction's products	-Balance redox equations
-Manipulative skills:	
-How to set up the titration apparatus	-How to pipette properly (with a rubber bulb)
-How to read a burette properly	-How to titrate properly
-How to use a Buchner funnel and water pump	-How to set up a filtration apparatus
-How to use an analytical balance	-The name of the apparatus
1.3- LABORATORY'S ORGANISATION	
-Location of the glassware	-Location of the Chemicals
-The students were not familiar with the lab	-Long queues to use the balances
-Glass bin for broken apparatus is not very obvious	-Crowed Fume Cupboard
2-DEMONSTRATOR'S OBSERVATIONS	
-The students are still struggling with the unit cancellation method;	
-Some students don't realise that a titration end point is the difference of one drop	
-The students tend to find the NEW version easier to follow and use both when allocated the OLD one.	
-At this stage they don't seem to ask as many questions regarding the written instructions but they are conferring with friends as to how they tackled the experiment.	
-Students work on but have to repeat part of experiment because they did not know the difference between accurately / roughly weighing;	
-Where the students have to tackle the short problem at the end of experiments, they cannot think how to tackle the problem,i.e., they really are not aware of what they have been doing.	
-The experiment 5 - OLD version finding difficulty in preparation of complex. Students seem overcome by the amount of information contained in this one large paragraph and they ask question at every step. Students also do not read past full stops.	
-When the students were working from the OLD version in experiment 5 they did not know the difference between clear and colourless.	
-Students do not read the instructions carefully.	
-Students should be asked to: -Read the instructions fully -Form a plan of operation -Consult a demonstrator to agree a course of action.	
-Students are not skilled at using the burette.	
-Students had some difficulty in locating the glassware and chemicals.	
-The chemicals and some apparatus had been misplaced and students could not find them.	
-The students have very little experience in doing chemistry practical work. They don't know how to calculate molarities.	
-A lot of students don't know how to use a balance;	
-A lot of students did not know why they did a titration and do not understand why they did the experiment.	
1.4- PRACTICAL PROBLEM (only FRIDAY'S session)	
-Most students have inadequate lab' experience	-What is the formula of acetic acid!
-The methods of titration and using the balances	-Calculation of molarity
-Products of the reactions and balancing equations	

Table 3.17 (B) - Comments of Demonstrators' Diary

Another problem, related to weighing, was the imprecision of the OLD version, i.e., students were instructed to weigh "a small sample". The question which would then arose would be "How small a sample?". This problem did not arise in the NEW version because after "small sample" the following instruction was added "that will fit on the end of a spatula".

Other problems were: concentration was expressed as "M/10"; instructions for "use beaker instead of a conical flask" in titrations; instructions to evaporate a solution "almost to dryness". Reflecting a lack of acquaintance among students with nomenclature, ignorance of lab equipment, and inexact language in instructions causing confusing.

B - EXPERIMENTS

Three problems arose:

i Students' difficulties in performing the calculations required in the experiments;

ii Students' difficulties in predicting and balancing chemical equations; and

iii A generally low level of manipulative skills when pipetting, titrating, and setting up apparatus.

C - LABORATORY ORGANISATION

The absence of instructions indicating where the chemicals and apparatus (which was not included in students' personal and communal kit) were located, was the main problem.

D - DEMONSTRATORS OBSERVATIONS

The demonstrators' views about the course reinforced the student claims and stressed students' preferred the NEW version because of the easy-to-follow step-by-step procedures it contained.

The demonstrators also pointed out that students had difficulties in working out the calculations involved in doing the titrations.

E - PRACTICAL PROBLEM

This item was answered by the demonstrators for the Friday session only when the practical problems were being done. The lack of ingenuity demonstrated by students doing the Practical-Problem was itself the main problem.

DEMONSTRATORS' COMMENTS

The Demonstrators' comments, besides reinforcing students' comments identify several students difficulties with the content and techniques involved in the experiments.

3 - MINI-PROJECTS

As shown in the Table 3.1 at the beginning of this chapter, of the FRIDAY session the students only used the NEW written instruction and were asked, at the end of each experiment, to do a Mini-Project (i.e. a problem to be solved by practical means).

The teaching aims of the Mini-Project were:

1. to reinforce the content of the experiment;
2. to demonstrate a practical application; and
3. to give the students an opportunity to plan their own experiment.

The Mini-Project consisted of a problem to be solved by practical means using the techniques and/or chemistry of the experiment given in the manual to provide an opportunity for the students to apply the concepts and/or techniques they had learnt. In other words, it was hoped that these Mini-Projects would encourage the students to work independently, planning their work and arriving at their own conclusions.

In order to avoid possible dangerous situations in the lab, arising from the students' lack of experience, they were asked to plan how they intended to solve the problem and list the apparatus and chemicals they thought necessary to do it. Once the plan was ready it had to be discussed with the demonstrator before the experiment was commenced.

On completing the experiment students were asked to write down as many observations and results as they possibly could followed by an evaluation of their own work and a conclusion.

Examples of the forms used by students are given in Appendix A-11 (page 300). Table 3.18 shows the Mini-Projects applied at the end of experiments 2, 3 and 4. Hence Mini-Project 2A is based upon experiment 2, Mini-Project 3A is based upon experiment 3 and Mini-Projects 4A, and 4B are based upon experiment 4.

MP	MINI-PROJECTS - MP
2A	-On the labels on lavatory cleaners the instructions say: "DO NOT MIX WITH ANY OTHER LAVATORY CLEANER" Why? You have a cleaner to mix and observe the result then try to explain what these cleaners are.
3A	-The solutions in flasks A; B; C; D and E contains STARCH; $Na_2S_2O_3$;I_2;KI and NaOCl. Using only these solution design an experiment to find out which flask contains which solutions.
4A	-Find out the amount of citric acid in a sample of orange juice. HINT: citric acid has three acidic hydrogens.
4B	-The solutions in flasks 1; 2; 3 and 4 contain HCl;NaOH; H_2O;and phenolphtalein. Using only these solutions, design an experiment to find out which flask contains which solutions. Find out the total number of H^+ in a given sample of wine.

Table 3.18 - Mini-Projects applied on Friday session.

3.1 - MINI-PROJECTS' EVALUATION

We evaluated the Mini-Projects by a two part questionnaire. The first consisted of Likert-type statements in which students were asked to state their opinion along with a preference scale: A = Strongly agree; B = Agree; C = Undecided; D = Disagree and E = Strongly Disagree;

1.I THINK THAT SOLVING THIS PRACTICAL PROBLEM

a) forced me to design and plan my own experiment
b) illustrated practical application of the laboratory
c) gave me confidence in my practical work
d) did not give me enough instruction to work
e) allowed me to use my knowledge of chemistry to investigate the problem
f) gave me a lot of satisfaction

2.I THINK THAT MORE EXPERIMENTS LIKE THIS SHOULD BE INCLUDED IN THIS COURSE

3.I THINK THAT SOLVING THIS PROBLEM HELPED ME TO UNDERSTAND THE THEORETICAL LECTURES.

In the second part a semantic differential technique which consisted of a five point scale between a pair of opposite adjectives was used. Students were asked to state their opinion about the experience in solving the practical problem by ticking the appropriate box.

The questions included in the questionnaire are listed below. A copy of the PRACTICAL PROBLEM QUESTIONNAIRE is in the Appendix A-12 (page 301).

1.	MEANINGFUL	_ _ _ _ _	MEANINGLESS
2.	DIFFICULT	_ _ _ _ _	EASY
3.	WASTE OF TIME	_ _ _ _ _	USEFUL
4.	ENJOYABLE	_ _ _ _ _	UNENJOYABLE
5.	UNIMPORTANT	_ _ _ _ _	IMPORTANT
6.	INTERESTING	_ _ _ _ _	BORING
7.	CONFUSING	_ _ _ _ _	UNDERSTANDABLE
8.	WELL-ORGANISED	_ _ _ _ _	DISORGANISED

Like the other sessions, the PRE and POST questionnaires were applied on Friday in order to detect any changes in the students' opinion about the practical course with practical problems.

3.2 - MINI-PROJECTS' RESULTS

The PRE, POST and PRACTICAL-PROBLEM questionnaires were analysed similarly to the other sessions. The results were grouped according to the students' previous experience, i.e., HGRD; SYS and OTHER. The frequencies and percentages of response were then calculated for each statement (see Table 3.19 and 3.20). The difference between positive and negative responses was calculated and added to the table (column %DIFF, the Level of Agreement).

The comparison of PRE and POST Questionnaires was carried out by applying normal Chi-square using the raw frequencies of response of the global sample. The results showed that only two questions obtained a significant difference at the 5% level (4. ENJOYABLE / UNENJOYABLE and 8. VARIED / REPETITIVE in favour of their previous experience (PRE-questionnaire). There was no significant difference between PRE and POST in other questions except 9. ADEQUATE / INADEQUATE WRITTEN INSTRUCTIONS positively favouring ADEQUATE WRITTEN INSTRUCTIONS.

The SYS sub-sample of student changed more positively than the HGRD students in answer to the following questions: 1. MEANINGFUL; 2. EASY; 5. SATISFYING; 7. UNDERSTANDABLE; 8. VARIED; 10. LEISURELY.

PRE and POST QUESTIONNAIRES - FRIDAY SESSION - MINI-PROJECTS

Q - 1	DEG	MEANINGFUL	UNDECIDED	MEANINGLESS	% DIFF	HGvsSYS
HGRD	PRE	18 (69)	7 (27)	1 (4)	65	
	POST	17 (65)	8 (31)	1 (4)	61	
SYS	PRE	14 (78)	3 (17)	1 (5)	73	
	POST	13 (72)	5 (28)	0 (0)	44	
GLBL	PRE	42 (75)	12 (21)	2 (4)	71	
	POST	39 (70)	15 (27)	2 (3)	67	

Q - 2	DEG	EASY	UNDECIDED	DIFFICULT	% DIFF	HGvsSYS
HGRD	PRE	5 (19)	14 (54)	7 (27)	-8	
	POST	1 (4)	15 (58)	10 (38)	-34	
SYS	PRE	2 (11)	15 (83)	1 (6)	5	
	POST	3 (17)	11 (61)	4 (22)	-5	
GLBL	PRE	9 (16)	36 (64)	11(20)	-4	
	POST	5 (9)	34 (61)	17(30)	-21	

Q - 3	DEG	USEFUL	UNDECIDED	WASTE OF TIME	% DIFF	HGvsSYS
HGRD	PRE	18 (69)	6 (23)	2 (8)	61	
	POST	17 (65)	7 (27)	2 (8)	57	
SYS	PRE	14 (78)	3 (17)	1 (5)	73	
	POST	12 (67)	4 (22)	2 (11)	56	
GLBL	PRE	42 (75)	10 (18)	4 (7)	68	
	POST	37 (66)	15 (27)	4 (7)	59	

Q - 4	DEG	ENJOYABLE	UNDECIDED	UNENJOYABLE	% DIFF	HGvsSYS
HGRD	PRE	12 (46)	11 (42)	3 (12)	34	
	POST	12 (46)	8 (31)	6 (23)	23	
SYS	PRE	14 (78)	2 (11)	2 (11)	67	5%
	POST	7 (39)	5 (28)	6 (33)	6	
GLBL	PRE	36 (64)	15 (27)	5 (9)	55	5%
	POST	24 (43)	19 (34)	13 (23)	20	

Q - 5	DEG	SATISFYING	UNDECIDED	FRUSTRATING	% DIFF	HGvsSYS
HGRD	PRE	8 (31)	9 (34)	9 (35)	-4	
	POST	7 (27)	8 (31)	11(42)	-15	
SYS	PRE	4 (22)	11 (61)	3 (17)	5	
	POST	4 (22)	8 (45)	6 (33)	-11	
GLBL	PRE	18 (32)	26 (46)	12 (21)	11	
	POST	14 (24)	21 (38)	21 (38)	-14	

Q - 6	DEG	INTERESTING	UNDECIDED	BORING	% DIFF	HGvsSYS
HGRD	PRE	17 (65)	3 (12)	6 (23)	42	
	POST	15 (58)	7 (27)	4 (15)	43	
SYS	PRE	15 (83)	3 (17)	0 (0)	83	
	POST	11 (61)	7 (39)	0 (0)	61	
GLBL	PRE	41 (73)	9 (16)	6 (11)	62	
	POST	33 (59)	18 (32)	5 (9)	50	

Table 3.19 (A) - Frequencies of responses of PRE and POST questionnaires FRIDAY session

Q - 7	DEG	UNDERSTAND-ABLE	UNDECIDED	CONFUSING	% DIFF	HGRD vsSYS
HGRD	PRE	16 (62)	4 (15)	6 (23)	39	
	POST	9 (35)	11 (42)	6 (23)	12	
SYS	PRE	8 (44)	8 (44)	2 (12)	32	
	POST	7 (39)	8 (44)	3 (17)	22	
GLBL	PRE	31 (55)	17 (30)	8 (14)	41	
	POST	21 (38)	25 (45)	10 (18)	20	

Q - 8	DEG	VARIED	UNDECIDED	REPETITIVE	% DIFF	HGvsSYS
HGRD	PRE	15 (58)	7 (27)	4 (15)	43	5%
	POST	11 (42)	3 (12)	12 (46)	-4	
SYS	PRE	12 (67)	1 (5)	5 (28)	39	
	POST	12 (67)	5 (28)	1 (5)	62	
GLBL	PRE	34 (61)	12 (21)	10 (18)	43	
	POST	25 (45)	14 (25)	17 (30)	15	

Q - 9	DEG	ADEQUATE WRITTEN INSTRUCTION	UNDECIDED	INADEQUATE WRITTEN INSTRUCTION	% DIFF	HGRD vsSYS
HGRD	PRE	14 (54)	5 (19)	7 (27)	27	
	POST	19 (73)	5 (19)	2 (8)	65	
SYS	PRE	12 (67)	4 (22)	2 (11)	56	
	POST	11 (61)	2 (11)	5 (28)	33	
GLBL	PRE	35 (63)	11(19)	10 (18)	45	
	POST	39 (70)	9 (16)	8 (14)	56	

Q - 10	DEG	LEISURELY	UNDECIDED	RUSHED	% DIFF	HGvsSYS
HGRD	PRE	8 (31)	8 (31)	10 (38)	-7	
	POST	9 (35)	10(38)	7 (27)	8	
SYS	PRE	6 (33)	4 (22)	8 (45)	-12	
	POST	5 (28)	7 (39)	6 (33)	-5	
GLBL	PRE	16 (29)	17 (30)	23 (41)	-12	
	POST	18 (32)	21 (38)	17 (30)	2	

Q - 11	DEG	WELL-ORGANISED	UNDECIDED	DIS-ORGANISED	% DIFF	HGRD vsSYS
HGRD	PRE	13 (50)	7 (27)	6 (23)	27	
	POST	12 (46)	10 (38)	4 (16)	30	
SYS	PRE	11 (61)	5 (28)	2 (11)	50	
	POST	8 (44)	9 (50)	1 (6)	38	
GLBL	PRE	33 (59)	15 (27)	8 (45)	45	
	POST	24 (43)	24 (43)	8 (14)	29	

Table 3.19 (B)- Frequencies of responses of PRE and POST-Questionnaires FRIDAY session.

MINI-PROJECTS QUESTIONNAIRES - FRIDAY SESSION PART I

1. I THINK THAT SOLVING THIS PRACTICAL PROBLEM

1a. forced me to design and plan my own experiment					
Q - 1A	AGREE	UNDECIDED	DISAGREE	%DIFF	HGvsSYS
HGRD	34 (94)	2 (6)	0 (0)	94	
SYS	21 (78)	2 (7)	4 (15)	63	
GLBL	64 (89)	4 (6)	4 (5)	83	

1b.illustrated practical applications of the laboratory					
Q - 1B	AGREE	UNDECIDED	DISAGREE	%DIFF	HGvsSYS
HGRD	28 (78)	7 (19)	1 (3)	75	
SYS	22 (81)	5 (19)	0 (0)	81	
GLBL	56 (78)	14 (19)	2 (3)	75	

1c.gave me confidence in my practical work					
Q - 1C	AGREE	UNDECIDED	DISAGREE	%DIFF	HGvsSYS
HGRD	22 (61)	10 (28)	4 (11)	50	
SYS	15 (56)	10 (37)	2 (7)	49	
GLBL	42 (58)	24 (33)	6 (9)	51	

1d.did not give me enough instructions to work					
Q - 1D	AGREE	UNDECIDED	DISAGREE	%DIFF	HGvsSYS
HGRD	7 (20)	8 (22)	21 (58)	-38	
SYS	5 (19)	5 (18)	17 (63)	-44	
GLBL	12 (17)	19 (26)	41 (57)	-40	

1e.allowed me to use my knowledge of chemistry to investigate the problem					
Q - 1E	AGREE	UNDECIDED	DISAGREE	%DIFF	HGvsSYS
HGRD	29 (81)	2 (5)	5 (14)	67	
SYS	22 (81)	3 (11)	2 (7)	74	
GLBL	58 (81)	6 (8)	8 (11)	70	

1f.gave me a lot of satisfaction					
Q - 1F	AGREE	UNDECIDED	DISAGREE	%DIFF	HGvsSYS
HGRD	20 (56)	8 (22)	8 (22)	34	5%
SYS	9 (33)	14 (52)	4 (15)	18	
GLBL	31 (43)	25 (35)	16 (22)	21	

QUESTION 2 - I THINK THAT MORE EXPERIMENTS LIKE THIS SHOULD BE INCLUDED IN THIS COURSE					
Q - 2	AGREE	UNDECIDED	DISAGREE	%DIFF	HGvsSYS
HGRD	22 (61)	8 (22)	6 (17)	44	5%
SYS	7 (26)	12 (44)	8 (30)	-4	
GLBL	34 (47)	22 (31)	16 (22)	25	

Table 3.20 (A) - Mini-Projects Questionnaires results

QUESTION 3 - I THINK THAT SOLVING THIS PROBLEM HELPED ME TO UNDERSTAND THE THEORETICAL LECTURES					
Q - 3	AGREE	UNDECIDED	DISAGREE	%DIFF	HGvsSYS
HGRD	8 (22)	8 (22)	20 (56)	-34	
SYS	4 (15)	11 (41)	12 (44)	-29	
GLBL	14 (19)	22 (31)	36 (50)	-31	

PART II

1	MEANINGFUL	UNDECIDED	MEANINGLESS	%DIFF	HGvsSYS
HGRD	25 (64)	14 (36)	0 (0)	64	
SYS	17 (63)	8 (30)	2 (7)	56	
GLBL	48 (64)	25 (33)	2 (3)	61	

2	EASY	UNDECIDED	DIFFICULT	%DIFF	HGvsSYS
HGRD	18 (46)	10 (26)	11 (28)	18	
SYS	14 (52)	8 (30)	5 (19)	33	
GLBL	37 (49)	21 (28)	17 (23)	26	

3	USEFUL	UNDECIDED	WASTE OF TIME	%DIFF	HGvsSYS
HGRD	25 (64)	12 (31)	2 (5)	59	
SYS	11 (41)	9 (33)	7 (26)	15	
GLBL	40 (53)	24 (32)	11 (15)	38	

4	ENJOYABLE	UNDECIDED	UNENJOYABLE	%DIFF	HGvsSYS
HGRD	19 (49)	14 (36)	6 (15)	34	
SYS	13 (48)	11 (41)	3 (11)	37	
GLBL	36 (48)	28 (37)	11 (15)	33	

5	IMPORTANT	UNDECIDED	UNIMPORTANT	%DIFF	HGvsSYS
HGRD	29 (74)	8 (21)	1 (3)	71	1%
SYS	9 (33)	12 (44)	6 (22)	11	
GLBL	42 (55)	24 (32)	9 (13)	42	

6	INTERESTING	UNDECIDED	BORING	%DIFF	HGvsSYS
HGRD	21 (54)	17 (44)	1 (2)	52	
SYS	13 (48)	8 (30)	6 (22)	26	
GLBL	39 (52)	28 (37)	8 (11)	41	

7	UNDERSTAND-ABLE	UNDECIDED	CONFUSING	% DIFF	HGRD vsSYS
HGRD	21 (54)	13 (33)	5 (13)	41	
SYS	20 (74)	6 (22)	1 (4)	74	
GLBL	45 (60)	24 (32)	6 (8)	52	

8	WELL-ORGANISED	UNDECIDED	DISORGANISED	%DIFF	HGvsSYS
HGRD	15 (38)	15 (38)	8 (21)	17	
SYS	12 (44)	14 (52)	1 (4)	40	
GLBL	31 (42)	32 (43)	11 (15)	27	

Table 3.20 (B) - MINI-PROJECTS Questionnaires results

and 11. WELL-ORGANISED. In other questions the HGRD students answered more positively. Significant differences were found in the questions 4. ENJOYABLE / UNENJOYABLE and 9. ADEQUATE / INADEQUATE WRITTEN INSTRUCTION in favour of the POST questionnaire.

A comparison between the MON-to-THU and FRIDAY level of agreement using the results of the cross-tabulation included in Table 3.8 is displayed in Figure 3.2, chart (A) Global sample, chart (B) HGRD sub-sample, and chart (C) SYS sub-sample.

The Global results of the Mini-Projects session were more negative than another sessions in almost all questions. There was a significant difference in the following questions, 1. MEANINGFUL and 9. ADEQUATE / INADEQUATE WRITTEN INSTRUCTION in favour of POST questionnaire and 4. UNENJOYABLE; 7. CONFUSING and 11. DISORGANISED in favour of PRE-questionnaire.

The comparison of sub-samples HGRD and SYS showed that there was no significant difference in the HGRD sub-sample. However, the SYS sub sample showed a positive improvement in the following questions: 1. MEANINGFUL; 5. SATISFYING; 6. INTERESTING; 10. LEISURELY and 11. WELL-ORGANISED.

	DIFFERENCE LEVEL OF SIGNIFICANCE							
	MO+TU vs WE+TH			HGRD vs SYS		MO to TH vs FRI		
QUEST.	HGRD	SYS	GLBL	GLBL	FRI	HGRD	SYS	GLBL
1		>1% MO+TU		>1% HGRD		>5% FRI	>5% FRI	>5% FRI
2				>10% SYS				
3		>10% WE+TH		>10% HGRD				
4		>5% MO+TU						
5								
6				>5% HGRD				
7				>5% SYS				
8	>5% WE+TH							
9	>5% MO+TU			>5% HGRD		>1% MO+TH	>5% MO+TH	>10% MO+TH
10							>10% FRI	
11								>10% MO+TH

Table 3.21 - Comparison between samples and sub-samples of the PRE and POST Questionnaires.

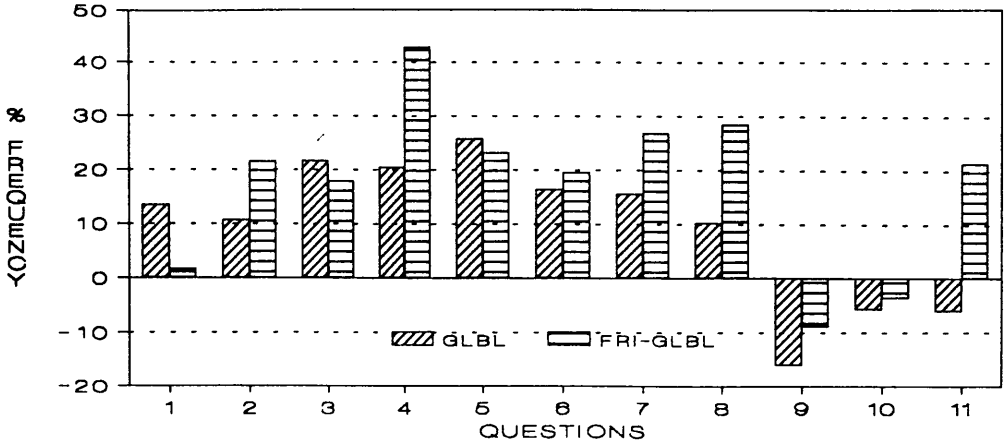


FIG. 3.13 (A) - ATTITUDE CHANGE
MO-to-TH vs FRIDAY - GLOBAL

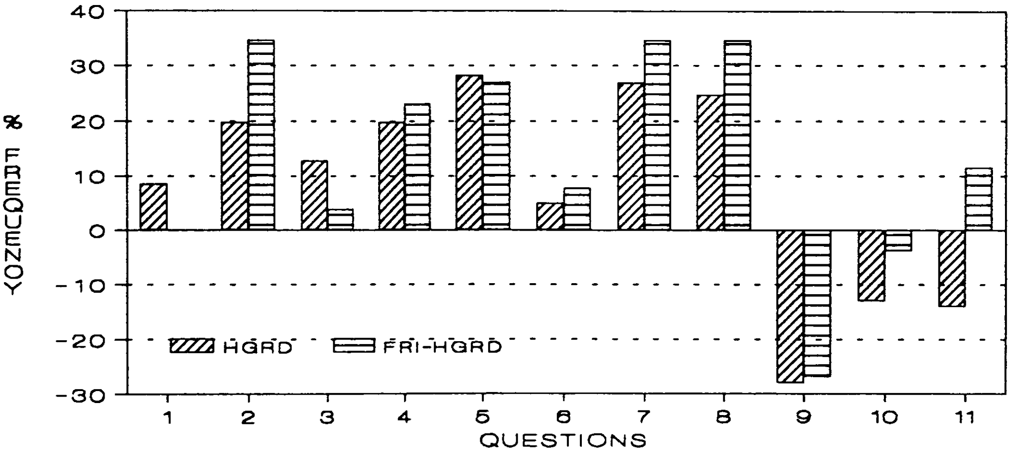


FIG. 3.13 (B) - ATTITUDE CHANGE
MO-to-TH vs FRIDAY - HGRD

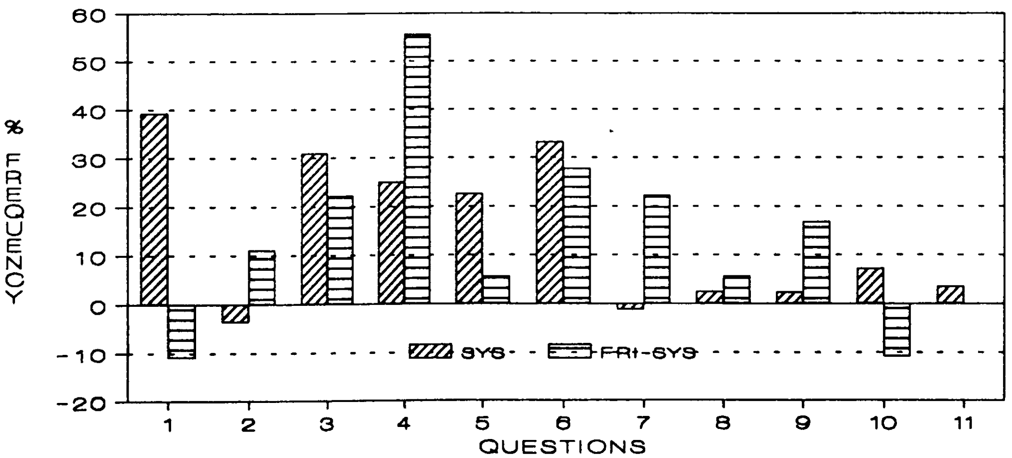


FIG. 3.13 (C) - ATTITUDE CHANGE
MO-to-TH vs FRIDAY - S Y S

Table 3.21 shows the level of significance of the differences between MONDAY plus TUESDAY (MON+TUE) versus WEDNESDAY plus THURSDAY (WED+THU) session; MONDAY to THURSDAY (MON to THU) versus FRIDAY (FRI) session; and the sub-samples HGRD versus SYS.

The practical problem questionnaire in which the students stated their opinion about the mini-projects had, in almost all questions, a frequency of agreement greater than 60%, i.e., about 60% of the students agreed that this kind of problem forced then to design and plan the experiment; illustrate applications of practical work and gave them more confidence in their work.

Most of the students agreed that the Mini-Projects allowed them to apply their own knowledge of chemistry and considered that the information given was adequate.

A slight difference in opinion was found between the HGRD and SYS sub-samples. The SYS students, it would appear, were less impressed than the HGRD by this kind of activity.

The raw frequency and percentages calculated for each statement are given in Table 3.21.

4 - CONCLUSION: A SUMMARY

The students all had experienced some practical work before commencing the first year inorganic chemistry course. The majority had completed the Higher grade (HGRD) or the Sixth Year Studies (SYS). Our results were thus analysed for both sub-samples in an attempt to obtain a more homogeneous population. The first part of the PRE-questionnaire provide more information about the population in each session and indicated that the students had the same kind of experience before coming to University though the form of lab work which they had been exposed to differed as coted above(see section 2.2.1 earlier in this chapter).

The students opinions about their previous experience in practical work were measured before and after the practical course. We sought their views on as many aspects of the laboratory as was possible. We found however that their opinions of practical work did not improved and indeed in most of the cases change negatively by the end of the lab sessions.

We found a significant negative ATTITUDE CHANGE in the response to questions 1, 3, 6, 7, 10 and 11. Only questions 2 and 9 displayed positive Attitude Change.

There was two quite different approaches used in the practical course, the "traditional" lab course held on Monday to Thursday sessions and the Practical Problem-Solving session introduce on Friday.

Comparison of the two sub-sample responses revealed that the SYS students had a more negative attitude to the "traditional" course than the HGRD. However for the Friday sessions, where the Mini-Projects were introduced, change occurred in opposite way; i.e. the HGRD students had a more negative attitude to the course than the SYS (see Figure 3.2).

More detailed information was required to attempt to establish the reasons for this; the diaries were thus devised for this purpose. They helped to show that experiments 2 and 3 of both versions presented more problems than the others, i.e. introduce "noise" and impaired effective learning

Our analysis of these experiments indicates that the amount of information necessary to perform them is greater than the experiments 1 and 4. The students were expected to know several halogen reactions, their products, physical properties, etc, in order to work on these experiment in a meaningful way. Similarly in experiment 3, the redox reaction of iodine is far more complex than the acid-base titration in experiment 4.

The Diaries further helped demonstrate that there were some common problems associated with the experiments; e.g. students' difficulties in calculating molarities, percentage yields and concentrations of unknown solution by titration.

The Demonstrator Diaries, confirmed the students' problems adding useful comments and suggestions as to how these might be overcome. The fact that students spent a lot of time trying to acquire proper pipetting, weighing, titrating skills and other basic techniques, disrupted their practical work. The literature suggests that is not possible for an individual to do tasks at the same time with the same accuracy unless one of them is performed automatically[61]. Simply, it is not possible for students to learn new manipulative skills and understand the content of an experiment at the same time[47].

Furthermore, the students wasted a lot of time in looking for apparatus, chemicals, and instruments due to the absence of information in the manual on their locations in the lab.

The main problems identified by our preliminary survey will receive more careful attention in the next stage.

In summary the preliminary survey found that:

i Students are not sufficiently prepared for the practical work. It therefore is necessary to adopt an approach that induce them to do the necessary preparatory work. Wham[1] suggested that the use of pre laboratory exercises can help overcome this problem. We suggest that Prelab Work might be more clearly linked with planned experimental content and, where possible, the results of Prelab exercises should be used in the experiment in order to demonstrate their applicability.

ii Students waste time because they lack necessary manipulative skills. This could be minimized by introducing specific training at the very beginning of the practical course supported by appropriate written instructions, i.e., a revision of basic lab techniques.

iii The NEW version of written instructions seemed to be more efficient than the OLD one and more acceptable to the students, but this still requires some improvement, i.e. terminology need to be more specific, requires clearer organisation and standardization of the information for all experiments, and the procedure ought to be clearly linked to the location of the apparatus and chemicals in the lab.

iv The Practical problem solving introduced at the end of each experiment seems to be a good instrument for demonstrating to the students the utility of the experimentation and how experiments relate to every day problems. Mini-Projects also gave the students the opportunity to become more involved in the planning of their experimental work.

CHAPTER 4

PLANNING A CHEMISTRY PRACTICAL COURSE FOR UNDERGRADUATES

The preliminary survey pointed out several negative aspects of the first year inorganic practical course similar to those found in Letton's[2] second year survey. The students' reported opinion about practical work before and after they completed the first year course did not improve. Indeed students' interest worsened, and they became more negative about lab; management, organisation, content, and the written instructions.

We planned to redesign the course mindful that factors such as, Written Instruction, Pre Laboratory Exercises, Laboratory Techniques, Practical Problems (Mini-Projects), and Organisation of the Laboratory could help prevent over-load of students' working memory so important in effective learning.

As a first step we chose to redesign the laboratory manual. Secondly, a lab techniques session was introduced at the outset of the practical course to familiarise students with the basic techniques required to perform the experiments. This training input was supported by written instructions included as an appendix to the lab manual. Thirdly, we introduced a problem to be solved before students started the practical work (termed Prelab Work). Finally, we introduced a practical problem, i.e., a problem to be solved by practical means, (termed Mini-Projects) at the end of each experiment.

To test the effects of these new features, four courses were designed in which each modification was changed one at a time, as follows:

COURSE-ONE - CONTROL GROUP (CTRL) - Used an Improved Lab Manual which was redesigned to avoid "overload" in its layout and language. The course was run in two stages as follows: (1) - Laboratory Technique Training; and (2) - a set of experiments. (See Figure 4.1)

COURSE TWO - PRELAB WORK GROUP (PLW) - Used the Improved Lab Manual which was amended with Prelab work designed to familiarise the students with the theoretical background involving them in prerequisite calculation and decision making. Course TWO was run in three stages as follows: (1) - Laboratory Techniques Training;

(2) - Pre-laboratory exercise (Prelab Work); and (3) - a set of experiments (see Figure 4.1)

COURSE THREE - MINI-PROJECT GROUP (MP) - Used the Improved Laboratory Manual with MINI-PROJECTS incorporated at the end of each experiment to give students a chance to design their own experiments. Course THREE was run in three stages as follows: (1) - Laboratory Techniques Training; (2) - a set of experiment; and (3) - Mini-Projects at the end of each experiment. (see Figure 4.1)

COURSE FOUR - PRELAB WORK and MINI-PROJECT (P&P) - Used the Lab Manual with Prelab work and involved both the Prelab work of course two and the Mini-Project from course three. The Manual with Prelab work being the version used. Course Four was the only one in which all design modifications were applied together as is shown in Figure 4.1.

1 Preparation stage	2 Preparation stage	3 Execution stage	4 Reinforcement stage
PRELAB WORK	LABORATORY TECHNIQUES TRAINING	EXECUTION OF THE PROPOSED EXPERIMENT	MINI-PROJECTS
courses 2 & 4	all courses	all courses	courses 3 & 5

Figure 4.1 - Stages of the course's versions

1 - IMPROVED LABORATORY MANUAL(version 3)

The written instructions added significantly to the load on working memory in practical work. Our comparison of the "OLD" (1) and "NEW" (2) versions in the preliminary survey suggested that the "NEW" was better than the "OLD" one. Despite its advantages however the "NEW" version still presented some problems, namely, the different sequences of procedures for each experiment; inexact language and obscure symbols which confused students, etc.

Our redesigned laboratory manual was an attempt to minimise the load in the students' working memory by presenting the written instructions more clearly and in a more understandable manner. Our aim was to reduce the load on the students in the lab situation to manageable proportions by linking the information in the manual to the experimental procedures, and improving the layout of the manual to make it easier for students to use.

Thus we redesigned the "NEW" Lab Manual (version 2), the version favoured by the students, retaining its basic theme and content. The Lab Manual redesigned was termed "Improved Lab Manual" (version 3) used in the course ONE and THREE.

We took the following steps to improve the Improved Lab Manual:

a. Establishment of a standard framework for all experimental procedures. - From our examination of the experimental procedures in the existing manual it was apparent that the sequence of these, (e.g., purpose, safety precautions, basic ideas behind the experiments, etc.), differed. This chopping and changing of procedural steps within a page, from one page to another, and from experiment to experiment meant that students had to reinterpret the instructions for each new experiment adding to the load on students' working memory.

   Care was thus taken in our redesigned manual to maintain the same format for procedures throughout the experiments as show below.

   Title
      Purpose
      Safety precautions
      The Experimental report requirements
      Outline of the Experiment
   The Experiments
      Basic Ideas Behind the Experiment (when necessary)
      The Experimental procedures

   This was intended to eliminate the need for students waste time trying to understand the organisation of procedures each time they started a new experiment. Moreover the improved design avoids students having to read all the experimental procedure each time when they needed to find out a specific piece of information and allow them to keep to the sequence of the experiment.

b. A clear statement of objectives for each experiment giving the directions the students should take and what should be achieved.

c. Hazard signs for all dangerous chemicals used in the experiments were introduced at the beginning of the experiment and in the right margin of experimental procedure as safety precautions and a Key of Symbols introduced on page 4 of the Lab Manual.

d. Instructions on what was expected in lab reports so students would not be distracted by unnecessary note-taking. Suggestions were given at specific stage in the experiment for systematically recording essential results and observations, e.g., suggestion of tables for recording the observations of the experiment 2.

e. An outline of the experiment was introduced to provide students with an overall picture of the experiment.

f. Theoretical questions were included in the experimental procedure to make students think about why they had to do certain tasks.

g. The Text of each the experiment was sub-divided using consistent vertical spacing. Single line-spacing was used throughout the experiments' procedures and double line-spacing to separate paragraphs and sections. Hence, procedures were grouped into small and easily understood portions.

h. Our choice of LINE LENGTH, LINE SPACING, TYPE SIZE, WORD-SPACING and TYPEFACE for the manual text was intended to space lines clearly, maximise the line length, and minimise image degradation during printing[57].

i. Symbols were introduced (e.g., demonstrator and balance) to indicate that demonstrator's assistance was required in more dangerous parts of the experiment and the type of balances (rough or analytical) that ought to be used to weigh chemicals. The objective being to clarify and reinforce the written instructions.

j. Illustrated procedures for basic techniques such as, weighing, and volumetric measurement involved in the experiments were included as an appendix of the Lab Manual (termed Yellow Pages). Specific references were included in the experimental procedures prompting students to consult the appendix when they were unsure how to use the apparatus and equipment.

k. Page 5 of the Improved Lab Manual gave a MAP OF THE LABORATORY indicating the locations of apparatus, chemicals and equipments. The organisation of the lab when compared with the preliminary survey was not changed significantly. The laboratory however was also signposted with labels in accord with our map. Experimental procedures also gave the location of apparatus, equipments and chemicals, such as, fume-cupboard (1 to 8), benches (A, B and C), technician room, balance room, first aid box, distilled water containers and staff and technician room. This was intended to reduce the frequency of queries (such as "Where's the filter paper?"; "Where's the distilled water?"; "Where's the chemicals?"; etc.) reported in the preliminary survey (see Table 3.17 - Chapter 3).

l. **A-4** page size of the manual was the same as that used previously. An attempt was also made to keep the number of pages approximately the same to contain the cost. (version 2(New) =43 pages and version 3(Improved)= 42 pages)

m. There were several drafts of the manual in its improved format, following the guidelines above before the final copy was agreed with advice from the member of staff in charge of the lab. The final print was chosen from three printouts with small differences in line spacing, character style, type face, etc., by colleagues and members of staff in charge of the course.

A copy of the Improved Lab Manual is included in the Appendix B-1 - (inside back cover).

2 - LABORATORY MANUAL WITH PRELAB WORK (version 4).

Providing the students with a theoretical grounding before began the experimental work was intended to extend their understanding of what they were to do.

As cited above during the preliminary survey students frequently stopped the experiment to get advice about techniques or calculations that they could not recall at the time. This breakdown in the experiment contributed to "noise" in the laboratory. Johnstone and Wham[47] suggested that this may result students not thinking about either the manipulative aspects of the experiment or the theory. In the event, they opt to follow the experiment's procedures without thinking about what they are doing or why they are doing it.

Meaningful practical work cannot be carried out without a strong theoretical base and mastery of laboratory techniques. If students are familiar enough with the theory and techniques involved they are effectively free to think about what they are doing.

The two approaches devised with the aim of making students gain some prerequisites in the theory and techniques were:

i PRELAB WORK (PLW) consisting of an exercise to be solved before starting any practical work; and

ii LABORATORY TECHNIQUES TRAINING which was introduced in the first session of the course. The students received training in weighing procedures, volumetric techniques and other minor techniques to make sure that they had skills needed to do the experiments.

A copy of the Improved Lab Manual with Prelab work is included in the Appendix B-2 (inside back cover).

2.1 - PRELAB WORK (PLW)

To deal with the problems that students reported in the Preliminary Survey we introduced Prelab exercises (termed PRELAB WORK) on the equations and calculations used in the experiments.

Students also complained that the practical work had been unrelated to the input on theory. In the case of experiments 5 and 6 this was understandable because they involved syntheses and analyses of complex compounds and the theoretical class was not due to be taught until two terms later. But, this was not true of the remaining experiments (1, 2, 3 and 4). To minimise this problem we design the Prelab Work linking it closely to the experimental procedures. Not only did the new theoretical problems relate to the experiment but the RESULTS from the Prelab Work were also to be used as DATA in the experiments.

The Improved Lab Manual was thus amended slightly to introduce these Prelab Works (termed PRELAB WORK LAB MANUAL). The amended version had added information on the experimental procedure and in it, students were instructed to use the results of the prelab exercise in their subsequent lab work, e.g., instead of giving the amount of chemicals needed for a specific reaction, students would now be expected to calculated this for themselves in advance.

In this way the Prelab Work designed to be completed <u>before</u> students started the practical work, helped to ensure that they attained some familiarity with the theoretical background and familiarise them with the calculation and balancing of given chemical equations. Students were not expected to be okay with all that the experiments would require, only with certain points which had impeded learning in the lab.

Moreover the Prelab Work was designed to allow it to be easily marked, so that demonstrators could quickly identify students' errors and to help overcome these. The Prelab Work was thus designed to be checked in the first 15 minutes of the lab, to avoid any waste of students and demonstrators time.

On page 6 of the Prelab Work Lab Manual, instructions were given on what was expected from students. It was made clear that they were not expected to do the problems on their own, but should discuss them with other students. Students were also urged to read the experiment carefully to see how it related to Prelab exercise.

The amendments (in bold) made to the Prelab Work Lab Manual were as follows:

EXPERIMENT 1 - INORGANIC PYROTECHNIC

IMPROVED LAB MANUAL - page 7 - last paragraph

A. The Ammonium dichromate 'Volcano'.

Using a rough balance (appendix-1) weigh out **about 3 grams** of ammonium dichromate. Also weigh a 100 ml beaker and record its weight. It will be used to collect and weigh the product of the reaction.

PRELAB WORK LAB MANUAL - page 7 - last paragraph

A. The Ammonium dichromate 'Volcano'.

Using a rough balance (appendix-1) weigh out **approximately the mass** of ammonium dichromate **calculated in your PRELAB WORK.**

PRELAB WORK

Part A - Balance the equation for the decomposition of ammonium dichromate [$(NH_4)_2Cr_2O_7$] to chromium(III) oxide (Cr_2O_3). Hence calculate the mass of ammonium dichromate required to make 2.0 g of Cr_2O_3.

Part B - Write the balanced equations for both the reduction of Cr_2O_3 and CrO_3 with Al to produce Cr Metal (thermite reaction). Hence calculate the theoretical yield of Cr metal from the complete reduction of 7.0g of Cr_2O_3 and 3.0 g of CrO_3.

EXPERIMENT - 2 - CHEMISTRY OF THE HALOGENS

In the specific case of experiment two there was no difference between the IMPROVED and PRELAB WORK Lab Manual. The Prelab Work in this experiment was intended to make students predict the products and balance some of the equations. There was no need therefore to change the experimental procedures.

PRELAB WORK

PART A - Write a balanced equation for each reaction and try to explain them.

a) $AlCl_3 + H_2O \longrightarrow$

b) $NaCl + H_2SO_4 \longrightarrow$

c) $NaCl + MnO_2 + H_2SO_4 \longrightarrow$

d) $NaBr + AgNO_3 \longrightarrow$

EXPERIMENT - 3 - ACID BASE TITRATIONS

IMPROVED LAB MANUAL- Page 18 - line 13

Using a rough balance (appendix 1) weigh out approximately **1 g of NaOH (3 pellets)** into a beaker.

PRELAB WORK LAB MANUAL - Page 18 - line 13

Using a rough balance (appendix 1) weigh out approximately **the mass of NaOH calculated in your PRELAB WORK** into a beaker.

IMPROVED LAB MANUAL - Page 18 - line 21

Using an analytical balance (weighing procedure - appendix 1) weigh out **about 0.6 g** of potassium hydrogen phthalate **accurately** and transfer it to a 250 ml conical flask.

PRELAB WORK LAB MANUAL - Page 18 - line 21

Using an analytical balance (weighing procedure - appendix 1) weigh **in a weighing bottle an amount** of potassium hydrogen phthalate **approximately equal to the mass calculated in your PRELAB WORK**. Transfer the hydrogen phthalate to a 250 ml conical flask.

PRELAB WORK

PART A- Calculate the mass of NaOH required to prepare 250 ml of a 0.1 M NaOH solution.

PART B - Calculate the mass of $KHC_8H_4O_4$ required to react with 25.00 ml of 0.10 M NaOH. The equation for the reaction is:

$NaOH + KHC_8H_4O_4 \longrightarrow KNaC_8H_4O_4 + H_2O$

Note: In this reaction $KHC_8H_4O_4$ is behaving as an acid in which the first hydrogen can be replaced by sodium. It is therefore a monoprotic acid.

PART C - It was found by titration that 22.50 ml of 0.120 M NaOH was required for complete reaction with 25.00 ml of a HCl solution. Calculate the molarity of the HCl solution.

EXPERIMENT 4 - IODIMETRY

IMPROVED LAB MANUAL - Page 22 - lines 4 to 7

A - Writing the equation

Write a balanced equation for the reaction of iodate ion with iodide ion.

Note: I_2 is the only iodine containing product. If you have a problem producing the equation for this reaction consult your demonstrator.

PRELAB WORK LAB MANUAL - Page 22 - line 4

The paragraph 'A - writing the equation' was omitted as it had been included as a Prelab Work.

IMPROVED LAB MANUAL - Page 22 - line 5

Using an analytical balance (weighing procedure - appendix 1), weigh out approximately **0.9 g** of Analar(analytically pure) KIO_3 **accurately** into a weighing bottle.

PRELAB WORK LAB MANUAL - Page 22 - line 9

Using an analytical balance (weighing procedure - appendix 1), weigh in a weighing bottle **an amount** of Analar(analytically pure) KIO_3 approximately **equal to the mass calculated in your PRELAB WORK.**

PRELAB WORK

PART A - Calculate the mass of KIO_3 required to prepare 250 ml of an 0.015M KIO_3 solution.

PART B - 1.Write the balanced equation for the reaction of the oxidising agent potassium iodate (KIO_3) with iodide ion in an acidic solution. The IO_3^- ion is reduced to I_2 and I^- is oxidised to I_2. (refer to lab manual appendix 4)

$IO_3^- + I^- + H^+ \longrightarrow I_2$ (unbalanced equation 1)

2. The I_2 obtained from the equation 1 reacts with thiosulphate ion ($S_2O_3^{2-}$) according to the balanced equation.

$I_2 + 2\ S_2O_3^{2-} \longrightarrow 2\ I^- + S_4O_6^{2-}$ (balanced equation 2)

3.Compare equation 2 with the equation you have written for the oxidation of I^- by IO_3^- in an acidic solution (equation 1), and decide the number of moles of $S_2O_3^{2-}$ that are equivalent to 1 mole of IO_3^-.

Using this relationship do the following titration calculation.

The molarity of a thiosulphate solution was determined by titration with a standard KIO_3 solution. In the titration, excess KI was added to 25.00 ml of a 0.0155 M KIO_3 solution that had been acidified with a few millilitres of sulphuric acid. The I_2 formed from this reaction was titrated with a thiosulphate solution. It was found that 22.42 ml of the thiosulphate solution was required for complete reaction with the I_2. Calculate the molarity of the thiosulphate solution.

EXPERIMENT 5 - PREPARATION AND ANALYSIS OF A THIOUREA COPPER(I) COMPLEX.

IMPROVED LAB MANUAL - Page 24 - line 16

1. Using a rough balance weigh out **about 2.5 g** of blue copper(II) sulphate crystals and dissolve them in about 15 ml of water.

PRELAB WORK LAB MANUAL - Page 24 - line 16.

1. Using a rough balance weigh out **approximately the mass** of blue copper (II) sulphate crystals **calculated in your PRELAB WORK** and dissolve them in about 15 ml of water.

IMPROVED LAB MANUAL - Page 26 - line 20

Calculate **the theoretical and practical(actual) %** Cu in your complex and compare them.

PRELAB WORK LAB MANUAL - Page 26 - line 20

Calculate **the actual % Cu** in your complex and compare with the % Cu **calculated in your PRELAB WORK(Theoretical)**

PRELAB WORK

PART A - Calculate the MASS OF $CuSO_4.5H_2O$ required to prepare 3.5 g of cooper(I) complex. The balanced equation for the reaction is:

$$2\,CuSO_4.5H_2O \;+\; 8\,SC(NH_2)_2 \longrightarrow \{Cu[SC(NH_2)_2]_3\}2SO_4.2H_2O \;+$$

$$\begin{array}{l}NH{=}C - S - S - C{=}NH \\ H_2N \qquad\qquad\qquad\quad NH_2\end{array} \;+\; H_2SO_4 \;+\; 8H_2O$$

PART B - Calculate the %Cu in the pure complex $\{Cu[SC(NH_2)_2]_2\}2SO_4.2H_2O$

EXPERIMENT 6 -PREPARATION AND ANALYSIS OF $K_3[Cr(C_2O_4)_3].3H_2O$

IMPROVED LAB MANUAL - Page 28 - line 8

2. Using a rough balance weigh out **1.5 g** of potassium dichromate and then add it a little at a time, to the oxalic acid solution. There will be a fairly vigorous reaction.

PRELAB WORK LAB MANUAL - Page 28 - line 8

2. Using a rough balance weigh out **approximately the mass** of potassium dichromate **calculated in your PRELAB WORK** and then add it, a little at a time, to the oxalic solution. There will be a fairly vigorous reaction.

IMPROVED LAB MANUAL - Page 29 - line 34

Now calculate the actual %Cr in your complex from your analysis and compare this value with the theoretical %Cr **calculated from the formula of the complex.**

PRELAB WORK LAB MANUAL - page 29 - line 34

Now calculate the actual %Cr in your complex from your analysis and compare with %Cr **calculated in your PRELAB WORK (theoretical).**

PRELAB WORK

PART A - In step 2 of the preparation of the complex the oxalic acid ($H_2C_2O_4$) is oxidised to carbon dioxide (CO_2) by potassium dichromate ($K_2Cr_2O_7$). Write the ion

electron half-equations for the oxidation of $H_2C_2O_4$ to CO_2 and for the reduction of $Cr_2O_7^{2-}$ to Cr^{3+}. Hence write the balanced ionic equation for the oxidation-reduction reaction.
Calculate the mass of potassium dichromate ($K_2Cr_2O_7$) required to prepare 5.0 g of $K_3[Cr(C_2O_4)_3].3H_2O$

PART B - Calculate the % Cr in the pure complex $K_3[Cr(C_2O_4)_3].3H_2O$.

A copy of the Manual version with PRELAB WORK is included in the Appendix B-2 (inside back cover).

3 - LABORATORY TECHNIQUES TRAINING

Both versions of the lab manual had, as an appendix, illustrated written instruction for weighing procedures, volumetric techniques and other minor techniques. This was used to support a laboratory session to train the students in the first week of the course. At the end of this session they were tested by members of staff who checked if they had mastered the skills of accurate weighing and titrations. All four courses had the same kind of training.

4 - MINI-PROJECTS

In the preliminary survey we had investigated the possibility of introducing mini-projects into the first year course. The result was encouraging as students recognised that this would be likely to make them organise and plan their own experiments. They also agreed that such problem-solving exercises should be more frequent.

MINI-PROJECTS (MP) give students the opportunity to plan and design their own experiments and make them to draw conclusions from experimental results, think independently and to develop skills in solving practical problems.

Practical problems from everyday life were chosen to motivate and develop students interest in chemistry, to engage them more and relate the subject to their own experience helping them to develop a better understanding of the subject.

Each of our experiments had at least two Mini-Projects associated with it. One related to everyday life; the other used the chemicals already used in the set experiment. Both Mini-Projects related to the chemistry involved in the experiments presented in the manual.

The Mini-Project was to be done at the end of each experiment. So while this had the purpose of engaging the students in the subject, recalling concepts and practising techniques, the Mini-Projects linked the subject to its application.

The Mini-Projects devised for and applied to experiments 1, 2, 3 and 4 were:

EXPERIMENT - 1

Mini-Project - 1A- On heating a mixture of solid copper(II) oxide and powdered charcoal(carbon) a reaction occurs. A colourless gas is produced with a solid deposit of an element on the inside the tube. What do you think are the products of the reaction? Is the reaction an oxidation-reduction reaction? If it is, what is the oxidising agent and what is the reducing agent? Write a balanced equation for your predicted reaction. Design a way of carrying out this reaction and of testing your prediction about the nature of the products.

Mini-Project - 1B - You have been given a black powder. Carry out the following reaction and then work out what the black powder is.

1.Heat half of the powder strongly and test for any gas given off. Keep the solid residue

2.When the tube has cooled, add few millilitres of concentrated nitric acid and observe the reaction and try to identify the products.

3.Take the other half of the black powder and boil it with dilute sulphuric acid for complete reaction (about 20 ml). Leave it to settle and make any deduction you can.

BEFORE STARTING THE EXPERIMENT checks your plan with your demonstrator for safety.

EXPERIMENT - 2

Mini-Project - 2A - The contents of the five flasks A; B; C; D; and E are CCl_4; $AgNO_3$(aq); NaCl(aq); NaBr(aq) and Chlorine water but not necessarily in that order. Using these chemicals only, design an experiment to find out which flask contains which chemical. Your experiment must be based on the chemistry involved in Experiment 2.

Mini-Project - 2B - Instructions on the labels of lavatory cleaners generally state the following: "Do not mix with any other lavatory cleaners." Two lavatory cleaners are DOMESTOS and HARPIC. One contains sodium hypochlorite($NaOCl$) and the other contains sodium hydrogen sulphate($NaHSO_4$). What would happen if these two cleaners were mixed? Design a way of testing your prediction about the nature of the product(s) of the reaction, and of identifying which cleaner contains which chemical. Your experiment must be based on the chemistry involved in Experiment 2.

HINT: HSO_4^- can act as an acid. Look at the part "D" entitled "Replacement of one halogen by another"

EXPERIMENT - 3

Mini-Project - 3A - Design an experiment to determine the concentration of acetic acid in vinegar. Your experiment must be based on the chemistry involved in Experiment 3.

Mini-Project - 3B - The content of the four flasks A; B; C and D are HCl(aq); NaOH(aq); H_2O and phenolphthalein but not necessarily in that order. Using these chemicals <u>only</u> design an experiment to find out which flask contains which chemical. Your experiment must be based on the chemistry involved in Experiment 3.

EXPERIMENT - 4

Mini-Project - 4A - The contents of the five flasks A; B; C; D; and E are starch; $Na_2S_2O_3$(aq); I_2(aq); KI(aq); and NaOCl(aq), but not necessarily in that order. Using these chemicals only, design an experiment to find out which flask contains which chemical. Your experiment must be based on the chemistry involved in Experiment 4.

Mini-Project - 4B - The active ingredient in bleaching powder is the oxidising agent the hypochlorite ion (OCl^-). It is reduced in acidic solution to Cl^- ion. Design an experiment to determine the concentration of OCl^- in an aqueous solution of bleaching powder. Your experiment must be based on the chemistry involved in Experiment 4.

HINT: Look at the section entitled "Basic Ideas Behind the Experiment".

Mini-Project - 4C - The contents of the five flasks A; B; C; D and E are starch; $Na_2S_2O_3$ (aq); KIO_3 (aq); KI (aq) and NaOCl (aq), but not necessarily in that order. Using the chemistry involved in Experiment 4 design an experiment to find out which flask contains which chemical.

Note that Mini-Projects were not devised for experiments 5 and 6 because they consisted of an application of techniques involved in experiments 4 and 3 respectively.

A copy of the form used to present the problems to the students is included in the Appendix B-3 (page 304).

5 - STAFF, DEMONSTRATORS and TECHNICIANS

Each session of the first year practical course was supervised by two member of the staff, five demonstrators and one technician. The staff member in charge of the course participated closely helping students throughout the course.

With the help of the demonstrators, post-graduate students of chemistry, by keeping diaries, common faults were noted from the lab sessions and from students' lab reports which they also carefully marked.

An important contributor to the running of the course were the technicians responsible for the upkeep of the apparatus and its replacement throughout the course. Though not asked to do any demonstration, nevertheless, the technicians often helped students to set up equipment properly. They were, without exception, vital to the smooth running of the laboratory.

6 - ASSESSMENT

6.1 - DESIGN RESEARCH

We assessed the improved courses of this survey by using questionnaires to record students' views on the course. For this purpose we devised the following instruments:

i PRE and POST questionnaires (Semantic Differential Scale) applied at the beginning and at the end of the practical course respectively, to reveal if student attitudes to practical work had changed after six weeks of the redesigned practical course.

ii DIARY (Likert-type Scale/questionnaire) was given to students for them to record their opinions about the practical work. Students were asked to complete one diary sheet for each experiment done.

iii PRACTICAL PROBLEM and PRELAB WORK questionnaires (Likert-type Scale) were applied to record the students' opinions about these two specific elements introduced in the improved practical course.

iv DEMONSTRATORS' DIARY was completed during each laboratory session reporting the main problems raised by students and their own opinions about the lab.

v DEMONSTRATORS' CHECK-LIST - the demonstrators were also asked to record the frequency of some specific questions posed by the students during the lab session in the preliminary survey, e.g, how to calculate of % yield of reactions, How to calculate the concentration of solutions, etc.

Table 4.1 summarises how the instruments were administered. Each sessions survey sheet were colour coded to facilitate sample identification if the instrument may returned later.

SESSIONS	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY
MANUAL	IMPROVED	*P L W	IMPROVED	*P L W	IMPROVED
VARIABLE	CONTROL	PLW	MP	PLW+MP	CONTROL
PRE-QUESTIONNAIRE	YES	YES	YES	YES	YES
POST-QUESTIONNAIRE	YES	YES	YES	YES	YES
DIARY	YES	YES	YES	YES	YES
PRELAB WORK QUESTIONNAIRE	-	YES	-	YES	-
PRACTICAL PROBLEM QUESTIONNAIRE	-	-	YES	YES	-
DEMONSTRATOR'S DIARY	YES	YES	YES	YES	YES
DEMONSTRATOR'S CHECK-LIST	YES	YES	YES	YES	YES
COLOUR OF INSTRUMENTS	WHITE	YELLOW	BLUE	PINK	GREEN

(*) PLW = PRELAB WORK

Table 4.1 - Summary of Instruments' application

The PRE, POST, PRELAB WORK, PRACTICAL PROBLEM and DIARY contained questions rated using a five point scale. The PRE and POST questionnaires also contained a group of open questions which were analysed to see if there was a pattern of response which might give hints about problems and deficiencies in teaching approach. The use of different teaching approaches or techniques allowed us to cross-check the students' responses and assess the validity and reliability of the instruments.

The population target of this survey was grouped according to the learning approach applied, in the following samples: CONTROL (CTRL); PRELAB WORK (PLW); MINI-PROJECTS (MP); and PRELAB WORK plus MINI-PROJECTS (P&P) samples.

The GLOBAL SAMPLES (GLBL) were also sub-divided into sub-samples according to the students' previous experience in chemistry at secondary school: HIGHER GRADE (HGRD); SIXTH YEAR STUDIES (SYS); and OTHER sub-samples.

We used two experimental designs in the survey.

i The questionnaires used in the observations (at the beginning and at the end) contained the same group of questions. The CONTROL and EXPERIMENTAL sample also ran in parallel as shown in Figure 4.2.

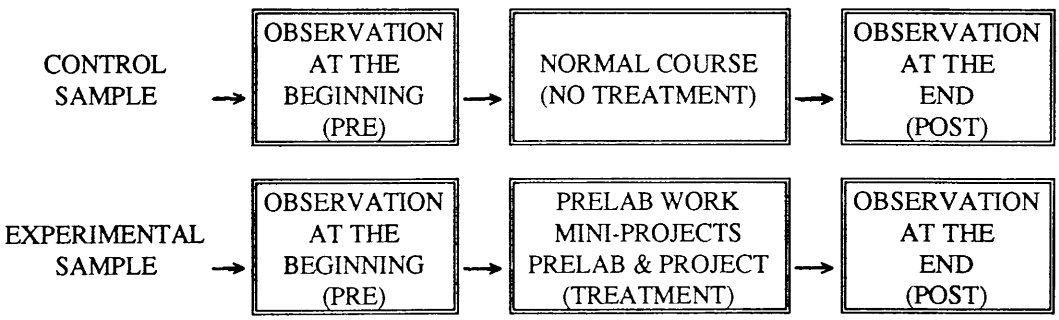


Figure 4.2 - Experimental design A

ii The Diaries were applied to each learning approach again the CONTROL and EXPERIMENTAL samples ran in parallel as shown in figure 4.3.

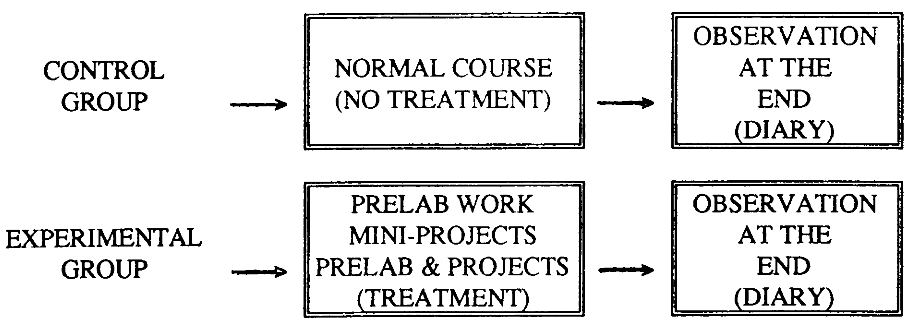


Figure 4.3 - Experimental design B

6.2 - STATISTICAL ANALYSIS

Most of the data collected by the survey was on a five point scale with responses classified as categorical data. Non-parametric statistical tests were thus considered appropriate for analysing the results. Three particular tests were chosen: CHI-SQUARE, PEARSON CORRELATION for grouped data and ZUBIN'S NOMOGRAPHS for testing the statistical significance of differences between percentages.

The Chi-Square test was used to calculate the significance level of the distribution of students' response to questions between the samples and sub samples (using the raw frequencies).

The Pearson correlation test for grouped data was used to calculate the correlation between questions answered under the same conditions. The correlation coefficient helped establish the validity of the questions through factor analysis.

Response frequencies and percentages for each category were calculated and compared with the samples and sub samples. The numbers used in these scales to denote a position on an attitude continuum, indicate a location rather than a quantity but are partly quantitative. But these numbers were not added or processed arithmetically further we did not assume a normal distribution, or compare them using the t-test. Numbers were used rather than letters to facilitate quicker computer processing. The Statistical Package for the Social Science (SPSS) was again used to compute and carry out the statistical analysis of the survey.

To facilitate the inspection of results, Zubin's Nomographs for testing the statistical significance of differences between the percentages of positive responses was applied. For "positive" responses the categories Agree plus Strongly Agree were added to give the positive statement and Strongly Disagree and Disagree for the negative statement.

This approach had the advantage of making it possible to estimate the significance of different proportions directly from the percentage figures. On the downside it lacked precision, so that, where the statement bordered on the limits of significance, it was necessary to calculate this by another method.

Hence, we used Zubin's Nomograph mainly to aid inspection of tendency of responses rather than to determine the statistical level of significance of the differences among samples.

Questionnaire responses were compared as follows:

i The percentage of frequencies were used to estimate the "Level of Agreement," i.e. the difference of positive minus negative responses percentages, ignoring the neutral response, [i.e.(1+2) minus (4+5) ignoring neutral category 3]. This approach was used for the DIARY, PRELAB WORK and MINI-PROJECT Questionnaires.

ii Positive response percentages were used to inspect the differences between samples and sub-samples using Zubin's nomographs.

iii Chi-Square was calculated using the raw frequencies to determine the level of significance of the differences between the samples and sub-samples; Chi-Square was calculated using a BASIC program[78].

iv Using the statistical package for social science (SPSS) cross tabulations were produced for the PRE and POST questionnaires questions to determine the frequency of students who had changed their opinion positively; not changed; or changed negatively. The "level of attitude change" was then calculated by subtracting the percentages of negative change from the positive ones. These indices were subsequently used to draw a bar chart to facilitate ease inspection and comparisons of the variables.

6.3 - VALIDATION OF THE INSTRUMENTS

We tested the extent to which the instruments actually measured what they were designed to measure by determining their reliability and the validity of the various scales in the instruments.

Of the various methods available for estimating reliability, the "internal consistency method" was chosen, since this was the most convenient procedure to apply to scales consisting of more than one item. Hence, we calculated Cronbach's alpha values for the scale items in the various instruments. (SPSS/PC+ subprogram RELIABILITY was used to do this).

We determined the validity of the instruments by FACTOR ANALYSIS and CORRELATION COEFFICIENT between items in each questionnaire. Factor analysis was carried out using the FACTOR sub-program, and Pearson's Correlation between items again using the SPSS/PC+ sub-programs.

The technique of factor analysis requires continuous sifting of data over an extended period to produce the most meaningful results. Several preliminary tests of the statements are usually carried out with subsequent omission of items which are found to have little variance. The factors which then emerge are clusters of many statements of high communality. Due to it was not our intention to develop an overly instrument due to the time constraint. We use a less precise form of this technique only to indicate factors of general importance; not to further elucidate their content. However, our analysis was more sensitive than a straightforward inspection of a correlation matrix.

The comparison of the proposed scales with the cluster of statements that emerged gave us a clear idea of the extent to which they measured what they were supposed to.

6.4 - PRE AND POST QUESTIONNAIRES

The Objective of the PRE-Questionnaires was to obtain students' general impressions of their practical work experience at the secondary school and find out if they had any practical work experience at all. Like the preliminary survey this questionnaire had two parts:

i The first part aimed to find out the students' level of qualification in chemistry and how they did practical work at secondary school.
Question 1 - What is your highest qualification in chemistry?
Question 2 - In your previous laboratory work have you experienced practical work which was done (tick more than one if required) Individually; in small groups or by teacher demonstrations?

ii The second part aimed to find the students' general impression of the practical work they had experienced before. Here as before in the Preliminary Survey a semantic differential questionnaire was devised with a five point scale between pairs of opposite adjectives. A total of ten pairs of opposite adjectives were offered for students to indicate their opinion about their previous experience of practical work. (as shown in the Table 4.4).

SCALE	item	PAIR OF ADJECTIVES		
DIFFICULTY	1	EASY	_ _ _ _ _	DIFFICULT
	4	CONFUSING	_ _ _ _ _	UNDERSTANDABLE
IMPORTANCE	2	USELESS	_ _ _ _ _	USEFUL
	9	LEARNT A LOT	_ _ _ _ _	LEARNT LITTLE
ENJOYMENT	3	INTERESTING	_ _ _ _ _	BORING
	5	SATISFYING	_ _ _ _ _	FRUSTRATING
	6	UNENJOYABLE	_ _ _ _ _	ENJOYABLE
ORGANISA-TION	7	ADEQUATE WRITTEN INSTRUCTIONS	_ _ _ _ _	INADEQ. WRITTEN INSTRUCTIONS
	8	RUSHED	_ _ _ _ _	LEISURELY
	10	DISORGANISED	_ _ _ _ _	WELL-ORGANISED

Table 4.4 - Semantic Differential items of the PRE and POST Questionnaire.

The question "WHAT DO YOU EXPECT TO LEARN FROM THIS LABORATORY COURSE?2 was introduced to try and find out the students' expectations of the university course.

The objective of the POST-Questionnaire was to record students general impressions of the practical course and find out if their attitude to this had changed afterwards. The POST questionnaire therefore contained only the semantic differential part of the PRE-Questionnaire introducing seven open questions to reveal students opinions about the good and bad points of the course. Students could make their comments as they wished. The questions were as follows:

Question 1 - Which experiment or experiments did you enjoy most of all? Could you please tell us why you found it(them) the most enjoyable?
Question 2 - Which experiment or experiments did you find most difficult? Could you please tell us why you found it (them) the most difficult?
Question 3 - Which experiment or experiments did you find most useful? Could you please tell us why you found it (them) the most useful?
Question 4 - What do you think were the good points about the lab course?
Question 5 - What do you think were the worst features of the lab course?
Question 6 - What changes do you think should be made to improve the lab course?
Question 7 - What would you like to learn next time you do a lab course?

A copy of the PRE and POST Questionnaire are included in Appendices B-4 (page 305) and B-5 (page 306) respectively.

6.5 - DIARY

The objective of the DIARY was to assess the load on working memory of the first year practical course. The DIARY was designed using the Likert method with statements on a five point scale ranging from STRONGLY AGREE to STRONGLY DISAGREE.

We devised the statements along the following lines:

i To assess the <u>Amount</u> <u>of</u> <u>information</u> to be dealt with at anyone time, the clarity of the instructions and if there was time allowed. The number of items of information that the students were required have been reduced to a minimum, in the knowledge that the lower the number of items of information with which students must deal at any time, the smaller is the load on working memory[52].
The statements pertaining to this were:

1 - There was enough information in the manual (lab map etc.) and in the laboratory to help me find the chemicals

2 - I had enough time in the laboratory to think about the chemistry involved in the laboratory.

13 - There was enough information in the manual (lab map, etc.) and in the laboratory to help me find the equipment

ii To assess the students Familiarity of response to teaching cues and their Familiarity with information required to carry out a given task. For example, their familiarity with chemical equations, calculations, terms, formulae, use of equipment, etc. As the survey of the literature suggested, the more familiar the response, the less working memory students needed to carry out a given task.[53].

The statements pertaining to this were:

5 - I would have liked more help with the calculations in this experiment.

11 - I was so confused in the laboratory that I ended up following the manual without really understanding what I was doing.

14 - I only understood what I had been doing in this experiment when I tried to write the lab report.

iii To assess the Clarity of purpose and procedures of the written instructions. The "signal / noise" ratio can be enhanced by giving a clear statement of the objectives also making clear what is preliminary, peripheral and preparatory in an experiment [47]

The items were as follow:

7 - The experimental procedure was clearly explained in the manual

10 - It was easy to follow the way the manual was organised (purpose, safety precautions, lab report, outline of experiment, procedure, etc.)

12 - The purpose of this experiment was clear to me

iv To assess the quality of the Laboratory Instruction - a feature related to other factors that influence the students' performance in the laboratory, e.g. clear instructions for the lab report; location of apparatus, chemicals and equipments; etc.

The statements pertaining to this were:

4 - It was clear to me what was expected in writing up my lab report.

9 - I had enough help in writing the chemical equation in this experiment

15 - I was confident enough with the lab techniques to be able to concentrate on the chemistry involved in the experiment.

v To assess the Salience of Stimulus - given that it is important that all stimuli to which the students must attend are salient. For example, Chemicals and equipment locations were clearly indicated in the experiment, the point of the experiment was clearly stated, etc. The theory here being, the more salient a stimulus is, the less working memory is needed to be devoted to the task of extracting it[54]. The statements pertaining to this were:

3 – The symbols in the manual (which are defined on page 4) were helpful in doing this experiment.

6 – The information in the appendices 1 to 6 was helpful

8 – The prelab introduction to the balances and volumetric techniques helped me when I came to use those techniques in this experiment.

A copy of the Diary is included in Appendix B-6 (page 307).

6.6 - PRELAB QUESTIONNAIRES

The Objective of the PRELAB WORK questionnaires was to record student opinions this approach and find out if it helped them to become familiar with the content of the experiment before starting the practical work.

Like the DIARY, the PRELAB WORK Questionnaire was devised using the Likert Method with a five point scale applied to the following statements:

1.I THINK THAT DOING THE PRELAB WORK

a) helped me to understand the experiment before I attempted them in the laboratory

b) gave me more confidence when I came to do the experiments in the laboratory

c) forced me to think about the experiments before I attempted them in the laboratory

d) meant that I was able to follow the manual in the laboratory with a greater understanding of what I was doing.

e) was difficult

2. I THINK THAT PRELAB WORK SHOULD ALWAYS BE INCLUDED BEFORE DOING AN EXPERIMENT

A copy of the PRELAB WORK Questionnaire is given in Appendix B-7 (page 308)

Questions 1a, 1b and 1c were intended to show if this teaching approach familiarised students with calculations and concepts of the experiment before they began the practical work.

Question 1d was included to find out if as was expected, the prelab exercise would help students better understand the experimental procedure and the concepts involved.

Questions 1e and 2 were intended to find out if the prelab exercise was easy enough for students to solve or whether it discouraged them and find out if they valued this kind of activity.

6.7 - MINI-PROJECT QUESTIONNAIRE

The MINI-PROJECTS Questionnaire was intended to record students' opinions about them again using the Likert Method with a five point scale but with the following statements:

1. I THINK THAT SOLVING THE PRACTICAL PROBLEMS
   a) forced me to design a plan my own experiment
   b) illustrated practical applications of the laboratory
   c) gave me confidence in my practical work
   d) was difficult
   e) allowed me to use my knowledge of chemistry to investigate the problem
   f) gave me a lot a satisfaction
   g) was enjoyable
   h) was interesting

2. I THINK THAT SOLVING THE PRACTICAL PROBLEM AT THE END OF THE EXPERIMENT HELPED ME TO UNDERSTAND THE EXPERIMENT WHICH HAD COME BEFORE

3. I THINK THAT MORE PRACTICAL PROBLEMS LIKE THESE SHOULD BE INCLUDED IN THIS COURSE.

A copy of the MINI-PROJECT Questionnaire is included in Appendix B-8 (page 309).

A questionnaire containing the questions of PRELAB WORK and MINI-PROJECT questionnaires was devised and applied in the course which had both PRELAB WORK and MINI-PROJECT (course FOUR). A copy of this questionnaire is included in Appendix B-9 (page 310).

6.8 - DEMONSTRATORS DIARY

The DEMONSTRATOR'S DIARY sought to pinpoint problems in the practical course through the eyes of the Demonstrators. They were asked to complete a diary for each lab session throughout the six week course.

The Demonstrator's Diary was structured as follows:

1. COMMENTS, QUERIES FROM STUDENTS ABOUT:
   1.1 - Written Instructions
   1.2 - laboratory organisation

The demonstrators were asked to record students problems, the experiment and the frequency these occurred.

2. THE DEMONSTRATORS' OWN OBSERVATION

In the first part of the Diary the demonstrator could record any kind of problem they noticed or which students encountered during the lab session. In the second part they were asked to comment on any other problem that did not fit into the diary's headings. A copy of the DEMONSTRATORS' DIARY is included in Appendix B-10 (page 311).

6.9 - DEMONSTRATORS' CHECK-LIST

This was designed to check two problems: a) students' difficulties with calculations; and b) their difficulties in writing and balancing chemical equations.

The preliminary survey, had shown that students had difficulties with calculating molarities, % yield and enthalpy changes involved in the experiments 1, 3 and 4. They also had difficulties predicting the products and balancing the equations for the reactions in experiments 2 and 4. We asked demonstrators to record the frequency of students request for help in these aspects in each of the experiments. To simplify their task a check-list with the following items was given to demonstrators:

Experiment - 1

Calculation of the yield (either % of theoretical)

Calculation of enthalpy

Experiment - 2

How to write balanced equations

Which effects do products produce in the litmus paper?

Experiment - 3

Calculations of the number of moles of $KHC_8H_4O_4$

Calculation of molarities.

Experiment - 4

How to write oxidation-reduction equations

Calculation of the molarities

Experiment - 5

Calculation of yield (either % or Theoretical)

Calculation of % Cu

Experiment - 6

Calculation of yield (either % or Theoretical)

Calculation of % Cr

A copy of the DEMONSTRATOR'S CHECK-LIST is included in the Appendix B-11 (page 312).

7 - SUMMARY

In summary: the foregoing chapter explains our decisions for redesigning the first year inorganic practical course in relation to the literature and theoretical base on which the survey was based, i.e., Information Processing which emphasises how students learn.

From this perspective it was considered vital that students' perceive the task clearly (salience of the cue), that we avoid or reduce the ever present possibility of working memory overload (amount of data and students familiarity with the subject). Further we considered it desirable that the redesigned course allows the student to construct for themselves sound and branched mental structure to help them to solve practical problems. It was expected the proposed changes would produce a course in which students had the opportunity of experiencing practical work closer to the real situation, hoping to give students the experience and confidence in doing all stages of practical work on their own.

The redesigned course is also a response to criticisms that not enough emphasis is placed on the design and planning of the experimental procedures in first year practical courses. Traditional course dish out a detailed procedure to students then requires them recall concepts and techniques, make observations, follow instructions and interpret results on demand. Under these conditions, students can find the overload so uncomfortable that they resort to recipe following with little understanding of the processes involved in experimentation.

Having assessed the first year practical course (see Chapter 3) at Glasgow University we identified the following criteria which should be dealt with if the practical course was to be improved.

i The redesigned course must embrace all components of practical work

ii The students must be given a chance to plan and design their own experimental procedures and to foster practical problems skills.

iii The practical work must be related to the theory and practical applications as far as possible.

iv The students must be familiarised with the content and the laboratory techniques involved in the experiment beforehand.

v The laboratory manual must be redesigned to improve the "signal" and reduce the "noise" by giving clearer instructions and eliminating unnecessary ones.

We then developed four versions of the same laboratory course in which one variable was changed at a time, in the expectation that these would offer four different levels of load.

Two activities were common to all redesigned versions:

i In the first session student were trained in the basic lab techniques involved in the proposed experiments, i.e weighing, volumetric and other minor techniques. This was supported by illustrated written instructions specially designed and incorporated as appendices to the manual. It was expected that having mastered the manipulative skills, students could have more working memory space to think about the experiment.

ii A set of six experiments with redesigned procedures was introduced.

The changed variables were PRELAB WORK and MINI-PROJECTS and the four versions were as follow:

COURSE CONTROL (CTRL) - containing only the common stages of the course with the Improved Lab Manual, i.e., high load

COURSE PRELAB WORK (PLW) - in which we set out to engage students in pre-planning experiments by solving problem before they came to the laboratory. The results of these exercises were then used by the students in the lab experiments to give them familiarity with the subject. It is expected to ease the load on working memory (lowest) at the time of doing the practical work.

COURSE MINI-PROJECTS (MP) - The MINI-PROJECT introduced open ended problems to be solved by practical means at the end of each experiment; intention being to give students the opportunity to apply what they had learnt in the lab to solve these(Highest load).

Here, it was expected that the load on working memory would be much higher than in the other courses. It was intended that having to extract meaningful information from the whole laboratory instruction and distinguish this would serve to strengthen students grasp on the course contents consolidating a branched approach to learning.

COURSE PLW plus MP (P&P) involved both the PRELAB WORK of course PLW and the MINI-PROJECTS of course MP having a greater load than the PLW but less than the MP course.

The courses were ranked according to the level of load on working memory that each was expected to produce as follows:

(low) **PLW < P&P < CTRL < MP** (high)

CHAPTER 5

RESULTS OF SURVEY ON THE REDESIGNED UNDERGRADUATE PRACTICAL COURSE IN CHEMISTRY

1 - PRE AND POST QUESTIONNAIRES

During the trial period, 508 students attended the first year inorganic practical course in five classes of about 100 (See Table 5.1). The Monday and Friday sessions shared the same course design so were added together for the purpose of analysis, i.e. the CONTROL group (sometimes denoted in this thesis by the abbreviation CTRL).

The Tuesday, Wednesday and Thursday sessions, had separate course designs; with Prelab Work; Mini-Projects; and Prelab Work plus Mini-projects respectively (sometimes denoted in this thesis by the abbreviations PLW; MP; and P&P respectively).

Q-1 PRE	CONTROL (CTRL) sample	PRELAB WORK (PLW) sample	MINI-PROJECT (MP) sample	PRELAB plus MINI-PROJECT (P&P) sample	TOTAL population
	MON+FRI	TUESDAY	WEDNESDAY	THURSDAY	POPULATION
HGRD	106 (52.7)	53 (53.0)	59 (57.3)	62 (59.6)	280 (55.1)
SYS	71 (35.3)	33 (33.0)	38 (36.9)	30 (28.8)	172 (33.9)
GLBL	201	100	103	104	508

Table 5.1 - Number of students enrolled in the FIRST YEAR PRACTICAL INORGANIC CHEMISTRY

As was with the preliminary survey, the population was also analysed in two sub-samples, HIGHER GRADE (HGRD) and SIXTH YEAR STUDIES (SYS). The term GLOBAL (or simply GLBL) is here used to refer to the total of the samples CTRL, PLW, MP and P&P.

The PRE-Questionnaires were answered by approximately 95% of the students enrolled. Question ONE asked students about their HIGHEST qualification in chemistry and identified two major but not exclusive groups, HGRD and SYS students. The students with only the Higher Grade(HGRD) were approximately 55% of the population. The students who had gone further completing the Sixth Year Studies (SYS) were 34% of the population. The proportion of students in the groups HGRD and SYS was approximately the same for all samples (See Table 5.1).

Although only 50% of the students answered both, the PRE and POST questionnaires, we still had a good sample. The comparison of Tables 5.1 and 5.2 show that the proportion of cases in each sample was approximately the same as that of the TOTAL population. Sometimes, the sub-samples were reduced to such a small number that it was not always possible to apply a statistical test to calculate the significance of the differences. Hence, we extrapolated these to determined tendencies and patterns in responses. In this survey, like was done in the Preliminary Survey, only the students who had answered both PRE and POST questionnaires were computed in the analysis to allow examination of attitude change over the period of the course.

POST-QUEST	CONTROL (CTRL)	PRELAB WORK (PLW)	MINI-PROJECT (MP)	PRELAB plus MINI-PROJECT (P&P)	TOTAL (TOT)
WEEK	MON+FRI	TUESDAY	WEDNESDAY	THURSDAY	POPULATION
HGRD	61 (54.5)	20 (41.7)	30 (54.5)	22 (48.9)	133 (51.1)
SYS	38 (33.9)	20 (41.7)	22 (40.0)	16 (35.6)	96 (36.9)
GLBL	112	48	55	45	260

Table 5.2 - Number of students that answered the PRE and POST - Questionnaires

Question two of the PRE-Questionnaire asked students about the nature of their experience of practical work at secondary school, i.e. did they practise individually, in small groups or were they taught by teacher demonstration?. They were asked to tick more than one choice if necessary. The frequencies and percentages are shown in Table 5.3. One can see that the SYS students had experienced practical work at secondary school in a more individual mode than the Higher students, while the Higher students who in turn had experienced more practical work by teacher demonstration. The results obtained for this question were similar to the results obtained for the same question in our preliminary survey (See Table 3.4 and 3.5 Chapter 3).

Q-2	PRE	CONTROL (CTRL) N=201	PRELAB WORK (PLW) N=100	MINI-PROJECT (MP) N=103	PRELAB plus PROJECT(P&P) N=104	TOTAL (TOT) N=508
		MON+FRI	TUESDAY	WEDNESDAY	THURSDAY	POPULATION
HGR	INDIV	56 (27.8)	25 (25.0)	22 (21.4)	20 (19.2)	123 (24.2)
	S.G.	96 (47.8)	45 (45.0)	47 (45.6)	47 (45.2)	235 (46.3)
	T.D.	94 (47.8)	40 (40.0)	43 (41.7)	39 (38.5)	216 (42.5)
SYS	INDIV	60 (29.9)	31 (31.0)	37 (35.9)	28 (26.9)	156 (30.7)
	S.G.	41 (20.4)	24 (24.0)	27 (26.2)	23 (22.1)	115 (22.6)
	T.D.	32 (15.9)	20 (20.0)	24 (23.3)	18 (17.3)	94 (18.5)
OTH	INDIV	18 (9.0)	8 (8.0)	4 (3.9)	9 (8.7)	39 (7.8)
	S.G.	18 (9.0)	7 (7.0)	5 (4.9)	10 (9.6)	40 (7.9)
	T.D.	14 (7.0)	6 (6.0)	5 (4.9)	6 (5.8)	31 (6.1)

Table 5.3 - Frequency of response for question TWO / PRE-Questionnaire

1.1 - VALIDATION OF THE PRE AND POST QUESTIONNAIRES

The initial task in our analysis of the data was to examine the extent to which the instruments could actually measure what they were designed to measure. The quality of the instruments themselves was investigated by determining the "reliability" and the "validity" of the various scales utilised in the instruments.

Of the various methods available for estimating test reliabilities, the "internal consistency method" was selected because it is the most convenient procedure to apply to scales consisting of more than one item. Hence, Cronbach's alpha values (reliability coefficient) were calculated for each item scale. The validity of the instruments was them checked by factor analysis and correlation coefficients between scales within the questionnaire.

The procedure which we adopted for these analyses was: An initial examination of the performance of an item as part of the scales to which they had originally been assigned to, by determining Cronbach's alpha values (reliability coefficient). Secondly, we determined the reliability coefficient for the scale considering all items. Finally, we performed a factor analysis to check the association of individual items with the scales and then compared these with the scales originally proposed.

	1	2	3	4	5	6	7	8	9	10
1	-			>1%						>1%
2		-	>1%		>1%	>1%			>1%	>1%
3		.416	-		>1%	>1%			>1%	>1%
4	.444			-	>1%	>5%			>1%	>1%
5		.424	.327	.287	-	>1%			>1%	>1%
6		.384	.696	.220	.341	-	>5%	>5%	>1%	>5%
7						.214	-	>5%		
8						.190	.200	-		
9		.380	.457	.291	.304	.530			-	>5%
10	.262	.253	.236	.354	.487	.208			.202	-

Table 5.4 - Correlation matrix of PRE-Questionnaires questions

For our factor analysis, we did a survey of the PRE questionnaire' statements in a correlation matrix using the coefficients to extract the factors. The correlation coefficient is shown in Table 5.4. Orthogonal rotation of the factors was restricted to those that had eigen-values greater than 1.0 which in all represented at least 50% of the total variance. The results shown in Table 5.5 were obtained using the FACTOR subprogram of SPSS/PC+.

The Cronbach's alpha values for the scales and items of pre questionnaires were determined using the RELIABILITY sub-program of the SPSS/PC+ and displayed in Table 5.5. The alpha item coefficient is the reliability coefficient calculated with that item deleted. The scales ENJOYMENT, IMPORTANCE AND DIFFICULTY presented an acceptable reliability coefficient considering the low number of items per scale.

FACTOR ANALYSIS						RELIABILITY	
SCALE	ITEMS (*) SIG. >1%	F-1	F-2	F-3	h^2	ITEM	SCALE
ENJOYMENT	3.INTERESTING / BORING	**0.794**	-0.001	0.215	0.677	0.69	0.77
	5.SATISFYING / FRUSTRATING	**0.564**	*0.486	*0.288	0.637	0.71	
	6.ENJOYABLE / UNENJOYABLE	**0.772**	0.105	*0.285	0.688	0.70	
IMPORTANCE	2.USEFUL / USELESS	**0.707**	0.086	-0.068	0.511	0.71	0.64
	9.LEARNT AL LOT / LITTLE	**0.725**	0.085	0.075	0.539	0.71	
DIFFICULTY	1.EASY / DIFFICULT	-0.200	**0.793**	0.118	0.683	0.75	0.56
	4.UNDERSTANDABLE / CONFUSING	0.149	**0.750**	0.032	0.586	0.73	
ORGANI-SATION	7.ADEQUATE / INADEQUATE WRITTEN INSTRUCTION	0.173	-0.083	**0.739**	0.553	0.74	0.32
	8.LEISURELY / RUSHED	0.031	0.177	**0.734**	0.572	0.77	
	10.WELL- / DIS-ORGANISED	*0.317	**0.646**	0.008	0.519	0.71	
% VARIANCE		31.7	16.0	12.0	59.7		
PRE-QUEST	10 ITEMS						0.75

Table 5.5 - FACTOR ANALYSIS and RELIABILITY COEFFICIENTS PRE-QUESTIONNAIRES

In interpreting the factor loading, items were taken to be significant when the factor value exceeded that value calculated by the method coted in section 3.5 of Chapter 2, at the 1% level of significance. Therefore we have included all the loadings in the above table only to show possible "near misses" and items that tended to load on more than one factor. The highest loading (in **bold**) usually indicated an item's association with a particular factor.

The factor loading indicated that most of the items were associated with each other inside the scales. The exception was the item 10. WELL- / DIS-ORGANISED which seems to be associated with the DIFFICULTY scale (which gave the highest load in factor 2 and a significant loading in factor 1).

The scales for ENJOYMENT and IMPORTANCE were expressly related to students' feelings and expectations about the course and presented the largest reliability coefficient. The items in both of these two scales loaded significantly on factor 1.

We considered the instrument reliability satisfactory (alpha value of 0.75 for the ten items of the instrument). Our findings of high loadings would seem to indicate that there was a good association of the items in each scale as planned.

1.2 - COMPARISON BETWEEN SAMPLES AND SUB SAMPLES

The response frequencies and percentages in each category of the PRE and POST questionnaires were calculated using the FREQUENCIES subprogram of SPSS/PC+. A summary of the results for all samples and sub-samples is presented in Table 5.6 (CTRL); 5.7 (PLW); 5.8 (MP); and 5.9 (P&P). We also calculated the MODE to show the tendency of response to each question, i.e. the category which had the highest frequency of response (indicated in **bold**).

The raw frequencies of the responses were used to calculate Chi-Square using a "BASIC" computer program developed by Cohen and Holliday[78]. Table 5.10 summarises the significance levels of the differences between PRE and POST questionnaires. Significances levels at 5% and 1% level are included there. If the test was favoured this is indicated by PRE or POST and if there was no significant difference found the cell was left blank.

	CONTROL N=112			PRELAB WORK N=48			MINI-PROJECT N=55			PLW plus MP N=45		
Q	HGRD	SYS	GLBL	HGRD	SYS	GLBL	HGRD	SYS	GLBL	HGRD	SYS	GLBL
1	>1% PRE		>1% PRE			>5% PRE	>1% PRE		>1% PRE			>1% PRE
2		>1% PRE	>1% PRE						>1% PRE			
3	>1% PRE		>1% PRE						>1% PRE		>5% PRE	>1% PRE
4	>1% PRE	>1% PRE	>1% PRE				>5% PRE		>1% PRE	>1% PRE		>1% PRE
5		>5% PRE	>5% PRE				>1% PRE		>1% PRE	>1% PRE		>1% PRE
6	>1% PRE	>1% PRE	>1% PRE			>5% PRE	>1% PRE	>1% PRE	>1% PRE	>5% PRE		>5% PRE
7												
8												
9	>1% PRE	>1% PRE	>1% PRE			>5% PRE			>5% PRE			
10						>5% PRE			>5% PRE			

>1% = level of significance and PRE = Test favoured

Table 5.10 -Comparison between PRE versus POST Questionnaires.

PRE AND POST QUESTIONNAIRES
(CTRL)

QUEST-1		EASY		NEUTRAL	DIFFICULT		%
		1	2	3	4	5	DIF
HGR	PRE	3 (3)	24 (39)	**31 (51)**	3 (5)	1 (2)	37.7
	POST	1 (2)	4 (7)	**30 (49)**	22 (36)	3 (5)	-32.7
SYS	PRE	-	10 (26)	**20 (53)**	8 (21)	-	5.3
	POST	-	10 (26)	**23 (61)**	5 (13)	-	13.2
GLB	PRE	5 (5)	40 (36)	**54 (48)**	12 (11)	1 (1)	28.6
	POST	1 (1)	19 (17)	**59 (53)**	29 (26)	3 (3)	-10.7

QUEST-2		USEFUL		NEUTRAL	USELESS		%
		1	2	3	4	5	DIF
HGR	PRE	9 (15)	**33 (54)**	13 (21)	6 (10)	-	59.0
	POST	7 (12)	**27 (44)**	23 (38)	4 (7)	-	49.2
SYS	PRE	6 (16)	**25 (66)**	4 (11)	2 (5)	1 (3)	73.7
	POST	3 (8)	**16 (42)**	13 (34)	3 (8)	3 (8)	34.2
GLB	PRE	16 (14)	**63 (56)**	14 (21)	8 (7)	1 (1)	62.5
	POST	10 (9)	**50 (45)**	39 (35)	9 (8)	4 (4)	42.0

QUEST-3		INTERESTING		NEUTRAL	BORING		%
		1	2	3	4	5	DIF
HGR	PRE	5 (8)	**41 (67)**	10 (16)	3 (5)	2 (3)	67.2
	POST	3 (5)	**30 (49)**	14 (23)	13 (21)	1 (2)	31.1
SYS	PRE	6 (16)	**20 (53)**	8 (21)	3 (8)	1 (3)	57.9
	POST	2 (5)	**16 (42)**	13 (34)	5 (13)	2 (5)	28.9
GLB	PRE	12 (11)	**70 (63)**	21 (19)	6 (5)	3 (3)	65.2
	POST	7 (6)	**48 (43)**	33 (30)	20 (18)	4 (4)	27.7

QUEST-4		UNDERSTANDABLE		NEUTRAL	CONFUSING		%
		1	2	3	4	5	DIF
HGR	PRE	10 (16)	**30 (49)**	16 (26)	4 (7)	1 (2)	57.4
	POST	1 (2)	19 (31)	**23 (38)**	16 (26)	2 (3)	3.3
SYS	PRE	2 (5)	16 (42)	**17 (45)**	2 (5)	-	42.1
	POST	1 (3)	11 (29)	**16 (42)**	10 (26)	-	5.3
GLB	PRE	14 (13)	**52 (46)**	36 (32)	8 (7)	1 (1)	50.9
	POST	2 (2)	36 (32)	**45 (40)**	27 (24)	2 (2)	8.0

QUEST-5		SATISFYING		NEUTRAL	FRUSTRATING		%
		1	2	3	4	5	DIF
HGR	PRE	2 (3)	22 (36)	**25 (41)**	11 (18)	1 (2)	19.7
	POST	1 (2)	17 (28)	**25 (41)**	12 (20)	5 (8)	-3.3
SYS	PRE	-	15 (40)	**20 (53)**	2 (5)	1 (3)	31.6
	POST	2 (5)	**13 (34)**	**13 (34)**	8 (21)	2 (5)	13.2
GLB	PRE	3 (3)	39 (35)	**53 (47)**	15 (13)	2 (2)	22.3
	POST	3 (3)	32 (29)	**45 (40)**	23 (21)	8 (7)	3.6

Table 5.6 (A) - PRE and POST questionnaires frequency of response (CTRL)

QUEST-6		ENJOYABLE		NEUTRAL	UNENJOYABLE		%
		1	2	3	4	5	DIF
HGR	PRE	12 (20)	**33 (54)**	13 (21)	3 (5)	-	68.9
	POST	3 (5)	20 (33)	**21 (34)**	14 (23)	2 (3)	9.8
SYS	PRE	6 (16)	**22 (58)**	9 (24)	1 (3)	-	71.1
	POST	1 (3)	**14 (37)**	13 (34)	7 (18)	3 (8)	13.2
GLB	PRE	21 (19)	**61 (55)**	25 (22)	4 (4)	1 (1)	68.8
	POST	5 (5)	**40 (36)**	37 (33)	24 (21)	5 (5)	14.3

QUEST-7		ADEQUATE WRITTEN INSTRUCTION		NEUTRAL	INADEQUATE WRITTEN INSTRUCTION		%
		1	2	3	4	5	DIF
HGR	PRE	10 (16)	**29 (48)**	12 (20)	5 (8)	5 (8)	47.5
	POST	9 (15)	**25 (41)**	16 (26)	10 (16)	1 (2)	36.1
SYS	PRE	11 (29)	**16 (42)**	6 (16)	5 (13)	-	57.9
	POST	7 (18)	**17 (45)**	4 (11)	10 (26)	-	36.8
GLB	PRE	23 (21)	**53 (47)**	19 (17)_	12 (11)	5 (5)	52.7
	POST	17 (15)	**51 (46)**	22 (20)	21 (19)	1 (1)	41.1

QUEST-8		LEISURELY		NEUTRAL	RUSHED		%
		1	2	3	4	5	DIF
HGR	PRE	4 (7)	14 (23)	17 (28)	**20 (33)**	6 (10)	-13.1
	POST	3 (5)	10 (16)	18 (30)	**23 (38)**	7 (12)	-27.9
SYS	PRE	1 (3)	4 (11)	**20 (53)**	9 (24)	4 (11)	-21.0
	POST	1 (3)	6 (16)	**18 (47)**	9 (24)	4 (11)	-15.8
GLB	PRE	8 (7)	18 (16)	**41 (37)**	35 (31)	10 (9)	-17.0
	POST	5 (5)	19 (17)	**40 (36)**	36 (32)	12 (11)	-21.4

QUEST-9		LEARNT A LOT		NEUTRAL	LEARNT LITTLE		%
		1	2	3	4	5	DIF
HGR	PRE	5 (8)	**28 (46)**	20 (33)	8 (13)	-	41.0
	POST	3 (5)	14 (23)	**30 (49)**	13 (21)	1 (2)	4.9
SYS	PRE	2 (5)	**22 (58)**	11 (29)	3 (8)	-	55.3
	POST	2 (5)	9 (24)	**19 (50)**	5 (13)	3 (8)	7.9
GLB	PRE	9 (8)	**54 (48)**	36 (32)	13 (12)	-	44.6
	POST	5 (5)	27 (24)	**55 (49)**	21 (19)	4 (4)	6.3

QUEST-10		WELL-ORGANISED		NEUTRAL	DISORGANISED		%
		1	2	3	4	5	DIF
HGR	PRE	6 (10)	**21 (34)**	18 (30)	14 (23)	2 (3)	16.4
	POST	5 (8)	20 (33)	**22 (36)**	14 (23)	-	18.0
SYS	PRE	2 (5)	12 (32)	**16 (42)**	7 (18)	1 (3)	15.8
	POST	2 (5)	**13 (34)**	12 (32)	6 (16)	5 (13)	10.5
GLB	PRE	10 (9)	**40 (36)**	37 (33)	21 (19)	4 (4)	22.3
	POST	7 (6)	**37 (33)**	36 (32)	23 (21)	9 (8)	10.7

Table 5.6 (B) - PRE and POST questionnaires frequency of response MONDAY plus FRIDAY session (CTRL)

PRE AND POST QUESTIONNAIRES
(PLW)

QUEST-1		EASY		NEUTRAL	DIFFICULT		%
		1	2	3	4	5	DIF
HGR	PRE	-	9 (45)(	**10 (50)**	1 (5)	-	40.0
	POST	-	3 (15)	**10 (50)**	7 (35)		-20.
SYS	PRE	-	8 (40)	**10 (50)**	2 (10)	-	30.0
	POST	-	6 (30)	**11 (55)**	3 (15)	-	15.0
GLB	PRE	-	19 (40)	**25 (52)**	4 (8)	-	31.3
	POST	-	10 (21)	**28 (58)**	10 (21)	-	0

QUEST-2		USEFUL		NEUTRAL	USELESS		%
		1	2	3	4	5	DIF
HGR	PRE	2 (10)	**10 (50)**	7 (35)	1 (5)	-	55.0
	POST	-	**13 (65)**	7 (35)	-	-	65.0
SYS	PRE	3 (15)	**14 (70)**	2 (10)	1 (5)	-	80.0
	POST	4 (20)	**7 (35)**	6 (30)	3 (15)	-	40.0
GLB	PRE	6 (13)	**29 (60)**	9 (19)	3 (6)	-	66.7
	POST	4 (8)	**23 (48)**	18 (38)	3 (6)	-	50.0

QUEST-3		INTERESTING		NEUTRAL	BORING		%
		1	2	3	4	5	DIF
HGR	PRE	2 (10)	**12 (60)**	2 (10)	4 (20)	-	50.0
	POST	1 (5)	**14 (70)**	4 (20)	1 (5)	-	70.0
SYS	PRE	7 (35)	**6 (30)**	6 (30)	1 (5)	-	60.0
	POST	2 (10)	**15 (75)**	1 (5)	2 (10)	-	75.0
GLB	PRE	12 (25)	**18 (38)**	11 (23)	7 (15)	-	47.9
	POST	3 (6)	**32 (67)**	8 (17)	4 (8)	1 (2)	62.5

QUEST-4		UNDERSTANDABLE		NEUTRAL	CONFUSING		%
		1	2	3	4	5	DIF
HGR	PRE	1 (5)	6 (30)	**11 (55)**	1 (5)	1 (5)	25.0
	POST	-	4 (20)	**10 (50)**	6 (30)	-	-10.0
SYS	PRE	2 (10)	**10 (50)**	3 (15)	5 (25)	-	35.0
	POST	2 (10)	**8 (40)**	**8 (40)**	1 (5)	1 (5)	40.0
GLB	PRE	4 (8)	**20 (42)**	16 (33)	7 (15)	1 (2)	33.3
	POST	3 (6)	16 (33)	**20 (42)**	8 (17)	1 (2)	20.8

QUEST-5		SATISFYING		NEUTRAL	FRUSTRATING		%
		1	2	3	4	5	DIF
HGR	PRE	1 (5)	7 (35)	**10 (50)**	2 (10)	-	30.0
	POST	1 (5)	5 (25)	**9 (45)**	5 (25)	-	5.0
SYS	PRE	3 (15)	**8 (40)**	7 (35)	1 (5)	1 (5)	45.0
	POST	1 (5)	**8 (40)**	7 (35)	2 (10)	2 (10)	25.0
GLB	PRE	5 (10)	16 (33)	**21 (44)**	5 (10)	1 (2)	31.3
	POST	2 (4)	13 (27)	**21 (44)**	8 (17)	4 (8)	6.3

Table 5.7 (A) - PRE and POST questionnaires frequency of responses (PLW)

QUEST-6		ENJOYABLE		NEUTRAL	UNENJOYABLE		%
		1	2	3	4	5	DIF
HGR	PRE	6 (30)	**10 (50)**	3 (15)	1 (5)	-	75.0
	POST	1 (5)	**12 (60)**	6 (30)	1 (5)	-	60.0
SYS	PRE	9 (45)	**8 (40)**	2 (10)	1 (5)	-	80.0
	POST	1 (5)	**11 (55)**	6 (30)	2 (10)	-	50.0
GLB	PRE	16 (33)	**22 (46)**	6 (13)	4 (8)	-	70.8
	POST	2 (4)	**25 (52)**	16 (33)	4 (8)	1 (2)	45.8

QUEST-7		ADEQUATE WRITTEN INSTRUCTION		NEUTRAL	INADEQUATE WRITTEN INSTRUCTION		%
		1	2	3	4	5	DIF
HGR	PRE	4 (20)	**6 (30)**	3 (15)	5 (25)	1 (5)	20.0
	POST	1 (5)	**14 (70)**	3 (15)	2 (10)	-	65.0
SYS	PRE	5 (25)	**11 (55)**	-	3 (15)	1 (5)	60.0
	POST	7 (35)	**9 (45)**	1 (5)	3 (15)	-	65.0
GLB	PRE	13 (27)	**21 (44)**	3 (6)	8 (17)	2 (4)	50.0
	POST	10 (21)	**27 (56)**	4 (8)	6 (13)	1 (2)	62.5

QUEST-8		LEISURELY		NEUTRAL	RUSHED		%
		1	2	3	4	5	DIF
HGR	PRE	1 (5)	4 (20)	4 (20)	**8 (40)**	3 (15)	-30.0
	POST	-	-	7 (35)	**10 (50)**	3 (15)	-65.0
SYS	PRE	-	2 (10)	5 (25)	**6 (30)**	7 (35)	-55.0
	POST	-	3 (15)	5 (25)	**9 (45)**	3 (15)	-45.0
GLB	PRE	3 (6)	9 (19)	13 (27)	**17 (35)**	6 (13)	22.9
	POST	1 (2)	5 (10)	14 (29)	**22 (46)**	6 (13)	45.8

QUEST-9		LEARNT A LOT		NEUTRAL	LEARNT LITTLE		%
		1	2	3	4	5	DIF
HGR	PRE	2 (10)	6 (30)	**8 (40)**	2 (10)	2 (10)	20.0
	POST	-	4 (20)	**13 (65)**	3 (15)	-	5.0
SYS	PRE	5 (25)	**10 (50)**	4 (20)	1 (5)	-	70.0
	POST	-	**10 (50)**	6 (30)	4 (20)	-	30.0
GLB	PRE	7 (15)	**18 (38)**	15 (31)	6 (13)	2 (4)	35.4
	POST	-	15 (31)	**24 (50)**	9 (19)	-	12.5

QUEST-10		WELL-ORGANISED		NEUTRAL	DISORGANISED		%
		1	2	3	4	5	DIF
HGR	PRE	3 (15)	5 (25)	**8 (40)**	3 (15)	1 (5)	20.0
	POST	-	**10 (50)**	8 (40)	1 (5)	1 (5)	40.0
SYS	PRE	1 (5)	**12 (60)**	5 (25)	2 (10)	-	55.0
	POST	1 (5)	**8 (40)**	4 (20)	7 (35)	-	10.0
GLB	PRE	5 (10)	**21 (44)**	14 (29)	6 (13)	2 (4)	37.5
	POST	12 (25)	4 (8)	**13 (27)**	12 (25)	4 (8)	0

Table 5.7 (B) - PRE and POST questionnaires frequency of response TUESDAY session (PLW)

PRE AND POST QUESTIONNAIRES
(MP)

QUEST-1		EASY		NEUTRAL	DIFFICULT		%
		1	2	3	4	5	DIF
HGR	PRE	4 (13)	11 (37)	**13 (43)**	2 (7)	-	43.3
	POST	-	6 (20)	**13 (43)**	10 (33)	1 (3)	-17.0
SYS	PRE	-	9 (41)	**12 (55)**	-	1 (5)	36.4
	POST	1 (5)	**10 (45)**	9 (41)	1 (5)	-	45.5
GLB	PRE	4 (7)	22 (40)	**26 (47)**	2 (4)	1 (2)	41.8
	POST	1 (2)	17 (31)	**24 (44)**	11 (20)	1 (2)	12.7

QUEST-2		USEFUL		NEUTRAL	USELESS		%
		1	2	3	4	5	DIF
HGR	PRE	6 (20)	**13 (43)**	7 (23)	3 (10)	1 (3)	50.0
	POST	2 (7)	**11 (37)**	14 (47)	2 (7)	1 (3)	33.3
SYS	PRE	**10 (46)**	7 (32)	3 (14)	2 (9)	-	68.2
	POST	4 (18)	**10 (46)**	4 (18)	2 (9)	1 (5)	50.0
GLB	PRE	17 (31)	**22 (40)**	10 (18)	5 (9)	1 (2)	60.0
	POST	6 (11)	**23 (42)**	18 (33)	5 (9)	2 (4)	40.0

QUEST-3		INTERESTING		NEUTRAL	BORING		%
		1	2	3	4	5	DIF
HGR	PRE	5 (17)	**16 (53)**	4 (13)	4 (13)	1 (3)	53.3
	POST	1 (3)	**12 (40)**	10 (33)	5 (17)	2 (7)	20.0
SYS	PRE	6 (27)	**13 (59)**	2 (9)	1 (5)	-	81.8
	POST	3 (14)	**13 (59)**	3 (14)	2 (9)	1 (5)	59.1
GLB	PRE	12 (22)	**31 (56)**	6 (11)	5 (9)	1 (2)	67.3
	POST	4 (7)	**27 (49)**	13 (24)	8 (15)	3 (6)	36.4

QUEST-4		UNDERSTANDABLE		NEUTRAL	CONFUSING		%
		1	2	3	4	5	DIF
HGR	PRE	3 (10)	11 (37)	**11 (37)**	5 (17)	-	30.0
	POST	-	6 (20)	**11 (37)**	10 (33)	3 (10)	-23.0
SYS	PRE	4 (18)	**12 (55)**	5 (23)	1 (5)	-	68.2
	POST	2 (9)	8 (36)	**10 (46)**	1 (5)	1 (5)	36.4
GLB	PRE	7 (13)	**25 (46)**	16 (29)	7 (13)	-	45.5
	POST	2 (4)	15 (27)	**23 (42)**	11 (20)	4 (7)	3.6

QUEST-5		SATISFYING		NEUTRAL	FRUSTRATING		%
		1	2	3	4	5	DIF
HGR	PRE	1 (3)	**15 (50)**	8 (27)	5 (17)	1 (3)	33.3
	POST	2 (7)	4 (13)	8 (27)	**13 (43)**	3 (10)	-33.0
SYS	PRE	4 (18)	6 (27)	**7 (32)**	5 (23)	-	22.7
	POST	1 (5)	6 (27)	**9 (41)**	2 (9)	3 (14)	9.1
GLB	PRE	**6 (11)**	**23 (42)**	15 (27)	10 (18)	1 (2)	32.7
	POST	3 (6)	12 (22)	**18 (33)**	15 (27)	6 (11)	-11.0

Table 5.8 (A) - PRE and POST questionnaire frequency of responses (MP)

QUEST-6		ENJOYABLE		NEUTRAL	UNENJOYABLE		%
		1	2	3	4	5	DIF
HGR	PRE	7 (23)	**15 (50)**	6 (20)	1 (3)	1 (3)	66.7
	POST	1 (3)	7 (23)	**13 (43)**	8 (27)	1 (3)	-3.3
SYS	PRE	**11 (50)**	5 (23)	4 (18)	2 (9)	-	63.6
	POST	3 (14)	5 (23)	**10 (46)**	3 (14)	-	22.7
GLB	PRE	20 (36)	**20 (36)**	11 (20)	3 (6)	1 (2)	65.5
	POST	5 (9)	12 (22)	**25 (46)**	11 (20)	1 (2)	9.1

QUEST-7		ADEQUATE WRITTEN INSTRUCTION		NEUTRAL	INADEQUATE WRITTEN INSTRUCTION		%
		1	2	3	4	5	DIF
HGR	PRE	9 (30)	**7 (23)**	7 (23)	4 (13)	3 (10)	30.0
	POST	2 (7)	**15 (50)**	11 (37)	1 (3)	1 (3)	50.0
SYS	PRE	6 (27)	**7 (32)**	5 (23)	2 (9)	2 (9)	40.9
	POST	6 (27)	**10 (46)**	4 (18)	1 (5)	1 (5)	63.6
GLB	PRE	16 (29)	**16 (29)**	12 (22)	6 (11)	5 (9)	38.2
	POST	8 (15)	**27 (49)**	16 (29)	2 (4)	2 (4)	56.4

QUEST-8		LEISURELY		NEUTRAL	RUSHED		%
		1	2	3	4	5	DIF
HGR	PRE	2 (7)	5 (17)	**9 (30)**	9 (30)	5 (17)	-23.0
	POST	-	6 (20)	6 (20)	**10 (33)**	8 (27)	-40.0
SYS	PRE	3 (14)	5 (23)	**8 (36)**	5 (23)	1 (5)	9.1
	POST	-	2 (9)	**9 (41)**	8 (36)	3 (14)	-41.0
GLB	PRE	5 (9)	11 (20)	**17 (31)**	14 (26)	8 (15)	-11.0
	POST	1 (2)	8 (15)	17 (31)	**18 (33)**	11 (20)	-36.0

QUEST-9		LEARNT A LOT		NEUTRAL	LEARNT LITTLE		%
		1	2	3	4	5	DIF
HGR	PRE	2 (7)	9 (30)	**8 (27)**	9 (30)	2 (7)	0
	POST	-	6 (20)	**14 (47)**	7 (23)	2 (7)	-10.0
SYS	PRE	5 (23)	**11 (50)**	3 (14)	3 (14)	-	59.1
	POST	-	**11 (50)**	7 (32)	3 (14)	1 (5)	31.8
GLB	PRE	8 (15)	**20 (36)**	12 (22)	13 (24)	2 (4)	23.6
	POST	-	18 (33)	**22 (40)**	11 (20)	3 (6)	7.3

QUEST-10		WELL-ORGANISED		NEUTRAL	DISORGANISED		%
		1	2	3	4	5	DIF
HGR	PRE	6 (20)	**9 (30)**	6 (20)	8 (27)	1 (3)	20.0
	POST	-	**10 (33)**	9 (30)	7 (23)	3 (10)	0
SYS	PRE	4 (18)	6 (27)	**7 (32)**	5 (23)	-	22.7
	POST	1 (5)	7 (32)	**8 (36)**	6 (27)	-	9.1
GLB	PRE	10 (18)	**17 (31)**	14 (26)	13 (24)	1 (2)	23.6
	POST	2 (4)	17 (31)	**17 (31)**	15 (27)	3 (6)	3.6

Table 5.8 (B) - PRE and POST questionnaires frequency of response WEDNESDAY session (MP)

PRE AND POST QUESTIONNAIRES (P&P)

QUEST-1		EASY		NEUTRAL	DIFFICULT		%
		1	2	3	4	5	DIF
HGR	PRE	-	5 (23)	**15 (68)**	1 (5)	1 (5)	13.6
	POST	-	1 (5)	**13 (59)**	7 (32)	1 (5)	-32.0
SYS	PRE	-	3 (19)	**13 (81)**	-	-	18.8
	POST	-	4 (25)	**9 (56)**	3 (19)	-	6.3
GLB	PRE	-	10 (22)	**32 (71)**	2 (4)	1 (2)	15.6
	POST	-	5 (11)	**29 (64)**	10 (22)	1 (2)	-13.0

QUEST-2		USEFUL		NEUTRAL	USELESS		%
		1	2	3	4	5	DIF
HGR	PRE	2 (9)	**15 (68)**	4 (18)	1 (5)	-	72.7
	POST	2 (9)	**11 (50)**	6 (27)	3 (14)	-	45.5
SYS	PRE	4 (25)	**10 (63)**	2 (13)	-	-	87.5
	POST	4 (25)	**9 (56)**	2 (13)	1 (6)	-	75.0
GLB	PRE	8 (18)	**29 (64)**	7 (16)	1 (2)	-	80.0
	POST	6 (13)	**24 (53)**	10 (22)	4 (9)	1 (2)	55.6

QUEST-3		INTERESTING		NEUTRAL	BORING		%
		1	2	3	4	5	DIF
HGR	PRE	5 (23)	**11 (50)**	4 (18)	2 (9)	-	63.4
	POST	2 (9)	**10 (46)**	2 (9)	4 (18)	4 (18)	18.2
SYS	PRE	4 (25)	**9 (56)**	-	2 (13)	1 (6)	62.5
	POST	-	6 (38)	**6 (38)**	3 (19)	1 (6)	12.5
GLB	PRE	10 (22)	**26 (58)**	4 (9)	4 (9)	1 (2)	68.9
	POST	2 (4)	**19 (42)**	10 (22)	9 (20)	5 (11)	15.6

QUEST-4		UNDERSTANDABLE		NEUTRAL	CONFUSING		%
		1	2	3	4	5	DIF
HGR	PRE	4 (18)	**10 (45)**	6 (27)	2 (9)	-	54.5
	POST	1 (5)	4 (18)	**9 (41)**	7 (32)	1 (5)	-14.0
SYS	PRE	2 (13)	**8 (50)**	4 (25)	1 (6)	-	56.3
	POST	-	**11 (69)**	2 (13)	2 (13)	1 (6)	50.0
GLB	PRE	6 (13)	**23 (51)**	12 (27)	3 (7)	-	57.8
	POST	1 (2)	**17 (38)**	14 (31)	11 (24)	2 (4)	11.1

QUEST-5		SATISFYING		NEUTRAL	FRUSTRATING		%
		1	2	3	4	5	DIF
HGR	PRE	1 (5)	7 (32)	**12 (55)**	2 (9)	-	27.3
	POST	1 (5)	6 (27)	5 (23)	**9 (41)**	1 (5)	-14.0
SYS	PRE	**6 (38)**	3 (19)	4 (25)	2 (13)	1 (6)	37.5
	POST	-	4 (25)	**8 (50)**	1 (6)	3 (19)	0
GLB	PRE	8 (18)	13 (29)	**19 (42)**	4 (9)	1 (2)	35.6
	POST	1 (2)	11 (24)	**17 (38)**	11 (24)	5 (11)	-8.9

Table 5.9 (A) - PRE and POST questionnaire frequency of response (P&P)

QUEST-6		ENJOYABLE		NEUTRAL	UNENJOYABLE		%
		1	2	3	4	5	DIF
HGR	PRE	5 (23)	**12 (55)**	5 (23)	-	-	77.3
	POST	-	**8 (36)**	6 (27)	5 (23)	3 (14)	0
SYS	PRE	**6 (38)**	5 (31)	4 (25)	1 (6)	-	62.5
	POST	2 (13)	**7 (44)**	6 (38)	1 (6)	-	50.0
GLB	PRE	13 (29)	**20 (44)**	11 (24)	1 (2)	-	71.1
	POST	2 (4)	**20 (44)**	13 (29)	7 (16)	3 (7)	26.7

QUEST-7		ADEQUATE WRITTEN INSTRUCTION		NEUTRAL	INADEQUATE WRITTEN INSTRUCTION		%
		1	2	3	4	5	DIF
HGR	PRE	4 (18)	**10 (46)**	3 (14)	4 (18)	1 (5)	40.9
	POST	6 (27)	**10 (46)**	3 (14)	3 (14)	-	59.1
SYS	PRE	3 (19)	**7 (44)**	2 (13)	4 (25)	-	37.5
	POST	4 (25)	**6 (38)**	1 (6)	4 (25)	1 (6)	31.3
GLB	PRE	11 (24)	**20 (44)**	5 (11)	8 (18)	1 (2)	48.9
	POST	12 (27)	**19 (42)**	5 (11)	7 (16)	1 (2)	51.1

QUEST-8		LEISURELY		NEUTRAL	RUSHED		%
		1	2	3	4	5	DIF
HGR	PRE	2 (9)	3 (14)	**7 (32)**	6 (27)	4 (18)	-23
	POST	1 (5)	-	**11 (50)**	4 (18)	6 (27)	-41
SYS	PRE	1 (6)	1 (6)	6 (38)	**7 (44)**	1 (6)	-38
	POST	-	4 (25)	**5 (31)**	4 (25)	3 (19)	-19
GLB	PRE	4 (9)	5 (11)	14 (31)	**16 (36)**	6 (13)	-29
	POST	1 (2)	4 (9)	**19 (42)**	10 (22)	11 (24)	-36

QUEST-9		LEARNT A LOT		NEUTRAL	LEARNT LITTLE		%
		1	2	3	4	5	DIF
HGR	PRE	-	5 (23)	**12 (55)**	5 (23)	-	0
	POST	1 (5)	4 (18)	**11 (50)**	5 (23)	1 (5)	-4.5
SYS	PRE	1 (6)	**11 (69)**	3 (19)	-	1 (6)	68.8
	POST	-	**8 (50)**	7 (44)	1 (6)	-	43.8
GLB	PRE	2 (4)	**21 (47)**	16 (36)	5 (11)	1 (2)	37.8
	POST	1 (2)	15 (33)	**21 (47)**	7 (16)	1 (2)	17.8

QUEST-10		WELL-ORGANISED		NEUTRAL	DISORGANISED		%
		1	2	3	4	5	DIF
HGR	PRE	4 (18)	5 (23)	**6 (27)**	2 (9)	5 (23)	9.1
	POST	2 (9)	5 (23)	**8 (36)**	6 (27)	1 (5)	0
SYS	PRE	1 (6)	**7 (44)**	4 (25)	4 (25)	-	25.0
	POST	1 (6)	**5 (31)**	5 (31)	2 (13)	3 (19)	6.3
GLB	PRE	6 (13)	**17 (38)**	11 (24)	6 (13)	5 (11)	26.7
	POST	3 (7)	12 (27)	**17 (38)**	8 (18)	4 (9)	6.7

Table 5.9 (B) - PRE and POST questionnaires frequency of response THURSDAY session (P&P)

Our comparison of PRE and POST questionnaires in the CONTROL sample revealed a significant difference in favour of the PRE-Questionnaire, indicating that the respondents considered their secondary school experience more positively than their university experience. The students considered their secondary school experience EASIER, more USEFUL, more INTERESTING, more UNDERSTANDABLE, more SATISFYING, and they felt they LEARNT MORE than in the university first year practical course. In contrast they felt that the university course gave more ADEQUATE WRITTEN INSTRUCTION, was more LEISURELY, and WELL ORGANISED, though the differences were not statistically significant. However students clearly indicated that the WRITTEN INSTRUCTION were considered to be better in the university than in the secondary school.

A similar comparison was done for the PRELAB WORK (PLW), MINI-PROJECTS (MP), and PRELAB plus MINI-PROJECT (P&P) samples.

The PRELAB WORK sample showed a different picture. In most of the questions the differences were not statistically significant although the students found the course at secondary school more DIFFICULT, more ENJOYABLE, and LEARNT MORE, as well as being better ORGANISED than the first year practical course. It is important to notice that the number of questions in which the differences were statistically significant is much smaller than in the CONTROL group and the level of significance reached only the 5% level (none reached the 1% level).

On the other hand, the MINI-PROJECT sample, showed a similar pattern to the CONTROL sample. The P&P sample showed more questions with statistically significant difference than the PRELAB WORK sample but also smaller than the MINI-PROJECTS and CONTROL samples. It is important to notice that the students in the P&P sample had also performed PRELAB WORK.

One might argue that the differences which occurred in the CONTROL sample were a consequence of the large number of respondents, which was twice that of the other samples. As a result of this, Chi-Square could be significantly inflated because of the CONTROL sample size and when compared to samples with same degree of freedom. We therefore compared PRE and POST frequency of responses for Monday and Friday session separately applying the same procedure as above.

QUEST.	1	2	3	4	5	6	7	8	9	10
MONDAY (N=62)	>5% PRE	>1% PRE	>1% PRE	>1% PRE	>5% PRE	>1% PRE			>1% PRE	
FRIDAY (N=50)	>1% PRE	5% PRE	>5% PRE	>5% PRE	* PRE	>1% PRE			>5% PRE	

(*) = Significant at 10% level

Table 5.11 - Comparison between Monday and Friday samples

The comparison between the PRE versus POST questionnaires for the MONDAY and FRIDAY sessions individually presented a pattern similar to the CONTROL group (as shown in the table 5.11). There were 62 students in the MONDAY sample class and 50 in the FRIDAY one, approximately the same number as in other samples (PLW, MP, and P&P courses).

A comparison between the Higher (HGRD) and SYS sub-samples showed that the students who had completed the SYS course found the course with PRELAB WORK, MINI-PROJECTS, and PRELAB plus MINI-PROJECTS a more positive experience than did the Higher students. This observation is derived from the questions in which the difference between PRE and POST questionnaires was statistically significant. While in most of the questions the difference between PRE and POST frequencies of responses were statistically significant for the Higher and SYS sub-samples of the CONTROL group, in the PLW, MP, and P&P samples the number of questions that showed a difference statistically significant in the SYS sub-sample was much smaller than in the Higher sub sample.

1.3 - ATTITUDE CHANGE (PRE versus POST)

When the samples were sub-divided into sub-samples such as Higher (HGRD) and SYS the problem was raised of small numbers in each cell thus weakening the statistical results. In order to get a better feeling for the results of PRE and POST questionnaires it was decided to use the McNemar Test[79] as an alternative test.

The CROSSTAB sub-program of the SPSS/PC+ and its option facilities were used to produce a joint frequency distribution of the categories for each question in the PRE and POST questionnaires. The frequency and percentage of students who had changed their opinion positively, negatively or not changed after the six week course were determined and summarised in Table 5.12.

The raw frequencies, displayed in Table 5.12, were used to calculate Chi-Square using the McNemar method. The comparisons between positive and negative attitude changes for each item are summarised in Table 5.13. The level of attitude change was calculated by subtracting the frequency of negative change from the positive one, it was used then to drawn charts comparing items and scales of the samples to aid the identification of trends in the results.

CROSS TABULATION of PRE versus POST QUESTIONNAIRES PLW and P&P

		PRELAB WORK (PLW) - TUE				MINI-PROJECTS (MP) - WED			
Q	DEG	POSITIVE CHANGE	NO CHANGE	NEGATIVE CHANGE	% DIFF	POSITIVE CHANGE	NO CHANGE	NEGATIVE CHANGE	% DIFF
1	HGRD	2 (10)	6 (30)	12 (60)	-50.0	1 (3.3)	13 (43)	16 (53)	-50.0
	SYS	6 (30)	5 (25)	9 (45)	-15.0	6 (27)	12 (55)	3 (14)	14.0
	GLBL	9 (19)	17 (35)	22 (46)	-27.1	7 (13)	27 (49)	20 (36)	-23.6
2	HGRD	3 (15)	13 (65)	4 (20)	-5.0	6 (20)	10 (33)	14 (47)	-26.7
	SYS	3 (15)	9 (45)	8 (40)	-25.0	3 (14)	7 (32)	11 (50)	-36.4
	GLBL	7 (15)	24 (50)	16 (33)	-18.8	9 (16)	19 (35)	26 (47)	-30.9
3	HGRD	6 (30)	11 (55)	3 (15)	15.0	7 (23)	8 (27)	15 (50)	-26.7
	SYS	5 (25)	8 (40)	7 (35)	-10.0	1 (5)	14 (64)	7 (32)	-27.3
	GLBL	13 (27)	21 (44)	14 (29)	-2.1	8 (15)	24 (44)	23 (42)	-27.3
4	HGRD	4 (20)	6 (30)	10 (50)	-30.0	3 (10)	12 (40)	15 (50)	-40.0
	SYS	9 (45)	5 (25)	6 (30)	15.0	3 (14)	8 (36)	11 (50)	-36.4
	GLBL	16 (33)	13 (27)	19 (40)	-6.3	7 (13)	21 (38)	27 (49)	-36.4
5	HGRD	5 (25)	6 (30)	9 (45)	-20.0	5 (17)	9 (30)	16 (53)	-36.7
	SYS	4 (20)	8 (40)	8 (40)	-20.0	6 (27)	6 (27)	9 (41)	-13.6
	GLBL	10 (21)	18 (38)	20 (42)	-20.8	11 (20)	16 (29)	27 (49)	-29.1
6	HGRD	2 (10)	9 (45)	9 (45)	-35.0	4 (13)	5 (17)	21 (70)	-56.7
	SYS	1 (5)	9 (45)	10 (50)	-45.0	3 (14)	4 (18)	14 (64)	-50.0
	GLBL	3 (6)	22 (46)	23 (48)	-41.7	7 (13)	11 (20)	36 (65)	-52.7
7	HGRD	8 (40)	6 (30)	5 (25)	15.0	14 (47)	4 (13)	12 (40)	6.7
	SYS	6 (30)	10 (50)	4 (20)	10.0	6 (27)	12 (55)	4 (18)	9.1
	GLBL	15 (31)	19 (40)	13 (27)	4.2	20 (36)	18 (33)	17 (31)	5.5
8	HGRD	6 (30)	5 (25)	9 (45)	-15.0	6 (20)	10 (33)	14 (47)	-26.7
	SYS	2 (10)	7 (35)	11 (55)	-45.0	5 (23)	4 (18)	13 (59)	-36.4
	GLBL	13 (27)	13 (27)	22 (46)	-18.8	13 (24)	14 (25)	28 (51)	-27.3
9	HGRD	5 (25)	7 (35)	8 (40)	-15.0	7 (23)	13 (43)	9 (30)	-6.7
	SYS	1 (5)	9 (45)	10 (50)	-45.0	2 (9)	7 (32)	13 (59)	-50.0
	GLBL	9 (19)	18 (38)	21 (44)	-25.0	10 (18)	21 (38)	23 (42)	-23.6
10	HGRD	7 (35)	8 (40)	5 (25)	10.0	6 (20)	9 (30)	14 (47)	-26.7
	SYS	3 (15)	9 (45)	8 (40)	-25.0	5 (23)	6 (27)	11 (50)	-27.3
	GLBL	12 (25)	19 (40)	17 (35)	-10.4	12 (22)	15 (27)	27 (49)	-27.3

Table 5.12 - Cross Tabulation of PRE versus POST Questionnaires PRELAB WORK(PLW) and MINI-PROJECTS (MP)

CROSS TABULATION of PRE versus POST QUESTIONNAIRES
CTRL and P&P

		MIN-PROJECTS PLUS PRELAB WORK				CONTROL GROUP (MON and FRI)			
Q	DEG	POSITIVE CHANGE	NO CHANGE	NEGATIVE CHANGE	% DIFF	POSITIVE CHANGE	NO CHANGE	NEGATIVE CHANGE	% DIFF
1	HGRD	2 (9)	10 (45)	10 (45)	-36.4	3 (5)	19 (31)	38 (62)	-57.4
	SYS	2 (13)	10 (63)	4 (25)	-12.5	9 (24)	21 (55)	8 (21)	2.6
	GLBL	5 (11)	24 (53)	16 (36)	-24.4	13 (12)	46 (41)	52 (46)	-34.8
2	HGRD	3 (14)	12 (55)	7 (32)	-18.2	14 (23)	26 (43)	21 (34)	-11.5
	SYS	4 (25)	7 (44)	5 (31)	-6.3	2 (5)	18 (47)	18 (47)	-42.1
	GLBL	7 (16)	22 (49)	16 (36)	-20.0	21 (19)	46 (41)	45 (40)	-21.4
3	HGRD	4 (18)	5 (23)	13 (59)	-40.9	7 (11)	32 (52)	22 (36)	-24.6
	SYS	1 (6)	6 (38)	9 (56)	-50.0	7 (18)	13 (34)	18 (47)	-28.9
	GLBL	5 (11)	14 (31)	26 (58)	-46.7	16 (14)	49 (44)	47 (42)	-27.7
4	HGRD	1 (5)	8 (36)	13 (59)	-54.5	6 (10)	22 (36)	33 (54)	-44.3
	SYS	4 (25)	6 (38)	5 (31)	-6.3	6 (16)	14 (37)	17 (45)	-28.9
	GLBL	7 (16)	14 (31)	23 (51)	-35.6	14 (13)	43 (38)	54 (48)	-35.7
5	HGRD	5 (23)	6 (27)	11 (50)	-27.3	15 (25)	20 (33)	25 (41)	-16.4
	SYS	2 (13)	5 (31)	9 (56)	-43.8	10 (26)	16 (42)	12 (32)	-5.3
	GLBL	7 (16)	14 (31)	24 (53)	-37.8	27 (24)	42 (38)	42 (38)	-13.4
6	HGRD	2 (9)	4 (18)	16 (73)	-63.6	6 (10)	20 (33)	34 (56)	-45.9
	SYS	2 (13)	7 (44)	7 (44)	-31.3	2 (5)	16 (42)	20 (53)	-47.4
	GLBL	4 (9)	15 (33)	26 (58)	-48.9	10 (9)	42 (38)	59 (53)	-43.8
7	HGRD	7 (32)	10 (45)	5 (23)	9.1	18 (30)	18 (30)	25 (41)	-11.5
	SYS	5 (31)	7 (44)	4 (25)	6.3	6 (16)	19 (50)	13 (34)	-18.4
	GLBL	12 (27)	21 (47)	11 (24)	2.2	26 (23)	43 (38)	43 (38)	-15.2
8	HGRD	6 (27)	8 (36)	8 (36)	-9.1	19 (31)	16 (26)	26 (43)	-11.5
	SYS	5 (31)	5 (31)	6 (27)	-6.3	16 (42)	9 (24)	13 (34)	7.9
	GLBL	13 (29)	16 (36)	16 (36)	-6.7	39 (35)	29 (26)	44 (39)	-4.5
9	HGRD	8 (36)	5 (23)	9 (41)	-4.5	8 (13)	28 (46)	25 (41)	-27.9
	SYS	2 (13)	9 (56)	5 (31)	-18.8	2 (5)	18 (47)	18 (47)	-42.1
	GLBL	10 (22)	17 (38)	18 (40)	-17.8	11 (10)	52 (46)	49 (44)	-33.9
10	HGRD	6 (27)	8 (36)	8 (36)	-9.1	16 (26)	22 (36)	23 (38)	-11.5
	SYS	3 (19)	7 (44)	6 (38)	-18.8	15 (39)	11 (29)	12 (32)	7.9
	GLBL	10 (22)	16 (36)	18 (40)	-17.8	33 (29)	35 (31)	44 (39)	-28.9

Table 5.12 - Cross Tabulation of PRE versus POST Questionnaires
PLW plus MP (P&P) and CONTROL (CTRL)

Q	CONTROL N=112			PRELAB WORK N=48			MINI-PROJECT N=55			PLW plus MP N=45		
	HGRD	SYS	GLBL	HGRD	SYS	GLBL	HGRD	SYS	GLBL	HGRD	SYS	GLBL
1	>1%	+	>1%	>5%		>5%	>1%		>5%	>5%		>5%
2		>1%	>1%						>1%			>5%
3	>1%	>5%	>1%	+					>5%	>5%	>5%	>1%
4	>1%	>5%	>1%	+			>1%		>1%	>1%		>1%
5							>5%		>5%			>1%
6	>1%	>1%	>1%	>5%		>1%	>1%	>5%	>1%			>1%
7			>5%	+	+	+	+	+	+	>1%+	+	+
8		+			>5%				>5%			
9	>1%	>1%	>1%		>5%	>5%		>5%	>5%			
10				+					>5%			

(+) = Positive attitude change   Others = Negative attitude change

Table 5.13 - Level of significance between positive versus negative attitude change (McNemar Chi-Square)

A comparison of Table 5.10 and 5.13 shows that no significant difference was present between the two methods of analysis employed, i.e. similar patterns were obtained by both methods.

A comparison between the Higher and SYS groups and the positive attitude change is indicated in the Table 5.14.

	HGRD versus SYS									
QUEST	1	2	3	4	5	6	7	8	9	10
CTRL	sys	hgrd		sys	sys			sys	hgrd	sys
PLW	sys	hgrd	hgrd	sys		hgrd		hgrd	hgrd	hgrd
MP	sys	hgrd			sys			hgrd	hgrd	
P&P	sys	sys		sys	hgrd	sys			hgrd	

Table 5.14 - Comparison between HGRD and SYS

The level of agreement for the ENJOYMENT scale showed a slight decrease in the courses which had the MINI-PROJECTS (MP and P&P) and was significantly different from item 3 (INTERESTING) for the Prelab Work (PLW). (See Figure 5.1).

The level of agreement for the IMPORTANCE scale showed a slight increase with the introduction of the MINI-PROJECTS, PRELAB WORK and both together (P&P). Despite a decrease in the level of ENJOYMENT when the MINI-PROJECT was introduced the students seemed to value these. (See Figure 5.2).

The level of agreement in item 1 (DIFFICULT) displayed no significant difference. However, the item (CONFUSING) showed a significant difference to that in the course with Prelab Work only and others considered at the same level. (See Figure 5.3).

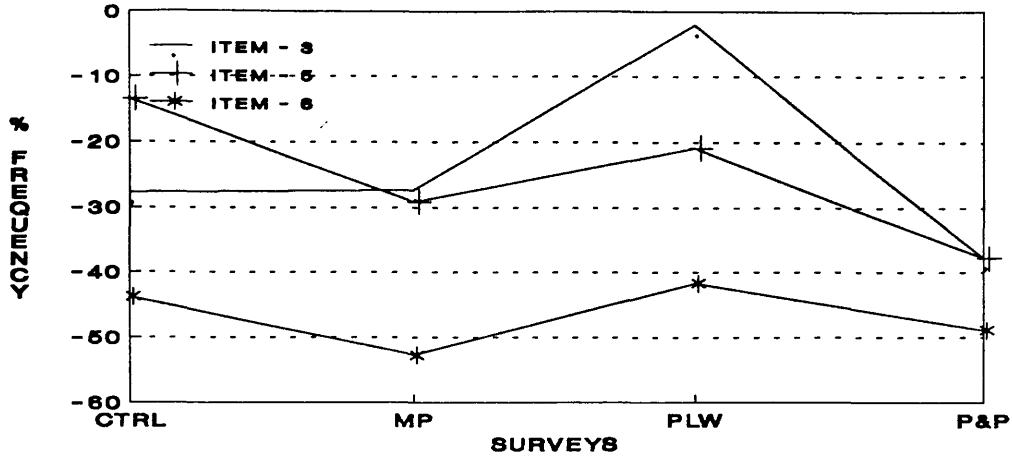


FIG. 5.1 - ENJOYMENT SCALE
(PRE vs POST)

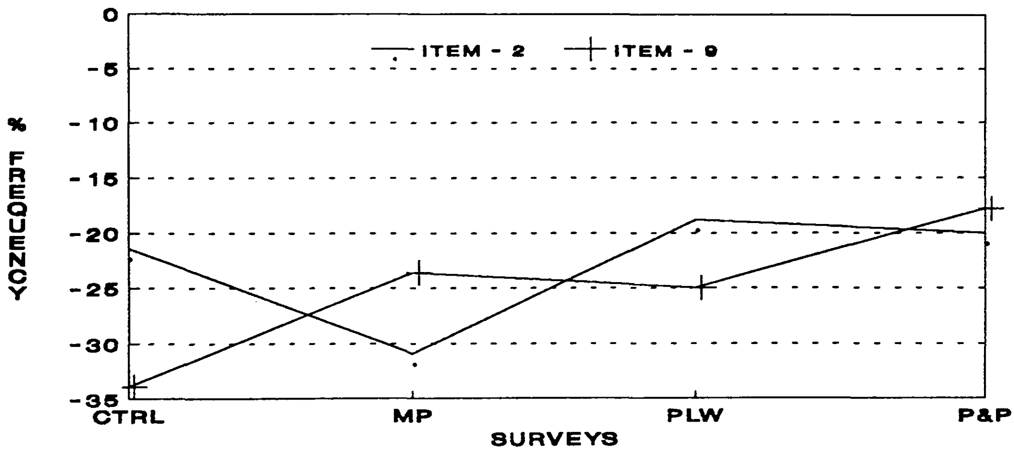


FIG. 5.2 - IMPORTANCE SCALE
(PRE vs POST)

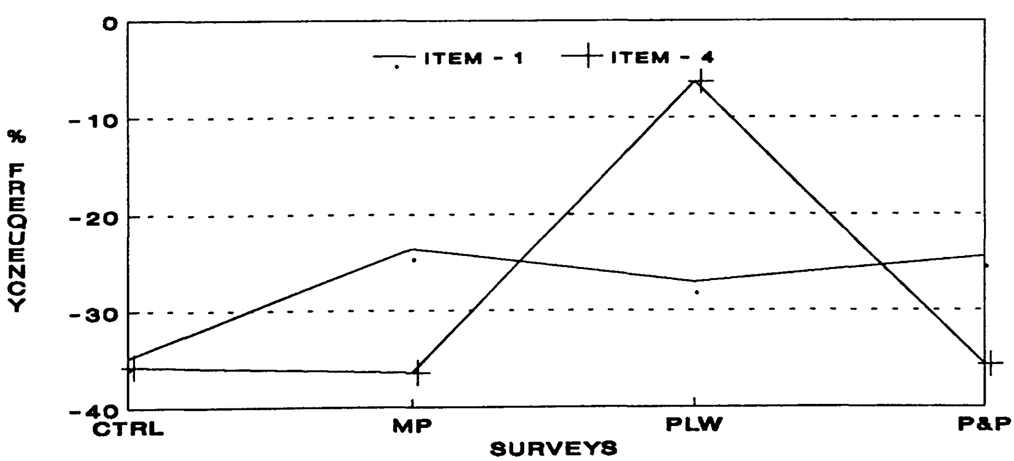


FIG. 5.3 - DIFFICULTY SCALE
(PRE vs POST)

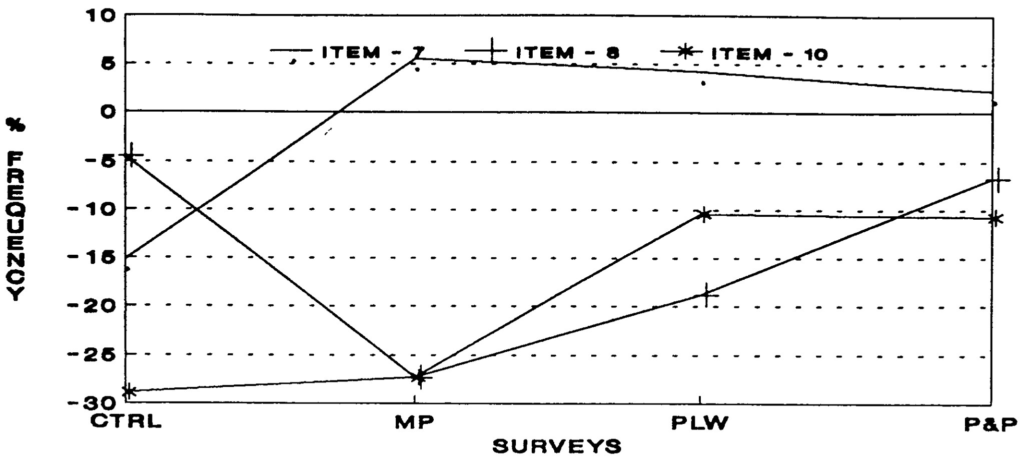


FIG. 5.4 - ORGANISATION SCALE (PRE vs POST)

Figure 5.4, the organisation scale contained two different aspects of the lab, the written instructions and time (which we assumed to be a key influence on organisation).

The item 7 (ADEQUATE WRITTEN INSTRUCTION) was rated more positively by the students when the course had MINI-PROJECTS (MP), PRELAB WORK (PLW), and both together (P&P) than in the CONTROL group. The students seemed to become more aware of the information in the written instruction when they have to carry out some activities on their own.

Item 8 (RUSHED), again revealed differences between the CONTROL group and the rest. The introduction of Mini-Projects and Prelab Work seemed to make students feel the course had been rushed.

1.4 - PRE-QUESTIONNAIRE OPEN QUESTION.

The second part of the PRE-questionnaire introduced the following question "WHAT DO YOU EXPECT TO LEARN FROM THIS LABORATORY COURSE": This was answered by roughly 75% of the students who completed the PRE-Questionnaire. Their responses can be summarised as follows:

1. 50% of replies indicated that students expected to learn/or improve their lab techniques, and ability to handle the apparatus, chemicals and equipment, properly and safely,

Here are some typical student comments:

"I expect to learn how to handle apparatus and equipment carefully and confidently. I also expect to learn how to obtain accurate experimental results"
"Laboratory techniques, experimental design and ways to produce sound analytical data."
"Learn about setting up apparatus and carrying out experiments safely and efficiently."

2. 25% of the respondents expected to learn more chemistry/or understand chemistry better;

Here again are some typical comments:
"To see how chemicals react together, to improve my understanding and increase my knowledge of chemistry"
"I believed that laboratory will give me the chance to understand chemistry better."
"I expect this course to give me a basic knowledge of chemistry that will enable me to go on and look at some more complex side of science."

3. 22% of the respondents expected to learn how to relate theoretical to practical work;

Typical comments being:
"I expect to learn how to apply the theory learned in lectures in practical experiments."
"A sound basis in practical experiments, be able to relate what happens in the laboratory with information given in lectures."
"The practical applications of the theory being learned in the lectures."

4. 15% of the respondents expected to learn useful and enjoyable chemistry;

Typical comments:
"A better understanding of the practical side of chemistry and an incentive to learn more chemistry topics etc."
"A wider understanding in the field of chemistry. Hopefully, answer a lot of questions as to what makes the work go round."
"I hope that his course will be useful and enjoyable and worthwhile doing it."

5. 8% of the respondents expected to gain confidence and to be able to work on their own, to design and plan their own experiments;

Typical comments:
"I hope to learn how to perform experiments and interpret the resulting information without the assistance of a tutor."
"To discovery things for my self and be able to carry out experiments successfully on my own."

6. other responses included:

"I expect to learn how to work accurately gathering meaningful results from experiments."

"Practical application of chemistry."

"I expect to learn how to do more difficult experiments than the ones I am used to, e.g. I have done titrations and other simple SYS experiments."

"Better and more methodical techniques in experimentation. How to make better / more detailed observations. Greater understanding of theoretical chemistry through experimentation."

"From the first year course I expect to learn how to work while not under constant guidance from a member of staff while still having someone who knows the course around."

The percentages shown for each item above represents the proportion of that comments occurrence relative to the number of students who answered the PRE-questionnaire. (The sum of percentage indices is larger than 100 because some students' comments were classified in more than one group).

There were approximately 47 different students' comments which we grouped under the six headings shown above. Students' expectation from the university course may explain their negative attitude to the first year practical course - they came to university expecting to use sophisticated equipment and apparatus, but indeed they were asked to do experiments akin to those they had done at secondary school.

1.5 - POST-QUESTIONNAIRE - OPEN QUESTIONS

The open questions in the POST-Questionnaire helped to identify why students' attitude to the practical course changed. Table 5.15 contains open question-1; Table 5.16 question-2; and Table 5.17 question-3.

The results of question 1; 2 and 3 were analysed for the samples: CONTROL GROUP; PRELAB WORK; MINI-PROJECTS; and PRELAB plus PROJECTS, and the sub-samples EXPERIMENT 1; 2; 3 & 4; and 5 & 6. The responses were analysed for experiments 3 & 4, 5 & 6 together because these experiments were similar, i.e. they were equivalents and the student were not asked to do both. Those did experiment 3, afterwards they would do experiment 6, and if they did experiment 4, they did experiment 6 afterwards. To make a comparison possible between experiments 1 and 2 the results of experiment 3 & 4; were added together.

QUESTION 1 responses showed that experiment 1 "Inorganic Pyrotechnics" was considered the most enjoyable in the students' opinion, followed by experiment 3 & 4. The students claimed this was because the experiment was easy and they were able to see a quite spectacular reaction, described by some of them as "FUNNY".

In fact this experiment is the easiest one. The decomposition of ammonium dichromate (the "volcano") and the exothermic reaction of chromium(III) oxide with Aluminium powder to produce metallic chromium are both visually exciting and very attractive reactions, features which contributed to the students' enjoyment. Moreover no accurate measurement was required in this experiment only the rough balance and fume cupboard were used.

Indeed the apparatus (described in page 8 of the Lab Manual), used to do the thermite reaction, was already set up in the fume cupboard! The major problem encountered by the students in the experiment was related to the calculation of the % yield of the reaction. No significant differences were found among the samples and sub samples for question one.

QUESTION 2 responses showed that experiment 2 "Chemistry of Halogens" was considered the most difficult, followed by experiments 3 & 4. The students found difficulty in predicting the end-products and writing the chemical equations. They also claimed that they did not know what should be observed when doing the reactions. Many complained that the experiment was too long, since its many stages could not possibly be completed in a single lab session. The relatively large number of students in each lab session also meant that the fume cupboard was always crowded. Though only 25 students were doing experiment 2 in each session, this created an organisational problem as one fume cupboard can only be shared by up to 3 students at a time, and experiment 2 had several reactions which had to be done in there.

In experiments 3 & 4, students had problems seeing the titration end-point, making burette readings and doing calculations. Lots of mistakes were made in reading the burette to the required accuracy (1%), consequently students had often to repeat the titration more than three times.

Again no significant differences were found among the samples and sub samples for question 2 results.

QUESTION 1 - WHICH EXPERIMENT OR EXPERIMENTS DID YOU ENJOY MOST OF ALL?

	CONTROL N=120			PRELAB WORK N=55			MINI-PROJECT N=58			PRELAB & PROJECT N=50		
EXP	HGRD	SYS	GLBL	HGRD	SYS	GLBL	HGRD	SYS	GLBL	HGRD	SYS	GLBL
1	**41** **(34)**	**17** **(14)**	**67** **(56)**	**18** **(33)**	**15** **(27)**	**38** **(69)**	**24** **(41)**	**18** **(31)**	**44** **(76)**	**18** **(36)**	**8** **(16)**	**30** **(60)**
2	6 (5)	1	7 (6)	2 (4)	1 (2)	5 (9)	2	-	2 (3)	1 (2)	1	2 (4)
3+4	8 (7)	7	18 (15)	3 (6)	5	13 (24)	5 (9)	5	12 (21)	3 (6)	5 (10)	8 (16)
5+6	3 (2)	4 (3)	13 (11)	1	2	4 (7)	2	-	2	1	2	8

COULD YOU PLEASE TELL US WHY YOU FOUND IT (THEM) THE MOST ENJOYABLE?

Answers:	CONTROL				PRELAB WORK				MINI-PROJECTS				PRELAB + PROJECTS			
	EXP 1	EXP 2	EXP 3+4	EXP 5+6	EXP 1	EXP 2	EXP 3+4	EXP 5+6	EXP 1	EXP 2	EXP 3+4	EXP 5+6	EXP 1	EXP 2	EXP 3+4	EXP 5+6
I FOUND THE MOST ENJOYABLE BECAUSE...	N=67	N=7	N=18	N=13	N=38	N=5	N=13	N=4	N=44	N=2	N=12	N=2	N=30	N=2	N=8	N=8
It was interesting and easy	**24** **(36)**	**4** **(57)**	1	2	2 (5)	**5** **(100)**	2	-	**8** **(18)**	2	**5** **(42)**		**10** **(33)**	-	2	1
I understood what I was doing	**19** **(28)**	3	**10** **(56)**	1	**10** **(26)**	1	3		3 (7)		1		5 (17)		2 (25)	
I learned lab techniques	1	-	3 (17)	1		1	**5** **(39)**	1	1		2 (17)			1	**4** **(50)**	
I could see a quite spectacular(fun) reaction;I could see an end-product	**32** **(48)**	1	2	2	**18** **(47)**				**25** **(57)**			1	**16** **(53)**		2	
The instruction was clear and easy to follow	9 (13)		3		2 (5)								2 (7)		1	
The experiments were straightforward and short	12 (18)				8 (21)		3						9 (30)		2	

Table 5.15 - Results of POST-Questionnaires open question - 1

QUESTION 2 - WHICH EXPERIMENT OR EXPERIMENTS DID YOU FIND MOST DIFFICULT?

	CONTROL N=120			PRELAB WORK N=55			MINIPROJECT N=58			PRELAB&PROJECT N=50		
EXP	HGRD	SYS	GLBL	HGRD	SYS	GLBL	HGRD	SYS	GLBL	HGRD	SYS	GLBL
1	2 (2)		2	-	-	2	2	-	2 (3)	1	-	3 (6)
2	**31 (26)**	**19 (16)**	**60 (50)**	**15 (27)**	**13 (24)**	**36 (65)**	**18 (31)**	**14 ((24)**	**35 (60)**	**10 (20)**	**9 (18)**	**25 (50)**
3+4	12 (10)	9 (16)	22 (18)	5 (9)	1	6 (11)	8 (14)	2 (3)	10 (17)	6 (12)	3 (6)	9 (18)
5+6	18 (15)	10 (8)	31 (26)	4 ((7)	6 (11)	12 (22)	5 (9)	2	8 (14)	7 (14)	-	10 (20)

COULD YOU PLEASE TELL US WHY DID YOU FIND IT (THEM) THE MOST DIFFICULT?

	CONTROL				PRELAB WORK				MINI-PROJECTS				PRELAB + PROJECTS			
Answers:	EXP 1	EXP 2	EXP 3+4	EXP 5+6	EXP 1	EXP 2	EXP 3+4	EXP 5+6	EXP 1	EXP 2	EXP 3+4	EXP 5+6	EXP 1	EXP 2	EXP 3+4	EXP 5+6
I FOUND IT THE MOST DIFFICULT BECAUSE..	N=2	N=60	N=22	N=31	N=2	N=36	N=6	N=12	N=2	N=35	N=10	N=8	N=3	N=25	N=9	N=10
It was hard to predict the end product write the chemical equations and know what sould be observed		**28 (47)**		5 (16)		**14 (39)**	1	2	1	**15 (43)**	2	3		**8 (32)**	1	
It was a long experiment / too much to do / had a lot of stages	1	**24 (40)**	1	**13 (42)**	1	**19 (53)**	2	1		**18 (51)**	1			**13 (52)**	2	2
It was disorganised/hard to find chemicals and apparatus/ fumecupboard crowded		**11 (18)**	1	3		**8 (22)**				**7 (20)**				1		
It was hard to do a titration / end-point/accuracy/calculations			**18 (82)**	**6 (19)**			**3 (50)**	**4 (33)**		4 (11)					2	**5 (50)**
The written instructions (procedures) and purpose of experiment were not clear		4 (7)		4 (13)		1					1					
I should had done background reading		2 (3)				1								1		

Table 5.16 - Results of POST Questionnaire Open Question - 2

QUESTION 3 - WHICH EXPERIMENT OR EXPERIMENTS DID YOU FIND MOST USEFUL?

	CONTROL N=120			PRELAB WORK N=55			MINIPROJECT N=58			PRELAB&PROJECT N=50		
EXP	HGRD	SYS	GLBL	HGRD	SYS	GLBL	HGRD	SYS	GLBL	HGRD	SYS	GLBL
1	8 (7)	7 (6)	15 (13)	2 (4)	3 (5)	7 (13)	1	1	3 (5)	1		4 (8)
2	**16 (13)**	6 (5)	**27 (23)**	**5 (9)**	**6 (11)**	**13 (24)**	**7 (12)**	4 (7)	**11 (19)**	**5 (10)**	**5 (10)**	**11 (22)**
3+4	**26 (22)**	7 (6)	**37 (31)**	**9 (16)**	2	**13 (24)**	**14 (24)**	**11 (19)**	**29 (50)**	**8 (16)**	3 (6)	**11 (22)**
5+6	3 (3)	6 (5)	10 (8)	2	4 (7)	6 (11)	1	-	1	2 (4)	1	3 (6)

COULD YOU PLEASE TELL US WHY YOU FOUND IT (THEM) THE MOST USEFUL?

	CONTROL				PRELAB WORK				MINI-PROJECTS				PRELAB + PROJECTS			
Answers:	EXP 1	EXP 2	EXP 3+4	EXP 5+6	EXP 1	EXP 2	EXP 3+4	EXP 5+6	EXP 1	EXP 2	EXP 3+4	EXP 5+6	EXP 1	EXP 2	EXP 3+4	EXP 5+6
I FOUND IT THE MOST USEFUL BECAUSE...	N=15	N=27	N=37	N=10	N=7	N=13	N=13	N=6	N=3	N=11	N=29	N=1	N=4	N=11	N=11	N=3
I learned more about halogens and their properties / chemical equations		**16 (59)**		1		**11 (85)**				**8 (73)**	1			**11 (100)**		
I learned/improved lab techniques (balance/titrations)	1		**19 (51)**	**3 (30)**	1		**10 (77)**	3		1	**16 (77)**	1			**9 (82)**	**2 (18)**
I learned/ understood calculations	2		**10 (27)**	1			1	**3 (50)**			2 (7)		1 (25)			
I enjoyed it / it was interesting	3 (20)	1	1			1 (8)							2 (50)			

Table 5.17 - Results of the POST Questionnaire Open Question - 3

QUESTION 3 responses showed that experiment 2, "Chemistry of Halogens", and experiments 3 & 4 ,"Acid Base Titration" and "Iodimetry", were considered the three most useful experiments. Students considered "Chemistry of Halogens" the most difficult topic but gave it top marks for its usefulness. Student claimed that they felt they had learnt more about halogens, their properties and chemical equations by practical means than through theoretical means.

In contrast experiments 3 & 4 were ranked highly for their usefulness, because explained the respondents, they taught and/or improved their lab techniques, such as how to use an analytical balance properly and carry out a titration.

QUESTION 4 responses provided a list of "good points" in the redesigned course from the students point of view. Students valued the fact that they had been allowed to work alone, i.e. they enjoyed working on they own, and that they had improved their lab techniques. Notably the latter point was also given as the reason they judged experiment 3 useful.

QUESTION 4 - WHAT DO YOU THINK WERE THE GOOD POINTS ABOUT THE LAB COURSE?				
	CTRL	PLW	MP	P&P
Answer: (%)	N=120	N=55	N=58	N=50
You are allowed to work alone and at your own pace	**28 (23)**	**17 (31)**	**17 (29)**	**7 (14)**
The demonstrators were helpful	16 (13)	7 (13)	7 (13)	3 (6)
It gave me practical experience/taught me how to use apparatus and equipment/improve lab techniques	**26 (22)**	**10 (18)**	**9 (16)**	**9 (18)**
The manual was well laid out / clear / organised	13 (11)	8 (15)	3 (5)	6 (12)
The experiments were varied	6 (5)	1	3 (5)	
It was interesting	10 (8)	5 (9)	2	1
It was well organised	5 (4)		3 (5)	2
It gave me a better understanding of chemistry		5 (9)	1	
Prelab Work was helpful		4 (7)		6 (12)

Table 5.18 - Response of Open Question 4 / POST QUESTIONNAIRE

QUESTION 5 responses suggest that the worst features for students was having to queue to use equipment and the large numbers of students per session. The queues were a direct consequence of the large numbers of students doing the same experiment at the same time. This was particularly noticeable in the experiment 2 "Chemistry of Halogens" and experiment 1 "Inorganic Pyrotechnics" which were done by almost all of the students. They complained too about disorganisation in the lab and felt a need for more demonstrators (more consequences of too many students doing the same experiments at one and few demonstrators to supervise them).

QUESTION 5 - WHAT DO YOU THINK WERE THE WORST FEATURES OF THE LAB COURSE?				
	CTRL	PLW	MP	P&P
Answer: (%)	N=120	N=55	N=58	N=50
The long queues for chemicals and equipment	**33 (28)**	**21 (38)**	**13 (22)**	1
It was too large class (crowded)	**26 (22)**	**12 (22)**	**16 (28)**	**8 (16)**
Disorganised	11 (9)	4 (7)	9 (16)	8 (16)
Some need for more demonstrators	**16 (13)**	**10 (18)**	**14 (26)**	**7 (14)**
Lack of time - rushed	15 (13)	12 (22)	5 (9)	7 (14)
Difficult to understand what to do	7 (6)	2		1
The experiments were not related to theory / lectures	3		4 (7)	4 (8)
Prelab work - too much to do		3 (5)		1
Practical problem solving (mini-projects)			7 (13)	**16 (32)**

Table 5.19 - Students' responses for Open question 5 - POST-Questionnaire

QUESTION 6 responses records students' suggestions for improvements to the course. Firstly students felt there was a need for smaller laboratory groups. Secondly more demonstrators, and thirdly a greater variety of equipment. From the labels above it can be seen that students responses were quite consistent with their expectations of the university course. For example: They expected to learn/improve lab techniques (50% open question PRE) and rated the experiment 3 & 4 as useful because their improvement of lab techniques(over 50% in open question POST)

QUESTION 6 - WHAT CHANGES DO YOU THINK SHOULD BE MADE TO IMPROVE THE LAB COURSE?				
	CTRL	PLW	MP	P&P
ANSWER: (%)	N=120	N=55	N=58	N=50
Provide more variety of equipment	11 (9)	4 (7)	6 (10)	1
Provide chemical easy to get	10 (8)	3 (2)	2	1
Smaller lab groups	**22 (18)**	**13 (23)**	**12 (21)**	**7 (14)**
More demonstrators	**9 (8)**	**11 (20)**	**11 (19)**	**8 (16)**
Clearer instructions	10 (8)	3 (2)	8 (14)	3 (6)
Theory instructions / relate to lectures	8 (7)	2		7
More organised lab	5 (4)	2	4 (7)	1
No problem solving (mini-projects)			2	6 (12)

Table 5.20 - Response of Open Question 6 -POST questionnaire

QUESTION 7 responses showed that students' expectations of the next course seemed almost the same as before they had commenced the first year practical course. They are still asked to be taught how to use other, more advanced, kinds of equipment and apparatus. We also took seriously their request that the laboratory should interact more with the input on theory, and that there ought to be more chemistry behind the experiment.

QUESTION 7 - WHAT WOULD YOU LIKE TO LEARN NEXT TIME YOU DO A LAB COURSE?				
	CTRL	PLW	MP	P&P
ANSWER: (%)	N=120	N=55	N=58	N=50
To use other kind of equipment / different apparatus	3(2)		1	
something new / more advanced	7 (6)	2 (4)	2 (3)	1
Organic chemistry	9 (8)	2	2	4 (8)
More interaction between theory and practice	6 (5)	**9 (16)**	4 (7)	**5 (10)**
More chemistry behind the experiment	5 (4)	1	-	4 (8)
Other techniques	4 (3)	2	3 (5)	2 (4)

Table 5.21 - Responses of Open Question 7 / POST Questionnaire

1.6 - CONCLUSION

The results of PRE-Questionnaire questions 1 and 2 gave us some idea about population characteristics in this study. Like the Preliminary Survey, question 1 revealed the existence of two main student groups, the Higher Grade (HGRD) and the Sixth Year Studies(SYS) undergraduates. The SYS students had benefited from having the opportunity of performing secondary school practical work more independently, i.e. by project. Question 2 also showed that the SYS students had experienced practical work in a more individual mode than the Higher Grade group. On the other hand, the Higher Grade students had no such experience, but reported lab work taught by teacher demonstrations.

The Overall pattern generated by the 10 questions in the PRE and POST questionnaires indicated that responses were generally negative and in favour of their experience at secondary school. However the PRELAB WORK (PLW) course had a less negative performance than the CTRL and MP. The difference between the PRE and POST in most of the questions in the PLW sample was not statistically significant.

The SYS students attitude change were less negative than the Higher Grade group for most of the scales.

2 - DIARIES

The diaries were collected for each lab session and the response frequencies and percentages calculated for each statement. The analysis was done for the CONTROL; PRELAB WORK; MINI-PROJECTS; and PRELAB WORK plus MINI-PROJECTS samples and for the sub-samples; EXPERIMENTS(1; 2; 3; 4; and 5 & 6);

Higher (HGRD) and SYS sub-samples. The results of experiments 5 & 6 were computed together because of the small number of respondents who completed the diaries.

The subprograms, FREQUENCY, RELIABILITY and FACTOR ANALYSIS of SPSS/PC+ and their statistical options were used in the analysis of the Diaries. The FREQUENCY subprogram was used to compute response frequencies and percentages for each category. MODE was used to determine the central tendency of responses in each statement (indicated in **BOLD** in the tables).

The reliability of the scales and items of the instruments was estimated like in the PRE Questionnaire. (See section 1.1 earlier in this Chapter) The Cronbach's alpha values are summarised in the Table 5.22 for the scale as originally designed.

2.1 - VALIDATION OF DIARY

The factor analysis survey of the diaries involved the preparation of a correlation matrix followed by an initial extraction of factors and their rotation to obtain a final solution. Correlation coefficient were calculated, crossing all statements, and arranged in a matrix as shown in Table 5.23.

RELIABILITY COEFFICIENT			
SCALE	STATEMENTS	ALPHA-ITEM	ALPHA-SCALE
1 . Clarity of purpose and procedure of written instruction	7	.51	.65
	10	.63	
	12	.47	
2. Laboratory Instruction	4	.29	.40
	9	.31	
	15	.31	
3 . Familiarity	5	.58	.64
	11	.47	
	14	.55	
4. Salience of Stimulus	3	.36	.54
	6	.47	
	8	.47	
5. Amount of Information	1	.33	.60
	13	.61	
	2	.51	
15 items	-	-	.49

Table 5.22 - The original Scale - RELIABILITY COEFFICIENT

The procedure for extracting the common factors were the same used in the validation of PRE Questionnaires. (i) Orthogonal rotation; (ii) eigen-value greater than 1.0; (iii) Loadings significance at the 1% level. The statements loadings on the factor are shown in Table 5.24 (highest loading is indicated in **BOLD**).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	-	>1%		>1%			>1%	>1%	>1%	>1%	>1%	>1%	>1%		>1%
2	.33	-	>1%	>1%	>1%		>1%		>1%	>1%	>1%	>1%	>1%	>1%	>1%
3		.20	-	>1%		>1%	>1%	>1%	>1%	>1%	>1%	>1%	>1%		>1%
4	.19	.22	.24	-	>1%		>1%		>1%	>1%	>1%	>1%	>1%	>1%	>1%
5		-.37		-.33	-		>1%		>1%	>1%	>1%	>1%		>1%	>1%
6			.30			-	>1%	>1%							
7	.15	.22	.27	.25	-.19	.18	-	>1%		>1%	>1%	>1%	>1%	>1%	>1%
8	.19		.20			.33	.15	-				>1%	>1%		
9	.16	.30	.19	.22	-.37				-	>1%	>1%	>1%		>1%	>1%
10	.28	.28	.21	.28	-.16		.46		.15	-	>1%	>1%		>1%	>1%
11	-.23	-.44	-.18	-.24	.43		-.23		-.28	-.42	-	>1%	>1%	>1%	>1%
12	.22	.33	.22	.26	-.29		.30	.15	.20	.36	-.42	-	>1%	>1%	>1%
13	.46	.20	.16	.24			.15	.22			-.15	.16	-		
14		-.37		-.16	.34		-.20		-.17	-.18	.45	-.38		-	>1%
15	.20	.46	.18	.17	-.38		.16		.18	.23	-.43	.39		-.39	-

Table 5.23 - Correlation coefficients (Pearson's Correlation)

FACTOR ANALYSIS (*) SIG. >1%							
SCALES	Q	FACTOR 1	FACTOR 2	FACTOR 3	FACTOR 4	FACTOR 5	h^2
1	7	.159	**.750**	.210*	.024	.051	.637
	10	.265*	**.773**	-.006	.151	.005	.691
	12	**.593**	.338*	.158	.115	.041	.506
2	4	.016	.450*	-.116	.222*	**.592**	.617
	9	.215*	-.103	.180	.102	**.742**	.650
	15	**.749**	.597*	-.050	.043	.096	.578
3	5	-.488*	-.063	.152	.079	**-.612**	.646
	11	**-.680**	-.261*	.004	-.093	-.198	.579
	14	**-.746**	-.036	-.086	.033	-.040	.567
4	3	.077	.324*	**.520**	.003	.353*	.506
	6	-.059	.143	**.783**	-.032	.000	.639
	8	.073	-.089	**.731**	.272*	-.085	.629
5	1	.210*	.114	.037	**.811**	.030	.717
	2	**.624**	.093	-.053	.285*	.254*	.547
	13	-.002	.082	.148	**.814**	.115	.705
	%V	27.2	11.9	8.1	7.3	6.9	61.5

Table 5.24 - FACTOR ANALYSIS of Diaries.

SCALE ONE

Clarity of purpose and procedures in the written instructions.

(Statements 7, 10 and 12)

STATEMENT 7 - "The experimental procedure was clearly explained in the manual." / POSITIVE RESPONSE = STRONGLY AGREE and AGREE.

The experimental procedure, students considered, was more clearly explained in the courses with Prelab Work than in the CTRL course. More SYS students felt the experimental procedures were clear than the HGRD students.

STATEMENT 10 - "It was easy to follow the way the manual was organised (purpose, safety precautions, lab report, outline of experiment, procedure, etc.)." / POSITIVE RESPONSE = STRONGLY AGREE and AGREE.

In this particular item no significant differences were found among the samples and sub samples. Therefore, the tendency of response for all of the courses was positive and the level of agreement was higher than 70%.

STATEMENT 12 - "The purpose of this experiment was clear to me." POSITIVE RESPONSE = STRONGLY AGREE and AGREE.

Students level of response indicates that the purpose of experiments was thought to be clearest in the MP course followed by the CTRL course. The comparison between HGRD and SYS students shows that more SYS students found it to be clear than did HGRD students.

SCALE COMMENTS:

The purpose and experimental procedures seemed clear to the majority of respondents - with a "Level of Agreement" higher than 70% - implying a very low frequency of disagreement and fewer neutral responses.

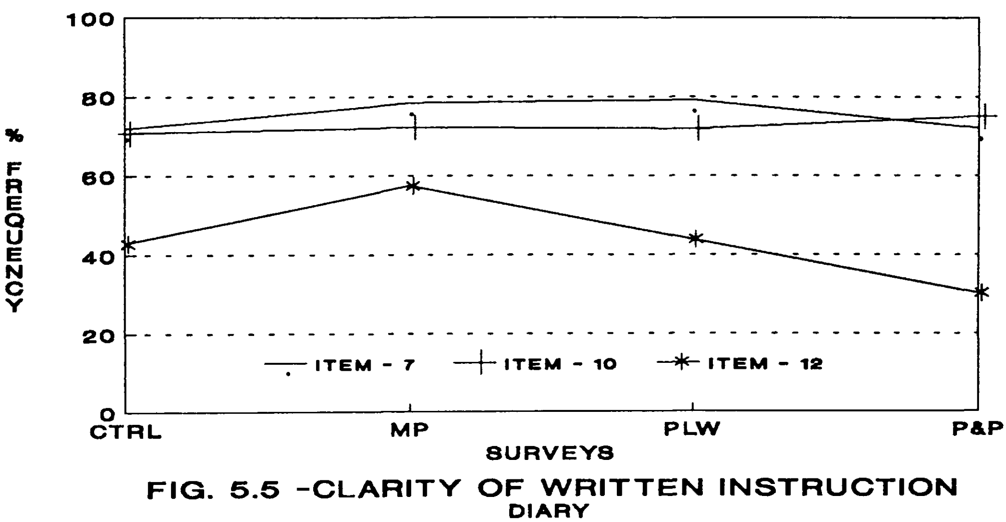


FIG. 5.5 -CLARITY OF WRITTEN INSTRUCTION
DIARY

The reliability of the scale was satisfactory considering the low number of items (Alpha value =0.65) and two out of three statements loaded on the same common factor (factor 5). The correlation coefficient between statements 7 and 10 was 0.46 (significant at 1% level).

Figure 5.5 shows the level of agreement for each scale item. Items 7 and 10 had good agreement. While the level of agreement for item 12 (about the clarity of purpose the experiment) decreased slightly with the introduction of PLW and PLW plus MP(P&P) though the difference was not statistically significant.

SCALE TWO
Laboratory Instructions (Statements 4, 9 and 15)

STATEMENT 4 - "It was clear to me what was expected in writing up my lab report." / POSITIVE RESPONSE = STRONGLY AGREE and AGREE.

It would appear from the results that students in the CTRL course felt to be more clearly instruct on what was required in the lab report. The comparison between the SYS and HGRD sub-samples suggests that this was clearer for the SYS students than for those in the HGRD sub-sample.

STATEMENT 9 - "I had enough help in writing the chemical equations in this experiment." / POSITIVE RESPONSE = STRONGLY AGREE and AGREE.

The global results demonstrated that in the CTRL course the students felt they had enough help in writing the chemical equations and more so than in the PLW, MP and P&P courses. In the P&P course the level of positive response was higher than in either the MP or PLW courses.

The HGRD students disagreed more strongly that they had enough help in writing the chemical equations than the SYS sub-sample which confirmed our findings on the previous experience of the two sub-samples groups.

STATEMENT 15 - "I was confident enough with the lab techniques to be able to concentrate on the chemistry involved in the experiment." POSITIVE RESPONSE = STRONGLY AGREE and AGREE.

The SYS sub-sample students indicated that they felt more confident in the practical course than the HGRD students. The results of this question are consistent with their responses to statements 1, 11, 12 and 14.

SCALE COMMENTS:

The results from the responses to statements in this scale show clearly that the HGRD students lacked in the experience and needed more help than the SYS students. This fact is reflected in their confidence (see question 15) in doing the experiments and in requiring help with the MINI-PROJECTS.

The coefficient of reliability for this scale is the lowest among all the scales (0.40). The correlation coefficients between the statements were also low when compared with that of scale 1 statements. Both statements 4 and 15 loaded significantly on factor 2 (see Table 5.24).

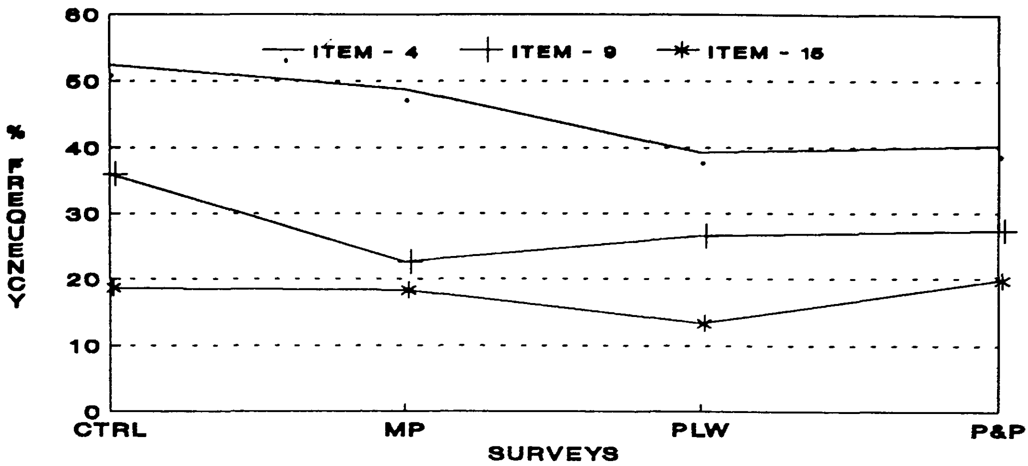


FIG. 5.6 - LABORATORY INSTRUCTION
DIARY

Figure 5.6 shows the level of agreement for Laboratory Instruction Scale. Item 4 (lab report) seemed to be well explained to the majority of students. Item 9 (help with chemical equations) and 15 (confidence with lab techniques) had a significant difference between the SYS and HGRD sub-samples. The HGRD students seemed to need more help in writing and balancing the chemical equations and also in lab techniques.

SCALE THREE

Familiarity (Statements 5, 11 and 14)

STATEMENT 5 - "I would have liked more help with the calculations in this experiment." / POSITIVE RESPONSE = STRONGLY DISAGREE and DISAGREE.

The students agreed that more help was needed with the calculations in the CTRL and MP courses than in the PLW and P&P. The comparison between the SYS and HGRD shows that the HGRD group would have liked more help with calculations than students in the SYS sub-samples.

STATEMENT 11 - "I was so confused in the laboratory that I ended up following the manual without really understanding what I was doing." POSITIVE RESPONSE = STRONGLY DISAGREE and DISAGREE.

The Prelab Work course had a greater positive response than either the CTRL or P&P courses. The comparison between HGRD and SYS sub-samples showed a significant difference in favour of SYS. The SYS students disagreed more strongly that they were confused in the laboratory and followed the manual without understanding than did HGRD students. It seemed that the HGRD students needed more help to do the experiments.

STATEMENT 14 - "I only understood what I had been doing in this experiment when I tried to write the lab report." / POSITIVE RESPONSE = STRONGLY DISAGREE and DISAGREE.

It is clear from the result of these statements that the students' level of experience plays an important role in being able to understand the laboratory instruction.

The HGRD students agreed more than SYS group that they only understood what they had been doing when they wrote up the lab report.

SCALE COMMENTS

The correlation coefficients among these statements were higher compared with the statement in other scales. Statement 5, also loaded significantly on factor 1 with the statements 11 and 14. The three statements had in common a negative loading which means that they had a opposite direction. These results are consistent with the negative nature of statement 11 and the negative response expected for statements 5 and 14.

The negative level of agreement (see Figure 5.7) means that the students' opinion was positive for statement 11; meaning that the majority they were not confused and understood what they were doing in the experiment.

Statements 5 and 14 showed a significant difference between the two groups SYS and HGRD.

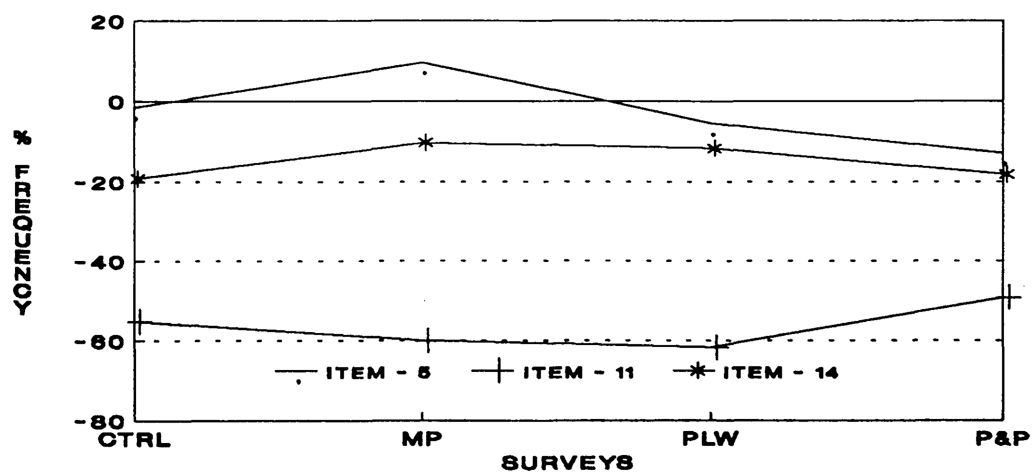


FIG. 5.7 - FAMILIARITY
DIARY

SCALE FOUR

Salience of Stimulus (Statements 3, 6 and 8)

STATEMENT 3 - "The symbols in the manual were helpful in doing this experiment". / POSITIVE RESPONSE = STRONGLY AGREE and AGREE.

The symbols in the manual seemed helpful to students when they were asked to do the MINI-PROJECTS which required them to plan, design and organise their own procedures.

The comparison between HGRD and SYS sub-samples showed no significant difference. In the MP course it seems that the symbols were more useful to the HGRD students than SYS students.

STATEMENT 6 - "The information in the appendices 1 to 6 was helpful." POSITIVE RESPONSE = STRONGLY AGREE and AGREE.

The information in the appendices seemed more helpful to students in the courses with MINI-PROJECTS followed by the CTRL course. Also, the appendices were found to be more helpful by the HGRD students than the SYS group. It is important to notice that as with the symbols, the appendices seemed to be more helpful to students in the course with Mini-Projects.

STATEMENT 8 - "The prelab introduction to the balances and volumetric techniques helped me when I came to use those techniques in this experiment." / POSITIVE RESPONSE = STRONGLY AGREE and AGREE.

The prelab introduction to the balances and volumetric techniques seemed to be considered more helpful by students in the CTRL and P&P courses.

The SYS students in the P&P course found the lab techniques more helpful than HGRD students in the same course. On the other hand, the HGRD students found it more helpful in the CTRL and MP course, than their SYS colleagues.

SCALE COMMENTS:

The results shown in this scale seem to be consistent with the students' previous experience. The SYS student, who is supposed to have more practical experience considered the stimuli less helpful than the HGRD student.

Statements 3,6 and 8 loaded on the same factor 3 but, similar to other scales the statements 3 and 8 loaded on other factors. See table 5.24. The correlation coefficient for these statements were fairly low and the reliability coefficient was acceptable (alpha value=.54).

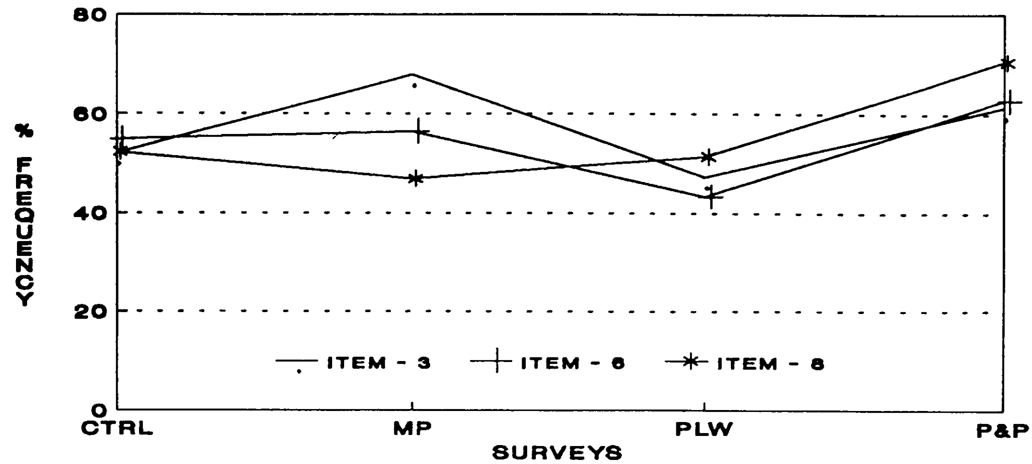


FIG. 5.8 - SALIENCE OF STIMULUS
DIARY

There was a good level of agreement among the three scale items and they were rated very positively by the students. The appendices containing the lab techniques, safety symbols, and also the training session in lab techniques seemed to be considered more helpful by students when they doing the Mini-Projects, than otherwise.

SCALE FIVE

The Amount of Information (Statements 1, 2 and 13)

STATEMENT 1 - "There was enough information in the manual (lab map etc) and in the laboratory to help me find the chemicals." / POSITIVE RESPONSE = STRONGLY AGREE and AGREE.

The results showed that the students in the courses PLW, MP and P&P answered this question more positively. Given that the four courses contained the same amount of information this difference in students' views may be attributed to inclusion of the Prelab Work and Mini-Projects. Our comparisons of PLW vs MP and MP vs P&P, showed a slight difference in favour of PLW and P&P - it would appear that the introduction of Prelab Work helped students cope better with the lab work.

The results confirm that the Prelab Work familiarise students with what is to be done in the laboratory and so improved their capacity to benefit from it.

Comparing HGRD and SYS sub-samples we found that in the PLW and P&P course (Prelab Work), had lower differences than did the CTRL and MP courses. The HGRD students in the CTRL course answered more positively, while the SYS students in the MP course answered more positively. It would appear from the results that the introduction of the MINI-PROJECTS caused these differences in responses between the sub-samples.

STATEMENT 2 - "I had enough time in the laboratory to think about the chemistry involved in the experiment." / POSITIVE RESPONSE = STRONGLY AGREE and AGREE.

The CTRL course was adjudged to be less rushed, in the students' opinion, than the rest. This finding is consistent with the course content. However we had expected that students in the PLW course would answer this question more positively than they in fact did.

Examination of the HGRD and SYS sub-samples show that the SYS students answered more positively when doing PLW, MP and P&P courses than did the HGRD students.

STATEMENT 13 - "There was enough information in the manual (lab map etc) and in the laboratory to help me find the equipment." POSITIVE RESPONSE = STRONGLY AGREE and AGREE.

There was a significant difference in favour of the PLW and P&P course - attributable to the SYS students. The HGRD students also felt that the manual in the CTRL course had enough information.

SCALE COMMENTS:

There was a good agreement between questions 1 and 13 which also loaded highly on the same common factor. The correlation coefficient seemed to be satisfactory and the reliability coefficient was equal to 0.60.

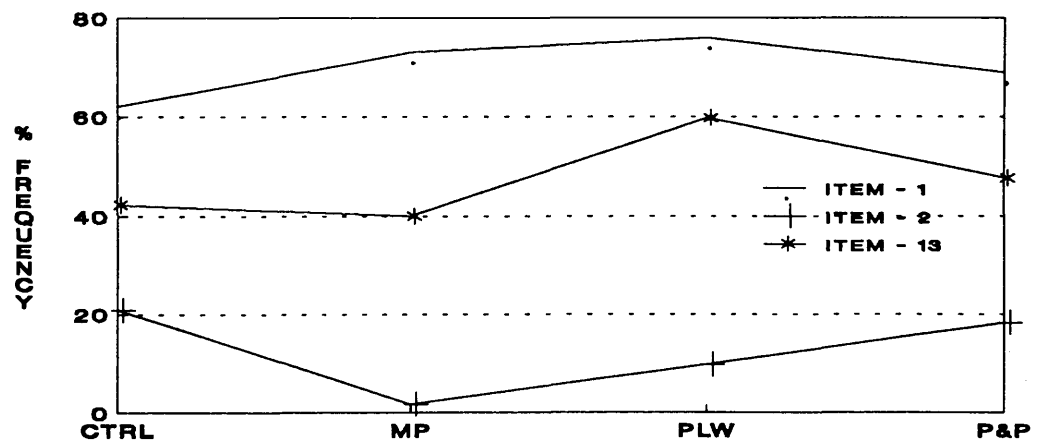


FIG. 5.9 - AMOUNT OF INFORMATION
DIARY

Items 1 and 13 were rated more positively than item 2. This result agreed with the statement 8 of the PRE and POST questionnaires where students opined that the course was rushed, a feeling which increased when the Mini-Projects and Prelab Work were introduced.

2.2 - COMPARISON AMONG SAMPLES and SUB-SAMPLES

We analysed the diaries by comparing the results of each statement for samples and sub-samples. Due to the large amount of data and variables to be compared some criteria had to be adopted to insure the efficiency of inferences and to simplify the task. Another reason for establishing the criteria was to overcome the problem of small samples, categories with zero frequencies, and expected frequencies lower than five when applying the Chi-Square test.

Considering that the research data collected in the diaries originally came from a five point scale rating they are considered somewhat "soft", i.e. the level of error in the measurements, the large number of uncontrollable factors which influence the students during the survey. It was thus thought worthwhile to look for a pattern instead of only making inferences based on the results of the statistical tests. Nonetheless we applied statistical tests to estimate the significance levels of the differences and to have an idea how strongly samples and sub-samples were favoured.

Three methods of estimating these differences were used throughout our analysis of the diaries:

FIRST. We estimated the comparative differences for "Levels of Agreement" (%DIFF);

SECOND. We estimated the significance level of the difference of positive responses (using Zubin's Nomograph); and

THIRD. We calculated the normal Chi-Square test to check the level of significance of the differences;

Table 5.25 (see Appendix C-1 - from page 314 to 328) contains the raw frequencies and the percentages for samples and sub samples. On the right hand side of the table a column was introduced under the heading "%DIFF", i.e. "PERCENTAGE OF THE DIFFERENCE". The %DIFF's were calculated by subtracting the percentage of positive responses from negative responses, e.g. for a positive statement the percentage of categories 1-Strongly Agree plus 2-Agree minus categories 4-Disagree plus 5-Strongly Disagree and ignoring the category 3-Neutral.

Table 5.26 gives summaries built by estimating the level of significance of the positive response differences (Agree plus Strongly Agree). The Nomographs for the Testing of Statistical Significance of Differences between Percentages were used aiding inspection and enabling us to focus attention on the most significant differences. However, this method lacks precision somewhat for small sample sizes and high percentages (>90%).

In the Tables, CAPITAL LETTERS and LOWER CASE LETTERS were used to differentiate the different methods applied to calculate the statistical level of significance.

Tables 5.27 (GLBL); Table 5.28 (HGRD); and Table 5.29 (SYS) contain a summary of the TOTAL result and of the HGRD and SYS sub-samples. The significance of differences were again calculated using the Chi-Square test, Zubin's Nomographs indicated by the CAPITAL and LOWER case letters respectively.

	CHI-SQUARE / DIARY'S QUESTIONS															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	RATIO
CTRL vs PLW	>1% PLW	>1% CTR	ctr	* CTR		>1% CTR	plw		** CTR		plw		>2% PLW		ctr	PLW/ CTR 6 : 4
CTRL vs MP	mp	ctr	>5% MP				mp	** CTR	ctr		mp	* MP		mp		CTR/ MP 3 : 6
CTRL vs P&P	p&p	ctr	** P&P	ctr	ctr	** P&P		* CTR	ctr			ctr	p&p			CTR/ P&P 5 : 5
PLW vs MP			>1% MP	mp	mp	>2% MP		>5% PLW				mp	>2% PLW	mp		PLW/ MP 2 : 6
PLW vs P&P	>1% PLW	p&p	>5% P&P		plw	>1% P&P		>2% P&P	p&p		plw	>5% PLW	>1% PLW		p&p	PLW/ P&P 5 : 5
MP vs P&P	mp	p&p	p&p		mp	p&p		>1% P&P			mp	>1% MP	p&p			MP/ P&P 4 : 5

* sig. at 10% level ** sig. at 20% level

Table 5.27- Summary of GLOBAL results of DIARIES

Q-1 - There was enough information in the manual(lab map etc) and in the laboratory to help me find the chemicals.

Q-1	CTRL vs PLW			CTRL vs MP			CTRL vs P&P			PLW vs MP			PLW vs P&P			MP vs P&P			HGRD vs SYS			
EXP	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	CTRL	PLW	MP	P&P
1		1% PLW	1% PLW		1% MP	1% MP					mp	10% MP		plw	10% PLW		mp	1% MP	H	S	S	H
2		plw		ctrl	mp	5% CTRL		p&p		plw		1% PLW				p&p	p&p		H		S	S
3		plw		mp	mp	1% MP		p&p	1% P&P	mp	plw	5% MP		p&p	1% P&P		p&p		H		H	
4	plw	plw	1% PLW	mp	mp	1% MP	p&p	p&p	1% P&P			10% PLW							S		S	
5+6		ctrl		ctrl	ctrl		ctrl	ctrl	1% CTRL	plw	plw	1% PLW	plw	p&p	1% PLW		p&p		S	H	H	
TOT		1% PLW	1% PLW		1% MP	1% MP		1% P&P	10% P&P						1% PLW			5% MP	H		S	

Q-2 - I had enough time in the laboratory to think about the chemistry involved in the experiment.

Q-2	CTRL vs PLW			CTRL vs MP			CTRL vs P&P			PLW vs MP			PLW vs P&P			MP vs P&P			HGRD vs SYS			
EXP	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	CTRL	PLW	MP	P&P
1				ctrl	mp		ctrl		5% CTRL	plw			plw		plw		mp	5% MP		S	S	S
2	ctrl	ctrl	1% CTRL	ctrl	ctrl	1% CTRL	ctrl	p&p	p&p	mp	plw		p&p	p&p	1% P&P		p&p	1% P&P		S	H	S
3	ctrl	plw	1% CTRL		mp	1% CTRL	ctrl	p&p					p&p		1% P&P	p&p		1% P&P	H	S	S	S
4	plw	plw	plw	mp				p&p	5% P&P	plw	plw	10% PLW	plw	p&p	5% PLW	mp	p&p		S	H	H	S
5+6	ctrl	ctrl	1% CTRL	ctrl	ctrl	1% CTRL					plw	5% PLW	p&p	p&p	5% P&P	p&p	p&p	1% P&P	S	S	H	H
TOT	1% CTRL		1% CTRL	1% CTRL		1% CTRL	1% CTRL	1% P&P	5% CTRL					1% P&P	5% P&P	10% P&P	1% P&P	1% P&P		S	S	S

Q3-The symbols in the manual (which are defined on page 4) were helpful in doing this experiment.

Q-3	CTRL vs PLW			CTRL vs MP			CTRL vs P&P			PLW vs MP			PLW vs P&P			MP vs P&P			HGRD vs SYS			
EXP	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	CTRL	PLW	MP	P&P
1	ctrl		1% CTRL	mp	mp	1% MP	ctrl	p&p	5% CTRL	mp		1% MP			10% P&P	mp		1% MP	H		H	S
2		ctrl		mp		1% MP	p&p	p&p	1% P&P	mp	mp	5% MP	p&p	p&p	1% P&P		p&p		S		S	S
3	plw	plw	5% PLW		mp	1% MP		p&p	5% P&P										H			
4	ctrl			mp	ctrl	1% MP			1% P&P	mp	plw	1% MP		p&p	1% P&P	mp	p&p			H	H	
5+6	ctrl	ctrl	5% CTRL	ctrl		1% CTRL				plw	p&p		p&p	p&p	5% P&P	p&p		1% P&P			S	
TOT	1% CTRL		1% CTRL	1% MP	1% MP	1% MP		1% P&P	1% P&P	1% MP	1% MP	1% MP	1% P&P	1% P&P	1% P&P	1% P&P	1% MP	1% P&P			H	S

Q4- It was clear to me what was expected in writing up my lab report.

Q-4	CTRL vs PLW			CTRL vs MP			CTRL vs P&P			PLW vs MP			PLW vs P&P			MP vs P&P			HGRD vs SYS			
EXP	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	CTRL	PLW	MP	P&P
1	ctrl	ctrl	1% CTRL	ctrl	mp		ctrl		1% CTRL		mp	1% MP	plw	p&p		mp	mp	1% MP		H	S	S
2		ctrl	10% CTRL	ctrl	ctrl	1% CTRL		ctrl		plw	plw	1% PLW				p&p	p&p	1% P&P	S	H		
3			1% CTRL		mp		ctrl	p&p		mp	mp	1% MP	plw	p&p	5% P&P	mp	mp	5% MP		S	S	S
4	plw			mp	mp	1% MP	ctrl	p&p		mp		1% MP	plw	p&p		mp	p&p	5% MP	S	S	S	S
5+6					mp	10% CTRL		p&p			mp	10% PLW		p&p					H	H	H	H
TOT	5% CTRL	1% CTRL	1% CTRL				1% CTRL		1% CTRL		1% MP	5% MP	plw	1% P&P		10% MP				H	S	S

Q5- I would liked more help with the calculations in this experiment

Q-5	CTRL vs PLW			CTRL vs MP			CTRL vs P&P			PLW vs MP			PLW vs P&P			MP vs P&P			HGRD vs SYS			
EXP	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	CTRL	PLW	MP	P&P
1				mp	ctrl		ctrl	ctrl	5% CTRL				plw	plw	5% PLW	mp		5% MP		H	H	H
2	ctrl	ctrl	1% CTRL					ctrl	1% CTRL	mp	mp	1% MP	p&p	mp		mp	mp	5% MP				H
3					mp	5% MP		p&p	1% CTRL			1% MP		p&p		mp	p&p	1% MP	H	H	H	S
4	plw		5% PLW	mp			p&p	ctrl	p&p	mp				plw		mp	mp			H	H	H
5+6	plw		5% PLW		mp	1% MP	p&p	ctrl	p&p	plw	mp	1% MP		plw	p&p	p&p	mp	p&p		H	S	H
TOT				mp				1% CTRL	1% CTRL			5% MP	5% PLW	1% PLW	1% PLW	5% MP	1% MP	1% MP		H	H	H

Q6 - The information in the appendices 1 to 6 was helpful.

Q-6	CTRL vs PLW			CTRL vs MP			CTRL vs P&P			PLW vs MP			PLW vs P&P			MP vs P&P			HGRD vs SYS			
EXP	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	CTRL	PLW	MP	P&P
1	ctrl		1% CTRL		mp		ctrl	p&p			mp	1% MP		p&p	10% P&P		p&p		H			S
2		plw					p&p	p&p	1% P&P		p&p		p&p	p&p	1% P&P	p&p	p&p	1% P&P	H		H	S
3	ctrl	ctrl	5% CTRL						10% CTRL		mp	5% MP					mp		H	H		H
4		ctrl	1% CTRL							mp	plw	5% MP	p&p	p&p	1% P&P		p&p	p&p			H	H
5+6			10% CTRL		ctrl	10% CTRL			10% CTRL		mp			p&p					H	H	H	H
TOT	1% CTRL	5% CTRL	1% CTRL				10% CTRL	1% P&P	5% P&P	5% MP	1% MP	1% MP	1% P&P	1% P&P	1% P&P		1% P&P	10% P&P	H	H	H	S

Q7-The experimental procedure was clearly explained in the manual.

Q-7	CTRL vs PLW			CTRL vs MP			CTRL vs P&P			PLW vs MP			PLW vs P&P			MP vs P&P			HGRD vs SYS			
EXP	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	CTRL	PLW	MP	P&P
1					mp		ctrl		1% CTRL		mp		plw		1% PLW	mp	mp	1% MP			S	
2	plw		1% PLW		mp	5% MP		p&p	1% P&P	plw	mp	5% PLW	plw	p&p		p&p				H	S	S
3	ctrl			ctrl	ctrl	1% CTRL	ctrl				plw	1% PLW	p&p	plw		p&p	p&p	1% P&P		S		
4	plw	plw	1% PLW		mp	1% MP	p&p	p&p	5% P&P	plw		10% PLW		plw	1% PLW	p&p	mp			S	S	
5+6	ctrl	plw		mp	mp	1% MP		p&p		mp		5% MP				mp		1% MP	H	S	H	
TOT		1% PLW	1% PLW		1% MP	5% MP		1% P&P		1% PLW	5% MP					5% P&P	10% MP				S	

Q8-The prelab introduction to the balances and volumetric techniques helped me when I came to use those techniques in this experiment.

Q-8	CTRL vs PLW			CTRL vs MP			CTRL vs P&P			PLW vs MP			PLW vs P&P			MP vs P&P			HGRD vs SYS			
EXP	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	CTRL	PLW	MP	P&P
1		plw		mp				p&p	1% P&P	mp	plw		p&p				p&p		H	S	H	S
2	plw	plw	1% PLW		ctrl	1% CTRL	p&p	p&p	1% P&P	plw	plw	1% PLW		p&p		p&p	p&p	1% P&P			H	S
3		ctrl	1% CTRL	ctrl	ctrl	1% CTRL				plw		10% PLW		p&p	1% P&P	p&p	p&p	1% P&P		H		H
4	ctrl		1% CTRL					p&p	5% P&P	mp		1% MP	p&p	p&p	1% P&P		p&p	10% P&P		S		S
5+6	ctrl		1% CTRL	ctrl		1% CTRL	ctrl	p&p					p&p	p&p	5% P&P		p&p	10% P&P	H	S	S	S
TOT	1% CTRL	10% PLW		1% CTRL	1% CTRL	1% CTRL		1% P&P	1% P&P		1% PLW	1% PLW	1% P&P	1% P&P	1% P&P	1% P&P	1% P%P	1% P&P			H	S

Q9 - I had enough help in writing the chemical equations in this experiment

Q-9	CTRL vs PLW			CTRL vs MP			CTRL vs P&P			PLW vs MP			PLW vs P&P			MP vs P&P			HGRD vs SYS			
EXP	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	CTRL	PLW	MP	P&P
1	ctrl	plw	1% CTRL	ctrl	plw		ctrl	p&p	1% CTRL			10% MP					mp	1% MP	H	S	S	S
2				ctrl	ctrl	1% CTRL		p&p	5% P&P	plw	plw	1% PLW		p&p		p&p	p&p	1% P&P		S		S
3			10% CTRL		ctrl		p&p	ctrl		mp	plw		p&p	plw	1% P&P		p&p		S	S	H	H
4	ctrl	ctrl	1% CTRL				ctrl	p&p			mp	1% MP		p&p	1% P&P	mp	p&p			S	S	S
5+6	ctrl						ctrl	p&p		mp				p&p			p&p		H		H	S
TOT	1% CTRL	plw	1% CTRL	1% CTRL		1% CTRL	5% CTRL	5% P&P	10% CTRL		plw		1% P&P		5% P&P		5% P&P		H	S		S

Q10 - It was easy to follow the way the manual was organised (purpose,safety precautions, lab report, outiline of experiment,procedure,etc).

Q10	CTRL vs PLW			CTRL vs MP			CTRL vs P&P			PLW vs MP			PLW vs P&P			MP vs P&P			HGRD vs SYS			
EXP	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	CTRL	PLW	MP	P&P
1											mp										S	
2		ctrl		ctrl	mp	1% CTRL				plw		1% PLW	plw	p&p		p&p	p&p	1% P&P		H	S	S
3		ctrl									mp		p&p				mp				S	
4	plw		1% PLW	mp		1% MP	p&p	p&p	1% P&P					p&p			p&p		S			S
5+6		plw	1% PLW	mp	ctrl			ctrl		mp	plw			plw						S	H	H
TOT																						

Q11 - I was so confused in the laboratory that I ended up following the manual without really understanding what I was doing.

Q11	CTRL vs PLW			CTRL vs MP			CTRL vs P&P			PLW vs MP			PLW vs P&P			MP vs P&P			HGRD vs SYS			
EXP	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	CTRL	PLW	MP	P&P
1		plw			mp	1% MP		p&p										1% MP		S	S	S
2		plw		ctrl	mp		ctrl	p&p		plw	plw	plw	plw	p&p		p&p	p&p		H		S	S
3	ctrl	plw			ctrl		ctrl	ctrl	1% CTRL	mp	plw	10% PLW		plw	1% PLW			10% MP	S	S		
4		plw	1% PLW	mp	mp	1% MP		p&p		plw			plw		1% PLW	mp	p&p	5% MP	S	S	S	S
5+6			1% PLW	ctrl	mp		ctrl	ctrl	ctrl	plw	plw	10% PLW	plw	plw	1% PLW		mp	mp	S	S	S	
TOT		1% PLW	1% PLW		1% MP	1% MP	1% CTRL	1% P&P		5% PLW	1% MP		1% PLW		1% PLW	10% MP	10% MP	1% MP		S	S	S

Q12 - The purpose of this experiment was clear to me.

Q12	CTRL vs PLW			CTRL vs MP			CTRL vs P&P			PLW vs MP			PLW vs P&P			MP vs P&P			HGRD vs SYS			
EXP	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	CTRL	PLW	MP	P&P
1	ctrl		5% CTRL		mp	1% MP	ctrl		5% CTRL	mp	mp	1% MP	plw			mp		1% MP		S	S	S
2	ctrl	plw		ctrl	mp		ctrl	p&p	1% CTRL	plw			plw		1% PLW	mp		5% MP		S	S	S
3	ctrl	plw	10% PLW		ctrl		p&p		1% P&P	mp	plw		p&p	plw		p&p		10% P&P	S	S		H
4		plw		mp	mp	1% MP		p&p		mp	mp	1% MP	plw			mp	mp	1% MP	S	S	S	S
5+6			10% PLW	mp	ctrl			ctrl	1% CTRL	mp	plw		plw	plw	1% PLW	mp	p&p	10% MP	S	S	H	
TOT	1% CTRL	1% PLW		ctrl	1% MP	1% MP	1% CTRL	p&p	5% CTRL	1% MP	5% MP	1% MP			5% PLW	1% MP	1% MP	1% MP		S	S	S

Q13 - There was enough information in the manual (lab map,etc) and in the laboratory to help me find the equipment.

Q13	CTRL vs PLW			CTRL vs MP			CTRL vs P&P			PLW vs MP			PLW vs P&P			MP vs P&P			HGRD vs SYS			
EXP	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	CTRL	PLW	MP	P&P
1	plw		10% PLW		mp	10% MP		p&p		plw	mp		plw	plw	10% PLW	mp				H		S
2	plw	plw	1% PLW	ctrl	ctrl			p&p	1% P&P	plw		1% PLW	plw	p&p		p&p	p&p	1% P&P	H	S	S	S
3	ctrl						p&p	p&p	1% P&P	mp			p&p		1% P&P	p&p	p&p	1% P&P	H		H	H
4		plw		ctrl		10% CTRL	ctrl	p&p		plw	plw	10% PLW	plw	p&p		p&p	p&p	p&p	H		S	S
5+6		plw	1% PLW	ctrl	ctrl	1% CTRL	ctrl	p&p		plw	plw	1% PLW	plw	p&p		p&p	p&p	1% P&P	H			S
TOT	5% PLW	5% PLW	1% PLW	1% CTRL	1% MP			1% P&P	1% P&P	1% PLW		1% PLW	5% PLW	1% P&P		5% P&P	5% P&P	1% P&P	H		S	S

Q14 - I only understood what I had been doing in this experiment when I tried to write the lab report.

Q14	CTRL vs PLW			CTRL vs MP			CTRL vs P&P			PLW vs MP			PLW vs P&P			MP vs P&P			HGRD vs SYS			
EXP	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	CTRL	PLW	MP	P&P
1				mp		1% MP		ctrl	5% P&P	mp	plw	5% MP	plw	plw	10% P&P	mp					H	H
2	plw		1% PLW	mp	ctrl			ctrl	1% CTRL		plw	10% PLW	plw	plw	1% PLW	mp	mp	5% MP	S	H	H	H
3	plw				mp		p&p		1% P&P	plw	mp	10% MP	plw		1% P&P	p&p	p&p	10% P&P	H	H	S	H
4	plw		plw		mp	10% MP	p&p		p&p	plw	mp		p&p			p&p	mp			H		H
5+6	ctrl		ctrl		mp	mp			5% P&P	mp	mp	1% MP			1% P&P	mp			H	H		H
TOT	1% PLW	10% CTRL		5% MP		1% MP	5% P&P	1% CTRL			1% MP	1% MP		10% PLW			1% MP			H	H	H

Q15 -I was confident enough with the lab techniques to be able to concentrate on the chemistry involved in the experiment.

Q15	CTRL vs PLW			CTRL vs MP			CTRL vs P&P			PLW vs MP			PLW vs P&P			MP vs P&P			HGRD vs SYS			
EXP	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	HGR	SYS	GLBL	CTRL	PLW	MP	P&P
1					mp	5% MP		p&p	5% P&P		mp	5% MP		p&p	1% P&P	p&p			S	S	S	S
2	ctrl		5% CTRL	ctrl		ctrl	ctrl		ctrl	plw				p&p		p&p			S	S	S	S
3	ctrl			mp	mp			p&p	5% P&P	mp			p&p	p&p	p&p		p&p		S	S	S	S
4	plw	plw	5% CTRL	mp	mp		ctrl	p&p	1% CTRL		plw	plw	plw	plw	5% PLW	mp		1% MP	S	S	S	S
5+6	ctrl	plw		ctrl	mp		p&p	p&p	p&p				p&p		p&p	p&p		p&p		S	S	
TOT	1% CTRL	5% PLW	10% CTRL	5% CTRL	1% MP			1% P&P			1% MP		1% * P&P	5% * P&P	10% * P&P				S	S	S	S

Table 5.26 - SUMMARY OF THE DIARIES QUESTIONS

	DIARY'S QUESTIONS															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	RATIO
CTRL vs PLW	5% PLW	5% CTR	ctr	ctr		5% CTR		5% CTR	1% CTR			5% CTR	plw	plw	5% CTR	CTR/ PLW 8 : 3
CTRL vs MP		5% CTR	mp					ctr	1% CTR			ctr	ctr	mp	ctr	CTR/ MP 6 : 2
CTRL vs P&P		5% CTR		ctr		ctr			5% CTR		ctr	5% CTR		p&p		CTR/ P&P 6 : 1
PLW vs MP			1% PLW		5% MP	mp	plw				plw	mp	5% PLW			PLW/ MP 5 : 3
PLW vs P&P	5% PLW		p&p	plw	plw	p&p		5% P&P	p&p		plw		plw		p&p	PLW/ P&P 5 : 5
MP vs P&P		p&p	p&p	mp	mp		p&p	p&p			mp	mp	p&p			MP/ P&P 4 : 5

Table 5.28 - Summary of HGRD sub-samples results

	DIARY'S QUESTIONS															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	RATIO
CTRL vs PLW	plw			5% CTR		ctr	plw	plw	plw		plw	plw	5% PLW	ctr	plw	CTR/ PLW 3 : 8
CTRL vs MP	5% MP		2% MP				5% MP	ctr			5% MP	mp	mp		5% MP	CTR/ MP 1 : 7
CTRL vs P&P	p&p	5% P&P	2% P&P		2% P&P	1% P&P	p&p	2% P&P	p&p		5% P&P		5% P&P	ctr	5% P&P	CTR/ P&P 1 : 11
PLW vs MP			5% MP	mp		mp	mp	5% PLW	plw		mp	mp		mp	mp	PLW/ MP 2 : 8
PLW vs P&P		5% P&P	5% P&P	5% P&P	plw	1% P&P		5% P&P					p&p	plw	p&p	PLW/ P&P 2 : 7
MP vs P&P		5% P&P	mp		5% P&P	5% P&P	mp	1% P&P	p&p		mp	5% MP	p&p	mp		MP/ P&P 5 : 6

Table 5.29 - Summary of the Diaries' SYS sub-sample

	DIARY'S QUESTIONS															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	RATIO
CTRL	H				H	1% HGR			1% HGR				5% HGR	S	1% SYS	4HGR: 2SYS
PLW		S		H	5% HGR	H	2% SYS		S		2% SYS	1% SYS		2% SYS	.1% SYS	3HGR: 7SYS
MP	S	S	5% HGR	S	5% HGR	5% HGR	1% SYS	H			1% SYS	S	5% SYS	5% SYS	.1% SYS	4HGR: 9SYS
P&P		1% SYS	S	1% SYS	1% HGR	S		S	S		1% SYS	2% SYS	S	2% SYS	.1% SYS	1HGR: 11SYS

HGR/SYS=Chi-Square Test H/S= %DIFF>15%

Table 5.30 - Summary of comparison between HGRD versus SYS

2.3 - CONCLUSION

The global analysis of the Diaries showed that in a few statements the differences were statistically significant because of opposite judgements were made by the HGRD and SYS sub-samples. It is therefore quite difficult to draw any conclusion from the summary.(see Table 5.27).

The HGRD were more positive about the CTRL than PLW, MP and P&P the SYS courses, while the SYS students were more negative about the CTRL course. For example,comparing the CTRL vs PLW in the HGRD sub-samples students rated 8 out 15 statements more positively than SYS group in favour of the CTRL course and only 3 was in favour of PLW. The SYS students, on the other hand, rated 3 out of 15 statements more positively in favour of the CTRL course and 8 was in favour of the PLW course. In almost all questions the SYS students gave a more positive response than the HGRD students.

From Table 5.28 (HGRD) it is possible to state that the HGRD students indicated a preference for the CTRL course. The P&P course was also favoured when compared to the MP course and was thus similarly scored.

From Table 4.29 (SYS) - the P&P course was favoured most followed by the MP course by the SYS students. It is clearly that the MINI-PROJECT were more preferred by the SYS sub-sample students than by the Higher Grade sub-sample.

3 - PRELAB WORK (PLW)

Prelab Work course was applied in the TUESDAY (PLW) and THURSDAY (P&P) sessions. Both of these used the manual with Prelab Work; the only difference being that the P&P course also had Mini-Projects at the end of each experiment.

We assessed the PRELAB WORK by collecting demonstrators and students opinion through the following questionnaires and Diaries:

i The PRE and POST QUESTIONNAIRES to determine the attitude change to practical work after the course. The results were discussed in section 1 of this chapter;

ii The DIARIES filled in for each completed experiment by the students.(discussed in section 2 of this Chapter);

iii Demonstrator Diaries and Check-list (to be discussed later in this chapter); and

iv PRELAB WORK QUESTIONNAIRES the results of which are discussed in this section.

Each course sample had about 100 students. However, only 71 questionnaire were collected from the PLW session (71% of the sample) and 77 from the P&P session (74.7% of the sample). Many students simply did not hand in their questionnaires and it was decided not to make this compulsory. The Prelab questionnaires were applied in the penultimate week of the course.

As with the other instruments, the PRELAB questionnaires were analysed with the help of the SPSS/PC+ computer sub-programs. The frequencies and percentages for each category were counted and are summarised in Table 5.31(A and B).

Table 5.32 gives correlation coefficients matrix for the Prelab Work questionnaires items used in the factor analysis.

	CORRELATION MATRIX					
ITEMS	1A	1B	1C	1D	1E	2
1A	-	>1%	>1%	>1%		>1%
1B	.47	-	>5%	>1%		>1%
1C	.34	.28	-	>5%	>1%	>1%
1D	.50	.34	.29	-		>1%
1E	**.02**	**-0.15**	**-0.30**	**-0.05**	-	
2	.46	.33	.39	**.39**	-0.20	-

Table 5.32 - Pearson's Correlation Coefficient of PRELAB WORK statements

PRELAB WORK QUESTIONNAIRE

1. I THINK THAT DOING THE PRELAB WORK

a) helped me to understand the experiments before I attempted them in the laboratory						
Q-1A	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	-	**20 (50)**	11 (28)	7 (18)	1 (3)	30.0
SYS	1 (4)	**14 (52)**	5 (19)	7 (26)	-	29.6
GLB	1 (1)	**34 (47)**	20 (28)	15 (21)	1 (1)	26.4

b) gave me more confidence when I came to do the experiments in the laboratory						
Q-1B	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	1 (3)	6 (15)	**23 (58)**	8 (20)	1 (3)	5.0
SYS	1 (4)	7 (26)	**14 (52)**	5 (19)	-	11.1
GLB	2 (3)	14 (19)	**39 (54)**	15 (21)	1 (1)	0.0

c) forced me to think about the experiments before I attempted them in the laboratory						
Q-1C	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	-	**22 (55)**	14 (35)	3 (8)	-	47.5
SYS	3 (11)	**17 (63)**	6 (22)	1 (4)	-	70.4
GLB	4 (6)	**41 (57)**	21 (29)	5 (7)	-	55.6

d) meant that I was able to follow the manual in the laboratory with a greater understanding of what I was doing.						
Q-1D	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	1 (3)	16 (40)	**18 (45)**	3 (8)	1 (3)	32.5
SYS	1 (4)	**15 (56)**	9 (33)	1 (4)	1 (4)	51.9
GLB	2 (3)	**32 (44)**	28 (39)	7 (10)	2 (3)	34.7

e) was difficult						
Q-1E	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	3 (8)	11 (28)	**15 (38)**	10 (25)	1 (3)	7.5
SYS	1 (4)	8 (30)	**15 (56)**	3 (11)	-	22.2
GLB	4 (6)	19 (26)	**32 (44)**	15 (21)	2 (3)	9.7

2. I THINK THAT PRELAB WORK SHOULD ALWAYS BE INCLUDED BEFORE DOING AN EXPERIMENT						
Q-2	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	3 (8)	**18 (45)**	15 (38)	2 (5)	2 (5)	42.5
SYS	3 (11)	**15 (56)**	8 (30)	-	1 (4)	63.0
GLB	7 (10)	**35 (49)**	25 (35)	2 (3)	3 (4)	51.4

Table 5.31 (A) - PRELAB WORK Questionnaire
TUESDAY session (PLW)

PRELAB WORK QUESTIONNAIRES (P&P)

1. I THINK THAT DOING THE PRELAB WORK

a) helped me to understand the experiments before I attempted them in the laboratory						
Q-1A	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	5 (12)	**24 (59)**	9 (22)	2 (5)	1 (2)	63.4
SYS	3 (14)	**13 (59)**	4 (18)	1 (5)	1 (5)	63.6
GLB	10 (13)	**45 (58)**	15 (20)	4 (5)	3 (4)	62.3

b) gave me more confidence when I came to do the experiments in the laboratory						
Q-1B	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	2 (5)	14 (34)	**19 (46)**	4 (10)	2 (5)	24.4
SYS	1 (5)	8 (36)	**12 (55)**	1 (5)	-	36.4
GLB	4 (5)	29 (38)	**34 (44)**	7 (9)	3 (4)	29.9

c) forced me to think about the experiments before I attempted them in the laboratory						
Q-1C	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	5 (12)	**19 (46)**	13 (32)	3 (7)	1 (2)	48.8
SYS	1 (5)	**16 (73)**	4 (18)	1 (5)	-	72.7
GLB	7 (9)	**43 (56)**	20 (26)	5 (6)	2 (3)	55.8

d) meant that I was able to follow the manual in the laboratory with a greater understanding of what I was doing.						
Q-1D	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	5 (12)	16 (39)	**17 (42)**	1 (2)	1 (2)	46.3
SYS	1 (5)	**13 (59)**	6 (27)	1 (5)	1 (5)	54.5
GLB	8 (10)	**37 (48)**	26 (34)	3 (4)	3 (3)	50.6

e) was difficult						
Q-1E	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	1 (2)	5 (12)	**21 (51)**	10 (24)	-	-9.8
SYS	-	4 (18)	**10 (46)**	8 (36)	-	-18.2
GLB	2 (3)	10 (13)	**38 (49)**	23 (30)	-	-14.3

2. I THINK THAT THE PRELAB WORK SHOULD ALWAYS BE INCLUDED BEFORE DOING AN EXPERIMENT						
Q-2	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	11 (27)	**18 (44)**	7 (17)	2 (5)	2 (5)	61.0
SYS	7 (32)	**8 (36)**	5 (23)	1 (5)	1 (5)	59.1
GLB	21 (27)	**34 (44)**	13 (17)	3 (4)	4 (5)	62.3

Table 5.31 (B) - PRELAB WORK Questionnaire
THURSDAY session (P&P)

The reliability and validity, like others questionnaires, were performed using the facilities of the RELIABILITY and FACTOR subprogram respectively. Both analysis are shown in Table 5.33. Two factors were extracted which had the eigen-value(latent root) greater than 1.0 and these were used for the analysis of the present questionnaire.

Most of the statements loaded on the same factor (one) with the exception of the statement (1E) "was difficult" which loaded on factor two. These results confirmed from an inspection of the correlation matrix, make it clear that statement 1E is weakly and negatively correlated with the others, i.e. statement 1E is not related to the others.

The reliability coefficients calculated for all statements together had a alpha value = 0.63. When item 1E is removed from the scale, the remaining five statements show an improvement in the Alpha value to 0.75.

	FACTOR ANALYSIS (*) Sig. >1%			RELIABILITY COEFFICIENT	
item	Factor 1	factor 2	communality	item alpha	item alpha-1e
1a	**0.813**	0.081	0.669	0.45	0.67
1b	**0.655**	-0.200	0.470	0.55	0.72
1c	**0.624**	0.015	0.390	0.55	0.74
1d	**0.727**	0.034	0.530	0.51	0.71
1e	-0.025	**0.973**	0.948	0.75	-
2	**0.697**	-0.294	0.543	0.53	0.70
%V	42.4	17.3	59.7	-	-
alp				0.63	0.75

Table 5.33 - FACTOR ANALYSIS and RELIABILITY COEFFICIENT of PRELAB WORK questionnaire

The Prelab Work questionnaire results were also sub-divided into the HGRD and SYS sub-samples. The raw frequencies were used to calculate Chi-Square and the significance level of the differences is indicated in Table 5.34 along with the favoured sample (in CAPITAL LETTERS). No significant differences were found between the HGRD and SYS sub-samples. The LOWER CASE letters in the Table 5.34 indicate the students preferences estimated by comparing percentages of positive response by Zubin's Nomograph.

QUES	HGRD vs SYS		PRELAB vs PRELAB&PROJECTS		
	PLW	P&P	HGRD	SYS	GLOBAL
1A			(p&p)	p&p	>2% P&P
1B	sys		>10% P&P		>5% P&P
1C	sys	sys			
1D	sys				p&p
1E			>10% P&P	p&p	>10% P&P
2			p&p		>2% P&P

Table 5.34 - comparison between prelab work questionnaires

The Prelab Questionnaires were also compared between the two course samples where Prelab Work had been applied, i.e., PLW and P&P courses. The differences were significant for statements 1A, 1B and 2 in favour of the P&P course.

There was a slight advantage in favour of SYS students. Surprisingly the Prelab Work in the P&P course was viewed more positively than in the PLW by both groups of students (SYS and HGRD). This again indicate that the MINI-PROJECTS influenced the results.

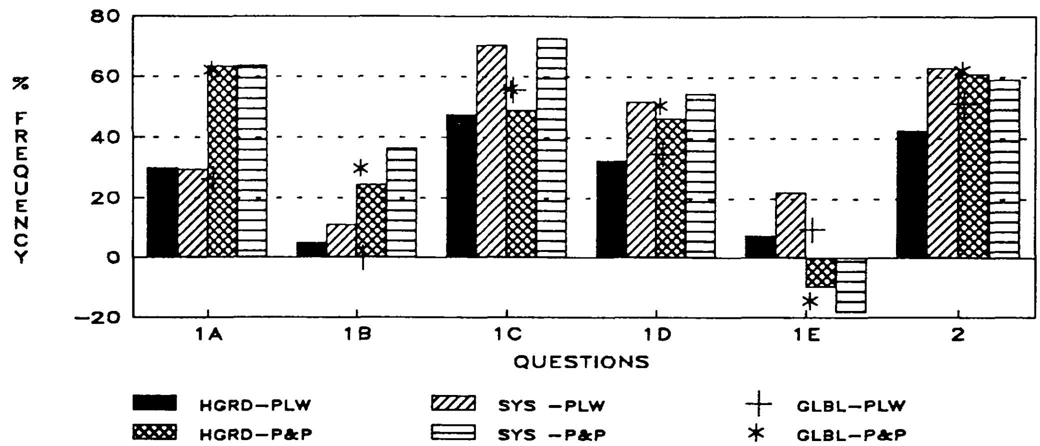


FIG. 5.10 — PRELAB WORK'S RESULTS
PLW and P&P

4 - MINI-PROJECTS

The MINI-PROJECTS were applied to the sessions on Wednesday (MP course) and Thursday (P&P course). The MP course used the our Improved Lab Manual (version 3) and with the Mini-Projects being issued at the end of each experiment. The P&P course used the Prelab Work Lab Manual (version 4) and also had the Mini-Projects at the end of each experiment. The difference between the two being is the Prelab Work.

We evaluated the Mini-Projects by collecting demonstrator and students opinions through the following questionnaires and Diaries in a similar way to our evaluation of the Prelab Work:

i PRE and POST Questionnaires were used to verify change in attitude to the practical work. (results discussed above).

ii DIARY was filled in by the students after each completed experiment (discussed above).

MINI-PROJECTS QUESTIONNAIRE (MP)

1. I THINK THAT SOLVING THE PRACTICAL PROBLEMS

a) forced me to design and plan my own experiments						
Q-1A	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	1 (2)	**19 (45)**	15 (36)	5 (12)	2 (5)	31.0
SYS	1 (3)	**20 (65)**	7 (23)	2 (7)	1 (3)	58.1
GLB	2 (3)	**43 (55)**	23 (30)	7 (9)	3 (4)	44.9

b) illustrated practical applications of the laboratory						
Q-1B	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	-	**30 (71)**	7 (17)	5 (12)	-	59.5
SYS	3 (10)	**17 (55)**	9 (29)	1 (3)	1 (3)	58.7
GLB	4 (5)	**49 (63)**	18 (23)	6 (8)	1 (1)	59.0

c) gave me more confidence in my practical work						
Q-1C	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	2 (5)	10 (24)	**16 (38)**	10 (24)	4 (10)	-4.8
SYS	1 (3)	12 (39)	**15 (48)**	2 (7)	1 (3)	32.3
GLB	3 (4)	23 (30)	**34 (44)**	13 (17)	5 (6)	10.3

d) was difficult						
Q-1D	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	5 (12)	13 (31)	**19 (45)**	5 (12)	-	31.0
SYS	2 (7)	10 (32)	**12 (39)**	6 (19)	1 (3)	16.1
GLB	7 (9)	23 (30)	**34 (44)**	13 (17)	1 (1)	20.5

e) allowed me to use my knowledge of chemistry to investigate the problems						
Q-1E	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	1 (2)	**17 (41)**	17 (41)	4 (10)	3 (7)	26.2
SYS	2 (7)	**23 (74)**	3 (10)	2 (7)	1 (3)	71.0
GLB	3 (4)	**44 (56)**	20 (26)	7 (9)	4 (5)	44.9

f) gave me a lot of satisfaction						
Q-1F	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	2 (5)	3 (7)	16 (38)	**17 (41)**	4 (10)	-38.1
SYS	2 (7)	3 (10)	**14 (45)**	10 (32)	2 (7)	-22.6
GLB	4 (5)	7 (9)	**32 (41)**	29 (37)	6 (8)	-30.8

g) was enjoyable						
Q-1G	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	1 (2)	8 (19)	**17 (41)**	11 (26)	5 (12)	-16.7
SYS	1 (3)	6 (19)	**14 (45)**	9 (29)	1 (3)	-9.7
GLB	2 (3)	14 (18)	**35 (45)**	20 (26)	7 (9)	-16.7

Table 5.35 (A) - Mini-Projects Questionnaires Wednesday session (MP)

h) was interesting						
Q-1H	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	1 (2)	9 (21)	**23 (55)**	6 (14)	3 (7)	2.4
SYS	1 (3)	13 (42)	**13 (42)**	3 (10)	1 (3)	32.3
GLB	2 (3)	24 (31)	**37 (47)**	10 (13)	5 (6)	14.1

2. I THINK THAT SOLVING THE PRACTICAL PROBLEM AT THE END OF THE EXPERIMENT HELPED ME TO UNDERSTAND THE EXPERIMENT WHICH HAD COME BEFORE						
Q-2	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	2 (5)	**20 (48)**	12 (29)	6 (14)	1 (2)	35.7
SYS	2 (7)	**16 (52)**	6 (19)	6 (19)	1 (3)	35.5
GLB	4 (5)	**38 (49)**	19 (24)	13 (17)	2 (3)	34.6

3. I THINK THAT MORE PRACTICAL PROBLEMS LIKE THESE SHOULD BE INCLUDED IN THIS COURSE						
Q-3	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	1 (2)	4 (10)	**17 (41)**	10 (24)	9 (21)	-33.3
SYS	1 (3)	4 (13)	**14 (45)**	9 (29)	3 (10)	-22.6
GLB	2 (3)	9 (12)	**32 (41)**	20 (26)	13 (17)	-28.2

Table 5.35 (B) - MINI-PROJECTS Questionnaires
WEDNESDAY session (MP)

MINI-PROJECTS QUESTIONNAIRES (P&P)

3. I THINK THAT SOLVING THE PRACTICAL PROBLEMS

a) forced me to design and plan my own experiment						
Q-3A	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	1 (2)	**21 (51)**	13 (32)	3 (7)	3 (7)	39.0
SYS	2 (9)	**7 (32)**	6 (27)	5 (23)	-	18.2
GLB	5 (7)	**34 (44)**	23 (30)	10 (13)	3 (4)	33.8

b) illustrate practical applications of the laboratory						
Q-3B	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	1 (2)	**17 (42)**	14 (34)	7 (17)	2 (5)	22.0
SYS	1 (5)	6 (27)	**9 (41)**	5 (23)	-	9.1
GLB	3 (4)	28 (36)	**29 (38)**	14 (18)	2 (3)	19.5

c) gave me confidence in my practical work						
Q-3C	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	-	8 (20)	**18 (44)**	11 (27)	3 (7)	-9.8
SYS	1 (5)	4 (18)	**9 (41)**	7 (32)	-	-9.1
GLB	2 (3)	16 (21)	**34 (44)**	19 (25)	4 (5)	-6.5

Table 5.35(C) - Mini-Projects Questionnaires - Thursday (P&P)

d) was difficult						
Q-3D	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	3 (7)	**16 (39)**	13 (32)	8 (20)	-	26.8
SYS	3 (14)	5 (23)	**11 (50)**	1 (5)	1 (5)	27.3
GLB	8 (10)	25 (33)	**30 (39)**	11 (14)	1 (1)	27.3

e) allowed me to use my knowledge of chemistry to investigate the problems						
Q-3E	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	-	**21 (51)**	14 (34)	3 (7)	2 (5)	36.4
SYS	1 (5)	**10 (46)**	7 (32)	3 (14)		36.4
GLB	2 (3)	**41 (53)**	23 (30)	7 (9)	2 (3)	44.2

f) gave me a lot of satisfaction						
Q-3F	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	-	4 (10)	**17 (42)**	14 (34)	6 (15)	-39.0
SYS	-	1 (5)	**9 (41)**	5 (23)	6 (27)	-45.5
GLB	1 (1)	8 (10)	**30 (39)**	24 (31)	13 (17)	-36.4

g) was enjoyable						
Q-3G	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	1 (2)	5 (12)	**20 (49)**	9 (22)	6 (15)	-22.0
SYS	-	2 (9)	**9 (41)**	3 (14)	7 (32)	-36.4
GLB	1 (1)	10 (13)	**33 (43)**	19 (25)	13 (17)	-27.3

h) was interesting						
Q-3H	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	-	9 (22)	**18 (44)**	8 (20)	6 (15)	-12.2
SYS	-	4 (18)	**7 (32)**	5 (23)	5 (23)	-27.3
GLB	1 (1)	18 (23)	**32 (42)**	14 (18)	11 (14)	-7.8

4. I THINK THAT SOLVING THE PRACTICAL PROBLEM AT THE END OF THE EXPERIMENT HELPED ME TO UNDERSTAND THE EXPERIMENT WHICH HAD COME BEFORE						
Q-4	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	5 (12)	11 (27)	**13 (32)**	8 (20)	3 (7)	12.2
SYS	-	5 (23)	**7 (32)**	5 (23)	3 (14)	-13.6
GLB	7 (9)	19 (25)	**23 (30)**	17 (22)	6 (8)	3.9

5. I THINK THAT MORE PRACTICAL PROBLEMS LIKE THESE SHOULD BE INCLUDED IN THIS COURSE						
Q-5	AGREE		NEUTRAL	DISAGREE		%
	1	2	3	4	5	DIF
HGR	2 (5)	5 (12)	**14 (34)**	10 (24)	9 (22)	-29.3
SYS	-	2 (9)	**8 (36)**	5 (23)	6 (27)	-40.9
GLB	3 (4)	9 (12)	**26 (34)**	19 (25)	16 (21)	-29.9

Table 5.35 (D)- MINI-PROJECT Questionnaires

THURSDAY Session

iii Demonstrator's DIARY and CHECK-LIST were collected (discussed below); and

iv PRELAB WORK QUESTIONNAIRES the results of which are discussed in this section.

The MP and P&P samples both had about 100 students each, but again, not all of them returned their questionnaires. In the MP course 78 students completed the questionnaire (75,7% of the sample) while the P&P course 75 students completed it (70% of the sample).

The frequency of response and their respective percentage were calculated for each statements of the Mini-Project questionnaires. The "level of Agreement" (%DIFF) were also calculated for each statement throughout the samples and subsamples. The results are shown in the Table 5.35 (A; B; C; and D).

Table 5.36 the correlation coefficients of the items from the Mini-Projects' Questionnaires which were used in our Factor Analysis.

	CORRELATION MATRIX									
ITEMS	1A	1B	1C	1D	1E	1F	1G	1H	2	3
1A	-	>1%			>1%	>1%		>5%	>5%	
1B	.46	-	>1%	>1%	>1%	>1%	>1%	>1%	>1%	>1%
1C	.18	.53	-	>1%	>1%	>1%	>1%	>1%	>1%	>1%
1D	**-.05**	**-.37**	**-.49**	-	>1%	>1%	>1%	>1%	>5%	
1E	.41	.66	.49	**-.33**	-	>1%	>1%	>1%	>1%	>1%
1F	.29	.61	.59	**-.35**	.69	-	>1%	>1%	>1%	>1%
1G	.05	.31	.39	**-.31**	.37	.72	-	>1%	>1%	>1%
1H	.27	.55	.52	**-.42**	.63	.81	.68	-	>1%	>1%
2	.23	.45	.57	**-.27**	.52	.68	.46	.64	-	>1%
3	.17	.38	.34	**-.16**	.45	.67	.64	.59	.60	-

Table 5.36 - Pearson's Correlation Coefficient of MINI-PROJECTS statements

The reliability of the results was checked by calculating Cronbach's Alpha values and the validity by factor analysis (see Table 5.37).

	FACTOR ANALYSIS (*) Sig. >1%				RELIABILITY
item	Factor 1	Factor 2	Factor 3	communality	Alpha
1a	.029	**.888**	-.072	.794	.83
1b	.296	**.686**	.423*	.737	.80
1c	.359	.256	**.702**	.688	.81
1d	-.108	-.012	**-.895**	.813	.89
1e	.445*	**.628**	.337	.706	.80
1f	**.804**	.346	.315	.866	.78
1g	**.850**	-.068	.201	.767	.80
1h	**.742**	.298	.368*	.775	.78
2	**.686**	.289	.259	.623	.79
3	**.864**	.146	-.160	.864	.80
%V	52.8	12.4	10.3	75.4	-
alpha	-	-	-	-	.83

Table 5.37- Factor Analysis and reliability of MINI-PROJECTS questionnaire.

Three factor were extracted which had the eigen-value (latent root) greater than 1.0 for use in the analysis of the present questionnaire.

Factor 1 was related to attitude such as, Enjoyment, Satisfaction, and Interest. Factor 2 was related to the application of students' knowledge and their opinion as to the importance of Mini-Projects. Factor 3 was related to the students' opinions about the difficulty and feeling of confidence in doing given tasks. We found that some statements loaded significantly on more than one factor which suggests that they are somehow related to the factor. Statement 1C is one that loaded significantly on all three factors. In contrast statement 1D "difficulty" was negatively related to all other statements.

We also divided the results of the MINI-PROJECTS questionnaire into the HGRD and SYS sub-samples. The raw frequencies were then used to calculate Chi-Square test. Table 5.38 show the significance level, followed by the favoured sample (in CAPITAL LETTERS). Only statement 1E, the difference was statistically significant in favour of SYS sub-sample. The LOWER CASE letters in Table 5.38 indicate the favoured sample when percentages of positive response were compared using Zubin's Nomograph.

The MINI-PROJECTS questionnaire results were compared for the two samples from where they had been applied, i.e. MP and P&P courses. The differences were significant for statements 1A and 2 in favour of the MP course (Table 5.38).

QUES	HGRD vs SYS		MIN-PROJECTS vs PRELAB&PROJECTS		
	MP	P&P	HGRD	SYS	GLOBAL
1A	sys		>5% P&P	mp	>1% MP
1B			p&p	mp	p&p
1C	sys			mp	mp
1D					
1E	>1% SYS			mp	
1F				p&p	
1G	sys			mp	mp
1H			mp	mp	mp
2		hgrd	mp	5% MP	mp
3					

Table 5.38 - Comparison between the mini-projects questionnaires

The above pattern suggests that the SYS students preferred the MP course, i.e. the course in which the Mini-Projects were applied without the Prelab Work, while the HGRD students were more inclined to favour the P&P course.

Despite students recognising some positive aspects of the Mini-Projects such as " that forced them to design and plan their own experiment", "that made them use their knowledge of chemistry to investigate problems", however they did not agree that Mini-Projects should be included in the course. We identified two related points:

Firstly, results from the item DIFFICULTY showed a significant negative correlation coefficient with the items IMPORTANCE (1B, 1C, and 1E) and ENJOYMENT (1F, 1G, and 1H). This suggests that the students who found the Mini-Projects difficult also found them UNIMPORTANT and UNENJOYABLE. However we do not consider a sound reason for not including them in the course.

The results showed that the HGRD students, who are the less experienced group, gave more negative response for most of these items than did the more experienced SYS students.

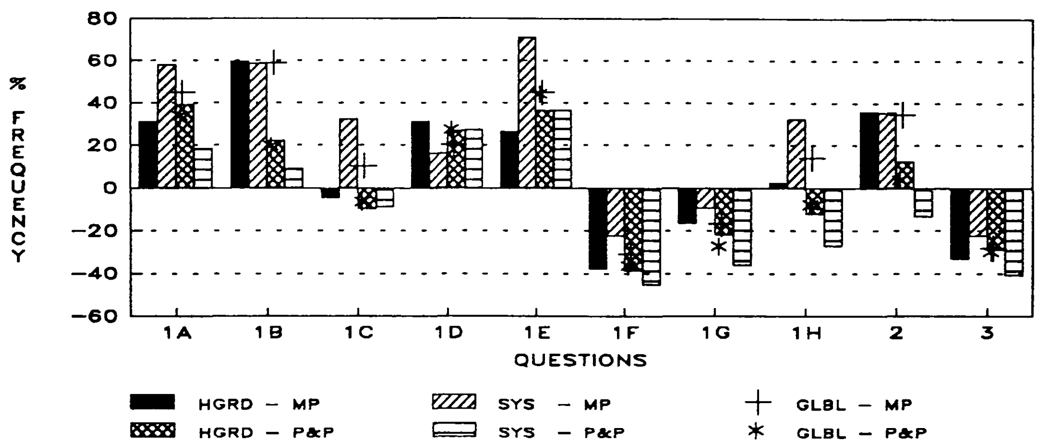


FIG. 5.11 — MINI-PROJECTS' RESULTS
MP and P&P

Secondly it is important to note the way in which the Mini-Project were administered. In the manual it was not made clear to students that the Mini-Projects were part of the course, they were presented simply as a trial.

It was noticed at the time the Mini-Projects were allocated to students that many of them were not pleased to be asked to carry out what they saw as an additional work. Often at the end of a lab period the students who had completed an experiment would go to the demonstrators and ask if they could have the "blue sheet" (as they called the Mini-Projects) in preparation for the next session. It was thus common to see students picking up the Mini-Projects in the last hour of a lab taking them away to use in the next lab period, i.e. students treated the Mini-Projects like "homework".

5 - DEMONSTRATORS' DIARY

The demonstrators' diaries were collected for every session (in total 125 diaries) over the 6 six week course. The comments made by the demonstrators were summarised in Table 5.39.

Note : Abbreviations used in Table 5.39 - 'Pgx', 'lnx', and Ex means page and line's numbers in the manual's page and the number of the experiment to which the comments refer. The full copy of both versions of the lab manual are included in the Appendix B-1 and B-2 (inside back cover).

Despite our effort to reduce the amount of misleading information and more clearly present the instructions, students still had problems in grasping these, even though when we compared the comments and suggestion of demonstrators in the present survey with their comments and suggestions in the preliminary survey, it is noticeable that there was a significant decrease in the number of students complaints. (Compare Table 5.39 with Table 3-17 Chapter 3).

Demonstrators' comments concerning lab organisation concentrated on the difficulties in getting the chemicals from bench A and B and crowding in the fume cupboards. This problem arose because large numbers of students were doing the same experiment in a single session (particularly experiments 1 and 2).

The demonstrators' own comments and observations presented here were in favour of the courses with Prelab Work (PLW and P&P). Comments like "Prelab work is perfect since it makes our work easier" were made by demonstrators with experience of the previous year's lab. So it would appear from the demonstrators' view point the laboratory instruction was an improvement on the previous year.

6 - DEMONSTRATOR'S CHECK-LIST

The demonstrators kept the check-list of the frequency of certain questions listed in Table 5.40 often raised by the students during the preliminary survey in the previous year. Figure 5.12 contains a chart drawn using the percentages of item "a" given in Table 5.40.

EXP	**1.1 WRITTEN INSTRUCTIONS**
1	-Pg8/ln6 - students did not realise that the reaction was a decomposition of the ammonium dichromate and not a combustion. -Pg9/ln12 - "Weigh the metal and calculate % yield based on the amount of Cr_2O_3 and CrO_3 used." should be "...in the mixture of Cr_2O_3 and CrO_3" or "...from available Cr in oxide". -Pg8/ln3 - setting up the volcano reaction; the students thought that a tripod with square gauze was required.
2	-Too much detail is expected from the test-tube reactions. -Equations were not immediately obvious for students -In PRELAB WORK part D - students thought that equation should involve all things at once - Cl_2/H_2O plus NaCl plus NaI ----> -Location of chemicals for experiment 2 must be included. -Pg15/ln18 - instead of "In the fume cupboard add a few drops of ... to any of the silver halides which are precipitated, and ..." should read "... to all of silver halides which...". -Pg12/ln20 - "... Why do CCl_4 and $SiCl_4$ behave differently from one another? Write a balanced equation for each reaction." The students thought this was for CCl_4 and $SiCl_4$ which had been referred in the previous sentence.
3 & 4	-E3 - pg18/ln16 - When to use volumetric flasks. -E3/4 - procedure for weighing accurately - to use rough balance and then analytical balance. -E3/4 - Pg22/ln32 -'Repeat the titration until two reproducible titres are obtained (difference <0.1ml). -Students did not read burette to 2 decimal places because the manual said the difference between two titres should be <0.1ml -E3 - students were unsure of concentration of HCl to use. -E4 - Pg21/ln30 - The equation of KIO_3 plus KI should be given as part of the basic ideas behind the experiment.
5 & 6	-E6- Pg29/ln15 - "Filter with a fluted filter paper into a 250 ml..." What is a <u>fluted</u> filter paper? -E5 - Pg24/ln34 - "...and 50ml of water plus 2-3 drops of dilute sulphuric acid." It should be specified the approximate concentration of it. -E6 - Pg26/ln12 - The amount of ethanol to be added should be specified.
	APPENDIX 2 Pg36/ln12 - Meaning of titre was not obvious - it should be titre (initial minus final reading).
	1.2-LABORATORY'S ORGANISATION -Where to find the chemicals and apparatus - Solutions out of place -Dilute hydrochloric acid to be used - Student cannot identify it as the bottle on bench A. -No equipment in designated drawer - Dirty test tube before use -Reagents bottles are unknown for some of them till now. -What is the molarity of the standard solutions. -lack of organisation - in the fume cupboards - far too many people in the lab -Prelab work is not helpful -practical problem solving takes up too much time
	2.DEMONSTRATORS COMMENTS -Some students are very dependent on demonstrator, especially for calculations -It seems that some students have forgotten the techniques they had learnt last week. -Laboratory is far more orderly than last year. -It appears that students have learnt to follow the written instructions and generally approach to experimental work with more confidence. Better results are also being produced. Laboratory management much better than last year. -Laboratory organisation has been very good - Same with management - Certainly a great improvement over that of the previous year. -Quiet, well disciplined class - Standard of Prelab work good -They do not know the name of some apparatus. -Prelab work is perfect since it makes our work easier. -Prelab work makes work easier for students

Table 5.39 - Results of the Demonstrators' Diaries

E	QUESTIONS	CTRL N=201	PLW N=100	MP N=103	P&P N=104
1a	**Calculation of the yield**	**79 (39.3)**	**19 (19.)**	**49 (47.6)**	**17 (16.3)**
1b	Calculation of enthalpy	26 (12.9)	8 (8.0)	13 (12.6)	15 (14.4)
2a	**How to write balanced equations**	**69 (34.3)**	**21 (21.0)**	**46 (44.7)**	**31 (29.8)**
2b	Which effects do products in the litmus paper?	17 (8.5)	6 (6.0)	15 (14.6)	12 (11.5)
3a	**Calculation of the number of moles of $KHC_8H_4O_4$**	**31 (15.4)**	**10 (10.0)**	**26 (25.2)**	**9 (8.7)**
3b	Calculations of molarities	52 (25.9)	20 (20)	46 (44.7)	11 (10.6)
4a	**How to write oxi-reduction equations**	**59 (29.4)**	**7 (7.0)**	**24 (23.3)**	**7 (6.7)**
4b	Calculations of molarities	67 (33.3)	11 (11.0)	26 (25.2)	10 (9.6)
5a	Calculations of yield	18 (9.0)	8 (8.)	12 (11.7)	14 (13.5)
5b	Calculations of % Cu	14 (7.0)	10 (10.0)	14 (13.6)	11 (10.6)
6a	Calculations of yield	18 (9.0)	11 (11.0)	15 (14.6)	8 (7.7)
6b	Calculations of % Cr	19 (9.5)	13 (13.0)	12 (11.7)	13 (12.5)

Table 5.40 - Results of Demonstrator CHECK-LIST

Noticeably the frequency of some QUESTIONS in the Prelab Work session was lower than in CTRL and MP courses. This result alone is not convincing, but when compared to the results of the other instruments, it seems to support the contention that the Prelab Work was effective in achieving out intended goal.

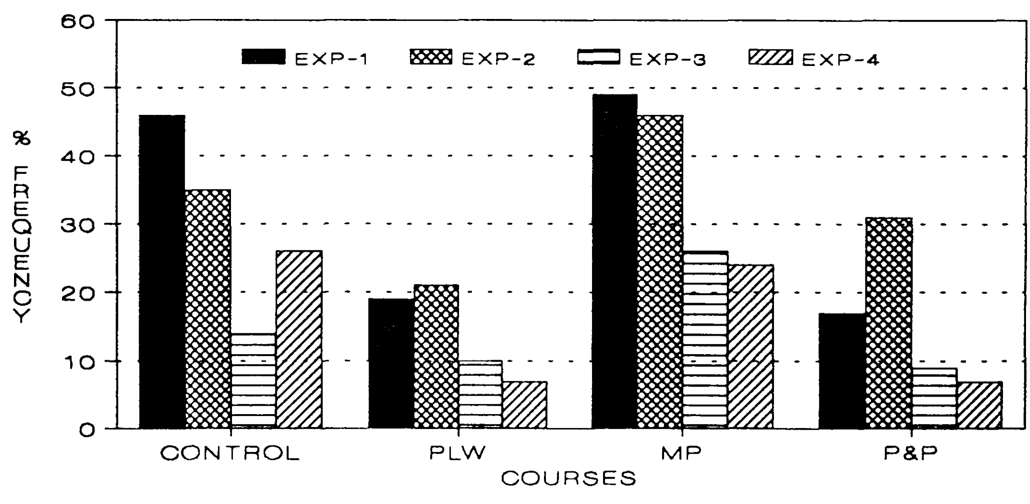


FIG. 5.12 - DEMONSTRATORS' CHECKLIST
ITEMS - A

The Prelab Lab group (PLW) showed a higher degree of independence than the Control (CTRL) in all experiments. The Mini-Projects group (MP), who had done no Prelab Work, asked more questions than did the CONTROL group. This was presumably due to the introduction of Mini-Projects. The group with both prelab and mini-projects (P&P) asked fewer questions for all experiments except experiment number 2.

7 - CONCLUSION: A SUMMARY

This summary attempts to pull together the findings in this chapter and examine them in the light of the existing theoretical background.

The summary of chapter 4 stated that the four courses had managed to take account of the problem of overloading students' working memory, by presenting different loading levels when we identified and ranked for each teaching approach.

From our comparison of PRE and POST Questionnaires it emerged that the students' opinions were dependent on two factors:

i The level of difficulties of the course which produce different levels of load on their working memory; and

ii Their previous experience. In this survey further examined the HGRD and SYS sub-samples.

Table 5.10, shows our comparison of PRE versus POST questionnaires. Students' ratings for each course were significantly different throughout. However the differences between the PRE and POST questionnaires were not found to be statistically significant for most of the 10 items in the PLW course, while for the CTRL and MP courses the difference was significant for almost all items.

It was thus apparent that the Pre and Post Questionnaires items demonstrated that students course preferences could be ranked as follows:

(+) **PLW > P&P > CTRL ~ MP** (-)

with the PLW course being viewed most positively by the students while the CTRL and MP were viewed most negatively.

Comparing this sequence with the sequence we presented in Chapter 4 we see that they are almost identical. The course rated most positively by the students is the one which we planned to contribute least to the load on their working memory. On the other hand, the MP and CTRL which we considered would contribute more to working memory loading gave differences which were statistically significant for almost all items.

Notice too, that this pattern was found to be practically the same when the method of determining the significance of the differences was changed(see Table 5.13).

When the HGRD versus SYS sub-samples were compared there emerge a different of results from the GLOBAL finding. Specifically the order of the HGRD students' ratings was slightly different from the GLOBAL results

(+) **PLW < P&P < MP ~ CTRL** (-)

which means that the MP course was seen as equivalent to the CTRL course.

On the other hand, the SYS students ratings were completely different.

(+) **PLW ~ P&P ~ MP < CTRL** (-)

This means that the PLW, MP and P&P were viewed as equivalent to each other. Comparison between the HGRD versus SYS sub-samples (Table 5.14), tell us more about these differences. The SYS sub-sample found all of the courses easier and more understandable than did the HGRD sub-sample. While the HGRD sub-sample found the course more difficult and more useful they also agreed that they had learnt more from it. Yet again these results reflected our findings on the differences in the knowledge base and experience of the two sub-samples.

The fact that some experiments was considered more difficult was not seen as a problem by the students who also considered it more useful than the others. The POST Questionnaire open questions confirmed this finding. Students considered experiment 1 "Inorganic Pyrothecnics" as the most enjoyable because it was easier than the rest and had a "funny" reaction. On the other hand, they considered experiment 2 "Chemistry of Halogens" the most difficult one. Curiously though they considered the same experiment 2 together with 3 and 4 as very useful too (gave them equal weighting).

The Diaries thus clarified and reinforced the evidence of the PRE and POST Questionnaires. Tables 5.27 for the Diaries GLBL results did not provide any clear evidence of students' preferences. However, when a breakdown for the HGRD and SYS sub-samples (Table 5.28 and 5.29) was done, a similar pattern to that in the PRE and POST Questionnaires emerged.

The HGRD students seemed to prefer the CTRL course and PLW course more than the MINI-PROJECTS (MP and P&P) courses. As opposed to the SYS students preferred the MINI-PROJECTS (MP and P&P) courses more than the CTRL and PLW courses.

Table 5.30 gives a comparison of the HGRD and SYS sub-samples which confirms the SYS students' preferences for these courses, while the HGRD students rated the CTRL course higher.

These results were further confirmed by the PRELAB and MINI-PROJECTS questionnaires (shown in Table 5.34 and Table 5.38 respectively).

The demonstrators' opinions were also very positively in favour of the Prelab Work (PLW) course which they considered eased their work load.

The Demonstrators' check-list results also show that the number of questions about calculations and balancing of equations was much smaller in the Prelab Work (PLW) course than in the rest.

Thus the evidence derived from the PRE and POST Questionnaires seemed to have been confirmed by the evidences from the DIARIES, PRELAB Questionnaires, Demonstrator's DIARIES and CHECK-LIST. The tendency of the results from all of the instruments have the same directional sense.

From the analysis of our data the following recommendations ares posed for planning the next course.

i The fact that the students interpreted the mini-projects as an "extra piece of work" because they were given in a separate worksheets during the course, suggests it is more desirable that Mini-Projects be incorporated in the laboratory manual.

ii Differences between the HGRD and SYS students ought to be taken into account. The course should be planned with a gradual increase in the students activities, i.e. by introducing the Mini-Projects at the end of the course, for those students who are more confident and experienced.

iii The laboratory may require reorganisation possibly increasing the number of rough balances and making more room at the fume cupboards in view of the problems relating to experiments 1 and 2.

iv Familiarisation is a key goal in practical work. We therefore recommend the replacement of experiments 5 and 6 in which the theory is only taught two terms later, by others with prior theoretical inputs.

CHAPTER 6

FINAL TRIAL

The foregoing comparative analyses of the four versions of the improved practical course for undergraduates, designed with reference to the preliminary survey, furnished us with evidence to support the following:

i The Prelab Work (PLW) and the Lab Techniques training were considered helpful by the students when doing their lab's experiments;

ii The Improved Laboratory Manual was considered to be written clearly, which avoided major student memory overload; and

iii The Mini-Projects (MP) were found to be considered more effective when applied with the PRELAB WORK (P&P course) and, as our sub-samples helped predict, the more experienced students seemed to have a better more positive attitude to the Mini-Projects than those who had not the Sixth Year Studies course (SYS).

The Mini-Projects, however, were viewed by students as an "extra piece of work" because they were administered at the end of each experiment and had not been included in the redesigned manual - The Mini-Projects were handed out in a separate worksheet from which students were asked to develop a experimental plan of how they intended to solve the problem, which had to be submitted to a staff member for approval for safety reasons.

Laboratory's organisation was another problem area. The students, yet again, complained about having to queue to use the fume cupboard, or to get chemicals particularly when doing experiments 1 and 2.

Experiments 5 and 6 which dealt with preparation and analyses inorganic complex compounds, were also found troublesome by the students since they lacked the necessary theoretical understanding to cope. As we had been said before, the theory underpining experiment 5 & 6 was only taught in the third term, i.e., two terms after students had undertaken the practical experiment.

Therefore, with these "good" and "bad" features in mind, we decided to introduce some further changes in the course Content, Prelab Work (PLW), and Mini-Projects (MP), expecting to improve and overcome the difficulties we had found in our design.

1 - COURSE CONTENT

The naked criticism that the students did not have the necessary knowledge base to perform and understand the synthesis and analysis of complex compounds was not enough to convince staff in charge to change the course content. However, the findings of the survey reported in the previous chapter produced clear evidence that this was the case so it was agreed to replace experiments five and six, preparation and analysis of complexes, with Mini-Projects. Now instead of students solving one small practical problem at the end of each experiment, they were asked to undertake a practical problem-solving (Mini-Projects) now included as an integral part of the manual, after they had completed the four proposed experiments (closed-ended).

Figure 6.1 shows the model we developed of the laboratory instruction framework of the first year practical inorganic course (termed PMP).

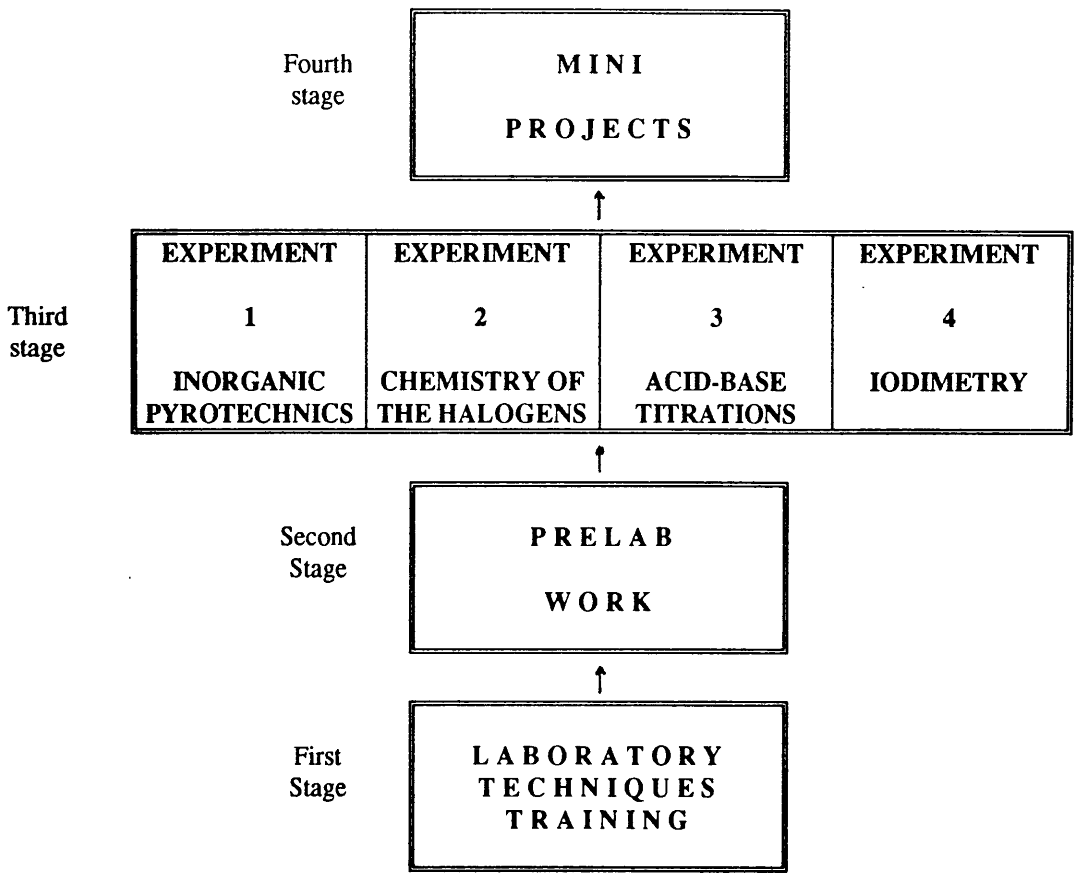


Figure 6.1 - Our First Year Practical Inorganic Course Model (PMP)

A copy of the Lab Manual (version 5) used in the Final Survey can be found in the Appendix D-1 (inside back cover).

1.1 - LABORATORY TECHNIQUES - First Stage

The laboratory techniques training, the first stage in our model, is intended to reduce the load on students memory and avoid overload on this when they are carrying out the experiments. In this stage we aim to give the student the necessary confidence in laboratory techniques so that they can do the experiments without any break down in the learning process due to time wasted in attempting to get to grips with the basic skills such as titration, pipetting, weighing, etc. (See appendices of the Lab Manual (version 5) - inside back cover)

Our survey results in the preceding year showed this previous training was useful and so we intended to repeat it. The lab techniques were supported by an illustrated written instructions included as appendices in the redesigned manual. In the current (90-91) year the students benefited from also attendance at an audio-visual instruction session about the weighing procedures which was devised by Khalid[84].

1.2 - PRELAB WORK - Second Stage

The PRE and POST Questionnaires, DIARIES and PRELAB WORK questionnaire results all supported the findings that the prelab exercise was considered useful by the students.

However, the demonstrators checklist gave even clearer evidence that the students who did the prelab exercise were more sure of themselves and asked fewer questions during the lab course than those who had not. So, it was decided to increase the number of exercises in experiments 1 and 2, "Inorganic Pyrotechniques" and "Chemistry of the Halogens," respectively and retain experiments 3 and 4 unchanged.

Experiment 1 - at the end of this experimental procedure (see Appendices B-1 or B-2 inside back cover) students were given a theoretical problem in which they were asked to calculate the enthalpy for the completed experimental reaction and compare it with their actual observations. This exercise we have now included as Prelab Work.

The PRELAB WORK for Experiment 1 has been presented below with our changes to it indicated in **BOLD** print (PART C).

PRELAB WORK for experiment 1

PART A - Balance the equation for the decomposition of ammonium dichromate to chromium(III) oxide. Hence calculate the mass of ammonium dichromate required to make 2.0 g of chromium(III) oxide.

PART B - Write the balanced equations for both the reduction of Cr_2O_3 and CrO_3 with Al to produce Cr metal (thermite reaction). Hence calculate the theoretical yield of Cr metal from the complete reduction of 7.0g of Cr_2O_3 and 3.0g of CrO_3.

PART C - Use the following data to calculate the enthalpy(heat) of reduction of Cr_2O_3 to Cr by aluminium.

$$Cr_2O_{3\,(s)} \longrightarrow 2\,Cr_{(s)} + {}^{3}/_{2}\,O_{2\,(g)} \quad \Delta H^o = +1041\ kJmol^{-1}$$

$$2\,Al_{(s)} \longrightarrow {}^{3}/_{2}\,O_{2\,(g)} + Al_2O_{3\,(s)} \quad \Delta H^o = -1668\ kJmol^{-1}$$

Experiment 2 - The criticism that it is impossible to make observations of an experiment without prior speculation about what is to be observed and how to perform the experiment guided the changes in Prelab of experiment-2. The qualitative character of the experiment required a higher number of observations from students, e.g., colour changes, evolving gas, pH change etc. It was considered vital that the students should know in advance what products the reactions would give to enable and prepare them to observe, interpret, and understand what would occur.

It was clear from the prior survey (see Chapter 5) that students felt were more confident about doing this experiment when they were primed about the properties of the halogens. It was decided to include in the Prelab Work all reactions involved in the experiment. Students were asked to write, balance and explain the chemical equations. In this way, the students could now have no complaints that the products were difficult to predict or that they did not know what ought to be observe. The changes are indicated below in **BOLD** print.

PRELAB WORK for experiment 2:

Write a balanced equation for each reaction and try to explain them.

PART A **$AlCl_3 + H_2O \longrightarrow$** **$CCl_4 + H_2O \longrightarrow$**

$SiCl_4 + H_2O \longrightarrow$ $PCl_5 + H_2O \longrightarrow$

PART B **$NaF + H_2SO_4 \longrightarrow$** $NaCl + H_2SO_4 \longrightarrow$

$NaBr + H_2SO_4 \longrightarrow$ **$NaI + H_2SO_4 \longrightarrow$**

PART C $NaCl + H_2SO_4 + MnO_2 \longrightarrow$

PART D **$NaF + Cl_2 \longrightarrow$** $NaCl + Cl_2 \longrightarrow$

$NaBr + Cl_2 \longrightarrow$ $NaI + Cl_2 \longrightarrow$

PART E **$NaF + AgNO_3 \longrightarrow$** $NaCl + AgNO_3 \longrightarrow$

$NaBr + AgNO_3 \longrightarrow$ $NaI + AgNO_3 \longrightarrow$

The Prelab Work for all experiments can be found in the Appendix D-1 (Lab Manual - version 5) inside back cover.

1.3 - EXPERIMENTS - Third Stage

The changes mentioned above reduced the proposed experiments (closed-ended) to four. The experimental procedures remained unchanged.

1 - "Inorganic Pyrotechnics"
2 - "Chemistry of the Halogens"
3 - "Acid-Base Titration"
4 - "Iodimetry"

The intention of the third stage of our course redesign was to teach the students fundamental basic laboratory skills with these four experiments and help them to gain confidence in practical problem-solving.

1.4 - MINI-PROJECTS - Fourth Stage

The mini-project were changed significantly to meet the requirements of our final laboratory course design.

Firstly, the level of difficult of the practical problem had to be adjusted. We aimed to make the Mini-Projects a little more difficult since they were replacing one of the main experiments. Secondly, we increased the number of Mini-Projects to reduce the likelihood of students copying. Thirdly, the Mini-Project solution were based on the chemistry and/or techniques involved in the experiments set out in the third stage. And finally, the Mini-Projects were designed , as far as possible, to relate to everyday life and/or illustrate an application of the chemistry taught in the course.

We also changed the way the Mini-Projects were administered. The students would now be asked to do the Mini-Projects after they had completed minimum of three experiment from the third stage. Similarly to the previous year students were asked to write down a plan explaining how they intend to solve the Mini-

Project and submit it to a member of staff so that the safety of the procedure could be checked.

A total of seventeen Mini-projects (practical problems) were devised so that if all students in a class had reached this stage together there would only be 5 students per session working on the same Mini-Project. A check of the lab records for the previous lab course found that only about 40% of the students completed more than four close-ended experiments over the duration of the course. So, we estimated that at least two students in each session would be attempting to solve each mini-project on the same day.

The mini-projects (practical-problems) devised and applied in the final course design were:

1 PRACTICAL PROBLEM - 5 - Design an experiment to find out the volume of oxygen at stp which could be liberated from one litre of a solution of H_2O_2 when the H_2O_2 is decomposed. Determine the molarity of the H_2O_2 solution.

2 PRACTICAL PROBLEM - 6 - Design an experiment to determine the percentage of acetic acid in a sample of vinegar.

3 PRACTICAL PROBLEM - 7 - assuming that there are no other impurities, design an experiment to determine the proportion of $CaCO_3$ and $Ca(OH)_2$ in the mixture provided.

4 PRACTICAL PROBLEM - 8 - Design an experiment to determine the proportion of Na_2CO_3 and NaOH in commercial caustic soda.

5 PRACTICAL PROBLEM - 9 - Design an experiment to determine the amount of ammonia in household ammonia.

6 PRACTICAL PROBLEM - 10 - Design an experiment to determine the percentage of iron in steel wool, using $KMnO_4$ as oxidising agent.

7 PRACTICAL PROBLEM - 11 - Carry out an experiment to investigate the extent of carbon dioxide and water absorbed by sodium hydroxide when exposed to the atmosphere over a period of one week.

8 PRACTICAL PROBLEM - 12 - Design an experiment to determine the solubility of iron (II) sulphate in water at room temperature, using $KMnO_4$ as oxidising agent.

9 PRACTICAL PROBLEM - 13 - Design an experiment to determine the percentage of $CuSO_4$ in a sample of $CuSO_4.xH_2O$.

10 PRACTICAL PROBLEM - 14 - Design an experiment to determine the value of x in $Na_2CO_3.xH_2O$ (washing soda).

11 PRACTICAL PROBLEM - 15 - Given a solution of a copper salt of unknown concentration, use a solution of Na_2CO_3 of known molarity to find the approximate concentration of the Cu(II) solution.

12 PRACTICAL PROBLEM - 16 - The reaction of Acid + Base ----> is Exothermic. Use a thermometer in place of indicator to find the molarity of one versus the other. Now compare with indicator results.

13 PRACTICAL PROBLEM - 17 - Assuming that the only impurity is water, design an experiment to determine the percentage (purity) of the $Na_2S_2O_3$ and calculate the number of waters of hydration.

14 PRACTICAL PROBLEM - 18 - Assuming that the only acid in the juice is citric acid, design an experiment to find out the amount of citric acid in samples of orange and lemon juice.

15 PRACTICAL PROBLEM - 19 - Design an experiment to find out the percentage of chlorine present in a bleach sample.

16 PRACTICAL PROBLEM - 20 - Design an experiment to determine the amount of magnesium hydroxide in magnesia tablets.

17 PRACTICAL PROBLEM - 21 - Design an experiment to determine the percentage of carbonate and bicarbonate in a sample of bath salts.

A copy of the form used for the Mini-Projects can be found in the Appendix D-2 (page).

The Mini-Projects (practical-problems) worksheet had the same layout as the rest of the manual and the instructions for their solution were included as part of this. We thus intended to make it clear to the students that the Mini-Projects were an integral part of the course and not at best an experimental trial, at worst, an afterthought.

It was expected that the Mini-Projects would motivate and give the more experienced students an opportunity to develop more demanding exercises than those proposed in the third stage, allowing the less experienced students to work at their own pace doing as much they could without being forced to solve the practical if they did not feel confident enough to tackle it. The students had the option of expending their time repeating another experiment till they felt that they had mastered the concept, and techniques of an experiment before moving on to attempt the Mini-Project.

Planning the first year chemistry course at Glasgow University is very complicated by the heterogeneity of the student. In previous surveys, we identified two main groups among the entrants with significant differences in their level of experience, the Higher Grade (HGRD) and Sixth Year Studies (SYS) students. We did not examine in detail the differences in teaching among the schools from which they came. As previously noted (Chapter 3) the Sixth Year Curriculum in the Scottish secondary school is based on the development of individual projects by the students - producing students who are much more experienced, capable of facing challenges and working on their own which gave them a built in advantage in the fourth stage of the redesigned course.

It was however made clear to the students, at the outset of the practical course, that there was no need to complete all experiments proposed in the manual but they should endeavour to get good results and if necessary repeat experiments until satisfactory results were obtained.

1.5 - ORGANISATION

The 1990 first year practical course, in which we planned to use and survey the full redesigned programme, had 525 enrolled students (Table 6.1) who were allocated to five classes of about 100 students each, who would attend a three hour session each week.

HGRD	SYS	OTHER	TOTAL
276 (52.6)	164 (31.2)	85 (16.2)	525

Table 6.1 - Students enrolled for the first year practical course

Because of the class size we might have expected some trouble with access to the chemicals and equipment which students had to share. Despite previous changes in the preceding course in the way the experiment were allocated, students still encountered problems of this kind in experiments 1 and 2. In experiment 1, "Inorganic Pyrotechnics," students had to share bottles of chemicals, rough balances and fume-cupboards. Even though only 25 student were doing the same experiment at one time the perennial problem of queueing to use the balances had been reported.

Experiment 2, "Chemistry of Halogens," had the similar problem of crowding in the fume cupboards - some reactions had to be done in one of only the three fume cupboards available, making this almost unavoidable.

However in final version of the course we attempt to control the number of students doing experiment 1 keeping the number as low as possible. We also increased the number of bottles of chemicals and rough balances available.

Another recurring student complaint was that they fount it difficult to get help from a demonstrator because the demonstrators were always busy. In the final survey year we increased the number of demonstrators reducing the ratio of demonstrators to students from 1:25 to 1:18 approximately.

We therefore expected that these measures would reduce student complaints about lab organisation and the availability of assistance significantly compared with the last survey.

2 - INSTRUMENTS OF ASSESSMENT

The instruments used in the assessment of the final survey were basically the same ones used in the previous year with minor changes: enabling us to compare the final results with the previous findings.

The changes we introduced were to reduce the number of questions in the questionnaires and reduce the number of questionnaires to be answered by each student - simplifying the procedure and improving our ability to handle the data collected.

2.1 - PRE AND POST QUESTIONNAIRES

From the PRE-Questionnaire we excluded two questions 1 in Part I, "In your previous lab work have you experienced practical work which was done, individually, in small group, or by teacher demonstration" considering the good agreement obtained between the results of two surveys 1988/89 and 1989/90 (Chapter 3 and 5 respectively).

In the Part II, the adjective pair RUSHED / LEISURELY was omitted considering that the course now contained only four experiments instead of six to be done over the six week. This was also omitted from the POST questionnaire. The results from the previous year showed that even the weak students had been able to do at least three experiments in the six weeks of the course. During the first week, in the preliminary talk by staff to students we emphasised that they were not required to do all experiments contained in the lab manual.

A copy of the PRE and POST Questionnaire can be found in Appendix D-3 and D-4 respectively.

2.2 - DIARY

The diary was the instrument which we changed most reducing the number of questions from 15 in the preceding year (1989-90) to 9 in the final year.

The criteria we applied for removing the questions was based upon the previous results relating to the laboratory manual. So, the scales Clarity of Written Instruction; Salience of Stimulus and Amount of Information were variables no longer examined in the survey. It was decided to keep only one item of each scale and omit the others (to give a global indication of students opinion on these points).

Two other scales, on Laboratory Instruction and Familiarity, remained unchanged. The familiarity Scale was considered necessary in order to check the influence of the Prelab Work which had been changed for experiments 1 and 2, while the Laboratory Instructions Scale was intended to check on the effectiveness of the laboratory organisation.

A copy of the Diary is included in Appendix D-5 (page).

2.3 - PRELAB WORK QUESTIONNAIRE

We reformulated some of the questions in the Prelab Work Questionnaire but kept them all in. The question about difficulty was replaced by questions asking the students to state in which experiment or experiments the Prelab Work was found to be difficult and why?. We changed this since the results of previous year showed that mainly the Higher Grade(HGRD) sub-samples of students expressed they had difficulties with some of the Prelab Work, i.e., we sought to pinpoint the sources of these difficulties. Besides two more questions were introduced:

i "In which experiment or experiments was(were) the PRELAB WORK USEFUL? Could you please tell us why you found it (them) useful?"

ii " In which experiment or experiments was(were) the PRELAB WORK DIFFICULT? Could you please tell us why you found it (them) DIFFICULT?"

A copy of the Prelab Work Questionnaire can be found in Appendix D-6 (page)

2.4 - MINI-PROJECT QUESTIONNAIRES

Four questions were removed from Mini-Projects questionnaires relating to enjoyment of doing the experiments. The Mini-Projects questionnaires were hand-out at the same time as the practical problems was allocated to the students, however questionnaire returns were very low (less than 30%).

A copy of the form used for the Mini-Projects can be found in Appendix D-7 (page)

2.5 - STATISTICAL ANALYSIS

Our analysis of the survey instruments was performed following the same procedure adopted in the previous survey (see Chapter 4).

3 - RESULTS OF ASSESSMENT

The following section therefore presents our analysis of the data obtained by the applications of the instruments to the final redesigned version of the six week practical course.

3.1 - RESULTS PRE vs POST QUESTIONNAIRES

The PRE and POST questionnaires were applied on only the Monday session of the course, and were answered by 64 students (12% of the total population). Only students who answered both the PRE and POST Questionnaires were included in the analysis. Table 6.2 shows the number of students in the sub-samples for which the data was analysed.

HGRD	SYS	OTHER	TOTAL
27 (42.2)	25 (39.1)	12 (18.8)	64

Table 6.2 - Students that answered the PRE and POST Questionnaires

The frequencies and percentages of response calculated for each statement are presented in Table 6.3 (A and B).

PRE versus POST QUESTIONNAIRES
SURVEY 1990 - MONDAY

QUEST-1		EASY		NEUTRAL	DIFFICULT		%
		1	2	3	4	5	DIF
HGR	PRE	1 (4)	**15 (54)**	11 (39)	1 (4)	-	53.6
	POST		7 (25)	**17 (61)**	3 (11)	-	14.3
SYS	PRE	1 (4)	7 (28)	**15 (60)**	2 (8)	-	24.0
	POST	1 (4)	**14 (56)**	10 (40)	-	-	53.6
GLB	PRE	3 (5)	25 (39)	**34 (52)**	3 (5)	-	38.5
	POST	3 (5)	26 (40)	**29 (45)**	5 (8)	1 (2)	35.9

QUEST-2		USEFUL			WASTE OF TIME		%
		1	2	3	4	5	DIF
HGR	PRE	3 (11)	**20 (71)**	2 (7)	2 (7)	1 (4)	71.4
	POST	3 (11)	**16 (57)**	4 (14)	3 (11)	1 (4)	53.6
SYS	PRE	3 (11)	**16 (57)**	4 (14)	3 (11)	1 (4)	53.6
	POST	2 (8)	**13 (52)**	9 (36)	1 (4)	-	56.0
GLB	PRE	15 (23)	**38 (59)**	8 (12)	2 (3)	2 (3)	76.6
	POST	8 (12)	**34 (52)**	16 (25)	5 (8)	1 (2)	56.3

QUEST-3		INTERESTING		NEUTRAL	BORING		%
		1	2	3	4	5	DIF
HGR	PRE	4 (14)	**11 (39)**	9 (32)	3 (11)	1 (4)	39.3
	POST	3 (11)	9 (32)	**10 (36)**	4 (14)	1 (4)	25.0
SYS	PRE	3 (12)	**16 (64)**	5 (20)	1 (4)	-	64.3
	POST	2 (8)	9 (36)	**11 (44)**	3 (12)	-	28.6
GLB	PRE	9 (14)	**32 (49)**	16 (25)	5 (8)	2 (3)	53.1
	POST	5 (8)	22 (34)	**25 (39)**	10 (15)	1 (2)	23.4

QUEST-4		UNDERSTANDABLE		NEUTRAL	CONFUSING		%
		1	2	3	4	5	DIF
HGR	PRE	8 (29)	**12 (43)**	6 (21)	2 (7)	-	64.3
	POST	-	**11 (39)**	10 (36)	5 (18)	1 (4)	17.9
SYS	PRE	4 (16)	**12 (48)**	6 (24)	3 (12)	-	52.0
	POST	6 (24)	**10 (40)**	7 (28)	2 (8)	-	56.0
GLB	PRE	14 (22)	**31 (48)**	13 (20)	7 (11)	-	59.4
	POST	8 (12)	**27 (42)**	19 (29)	8 (12)	2 (3)	39.1

QUEST-5		SATISFYING		NEUTRAL	FRUSTRATING		%
		1	2	3	4	5	DIF
HGR	PRE	2 (7)	11 (39)	**12 (43)**	1 (4)	1 (4)	39.3
	POST	1 (4)	8 (29)	**16 (57)**	2 (7)	-	25.0
SYS	PRE	3 (12)	7 (28)	**9 (36)**	5 (20)	1 (4)	12.0
	POST	-	**13 (52)**	9 (36)	3 (12)	-	40.0
GLB	PRE	6 (9)	23 (35)	**24 (37)**	9 (14)	2 (3)	28.1
	POST	2 (3)	26 (40)	**27 (42)**	7 (11)	2 (3)	28.1

Table 6.3 (A) - Frequencies of response of the PRE and POST questionnaires

QUEST-6		ENJOYABLE		NEUTRAL	UNENJOYABLE		%
		1	2	3	4	5	DIF
HGR	PRE	3 (11)	**16 (57)**	6 (21)	2 (7)	1 (4)	53.6
	POST	1 (4)	**14 (50)**	10 (36)	2 (7)	-	28.6
SYS	PRE	6 (24)	**13 (52)**	6 (24)	-	-	76.0
	POST	2 (8)	**10 (40)**	10 (40)	3 (12)	-	36.0
GLB	PRE	13 (20)	**31 (48)**	15 (23)	3 (5)	3 (5)	59.4
	POST	4 (6)	**28 (43)**	25 (39)	7 (11)	-	38.5

QUEST-7		ADEQUATE WRITTEN INSTRUCTION		NEUTRAL	INADEQUATE WRITTEN INSTRUCTION		%
		1	2	3	4	5	DIF
HGR	PRE	9 (32)	**13 (46)**	1 (4)	3 (11)	2 (7)	60.7
	POST	**14 (50)**	10 (36)	0 (0)	2 (7)	1 (4)	75.0
SYS	PRE	4 (16)	**14 (56)**	3 (12)	3 (12)	1 (4)	56.0
	POST	7 (28)	**12 (48)**	6 (24)	-	-	76.0
GLB	PRE	17 (26)	**30 (46)**	7 (11)	7 (11)	4 (6)	56.3
	POST	**28 (43)**	24 (37)	7 (11)	3 (5)	2 (3)	73.4

QUEST-8		LEARNT A LOT		NEUTRAL	LEARN LITTLE		%
		1	2	3	4	5	DIF
HGR	PRE	3 (11)	**13 (46)**	9 (32)	3 (11)	-	46.4
	POST	4 (14)	**14 (50)**	5 (18)	2 (7)	2 (7)	50.0
SYS	PRE	4 (16)	**14 (56)**	5 (20)	2 (8)	-	64.0
	POST	-	**9 (36)**	9 (36)	6 (24)	1 (4)	8.0
GLB	PRE	10 (15)	**30 (46)**	19 (29)	5 (8)	1 (2)	56.3
	POST	7 (11)	**27 (42)**	16 (25)	11 (17)	3 (5)	31.3

QUEST-9		WELL-ORGANISED		NEUTRAL	DISORGANISED		%
		1	2	3	4	5	DIF
HGR	PRE	5 (18)	**9 (32)**	**9 (32)**	4 (14)	1 (4)	32.1
	POST	4 (14)	**10 (36)**	**10 (36)**	2 (7)	1 (4)	39.3
SYS	PRE	3 (12)	**11 (44)**	9 (36)	2 (8)	-	48.0
	POST	3 (12)	6 (24)	**8 (32)**	7 (28)	1 (4)	4.0
GLB	PRE	13 (20)	**22 (34)**	20 (31)	8 (12)	2 (3)	39.1
	POST	12 (19)	17 (26)	**19 (29)**	11 (17)	5 (8)	20.3

Table 6.3 (B) - Frequencies of response of the PRE and POST questionnaires

The Reliability coefficient (Cronbach's alpha values) of the PRE-Questionnaire and its sub scales were calculated and are shown in Table 6.4. Given the relatively small number of items in the scales an alpha reliability in excess of 0.6 was considered acceptable.

The results of our factor analysis (see Table 6.4) showed a relatively good agreement with the original scale design (see Chapter 4) of the previous survey.

SCALE	PRE-QUESTIONNAIRE ITEMS (*)Sig. >1%	FACTOR ANALYSIS F - I	F - II	F - III	h^2	RELIABILITY ITEMS	SCALE
	3.INTERESTING / BORING	.160	**.808**	.052	.682	.73	
ENJOYMENT	5.SATISFYING / FRUSTRATING	.299	**.599**	.272	.523	.72	.70
	6.ENJOYABLE / UNENJOYABLE	.026	**.780**	.194	.647	.74	
IMPORTANCE	2.USEFUL / WASTE OF TIME	**.591**	.439	-.193	.580	.74	.65
	9.LEARNT A LOT / LEARNT LITTLE	**.736**	.256	-.026	.608	.73	
DIFFICULTY	1. EASY / DIFFICULT	-.200	.109	**.818**	.681	.76	.60
	4.UNDERSTANDABLE/CONFUSING	.231	.249	**.721**	.636	.73	
ORGANI-	7.ADEQUATE/INADEQUATE WRITTEN INSTRUCTION	**.732**	-.156	.386*	.709	.75	.48
SATION	9.WELL-/DISORGANISED	**.690**	.151	.160	.525	.73	
	% VARIANCE	35.2	13.6	13.4	62.1		
	Alpha value(9 ITEMS)						.76

Table 6.4 - Factor Analysis and Reliability coefficient of the PRE- Questionnaires items

3.1.1 - OPEN QUESTION OF PRE QUESTIONNAIRE

Our analysis of the responses of the PRE-Questionnaire's open question is summarised in Table 6.5. The students expectation from the laboratory course this year seemed to be very similar to those of last year students' expectation. The only difference appeared in item 7, which was significantly rated. Clearly they expected to learn how to obtain data and conclusion from the experiments.

WHAT WOULD YOU LIKE TO LEARN FROM THIS LABORATORY COURSE? ANSWERS:	N = 64
To learn or improve lab techniques	**34 (56%)**
To solve chemical problems	4 (6%)
To learn and understand chemistry	7 (12%)
To learn how to relate theory and practical	**11 (18%)**
To gain confidence	**11 (18%)**
Practical application of chemistry	6 (10%)
How to obtain data and conclusions from experiment	**11 (18%)**

Table 6.5 - Answers to the Open Question of PRE-Questionnaire

This expectations may represent a point in favour of the Mini-Projects which gives then the opportunity to plan, develop the experiments, and draw their own conclusion.

3.1.2 - ATTITUDE CHANGE (Cross-tabulation of PRE vs POST)

Using the raw frequencies of responses for each statement a Cross-tabulation of PRE and POST-Questionnaires' results was done (summarised in Table 6.6). The McNemar Chi-Square test was applied to estimate the level of significance of the differences between Positive and Negative changes in attitude, the results being displayed in column headed McNemar Chi-Square (χ^2). The column headed HGRD vs SYS displays the results of normal Chi-Square which we calculated using the frequencies of response in the three categories.

QUEST	DEG.	POSITIVE CHANGE	NO CHANGE	NEGATIVE CHANGE	% DIFF	McNemar Chi-Sq.	HGRD vs SYS
	HGRD	3 (11)	11 (41)	13 (48)	-37.0	>5%	
1	SYS	11 (44)	11 (44)	3 (12)	32.0	>5%	>1%
	GLBL	18 (28)	27 (42)	19 (30)	-1.6		
	HGRD	6 (22)	12 (44)	9 (33)	-11.1		
2	SYS	4 (16)	8 (32)	13 (52)	-36.0	>5%	
	GLBL	15 (23)	23 (36)	26 (41)	-17.2		
	HGRD	7 (26)	11 (41)	9 (33)	-7.4		
3	SYS	3 (12)	11 (44)	11 (44)	-32.0	>5%	
	GLBL	12 (19)	26 (41)	26 (41)	-21.9	>5%	
	HGRD	5 (19)	6 (22)	16 (59)	-40.7	>5%	
4	SYS	8 (32)	10 (40)	7 (28)	4.0		>10%
	GLBL	16 (25)	22 (34)	26 (41)	-15.6		
	HGRD	6 (22)	10 (37)	10 (37)	-14.8		
5	SYS	9 (36)	11 (44)	5 (20)	16.0		
	GLBL	19 (30)	25 (39)	19 (30)	0.0		
	HGRD	8 (30)	8 (30)	11 (41)	-11.1		
6	SYS	1 (4)	12 (48)	12 (48)	-44.0	>1%	
	GLBL	13 (20)	24 (38)	27 (42)	-21.9	>5%	
	HGRD	12 (44)	9 (33)	6 (22)	22.2		
7	SYS	10 (40)	12 (48)	3 (12)	28.0		>5%
	GLBL	29 (45)	24 (38)	11 (17)	28.1	>1%	
	HGRD	10 (37)	10 (37)	7 (26)	11.1		
8	SYS	4 (16)	5 (20)	16 (64)	-32.0	>1%	
	GLBL	18 (28)	20 (31)	26 (41)	-12.5		
	HGRD	9 (33)	11 (41)	7 (26)	7.4		
9	SYS	6 (24)	7 (28)	12 (48)	-24.0		
	GLBL	18 (28)	22 (34)	24 (38)	-10.7		

Table 6.6 - Cross-tabulation of PRE versus POST QUESTIONNAIRES items

The Table 6.7 below summarises our comparison of the PRE and POST Questionnaires which we performed in two independent ways.

	PRE AND POST QUESTIONNAIRES RESULTS - 1990						
	McNEMAR CHI-SQUARE POSITIVE vs NEGATIVE			HGRD vs	NORMAL CHI-SQUARE PRE vs POST		
ITEM	HGRD	SYS	GLOBAL	SYS	HGRD	SYS	GLOBAL
1	>5%	>5% +		>1% SYS	>5% PRE	>10%POST	
2		>5%					
3		>5%	>5%			>5% PRE	>5% PRE
4	>5%	+		>10%SYS	>5% PRE		
5		+				>10%POST	
6		>1%	>5%				
7	+	>5% +	>1% +	>5% SYS			
8	+	>5%				>5% PRE	
9	+						

Table 6.7 - Comparison between PRE and POST questionnaires McNEMAR and NORMAL Chi-Square.

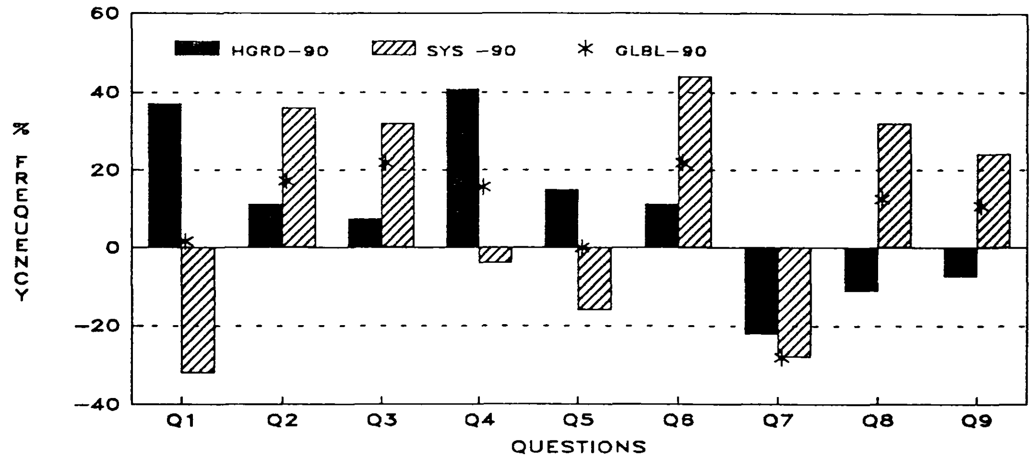


FIG. 6.2 ATTITUDE CHANGE
HGRD VS SYS

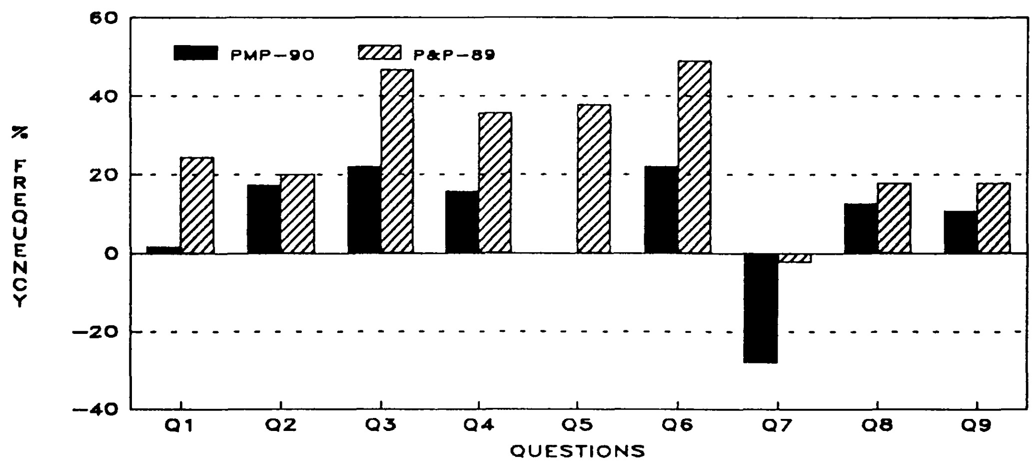


FIG. 6.3 — ATTITUDE CHANGE
P&P-89 vs PMP-90 — GLBL

Firstly, the level of significance shown in the column headed PRE vs POST was derived from the original response frequencies, (Table 6.3) for the five categories to which we then applied normal Chi-Square to obtain an estimate of whether the differences were significant or not.

Secondly, from our cross-tabulation of the PRE and POST questionnaires frequencies of response (Table 6.6) McNEMAR Chi-Square were calculated from the POSITIVE and NEGATIVE attitude changes ignoring the NO CHANGE category.

Finally, the HGRD vs SYS column presents the levels of significance of the differences between these two sub-samples which we calculated using normal Chi-Square and using the crossed frequencies from the PRE and POST Questionnaires (Table 6.6).

We further compared the SYS and HGRD sub-samples (see Figure 6.2). Despite the innovations introduced in the final course, SYS students still considered it as WASTE OF TIME, UNENJOYABLE, BORING, and complained that they had LEARNT LITTLE in the course.

Figure 6.3 presents a comparison of the PMP (1990's survey) and P&P (1989's survey). In general students were more positive about the PMP than the P&P course. Most of the differences found were at >5% level of significance with only two items presenting >1% level. These results when compared with the previous year (Table 5.15), reveal a positive result in favour of the final course design (PMP).

However the level of significance of the differences is weak (>5%) (though considered acceptable in most Social Science research). The number of statements which gave statistically significant differences was also comparable to the PLW course, and the number of items where we found positive changes in students' opinion of the final course design were higher than last year.

It is not our intention to claim that these results are an absolute proof that our final course design performed better than any other previous design, but there is evidence that suggests that some improvement in performance did occurred.

3.1.3 - POST QUESTIONNAIRE OPEN QUESTION

To facilitate a comparative analysis of students' responses to the POST questionnaire open questions, we grouped the results in a way similar to the preceding survey. Tables 6.8 to 6.14 contain summaries of the responses for questions 1 to 7. The percentage of response was calculated from the number of student who answered both PRE and POST questionnaires (N=64) which further facilitated our comparisons of the questions between samples and sub samples. In all case in which a different base was used the number "N" is indicated in the table, column or cell.

1.WHICH EXPERIMENT OR EXPERIMENTS DID YOU ENJOY MOST OF ALL?

N=64	EXP-1	EXP-2	EXP-3	EXP-4	MP	TOT
HGRD	**22 (34)**	1 (2)	3 (5)	4 (6)	1 (2)	31 (48)
SYS	**21 (33)**	3 (5)	3 (5)	2 (3)		29 (45)
OTHER	**5 (8)**	2 (3)	1 (2)	2 (3)	1 (2)	11 (17)
GLOBAL	**48 (75)**	6 (9)	7 (11)	8 (13)	2 (3)	N=64

COULD YOU PLEASE TELL US WHY YOU FOUND IT(THEM) THE MOST ENJOYABLE?				
ANSWERS: (%)	EXP-1 N=48	EXP-2 N=6	EXP-3 N=7	EXP-4 N=8
I understood what I was doing / I learnt a lot		**2 (33)**	1	
I learnt lab techniques	1		1	1
It was a Fun reaction / I could see end-product	**25 (52)**			
Interesting / Satisfying / enjoyable	**16(33)**			1
It was easy / straightforward	9 (19)			1
I like to do titrations			**4 (57)**	**3 (38)**

Table 6.8 - OPEN QUESTION - 1 - POST QUESTIONNAIRE

2.WHICH EXPERIMENT OR EXPERIMENTS DID YOU FIND THE MOST DIFFICULT?

N=64	EXP-1	EXP-2	EXP-3	EXP-4	MP	TOT
HGRD	-	**15 (23)**	9 (14)	5 (8)	-	29 (45)
SYS	-	**17 (27)**	1 (2)	2 (3)	4 (6)	24 (38)
OTHER	-	**5 (8)**	1 (2)	1 (2)	-	7 (11)
GLOBAL	-	**37 (58)**	11 (17)	8 (13)	4 (6)	64

COULD YOU PLEASE TELL US WHY YOU FOUND IT(THEM) THE MOST DIFFICULT?				
ANSWERS: (%)	EXP-1 N=0	EXP-2 N=37	EXP-3 N=11	EXP-4 N=8
It was a long experiment / A lot to do		**16(43)**		
Fume cupboard was always crowded /queues		1		
IT WAS HARD TO PREDICT END PRODUCTS		**1**		
Written instruction was not clear		3 (8)		2
It was difficult to judge results		3 (8)		
It was disorganised		1		
It was confusing		4 (11)	1	
Prelab Work was hard		2		
It was difficult to get accurate results			2	3 (38)
It was hard to titrate / end point			4 (36)	5 (63)

Table 6.9 - OPEN QUESTION - 2 - POST QUESTIONNAIRES

3.WHICH EXPERIMENT OR EXPERIMENTS DID YOU FIND THE MOST USEFUL?

N = 64	EXP-1	EXP-2	EXP-3	EXP-4	M P	TOT
HGRD	1 (2)	**9 (14)**	**10 (16)**	7 (11)	-	27 (42)
SYS	2 (3)	**9 (14)**	**8 (13)**	7 (11)	-	26 (41)
OTHER	2 (3)	2 (3)	5 (8)	4 (6)	-	13 (20)
GLOBAL	5 (8)	**20 (31)**	**23 (36)**	18 (28)	-	64

COULD YOU PLEASE TELL US WHY YOU FOUND IT(THEM) THE MOST USEFUL?				
ANSWERS:	EXP-1 N=5	EXP-2 N=20	EXP-3 N=23	EXP-4 N=18
I learnt about halogens		16(80)		
I learnt calculations			9 (39)	7 (39)
I learnt titrations			**18(78)**	**13(72)**
I understood the experiments	1			

Table 6.10 - OPEN QUESTION - 3 - POST QUESTIONNAIRE

4.WHAT DO YOU THINK WERE THE GOOD POINTS ABOUT THE LAB COURSE?	
ANSWER: (%)	N = 64
To work at your own pace / alone	**34 (57)**
Demonstrators were helpful	**10 (17)**
It gave me practical experience / Lab techniques	**8 (13)**
Written Instructions	5 (8)
Varied experiments	1
Practical work linked with lectures	3 (5)
Pre-Lab Work	5 (8)
It was Interesting / enjoyable	5 (8)
Mini-Projects	1

Table 6.11 - OPEN QUESTION - 5 - POST QUESTIONNAIRE

5.WHAT DO YOU THINK WERE THE WORST FEATURES ABOUT THE LAB-COURSE?	
ANSWER: (%)	N = 64
Long queues in the fume cupboard / to get chemicals	**21 (35)**
Large class size	3 (5)
Disorganised	**6 (10)**
Demonstrators / Staff hard to get help	**8 (13)**
It was not related to the Theoretical course	1
Prelab Work	1
Mini-Projects	1
To have to work alone	2 (3)

Table 6.12 - OPEN QUESTION 6 - POST QUESTIONNAIRE

6.WHAT CHANGES DO YOU THINK SHOULD BE MADE TO IMPROVE THE LAB COURSE?	
ANSWER: (%)	N = 64
To train and prepare better the demonstrator / More demonstrators Helpful demonstrators	**20 (33)**
To be able to work in pairs	**6 (10)**
To discuss the theory behind the experiment before doing it More theory about the experiment	4 (7)
More staff member / Staff member more approachable	4 (7)
More chemical and apparatus available	**6 (10)**
Better organised	5 (8)
Experiments related to the lectures	5 (8)
Smaller class	**6 (10)**

Table 6.13 - OPEN QUESTION 7 - POST QUESTIONNAIRE

7.WHAT WOULD YOU LIKE TO LEARN NEXT TIME YOU DO A LAB COURSE?	
ANSWERS: (%)	N = 64
Analytical Work	2
Something relevant to the course	2
More about what is happening in lectures/experiments related to lectures	**6 (10)**
Something not taught at the secondary school	3 (5)
Organic Chemistry / Industrial chemistry	4 (7)
Something new	3 (5)
More lab techniques	2

Table 6.14 - OPEN QUESTION -8 - POST QUESTIONNAIRE

In the summary of responses for question 1, students found the experiment "Inorganic Pyrotechnics" the most enjoyable because they thought it was "FUNNY", were able to see a spectacular reaction taking place, and found it was easy and straightforward. This responses was not significantly different from those given in the preceding survey.

The "Chemistry of Halogens", experiment 2, was considered the most difficult, however, the reasons they gave differed significantly from the previous survey. Difficulties were no longer justified by complaints that it was difficult to predict the end products and write the chemical equations. This may evidence our suggestion that the Prelab Work in the final course improved the students' familiarity with the background theory of the experiment - as noted above (section 1.2) the Prelab Work for experiment 2 entailed writing and balancing all the equations for all reactions involved in it and attempting to explain them.

Experiment 2 - "Chemistry of Halogens" and experiment 3 - "Acid-Base Titration" were those considered the most useful. The students prompted their response by claiming that experiment 2 had taught them something about halogens, their properties and chemical equations, while experiment 3 had improved their understanding of how to do titrations. thus despite identifying experiment 2 as the most difficult, students also said it was a useful experiment. The results also evidence that students were conscientious about answering the questionnaires.

The problem of queues at the fume cupboards and at the lab benches to get chemicals for experiments 1 and 2 was one major problem in lab organisation which remained unresolved from the previous year despite the our changes in the way experiments were allocated to students and increased numbers of bottles and rough balances. (see Table 6.12)

From direct observation the persistence of this problem was due in part to the students' preference for using the rough balance with a digital scale, instead of the other non-digital, ones since they found these more difficult to use. The fume cupboard problem is more difficult to solve because of the limited physical space in the laboratory. It would be necessary to make available at least two more fume cupboards to ease crowding, given the toxicity of the chemicals used in experiment 2.

Another feature of the course criticised by the students was their concern about the quality of the assistance provided by the staff, demonstrators and technicians. They suggested that the demonstrators and technicians ought to have more training to be better prepared for the lab. Surprisingly complaints about the demonstrators and technicians increased significantly compared to the two previous surveys.

The students however appreciated the opportunities that lab gave them to work independently and the improve their lab techniques (see Table 6.11).

3.2 - DIARY RESULTS

The response frequencies from the Diaries were counted and percentages calculated for each statement. The sample and sub-sample numbers of students who answered the Diary's questions is given in Table 6.15.

HGRD	SYS	OTHER	GLOBAL
75 (45.5)	61 (37.0)	29 (17.6)	165

Table 6.15 - Total numbers of Diaries collected in each sample and sub-sample

The diaries were analysed by the sub-samples Experiment 1, 2, 3, and 4. The frequencies of responses for each category statements is shown in Table 6.16 (A; B; and C).

Q1- I had enough time in the laboratory to think about the chemistry involved in the experiment.

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	5 (29)	**12 (71)**	-	-	-	100.0
	SYS	2 (13)	**10 (67)**	2 (13)	-	-	80.0
	GLB	8 (19)	**26 (62)**	5 (12)	2 (5)	-	76.2
2	HGR	-	5 (36)	**6 (43)**	2 (14)	1 (7)	14.3
	SYS	1 (13)	3 (38)	**3 (38)**	1 (13)	-	37.5
	GLB	1 (4)	8 (35)	**9 (39)**	4 (17)	1 (4)	17.4
3	HGR	2 (11)	**10 (56)**	4 (22)	2 (11)	-	55.6
	SYS	2 (11)	**9 (47)**	5 (26)	3 (16)	-	42.1
	GLB	4 (9)	**20 (47)**	13 (30)	5 (12)	1 (2)	41.9
4	HGR	1 (6)	**7 (44)**	5 (31)	2 (13)	-	37.5
	SYS	1 (7)	**11 (73)**	3 (20)	-	-	80.0
	GLB	5 (12)	**20 (47)**	13 (30)	3 (7)	1 (2)	48.8
	HGR	11 (15)	**40 (53)**	17 (22)	6 (8)	1 (1)	59.2
	SYS	6 (10)	**36 (58)**	15 (24)	4 (7)	-	61.3
	GLB	21 (13)	**83 (50)**	44 (26)	14 (8)	3 (2)	52.1

Q2- It was clear to me what was expected in writing up my lab report.

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	3 (18)	3 (18)	**7 (41)**	3 (18)	1 (6)	11.8
	SYS	3 (20)	**7 (47)**	2 (13)	3 (20)	-	46.7
	GLB	8 (19)	**14 (33)**	12 (29)	7 (17)	1 (2)	33.3
2	HGR	1 (7)	4 (29)	**6 (46)**	2 (14)	1 (7)	14.3
	SYS	1 (13)	**5 (63)**	1 (13)	1 (13)	-	62.5
	GLB	2 (9)	**10 (44)**	7 (30)	3 (13)	1 (4)	34.8
3	HGR	-	**13 (72)**	3 (17)	2 (11)	-	61.1
	SYS	3 (16)	**9 (47)**	4 (21)	3 (16)	-	47.4
	GLB	3 (7)	**27 (68)**	7 (16)	5 (12)	1 (2)	55.8
4	HGR	-	**10 (63)**	1 (6)	4 (25)	1 (6)	31.3
	SYS	2 (13)	**8 (53)**	3 (20)	2 (13)	-	53.3
	GLB	3 (7)	**21 (49)**	7 (16)	9 (21)	3 (7)	27.9
	HGR	5 (7)	**35 (46)**	20 (26)	13 (17)	3 (4)	31.6
	SYS	9 (15)	**32 (52)**	12 (19)	9 (15)	-	51.6
	GLB	17 (10)	**80 (48)**	38 (23)	26 (16)	6 (4)	38.9

Table 6.16(A)-DIARIES RESULTS(QUEST. 1,2,3,4)

Q3 - I would have liked more help with the calculations in this experiment.

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	1 (6)	-	**8 (47)**	6 (35)	2 (12)	-41.2
	SYS	-	-	5 (33)	**6 (40)**	4 (27)	-66.7
	GLB	2 (5)	-	16 (38)	**18 (43)**	6 (14)	-52.4
2	HGR	-	3 (21)	4 (29)	**7 (50)**	-	-28.6
	SYS	-	2 (25)	**4 (50)**	2 (25)	-	0.0
	GLB	-	5 (22)	**9 (39)**	9 (39)	-	-17.4
3	HGR	1 (6)	1 (6)	**12 (67)**	4 (22)	-	-11.1
	SYS	-	3 (16)	6 (32)	**9 (47)**	1 (5)	-36.8
	GLB	1 (2)	6 (14)	**20 (47)**	15 (35)	1 (2)	-20.9
4	HGR	-	3 (19)	6 (38)	**6 (38)**	1 (6)	-25.0
	SYS	-	3 (20)	5 (33)	**6 (40)**	1 (7)	-26.7
	GLB	1 (2)	10 (23)	**14 (33)**	13 (20)	4 (9)	-14.0
	HGR	2 (3)	10 (13)	**36 (47)**	25 (33)	3 (4)	-21.1
	SYS	-	8 (13)	20 (32)	**28 (45)**	6 (10)	-41.9
	GLB	4 (2)	24 (14)	**65 (39)**	62 (37)	11 (7)	-26.9

Q4- The prelab introduction to the balances and volumetric techniques helped me when I came to use those techniques in this experiment.

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	2 (12)	**7 (41)**	7 (41)	1 (6)	-	47.1
	SYS	3 (20)	**6 (40)**	5 (23)	1 (7)	-	53.3
	GLB	7 (17)	**21 (50)**	12 (29)	2 (5)	-	61.9
2	HGR	1 (7)	5 (36)	**7 (50)**	1 (7)	-	35.7
	SYS	1 (13)	**4 (50)**	-	1 (13)	-	50.0
	GLB	2 (9)	**10 (44)**	7 (30)	2 (9)	-	43.5
3	HGR	5 (28)	**11 (61)**	1 (6)	1 (6)	-	83.3
	SYS	7 (37)	**11 (58)**	1 (5)	-	-	94.7
	GLB	12 (28)	**27 (63)**	3 (7)	1 (2)	-	88.4
4	HGR	4 (25)	**10 (63)**	1 (6)	-	-	87.5
	SYS	1 (7)	**7 (47)**	5 (33)	2 (13)	-	40.0
	GLB	5 (12)	**24 (56)**	10 (23)	2 (5)	1 (2)	60.5
	HGR	14 (18)	**39 (51)**	19 (25)	3 (4)	-	65.8
	SYS	13 (21)	**31 (50)**	12 (19)	4 (7)	-	64.5
	GLB	29 (17)	**91 (55)**	36 (22)	7 (4)	1 (1)	55.1

Q5-I had enough help in writing the chemical equations in this experiment.

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	2 (12)	**8 (47)**	5 (29)	2 (12)	-	47.1
	SYS	-	**10 (67)**	4 (27)	-	-	66.7
	GLB	2 (5)	**23 (55)**	13 (31)	3 (7)	-	52.4
2	HGR	-	**8 (57)**	4 (29)	2 (14)	-	42.9
	SYS	-	**4 (50)**	2 (25)	2 (25)	-	25.0
	GLB	-	**12 (52)**	7 (30)	4 (17)	-	34.8
3	HGR	-	**9 (50)**	8 (44)	1 (6)	-	44.4
	SYS	3 (16)	7 (37)	**8 (42)**	1 (5)	-	47.4
	GLB	4 (9)	**19 (44)**	16 (37)	4 (9)	-	44.2
4	HGR	5 (31)	5 (31)	**6 (38)**	-	-	62.5
	SYS	2 (13)	**9 (60)**	3 (20)	1 (7)	-	66.7
	GLB	7 (16)	**18 (42)**	15 (35)	2 (5)	1 (2)	51.2
	HGR	8 (11)	**37 (49)**	26 (34)	5 (7)	-	52.6
	SYS	7 (11)	**31 (50)**	18 (29)	5 (8)	-	53.2
	GLB	16 (10)	**80 (48)**	55 (33)	14 (8)	1 (1)	48.5

Q6- I was so confused in the laboratory that I ended up follwoing the manual without really understanding what I was doing.

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	-	1 (6)	-	**8 (47)**	8 (47)	-88.2
	SYS	-	-	-	**11 (73)**	4 (27)	-100.
	GLB	-	2 (5)	2 (5)	**25 (60)**	13 (31)	-85.7
2	HGR	-	2 (14)	3 (21)	**9 (64)**	-	-50.0
	SYS	1 (13)	-	1 (13)	**4 (63)**	1 (13)	-62.5
	GLB	1 (4)	2 (9)	5 (22)	**14 (61)**	1 (4)	-52.2
3	HGR	-	-	5 (28)	**11 (61)**	2 (11)	-72.2
	SYS	-	-	3 (16)	**11 (58)**	5 (26)	-84.2
	GLB	-	-	9 (21)	**27 (63)**	7 (16)	-79.1
4	HGR	-	-	4 (25)	**8 (50)**	4 (25)	-75.0
	SYS	-	-	-	**12 (80)**	3 (20)	-100.
	GLB	1 (2)	1 (2)	4 (9)	**26 (61)**	11 (26)	-81.4
	HGR	-	3 (4)	15 (20)	**43 (57)**	15 (20)	72.4
	SYS	1 (2)	-	5 (8)	**42 (68)**	14 (23)	88.7
	GLB	2 (1)	5 (3)	24 (14)	**102(61)**	34 (20)	77.2

Table 6.16(B) - DIARIES RESULTS (QUEST.5,6,7,8)

Q7 - I only understood what I had been doing in this experiment when I tried to write the lab report.

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	-	1 (6)	1 (6)	**11 (65)**	4 (24)	-82.4
	SYS	-	-	4 (27)	**10 (67)**	1 (7)	-73.3
	GLB	-	1 (2)	10 (24)	**25 (60)**	6 (14)	-71.4
2	HGR	-	1 (7)	4 (29)	**9 (64)**	-	-57.1
	SYS	-	3 (38)	1 (13)	**3 (38)**	1 (13)	-12.5
	GLB	-	5 (22)	5 (22)	**12 (52)**	1 (4)	-34.8
3	HGR	-	3 (17)	3 (17)	**11 (61)**	1 (6)	-50.0
	SYS	-	1 (5)	3 (16)	**13 (68)**	2 (11)	-73.7
	GLB	-	4 (9)	6 (14)	**29 (67)**	4 (9)	-67.4
4	HGR	-	3 (19)	**8 (50)**	4 (25)	1 (6)	-12.5
	SYS	-	2 (13)	2 (13)	**9 (60)**	2 (13)	-60.0
	GLB	-	6 (14)	15 (35)	**17 (40)**	5 (12)	-37.2
	HGR	-	10 (13)	18 (24)	**42 (55)**	6 (8)	-50.0
	SYS	-	6 (10)	13 (21)	**36 (58)**	7 (11)	-59.7
	GLB	-	18 (11)	41 (25)	**91 (55)**	17 (10)	-53.9

Q8 - I was confident enough with the lab techniquesto be able to concentrate on the chemistry involvedin the experiment.

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	-	4 (24)	**11 (65)**	1 (6)	1 (6)	11.8
	SYS	3 (20)	4 (27)	**7 (47)**	1 (7)	-	40.0
	GLB	4 (10)	15 (36)	**18 (43)**	4 (10)	1 (2)	33.3
2	HGR	-	**7 (50)**	5 (36)	2 (14)	-	35.7
	SYS	1 (13)	**5 (63)**	2 (25)	-	-	75.0
	GLB	1 (4)	**12 (52)**	8 (35)	2 (9)	-	47.8
3	HGR	-	**7 (39)**	5 (28)	6 (33)	-	5.6
	SYS	1 (5)	**11 (58)**	5 (26)	2 (11)	-	52.6
	GLB	1 (2)	**22 (51)**	12 (28)	8 (19)	-	34.9
4	HGR	-	5 (31)	**8 (50)**	3 (19)	-	12.5
	SYS	2 (13)	**8 (53)**	5 (33)	-	-	66.7
	GLB	2 (5)	**19 (44)**	17 (40)	3 (7)	1 (2)	39.5
	HGR	1 (1)	28 (37)	**34 (45)**	12 (16)	1 (1)	21.1
	SYS	9 (15)	**28 (45)**	21 (34)	4 (7)	-	53.2
	GLB	11 (7)	**73 (44)**	62 (37)	18 (11)	2 (1)	38.3

Q9-The objective of this experiment was clear to me

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	3 (18)	**7 (41)**	6 (35)	1 (6)	-	52.9
	SYS	2 (13)	**9 (60)**	4 (26)	-	-	73.3
	GLB	6 (14)	**22 (52)**	11 (26)	3 (7)	-	59.5
2	HGR	-	**9 (64)**	3 (21)	2 (14)	-	50.0
	SYS	-	**5 (63)**	2 (25)	1 (13)	-	50.0
	GLB	-	**14 (61)**	5 (22)	4 (17)	-	43.5
3	HGR	1 (6)	**13 (72)**	2 (11)	2 (11)	-	66.7
	SYS	5 (26)	**13 (68)**	1 (5)	-	-	94.7
	GLB	6 (14)	**31 (72)**	4 (9)	2(5)	-	81.4
4	HGR	2 (13)	**9 (56)**	4 (25)	1 (6)	-	62.5
	SYS	-	**15(100)**	-	-	-	100.0
	GLB	4 (9)	**31 (72)**	6 (14)	1 (2)	1 (2)	76.7
	HGR	6 (8)	**46 (61)**	16 (21)	7 (9)	1 (1)	57.9
	SYS	8 (13)	**45 (73)**	7 (11)	2 (3)	-	82.3
	GLB	17 (10)	**109(65)**	27 (16)	12 (7)	2 (1)	67.1

SA = Strongly Agree A = Agree N=Neutral
SD = Strongly Disagree D = Disagree

EXP.	HGRD	S Y S	GLOBAL
1	17 (10.4)	15 (9.1)	42 (25.6)
2	14 (8.5)	8 (4.9)	23 (14.0)
3	18 (11.0)	19 (11.6)	43 (26.2)
4	16 (9.8)	15 (9.1)	43 (26.2)
TOT	75 (45.7)	60 (36.6)	164

Number of students per sample and sub-sample

Table 6.16 (C) - DIARIES' RESULTS (QUESTION 9)

Our Factor Analysis and the reliability coefficients estimated for the diary responses are displayed IN TABLE 6.17. Factor analysis showed an acceptable level of interaction among the items of each scale with high loading for at least two items of these, and the third one with loading significant at 1% level.

Overall the reliability coefficients for these instruments, however, were very low. When we grouped the items in scales, only the familiarity scale had a significant improvement (0.61) which we considered acceptable given the low number of items in the scale.

FACTOR ANALYSIS		(*) Sig. >1%				RELIABILITY	
SCALE	ITEM	F - I	F - II	F - III	h^2	ITEM	SCALE
1 . LABORATORY INSTRUCTION	2	-.003	**.664**	-.085	.448	.23	
	5	-.148	**.626**	-.070	.418	.22	.37
	8	-.049	.373*	**-.680**	.604	.38	
2 . FAMILIARITY	3	.378*	-.012	**.661**	.580	.65	
	6	**.788**	-.331*	-.041	.732	.42	.61
	7	**.828**	.119	.051	.703	.45	
3.CLARITY OF WRITTEN INSTRUCTIONS	9	-.409*	**.492**	-.205	.452	.09	
4.SALIENCE OF STIMULUS	4	-.090	**.579**	.557*	.653	.41	.32
5.AMOUNT OF INFORMATION	1	**-.633**	.188	-.203	.478	.18	
% variance		30.7	14.8	10.9	56.4		
alpha value						9 item	0.09

Table 6.17 - The original Scale FACTOR ANALYSIS and RELIABILITY COEFFICIENT

To determine if the changes made to the final course design (PMP) had actually improved its performance as a teaching vehicle we decided to compare the results with those obtained in the previous survey. We therefore matched the results of the 1990 (PMP) survey with those from four course designs of 1989, namely, CONTROL (CTRL); PRELAB WORK (PLW); MINI-PROJECTS (MP); and PLW with MP (P&P).

We first estimated the level of significance of the differences found by comparing the global results using the normal Chi-Square test; the results are presented in Table 6.18.

The levels of agreement for the 1990's survey(PMP) were higher than those for the 1989's survey in all cases (CTRL, PLW, MP, and P&P) differences were significant at the 5%, 2%, and 1% level (see Table 6.18), i.e., most of the items were rated significantly higher in the 1990's survey (PMP), which may be explained by our design changes.

	CTRL vs PMP			MP vs PMP			PLW vs PMP			P&P vs PMP		
Q	HGRD	SYS	GLBL	HGRD	SYS	GLBL	HGRD	SYS	GLBL	HGRD	SYS	GLBL
1	>1%	>1%	>0.1%	>0.1%	>1%	>0.1%	>0.1%	>1%	>0.1%	>0.1%		>0.1%
2												
3	>1%	>2%	>1%	>1%		>0.1%	>1%		>2%	>5%		
4			>5%		>1%	>1%			>5%			
5		>5%		>1%		>1%	>1%		>2%	>2%		>1%
6		>1%	>0.1%	>5%		>5%			>5%	>1%		>0.1%
7	0.1%	>1%	>0.1%	>0.1%		>0.1%	>0.1%	>5%	>0.1%	>1%		>0.1%
8			>2%			>5%	>1%		>1%			
9		>1%	>1%				>1%	>5%	>1%	>1%	>5%	>0.1%

Table 6.18 - Comparison of the results -
CTRL/PLW/MP/P&P(1989) versus PMP (1990)

Since students did not have to do the practical problem if they do not want to or they do not feel confident enough to in the final survey, while in courses MP and P&P of the previous survey, every students had to do these applied at the end of each experiment, it may be the case that this boasted the positive response to the final course design, i.e., students who may have reported difficulties in doing the Mini-Projects where not included as respondents in certain important survey items.

Nonetheless the problem-solving at the end of the course enabled students to progress gradually at their own pace and minimised the negative feeling they expressed when they had been forced to perform tasks which they did not feel confident to undertake.

On the other hand, some students were not effectively challenged and probably never ca be in a course designed to make problem-solving optional.

3.3 - PRELAB WORK RESULTS

We applied Prelab Work questionnaire, answered by a total of 201 students, on Monday, Wednesday and Friday sessions. The results were divided into the HGRD and SYS sub-samples and the response frequencies and percentages were calculated (see Table 6.19).

We also estimated the reliability coefficients and tested the validity of each item (see results in Table 6.20). A good agreement was obtained from the factor analysis also applied in the previous survey. The reliability coefficient was considered acceptable, given the small number of items in the instrument.

PRELAB QUESTIONNAIRES RESULTS

1.THINK THAT DOING THE PRELAB WORK

a. helped me to understand the experiments before I attempted them in the laboratory						
QUEST	AGREE		NEUTRAL	DISAGREE		%
1a	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	DIFF
HGRD	14 (14)	**75 (74)**	11 (11)	2 (2)	-	85.3
SYS	13 (19)	**47 (69)**	7 (10)	2 (3)	-	84.1
GLBL	33 (16)	**143 (71)**	20 (10)	4 (2)	-	85.6

b. gave me more confidence when I came to do the experiments in the laboratory.						
QUEST	AGREE		NEUTRAL	DISAGREE		%
1b	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	DIFF
HGRD	6 (6)	42 (41)	**47 (46)**	7 (7)	-	40.2
SYS	4 (6)	27 (39)	**33 (48)**	4 (6)	1 (1)	37.7
GLBL	15 (8)	79 (39)	**93 (46)**	13 (7)	1 (.5)	39.8

c. forced me to think about the experiments before I attempted them in the laboratory						
QUEST	AGREE		NEUTRAL	DISAGREE		%
1c	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	DIFF
HGRD	19 (19)	**57 (56)**	20 (20)	6 (6)	-	68.6
SYS	10 (15)	**47 (68)**	10 (15)	2 (3)	-	79.7
GLBL	36 (18)	**122 (61)**	34 (17)	9 (5)	-	74.1

d.meant that I was able to follow the manual in the laboratory with a greater understanding of what I was doing.						
QUEST	AGREE		NEUTRAL	DISAGREE		%
1d	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	DIFF
HGRD	17 (17)	**66 (65)**	17 (17)	2 (2)	-	79.4
SYS	2 (3)	**47 (68)**	18 (26)	2 (3)	-	68.1
GLBL	22 (11)	**130 (65)**	44 (22)	5 (3)	-	73.1

2.I THINK THAT PRELAB WORK SHOULD ALWAYS BE INCLUDED BEFORE DOING AN EXPERIMENT						
QUEST	AGREE		NEUTRAL	DISAGREE		%
3	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	DIFF
HGRD	22 (22)	**57 (56)**	19 (19)	2 (2)	1 (1)	74.5
SYS	8 (12)	**41 (54)**	19 (28)	1 (1)	-	69.6
GLBL	36 (18)	**117 (58)**	41 (20)	4 (2)	1 (.5)	73.6

Table 6.19 - Frequency of response - PRELAB QUESTIONNAIRES

item	Factor 1	factor 2	h^2	RELIABILITY COEFFICIENT ITEM
	FACTOR ANALYSIS (*) = Sig. >1%			
1a	**.764**	.144	.604	.56
1b	**.578**	.465*	.551	.52
1c	**.744**	-0.075	.559	.61
1d	**.388**	.360*	.280	.60
2	.133	**.687**	.490	.59
3	-0.013	**.805**	.648	.60
%V	35.3	17.0	52.2	
alpha				.63

Table 6.20 - FACTOR ANALYSIS and RELIABILITY COEFFICIENT of Prelab Work questionnaire

3.IN WHICH EXPERIMENT or EXPERIMENTS WAS (WERE) THE PRELAB WORK DIFFICULT?

	HGRD	SYS	OTHER	GLOBAL
EXP-1	2 (1.2)	1 (0.6)	1 (0.6)	4 (2.4)
EXP-2	**44 (27.2)**	**38 (23.5)**	**18 (11.1)**	**100 (61.7)**
EXP-3	-	1 (0.6)	1 (0.6)	2 (1.2)
EXP-4	**21 (13.0)**	**9 (5.6)**	**7 (4.3)**	**37 (22.8)**
ALL	2 (1.2)	1 (0.6)	1 (0.6)	4 (2.4)
NONE	7 (4.3)	11 (6.8)	2 (1.2)	20 (12.3)
TOTAL	76 (46.9)	61 (37.7)	30 (18.5)	167

COULD YOU PLEASE TELL US WHY YOU FOUND IT (THEM) DIFFICULT?

Here are some of the main comments:

EXPERIMENT 2

"It was hard to obtain the equations required by the text book"
"I had never written equations like these before"
"I could not find the equations anywhere and I did not know how to do them"
"many unfamiliar reactions, had to use my limited knowledge (Higher) to try and work out answers, difficult but challenging"
"very difficult - I had no idea what products would be formed. I do not understand when a reaction occurs what products are formed"

EXPERIMENT 4

"The part C of Prelab was slightly ambiguous"
"A great deal of written instruction, difficult to understand"
"I find calculating balanced redox equations difficult"
"Working out the molarity as the way was worded was hard for me to understand"
"The prelab work was difficult for the second part as it meant that you had to really think about the information given and to work out the following equation"

Table 6.21 - Frequencies of response and comments question 3 - PRELAB WORK QUESTIONNAIRES

4.IN WHICH EXPERIMENT or EXPERIMENTS WAS (WERE) THE PRELAB WORK USEFUL?

N=162	HGRD	SYS	OTHER	GLOBAL
EXP-1	12 (7.4)	12 (7.4)	8 (4.9)	32 (19.8)
EXP-2	16 (9.9)	4 (2.4)	11 (6.8)	31 (19.1)
EXP-3	13 (8.0)	12 (7.4)	11 (6.8)	36 (22.2)
EXP-4	13 (8.0)	11 (6.8)	4 (2.4)	28 (17.3)
ALL	**45 (27.8)**	**33 (20.4)**	**11 (6.8)**	**89 (54.9)**
NONE	-	-	-	-
TOTAL	99 (61.1)	72 (44.4)	45 (27.8)	216

COULD YOU PLEASE TELL US WHY YOU FOUND IT (THEM) USEFUL?

Here are a selection typical responses:

ALL OF THEM

"The prelab saved the effort of doing calculations as you went along. This made the experiment less of a hassle to do"

"Because it enable me to understand better the redox reaction which were taking place in the experiment"

"The prelab was useful in experiment 2 because it actually was the total experiment and told you what to expect"

"They were helpful for doing the report at the end"

"Because the calculations done in the prelab work helped you in the titration calculations and in the understanding of the experiment"

"I found it useful because the prelab gave you an idea of what was actually going on in the experiment"

"Halogens chemistry can be tricky and helped to predict the products"

"I knew exactly what I was doing although the experiment was difficult and hence wasted as little time as possible"

Table 6.22 - Frequency of response and comments - question 4 PRELAB QUESTIONNAIRE

Question 3 results (Table 6.21) showed that for Prelab Work for experiments 2 and 4 was not considered easy by students. There was no significant differences between the two sub-samples. In view of students' comments it is likely that they experienced difficulty in finding references in the literature to help them solve it. We therefore recommended that a specific list of references should be given to overcome this in future lab course.

Question 4 (Table 6.22) gave similar results to those in the POST questionnaire - open question 2 and 3 (Tables 5.26 and 5.17). Students considered all of the Prelab exercises useful despite the varying degree of difficulty they encountered doing these.

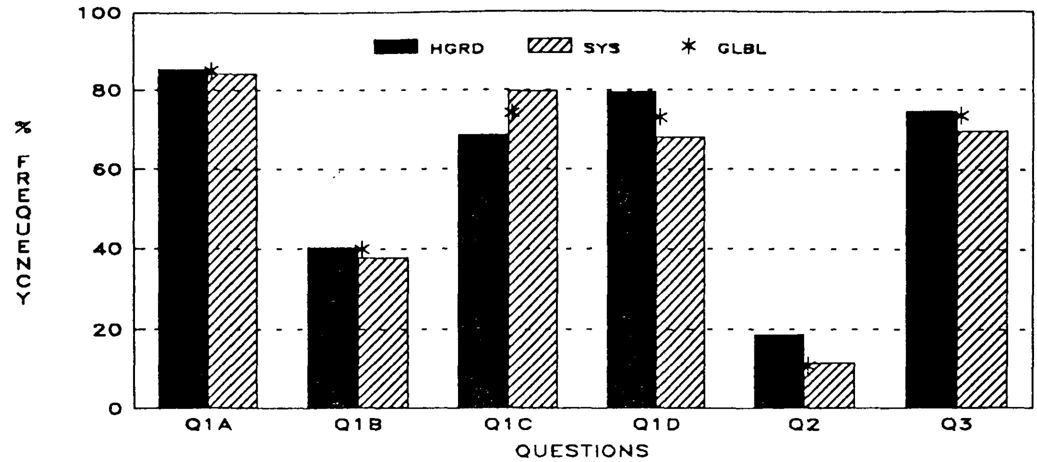


FIG. 6.4 — PRELAB WORK — PMP—90
HGRD vs SYS

Figure 6.4 gives a graphic comparison of the results of the Prelab Work Questionnaire for our HGRD and SYS sub-samples. Again there were no statistical significant differences between the sub-samples.

A comparison between of 1989 and1990 results (level of agreement) is given in Table 6.23. For all items which presented a significant difference the level is indicated. All of these comparative results favoured the final survey (PMP).

	PLW vs PMP			P&P vs PMP		
Q.	HGRD	SYS	GLBL	HGRD	SYS	GLBL
1A	>1%	>1%	>1%	>10%		>1%
1B	>1%		>1%			
1C	>10%		>5%			>5%
1D	>1%		>1%	>1%		>1%
3	>1%		>1%			>5%

Table 6.23 - Comparison between the PLW results of 1989 and 1990's survey (PMP)

3.4 - MINI-PROJECT RESULTS

The Mini-Projects were attempted by 149 students (28.4% of the overall first year population, see Table 6.24). However, only 35 students answered and returned the Mini-Projects questionnaires. The frequencies and percentages for each statement were calculated and displayed in the Table 6.25.

HGRD N=149	SYS N=149	OTHER N=149	GLOBAL N=525
73 (48%)	51 (34.2%)	25 (16.7%)	149 (28.4%)

Table 6.24 - Percentages of students did the Mini-Projects

MINI-PROJECTS QUESTIONNAIRES

1.I THINK THAT SOLVING THE PRACTICAL PROBLEMS

1a. forced me to design and plan my own experiments						
QUEST	AGREE		NEUTRAL	DISAGREE		%
QUEST-1a	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	DIFF
HGRD	5 (26)	**13 (68)**	-	-	-	94.7
SYS	2 (29)	**5 (71)**	-	-	-	100.0
GLBL	8 (22)	**25 (69)**	1 (3)	-	-	94.4

1b. illustrated practical applications of the laboratory						
QUEST	AGREE		NEUTRAL	DISAGREE		%
1b	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	DIFF
HGRD	4 (21)	**9 (47)**	5 (26)	1 (5)	-	63.2
SYS	-	**5 (71)**	1 (14)	-	-	71.4
GLBL	5 (14)	**20 (56)**	9 (25)	1 (3)	-	66.7

1c. gave me confidence in my practical work						
QUEST	AGREE		NEUTRAL	DISAGREE		%
1c	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	DIFF
HGRD	-	**10 (53)**	7 (37)	2 (11)	-	42.1
SYS	1 (14)	**4 (57)**	1 (14)	-	-	71.4
GLBL	3 (8)	**18 (50)**	11 (31)	2 (6)	-	52.8

1d. allowed me to use my knowledge of chemistry to investigate the problems.						
QUEST	AGREE		NEUTRAL	DISAGREE		%
1d	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	DIFF
HGRD	2 (11)	**10 (53)**	6 (32)	1 (5)	-	57.9
SYS	1 (14)	**5 (71)**	-	-	-	85.7
GLBL	4 (11)	**20 (56)**	9 (25)	1 (3)	1 (3)	61.1

2. I THINK THAT MORE PRACTICAL PROBLEMS LIKE THESE SHOULD BE INCLUDED IN THIS COURSE.						
QUEST	AGREE		NEUTRAL	DISAGREE		%
QUEST-2	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIFF
HGRD	3 (16)	**7 (37)**	4 (21)	5 (26)	-	26.3
SYS	2 (29)	**4 (57)**	1 (14)	-	-	85.7
GLBL	7 (19)	**14 (39)**	10 (28)	5 (14)	-	44.4

3. I THINK THAT SOLVING THE PRACTICAL PROBLEM AT THE END OF THE COURSE HELPED ME TO UNDERSTAND THE EXPERIMENT WHICH HAD COME BEFORE.						
QUEST	AGREE		NEUTRAL	DISAGREE		%
3	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	DIFF
HGRD	4 (21)	3 (16)	**9 (47)**	2 (11)	1 (5)	21.1
SYS	-	**3 (43)**	2 (29)	2 (29)	-	14.3
GLBL	5 (14)	9 (25)	**14 (39)**	6 (17)	2 (6)	16.7

Table 6.25 - Frequency of response of MINI-PROJECT questionnaires

The reliability coefficients and the validity of the instrument appear to be satisfactory (see Table 6.26).

	FACTOR ANALYSIS (*) = Sig. 1% level				RELIABILITY
item	Factor 1	Factor 2	Factor 3	h^2	alpha
1a	-.119	.047	**.917**	.850	.79
1b	.300	.213	**.749**	.696	.75
1c	**.948**	.019	.050	.902	.76
1d	.161	**.807**	.281	.756	.73
2	**.807**	.317	.232	.805	.70
3	.106	**.900**	.029	.823	.75
%V	43.7	19.8	14.3	77.7	
alpha					.77

Table 6.26 - FACTOR ANALYSES of MINI-PROJECTS Questionnaires

Our comparison of the results from the two surveys examined here is presented in Table 6.27. Students rated the final version of the Mini-Projects more positively than the previous ones in almost all statements. The level of significance of the differences were calculated using the normal Chi-Square test. Where the frequency numbers were too small to do this, the differences were estimated using Zubin's Nomographs to allow a comparison of the positive response percentages (indicated by (*) in the Table 6.27).

	MP vs PMP			P&P vs PMP		
Q.	HGRD	SYS	GLBL	HGRD	SYS	GLBL
1A	>1% *	>1%*	>1%*	>1%*	>1%*	>1%*
1B		>5%*			>1%*	>1%
1C		>1%*	>1%	>5%	>1%*	>1%
1D						
2	>1%	>1%*	>1%	>5%	>1%*	>1%
3						

Table 6.27- Comparison between the results of 1989 and 1990's surveys (PMP) - Chi-Square Test.

Figure 6.5 shows a comparison between the SYS and HGRD sub-samples. The SYS students in general displayed a more positive attitude to the Mini-Projects than did the HGRD students.

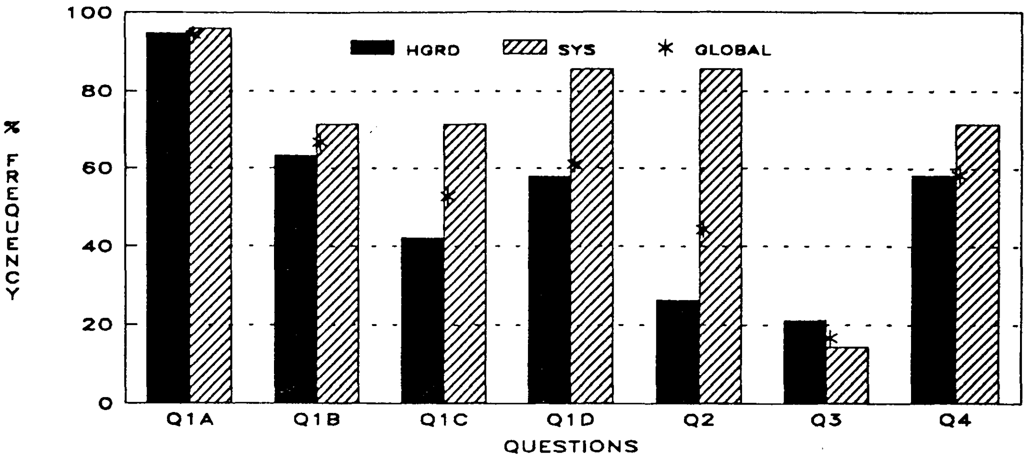


FIG. 6.5 — MINI-PROJECTS —PMP—90
HGRD vs SYS

4 - CONCLUSION: A SUMMARY

The students rated the final laboratory instruction design more positively than the other four designs applied in the previous year. For all instruments used, and most of the statements, the levels of agreement were higher than before one. This can easily be seen in the summaries shown in Table 6.7 our comparison of the Pre versus Post-Questionnaires; of the Diaries (Table 6.18); of the Prelab Work Questionnaires (table 6.23); and of the Mini-Projects Questionnaires (Table 6.27).

For all statistically significant differences found, the results favoured the final version of the laboratory instruction (PMP).

We suggest that these findings are a direct consequence of the changes made to produce the final design (PMP), namely:

i Moving the Mini-Project to the end of the course instead of being the end of each experiment as before.

ii Removing the experiments 5 and 6, "analysis of complex compounds", from the course which made the content easier.

However, the reported "helpfulness" of the course varied between our sub-samples groups of students (HGRD and SYS) and according with differing level of competence or confidence (i.e.,those who managed to do the Mini-Projects). We therefore express the qualification that the less experienced and the less competent or confident students by missing the opportunity to improve their ability in solving practical problems may not benefit from undertaking the redesigned laboratory practical course.

CHAPTER 7

SUMMARY AND CONCLUSION

The large amount of information collected and processed over the three surveys periods (1988, 1989 and 1990) and many factors involved in analysing it imposed certain limitations on how we could present comparisons of variables from our samples and sub-samples. For instance, it was not always possible to draw charts to make comparisons because of the numbers of variables involved. Therefore, for the sake of clarity, most of our data has been simply summarised in tables throughout this thesis, using graphs to demonstrate the tendencies apparent from statistical analysis in the survey and to present results importance to the argument.

Our approach in the preceding chapters has been to collate the raw data, subject it to systematic statistical analysis, testing the reliability and validity of the instruments which we originated, and after processing to produce graphic presentation of comparative analyses. We have produced a commentary on our findings which we have related to the theoretical underpining of the thesis and the goal in redesigning the first year practical laboratory instruction.

Here we attempt to look at the main controlled variables in the surveys, namely, the Written Instruction, Laboratory Techniques Training, Prelab Work, and Mini-Projects.

The main criticisms of the lack of statistical support and inadequate sample size in research measuring attitude to practical work is often found in the literature. By establishing a population sample of approximately 100 students in our surveys for each of the main controlled variables with returns on each instrument of approximately 60% of the sample, we believe we have avoided these pitfalls.

Our samples were large enough to have statistical tests applied to them as reported in the earlier chapters. However a clear limitation arose when we tried to analyse sub-samples groups founded on students' levels of previous experience (HGRD and SYS). Here the sample size was reduced significantly and in many cases it was not possible to apply statistical tests.

WRITTEN INSTRUCTION

The response to the item Adequate Written Instructions of the PRE and POST Questionnaires in the preliminary survey (1988) showed a significant difference for the two sub-samples (HGRD and SYS) in favour of the SYS.

The responses to the same item in the four course versions investigated in 1989 showed a significant difference with the control group (CTRL) presenting the lowest level of positive response, Here being no significant the differences among the three other versions (PLW, MP, and P&P). However the responses to the item Adequate/Inadequate Written Instruction in the final survey showed a significant improvement in the level of agreement when compared to the previous courses one (1989). (see Figure 7.1)

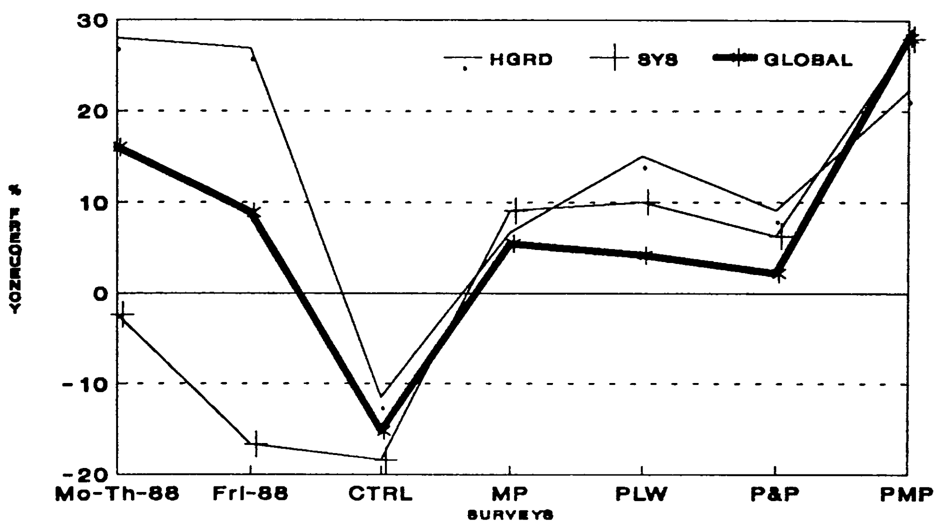


FIG.7.1 - ADEQUATE WRITTEN INSTRUCTIONS

Figure 7.1(PRE and POST Questionnaire item) shows that there was no significant difference between HGRD and SYS sub-sample responses in 1989 (CTRL, PLW, MP, and P&P) and 1990 (PMP) survey. A possible explanation is that the written instruction was clear for both groups of students independent of their background experience. On the other hand, the 1988 survey showed significant difference between the two sub samples, independent of the version used by the students (Old or New).

The Adequate Written Instruction item showed a students' positive attitude change when the PRE versus POST questionnaire results were compared. The difference was statistically significant in favour of the Improved Written Instruction which students rated higher than the one they had at secondary school.

Figure 7.2 (SCALE ONE - DIARY) shows the global level of agreement for the CLARITY OF WRITTEN INSTRUCTION scale in the different versions of the course surveyed in 1989 and 1990. Items 7 and 10 shows that the students strongly agreed that the experimental procedures were clearly explained and were easy to follow.

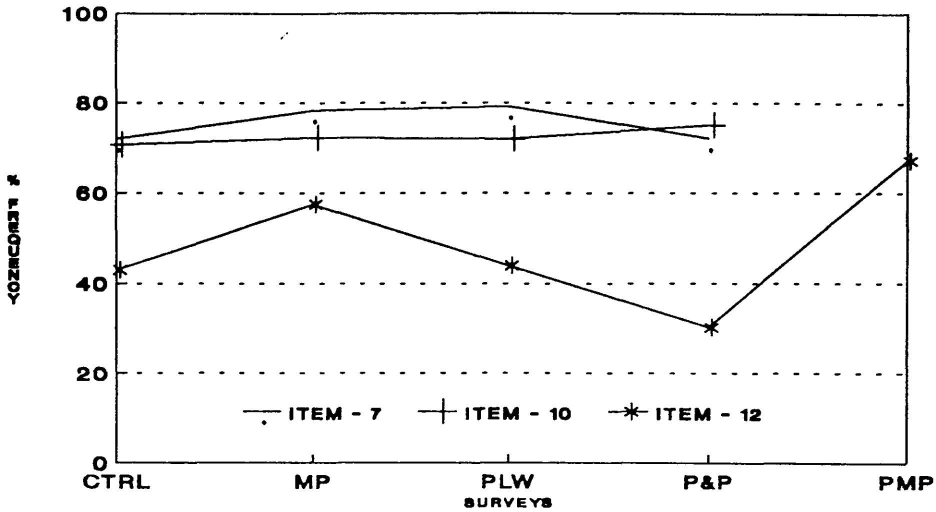


FIG.7-2 - CLARITY OF WRITTEN INSTRUCTION

In the sub-sample (HGRD and SYS) comparison of item 12 (DIARY), there was a significant difference in favour of the SYS students, suggesting that the purpose of the experiment was clearer to the SYS group.

In addition to these results the high number of positive responses to questions 1, 3, 4, 6, and 13 in the DIARY suggest that the lab manual was considered by the students to have been clearly written.

Another source of evidence which supports the conclusion that the written instruction was clear and unambiguous teaching signal was the demonstrators' diaries. A comparison of their comments in the preliminary survey (1988 survey, Table 3.17) with the 1989 survey (Section 5 - Chapter 5) clearly reveals that students' complaints were reduced significantly.

Information processing theory on text comprehension considers that readers' prior knowledge and the organisation of ideas in this are the two most important components required. The lab manuals developed and designed in this survey seemed to have attended to them adequately. Both the organisation of ideas and the clarity of the information was considered to be satisfactory by both HGRD and SYS students, despite their different levels of experience in chemistry.

Our main objective, of minimising the students working memory overload, by eliminating unnecessary and unclear instructions appears to have been satisfactorily achieved. We can summarise the evidences as follows:

i The item ADEQUATE WRITTEN INSTRUCTION in both the PRE and POST questionnaires(courses CTRL, PLW, MP, P&P and PMP) were singularly given a positive voting by the students as being better than the written instructions received at secondary school;

ii Questions 1, 3, 4, 6, 7, 10, and 13 in the DIARY (CTRL, PLW, MP, and P&P) produced high levels of agreement under statistical scrutiny suggesting that the lab manual have been clearly written; and

iii The Demonstrators' Diaries also recorded a much lower numbers of students' complaints about the written instructions in each successive survey period.

LABORATORY TECHNIQUES TRAINING

Two items were included in the 1989 DIARY (item 8 and 15) to evaluate the lab techniques session introduced at the beginning of the course. Item 8 meant establish if the lab techniques helped the students when they come to do the experiments; thus item 8 was included in our SALIENCE OF STIMULUS scale. Item 15 was an attempt to check whether students' confidence in executing the lab techniques was sufficient to allow them to wholly concentrate on the experiment; item 15 was related to our LABORATORY INSTRUCTION scale.

We found that the students seemed to find the lab techniques more helpful in the course with prelab work and mini-projects (P&P), and there was a good agreement between the HGRD and SYS students sub samples over all four course versions (CTRL; PLW; MP; and P&P). We also found that the students' confidence in lab techniques showed a significant difference in favour of the SYS sub-sample. Though students seemed to find the prelab introduction to the use of balances and volumetric techniques helpful, many of HGRD sub-sample felt they had still not mastered the lab techniques. It would therefore appear that the more inexperienced student needs even more help with lab techniques than our redesigned course provided.

The 1990 survey (PMP) results revealed a significant increase in the HGRD grade students' positive response from the previous year. We account for this improvement by suggesting that since only the more experienced students did the mini-projects, the less experienced HGRD sub-sample did not have to attempt these kind of task what made the course easier for them.

However demonstrators' comments also provided evidence that the students' performance of lab techniques did improve when compared to the 1988 survey results.

From our direct observation over the 12 weeks of course time in 1988 and 1989, it was clear that there was some improvement in the performance of techniques due to the training impulse, e.g., in doing titration, use of balances, and making proper use of a simple test tube. Before the lab techniques training was introduced, in 1988 lab it was quite common to come across student with their thumb on top of test tube and shaking it to mix up the solutions!

The goal of the training was however more than just students misusing apparatus or the use of equipment properly. Research in educational psychology had shown that very little working memory capacity is required to perform a task automatically. We hoped that if the lab techniques were performed by the students were "automatically" they could better attend to the chemistry involved in the experiments, i.e. by reducing interference to a minimum the lab techniques training was intended to improve learning in the lab.

The laboratory techniques training seemed to succeed in giving most students mastery of the skills needed for doing the experiments thus freeing working memory space for students to develop the thinking skills which practical work is intended to foster.

PRELAB WORK

Evidence that the Prelab Work helped students to understand the experiments and that it should always be included can be found in the results from the following instruments: Prelab Questionnaire, Diary; and the demonstrators' checklist.

The results from the Prelab Work questionnaire(see Table 5.31) showed that the students agreed that this helped their understanding of the experiment and also forced them to think about the experiments before attempting these in the laboratory. They also agreed that the prelab work should always be done before they were asked to do an experiment in the laboratory.

The Diary results, and in particular the FAMILIARITY scale (Figure 7.3) also provides supporting evidence. Item 5 indicated that the students required less help after the introduction of the Prelab Work, with this positive response increasing for the courses as follow: CTRL ~ MP < PLW < P&P < PMP (surveys 1989 and 1990).

Moreover there was a significant difference between the HGRD and SYS sub-samples in favour of the SYS, the tendency being similar to that shown in the FAMILIARITY Scale (Figure 7.3).

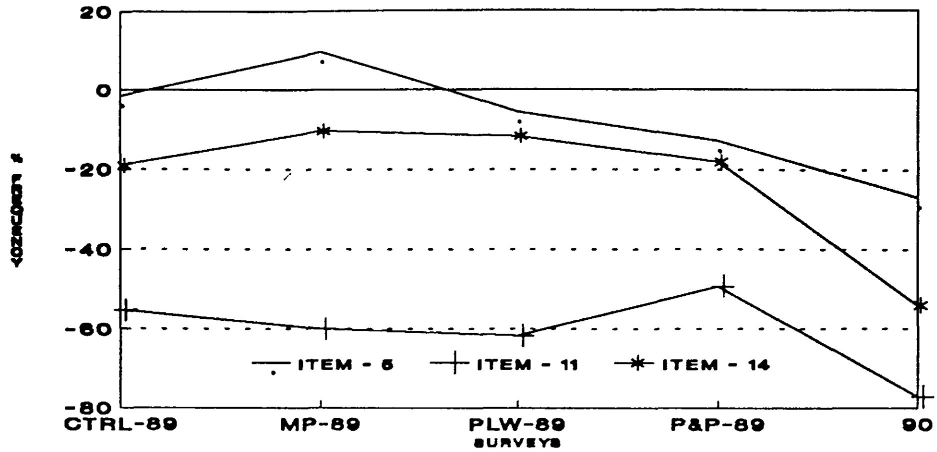


FIG. 7-3 FAMILIARITY

The clearest evidence that the PRELAB WORK was found to be of help in preparing students to do the experiments was given in the Demonstrators' checklist. Figure 5.10 (chapter 5) shows that the students who did the Prelab Work (course PLW and P&P) asked fewer questions of the demonstrators than those students who did the CTRL and MP courses.

In the 1989's survey the students found experiment 2 "Chemistry of Halogens" difficult because "it was hard to predict the end-product of the reactions and they did not know what to observe in the reactions" (See Table 5.15 B). In 1990 (PMP) with the Prelab Work presenting all the equations included in the experiments there were fewer complaints (See Table 6.9).

These combined results suggest that the Prelab Work succeed in reducing the students' working memory load in the laboratory by prompting them organise their thinking in advance, in accord with psychological theories which have demonstrated the importance of previously acquired knowledge in assisting the process of comprehension.

Our findings in general favoured the Prelab Work and supports the contention that this kind of activity can students construct links between their experience, the concept underlying an experiment, allow them to approach practical work in a meaningful way.

MINI-PROJECTS

It seems that while some of the students felt the mini-projects were helpful and interesting (particularly in the MP group - 1989 survey), many of the students did not enjoy doing them. They tended to find them difficult, and were opposed to the introduction of more Mini-Projects they felt that more mini-projects should not be included.

The Mini-Projects questionnaires evidenced that students who found the Mini-Projects DIFFICULT also considered them UNIMPORTANT and UNENJOYABLE. We found a significant and negative correlation between the items DIFFICULT (1d) and IMPORTANCE (1B, 1C, and 1E) and ENJOYMENT items (1F, 1G, and 1H). (See Table 5.37, Chapter 5)

Our results also highlighted that the HGRD students, the less experienced sub-sample of students, responded more negatively for most of these items than did the SYS students.

The way we administered the Mini-Project in 1989 (MP and P&P) gave the students cause to interpret them as an additional task rather than a planned activity necessary to fully complete the course.

In the 1990 trial (PMP) we decided to introduce the mini-projects at the end of course instead of after each experiment. The Mini-Projects were allocated after students had completed at least three of the experiments in the manual. This not only avoided the problems of the previous year but also gave the students more time to do solve the practical problems and an opportunity to use the library resources if they wished to further research these.

There was an expected significant improvement in the students' positive responses but most of the improvement may be attributable to the fact that the less experienced students were no longer forced to do the Mini-Projects.

The disadvantage of this design was that the students who did not attempt the Mini-Projects may feel neglected and probably will never attempt to develop practical problem solving skills.

ATTITUDE CHANGE

The first year students all had experienced some practical work before entering the university. They had completed a variety of practical courses at various secondary school and their opinions about there were recorded before they began the first year practical course, using the PRE-Questionnaires. The instrument's scale was devised to cover the following aspects of the laboratory: ENJOYMENT, IMPORTANCE, DIFFICULTY, and ORGANISATION. After the six week course ended their opinions were again sought using the POST questionnaires which contained the same set of questions as the PRE. Their opinions about practical work did not improve and in most of the cases showed a negative change, after having completed the first year practical course.

We have interpreted the students more negative attitude as probably due to the following reasons:

i The university lab group was too large (about 100 students) particularly when compared to secondary school classes (about 35);

ii The demand equipment and chemicals in certain experiments meant students had to stand about in queues, disrupting their lab work;

iii The responses in the post questionnaires showed that many HGRD students found the lab course more difficult than the SYS group, reflecting differing level of experience;

iv Many student reported that their expectations of learning new skills and learning how to use new equipment were not fulfilled; and

v Leading us to suggest that the University course was too brief to allow all the students' expectations to be fulfilled, or that the students had unrealistic expectation which required adjustment.

There was also the possibility that students' responses to the questionnaires were subject to a "halo" effect, i.e., their responses were influenced by the overall impression of university chemistry, and by their overall impression of their first few months of University life (a period in which the undergraduate entrant has to adjust high expectation to the new environment).

The negative attitude change to practical work found in our survey was in line with that found by other researchers. Waddington[75] comparing the attitudes of A-level students to university practical work found that the enjoyment of practical work fell significantly at university. The students' complained: "that they were taken into a laboratory, given a sheet of instruction and told to get on with it. This leaves you feeling very disoriented as it is a complete change from personal help readily available at school". Similar responses were recorded in students' comments given to the POST questionnaires open-questions (see Table 5.19).

Letton[2] also found that the students opinions of practical work did not improve and in many cases had changed negatively, after completing the second year practical course which she researched.

It would thus appear that there is a tendency among students to rate the course lower than their previous experience. This may result from the fact that it is usual to apply the POST test is applied at the end of courses when students are under a lot of pressure and stress because of their examinations, i.e. they answered the POST questionnaire in our survey a few days before they sat their examinations. However the ratchet effect of successive periods of practical experience may in fact be a process whereby students expectations gradually shift to "fit" the reality: that lab work is difficult sometimes arduous and require dedication as much as possible to produce significant results.

The POST Questionnaire should be applied at the beginning of the next term. The students after a break of a few weeks and free of the pressure of examinations might show a more positive attitude to the practical work they had experienced in the previous term or year.

The results of the research mentioned above[2,75], plus our own, confirms that the students' attitudes are more positive at the beginning of the course than at the end of it. Figure 7.4 attempts to illustrate this:

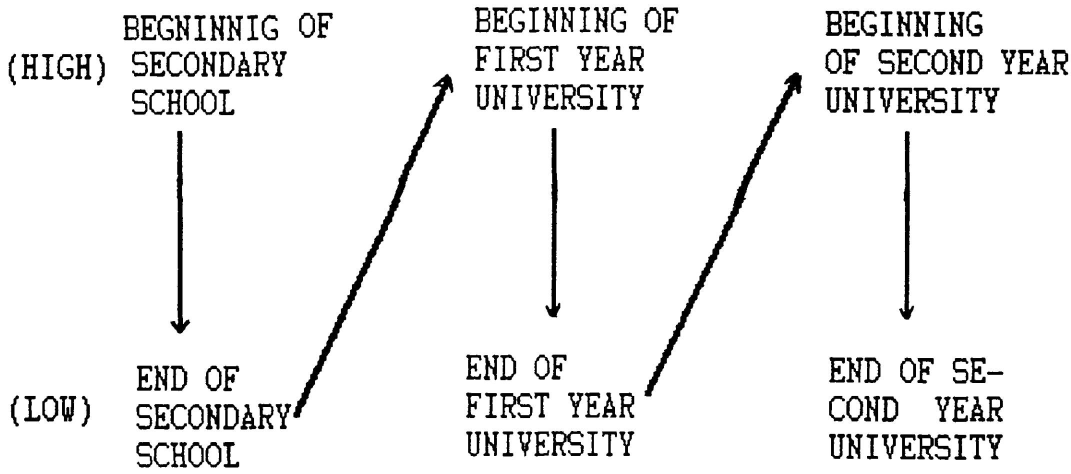


Figure 7.4 - Level of attitude change to practical work

The level of agreement for the ENJOYMENT SCALE however showed that PLW(1989) and PMP(1990) courses had a more positive attitude change than the others. The IMPORTANCE SCALE also showed a relative improvement for the course as follows: CTRL < MP < PLW < P&P < PMP, while the DIFFICULTY SCALE showed PLW and PMP course were viewed most positively. These results support our contention that the introduction of the Prelab Work was valuable for students, while the course with both Prelab Work and Mini-Projects were highly valued by the students.

SUGGESTIONS FOR FURTHER RESEARCHES

i Further research is considered necessary to determine the gain from improvements of the practical course in terms of cognitive achievement.

ii In particular, it has not been clearly established which course was the most valuable to the students, i.e., the version with mini-projects at the end of each experiment or the version with the mini-projects at the end of the course.

iii Although students' sex was considered a very important variable, related to attitudes to and expectations of science, we did not examine this, though the field of expectations may prove a fruitful one.

iv An important question arose in these final discussions about the negative attitudes to the course at successive stages.(see Figure 7.4). A more thorough examination of this is required.

v Another method of measuring attitude change could be used, such as interview, to establish the differences between the two courses P&P and PMP, and investigate reasons behind the negative attitude changes we found. Although large samples allow statistical measurements to be undertaken, individual comments would give extra insights

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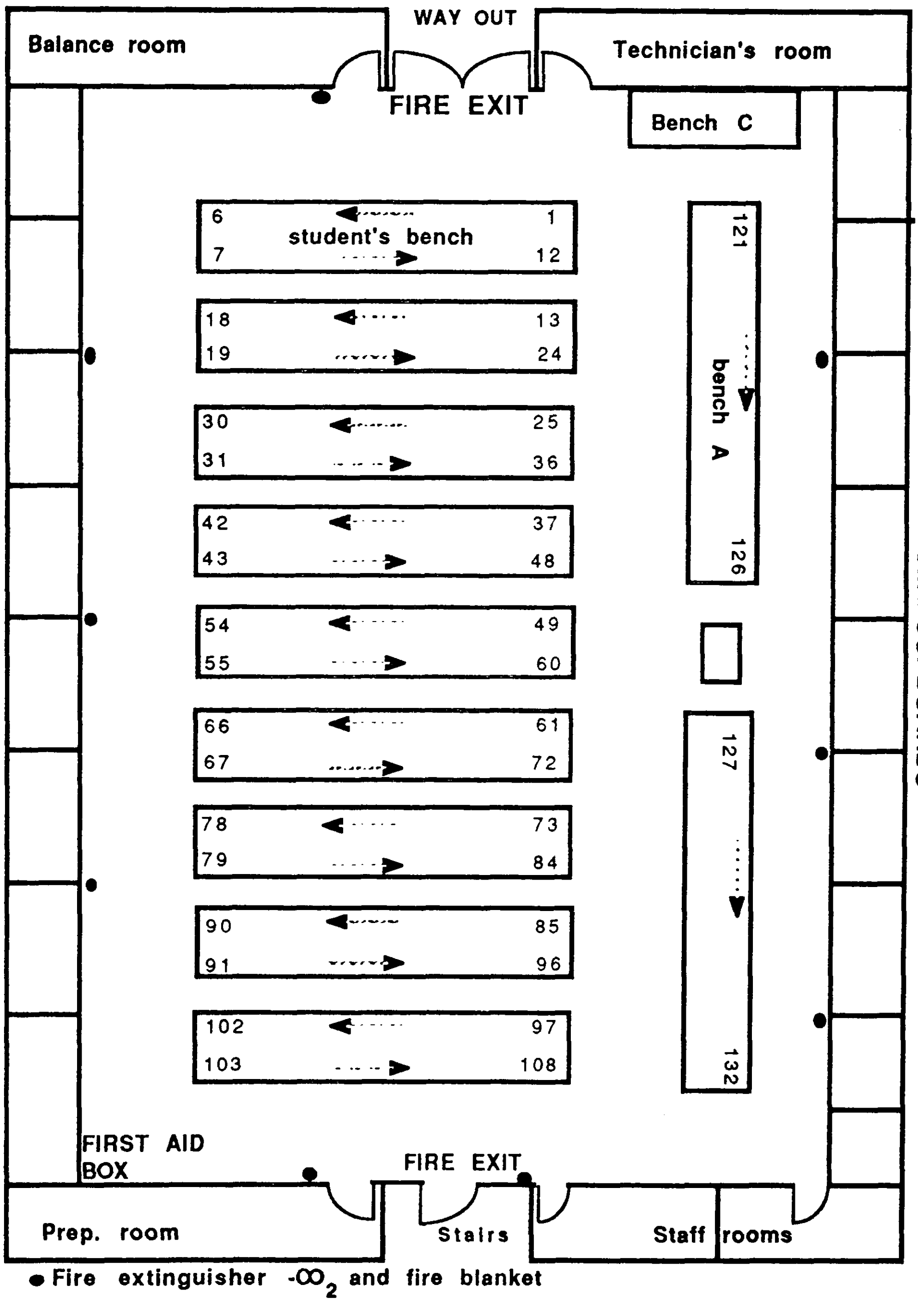
APPENDICES A

CHAPTER 3
(From PAGE 248 to 301)

APPENDIX A - 1 - LAB MAP



APPENDIX A-2
(CHAPTER 3)

"OLD" LAB MANUAL

VERSION - 1
(page 249 to 269)

Contents

SAFETY AND LABORATORY PRACTICE

Experiments involving the use of glass apparatus and chemicals should always be regarded as potentially hazardous. Some of the compounds you will work with are corrosive, poisonous or inflammable; therefore you should always exercise extreme care in the laboratory and AT ALL TIMES IN THE LABORATORY YOU MUST WEAR SAFETY SPECTACLES. This is to protect you from your neighbours' mistakes as well as your own. Follow instructions closely; avoid spillages on skin and clothing. Report any accident immediately even if it does not involve personal injury as in spillage of chemicals or breakage of glassware.

Some of the equipment necessary for the experiments is both delicate and expensive and will have to be used by your fellow students in this and subsequent years. Extreme care should be exercised at all times when handling equipment. If you are in any doubt at all as to how a piece of equipment should be operated then ASK A DEMONSTRATOR.

Ensure that all glass apparatus used by you is cleaned before you leave the laboratory and replaced in the drawer in which you found it. Replace empty reagent bottles on the shelves where you found them at the beginning of the laboratory period. DO NOT return used reagents into the reagent bottles on the benches but where appropriate as with silver nitrate solutions pour into the residue bottles.

FIRE REGULATIONS

FIRE is a serious hazard in any laboratory and is usually caused by the careless handling of organic solvents. These must NOT be heated using a Bunsen flame, nor used in the near vicinity of a flame.

PLEASE MAKE A POINT OF READING THE NOTICES RELATING TO FIRE EVACUATION PROCEDURE.

When the alarm sounds

1. Do not stay to collect personal belongings.
2. Follow the instructions of responsible members of staff and WALK via the nearest emergency exit to your assembly point in UNIVERSITY PLACE.
3. Those in toilets and lifts must leave without delay and make for the nearest emergency exit.

IMPORTANT **If smoke or other obstacles are found, make for the nearest clear exit.**

LABORATORY NOTEBOOKS

You will require for the laboratory a hard-backed notebook in A4 size. We require you to keep an up-to-date written account of your laboratory work including all measurements and observations made and all rough working. Ancillary notebooks, loose pieces of paper, etc. are NOT allowed as they are a fire hazard.

For the purposes of the CHEMISTRY Ordinary laboratory course your manual contains most of the necessary background work and details of the experimental procedure. There is no need for you to copy this into your notebook. Your write up should include: all results and observations, calculations where appropriate, interpretation of results and observations including equations where appropriate, and conclusions.

Drawing and Using Graphs

In some of the experiments in this manual, you will be asked to display your results in graphical form. Presenting experimental data in this way has several advantages over a simple tabulation of results.

(1) A graph shows clearly the functional relationship between the variables concerned. For example, a straight line (a linear relationship between variables) is usually obvious.
(2) Any points which have been seriously mis-measured or incorrectly calculated, are also immediately obvious.
(3) The deviation of the points from the line drawn through them gives a good idea of the accuracy of the results, or possibly, the adequacy of the theory that predicted the functional relationship.

In order to realise these advantages to the full, it is important that several basic principles are followed when drawing graphs:

(1) Work exclusively in pencil, using a sharp, fairly hard (1H, 2H) pencil.
(2) Use the fullest possible extent of the graph paper. If the graph will not fit one way round try the other - a sheet of graph paper is not usually square. Do not, for example, plot 3 x 3 inches on paper measuring 12 x 9 inches.
(3) Label the axes clearly, stating the physical property represented and its units.
(4) Mark each experimental result clearly by using a point, or ⊙ △ ⊡ etc.
(5) Give the graph a title stating the variables which are being plotted against each other.
(6) Draw straight lines with a ruler in such a way that the deviations of the experimental points from the line are minimised.
(7) Draw curves neatly, again minimising the deviations of the experimental points from the line. With curves, it is often helpful to sketch the curve lightly in pencil at first to get the smoothest possible line, and subsequently draw over the sketch more heavily. The light sketch lines can then be erased.
(8) Some graphs have linear and curved regions. Use a ruler for the former and merge it into the latter.
(9) For maximum accuracy, the gradients of straight lines should be derived using the entire linear portion of the graph, and not just a small portion of it.

PROCEDURE FOR WEIGHING

A. Analytical work - use of a Stanton CL41 or an Oertling R40 balance.

Both balances are capable of weighing to 0.0001 g.

The Stanton CL41 has the following controls: (i) off/partial release/full release; (ii) zero adjustment ; (iii) levelling; (iv) weight change 100 g/Tare (grey knob, not normally required), tens g (red), units g (yellow), $^1/10$ths g (blue). The balance point is shown on an illuminated scale, 0-100 mg, equipped with a vernier scale for the range 0.1-0.9 mg.

The following points must be observed when using the balance:

(1) Check the spirit level and, with the full release on, the zero position before weighing. Adjust if necessary.

(2) Weight changes $\geqslant$ 1g must be made with the partial release/full release control off.

(3) Weight changes < 1g may be made with the partial release control on but never with the full release control on.

(4) All weighings must be performed with samples contained in capped weighing bottles.

(5) Return all weight control knobs to their zero positions after use.

The Oertling R40 has the following controls:

(i) off/pre-weigh/full release; (ii) zero adjustment;
(iii) levelling; (iv) weight change tens g (front left knob), units g (front middle), 1/1000ths and 1/10000ths g (front right).

Readout is completely digital.

The following points must be observed when using the balance:

(1) Check the spirit level, and with the full release on, the zero position before weighing. Adjust if necessary.

(2) Weight changes of $\geqslant$ 1g must be made with the pre-weigh/full release control off.

(3) All weighing must be performed with samples contained in capped weighing bottles.

(4) Return all weight control knobs to their zero positions after use.

Weighing procedure

In many experiments the instructions state 'Weigh accurately about 0.X g of ....'. At first sight this is a contradiction but it means that the mass of the sample does not need to be exactly 0.X000 g. However its mass is required to four decimal places of grams.

Use the following procedure to ensure accuracy and cleanliness of the balance pan and case:

(1) At your bench, transfer a suitable quantity of the substance to be weighed to a clean, dry weighing bottle. Place the capped bottle in a dessicator and carry this with a clean beaker, watch glass, tongs, and your lab book to the balance.

(2) Transfer the weighing bottle to the balance pan. This, and all subsequent manipulations involving the weighing bottle, must be carried out using the tongs.

(3) Determine the weight of the bottle + sample and record this in your lab book.

(4) Tip a small quantity of the substance into the beaker. Experience will soon enable you to judge the quantity required, but in the early stages of the course you will find it helpful to weigh the bottle empty before starting.

(5) Reweigh the bottle. Repeat the procedure if necessary until the required quantity has been transferred to the beaker. Record the weight of bottle + residue and hence obtain the mass of the sample taken.

(6) Any material remaining in the bottle must not be returned to the reagent bottle but should be deposited in the jars provided.

B. <u>Preparative work - use of a Stanton D20T, or D40T, or a Sartorius 1106 top loading balance</u>

These are of lower precision (0.01g) than the analytical balances but are perfectly adequate for weighing reagents, and products in preparative work. Solids must be weighed on a watch glass or in a small beaker; liquids must be weighed in a beaker. The vessel used for weighing is tared, i.e. its weight is subtracted from the total by rotating the illuminated scale back to zero, then the reagent is added until the desired weight appears on the scale.

USE OF THE BURETTE AND PROCEDURE FOR TITRATION

A. <u>The Burette</u>

A standard 50 ml burette, when used properly, is capable of delivering volumes accurate to $\pm$ 0.02 ml. To reach this level of accuracy, certain important points must be adhered to.

(1) The burette must be scrupulously clean and when not in use should be stored, filled with cleaning solution. To test the cleanliness, fill the burette with distilled water and let it run out. If there are any droplets left on the sides of the burette, it is not clean.

(2) The tap must be well (but not over) greased and leak free. When turning the tap apply pressure to push it into the barrel, using two hands if necessary. If the stopcock barrel is streaked, it must be regreased otherwide the tap will leak.

(3) Rinse the burette with a small amount of the titrant (this will often be a solution of known concentration) then fill to any mark near the top of the burette scale. Ensure that there are no air traps or bubbles in the burette, particularly around the tap and the tip by opening the tap to discard some of the titrant.

(4) Read the burette at the bottom of the meniscus which will show up as a thin dark line if outlined by a white background. The scale will give a value to 0.1 ml and you must estimate the second decimal place to $\pm$ 0.02 ml.

B. <u>The Titration</u>

Place the solution to be titrated into a clean 250 ml beaker. Alternatively, weigh out the required weight of solid into a clean 250 ml beaker and dissolve this in distilled water. In either case the solution is termed the titrand.

Remember to add indicator, if required, at the appropriate moment. Fill the burette with the titrant and note the reading at the start of the titration. Add the titrant a little at a time, stirring the titrand with a glass rod in between additions, until you are close to the end point. Near the end point, add the titrant dropwise by opening the tap sufficiently to allow a single drop to appear at the tip of the burette and then transfer the drop to the titrand using the glass rod. When the first permanent change in colour appears, note the burette reading. Repeat the titration if necessary or wash the burette out thoroughly and fill with cleaning solution for storage.

Set out your results as follows:

Final burette reading	=	ml
Initial burette reading	=	ml
Titre	=	ml

Each reading, and the titre, should be recorded to two decimal places. If the second figure after the point would be zero it must be shown as such and not omitted.

USE OF THE PIPETTE

A pipette is a device for measuring a precise volume of liquid and transferring it from one container to another. The '25 ml' pipette you will use delivers exactly 25.00 $\pm$ 0.06 ml of liquid if properly used; the '10 ml' pipette 10.00 $\pm$ 0.04 ml. The pipettes are calibrated at 20°C and should, strictly speaking, be used at that temperature. The laboratory temperature is unlikely to be sufficiently far from 20°C for this to be important. Do not use a pipette if a precise volume is not required. Use a measuring cylinder.

The pipette is used by inserting the pointed end into the liquid to be measured, sucking up the liquid till it reaches the mark on the upper stem of the pipette, removing the pipette from the liquid and letting it empty into the container, usually a beaker, into which the liquid is to be transferred. Because many of the liquids you will be using are mildly corrosive you must not suck them up by mouth - a pipette bulb is used. The exact procedure is as follows:-

(1) First rinse out the pipette with a little of the liquid to be measured.

(2) Using the pipette bulb suck liquid into the pipette till it is 2-3 cm. above the mark on the upper stem. Be careful not to jam the bulb too tightly on the pipette - you must be able to remove it easily.

(3) Hold the pipette in your left hand (if you are right handed) and ease the bulb off with the thumb of the top left hand. As the bulb comes off cover the top of the pipette with the index finger of the right hand. This changeover must be done rapidly. If the liquid level falls beneath the mark you will have to start all over again.

(4) Ease the pressure of the index finger slightly and allow the liquid level to drop slowly till the bottom of the meniscus is level with the mark.

(5) Remove any drops adhering to the outside of the pipette.

(6) Place the end of the pipette against the side of the beaker to which the liquid is being transferred (at an angle of about 60°) and remove your index finger from the pipette.

(7) When all the liquid has run out of the pipette wait 15 secs longer then remove the pipette. Do not blow out any liquid remaining in the tip of the pipette. This has been allowed for in the calibration.

(8) Rinse out the pipette with distilled water.

PROCEDURE FOR BALANCING REDOX EQUATIONS

Although there is no single 'correct' method of balancing a redox reaction, the following systematic procedure (appropriate for reactions taking place in aqueous solution) is recommended.

Building up the equation by the following systematic procedure is recommended.

1. Begin the equation by writing the formula of one of the reactants on the left hand side, and on the right the formula of the product to which it is converted.
2. Balance the equation with respect to the principal atom.
3. Balance the oxygen atoms (if any) by adding the appropriate number of H_2O molecules to the oxygen-deficient side of the equation.
4. Balance the hydrogen atoms by adding H^+ ions to the appropriate side of the equation.
5. Balance ion charges by adding electrons to the appropriate side of the equation. Call this equation (A).
6. Repeat steps 1-5 for the other reactant, to obtain another equation. (Equation (B)).
7. Multiply equations (A) and (B) by suitable factors such that the number of electrons on the left of one of the equations is equal to the number on the right of the other.
8. Add the equations together to obtain the required overall equation for the reaction.

This approach is appropriate for reactions in acidic or neutral solutions. For reactions taking place in alkaline solution, it is unrealistic to write an equation involving H^+ ions.

To balance an equation for an alkaline solution reaction we proceed by applying the series of steps 1-8, then add one further step:

9. Note the number of H^+ ions which appear in your equation, add the same number of OH^- ions to each side of the equation, then write H_2O in place of each H^+, OH^- pair.

You might sometimes have to face problems in which the reactive species are not specified, but rather the names of compounds are given. For example, if one of the compounds is iron (III) chloride you will have to decide if the reactant species is Fe^{3+} or Cl^-. This can be done rigorously using information about redox potentials, but without having recourse to this, some rough working rules may be useful.

1. If the compound is a salt of a main group 1 or main group 2 metal the reactant will be the associated anion, because the metal ion cannot change its oxidation state to anything else which would be stable in aqueous solution.
2. If it is a salt of any other non-transition metal the reactant is likely to be the anion, unless it is a reaction in which the metal ion is reduced to the free metal.
3. In a transition metal compound it is likely that the ion which contains the transition metal will be the reactant. In some instances this will be a cation (e.g. Mn^{2+}) and in others an anion (e.g. MnO_4^-).
4. If there is still doubt, this can often be resolved by considering whether the other reactant is likely to be an oxidising agent or a reducing agent, e.g. iron (III) chloride will react with a reducing agent:

$$Fe^{3+} + \epsilon \rightarrow Fe^{2+}$$

and with an oxidising agent:

$$2Cl^- \rightarrow Cl_2 + 2\epsilon$$

GUIDE TO THE WATER-SOLUBILITY OF THE COMMONER INORGANIC COMPOUNDS

SOLUBLE

A. All alkali metal salts (Na^+, K^+, Rb^+ and Cs^+)

B. All ammonium salts (NH_4^+)

C. All strong acids (H^+)

D. All nitrates (NO_3^-)

E. Sulphates (SO_4^{2-}) except Pb^{2+}, Ba^{2+}, Sr^{2+} and Ca^{2+}

F. Chlorides (Cl^-) except Pb^{2+}, Ag^+ and Hg_2^{2+}.

INSOLUBLE

G. Carbonates and sulphides except those of groups A and B above.

H. Hydroxides except those in group A above, and $Ba(OH)_2$.

BORDERLINE CASES

$Ca(OH)_2$, $Sr(OH)_2$ and Ag_2SO_4 are sparingly soluble.

$PbCl_2$ is soluble in hot water.

GUIDE TO THE COLOUR OF COMMON INORGANIC IONIC COMPOUNDS

A. Coloured compounds

The following cations and anions give hydrated crystalline solids or solutions in water with the following colours:

BLUE	Cu^{2+}
GREEN	Cr^{2+}, Ni^{2+}, Fe^{2+} (pale green)
YELLOW	Fe^{3+} (yellow-brown)
ORANGE	$Cr_2O_7^{2-}$
RED/PINK	Co^{2+} (purple-red), Mn^{2+} (pale pink)
PURPLE	MnO_4^-

B. Colourless compounds

The following cations and anions form colourless compounds except when in compounds with a coloured anion or cation:

Alkali metals	Na^+, K^+ etc.
Alkaline earth metals	Mg^{2+}, Ca^{2+} etc.
Ammonium salts	NH_4^+
Other ions	Ag^+, Al^{3+}, Pb^{2+}, Zn^{2+}, Sn^{2+}, Hg_2^{2+}, Hg^{2+}, SO_4^{2-}, NO_3^-, CO_3^{2-}, OH^-, Cl^-

C. **Oxides and sulphides**

Those which are insoluble generally do not show the characteristic colour of the metal ion, and are often black.

QUALITATIVE TESTS FOR OXYGEN AND CHLORINE

1. Oxygen (O_2)

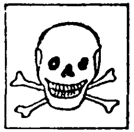
A colourless and odourless gas. Best detected by its ability to support combustion, i.e. it will ignite a glowing wood splinter.

2. Chlorine (Cl_2)

A greenish, toxic gas which is more dense than air. If chlorine is suspected to be present, it must not be sniffed. Best detected by its action on moist litmus paper: colour change blue → red (formation of HCl as a product from the reaction of Cl_2 and H_2O) then paper becomes bleached.

EXPERIMENT 1

INORGANIC PYROTECHNICS



Special precautions: The Thermite reaction must be ignited under the supervision of a demonstrator. CrO_3 is a strong acid. Cr_2O_3 is a suspected carcinogen.

Oxidation and reduction are very important processes in Chemistry. You will encounter a number of redox reactions during this laboratory course and in your lectures; the titration of iodine with sodium thiosulphate and the Andrews titration (experiments 7 and 9) are examples. Most redox reactions take place in solution, and no great heat changes can be detected due to the low concentrations of the reactants. We have chosen two redox reactions which occur in the solid state and which are quite spectacular.

(a) The ammonium dichromate 'volcano'

Place a large filter-paper on the bench in a fume cupboard and on top of this place your asbestos-centred wire gauze. In the middle of the asbestos make a pile of about 3 g of ammonium dichromate, $(NH_4)_2Cr_2O_7$. Light the apex of the pile with a match. It may take two or three attempts, but once the volcano starts the reaction is spontaneous. Collect the chromium (III) oxide, Cr_2O_3, which is produced in a clean dry 100 ml beaker which you have previously weighed on the rough balance. During the volcano reaction a gas is evolved. Write a balanced equation for the reaction.

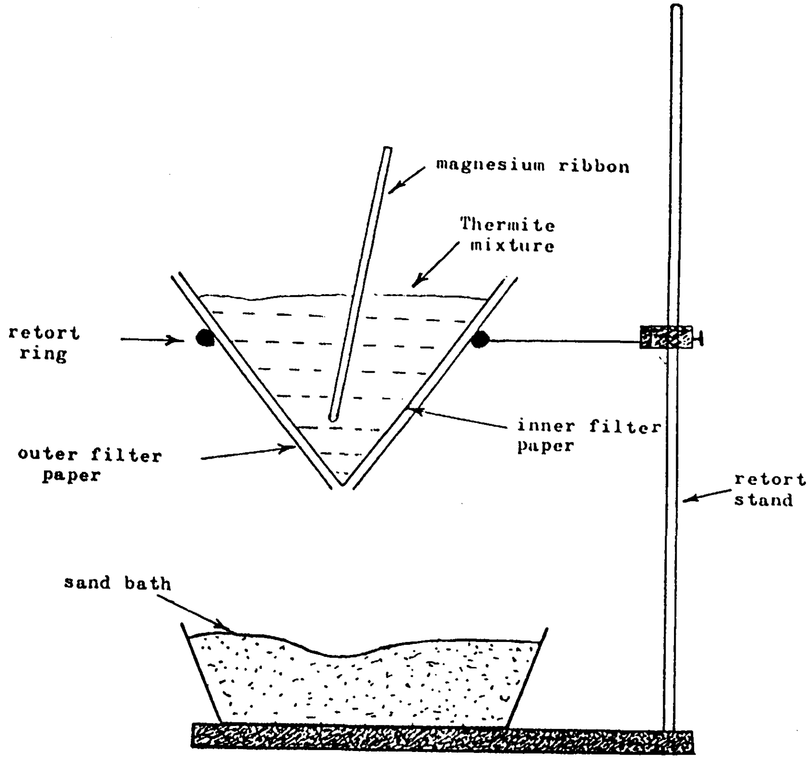


Diagram for the Thermite Reaction

For background information on NH_4^+ and $Cr_2O_7^{2-}$ salts see 'Basic Inorganic Chemistry' by Cotton and Wilkinson, pp. 279-80 and 393-5.

(b) The Thermite reaction - the production of chromium metal

Weigh the Cr_2O_3 which you produced by the ammonium dichromate volcano and add additional Cr_2O_3 to make the total weight up to 7 g. Because the Cr_2O_3 produced by the volcano is very 'fluffy', crush the oxide in the beaker with a glass rod to make it as compact as possible. Now add successively 5.5 g of aluminium powder and 3 g of chromium (VI) oxide, CrO_3. Mix the ingredients as homogeneously as possible using a glass rod.

Fold two 15-20 cm filter papers, tear the apex off one of them and place them one inside the other, the intact one to the inside. Fill it with the thermite mixture from the beaker (Cr_2O_3, CrO_3, Al). Support the filter papers in a retort ring clamped to a retort stand, and place a sand bath beneath them. Finally, insert about 6 inches of magnesium ribbon into the thermite mixture to act as a fuse.

See diagram opposite

From this point on you must be supervised by a demonstrator

Transfer the retort stand etc. to a designated fume cupboard. Light the Bunsen burner. Remove the inner filter paper and moisten the outer one with water from a wash bottle. Replace the inner filter paper and light the magnesium ribbon with the Bunsen burner. As soon as the magnesium begins to burn put down the Bunsen, close the fume cupboard lid and retire at least 3 or 4 feet. Do not look directly at the burning magnesium but if you look at the sand bath you should see the molten chromium pouring down.

When it is cold, remove the chromium metal. It may be necessary to break a crust of fused oxide/sand surrounding it. Weigh the chromium and calculate the % yield based on the amount of Cr_2O_3 and CrO_3 used.

Put the chromium in a test tube or beaker and add a little 2 mol ℓ^{-1} HCl. It may be necessary to warm the solution to initiate the reaction. How does its behaviour compare with iron?* Remove the Cr from the vessel, wash it in water and dry it.

Use the following thermodynamic data to calculate the enthalpy (heat) of the reduction of Cr_2O_3 to Cr by aluminium.

$$Cr_2O_3(s) \longrightarrow 2Cr(s) + {}^3/_2\, O_2(g) \qquad \Delta H^\circ = +1041\ kJmol^{-1}$$

$$2Al(s) + {}^3/_2\, O_2(g) \longrightarrow Al_2O_3(s) \qquad \Delta H^\circ = -1668\ kJmol^{-1}$$

Does this heat of reaction agree with your observations?

* Iron wire is available if you have not performed this reaction previously.

EXPERIMENT 2

CHEMISTRY OF THE HALOGENS

<u>Special precautions</u>: Unlike sodium chloride, the sodium salts of the other halogens are poisonous and should be handled with care. Many of the other chemicals in this experiment are toxic and corrosive. Hydrogen fluoride, formed when covalent fluorides undergo hydrolysis, and from the reaction of fluoride ion with acid, causes severe burns. CCl_4 and $CHCl_3$ are toxic and volatile.

The halogens are an important family of elements because they form compounds with the vast majority of other elements in the periodic table. The study of fluorine compounds is one of the major research activities of the Chemistry Department. Background information about the halogens and their compounds can be found in "Basic Inorganic Chemistry" by Cotton and Wilkinson, ch. 20 particularly pp. 321 - 29, in "Chemistry the Central Science" by Brown and Kemay, pp. 633 - 43, and in "Introduction to Modern Inorganic Chemistry" by Mackay and Mackay, pp. 308 - 14, and is required reading for this experiment.

Naturally occuring sources of the halogens include: salt deposits - England, Germany, etc. ($NaCl$), Stassfurt, Germany (KCl, $MgCl_2$, $MgBr_2$), Chile sodium nitrate deposits ($NaIO_3$); fluorapatite $3Ca_3(PO_4)_2 \cdot Ca(F,Cl)_2$; sea water ($Cl^-$ and Br^-); seaweed (I^-).

Many fluorine-containing compounds are important industrially, usually for specialised applications, for example uranium hexafluoride, poly(tetrafluoroethylene). In terms of scale of manufacture chlorine is the most important halogen element (world production <u>ca</u>. 8M tonnes in 1960). Derived from Cl_2 are a number of high tonnage secondary products, e.g. HCl, vinyl chloride, and

other chlorocarbons. In the U.K. this industry is centred in Cheshire and South Lancashire due to the proximity of large NaCl deposits.

In this experiment you will study a very limited selection of reactions involving halogens and their compounds. Interpret your observations while you are doing the practical work making use of Brown and Lemay or Cotton and Wilkinson where necessary. In most investigations you are asked to write balanced equations to describe the reactions which have occurred. See procedure for balancing redox reactions. Halogen compounds are often prepared by direct combination of the halogen with another element and they are conveniently classified as ionic or covalent, although the dividing line is not sharp.

<u>Experimental Investigations</u>

(a) <u>Covalent halides</u>

(1) <u>Carefully</u> add water dropwise (using a Pasteur pipette) to small samples of aluminium chloride ($AlCl_3$), carbon tetrachloride (CCl_4), silicon tetrachloride ($SiCl_4$), and phosphorus pentachloride (PCl_5). Each sample should be contained in a clean, dry test tube and the experiment must be carried out in a fume cupboard. When any reaction has ceased, add more water (to a total of 5 ml); note whether the reaction products are completely soluble and test the solutions with litmus paper. Record your observations and write balanced equations where appropriate. Why do CCl_4 and $SiCl_4$ behave differently?

(b) <u>Ionic halides - acid displacement reactions</u>

Reactions represented by the equation $H_nY + nX^- \rightleftharpoons nHX + Y^{n-}$ can be driven from left to right providing HX is more volatile than H_nY. They are a good method for preparing HX (X = halide) compounds.

Investigations 2 and 3 should be performed in a fume cupboard using test tubes.

(2) Warm a little solid NaCℓ with about 2 ml concentrated H_2SO_4. Test the gas evolved with litmus paper and a glass rod wet with concentrated NH_3 solution. Do not allow NH_3 solution to fall into the acid. Repeat using (i) NaBr and (ii) NaI in place of NaCℓ. Note any colour changes as well as testing the gases involved.

(3) Warm a little solid NaF with concentrated H_2SO_4. Note the appearance of the test tube wall and test the gas evolved with a glass rod wet with water.
Explain your observations and write balanced equations.

(c) Redox reactions

(4) Warm a little solid NaCℓ with manganese dioxide (MnO_2) and concentrated H_2SO_4. Identify the gas evolved. This investigation should be carried out in a fume cupboard.

(5) Prepare dilute aqueous solutions (about 10 ml) of NaF, NaCℓ, NaBr, and NaI. 5 ml portions are to be used here.
Prepare a solution of $Cℓ_2$ in H_2O by diluting sodium hypochlorite (NaOCℓ) solution with about five times its volume of water, then acidifying it with 1 mol $ℓ^{-1}$ H_2SO_4. Add a few drops of this solution to samples of each of the halide solutions in turn, followed by 1 ml $CHCℓ_3$. Now add more of the $Cℓ_2$ solution and observe if any further reaction occurs.

(6) Heat strongly some potassium chlorate ($KCℓO_3$) in a dry ignition tube. Identify the gas evolved.

Write balanced equations for the reactions involved in 4 - 6.

(d) Silver halides

(7) Prepare dilute aqueous solutions of NaF, NaCℓ, NaBr, and NaI in four test tubes. To each, add a small quantity of 2 mol $ℓ^{-1}$ HNO_3, followed by a few drops of aqueous $AgNO_3$ (obtainable from the front bench).
Record your observations of solubility and colour.
Add a little conc. NH_3 solution (fume hood) to any Ag^+ salts which are insoluble in H_2O. Note what happens, and explain your results by reference to Cotton and Wilkinson, p.442, Brown and Lemay, p.494, or Mackay and Mackay, p 95.

EXPERIMENT 3

IODIMETRY

The quantitative determination of iodine by volumetric analysis using sodium thiosulphate has many applications in inorganic chemistry. The redox processes involved are $S_4O_6^{2-} + 2e \longrightarrow 2S_2O_3^{2-}$, $E° = 0.17$ V, and $\frac{1}{2}I_2 + e \longrightarrow I^-$, $E° = 0.53$ V. For background information on the thiosulphate ($S_2O_3^{2-}$) and tetrathionate ($S_4O_6^{2-}$) anions see Cotton and Wilkinson p. 318, Brown and Lemay, p.652, or Mackay and Mackay, pp. 307 - 8. Direct iodimetry, which is more important in analytical work, involves the oxidation of I^- to I_2, then the titration of the I_2 formed with a standard $S_2O_3^{2-}$ solution.

This exercise involves the quantitative study of the reaction between potassium iodate (KIO_3), which is a primary standard and an oxidising agent, and excess potassium iodide in acid solution. I_2 is the sole iodine-containing product from the reaction and is determined quantitatively by accurate titration against thiosulphate solution. Hence if the stoichiometry of the reaction and the weight of KIO_3 used are known, the molarity of the sodium thiosulphate can be calculated.

1. The first step in the exercise is to write balanced equations for the reactions between IO_3^- and I^- and between I_2 and $S_2O_3^{2-}$.

2. Preparation of standard KIO_3 solution. Weigh accurately about 0.9 g Analar KIO_3 into a clean beaker which can be covered with a clean watch glass. Dissolve the solid in distilled water and transfer the solution quantitatively, i.e. with the washings, to a 250 ml volumetric flask. Dilute to 250 ml with distilled water. Calculate the molarity of the solution and transfer it to a labelled reagent bottle.

3. Preparation of standard $Na_2S_2O_3$ solution. $Na_2S_2O_3$ is not a primary standard but for many purposes the commercially available concentrated volumetric solution (containing a stabiliser) is suitable. Standard $Na_2S_2O_3$ solution prepared by this means is available in the lab. 100 ml should be more than sufficient for the experiment. Its concentration should be 0.100 mol ℓ^{-1} or near to this value. Store in a labelled reagent bottle.

4. Titration of $S_2O_3^{2-}$. Transfer 25 ml standard KIO_3 solution to a clean beaker ($\geq$ 250 ml) using a pipette then add 1 g KI and 5 ml mol ℓ^{-1} H_2SO_4. Iodine will be formed and will react with the excess I^- present to give the I_3^- anion. This will not affect the chemical behaviour of I_2 however. Fill a burette with $Na_2S_2O_3$ solution and titrate the liberated I_2 against $S_2O_3^{2-}$.

In the early stages of the titration the solution will be red/brown in colour. When the colour becomes pale yellow add a few drops of starch indicator. This will produce an intense blue/black colouration, due to the formation of a "starch/I_2" complex. Continue the titration; end end point is reached when the solution becomes colourless. If the starch solution is added too early in the titration, the iodine penetrates into the starch particles resulting in a slow reaction with $S_2O_3^{2-}$ and an inaccurate end point.

Repeat the procedure until two reproducible (difference < 0.1 ml) titres are obtained. Calculate the molarity of the NaS_2O_3 solution; obviously this should be identical to the molarity stated providing your technique is satisfactory. If this is not the case consult your demonstrator or the member of staff.

KIO_3 and $Na_2S_2O_3$ remaining at the conclusion of experimental work should not be thrown away, but kept for later experiments.

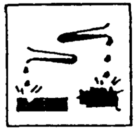
N.B. $I_2/S_2O_3^{2-}$ titrations should be performed only with cold solutions as:

(i) I_2 is appreciably volatile and its loss from a hot solution would be significant.

(ii) Starch functions as an indicator only below 30°C.

EXPERIMENT 4

ACID-BASE TITRATIONS



<u>Special precautions</u>: *The reagents to be used are potentially dangerous and must be treated with respect. Sodium hydroxide pellets will cause burns if they come into contact with the skin.*

A knowledge of the absolute concentrations of solutions of analytical reagents is important for many applications in chemistry. Often, however, the most useful reagents, particularly strong acids and strong bases, are difficult to prepare and store in a pure form and so the simple procedure of dissolving an accurately weighed amount of reagent in an accurately measured volume of solvent cannot be used to prepare a solution for quantitative work. For example, hydrogen chloride is a corrosive, moisture sensitive gas in pure form at room temperature and pressure. Sodium hydroxide is a white solid which is very hygroscopic and reacts rapidly with carbon dioxide in the air.

$$2NaOH + CO_2 \longrightarrow Na_2CO_3 + H_2O$$

The importance of strong acids and bases lies in the fact that they are totally ionised in aqueous solution. Weak acids and bases are not fully ionised and an equilibrium exists between ionised and unionised forms. For example, the weak acid HA is in equilibrium with H^+ and A^-,

$$HA = H^+ + A^-$$

and the equilibrium constant K_a is given by

$$K_a = \frac{[H^+][A^-]}{[HA]} .$$

where $[H^+]$, $[A^-]$ and [HA] denote the concentrations of H^+, A^- and HA respectively.

Approximate solution concentrations of strong acids and bases can be prepared but for analytical work they must be standardised by accurate quantitative titration against an acid or base of known concentration. There are a number of weak acids and bases which can be obtained as pure solids, which are not hygroscopic, and do not react with molecular oxygen or carbon dioxide. Moreover, they react quantitatively with strong acids or bases and, since they are easily handled, they can be used as primary standards.

For standardisation of a strong acid, the weak base disodium tetraborate decahydrate, $Na_2B_4O_7(H_2O)_{10}$ (borax) is a useful primary standard. It is easily purified, practically non-hygroscopic and has a large molecular weight.

$$B_4O_7^{2-} + 2H^+ + 5H_2O \longrightarrow 4H_3BO_3$$

For standardisation of a strong base, the weak acid potassium hydrogen phthalate, $KHC_8H_4O_4$ is a primary standard. This has a fairly large molecular weight.

$$[HC_8H_4O_4]^- + OH^- \longrightarrow [C_8H_4O_4]^{2-} + H_2O$$

In order to standardise the strong acid or base, it is necessary to be able to detect the exact point of neutralisation, or end point, in these reactions. This can be a problem if both acid and base forms of the reagents are colourless. However, the reactions can be coupled to suitable indicators.

An indicator is a weak acid or base which has a different colour in its acid and base forms. The equilibrium between the two forms is very sensitive to hydrogen ions as shown

$$\underset{\text{acid colour}}{HIn} \rightleftharpoons H^+ + \underset{\text{base colour}}{In^-}$$

by the expression for the equilibrium where K_{In} is the acidity constant

$$K_{In} = \frac{[H^+][In^-]}{[HIn]}$$

for the indicator. Hydrogen ion concentration can be varied over many orders of magnitude and is often considered on a logarithmic scale where

$$pH = -\log_{10}[H^+]$$

where $[H^+]$ is the H^+ ion concentration. The equilibrium expression can be rewritten where $pK_{In} = -\log_{10}K_{In}$

$$pH = pK_{In} + \log_{10}\frac{[In^-]}{[HIn]}$$

If one colour can be recognised over the other when the activity (approximately equal to the concentration) of that form is in 10-fold excess then the pH range over which the indicator changes colour will be $pK_{In} \pm 1$. Because of the buffering effect of the weak acid or base primary standard, when titrating a weak acid with a strong base, the pK_{In} should be greater than 7, and when titrating a weak base with a strong acid, the pK_{In} should be less than 7. It must be remembered that the indicator is also an acid or base and to prevent interference, it should be at very low concentration compared with the concentration of primary standard. Hence only one or two drops of the indicator solution provided should be used.

Experimental procedure

The objective of this exercise is the preparation and standardisation of a solution of sodium hydroxide, and to use it to check the molarity of a hydrochloric acid solution provided.

(a) Preparation of stock solution of sodium hydroxide

Weigh 1.0 g sodium hydroxide pellets on a rough balance and place in a 500 ml beaker. Add 100 ml distilled water and stir the solution until all the pellets have dissolved.

Transfer the solution to a 500 ml reagent bottle and add a further 150 ml distilled water. Stopper and label the bottle and shake it to ensure that the contents are thoroughly mixed.

(b) Standardisation of sodium hydroxide with $KHC_8H_4O_4$

Weigh out accurately 0.6 - 0.7 g of potassium hydrogen phthalate into a 250 ml beaker. Dissolve the solid in about 75 ml distilled water and add a few drops of phenolphthalein (pK_{In} 9.6, colour change colourless-red). Titrate with sodium hydroxide until the first indication of a colour change to pink can be detected.

Calculate the molarity of the sodium hydroxide solution.

Repeat with a further portion of the salt or until two calculated results agree to within 1%.

(c) Titration of hydrochloric acid with standard sodium hydroxide

This part of the experiment acts as a check of your technique in part (b). Pipette 25 ml of the special hydrochloric acid solution provided for this experiment into a 250 ml beaker.
Add about 50 ml of distilled water and a few drops of phenolphthalein indicator, and titrate with NaOH in your burette.
Repeat with a further 25 ml aliquot or until two titrations agree to within 1%.
Write a balanced equation for the reaction.
Calculate the molarity of the HCl.

EXPERIMENT 5

PREPARATION AND ANALYSIS OF A COPPER(I) THIOUREA COMPLEX

__Special precautions:__ Although trace amounts of copper are essential for plant and animal metabolism, larger amounts are toxic. Thiourea is a suspected carcinogen and should be used with caution. Concentrated nitric acid is dangerous and should be used in a fume hood.

The aqueous solution chemistry of most transition metal elements is characterised by a number of readily accessible oxidation states. For example vanadium exhibits oxidation states from +2 to +5. By way of contrast, copper exists mainly in its divalent oxidation state in aqueous solution although many important biological processes utilise both copper (I) and copper (II). Background reading material on the chemistry of copper can be found in 'Basic Inorganic Chemistry' by Cotton and Wilkinson, chapter 24, pp. 411 - 16, and in Mackay and Mackay, pp. 221 - 23. Copper (I) can be prepared in very acidic aqueous solution, but it readily disproportionates to copper metal and the divalent ion.

Using the standard reduction potentials which refer to conditions of 1.0 mol l^{-1} copper (I) and copper (II) ion concentrations at 25°C,

$$Cu^{+} + e \longrightarrow Cu^{\circ} \qquad E^{\circ} = 0.52\ V$$

$$Cu^{2+} + e \longrightarrow Cu^{+} \qquad E^{\circ} = 0.15\ V$$

calculate E° for the disproportionation reaction

$$2Cu^{+} \longrightarrow Cu^{\circ} + Cu^{2+}$$

The standard potential, E°, can be related to the potential E of any solution containing both copper (I) and copper (II) ions by the Nernst equation

$$E = E^{\circ} - 0.059 \log (a_{Cu^{2+}}/(a_{Cu^{+}})^2)$$

By recognising that activities are approximately equal to concentration, this can be written:

$$E = E^{\circ} - 0.059 \log ([Cu^{2+}]/[Cu^{+}]^2)$$

Work out a relationship between the concentrations of the two ions at equilibrium when the electrochemical potential (or driving force) for the reaction, E, is zero. This relationship should illustrate that copper (I) can be stabilised in an aqueous environment if the concentration of free copper (I) can be restricted to a very small value relative to copper (II).

The copper (I) concentration can be restricted by the formation of compounds in two ways.

(1) If the compound is sufficiently insoluble for the copper (I) concentration to be below the value necessary to give E=O even at very small copper (II) concentrations.

(2) If the free copper (I) concentration is lowered by formation of a complex which is sufficiently stable for the equilibrium

$$(CuL_x)^{+} \rightleftharpoons Cu^{+} + xL$$

to lie well to the left. Ligands, L which have sulphur donor atoms are particularly effective in the stabilisation of copper (I) and it is worth noting that sulphur containing amino acids are found at metal sites in copper containing proteins which use both +1 and +2 oxidation states.

In the following preparation, thiourea acts both as a reducing agent and a complexing agent, and you will make a compound in which the copper (I) oxidation state is stabilised by thiourea ligands. The reaction is represented by the equation

$$2Cu^{2+} + 8SC(NH_2)_2 \longrightarrow 2Cu[SC(NH_2)_2]^+_3 + 2H^+ + \underset{H_2N}{\overset{HN}{\diagdown\!\!\!\!/}}\!C\text{-}S\text{-}S\text{-}C\!\underset{NH_2}{\overset{NH}{}}$$

The second part of the experiment involves the analysis of the complex.

(a) Preparation of tris(thiourea)copper(I)sulphate

Dissolve 2.5g copper sulphate pentahydrate in 15 ml water. Prepare a solution of 5g thiourea in 30 ml water and divide it into two equal portions. It may be necessary to heat the thiourea solution gently to get it to dissolve. Ensure that the solutions are cold, then slowly add the copper sulphate solution to one portion of the thiourea with continuous stirring. Allow the solution to stand for about 5 minutes, then add more thiourea solution 1 ml at a time until the solution is no longer blue. Filter off the white solid under suction using a Buchner funnel and flask and recrystallise it as follows. Prepare a solution by diluting about 5 ml of the remaining thiourea solution to 50 ml with distilled water and adding a few drops of 1 mol ℓ^{-1} sulphuric acid. Dissolve the solid in this solution heated to a temperature not exceeding 70°C. Allow the solution to cool, then filter by suction using a Buchner funnel and flask. Wash the crystals with a little water, then with 10-20 ml ethanol. Dry the product on the filter, weigh on a rough balance and record the yield.

(b) Experiment 3 must be carried out before the analysis is undertaken, unless you have done it earlier.

(c) Analysis of tris(thiourea)copper(I)sulphate

This analysis is designed to determine the percentage of copper in the compound. The basis of the analytical method is to decompose the complex and oxidisé the copper to hydrated copper (II) ions. These then react with iodide ions to give copper (I) iodide and free iodine.

$$2Cu^{2+} + 4I^- \longrightarrow 2CuI + I_2$$

The free iodine is titrated with standard thiosulphate solution. Note that the amount of iodine produced depends only on the amount of copper not on the amount of iodide, provided the latter is held in excess.

Weigh accurately 0.5 - 1.0 g of the compound and place in a small clean beaker. Add 20 ml of nitric acid (conc $HNO_3:H_2O$ = 1:1), slowly and in a fume hood as brown NO_2 gas is given off. Cover the beaker with a watch glass and boil the solution until it has evaporated almost to dryness. Dilute the solution with about 20 ml distilled water and transfer quantitatively to a 250 ml beaker. Ensure that you wash all the copper residue into the flask including any spots on the watch glass. Neutralise the excess nitric acid by adding 4 mol ℓ^{-1} ammonia solution dropwise until there is a faint blue precipitate, then add 4 mol ℓ^{-1} acetic acid dropwise until the solution becomes clear. At this point the solution is buffered at the correct pH for the analytical procedure. Add excess, 1 - 2 g, of solid potassium iodide and titrate the liberated iodine with the sodium thiosulphate solution which you have standardised in experiment 3.

Calculate the % of copper in your sample and express the result as: Found Cu %, $[Cu(thiourea)_3]_2SO_4 \cdot 2H_2O$ requires Cu %. Submit the remainder of your sample of the complex to the demonstrator in a labelled sample bottle.

EXPERIMENT 6

PREPARATION AND ANALYSIS OF HEXAMMINECOBALT(III) TRICHLORIDE

Special precautions: Concentrated acids and ammonia should be used carefully. Do not inhale ammonia vapour.

In aqueous solution, and in its salts with most simple anions, cobalt occurs in the +2 oxidation state as the aquated cation, $[Co(H_2O)_6]^{2+}$. Oxidation of this ion to the +3 oxidation state ion, $[Co(H_2O)_6]^{+3}$, in aqueous acid requires a very strong oxidising agent and is normally accomplished by electrolysis. Reference to the relevant standard reduction potentials, $Co^{3+}(aq) + e \rightarrow Co^{2+}(aq)$, $E° = 1.84V$; $O_2 + 4H^+ + 4e \rightarrow 2H_2O$, $E° = 1.229V$ indicates that $Co^{3+}(aq)$ will oxidise water under acid conditions. In basic solution the +3 oxidation state of cobalt is far less oxidising, $CoO(OH)(s) + H_2O + e \rightarrow Co(OH)_2(s) + OH^-$, $E° = 0.17V$; $[Co(NH_3)_6]^{3+} + e \rightarrow [Co(NH_3)_6]^{2+}$, $E = 0.1V$ and $Co(NH_3)_6{}^{2+}$ is readily oxidised to $Co(NH_3)_6{}^{3+}$ by molecular oxygen, $O_2 + 2H_2O + 4e \rightarrow 2H_2O$, $E° = 1.229V$ or by a variety of oxidising agents.

In this experiment you will prepare the hexammine-cobalt(III) cation as its chloride salt, perform some qualitative tests on your product and, after doing experiment 3, analyse your compound for cobalt.

An account of the chemistry of cobalt, and of this reaction in particular, is given in Cotton and Wilkinson, pp. 404 - 7, and in Mackay and Mackay, pp. 217 - 19. A general introduction to coordination chemistry is given in chapter 6 of Cotton and Wilkinson, in chapter 23 of Brown and Lemay, and in chapter 13 of Mackay and Mackay.

Experimental

(a) Preparation of $Co(NH_3)_6Cl_3$

Weigh, on a rough balance, 9 g $CoCl_2.6H_2O$ and 6 g NH_4Cl. Transfer to a 100 ml beaker, add 10 ml distilled water, and warm gently till the solids are both dissolved. Now add about 1 g of charcoal (to act as a catalyst) and 20 ml of concentrated (0.880) ammonia solution. Cool the solution to room temperature (in an ice-bath if necessary) and add slowly (use a glass dropper) 20ml of 6% (20 vol) hydrogen peroxide. When all the hydrogen peroxide has been added heat the solution to 60°C for 15 - 20 minutes in a fume cupboard till the pink colour of $[Co(NH_3)_6]^{2+}$ has been replaced by the brown colour of $[Co(NH_3)_6]^{3+}$, cool the solution in an ice-bath. Filter the solid (a mixture of $Co(NH_3)_6Cl_3$ and charcoal) by suction using a Buchner funnel. Remove the solid from the filter paper and transfer it to a beaker containing a mixture of 80 ml distilled water and 3 ml concentrated HCl which has been heated to boiling. When the $Co(NH_3)_6Cl_3$ has all dissolved, filter the solution through a fluted filter paper to remove the charcoal. Add 10 ml concentrated HCl to the filtrate and cool in an ice-bath. Filter the crystals of $Co(NH_3)_6Cl_3$ on a Buchner funnel and dry them between two filter papers. When the product is dry, weigh it and calculate the % yield based on the weight of $CoCl_2.6H_2O$ used.

(b) Reactions

(i) To a small sample of your product in a test-tube, add a few drops of concentrated HCl. Treat a few crystals of $CoCl_2.6H_2O$ in a similar manner. Try to explain your observations.

(ii) Boil a small sample of $Co(NH_3)_6Cl_3$ with a little 4 mol l^{-1} NaOH in a test-tube. Test the gas evolved with red litmus paper. The solid produced is Co(O)(OH). Write a balanced equation for the reaction.

(iii) Dissolve a few crystals of $Co(NH_3)_6Cl_3$ in water and add a few drops of $AgNO_3$ solution. What does this tell you about the way in which the Cl^- ion is bound in $Co(NH_3)_6Cl_3$?

(c) Now do Experiment 3 if you have not already done so.

(d) Analysis of $Co(NH_3)_6Cl_3$ for cobalt

Weigh accurately approximately 0.25 g $Co(NH_3)_6Cl_3$ and transfer it to a 100 ml beaker. Add 10 ml 4 mol ℓ^{-1} NaOH solution and heat the mixture in a fume cupboard until no more ammonia is evolved. It may be necessary to add a little more distilled water from time to time to prevent the mixture boiling dry. Cool the solution, add approximately 0.5 g of KI and acidify with 2 mol ℓ^{-1} HCl. When the Co(O)(OH) has all dissolved and the solution is clear, titrate the iodine liberated with sodium thiosulphate solution which you have previously standardised. The experimental procedure is given in Experiment 3.

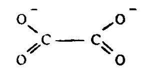
The analytical method depends on the fact that I^- anion is quantitatively oxidised to I_2 by Co^{III} in acid solution. Construct a balanced equation for the $Co(O)(OH)/I^-$ redox reaction and hence determine the percentage of cobalt in your sample. Express your results as follows:

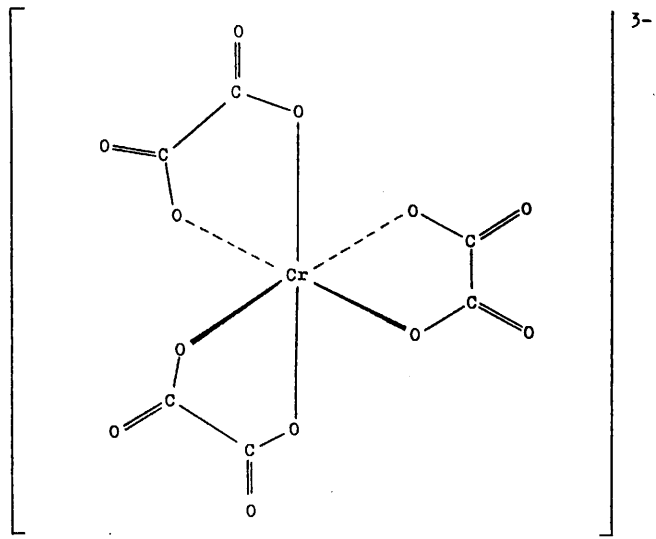
Found %; $Co(NH_3)_6Cl_3$ requires Co %.

EXPERIMENT 7

PREPARATION AND ANALYSIS OF $K_3[Cr(C_2O_4)_3]\cdot 3H_2O$

Special precautions: Oxalic acid and oxalates are toxic. Some chromium compounds are suspected of being carcinogenic.

Oxalate (ethanedioate, ) is able to form coordination complexes with many elements. Using an oxygen atom from each end, it can readily span two sites of the octahedral coordination arrangement commonly found with first row transition metal ions. This experiment involves the preparation of $K_3[Cr(C_2O_4)_3]\cdot 3H_2O$, which includes the complex ion shown below, and an estimate of its purity using the ability of MnO_4^- to oxidise oxalate to CO_2.



(a) Preparation of potassium tris(oxalato)chromate(III) trihydrate

Dissolve 4.5 g of oxalic acid dihydrate, $(COOH)_2 \cdot 2H_2O$, in 10 ml warm water and add in portions 1.5 g of potassium dichromate, $K_2Cr_2O_7$. When the vigorous reaction has subsided, gently heat the solution to its boiling point, and add 1.75 g of potassium oxalate, $K_2C_2O_4 \cdot H_2O$, allowing it to dissolve. Cool the mixture and add 2 ml ethanol. Blue-green crystals of the product, $K_3[Cr(C_2O_4)_3] \cdot 3H_2O$, should grow in the near-black solution. Collect the product by filtration (Buchner funnel), and wash the crystals on the filter first with a small amount of 1:1 ethanol-water, then with a small volume of ethanol. Dry between filter papers and record your yield.

Write a balanced equation for the formation of the complex ion. Why do you think so many oxalates are hydrated?

(b) Analysis of $K_3[Cr(C_2O_4)_3] \cdot 3H_2O$

The method is based on the reaction of oxalate with MnO_4^- in acid solution to form CO_2 and Mn^{2+}. Oxalate is released from the complex ion on treatment with a strong base. The colour change from purple MnO_4^- to near colourless Mn^{2+} makes the titration self indicating.

Accurately weigh about 0.3 g of your compound into a clean beaker, and add 10 ml water followed by 10 ml of 4M KOH solution. Cover the beaker with a watch glass and gently bring to the boil. Maintain the solution at its boiling point (do not let it boil dry) until no more green precipitate of chromium(III) hydroxide appears to be forming. Filter off the precipitate using a fluted filter paper, carefully collecting the liquid, which contains the oxalate, in a 250 ml conical flask. Wash the precipitate thoroughly with hot distilled water, collecting the washings in the flask.

Acidify the solution with 4M sulphuric acid, and, maintaining the solution at about 70°C, titrate it against standard potassium permanganate (ca. 0.02 molar).

Write balanced equations for the reactions of $K_3[Cr(C_2O_4)_3] \cdot 3H_2O$ with KOH, and of oxalate with $KMnO_4$, and use them to establish the equivalence factor of $K_3[Cr(C_2O_4)_3] \cdot 3H_2O$ to MnO_4^-. Calculate the % purity of your sample.

APPENDIX A - 3
(CHAPTER 3)

"NEW" LAB MANUAL

VERSION - 2
(Page 270 to 287)

Contents

SAFETY AND LABORATORY PRACTICE

Experiments involving the use of glass apparatus and chemicals should always be regarded as potentially hazardous. Some of the compounds you will work with are corrosive, poisonous or inflammable; therefore you should always exercise extreme care in the laboratory and AT ALL TIMES IN THE LABORATORY YOU MUST WEAR SAFETY SPECTACLES. This is to protect you from your neighbours' mistakes as well as your own. Follow instructions closely; avoid spillages on skin and clothing. Report any accident immediately even if it does not involve personal injury as in spillage of chemicals or breakage of glassware.

Some of the equipment necessary for the experiments is both delicate and expensive and will have to be used by your fellow students in this and subsequent years. Extreme care should be exercised at all times when handling equipment. If you are in any doubt at all as to how a piece of equipment should be operated then ASK A DEMONSTRATOR.

Ensure that all glass apparatus used by you is cleaned before you leave the laboratory and replaced in the drawer in which you found it. Replace empty reagent bottles on the shelves where you found them at the beginning of the laboratory period. DO NOT return used reagents into the reagent bottles on the benches but where appropriate as with silver nitrate solutions pour into the residue bottles.

FIRE REGULATIONS

FIRE is a serious hazard in any laboratory and is usually caused by the careless handling of organic solvents. These must NOT be heated using a Bunsen flame, nor used in the near vicinity of a flame.

PLEASE MAKE A POINT OF READING THE NOTICES RELATING TO FIRE EVACUATION PROCEDURE.

When the alarm sounds

1. Do not stay to collect personal belongings.
2. Follow the instructions of responsible members of staff and WALK via the nearest emergency exit to your assembly point in UNIVERSITY PLACE.
3. Those in toilets and lifts must leave without delay and make for the nearest emergency exit.

IMPORTANT If smoke or other obstacles are found, make for the nearest clear exit.

LABORATORY NOTEBOOKS

You will require for the laboratory a hard-backed notebook in A4 size. <u>We require you to keep an up-to-date written account of your laboratory work including all measurements and observations made and all rough working</u>. Ancillary notebooks, loose pieces of paper, etc. are <u>NOT</u> allowed as they are a fire hazard.

For the purposes of the CHEMISTRY Ordinary laboratory course your manual contains most of the necessary background work and details of the experimental procedure. There is no need for you to copy this into your notebook. Your write up should include: all results and observations, calculations where appropriate, interpretation of results and observations including equations where appropriate, and conclusions.

Drawing and Using Graphs

In some of the experiments in this manual, you will be asked to display your results in graphical form. Presenting experimental data in this way has several advantages over a simple tabulation of results.

(1) A graph shows clearly the functional relationship between the variables concerned. For example, a straight line (a linear relationship between variables) is usually obvious.
(2) Any points which have been seriously mis-measured or incorrectly calculated, are also immediately obvious.
(3) The deviation of the points from the line drawn through them gives a good idea of the accuracy of the results, or possibly, the adequacy of the theory that predicted the functional relationship.

In order to realise these advantages to the full, it is important that several basic principles are followed when drawing graphs:

(1) Work exclusively in pencil, using a sharp, fairly hard (1H, 2H) pencil.
(2) Use the fullest possible extent of the graph paper. If the graph will not fit one way round try the other - a sheet of graph paper is not usually square. Do not, for example, plot 3 x 3 inches on paper measuring 12 x 9 inches.
(3) Label the axes clearly, stating the physical property represented and its units.
(4) Mark each experimental result clearly by using a point, or ⊙ △ ⊡ etc.
(5) Give the graph a title stating the variables which are being plotted against each other.
(6) Draw straight lines with a ruler in such a way that the deviations of the experimental points from the line are minimised.
(7) Draw curves neatly, again minimising the deviations of the experimental points from the line. With curves, it is often helpful to sketch the curve lightly in pencil at first to get the smoothest possible line, and subsequently draw over the sketch more heavily. The light sketch lines can then be erased.
(8) Some graphs have linear and curved regions. Use a ruler for the former and merge it into the latter.
(9) For maximum accuracy, the gradients of straight lines should be derived using the entire linear portion of the graph, and not just a small portion of it.

PROCEDURE FOR WEIGHING

A. Analytical work - use of a Stanton CL41 or an Oertling R40 balance.

Both balances are capable of weighing to 0.0001 g.

The Stanton CL41 has the following controls: (i) off/partial release/full release; (ii) zero adjustment ; (iii) levelling; (iv) weight change 100 g/Tare (grey knob, not normally required), tens g (red), units g (yellow), $^1/10$ths g (blue). The balance point is shown on an illuminated scale, 0-100 mg, equipped with a vernier scale for the range 0.1-0.9 mg.

The following points must be observed when using the balance:

(1) Check the spirit level and, with the full release on, the zero position before weighing. Adjust if necessary.

(2) Weight changes $\geqslant$ 1g *must* be made with the partial release/full release control *off*.

(3) Weight changes < 1g may be made with the partial release control on but *never* with the full release control on.

(4) All weighings must be performed with samples contained in capped weighing bottles.

(5) Return all weight control knobs to their zero positions after use.

The Oertling R40 has the following controls:

(i) off/pre-weigh/full release; (ii) zero adjustment; (iii) levelling; (iv) weight change tens g (front left knob), units g (front middle), 1/1000ths and 1/10000ths g (front right). Readout is completely digital.

The following points must be observed when using the balance:

(1) Check the spirit level, and with the full release on, the zero position before weighing. Adjust if necessary.

(2) Weight changes of $\geqslant$ 1g *must* be made with the pre-weigh/full release control *off*.

(3) All weighing must be performed with samples contained in capped weighing bottles.

(4) Return all weight control knobs to their zero positions after use.

Weighing procedure

In many experiments the instructions state 'Weigh accurately about 0.X g of ....'. At first sight this is a contradiction but it means that the mass of the sample does not need to be exactly 0.X000 g. However its mass is required to four decimal places of grams.

Use the following procedure to ensure accuracy and cleanliness of the balance pan and case:

(1) *At your bench*, transfer a suitable quantity of the substance to be weighed to a clean, dry weighing bottle. Place the capped bottle in a dessicator and carry this with a clean beaker, watch glass, tongs, and your lab book to the balance.

(2) Transfer the weighing bottle to the balance pan. This, and all subsequent manipulations involving the weighing bottle, must be carried out using the tongs.

(3) Determine the weight of the bottle + sample and record this in your lab book.

(4) Tip a small quantity of the substance into the beaker. Experience will soon enable you to judge the quantity required, but in the early stages of the course you will find it helpful to weigh the bottle empty before starting.

(5) Reweigh the bottle. Repeat the procedure if necessary until the required quantity has been transferred to the beaker. Record the weight of bottle + residue and hence obtain the mass of the sample taken.

(6) Any material remaining in the bottle must not be returned to the reagent bottle but should be deposited in the jars provided.

B. Preparative work - use of a Stanton D20T, or D40T, or a Sartorius 1106 top loading balance

These are of lower precision (0.01g) than the analytical balances but are perfectly adequate for weighing reagents, and products in preparative work. Solids must be weighed on a watch glass or in a small beaker; liquids must be weighed in a beaker. The vessel used for weighing is tared, i.e. its weight is subtracted from the total by rotating the illuminated scale back to zero, then the reagent is added until the desired weight appears on the scale.

USE OF THE BURETTE AND PROCEDURE FOR TITRATION

A. The Burette

A standard 50 ml burette, when used properly, is capable of delivering volumes accurate to ± 0.02 ml. To reach this level of accuracy, certain important points must be adhered to.

(1) The burette must be scrupulously clean and when not in use should be stored, filled with cleaning solution. To test the cleanliness, fill the burette with distilled water and let it run out. If there are any droplets left on the sides of the burette, it is not clean.

(2) The tap must be well (but not over) greased and leak free. When turning the tap apply pressure to push it into the barrel, using two hands if necessary. If the stopcock barrel is streaked, it must be regreased otherwide the tap will leak.

(3) Rinse the burette with a small amount of the titrant (this will often be a solution of known concentration) then fill to any mark near the top of the burette scale. Ensure that there are no air traps or bubbles in the burette, particularly around the tap and the tip by opening the tap to discard some of the titrant.

(4) Read the burette at the bottom of the meniscus which will show up as a thin dark line if outlined by a white background. The scale will give a value to 0.1 ml and you must estimate the second decimal place to ± 0.02 ml.

B. The Titration

Place the solution to be titrated into a clean 250 ml beaker. Alternatively, weigh out the required weight of solid into a clean 250 ml beaker and dissolve this in distilled water. In either case the solution is termed the titrand.

Remember to add indicator, if required, at the appropriate moment. Fill the burette with the titrant and note the reading at the start of the titration. Add the titrant a little at a time, stirring the titrand with a glass rod in between additions, until you are close to the end point. Near the end point, add the titrant dropwise by opening the tap sufficiently to allow a single drop to appear at the tip of the burette and then transfer the drop to the titrand using the glass rod. When the first permanent change in colour appears, note the burette reading. Repeat the titration if necessary or wash the burette out thoroughly and fill with cleaning solution for storage.

Set out your results as follows:

Final burette reading	=	ml
Initial burette reading	=	ml
Titre	=	ml

Each reading, and the titre, should be recorded to two decimal places. If the second figure after the point would be zero it must be shown as such and not omitted.

USE OF THE PIPETTE

A pipette is a device for measuring a precise volume of liquid and transferring it from one container to another. The '25 ml' pipette you will use delivers exactly 25.00 $\pm$ 0.06 ml of liquid if properly used; the '10 ml' pipette 10.00 $\pm$ 0.04 ml. The pipettes are calibrated at 20°C and should, strictly speaking, be used at that temperature. The laboratory temperature is unlikely to be sufficiently far from 20°C for this to be important. Do not use a pipette if a precise volume is not required. Use a measuring cylinder.

The pipette is used by inserting the pointed end into the liquid to be measured, sucking up the liquid till it reaches the mark on the upper stem of the pipette, removing the pipette from the liquid and letting it empty into the container, usually a beaker, into which the liquid is to be transferred. Because many of the liquids you will be using are mildly corrosive you must not suck them up by mouth - a pipette bulb is used. The exact procedure is as follows:-

(1) First rinse out the pipette with a little of the liquid to be measured.

(2) Using the pipette bulb suck liquid into the pipette till it is 2-3 cm. above the mark on the upper stem. Be careful not to jam the bulb too tightly on the pipette - you must be able to remove it easily.

(3) Hold the pipette in your left hand (if you are right handed) and ease the bulb off with the thumb of the top left hand. As the bulb comes off cover the top of the pipette with the index finger of the right hand. This changeover must be done rapidly. If the liquid level falls beneath the mark you will have to start all over again.

(4) Ease the pressure of the index finger slightly and allow the liquid level to drop slowly till the bottom of the meniscus is level with the mark.

(5) Remove any drops adhering to the outside of the pipette.

(6) Place the end of the pipette against the <u>side</u> of the beaker to which the liquid is being transferred (at an angle of about 60°) and remove your index finger from the pipette.

(7) When all the liquid has run out of the pipette wait 15 secs longer then remove the pipette. Do <u>not</u> blow out any liquid remaining in the tip of the pipette. This has been allowed for in the calibration.

(8) Rinse out the pipette with distilled water.

PROCEDURE FOR BALANCING REDOX EQUATIONS

Although there is no single 'correct' method of balancing a redox reaction, the following systematic procedure (appropriate for reactions taking place in aqueous solution) is recommended.

Building up the equation by the following systematic procedure is recommended.

1. Begin the equation by writing the formula of one of the reactants on the left hand side, and on the right the formula of the product to which it is converted.
2. Balance the equation with respect to the principal atom.
3. Balance the <u>oxygen</u> atoms (if any) by adding the appropriate number of H_2O molecules to the oxygen-deficient side of the equation.
4. Balance the <u>hydrogen</u> atoms by adding H^+ ions to the appropriate side of the equation.
5. Balance ion charges by adding electrons to the appropriate side of the equation. Call this equation (A).
6. Repeat steps 1-5 for the other reactant, to obtain another equation. (Equation (B)).

7. Multiply equations (A) and (B) by suitable factors such that the number of electrons on the left of one of the equations is equal to the number on the right of the other.
8. Add the equations together to obtain the required overall equation for the reaction.

This approach is appropriate for reactions in acidic or neutral solutions. For reactions taking place in alkaline solution, it is unrealistic to write an equation involving H^+ ions.

To balance an equation for an alkaline solution reaction we proceed by applying the series of steps 1-8, then add one further step:

9. Note the number of H^+ ions which appear in your equation, add the same number of OH^- ions to each side of the equation, then write H_2O in place of each H^+, OH^- pair.

You might sometimes have to face problems in which the reactive species are not specified, but rather the names of compounds are given. For example, if one of the compounds is iron (III) chloride you will have to decide if the reactant species is Fe^{3+} or Cl^-. This can be done rigorously using information about redox potentials, but without having recourse to this, some rough working rules may be useful.

1. If the compound is a salt of a main group 1 or main group 2 metal the reactant will be the associated anion, because the metal ion cannot change its oxidation state to anything else which would be stable in aqueous solution.
2. If it is a salt of any other non-transition metal the reactant is likely to be the anion, unless it is a reaction in which the metal ion is reduced to the free metal.

3. In a transition metal compound it is likely that the ion which contains the transition metal will be the reactant. In some instances this will be a cation (e.g. Mn^{2+}) and in others an anion (e.g. MnO_4^-).
4. If there is still doubt, this can often be resolved by considering whether the other reactant is likely to be an oxidising agent or a reducing agent, e.g. iron (III) chloride will react with a reducing agent:

$$Fe^{3+} + e \rightarrow Fe^{2+}$$

and with an oxidising agent:

$$2Cl^- \rightarrow Cl_2 + 2e$$

GUIDE TO THE WATER-SOLUBILITY OF THE COMMONER INORGANIC COMPOUNDS

SOLUBLE

A. All alkali metal salts (Na^+, K^+, Rb^+ and Cs^+)

B. All ammonium salts (NH_4^+)

C. All strong acids (H^+)

D. All nitrates (NO_3^-)

E. Sulphates (SO_4^{2-}) except Pb^{2+}, Ba^{2+}, Sr^{2+} and Ca^{2+}

F. Chlorides (Cl^-) except Pb^{2+}, Ag^+ and Hg_2^{2+}.

INSOLUBLE

G. Carbonates and sulphides except those of groups A and B above.

H. Hydroxides except those in group A above, and $Ba(OH)_2$.

BORDERLINE CASES

$Ca(OH)_2$, $Sr(OH)_2$ and Ag_2SO_4 are sparingly soluble.

$PbCl_2$ is soluble in hot water.

GUIDE TO THE COLOUR OF COMMON INORGANIC IONIC COMPOUNDS

A. **Coloured compounds**

The following cations and anions give hydrated crystalline solids or solutions in water with the following colours:

BLUE	Cu^{2+}
GREEN	Cr^{2+}, Ni^{2+}, Fe^{2+} (pale green)
YELLOW	Fe^{3+} (yellow-brown)
ORANGE	$Cr_2O_7^{2-}$
RED/PINK	Co^{2+} (purple-red), Mn^{2+} (pale pink)
PURPLE	MnO_4^-

B. Colourless compounds

The following cations and anions form colourless compounds except when in compounds with a coloured anion or cation:

Alkali metals	Na^+, K^+ etc.
Alkaline earth metals	Mg^{2+}, Ca^{2+} etc.
Ammonium salts	NH_4^+
Other ions	Ag^+, Al^{3+}, Pb^{2+}, Zn^{2+}, Sn^{2+}, Hg_2^{2+}, Hg^{2+}, SO_4^{2-}, NO_3^-, CO_3^{2-}, OH^-, Cl^-

C. Oxides and sulphides

Those which are insoluble generally do not show the characteristic colour of the metal ion, and are often black.

QUALITATIVE TESTS FOR OXYGEN AND CHLORINE

1. Oxygen (O_2)

A colourless and odourless gas. Best detected by its ability to support combustion, i.e. it will ignite a glowing wood splinter.

2. Chlorine (Cl_2)

A greenish, toxic gas which is more dense than air. If chlorine is suspected to be present, it must not be sniffed. Best detected by its action on moist litmus paper: colour change blue → red (formation of HCl as a product from the reaction of Cl_2 and H_2O) then paper becomes bleached.

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EXPERIMENT 1

INORGANIC PYROTECHNICS

Purpose

The purpose of this experiment is to illustrate solid state oxidation reduction reactions.

Safety Precautions

Chromium salts are toxic, particularly by skin absorbtion. The materials should be handled in the fume cupboard.
Both of these reactions are exothermic and involve toxic materials. They must be carried out in the fume cupboard.
The thermite reaction (experiment B) is so vigorous and exothermic that you must be supervised by a demonstrator when it is performed

Danger Signs

IRRITANT EXPLOSIVE OXIDISER FLAMMABLE CORROSIVE

Notes

For background information on ammonium ion (NH_4^+) and dichromate ion ($Cr_2O_7^{2-}$) see 'Basic Inorganic Chemistry' by Cotton and Wilkinson pp. 279-80 and 393-5.

Experimental Design

The experiment is in two parts:
A. The oxidation reduction of ammonium dichromate. "The ammonium dichromate volcano", to produce chromium (III) oxide.
B. The reduction of the chromium (III) oxide produced in part 1 with aluminium. The thermite reaction.

The Experiments

Experiment A. The Ammonium Dichromate 'Volcano'

Weigh out about three grams of ammonium dichromate $(NH_4)_2Cr_2O_7$. Also weigh a 100 ml beaker on the rough balance and record its weight. It will be used to collect and weigh the product of the reaction.

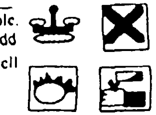
Place a large filter paper on the bench in the fume cupboard and on top of this your "asbestos"-centered wire gauze. Pour the ammonium dichromate on to the gauze so that it forms a cone shaped pile in the centre.

Light the apex of the cone with a match. It may take two or three attempts, but once the reaction has started it will continue by itself. Record your observations. The solid product is chromium (III) oxide. There is also a gaseous product. What do you think it is?
Collect and weigh the chromium (III) oxide product and save it for experiment B.

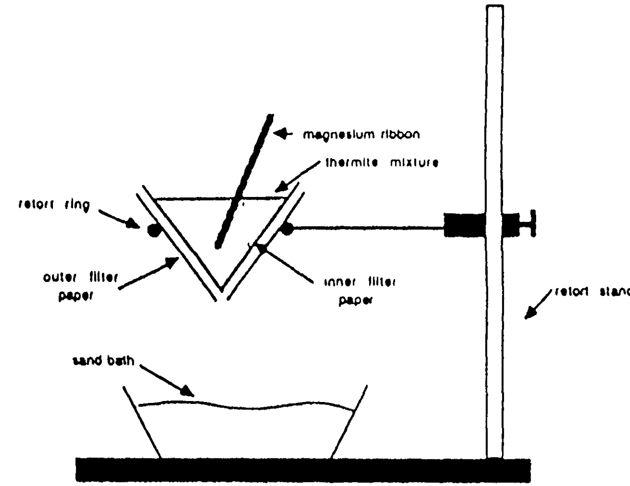
Write a balanced equation for the reaction

22

Experiment B. The Thermite reaction



Crush the chromium (III) oxide product from part A in a beaker to make it as compact as possible. Add enough additional chromium (III) oxide (Cr_2O_3) to make the total weight up to 7g. Now add 5.5 g. of aluminium powder and 3 g. of chromium (VI) oxide (CrO_3) Mix the ingredients as well as possible using a glass rod. This is the thermite mixture.
Prepare the apparatus for the thermite reaction as shown in the diagram below



Fold two 15-20 cm. filter papers; tear the apex off one of them and place them one inside the other, the intact one to the inside. Fill it with all the prepared thermite mixture. Support the filter paper cone in a retort ring, with a sand bath beneath it, as shown in the diagram. This retort ring, stand and sand bath arrangement can be found already set up in the fume cupboards. When the apparatus is complete insert about 4 inches of magnesium into the centre of the thermite mixture to act as a fuse.

FROM THIS POINT ON YOU MUST BE SUPERVISED BY A DEMONSTRATOR.

Remove the inner cone of filter paper and then moisten the outer cone with water from a wash bottle. Replace the inner filter paper cone. Light the top of the magnesium ribbon with a Bunsen burner. AS SOON AS the magnesium begins to burn put down the burner, close the fume cupboard and retire at least 3 to 4 feet. Do not look directly at the burning magnesium. Focus on the bottom of the filter paper cone and the sand bath. Molten metal should be observed.
Which metal is it ? How could you determine this?

When the metal in the sand bath appears cool, (use care; appearances can be deceiving) use tongs to remove the metal and quench it in cold water. Break off any encrusted sand or fused oxide surrounding the metal. Weigh the metal and calculate % yield based on the amount of Cr_2O_3 and CrO_3 used.

Place the metal in a test tube and observe what happens when the metal is covered with 2 mol l^{-1} HCl. It may be necessary warm the test tube to initiate any reaction. Remove the metal from the acid. Wash and dry it.

Calculations

Use the following data to calculate the enthalpy (heat) of reduction of Cr_2O_3 to Cr by aluminium.

$Cr_2O_3\,(s) \rightarrow 2\,Cr + 3/2\,O_2 \quad \Delta H° = +1041\ kJmol^{-1}$

$2Al + 3/2\,O_2 \rightarrow Al_2O_3\,(s) \quad \Delta H° = -1668\ kJmol^{-1}$

Is the value you calculated consistent with your observations of the experiment?

EXPERIMENT 2

CHEMISTRY OF THE HALOGENS

There are two main purposes to this experiment:

1. To do a series of comparative reactions on halogen compounds and to look for patterns among them.
2. To test your ingenuity, using your knowledge of halogen chemistry gained from this experiment, to solve a practical chemical problem.

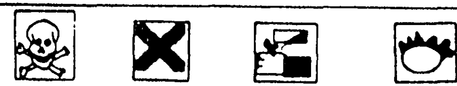
Experimental Report

1. The balanced equations describing the reactions should be reported along with the tablular comparisons that you make. Check with your demonstrator that you have interpreted them correctly.
2. When you have solved the problem, show your results to your demonstrator.

Safety Precautions

Unlike sodium chloride, the sodium salts of the other halides are poisonous and should be handled with care. Many of the other chemicals in this experiment are toxic and corrosive. Hydrogen fluoride, formed when covalent fluorides undergo hydrolysis, and from the reaction of fluoride ion with acid, causes severe burns. CCl_4 and $CHCl_3$ are toxic and volatile. Always check the hazard signs in the right hand margin.

Danger Signs



TOXIC IRRITANT CORROSIVE OXIDISER

Notes

For your own benefit, draw up a table of comparisons while doing the following experiments and make a note of each observation.

Information about the halogens, which will help you explain your observations, can be found in "Basic Inorganic Chemistry" by Cotton and Wilkinson, pp. 321-29, "Chemistry the Central Science" By Brown and Lemay, pp. 633-43, and "Introduction to Modern Inorganic Chemistry" by Mackay and Mackay, pp.308-314.

A. THE EXPERIMENT: Covalent Chlorides

This experiment should be carried out in the fume cupboard.

In the following experiments you are going to observe how some COVALENT CHLORIDE compounds react when water is added to them drop by drop.

Before you start - think what might happen. Will a gas be evolved?
If so - what is it likely to be? What will the other products of the reaction be?

If you mix XCl + HOH, there is a possibility that you will get HCl + XOH,
BUT it does not happen in every case.

See what happens in the following cases:

To small samples of the following covalent chlorides in a clean dry test tube (either 1cm of a liquid in a test tube or the amount of a solid that will fit on the end of a spatula) carefully add water drop by drop (using a glass dropper).

1. Aluminum Chloride ($AlCl_3$)
2. Carbon Tetrachloride (CCl_4)
3. Silicon tetrachloride ($SiCl_4$)
4. Phosphorus Pentachloride (PCl_5)

When any reaction has ceased, add more water - up to about 5 ml.

Are any reaction products soluble? What effect do these solutions have on litmus paper? Why do CCl_4 and $SiCl_4$ behave differently? Write equations for each reaction.

Table 1: Covalent Halides

	Observations	Litmus
Aluminium Chloride $AlCl_3$		
Carbon Tetrachloride CCl_4		
Silicon Tetrachloride $SiCl_4$		
Phosphorus Pentachloride PCl_5		

Ionic Halides

Notes

You are going to compare the reaction of conc. sulphuric acid on a few crystals of sodium fluoride, sodium chloride, sodium bromide and sodium iodide.

Consider for a moment, before beginning the experiment, what possible reactions could occur?

$H_2SO_4 + NaX \rightarrow ?$

The obvious result is HX, but HX might, itself, be attacked by H_2SO_4 so you could have any of the following gases HX, X_2 or reduction products of H_2SO_4 such as SO_2, H_2S or even sulphur. How will you recognise these products if they should be produced? Think this through before you begin the experiment.

How would you expect each of the possible gaseous products - HX, X_2, SO_2, or H_2S to react with litmus paper?

Record all your observations in a table like the one on the next page. Note the evidence for the occurrence of a chemical reaction such as colour changes, gas evolution or the production of heat. Write an equation for each reaction that occurs.

THE EXPERIMENT: Reactions with H_2SO_4

B

This experiment should be carried out in the fume cupboard.

Have some wet litmus ready to use.
Line up 4 test tubes, one for each of the halide compounds. Use a few crystals of each.
Carefully add about 2ml. of concentrated H_2SO_4 to each test tube. If necessary warm each test tube gently. Observe what happens. Note your observations in the table.
Test each gas evolved for its reaction with wet litmus paper by holding a piece of litmus paper in the mouth of the test tube.
Note: In the case of sodium fluoride the gas evolved may react with glass.
Rinse out that test tube with water and look for evidence of this on the walls of the test tube. What is happening in this reaction? Remember that glass is a chemical substance. This reaction is one of the methods used for etching glass.

Table 2: Reactions with H_2SO_4

	Litmus paper	Gas(es) evolved	General observations
$NaF + H_2SO_4$			
$NaCl + H_2SO_4$			
$NaBr + H_2SO_4$			
$NaI + H_2SO_4$			

THE EXPERIMENT: A Redox Reaction of chloride

C

The experiment should be carried out in the fume cupboard.

In a test tube mix a few crystals of sodium chloride with a small amount of MnO_2 (a good oxidising agent), then add about 2 ml. of concentrated H_2SO_4 and gently warm the test tube. Compare this result with that in the previous section in which sodium chloride by itself was allowed to react with H_2SO_4. What gas has been evolved? What made the difference? Why?
Write an equation for this reaction.

	Observations and Gas evolved
$NaCl + H_2SO_4 + MnO_2$	

THE EXPERIMENT: Replacement of One Halogen By Another

D

Notes

In this section you are going to to use dilute aqueous solutions of the ionic halides. Prepare about 10 mls. of each solution by dissolving a few crystals (about the amount on the end of a spatula) of each in water. Take about 2 cm. depth of each solution in test tubes for the following reactions and keep the remaining solutions to use in part E.

Experimental Procedure

Prepare 10 ml of a chlorine water solution by acidifying a dilute solution of sodium hypochlorite with dilute sulphuric acid.

Add a few drops of the chlorine solution to your samples of dilute sodium fluoride, sodium chloride, sodium bromide, and sodium iodide, in test tubes, and note what you see. Record your observations in a table like the one shown below.

Add 1 ml of chloroform (trichloromethane) to each of the solutions. It will form a lower layer. Shake the test tubes and observe the colour of the chloroform layer. Halogens are more soluble in chloroform than they are in water so that any free halogen is removed from the water and ends up in the chloroform layer giving a distinctive colour.

Add more chlorine water drop by drop and shake. Continue adding the chlorine water gradually and observe the colour of the chloroform and any changes that occur in the table.

Table 3: Observations $NaX + Cl_2$

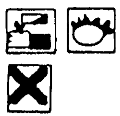
	Initially	With Chloroform	Chlorine water in excess
$NaF + Cl_2$			
$NaCl + Cl_2$			
$NaBr + Cl_2$			
$NaI + Cl_2$			

How do you explain these observations? Try to write equations to explain the reactions that took place.
To show what a sensitive test this is for iodide, empty out your iodide test tube add water and repeat the chloroform test. Can you still detect the traces of iodine left?

THE EXPERIMENT: Silver Halides

E

You are going to study the reaction of silver nitrate with your remaining solutions of sodium fluoride, sodium chloride, sodium bromide, and sodium iodide.



Take about 2cm. depth of each halide solution (prepared previously) in test tubes, and to each add a few drops of aqueous silver nitrate. (obtainable from the front bench - it is expensive !). Record your observations of solubility and colour in the table.
In the fume cupboard add a few drops of conc. ammonia to any of the silver halides which are insoluble, and shake the tube. Does the halide solid disappear?

Table 4: Silver Halides

	$AgNO_3$	General Observations
NaF		
NaCl		
NaBr		
NaI		

The Problem

F

**Ordinary table salt sometimes has another of the halides added to it.
From the experiments you should be able to find out what it is and demonstrate its presence.
Before you start, plan how you might do this using only the reactions you have studied in this experiment. Get a sample of salt from your demonstrator and try your method.**

EXPERIMENT 3

IODIMETRY

Purpose

The main purpose of this experiment is to show you how to perform an analysis using iodimetric titration and to standardise a solution of sodium thiosulphate for use in future iodimetric analysis.

Basic ideas behind the experiment

There are many substances that can oxidise the iodide ion to iodine, which is brown in solution.

$$2I^- \rightarrow I_2 + 2e$$

The amount of iodine produced can then be determined by titrating it with a standardised solution of thiosulphate ion. The iodine is reduced to iodide and the thiosulphate ion is oxidised to tetrathionate ion.

$$I_2 + 2S_2O_3^{2-} \rightarrow S_4O_6^{2-} + 2I^-$$

Therefore, an outline of the reaction sequence for an iodimetric titration is the following:

$$\text{Unknown} + 2I^- \rightarrow I_2$$

$$I_2 + 2S_2O_3^{2-} \rightarrow S_4O_6^{2-} + 2I^-$$

In this particular experiment this sequence will be changed. Iodate of known concentration will be used to liberate iodine so that the exact concentration of a thiosulphate solution can be calculated. The reason for this is that it is not possible to prepare a thiosulphate solution of exact concentration by simply weighing out the compound. However, iodate solutions can be prepared accurately by weighing out a sample of potassium iodate KIO_3.

Safety precautions

There no special precautions for this experiment except for the fact that some of the chemicals are moderately toxic.

Safety symbols for this experiment

OXIDISER

Outline of the experiment

There are five steps in the experiment.

1. Writing the balanced equation for the reaction of the unknown with iodide ion. In this experiment KIO_3 (potassium iodate)
2. Preparation of a KIO_3 solution of known concentration.
3. Preparation of a $Na_2S_2O_3$ (sodium thiosulphate) solution.
4. Titration of the known amount of iodine (liberated by iodate solution) with the thiosulphate.
5. Calculation of the molarity of the thiosulphate solution.

The report

Your report should have the following information:

1. The balanced equations for the reactions used in the experiment.
2. The calculations used in the determination of the molarities of the solutions.
3. The actual readings obtained in the titrations.

The experiment

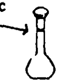
Writing the equation

Write a balanced equation for the reaction of Iodate ion with Iodide ion.

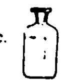
Note: I_2 is the only iodine containing product. If you have a problem producing the equation for this reaction consult your demonstrator.

Preparation of standard potassium iodate (KIO_3) solution

Weigh accurately about 0.9 g Analar KIO_3 into a weighing bottle. Transfer the iodate to a beaker and take your second weighing of the weighing bottle. Dissolve the iodate in a few mls of distilled water and transfer the solution carefully, with washings to a 250 ml volumetric flask. Make up to the mark with distilled water.



Calculate the molarity of the solution and transfer it to a labelled reagent bottle.



Preparation of Sodium thiosulphate $Na_2S_2O_3$ solution

A sodium thiosulphate solution of approximately 0.1 mol/l. is available in the laboratory. Obtain a 100 ml. sample of the solution to use for the analysis.

The titration

1. Rinse your burette with a small amount of the sodium thiosulphate solution. Then fill it with the solution.
2. Weigh out approximately 1 gram of potassium iodide (KI) and measure out about 5 ml of 1 molar sulphuric acid. These will be used shortly.
3. Rinse your pipette with a little of the potassium iodate solution. Use the pipette to transfer 25.00 ml of potassium iodate solution to a clean 250 ml conical flask.

4. Add the 1 gram of KI to the conical flask. What do you expect to happen? Add the 1 molar sulphuric acid. What is the explanation for what you observe?
5. Titrate the iodine released with the sodium thiosulphate solution. At first the solution will be intense red-brown. As the titration proceeds the colour will lighten to a pale yellow. At this point add a few drops of starch indicator. This produces an intense blue-black starch iodine complex. Continue adding sodium thiosulphate solution drop by drop until the blue colour just disappears.

Repeat the titration until two reproducible titres are obtained (difference <0.1ml).

Iodine can easily be lost from the solution as a vapour. How will the result of the titration be changed if some of the iodine was lost in this way from the titration mixture?

Note: Do not throw your solutions away. Save your remaining standardized potassium iodate and sodium thiosulphate solutions for later experiments.

6. Calculate the molarity of the sodium thiosulphate solution and consult your demonstrator to see if your results agree with the stated molarity of the solution.

EXPERIMENT 4

Acid-Base Titrations

There are three main purposes to this experiment:

1. To prepare and standardize a solution of sodium hydroxide.
2. To use the sodium hydroxide to determine the concentration of an unknown hydrochloric acid solution.
3. To test your ingenuity, using your knowledge of acid base chemistry, to solve a practical chemical problem.

EXPERIMENTAL REPORT

1. The calculations for the molarities should be noted in your report.
2. A brief explanation of how you solved the problem along with the calculations used.

SAFETY PRECAUTIONS

Sodium hydroxide pellets are extremely corrosive and will cause burns if they come in contact with your skin. The pellets also absorb moisture from the air. A pellet left on a desk top will absorb enogh moisture to form an extremely corrosive solution. The acids are dilute and therefore not as hazardous but should still be handled with care.

Danger Signs For This Experiment

CORROSIVE

NOTES

For a lot of chemical work, solutions of accurately known concentrations are required. The process of measuring the accurate molarity of a solution is called STANDARDISATION.

The preparation of these accurate solutions may not be easy for a variety of reasons. For example, concentrated hydrochloric acid comes in to the department as a solution of about 11 molar. Even when it has been diluted 11 times it is still only approximately 1 molar.

Sodium hydroxide has a molecular weight of 40. It would seem to be an easy matter to weigh out 40 grams of pellets, dissolve them in water and make up to one litre. However, NaOH pellets absorb moisture and CO_2 from the air.

$$2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$$

It is therefore impossible to weigh out exactly 40 grams of pure NaOH.

The point of this experiment is to show you how these problems are overcome so that solutions af accurately known molarity can be produced.

Outline of the Experiment

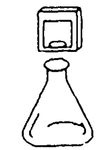
A. Preparation of an approximately M/10 solution of NaOH.
B. Standardisation of the NaOH against a solid acid potassium hydrogen phthalate [KH $C_8H_4O_4$].
C. Use the standardised NaOH solution to determine the exact molarity of an approximately M/10 solution of hydrochloric acid.
D. Solution of a a chemical problem using the procedures and chemistry you have learned.

The Experiments

A. Preparation of a M/10 Sodium Hydroxide Solution

If the molecular weight of NaOH is about 40, what weight of pellets would be required to make 250 ml. of about M/10 sodium hydroxide solution?
Weigh out this amount of NaOH pellets on a rough balance, place in a 500ml. conical flask and add 100ml. of distilled water. Swirl the flask gently until all the pellets have dissolved. Transfer the solution to a 500 ml. reagent bottle and add a further 150 ml. of distilled water. Stopper the bottle and shake gently to ensure that the contents are well mixed. Label the bottle.

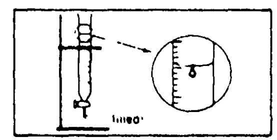
B. Standardisation of a Sodium Hydroxide Solution



Weigh a sample of between 0.6 and 0.7g of potassium hydrogen phthalate [$KHC_8H_4O_4$] on an accurate balance, and transfer it to a 250 ml conical flask. Take care to transfer the entire sample. Calculate the number of moles of [$KHC_8H_4O_4$] in the flask.

To the flask add about 75ml. of distilled water to dissolve the [$KHC_8H_4O_4$], and few drops of phenolphthalein indicator.

Prepare the burette with sodium hydroxide in the following way:
1. Put about 10ml. of the prepared NaOH solution in a small beaker.
2. Pour this solution into the burette making sure that the stopcock is closed. (If the burette stopcock is jammed see the demonstrator.)
3. Rinse the inside of the burette with this solution by tilting and rotating the burette. Then drain the solution through the tap.
4. Fill the burette with more NaOH solution. The burette need not be filled to exactly zero. The initial level need not be at zero as long as the reading is taken accurately to two decimal places. (See diagram)



Titrate the sample of potassium hydrogen phthalate solution in the following way:
1. Place the burette in the holder. Place the flask on a white tile just below the tip of the burette. Remember to take the initial reading.
2. Operate the stopcock of the burette with your left hand while swirling the contents of the flask with you right hand.
3. Add the sodium hydroxide solution in a very slow stream, while swirling the flask, until you see a pink colour at the point of entry. Then regulate the addition of the sodium hydroxide solution so that it is added drop by drop.
4. As you near the end point, the pink colour at the point of entry persists. The endpoint of the titration is reached when 1 drop causes a persistent pink colour thoughout the entire solution.
5. When the end point is reached stop the titration. Read the level of the solution in the burette accuratcly.

1 How many moles of NaOH react with the sample of [$KHC_8H_4O_4$]? Calculate the molarity of the NaOH solution.

6. Repeat with a further portion of phthalate until two values of the molarity of NaOH agree to within 1%. If you are unable to get this agreement see your demonstrator.

C: Titration of Hydrochloric Acid with Standardised Sodium Hydroxide

Pipette exactly 25 ml. of the special hydrochloric acid provided into a conical flask in the following way:

1. Pour about 10 ml of the hydrochloric acid in a small beaker.
2. Using a rubber bulb suck about half of this amount into the pipette to rinse the pipette. With your finger of the top end of the pipette tilt to rinse the pipette with the Hydrochloric acid solution.
3. Drain the pipette. Notice that a small amount of liquid remains in the tip of the pipette. Pipettes are designed to <u>deliver</u> the volume stated leaving a small amount of liquid in the pipette tip. If you blow this liquid out too much liquid will be delivered.
4. Using a rubber bulb to suck up the liquid, fill the pipette to an inch or two above the volume mark.

Remove the the bulb and quickly put your finger over the top of the pipette. Slowly release the pressure of your finger to adjust the level of the liquid in the pipette to the mark.

5. Allow the pipette to drain into the conical flask. Touch the tip of the pipette to the inside edge of the flask to get the last drop. A small amount of liquid will remain in the pipette.

Titrate the sample of hydrochloric acid in the following way.

1. Add a few drops of phenolphthalein to each flask.
2. Add about 50 ml. of distilled water to each flask.
3. Titrate in the same way as in part B.

Repeat this with other 25 ml samples of HCl until two titrations agree to with in 1%.

Write a balanced equation for the reaction.

Calculate the molarity of the HCl solution. Report you answer to your demonstrator.

D: The Problem

All of the acid in vinegar is present as acetic acid (ethanoic acid). Acetic acid has 1 acidic hydrogen. Using the chemical knowledge and skills you have learned in this experiment determine the amount of acetic acid in a vinegar sample. Discuss your method with a demonstrator before beginning the work.

EXPERIMENT 5

Preparation and Analysis of a Thiourea Copper (I) Complex

Basic Ideas behind the experiment

1. Metal ions readily accept electrons from electron pair donors. Substances which are <u>electron pair donors are classified as bases</u>. In inorganic chemistry such bases are called ligands. A combination of a metal ion and a ligand (or group of ligands) is called a COMPLEX. In this experiment the metal is Cu^+ and the ligand is thiourea :$SC(NH_2)_2$.
2. Metals in the middle block (d-block) of the Periodic Table have the ability to form ions in several oxidation states. For example you already know that iron ions exist as Fe^{2+} and Fe^{3+} and that copper ions exist a Cu^+ and Cu^{2+}. The Cu^{2+} in water gives the familiar blue of $CuSO_{4(aq)}$. The Cu^+ ion is much less common and its compounds are usually either insoluble in water, or decompose in it. You will prepare a copper (I) compound in which the Cu^+ is protected from water by forming a stable complex with thiourea
3. In preparations of Cu^+ complexes it is usual to begin with a Cu^{2+} compound so that we can make use of a solution of it in water. However, to make the complex it will have to be reduced to Cu^+. The thiourea is both a reducing agent and a complexing base and so it can do both jobs.

Experimental report

1. Calculations for the molecular weight of the complex and the theoretical % Cu in the complex.
2. Calculations for the actual % Cu in the complex you have prepared and analysed.
3. A comparison of the actual % Cu with the theoretical % Cu.

Safety precautions

Thiourea should be used with care since it is toxic and may cause cancer. Copper compounds are also toxic. Concentrated nitric acid will be used during the analysis of the complex and should be treated with care and caution. The preparation of the complex for analysis must be carried out in a fume cupboard.

Safety symbols for this experiment

IRRITANT

CORROSIVE

OXIDISER

Preparation of the Complex

<u>Preparing the Solutions</u>

1. Weigh out roughly 2.5 g. of blue copper sulphate crystals ($CuSO_4 \cdot 5H_2O$) and dissolve them in about 15 ml. of water.
2. Make a solution of about 5 g. of thiourea in 30 ml. of water. (You may have to warm the solution gently to get all the thiourea to dissolve: do not heat strongly.) Cool and divide this solution into two roughly equal portions.

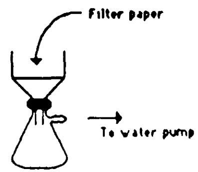
<u>Making the Complex</u>

<u>Slowly</u> add the copper sulphate solution to one of the portions of the thiourea solution while stirring continuously. A white crystalline substance (the complex) should form. If a sticky material results, rub it firmly against the side of the beaker with a glass rod and soon the white crystals will form. Let the solution stand for five minutes to allow the crystallization to be completed.

If the solution above the crystal layer is still blue add some of the other portion of thiourea (1 ml. at a time) until the blue colour disappears.

Filtration and Purification

Filter the crystals through a filter paper in a Buchner funnel and flask attached to a water pump. (See diagram below.)



When the filtration is complete, scrape the crystals off the paper and transfer them to a 250 ml. beaker. Add about 5 ml. of your remaining thiourea solution and 50 ml. of water plus 2-3 drops of dilute sulphuric acid. Warm the solution and stir until the crystals dissolve. DO NOT allow the temperature of the solution to exceed 70 °C (about as hot as you can bear on the palm of your hand) or you will be destroying the complex.

Allow the solution to cool. Crystals of the complex will reappear. Filter through a fresh piece of paper using the Buchner apparatus. Wash the crystals with a few ml. of cold water and then with about 10 ml. of ethanol. Continue to draw air through the crystals until the ethanol has evaporated and the crystals are dry. Weigh your crystals on a rough balance and record your yield. The preparation of the complex has been completed.

Notes

Theoretically three molecules of thiourea are attached to each Cu^{+} giving a complex ion with the formula $[Cu(thiourea)_3]^{+}$. The anion we have is the sulphate ion from the original $CuSO_4$. The expected formula of the complex will therefore be $[Cu(thiourea)_3]_2\ SO_4$ since the complex ion has a +1 charge and the sulphate ion has a -2 charge. There is also evidence that two molecules of water are associated with this to give an overall formula:

$$[Cu(thiourea)_3]_2\ SO_4 \cdot 2H_2O$$

Calculate the molecular weight of the complex (given that the molecular weight of thiourea is 76). Now calculate the percentage of copper in the complex.

If the complex you have made has the same % of Cu as you have calculated above, the formula of your complex is probably the same as that shown above. Differences in the % Cu could indicate that your compound is not pure

Analysing for the % Copper in Your Complex

Basic idea behind the analysis method:

1. By heating the complex with an oxidising acid like nitric acid we can do two things at once (a) destroy the thiourea ligands and (b) oxidise the Cu^{+} to Cu^{2+}
2. Having obtained a Cu^{2+} solution, we can analyse for copper ion in solution by a method similar to that in experiment 3. When iodide ions (from KI) are added to $Cu^{2+}(aq)$ solutions the Cu^{2+} is reduced to Cu^{+} and some of the iodide ions are oxidised to I_2.

   $$2\ Cu^{2+} + 4I^{-} \rightarrow 2CuI + I_2$$

   The equation shows that 2 moles of $Cu^{2+} \equiv 1$ mole of I_2.
3. The I_2 which is released can be titrated with thiosulphate as in experiment 3.

   $$2S_2O_3^{2-} \rightarrow S_4O_6^{2-} + 2e$$

   $$2I_2 + 2e \rightarrow 2I^{-}$$

hence: $$2\ S_2O_3^{2-} + I_2 \rightarrow S_4O_6^{2-} + 2I^{-}$$

2 moles thiosulphate $\equiv$ 1 mole $I_2 \equiv$ 2 moles Cu^{2+}

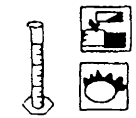
Method of Analysis

Preparing the sample for analysis

Weigh accurately a sample of your complex (between 0.5 g and 1.0 g) into a 100 ml. beaker.

Caution carry out the next part of the analysis in a fume cupboard.

Throughout this section, take care not to lose any of your sample by splashing. Take 10 ml. of concentrated nitric acid (located in the fume cupboard) and add it to 10 ml. of water. Add this diluted acid to the sample of the complex and cover the beaker with a watch glass. After a few minutes a vigorous reaction will take place.

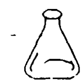


From your observations how do you know that Cu^{2+} (aq) is being made and that the nitric acid is being reduced?

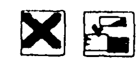
After the reaction subsides, gently boil the solution until it has evaporated almost to dryness. This gets rid of most of the unused nitric acid and also removes the ligands.

The analysis

When the beaker has cooled, add about 20 ml. of water to dissolve the Cu^{2+} compound. Transfer this to a conical flask and rinse the beaker twice with distilled water and add the rinsing to the conical flask. The pH of this solution will be too low for the next part of the analysis so it is adjusted as follows:



Add 4M ammonium solution ("ammonium hydroxide") drop by drop to the blue solution until a faint cloudiness remains even after shaking. Now add 4M ethanoic (acetic) acid drop by drop until the cloudiness just disappears and a transparent blue solution is left.



Now add about 2 g. of KI. This will react with the Cu^{2+} to give a brown solution of iodine and a white milky suspension of CuI. Titrate this with standardised thiosulphate solution until the brown almost disappears. Add a few drops of starch solution and continue the titration until the blue colour disappears and the milky white liquid (CuI in suspension) is left.

Calculate the % Cu in your complex and compare your result with the theoretical value you calculated above.

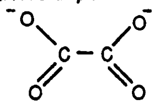
Give to your demonstrator any of your complex which is left over.

Experiment 6

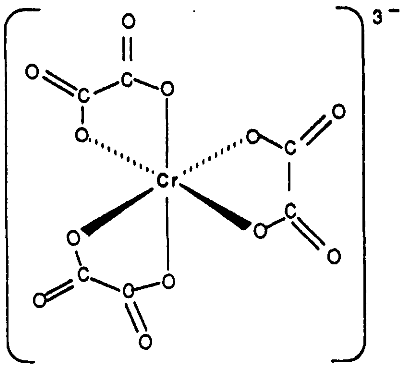
Preparation and Analysis of $K_3[Cr(C_2O_4)_3]\cdot 3H_2O$

Basic ideas behind the formation of the complex

Metal ions can accept electrons from electron pair donors. These donors are bases; sometimes called LIGANDS in inorganic systems. An example is the oxalate (ethanedioate) ion.



The oxygen atom at each end of the molecule has a lone pair of electrons which it can donate. These ions are arranged around an imaginary octahedron with the metal ion at the centre.
In this case:



The new complex ion has an all over charge of 3^- since the Cr^{3+} ion is surrounded by three oxalate ions each of which has a 2^- charge.

Experimental report

1. The balanced equations for the reactions in the experiment.
2. The percentage purity of the compound you prepared.

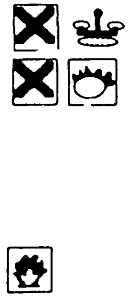
Safety Precautions

Oxalate salts are toxic and should be handled with care. Chromium compounds are potential skin irritants and can cause cancer.

Safety symbols for this experiment

IRRITANT OXIDISER FLAMMABLE CORROSIVE

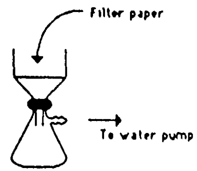
Preparation of the complex



1. Dissolve about 4.5 g of oxalic acid dihydrate, $(COOH)_2\cdot 2H_2O$ in 10 ml of warm water.
2. Weigh about 1.5 g of potassium dichromate and then add it, a little at a time, to the oxalic acid solution. There will be a fairly vigorous reaction.
3. While the reaction is subsiding, weigh out about 1.75 g of potassium oxalate $K_2C_2O_2\cdot H_2O$. Gently heat the reaction mixture until it is just beginning to boil and add the potassium oxalate and allow it to dissolve.

Note
We have now completed two operations.
(a) The chromium in the dichromate ion was in the 6+ oxidation state and the oxalic acid has reduced it to the 3+ oxidation state.
(b) The excess of the oxalate and potassium ions have now been added to complete the formation of the complex $K_3[Cr(C_2O_4)_3]\cdot 3H_2O$.

4. Cool the solution and add 2 ml of ethanol. Blue-green crystals of the complex now grow in the nearly black solution.
5. Filter off the crystals on a paper in a Buchner apparatus. (see below)



6. Wash the crystals (which are still on the filter) with a mixture of 5 ml of ethanol and 5 ml of water. Finally wash the crystals with five ml of pure ethanol. Continue to draw air through the filter to dry the crystals, but finally dry them by pressing them between two sheets of filter paper.

Notes

To clear your mind about what has been done so far, write and balance the equations for:

dichromate -> Chromium (III) (reduction)

oxalate ion -> carbon dioxide (oxidation)

oxalate ion + chromium (III) -> complex ion

Why do you think so many oxalates are hydrated?

Basic ideas behind the analysis of the complex

How pure is the complex you have made ? This can be found out by analysis, but we need to stop for a bit of theory before beginning the analysis.

The oxalate ions in the complex can be released by adding a strong base, which removes the chromium (III) as its hydroxide.

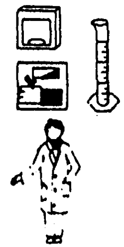
$$\text{Complex} \xrightarrow{\text{base}} Cr(OH)_3 + \text{oxalate ions}$$

These free oxalate ions can be oxidised to CO_2 (see above).
A suitable oxidizing agent is MnO_4^- which, in the presence of acid, is reduced to Mn^{2+}. However, the reaction between oxalate and permanganate is so slow that we have to operate at about 70 °C to speed things up.

$$\text{Complex} \rightarrow \text{Oxalate ions} \xrightarrow{MnO_4^-} CO_2 + Mn^{2+}$$

As MnO_4^- is intensely purple and Mn^{2+} (aq) is nearly colourless we have a built-in indicator of when the reaction is complete. One drop extra of MnO_4^- will make the solution pink.

Method of Analysis



1. Accurately weigh out a sample of your complex (in the region of 0.3 g) and transfer it to a 100 ml beaker.
2. Add 10 ml of water followed by 10 ml of 4 M KOH .
3. Cover the beaker with a watch glass and gently bring to a boil. Allow the solution to boil gently until no more green $Cr(OH)_3$ is precipitated.
   DO NOT LET THIS SOLUTION BOIL DRY.
4. This has now released the oxalate. The $Cr(OH)_3$ is a sticky substance which is difficult to filter . Ask your demonstrator to show you how to set up a fluted filter paper to speed up your filtration into a 250 ml conical flask.
5. The liquid which comes through the paper contains the oxalate which is needed for analysis. Wash the precipitate with 25 ml of hot distilled water and collect these washings in the conical flask.

<u>Note</u>

For the MnO_4^- to go to Mn^{2+} the solution must be acid, whereas the solution collected above is very alkaline.

6. Add 4M sulphuric acid until the solution is distinctly acid (test with litmus paper).
7. Heat the solution to about 70 °C (the temperature you can just bear on the palm of your hand) and titrate with the standard potassium permanganate.

<u>Note</u>

You may have to raise the temperature several times during the titration to keep it near 70 °C. The end point is a pale pink colour which lasts even when warmed up.

How pure was your complex?

$$K_3[Cr(C_2O_4)_3]\cdot 3H_2O \rightarrow 3\,(C_2O_4)^{2-}$$

1 mole 3 moles

Work out the ion electron half equations for the oxidation of oxalate to CO_2 and for the reduction of MnO_4^- to Mn^{2+} and hence establish how many moles of oxalate are equivalent to 1 mole of MnO_4^-. How many moles of MnO_4^- are equivalent therefore to 1 mole of complex? This is the theroretical value.

Work out your experimental value for the moles of MnO_4^- equivalent to 1 mole of complex, and hence the purity of your complex.

APPENDIX A - 4 - PRE QUESTIONNAIRE

]

FIRST YEAR LABORATORY SURVEY

NAME ______________________________________LAB-DAY__________(Mon; Tue; etc.)

We are carrying out a survey of Laboratory Work in the First Year. To help us with this, we would like to know what you think of any <u>previous</u> laboratory work you have experienced before this session's laboratories. Your sincere opinions will be valued and they will have no bearing whatsoever on your laboratory performance or test mark in this laboratory course. Firstly, we would like to know some information about your <u>previous</u> experience in chemistry.

1) What is your HIGHEST qualification in chemistry?

"O" GRADE	☐	**"O" LEVEL**	☐	**"H" GRADE**	☐
"A" LEVEL	☐	**6th YEAR STUDIES**	☐	**OTHER**	☐

2) How many years of secondary schooling did you complete?
____

3) In your <u>previous</u> laboratory work have you experienced practical work which was done (tick more than one if required)

☐ individually? ☐ in small groups? ☐ by teacher demonstration?

The grid below is for you to make judgements on a series of scales. If you have found previous laboratory work extremely boring you tick the box as follows.

INTERESTING	☐	☐	☐	☐	☐	BORING

If you have found previous laboratory work fairly interesting you would tick the box as follow:

INTERESTING	☐	☐	☐	☐	☐	BORING

Please tick <u>one</u> of the boxes in each line, according to your opinion of any <u>previous</u> laboratory work you have experienced.

MEANINGFUL	☐	☐	☐	☐	☐	MEANINGLESS
DIFFICULT	☐	☐	☐	☐	☐	EASY
WASTE OF TIME	☐	☐	☐	☐	☐	USEFUL
ENJOYABLE	☐	☐	☐	☐	☐	UNENJOYABLE
FRUSTATING	☐	☐	☐	☐	☐	SATISFYING
INTERESTING	☐	☐	☐	☐	☐	BORING
CONFUSING	☐	☐	☐	☐	☐	UNDERSTANDABLE
VARIED	☐	☐	☐	☐	☐	REPETITIVE
ADEQUATE WRITTEN INSTRUCTIONS	☐	☐	☐	☐	☐	INADEQUATE WRITTEN INSTRUCTIONS
RUSHED	☐	☐	☐	☐	☐	LEISURELY
WELL-ORGANISED	☐	☐	☐	☐	☐	DISORGANISED

THANK YOU FOR YOUR CO-OPERATION

APPENDIX A - 5 - POST QUESTIONNAIRE

FIRST YEAR LABORATORY SURVEY

NAME____________________________LAB DAY__________(Mon;Tue;etc)

Continuing our survey of laboratory work in the First Year, we would like to know what you thought of the practical work you have experienced during this term.
Your frank opinions will be valued and they will be treated in strict confidence and will not be used in any way to alter the assessment of your performance or test marks in this laboratory course.
The grid below is for you to make judgements on a series of scales. If you have found the laboratory work extremely boring you would tick the box as follows:

INTERESTING						BORING

If you have found the laboratory work fairly interesting you would tick the box as follow:

INTERESTING						BORING

Please tick one of the boxes in each line, according to your opinion of the laboratory work you have experienced this term:

MEANINGFUL						MEANINGLESS
DIFFICULT						EASY
WASTE OF TIME						USEFUL
ENJOYABLE						UNENJOYABLE
FRUSTATING						SATISFYING
INTERESTING						BORING
CONFUSING						UNDERSTANDABLE
VARIED						REPETITIVE
ADEQUATE WRITTEN INSTRUCTIONS						INADEQUATE WRITTEN INSTRUCTIONS
RUSHED						LEISURELY
WELL-ORGANISED						DISORGANISED

We would appreciate very much if you could give us any suggestions or comments about this laboratory course. Use the other side of this page if necessary.

THANK YOU FOR YOUR CO-OPERATION

APPENDIX A - 6 - DIARY ONE

DIARY-1 LAB-DAY__________(Mon;Tue; etc)

1) What experiment did you do to-day? [ ]

1a. Were you starting it to-day? [ ]

1b. or finishing it from the previous day? [ ]

2) Which kind of written instruction did you use?

Manual? ____________________ or worksheet? ______________________________

3) Were the written instructions well-organised? [ ]

4) Were the written instructions easy to follow? [ ]

5) Did you find any word, sentence or paragraph that you didn't understand? [ ]

5a. If so, please specify____

6) Were the objectives of the experiment clear to you? [ ]

7) Did the written instructions have all the information necessary for understanding the experiment? [ ]

8) Did you have to ask for any help to interpret the instructions? [ ]

9) Did you have enough time to do the experiment? [ ]

10) Were the written instructions helpful for completing your report? [ ]

11) Did the theoretical lectures help you to understand this experiment? [ ]

12) When you finished the laboratory to-day had you learned anything in particular? [ ]

12.a If so, please specify____

We would appreciate very much if you could give us any suggestion or comments about the laboratory worksheet or manual (written instructions) for to-day's experiment. Use the other side of this page if necessary.

THANK YOU FOR YOUR CO-OPERATION

APPENDIX A - 7 - DIARY TWO

DIARY-2 LAB-DAY________(Mon;Tue; etc)

`1) What experiment did you do to-day? ____________
Were you starting it to-day? ____________
or finishing it from the previous day? ____________
2)When did the point of to-day's experiment become clear to you?
at the beginning?____________ part way through?__________
at the end? __________ or not at all? ______________

3) Did you find the experiment interesting? [ ]

4) Did you find the experiment difficult? [ ]

5) Was the Laboratory session well-organised? [ ]

6) Did you enjoy doing this experiment? [ ]

7) Did you think it was a waste of time? [ ]

8) Did you gain some satisfaction from this laboratory's work? [ ]

9) Did you have enough time to complete the experiment? [ ]

10)Did you find the experiment itself, confusing in any way? [ ]

11)Did you get all the help you needed from the staff and demonstrators available? [ ]

12)Have you already had a lecture covering the topic of to-day's experiment? [ ]

13)Were all the chemicals & equipment that you needed to-day, easily located? [ ]

If not, please specify______________________________________

13)Did you encounter any new equipment to-day? [ ]

14)If you did, were you taught how to use it? [ ]

15)Are you confident that you will be able to use it again next time? [ ]

16)Were you in any doubt about what was expected of you in your laboratory report? [ ]

17)Have you learned anything in particular from this experiment to-day? [ ]

If so,please specify______________________________________

We would appreciate very much if you could give us any suggestions or comments about this experiment. Use the other side of this page if necessary.

APPENDIX A - 8 - FREQUENCIES OF RESPONSES - DIARY ONE / (1/3)

3. WERE THE WRITTEN INSTRUCTIONS WELL-ORGANISED?

	HGRD		SYS		GLOBAL		GLBL
EXP	Y (%)	N (%)	Y (%)	N (%)	Y (%)	N (%)	%DIF
1/O	30 (88)	1 (3)	12 (92)	0 (0)	49 (91)	1 (2)	89
1/N	22 (92)	0 (0)	18 (100)	0 (0)	43 (94)	0 (0)	94
2/O	16 (89)	0 (0)	18 (90)	1 (5)	41 (91)	1 (2)	89
2/N	19 (95)	0 (0)	17 (100)	0 (0)	40 (95)	0 (0)	95
3/O	35 (92)	0 (0)	18 (90)	1 (5)	57 (95)	2 (3)	92
3/N	19 (91)	2 (10)	11 (92)	0 (0)	33 (92)	2 (6)	86
4/O	28 (100)	0 (0)	14 (88)	1 (6)	45 (93)	2 (4)	89
4/N	32 (97)	0 (0)	16 (100)	0 (0)	51 (98)	0 (0)	98
5/O	6 (75)	1 (13)	6 (100)	0 (0)	13 (87)	1 (7)	80
5/N	6 (86)	1 (14)	4 (100)	0 (0)	12 (92)	1 (8)	84
6/O	0 (0)	0 (0)	2 (67)	1 (33)	3 (75)	1 (25)	50
6/N	3 100)	0 (0)	6 (100)	0 (0)	9 (100)	0 (0)	100

4. WERE THE WRITTEN INSTRUCTIONS EASY TO FOLLOW?

	HGRD		SYS		GLOBAL		GLBL
EXP	Y (%)	N (%)	Y (%)	N (%)	Y (%)	N (%)	%DIF
1/O	30 (88)	1 (3)	13 (100)	0 (0)	49 (91)	1 (2)	89
1/N	22 (92)	0 (0)	18 (100)	0 (0)	43 (94)	0 (0)	94
2/O	17 (94)	0 (0)	20 (100)	0 (0)	41 (91)	2 (4)	89
2/N	20 (95)	0 (0)	14 (82)	0 (0)	38 (90)	0 (0)	90
3/O	33 (87)	2 (5)	18 (90)	0 (0)	56 (89)	2 (3)	86
3/N	18 (86)	3 (14)	12 (100)	0 (0)	33 (92)	3 (8)	84
4/O	25 (89)	1 (4)	13 (81)	1 (6)	42 (87)	2 (4)	83
4/N	30 (91)	1 (3)	13 (81)	2 (13)	46 (89)	3 (6)	83
5/O	5 (63)	2 (25)	6 (100)	0 (0)	12 (80)	2 (13)	67
5/N	6 (86)	1 (14)	4 (100)	0 (0)	12 (92)	1 (8)	84
6/O	0 (0)	0 (0)	2 (67)	1 (33)	3 (75)	1 (25)	50
6/N	3 (100)	0 (0)	5 (83)	1 (17)	8 (89)	1 (11)	78

5. DID YOU FIND ANY WORD, SENTENCE OR PARAGRAPH THAT YOU DIDN'T UNDERSTAND?

	HGRD		S Y S		GLOBAL		GLBL
EXP	Y (%)	N (%)	Y (%)	N (%)	Y (%)	N (%)	%DIF
1/O	0 (0)	34 (100)	1 (8)	12 (92)	1 (2)	53 (98)	96
1/N	1 (4)	21 (88)	0 (0)	17 (94)	1 (2)	41 (89)	87
2/O	2 (11)	16 (89)	0 (0)	20 (100)	2 (4)	43 (96)	92
2/N	1 (5)	20 (95)	0 (0)	16 (94)	1 (2)	40 (95)	93
3/O	5 (13)	31 (82)	0 (0)	19 (95)	5 (8)	55 (87)	79
3/N	2 (10)	18 (86)	1 (8)	10 (83)	3 (8)	31 (86)	78
4/O	4 (14)	23 (82)	2 (13)	13 (81)	7 (15)	39 (81)	66
4/N	1 (3)	30 (91)	0 (0)	16 (100)	1 (2)	48 (92)	90
5/O	1 (13)	7 (88)	1 (17	5 (83)	2 (13)	13 (87)	74
5/N	0 (0)	6 (86)	0 (0)	4 (100)	1 (8)	11 (85)	77
6/O	0 (0)	0 (0)	0 (0)	3 (100)	0 (0)	4 (100)	100
6/N	0 (0)	3 (100)	1 (16)	4 (84)	1 (11)	7 (78)	67

6. WERE THE OBJECTIVES OF THE EXPERIMENT CLEAR TO YOU?

	HGRD		SYS		GLOBAL		GLBL
EXP	Y (%)	N (%)	Y (%)	N (%)	Y (%)	N (%)	%DIF
1/O	29 (85)	1 (3)	12 (92)	1 (8)	48 (89)	2 (4)	85
1/N	19 (79)	2 (8)	16 (89)	2 (11)	38 (83)	4 (9)	74
2/O	12 (67)	6 (33)	14 (70)	5 (25)	30 (67)	12 (27)	40
2/N	16 (76)	4 (19)	14 (82)	2 (12)	34 (81)	6 (14)	67
3/O	35 (92)	3 (8)	16 (80)	3 (15)	56 (89)	6 (10)	79
3/N	16 (76)	3 (14)	11 (92)	0 (0)	30 (83)	3 (8)	75
4/O	26 (93)	2 (7)	15 (94)	1 (6)	44 (92)	4 (8)	84
4/N	30 (91)	3 (9)	15 (94)	1 (6)	48 (92)	4 (8)	84
5/O	6 (75)	1 (13)	6 (100)	0 (0)	13 (87)	1 (7)	80
5/N	6 (86)	1 (14)	3 (75)	1 (25)	11 (85)	2 (15)	70
6/O	0 (0)	0 (0)	2 (67)	1 (33)	3 (75)	1 (25)	50
6/N	3 (100)	0 (0)	5 (83)	1 (17)	8 (89)	1 (11)	78

APPENDIX A - 8 / (2/3)

7. DID THE WRITTEN INSTRUCTIONS HAVE ALL THE INFORMATION NECESSARY FOR UNDERSTANDING THE EXPERIMENT?

	HGRD		SYS		GLOBAL		GLBL
EXP	Y (%)	N (%)	Y (%)	N (%)	Y (%)	N (%)	%DIF
1/O	30 (88)	2 (6)	12 (92)	1 (8)	49 (91)	3 (6)	43
1/N	19 (79)	3 (13)	16 (89)	2 (11)	38 (83)	5 (11)	27
2/O	9 (50)	8 (44)	3 (15)	15 (75)	16 (36)	26 (58)	-22
2/N	18 (86)	3 (14)	12 (71)	4 (24)	33 (79)	8 (20)	59
3/O	31 (82)	6 (16)	15 (75)	5 (25)	50 (79)	12 (19)	60
3/N	15 (71)	5 (24)	10 (83)	2 (17)	28 (78)	7 (19)	59
4/O	22 (79)	5 (18)	12 (75)	4 (25)	36 (75)	11 (23)	72
4/N	30 (91)	2 (6)	12 (75)	4 (25)	45 (87)	6 (12)	75
5/O	6 (75)	1 (13)	6 (100)	0 (0)	13 (87)	1 (7)	80
5/N	6 (86)	1 (14)	4 (100)	0 (0)	12 (92)	1 (8)	84
6/O	0 (0)	0 (0)	2 (67)	1 (33)	2 (50)	2 (50)	0
6/N	1 (33)	2 (67)	4 (67)	2 (33)	5 (56)	4 (44)	12

8. DID YOU HAVE TO ASK FOR ANY HELP TO INTERPRET THE INSTRUCTIONS?

	HGRD		SYS		GLOBAL		GLBL
EXP	Y (%)	N (%)	Y (%)	N (%)	Y (%)	N (%)	%DIF
1/O	7 (21)	26 (77)	4 (31)	9 (69)	12 (22)	41 (76)	-54
1/N	4 (17)	17 (71)	6 (33)	12 (67)	10 (22)	32 (70)	-48
2/O	9 (50)	9 (50)	9 (45)	11 (55)	20 (44)	25 (56)	-12
2/N	4 (19)	17 (81)	2 (12)	14 (82)	6 (14)	35 (83)	-69
3/O	8 (21)	29 (76)	6 (30)	14 (70)	15 (24)	46 (73)	-49
3/N	11 (52)	10 (48)	6 (50)	6 (50)	17 (47)	19 (53)	-6
4/O	9 (32)	19 (68)	4 (25)	12 (75)	14 (29)	34 (71)	-42
4/N	10 (30)	23 (70)	6 (38)	10 (63)	18 (35)	34 (65)	-30
5/O	4 (50)	4 (50)	4 (67)	2 (33)	8 (53)	7 (47)	6
5/N	2 (29)	5 (71)	1 (25)	3 (75)	4 (31)	9 (69)	-38
6/O	0 (0)	0 (0)	0 (0)	3 (10(	1 (25)	3 (75)	-50
6/N	2 (67)	1 (33)	2 (33)	4 (67)	4 (44)	5 (56)	-12

9. DID YOU HAVE ENOUGH TIME TO DO THE EXPERIMENT?

	HGRD		S Y S		GLOBAL		GLBL
EXP	Y (%)	N (%)	Y (%)	N (%)	Y (%)	N (%)	%DIF
1/O	33 (97)	0 (0)	10 (77)	3 (23)	49 (91)	4 (7)	84
1/N	20 (83)	2 (8)	16 (89)	2 (11)	39 (85)	4 (9)	76
2/O	6 (33)	10 (56)	6 (30)	13 (65)	14 (31)	28 (62)	-31
2/N	15 (71)	6 (29)	3 (18)	11 (65)	21 (50)	18 (43)	7
3/O	20 (53)	15 (40)	15 (75)	5 (25)	39 (62)	21 (33)	29
3/N	6 (29)	13 (62)	11 (92)	1 (8)	18 (50)	16 (44)	6
4/O	9 (32)	19 (68)	8 (50)	8 (50)	19 (40)	29 (60)	-20
4/N	13 (39)	18 (30)	8 (50)	8 (50)	23 (44)	27 (52)	-8
5/O	3 (38)	5 (62)	4 (67)	2 (33)	7 (47)	8 (53)	-6
5/N	4 (57)	3 (43)	1 (25)	3 (75)	7 (54)	6 (46)	8
6/O	0 (0)	0 (0)	1 (33)	2 (67)	1 (25)	3 (75)	-50
6/N	1 (33)	2 (67)	1 (17)	5 (83)	2 (22)	7 (78)	-56

10. WERE THE WRITTEN INSTRUCTIONS HELPFUL FOR COMPLETING YOUR REPORT?

	HGRD		S Y S		GLOBAL		GLBL
EXP	Y (%)	N (%)	Y (%)	N (%)	Y (%)	N (%)	%DIF
1/O	28 (82)	4 (12)	11 (85)	1 (8)	45 (83)	6 (11)	72
1/N	18 (75)	4 (17)	18 (100)	0 (0)	39 (85)	4 (9)	76
2/O	13 (72)	3 (17)	10 (50)	8 (40)	28 (62)	13 (29)	33
2/N	14 (67)	3 (14)	15 (88)	0 (0)	33 (79)	3 (7)	72
3/O	28 (74)	4 (11)	15 (75)	4 (20)	46 (73)	9 (14)	59
3/N	15 (71)	3 (14)	10 (83)	1 (8)	28 (78)	4 (11)	67
4/O	19 (68)	5 (18)	12 (75)	3 (19)	33 (69)	9 (19)	50
4/N	26 (79)	3 (9)	13 (81)	2 (13)	42 (81)	5 (10)	71
5/O	8 (10(	0 (0)	5 (83)	1 (17)	14 (93)	1 (7)	86
5/N	6 (86)	1 (14)	3 (75)	0 (0)	11 (85)	1 (8)	77
6/O	0 (0)	0 (0)	2 (67)	1 (33)	2 (50)	2 (50)	0
6/N	1 (33)	2 (33)	3 (50)	2 (33)	4 (44)	4 (44)	0

APPENDIX A - 8 / (3/3)

11.DID THE THEORETICAL LECTURES HELP YOU TO UNDERSTAND THIS EXPERIMENT?

	HGRD		S Y S		GLOBAL		GLBL
EXP	Y (%)	N (%)	Y (%)	N (%)	Y (%)	N (%)	%DIF
1/O	11 (32)	19 (56)	9 (69)	3 (23)	25 (48)	24 (44)	4
1/N	4 (17)	17 (71)	5 (28)	13 (72)	10 (22)	32 (70)	-48
2/O	2 (11)	15 (83)	8 (40)	11 (55)	12 (27)	28 (62)	-35
2/N	4 (19)	16 (76)	5 (29)	11 (65)	10 (24)	30 (71)	-47
3/O	9 (24)	27 (71)	5 (25)	14 (70)	16 (25)	44 (70)	-45
3/N	2 (10	17 (81)	6 (50)	6 (50)	9 (25)	24 (67)	-42
4/O	2 (7)	24 (86)	6 (38)	10 (62)	9 (19)	37 (77)	-68
4/N	6 (18)	25 (76)	5 (31)	10 (63)	11 (21)	38 (73)	-52
5/O	0 (0)	8 (100)	1 (17)	4 (67)	1 (7)	13 (87)	-80
5/N	7 (100)	0 (0)	1 (25)	3 (75)	9 (69)	4 (31)	38
6/O	0 (0)	0 (0)	0 (0)	3 (100)	0 (0)	3 (75)	-75
6/N	0 (0)	3 (100)	1 (17)	4 (67)	1 (11)	7 (78)	-67

12.WHEN YOU FINISHED THE LABORATORY TO-DAY HAD YOU LEARNED ANYTHING IN PARTICULAR?

	HGRD		S Y S		GLOBAL		GLBL
EXP	Y (%)	N (%)	Y (%)	N (%)	Y (%)	N (%)	%DIF
1/O	10 (29)	21 (62)	4 (31)	8 (62)	16 (30)	34 (63)	-33
1/N	6 (25)	15 (63)	6 (33)	11 (61)	14 (30)	27 (59)	-29
2/O	4 (22)	14 (78)	6 (30)	14 (70)	14 (31)	31 (69)	-38
2/N	10 (48)	9 (43)	7 (41)	9 (53)	17 (41)	22 (42)	-1
3/O	15 (40)	20 (53)	4 (20)	16 (80)	20 (32)	40 (64)	-32
3/N	5 (24)	16 (76)	6 (50)	6 (50)	13 (36)	23 (64)	-28
4/O	7 (25)	20 (71)	7 (44)	9 (56)	15 (31)	32 (67)	-36
4/N	11 (33)	22 (67)	5 (31)	11 (69)	17 (33)	34 (65)	-32
5/O	3 (38)	5 (63)	2 (33)	4 (67)	6 (40)	9 (60)	-20
5/N	1 (14)	6 (86)	2 (50)	2 (50)	4 (31)	9 (69)	-38
6/O	0 (0)	0 (0)	0 (0)	3 (100)	0 (0)	4 (100)	-100
6/N	1 (33)	2 (67)	0 (0)	5 (83)	1 (11)	7 (78)	-67

APPENDIX A - 9 - FREQUENCIES OF RESPONSES - DIARY TWO / (1/4)

3. DID YOU FIND THE EXPERIMENT INTERESTING?

	HGRD		S Y S		GLOBAL		
EXP	Y (%)	N (%)	Y (%)	N (%)	Y (%)	N (%)	%DIF
1/O	30 (86)	2 (6)	16 (94)	0 (0)	48 (89)	2 (4)	85
1/N	15 (79)	2 (11)	7 (70)	1 (10)	30 (81)	3 (8)	73
2/O	9 (38)	13 (54)	3 (33)	3 (33)	16 (41)	18 (46)	-5
2/N	14 (66)	8 (32)	7 (50)	3 (21)	23 (55)	11 (26)	29
3/O	30 (68)	8 (18)	15 (79)	2 (11)	47 (71)	10 (15)	56
3/N	13 (77)	4 (24)	10 (77)	3 (23)	29 (78)	7 (19)	59
4/O	16 (49)	13 (39)	7 (70)	2 (20)	30 (58)	16 (31)	27
4/N	18 (58)	10 (32)	13 (65)	4 (20)	33 (62)	14 (26)	36
5/O	9 (90)	1 (10)	2 (67)	0 (0)	11 (79)	1 (7)	72
5/N	4 (100)	0 (0)	1 (50)	0 (0)	6 (86)	0 (0)	86
6/O	2 (33)	4 (67)	1 (100)	0 (0)	4 (50)	4 (50)	0
6/N	2 (33)	4 (67)	1 (100)	0 (0)	4 (50)	4 (50)	0

4.DID YOU FIND THE EXPERIMENT DIFFICULT?

	HGRD		S Y S		GLOBAL		
EXP	Y (%)	N (%)	Y (%)	N (%)	Y (%)	N (%)	%DIF
1/O	3 (9)	28 (80)	1 (6)	14 (82)	4 (7)	44 (82)	-75
1/N	2 (11)	16 (84)	0 (0)	10 (100)	2 (5)	34 (92)	-87
2/O	6 (25)	17 (71)	2 (22)	6 (67)	9 (23)	27 (69)	-46
2/N	2 (8)	22 (88)	3 (21)	10 (71)	5 (12)	35 (83)	-71
3/O	6 (14)	29 (66)	2 (11)	17 (89)	8 (12)	49 (74)	-62
3/N	5 (29)	9 (53)	2 (15)	11 (85)	9 (24)	24 (65)	-41
4/O	8 (24)	23 (52)	1 (10)	9 (90)	9 (17)	41 (79)	-62
4/N	1 (3)	22 (71)	0 (0)	20 (100)	1 (2)	44 (83)	-81
5/O	5 (50)	5 (50)	0 (0)	3 (100)	5 (36)	9 (64)	-28
5/N	0 (0)	4 (100)	0 (0)	2 (100)	0 (0)	7 (100)	-100
6/O	2 (33)	4 (67)	0 (0)	1 (100)	2 (25)	6 (75)	-50
6/N	3 (50)	2 (33)	2 (40)	3 (60)	6 (50)	5 (42)	8

5.WAS THE LABORATORY SESSION WELL-ORGANISED?

	HGRD		S Y S		GLOBAL		
EXP	Y (%)	N (%)	Y (%)	N (%)	Y (%)	N (%)	%DIF
1/O	23 (66)	6 (17)	13 (77)	0 (0)	38 (70)	6 (11)	59
1/N	13 (68)	1 (5)	4 (40)	4 (40)	24 (65)	5 (14)	51
2/O	13 (54)	8 (33)	5 (56)	4 (44)	22 (56)	14 (36)	20
2/N	16 (64)	7 (28)	9 (64)	3 (21)	26 (62)	12 (29)	33
3/O	33 (75)	9 (21)	16 (84)	1 (5)	52 (79)	10 (15)	64
3/N	9 (53)	7 (41)	6 (46)	4 (31)	22 (60)	11 (30)	30
4/O	24 (73)	6 (18)	5 (50)	4 (40)	37 (71)	10 (19)	52
4/N	23 (74)	3 (10)	17 (85)	1 (5)	42 (79)	4 (8)	71
5/O	7 (70)	1 (10)	2 (67)	0 (0)	10 (71)	1 (7)	64
5/N	4 (100)	0 (0)	1 (50)	0 (0)	6 (86)	0 (0)	86
6/O	6 (100)	0 (0)	1 (100)	0 (0)	8 (100)	0 (0)	100
6/N	4 (67)	1 (17)	4 (80)	1 (20)	9 (75)	2 (17)	58

6.DID YOU ENJOY DOING THIS EXPERIMENT?

	HGRD		S Y S		GLOBAL		
EXP	Y (%)	N (%)	Y (%)	N (%)	Y (%)	N (%)	%DIF
1/O	32 (91)	3 (9)	16 (94)	0 (0)	50 (93)	3 (6)	87
1/N	17 (90)	1 (5)	8 (80)	1 (10)	33 (89)	2 (5)	84
2/O	10 (42)	10 (42)	7 (78)	2 (22)	21 (54)	13 (33)	21
2/N	17 (68)	7 (28)	8 (57)	3 (21)	28 (67)	10 (24)	43
3/O	30 (68)	9 (21)	15 (79)	2 (11)	47 (71)	12 (18)	53
3/N	13 (77)	3 (18)	9 (69)	4 (31)	29 (78)	7 (19)	61
4/O	16 (49)	13 (39)	7 (70)	2 (20)	31 (60)	16 (31)	29
4/N	21 (68)	9 (30)	10 (50)	9 (45)	33 (62)	18 (34)	28
5/O	6 (60)	3 (30)	3 (100)	0 (0)	9 (64)	4 (29)	35
5/N	4 (100)	0 (0)	2 (100)	0 (0)	7 (100)	0 (0)	100
6/O	3 (50)	3 (50)	1 (100)	0 (0)	5 (63)	3 (37)	26
6/N	5 (83)	1 (17)	3 (60)	2 (40)	9 (75)	3 (25)	50

APPENDIX A - 9 / (2/4)

7.DID YOU THINK IT WAS A WASTE OF TIME?

	HGRD		S Y S		GLOBAL		
EXP	Y (%)	N (%)	Y (%)	N (%)	Y (%)	N (%)	%DIF
1/O	0 (0)	34 (97)	0 (0)	17 (100)	0 (0)	53 (98)	-98
1/N	1 (5)	18 (95)	0 (0)	10 (100)	1 (3)	36 (97)	-94
2/O	3 (13)	18 (75)	0 (0)	9 (100)	3 (8)	33 (85)	-77
2/N	0 (0)	23 (92)	0 (0)	13 (93)	0 (0)	39 (93)	-93
3/O	1 (2)	43 (98)	0 (0)	18 (95)	1 (2)	64 (97)	-95
3/N	1 (6)	16 (94)	1 (8)	12 (92)	2 (5)	35 (95)	-90
4/O	3 (9)	28 (85)	0 (0)	10 (100)	3 (6)	47 (90)	-84
4/N	2 (7)	28 (90)	1 (5)	18 (90)	3 (6)	48 (91)	-85
5/O	1 (10)	9 (90)	0 (0)	3 (100)	1 (7)	13 (93)	-86
5/N	0 (0)	4 (100)	0 (0)	2 (100)	0 (0)	7 (100)	-100
6/O	1 (17)	5 (83)	0 (0)	1 (100)	1 (13)	7 (87)	-74
6/N	1 (17)	5 (83)	0 (0)	5 (100)	1 (8)	11 (92)	-84

8.DID YOU GAIN SOME SATISFACTION FROM THIS LABORATORY'S WORK?

	HGRD		S Y S		GLOBAL		
EXP	Y (%)	N (%)	Y (%)	N (%)	Y (%)	N (%)	%DIF
1/O	31 (89)	2 (6)	11 (65)	1 (6)	44 (82)	3 (6)	76
1/N	17 (90)	1 (5)	8 (80)	2 (20)	33 (89)	3 (8)	81
2/O	13 (54)	8 (33)	4 (44)	4 (44)	20 (51)	14 (36)	15
2/N	18 (72)	6 (24)	8 (57)	4 (29)	28 (67)	11 (26)	41
3/O	35 (80)	8 (18)	17 (90)	1 (5)	54 (82)	10 (15)	67
3/N	12 (71)	5 (29)	10 (77)	3 (23)	28 (76)	8 (22)	54
4/O	20 (61)	10 (30)	9 (90)	1 (10)	37 (71)	12 (23)	48
4/N	21 (68)	7 (23)	16 (80)	1 (5)	39 (74)	8 (15)	59
5/O	6 (60)	4 (40)	2 (67)	0 (0)	8 (57)	5 (36)	21
5/N	3 (75)	0 (0)	2 (100)	0 (0)	6 (86)	0 (0)	86
6/O	3 (50)	2 (33)	1 (100)	0 (0)	5 (63)	2 (25)	38
6/N	2 (33)	4 (67)	2 (40)	1 (20)	5 (42)	5 (42)	0

9.DID YOU HAVE ENOUGH TIME TO COMPLETE THE EXPERIMENT?

	HGRD		S Y S		GLOBAL		
EXP	Y (%)	N (%	Y (%)	N (%)	Y (%)	N (%	%DIF
1/O	29 (83)	5 (14)	16 (94)	1 (6)	47 (87)	6 (4)	83
1/N	14 (74)	4 (21)	9 (90)	1 (10)	31 (84)	5 (14)	70
2/O	10 (42)	13 (54)	2 (22)	7 (78)	17 (44)	21 (54)	-10
2/N	3 (12)	22 (88)	1 (7)	12 (86)	5 (12)	36 (86)	-74
3/O	24 (54)	19 (43)	13 (68)	6 (32)	40 (61)	25 (38)	23
3/N	12 (71)	5 (29)	10 (76)	3 (23)	26 (70)	10 (27)	43
4/O	20 (61)	13 (39)	6 (60)	3 (30)	35 (67)	16 (31)	36
4/N	9 (29)	22 (71)	13 (65)	7 (35)	24 (45)	29 (55)	-10
5/O	3 (30)	7 (70)	1 (33)	2 (67)	5 (36)	9 (64)	-28
5/N	1 (25)	3 (75)	1 (50)	1 (50)	3 (43)	4 (57)	-14
6/O	4 (67)	2 (33)	1 (100)	0 (0)	6 (75)	2 (25)	50
6/N	1 (17)	4 (67)	1 (20)	4 (80)	3 (25)	8 (67)	-42

10.DID YOU FIND THE EXPERIMENT ITSELF, CONFUSING IN ANY WAY?

	HGRD		S Y S		GLOBAL		
EXP	Y (%)	N (%)	Y (%)	N (%)	Y (%)	N (%)	%DIF
1/O	4 (11)	29 (83)	1 (6)	15 (88)	5 (9)	46 (85)	-76
1/N	3 (16)	16 (84)	4 (40)	6 (60)	7 (19)	30 (81)	-62
2/O	6 (25)	18 (75)	6 (67)	3 (33)	12 (31)	27 (69)	-38
2/N	3 (12)	21 (84)	4 (29)	10 (71)	7 (17)	34 (81)	-64
3/O	22 (50)	16 (36)	2 (10)	17 (90)	25 (38)	35 (53)	-15
3/N	5 (29)	11 (65)	1 (8)	12 (92)	6 (16)	29 (78)	-62
4/O	8 (24)	24 (73)	3 (30)	7 (70)	12 (23)	39 (75)	-52
4/N	8 (26)	23 (74)	1 (5)	18 (90)	9 (17)	43 (81)	-64
5/O	4 (40)	6 (60)	1 (33)	2 (67)	5 (36)	9 (64)	-28
5/N	0 (0)	4 (100)	0 (0)	2 (100)	1 (14)	6 (86)	-72
6/O	3 (50)	3 (50)	0 (0)	1 (100)	3 (38)	5 (62)	-24
6/N	3 (50)	2 (33)	1 (20)	2 (40)	5 (42)	4 (33)	9

APPENDIX A - 9 (3/4)

11.DID YOU GET ALL THE HELP YOU NEEDED FORM THE STAFF AND DEMONSTRATORS AVAILABLE?

	HGRD		S Y S		GLOBAL		
EXP	Y (%)	N (%)	Y (%)	N (%)	Y (%)	N (%)	%DIF
1/O	33 (94)	1 (3)	17 (100)	0 (0)	52 (96)	1 (2)	94
1/N	17 (90)	2 (10)	10 (100)	0 (0)	35 (95)	2 (5)	90
2/O	20 (83)	3 (13)	8 (89)	1 (11)	33 (85)	5 (13)	72
2/N	19 (76)	4 (16)	12 (86)	1 (7)	33 (79)	6 (14)	65
3/O	40 (91)	2 (5)	18 (95)	1 (5)	61 (92)	3 (5)	87
3/N	14 (82)	2 (12)	12 (92)	1 (8)	33 (89)	3 (8)	81
4/O	30 (91)	2 (6)	9 (90)	0 (0)	48 (92)	2 (4)	88
4/N	27 (87)	3 (10)	18 (90)	1 (5)	47 (89)	4 (8)	81
5/O	9 (90)	1 (10)	2 (67)	1 (33)	12 (86)	2 (14)	72
5/N	4 (100)	0 (0)	1 (50)	0 (0)	6 (86)	0 (0)	86
6/O	6 (100)	0 (0)	1 (100)	0 (0)	7 (88)	1 (12)	76
6/N	5 (83)	1 (17)	4 (80)	1 (20)	10 (83)	2 (17)	66

12.HAVE YOU ALREADY HAD A LECTURE COVERING THE TOPIC OF TO-DAY'S EXPERIMENT?

	HGRD		S Y S		GLOBAL		
EXP	Y (%)	N (%)	Y (%)	N (%)	Y (%)	N (%)	%DIF
1/O	6 (17)	28 (80)	4 (24)	10 (59)	11 (20)	39 (72)	-52
1/N	3 (16)	16 (84)	2 (20)	8 (80)	9 (24)	28 (76)	-67
2/O	0 (0)	23 (96)	0 (0)	8 (89)	0 (0)	37 (95)	-95
2/N	0 (0)	25 (100)	1 (7)	13 (93)	2 (5)	40 (95)	-90
3/O	7 (16)	37 (84)	1 (5)	17 (90)	8 (12)	57 (86)	-74
3/N	0 (0)	16 (94)	0 (0)	12 (92)	0 (0)	35 (95)	-95
4/O	1 (3)	29 (88)	2 (20)	8 (80)	6 (12)	43 (83)	-71
4/N	2 (7)	29 (93)	1 (5)	17 (85)	3 (6)	48 (91)	-85
5/O	1 (10)	9 (90)	0 (0)	3 (100)	1 (7)	13 (93)	-86
5/N	0 (0)	4 (100)	0 (0)	2 (100)	0 (0)	7 (100)	-100
6/O	1 (17)	5 (83)	0 (0)	1 (100)	1 (13)	7 (87)	-74
6/N	0 (0)	6 (100)	0 (0)	5 (100)	0 (0)	12 (100)	-100

13.WERE ALL THE CHEMICALS AND EQUIPMENT THAT YOU NEEDED TO-DAY, EASILY LOCATED?

	HGRD		S Y S		GLOBAL		
EXP	Y (%)	N (%)	Y (%)	N (%)	Y (%)	N (%)	%DIF
1/O	29 (83)	4 (11)	17 (100)	0 (0)	47 (87)	44 (7)	80
1/N	14 (74)	5 (26)	6 (60)	2 (20)	27 (73)	8 (22)	51
2/O	15 (63)	7 (29)	5 (56)	4 (44)	24 (62)	13 (33)	29
2/N	17 (68)	8 (32)	12 (86)	2 (14)	31 (74)	11 (26)	48
3/O	37 (84)	7 (16)	16 (84)	3 (16)	56 (85)	10 (15)	70
3/N	12 (71)	4 (24)	11 (85)	2 (15)	30 (81)	6 (16)	65
4/O	30 (91)	3 (9)	9 (90)	1 (10)	47 (90)	4 (8)	82
4/N	25 (81)	4 (13)	19 (95)	1 (5)	46 (87)	5 (9)	78
5/O	10 (100)	0 (0)	3 (100)	0 (0)	14 (100)	0 (0)	100
5/N	3 (75)	1 (25)	1 (50)	1 (50)	5 (71)	2 (29)	42
6/O	5 (83)	1 (17)	1 (100)	0 (0)	7 (88)	1 (12)	76
6/N	5 (83)	1 (17)	3 (60)	2 (40)	9 (75)	3 (25)	50

13A.DID YOU ENCOUNTER ANY NEW EQUIPMENT TO-DAY?

	HGRD		S Y S		GLOBAL		
EXP	Y (%)	N (%)	Y (%)	N (%)	Y (%)	N (%)	%DIF
1/O	8 (42)	11 (58)	1 (10)	9 (90)	10 (27)	27 (73)	-46
1/N	12 (34)	23 (66)	3 (18)	14 (82)	16 (30)	38 (70)	-40
2/O	0 (0)	25 (100)	1 (7)	13 (93)	1 (2)	41 (98)	-96
2/N	3 (13)	21 (87)	0 (0)	8 (89)	3 (8)	35 (90)	-82
3/O	11 (65)	6 (35)	4 (31)	8 (62)	18 (49)	16 (43)	6
3/N	23 (52)	21 (48)	10 (53)	9 (47)	34 (52)	32 (48)	4
4/O	9 (29)	21 (68)	6 (30)	13 (65)	16 (30)	35 (66)	-36
4/N	10 (30)	22 (67)	2 (20)	8 (80)	12 (23)	39 (75)	-52
5/O	2 (50)	2 (50)	0 (0)	2 (100)	2 (29)	5 (71)	-42
5/N	3 (30)	6 (60)	1 (33)	2 (67)	4 (29)	9 (64)	-35
6/O	5 (83)	1 (17)	0 (0)	4 (80)	6 (50)	5 (42)	8
6/N	2 (33)	4 (67)	0 (0)	1 (100)	2 (25)	6 (75)	-50

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14.IF YOU DID, WERE YOU TAUGHT HOW TO USE IT?

	HGRD		S Y S		GLOBAL		
EXP	Y (%)	N (%)	Y (%)	N (%)	Y (%)	N (%)	%DIF
1/O	6 (32)	2 (11)	1 (10)	0 (0)	8 (22)	2 (5)	17
1/N	9 (26)	1 (3)	2 (12)	1 (6)	12 (22)	2 (4)	18
2/O	0 (0)	0 (0)	1 (7)	0 (0)	1 (2)	0 (0)	2
2/N	1 (4)	4 (17)	0 (0)	0 (0)	1 (3)	4 (10)	-7
3/O	9 (53)	1 (6)	3 (23)	2 (15)	17 (46)	3 (8)	38
3/N	22 (50)	2 (5)	10 (53)	0 (0)	33 (50)	2 (3)	47
4/O	8 (26)	2 (7)	6 (30)	0 (0)	15 (28)	2 (4)	24
4/N	8 (24)	2 (6)	2 (20)	1 (10)	10 (19)	3 (6)	13
5/O	1 (25)	1 (25)	0 (0)	0 (0)	1 (14)	1 (14)	0
5/N	4 (40)	0 (0)	1 (33)	0 (0)	5 (36)	0 (0)	36
6/O	3 (50)	1 (17)	1 (20)	0 (0)	5 (42)	1 (8)	34
6/N	1 (17)	1 (17)	0 (0)	0 (0)	1 (13)	1 (13)	0

15.ARE YOU CONFIDENT THAT YOU WILL BE ABLE TO USE IT AGAIN NEXT TIME?

	HGRD		S Y S		GLOBAL		
EXP	Y (%)	N (%)	Y (%)	N (%)	Y (%)	N (%)	%DIF
1/O	17 (49)	0 (0)	4 (24)	0 (0)	22 (41)	0 (0)	41
1/N	9 (47)	1 (5)	3 (30)	0 (0)	14 (38)	1 (3)	35
2/O	6 (25)	3 (13)	1 (11)	0 (0)	7 (18)	3 (8)	10
2/N	6 (24)	0 (0)	3 (21)	0 (0)	9 (21)	0 (0)	21
3/O	27 (61)	0 (0)	12 (63)	1 (5)	40 (61)	1 (2)	59
3/N	11 (65)	0 (0)	3 (23)	3 (23)	21 (57)	3 (8)	49
4/O	16 (49)	2 (6)	4 (40)	0 (0)	24 (46)	2 (4)	42
4/N	18 (58)	1 (3)	5 (25)	2 (10)	24 (45)	3 (6)	39
5/O	5 (50)	0 (0)	1 (33)	0 (0)	6 (43)	0 (0)	43
5/N	2 (50)	0 (0)	1 (50)	0 (0)	4 (57)	0 (0)	57
6/O	2 (33)	1 (17)	0 (0)	0 (0)	3 (38)	1 (13)	25
6/N	4 (67)	1 (17)	1 (20)	0 (0)	6 (50)	1 (8)	42

x/N = "NEW" Writte Instruction

16.WERE YOU IN ANY DOUBT ABOUT WHAT WAS EXPECTED OF YOU IN YOUR LABORATORY REPORT?

	HGRD		S Y S		GLOBAL		
EXP	Y (%)	N (%)	Y (%)	N (%)	Y (%)	N (%)	%DIF
1/O	12 (34)	22 (63)	2 (12)	15 (88)	15 (28)	38 (70)	-42
1/N	4 (21)	13 (68)	5 (50)	3 (30)	10 (27)	23 (62)	-35
2/O	10 (42)	12 (50)	2 (22)	7 (78)	12 (31)	25 (64)	-33
2/N	9 (36)	13 (52)	9 (64)	5 (36)	19 (45)	20 (48)	-3
3/O	13 (30)	27 (61)	10 (53)	9 (47)	24 (36)	38 (58)	-22
3/N	5 (29)	11 (65)	1 (8)	10 (77)	6 (16)	27 (73)	-57
4/O	14 (42)	19 (58)	1 (10)	8 (80)	15 (29)	36 (69)	-40
4/N	9 (29)	21 (68)	5 (25)	13 (65)	14 (26)	36 (68)	-42
5/O	2 (20)	7 (70)	1 (33)	2 (67)	3 (21)	10 (71)	-50
5/N	0 (0)	4 (100)	0 (0)	2 (100)	0 (0)	7 (100)	-100
6/O	2 (33)	4 (67)	0 (0)	1 (100)	2 (25)	6 (75)	-50
6/N	0 (0)	6 (100)	1 (20)	4 (80)	1 (8)	11 (92)	-84

17.HAVE YOU LEARNED ANYTHING IN PARTICULAR FROM THIS EXPERIMENT TO-DAY?

	HGRD		S Y S		GLOBAL		
EXP	Y (%)	N (%)	Y (%)	N (%)	Y (%)	N (%)	%DIF
1/O	11 (31)	22 (63)	3 (18)	11 (65)	15 (28)	34 (63)	-35
1/N	5 (26)	10 (53)	2 (20)	4 (40)	9 (24)	19 (51)	-27
2/O	6 (25)	17 (71)	4 (44)	4 (44)	12 (31)	25 (64)	-33
2/N	8 (32)	10 (40)	3 (21)	9 (64)	12 (29)	21 (50)	-21
3/O	14 (32)	26 (59)	3 (16)	16 (84)	19 (29)	43 (65)	-36
3/N	7 (41)	8 (48)	4 (31)	9 (69)	12 (32)	23 (62)	-30
4/O	9 (27)	23 (52)	2 (20)	7 (70)	12 (23)	38 (73)	-50
4/N	7 (23)	23 (74)	3 (15)	16 (80)	11 (21)	40 (76)	-55
5/O	0 (0)	6 (60)	0 (0)	3 (100)	0 (0)	10 (71)	-71
5/N	1 (25)	3 (75)	1 (50)	1 (50)	2 (29)	5 (71)	-32
6/O	0 (0)	6 (100)	0 (0)	1 (100)	0 (0)	7 (88)	-88
6/N	3 (50)	3 (50)	1 (20)	4 (80)	5 (42)	7 (58)	-16

x/O = "OLD" Written Instuction

APPENDIX A - 10 - DEMONSTRATORS' DIARY

1) COMMENTS, QUERIES FROM STUDENTS ABOUT: (e.g. Misleading items; Misunderstandings; obscurities; etc,etc)		tick for every occurrence
1.1) Written instructions	version 1 or 2	
1.2) Experiments	Number	
1.3) Laboratory's organization	week day	
1.4) Practical Problem	Number	
2) YOUR OWN OBSERVATION (e.g. students behaviour; organization and management of laboratory, etc)		

APPENDIX A - 11 - PRACTICAL PROBLEM-SOLVING (FORM)

PRACTICAL PROBLEM SOLVING

NAME____________________________________Bench Nº__________

This is a problem to be solved by practical means using some of the chemistry and techniques you have experienced to-day. You should plan how to solve it and list below the apparatus and chemicals you need to do it.

PROBLEM:

Write down here any ideas you have about how you can solve this problem.
How do you intend to do it?
List the apparatus and chemicals necessary to solve it.

NOW ASK YOUR DEMONSTRATOR TO CHECK YOUR IDEAS BEFORE STARTING

Write down your observations, results and conclusions about your practical problem.

THANK YOU FOR YOUR CO-OPERATION

APPENDIX A - 12 - MINI-PROJECTS QUESTIONNAIRES

PRACTICAL-PROBLEM QUESTIONNAIRE

We would like to know your opinion about your experience in solving this practical problem to enable us to see if we can improve it. Your replies will be treated in strict confidence and in no way will it affect your assessment or mark for this laboratory course.

What we want you to do is to place in the boxes besides the statements the letter of the response that most closely corresponds to your opinion.
A = Strongly agree **B** = agree **C** = Undecided **D** = Disagree **E** = Strongly disagree

1)I think that solving this practical problem
a) forced me to design and plan my own experiment ☐
b) illustrated practical applications of the laboratory ☐
c) gave me confidence in my practical work ☐
d) did not give me enough instructions to work ☐
e) allowed me to use my knowledge of chemistry to investigate the problem ☐
f) gave me a lot of satisfaction ☐
2)I think that more experiments like this should be included in this course. ☐
3)I think that solving this problem helped me to understand the theoretical lectures ☐

The grid below is for you make judgements on a series of five scales, if you have found this practical problem solving extremely boring you would tick the box as follows:

INTERESTING ☐☐☐☐☐ **BORING**

If you have found it fairly interesting you would tick the box as follow:

INTERESTING ☐☐☐☐☐ **BORING**

Please tick one of the box in each line, according to your opinion of the practical problem-solving you have experienced:

MEANINGFUL	☐	☐	☐	☐	☐	**MEANINGLESS**
DIFFICULT	☐	☐	☐	☐	☐	**EASY**
WASTE OF TIME	☐	☐	☐	☐	☐	**USEFUL**
ENJOYABLE	☐	☐	☐	☐	☐	**UNENJOYABLE**
UNIMPORTANT	☐	☐	☐	☐	☐	**IMPORTANT**
INTERESTING	☐	☐	☐	☐	☐	**BORING**
CONFUSING	☐	☐	☐	☐	☐	**UNDERSTANDABLE**
WELL-ORGANIZED	☐	☐	☐	☐	☐	**DISORGANIZED**

We would appreciate very much if you could give us any suggestions or comments about this practical problem-solving. Use the other side of this page if necessary.

THANK YOU FOUR YOUR CO-OPERATION

APPENDICES B

CHAPTER 4

(From PAGE 303 to 312)

APPENDIX B - 1
(CHAPTER 4)

"IMPROVED" LAB MANUAL

VERSION 3
(INSIDE BACK COVER)

APPENDIX B - 2
(CHAPTER 4)

"PRELAB WORK" MANUAL

VERSION 4
(INSIDE BACK COVER)

APPENDIX B - 3 - MINI-PROJECTS (FORM)

PRACTICAL PROBLEM SOLVING

NAME____Bench Nº___________

This is a problem to be solved by practical means using some of the chemistry and techniques you have experienced to-day. You should plan how to solve it and list below the apparatus and chemicals you need to do it.

PROBLEM:

Write down here any ideas you have about how you can solve this problem.
How do you intend to do it?
List the apparatus and chemicals necessary to solve it.

NOW ASK YOUR DEMONSTRATOR TO CHECK YOUR IDEAS BEFORE STARTING

Write down your observations, results and conclusions about your practical problem.

THANK YOU FOR YOUR CO-OPERATION

APPENDIX B - 4 - PRE QUESTIONNAIRE

FIRST YEAR LABORATORY SURVEY

NAME____Bench №____________

We are carrying out a survey of laboratory work in the First Year. To help us, we would like to know what you think of any previous laboratory work you did before coming to the university. Your sincere opinions will be valued and they will have no bearing whatsoever on your laboratory performance or mark in this laboratory course.
First, we would like to know some information about your previous experience in chemistry.

1) What is your HIGHEST qualification in chemistry?

"O" GRADE	☐	"O" LEVEL	☐	"H" GRADE	☐
"A" LEVEL	☐	6th YEAR STUDIES	☐	OTHER	☐

2) In your previous laboratory work have you experienced practical work which was done (tick more than one if required)

☐ individually? ☐ in small groups? ☐ by teacher demonstration?

The grid below is for you to make judgements on a series of scales. For example, if you STRONGLY AGREE that previous laboratory work was boring you should tick the box as follows.

INTERESTING	☐	☐	☐	☐	✓	BORING

If you AGREE that previous laboratory work was interesting you should tick the box as follows:

INTERESTING	☐	✓	☐	☐	☐	BORING

Please tick one of the boxes in each line, according to your opinion of any previous laboratory work you have experienced.

EASY	☐	☐	☐	☐	☐	DIFFICULT
USELESS	☐	☐	☐	☐	☐	USEFUL
INTERESTING	☐	☐	☐	☐	☐	BORING
CONFUSING	☐	☐	☐	☐	☐	UNDERSTANDABLE
SATISFYING	☐	☐	☐	☐	☐	FRUSTRATING
UNENJOYABLE	☐	☐	☐	☐	☐	ENJOYABLE
ADEQUATE WRITTEN INSTRUCTIONS	☐	☐	☐	☐	☐	INADEQUATE WRITTEN INSTRUCTIONS
RUSHED	☐	☐	☐	☐	☐	LEISURELY
LEARNT A LOT	☐	☐	☐	☐	☐	LEARNT LITTLE
DISORGANISED	☐	☐	☐	☐	☐	WELL-ORGANISED

WHAT DO YOU EXPECT TO LEARN FROM THIS LABORATORY COURSE?

THANK YOU FOR YOUR CO-OPERATION

APPENDIX B - 5 - POST QUESTIONNAIRE

FIRST YEAR LABORATORY SURVEY

NAME______________________________ Bench №________

Continuing our survey of laboratory work in the First Year, we would like to know what you thought of the practical work you have experienced during this term.
Your frank opinions will be valued and they will be treated in strict CONFIDENCE and will not be used in any way to assess your performance or mark in this laboratory course.
The grid below is for you to make judgements on a series of scales. For example, if you STRONGLY AGREE that the laboratory work this term was boring you should tick the box as follows:

INTERESTING					✓	BORING

If you AGREE that the laboratory work this term was interesting you should tick the box as follows:

INTERESTING		✓				BORING

Please tick one of the boxes in each line, according to your opinion of the laboratory work you have experienced this term:

EASY						DIFFICULT
USELESS						USEFUL
INTERESTING						BORING
CONFUSING						UNDERSTANDABLE
SATISFYING						FRUSTRATING
UNENJOYABLE						ENJOYABLE
ADEQUATE WRITTEN INSTRUCTIONS						INADEQUATE WRITTEN INSTRUCTIONS
RUSHED						LEISURELY
LEARNT A LOT						LEARNT LITTLE
DISORGANISED						WELL-ORGANISED

1. Which experiment or experiments did you enjoy most of all?________________
   Could you please tell us why you found it (them) the most enjoyable?

2. Which experiment or experiments did you find most difficult?________________
   Could you please tell us why you found it (them) the most difficult?

3. Which experiment or experiments did you find most useful?________________
   Could you please tell us why you found it (them) the most useful?

4. What do you think were the good points about the lab course?

5. What do you think were the worst features of the lab course?

6. What changes do you think should be made to improve the lab course?

7. What would you like to learn next time you do a lab course?

THANK YOU FOR YOUR CO-OPERATION

APPENDIX B - 6 - DIARY FOR EXPERIMENT

DIARY for EXPERIMENT Nº____

NAME____Bench Nº____________

You are asked to rate statements about your experience in doing this EXPERIMENT on a '1 to 5' scale. Please indicate the extent to which you agree or disagree with each of the following statements by circling an appropriate number.
Your replies will be treated in strict CONFIDENCE and in no way will they affect your assessment or mark for this laboratory course.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. There was enough information in the manual (lab map etc) and in the laboratory to help me find the chemicals	1	2	3	4	5
2. I had enough time in the laboratory to think about the chemistry involved in the experiment	1	2	3	4	5
3. The symbols in the manual (which are defined on page 4) were helpful in doing this experiment	1	2	3	4	5
4. It was clear to me what was expected in writing up my lab report	1	2	3	4	5
5. I would have liked more help with the calculations in this experiment	1	2	3	4	5
6. The information in the appendices 1 to 6 was helpful	1	2	3	4	5
7. The experimental procedure was clearly explained in the manual.	1	2	3	4	5
8. The prelab introduction to the balances and volumetric techniques helped me when I came to use those techniques in this experiment.	1	2	3	4	5
9. I had enough help in writing the chemical equations in this experiment	1	2	3	4	5
10. It was easy to follow the way the manual was organised (purpose, safety precautions, lab report, outline of experiment, procedure, etc).	1	2	3	4	5
11. I was so confused in the laboratory that I ended up following the manual without really understanding what I was doing	1	2	3	4	5
12. The purpose of this experiment was clear to me	1	2	3	4	5
13. There was enough information in the manual (lab map, etc) and in the laboratory to help me find the equipment	1	2	3	4	5
14. I only understood what I had been doing in this experiment when I tried to write the lab report	1	2	3	4	5
15. I was confident enough with the lab techniques to be able to concentrate on the chemistry involved in the experiment	1	2	3	4	5

THANK YOU FOR YOUR CO-OPERATION

APPENDIX B - 7 - PRELAB WORK QUESTIONNAIRE

PRACTICAL-PROBLEM QUESTIONNAIRE

NAME____BENCH №__________

You are asked to rate statements about your experience in solving the **PRACTICAL PROBLEMS** on a '1 to 5' scale. Please indicate the extent to which you agree or disagree with each of the following statements by circling an appropriate number.
Your replies will be treated in strict **CONFIDENCE** and in no way will they affect your assessment or mark for this laboratory course.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. I THINK THAT SOLVING THE PRACTICAL PROBLEMS					
a) forced me to design and plan my own experiments	1	2	3	4	5
b) illustrated practical applications of the laboratory	1	2	3	4	5
c) gave me confidence in my practical work	1	2	3	4	5
d) was difficult	1	2	3	4	5
e) allowed me to use my knowledge of chemistry to investigate the problems	1	2	3	4	5
f) gave me a lot of satisfaction	1	2	3	4	5
g) was enjoyable	1	2	3	4	5
h) was interesting	1	2	3	4	5
2. I THINK THAT SOLVING THE **PRACTICAL PROBLEM** AT THE END OF THE EXPERIMENT HELPED ME TO UNDERSTAND THE EXPERIMENT WHICH HAD COME BEFORE	1	2	3	4	5
3. I THINK THAT MORE **PRACTICAL PROBLEMS** LIKE THESE SHOULD BE INCLUDED IN THIS COURSE	1	2	3	4	5

THANK YOU FOR YOUR CO-OPERATION

APPENDIX B - 8 - MINI-PROJECT QUESTIONNAIRE

PRACTICAL-PROBLEM QUESTIONNAIRE

NAME____ BENCH №____________

You are asked to rate statements about your experience in solving the **PRACTICAL PROBLEMS** on a '1 to 5' scale. Please indicate the extent to which you agree or disagree with each of the following statements by circling an appropriate number.
Your replies will be treated in strict **CONFIDENCE** and in no way will they affect your assessment or mark for this laboratory course.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. I THINK THAT SOLVING THE PRACTICAL PROBLEMS					
a) forced me to design and plan my own experiments	1	2	3	4	5
b) illustrated practical applications of the laboratory	1	2	3	4	5
c) gave me confidence in my practical work	1	2	3	4	5
d) was difficult	1	2	3	4	5
e) allowed me to use my knowledge of chemistry to investigate the problems	1	2	3	4	5
f) gave me a lot of satisfaction	1	2	3	4	5
g) was enjoyable	1	2	3	4	5
h) was interesting	1	2	3	4	5
2. I THINK THAT SOLVING THE **PRACTICAL PROBLEM** AT THE END OF THE EXPERIMENT HELPED ME TO UNDERSTAND THE EXPERIMENT WHICH HAD COME BEFORE	1	2	3	4	5
3. I THINK THAT MORE **PRACTICAL PROBLEMS** LIKE THESE SHOULD BE INCLUDED IN THIS COURSE	1	2	3	4	5

THANK YOU FOR YOUR CO-OPERATION

APPENDIX B - 9 - PRELAB WORK and MINI-PROJECT QUESTIONNAIRE

PRELAB AND PRACTICAL PROBLEMS QUESTIONNAIRE

NAME____ BENCH № ____________

You are asked to rate statements about your experience in doing **PRELAB WORK and SOLVING PRACTICAL PROBLEMS** on a '1 to 5' scale. Please indicate the extent to which you agree or disagree with each of the following statements by circling an appropriate number.
Your replies will be treated in strict CONFIDENCE and in no way will they affect your assessment or mark for this laboratory course.

<u>ABOUT PRELAB WORK</u>	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. I THINK THAT DOING THE **PRELAB WORK**					
a) helped me to understand the experiments before I attempted them in the laboratory	1	2	3	4	5
b) gave me more confidence when I came to do the experiments in the laboratory	1	2	3	4	5
c) forced me to think about the experiments before I attempted them in the laboratory	1	2	3	4	5
d) meant that I was able to follow the manual in the laboratory with a greater understanding of what I was doing	1	2	3	4	5
e) was difficult	1	2	3	4	5
2. I THINK THAT **PRELAB WORK** SHOULD ALWAYS BE INCLUDED BEFORE DOING AN EXPERIMENT	1	2	3	4	5
<u>ABOUT PRACTICAL PROBLEMS</u>					
3. I THINK THAT SOLVING THE **PRACTICAL PROBLEMS**					
a) forced me to design and plan my own experiments	1	2	3	4	5
b) illustrated practical applications of the laboratory	1	2	3	4	5
c) gave me confidence in my practical work	1	2	3	4	5
d) was difficult	1	2	3	4	5
e) allowed me to use my knowledge of chemistry to investigate the problems	1	2	3	4	5
f) gave me a lot of satisfaction	1	2	3	4	5
g) was enjoyable	1	2	3	4	5
h) was interesting	1	2	3	4	5
4. I THINK THAT SOLVING THE **PRACTICAL PROBLEM** AT THE END OF THE EXPERIMENT HELPED ME TO UNDERSTAND THE EXPERIMENT WHICH HAD COME BEFORE	1	2	3	4	5
5. I THINK THAT MORE **PRACTICAL PROBLEMS LIKE** THESE SHOULD BE INCLUDED IN THIS COURSE	1	2	3	4	5

THANK YOU FOR YOUR CO-OPERATION

APPENDIX B - 10 - DEMONSTRATORS' DIARY

DEMONSTRATOR'S DIARY

1) COMMENTS, QUERIES FROM STUDENTS ABOUT: (e.g. Misleading items; Misunderstandings; obscurities; etc,etc)	**Experiment Number**	tick for every occurrence
1.1) Written instructions		
1.2) Laboratory's organization		

2) YOUR OWN OBSERVATION
(e.g. student's behaviour; organization and management of laboratory, etc)

THANK YOU FOR YOUR CO-OPERATION

APPENDIX B - 11 - DEMONSTRATORS' CHECKLIST

DEMONSTRATOR'S CHECKLIST

PLEASE PLACE A CROSS (X) IN THE APPROPRIATE BOX FOR EACH STUDENT WHO ASKS A QUESTION(s) ABOUT:

	FREQUENCY
EXPERIMENT 1	
Calculation of the yield (either % or theoretical)	
Calculation of enthalpy	
EXPERIMENT 2	
How to write balanced equations	
Which effects do products produce in the litmus paper?	
EXPERIMENT 3	
Calculation of the number of moles of $KHC_8H_4O_4$.	
Calculation of molarities.	
EXPERIMENT 4	
How to write oxidation-reduction equations	
Calculation of the molarities	
EXPERIMENT 5	
Calculation of yield (either % or theoretical)	
Calculation of % Cu	
EXPERIMENT 6	
Calculation of yield (either % or theoretical)	
Calculation of % Cr	

THANK YOU FOR YOUR CO-OPERATION

APPENDICES C

CHAPTER 5

(From PAGE 314 to 328)

APPENDIX C - 1 - TABLE 5.25 - DIARY'S RESULTS / (1/15)

QUESTION 1 - CONTROL (CTRL)

EXP	DEG	1(SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	10 (19)	**30 (57)**	9 (17)	3 (6)	1 (2)	67.9
	SYS	4 (12)	**19 (56)**	5 (15)	6 (17)	-	50.0
	GLB	19 (18)	**56 (54)**	19 (18)	9 (9)	1 (1)	62.5
2	HGR	3 (10)	**20 (65)**	5 (16)	3 (10)	-	64.5
	SYS	3 (13)	**10 (42)**	7 (29)	1 (4)	3 (13)	37.5
	GLB	7 (10)	**38 (57)**	14 (21)	5 (8)	3 (5)	55.2
3	HGR	9 (27)	**21 (62)**	3 (9)	1 (3)	-	85.3
	SYS	3 (15)	**7 (35)**	6 (30)	4 (20)	-	30.0
	GLB	12 (21)	**30 (52)**	9 (16)	6 (10)	-	62.1
4	HGR	2 (10)	**9 (45)**	7 (35)	2 (10)	-	45.0
	SYS	2 (11)	**13 (68)**	3 (16)	1 (5)	-	73.7
	GLB	9 (18)	**26 (53)**	11 (22)	3 (6)	-	65.3
5	HGR	6 (29)	**10 (47)**	4 (19)	1 (5)	-	71.4
&	SYS	2 (17)	**9 (75)**	-	-	1 (8)	83.3
6	GLB	9 (24)	**21 (55)**	5 (13)	2 (5)	1 (3)	71.0
	HGR	30 (19)	**90 (57)**	28 (18)	10 (6)	1 (.6)	68.6
CTR	SYS	14 (13)	**58 (53)**	22 (20)	12 (11)	4 (4)	50.9
	GLB	56 (18)	**171(54)**	59 (19)	25 (8)	5 (2)	62.1

QUESTION 1 - PRELAB WORK (PLW)

EXP	DEG	1	2	3	4	5	% DIF
1	HGR	6 (16)	**18 (58)**	6 (19)	2 (7)	-	67.7
	SYS	1 (5)	**15 (79)**	3 (16)	-	-	84.2
	GLB	7 (11)	**44 (71)**	9 (15)	2 (3)	-	79.0
2	HGR	2 (9)	**13 (59)**	6 (27)	1 (5)	-	63.6
	SYS	1 (8)	**8 (67)**	2 (17)	1 (8)	-	66.7
	GLB	3 (8)	**25 (66)**	8 (21)	1 (3)	1 (3)	68.4
3	HGR	1 (8)	**9 (75)**	2 (17)	-	-	83.3
	SYS	3 (25)	**6 (50)**	2 (17)	1 (8)	-	66.7
	GLB	6 (19)	**19 (59)**	5 (16)	2 (6)	-	71.9
4	HGR	-	**10(100)**	-	-	-	100.0
	SYS	2 (22)	**7 (78)**	-	-	-	100.0
	GLB	2 (10)	**18 (90)**	-	-	-	100.0
5	HGR	1 (6)	**14 (82)**	1 (6)	1 (6)	-	82.4
&	SYS	2 (12)	**10 (59)**	2 (12)	3 (18)	-	52.9
6	GLB	4 (9)	**32 (73)**	3 (7)	5 (11)	-	70.5
	HGR	9 (10)	**64 (70)**	15 (16)	4 (4)	-	75.0
PLW	SYS	9 (13)	**46 (67)**	9 (13)	4 (6)	1 (1)	72.5
	GLB	22 (11)	**138(70)**	25 (13)	10 (5)	1 (.5)	76.0

QUESTION 1 - MINI-PROJECTS (MP)

EXP	DEG	1	2	3	4	5	% DIF
1	HGR	3 (16)	**12 (63)**	2 (11)	1 (5)	1 (5)	68.4
	SYS	6 (32)	**13 (68)**	-	-	-	100.0
	GLB	10 (24)	**28 (67)**	2 (5)	1 (2)	1 (2)	85.7
2	HGR	3 (21)	3 (21)	**6 (43)**	2 (14)	-	28.6
	SYS	2 (18)	**6 (55)**	1 (9)	2 (18)	-	54.5
	GLB	5 (20)	**9 (36)**	7 (28)	4 (16)	-	40.0
3	HGR	1 (6)	**16 (94)**	-	-	-	100.0
	SYS	**2 (40)**	1 (20)	1 (20)	1 (20)	-	40.0
	GLB	3 (13)	**18 (75)**	2 (8)	1 (4)	-	83.3
4	HGR	2 (22)	**6 (67)**	1 (11)	-	-	88.9
	SYS	2 (33)	**4 (67)**	-	-	-	100.0
	GLB	4 (24)	**12 (71)**	1 (6)	-	-	94.1
5	HGR	-	2 (50)	2 (50)	-	-	50.0
&	SYS	-	1 (33)	1 (33)	1 (33)	-	0.0
6	GLB	-	(43)00)	3 (43)	1 (14)	-	28.6
	HGR	9 (14)	**39 (62)**	11 (18)	3 (5)	1 (2)	69.8
MP	SYS	12 (27)	**25 (57)**	3 (7)	4 (9)	-	75.0
	GLB	22 (19)	**70 (61)**	15 (13)	7 (6)	1 (1)	73.0

QUESTION 1 - PRELAB WORK plus MINI-PROJECTS (P&P)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	6 (26)	**13 (57)**	2 (9)	2 (9)	-	73.9
	SYS	3 (19)	**8 (50)**	5 (31)	-	-	68.8
	GLB	11 (24)	**24 (52)**	9 (20)	2 (4)	-	71.7
2	HGR	5 (25)	**7 (35)**	**7 (35)**	1 (5)	-	55.0
	SYS	2 (25)	**4 (50)**	2 (25)	-	-	75.0
	GLB	7 (21)	**13 (39)**	3 (30)	3 (9)	-	51.5
3	HGR	1 (8)	**11 (85)**	1 (8)	-	-	92.3
	SYS	3 (33)	**5 (56)**	1 (11)	-	-	88.9
	GLB	4 (16)	**18 (72)**	3 (12)	-	-	88.0
4	HGR	3 (30)	**6 (60)**	1 (10)	-	-	90.0
	SYS	2 (40)	**3 (60)**	-	-	-	100.0
	GLB	5 (31)	**10 (63)**	1 (6)	-	-	93.8
5	HGR	1 (13)	**3 (38)**	**3 (38)**	1 (13)	-	37.5
&	SYS	-	**2 (67)**	1 (33)	-	-	66.7
6	GLB	1 (8)	**5 (42)**	4 (33)	2 (17)	-	33.3
	HGR	16 (22)	**40 (54)**	14 (19)	4 (5)	-	70.3
P&P	SYS	10 (24)	**22 (54)**	9 (22)	-	-	78.0
	GLB	28 (21)	**70 (53)**	27 (21)	7 (5)	-	68.9

SA=Strongly Agree A=Agree N=Neutral D=Disagree SD=Strongly Disagree DIF=(1+2)-(4+5)

APPENDIX C - 1 / (2/15)

QUESTION 2 - CONTROL (CTRL)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
	HGR	4 (8)	**30 (57)**	13 (25)	4 (8)	2 (4)	52.8
1	SYS	3 (9)	**17 (50)**	10 (29)	4 (12)	-	47.1
	GLB	14 (14)	**51 (49)**	26 (25)	11 (11)	2 (2)	50.0
	HGR	1 (3)	**10 (32)**	8 (26)	**9 (29)**	3 (10)	-3.2
2	SYS	-	**8 (33)**	5 (21)	**9 (38)**	2 (8)	-12.5
	GLB	2 (3)	**21 (31)**	15 (22)	**20 (30)**	9 (13)	-9.0
	HGR	1 (3)	**17 (50)**	6 (18)	**10 (29)**	-	23.5
3	SYS	-	**9 (45)**	3 (15)	**6 (30)**	2 (10)	5.0
	GLB	1 (2)	**27 (47)**	10 (17)	**16 (28)**	4 (7)	13.8
	HGR	-	**7 (35)**	4 (20)	**9 (45)**	-	-10.0
4	SYS	1 (5)	**6 (32)**	6 (32)	**6 (32)**	-	5.3
	GLB	6 (12)	**15 (31)**	12 (25)	**15 (31)**	1 (2)	10.2
5	HGR	1 (5)	**9 (43)**	4 (19)	**6 (29)**	1 (5)	14.3
&	SYS	-	**8 (67)**	1 (8)	**3 (25)**	-	41.7
6	GLB	2 (5)	**18 (47)**	6 (16)	**10 (26)**	2 (5)	21.1
	HGR	7 (4)	**73 (46)**	35 (22)	**38 (24)**	6 (4)	22.6
CTR	SYS	4 (4)	**48 (44)**	25 (23)	**29 (26)**	4 (4)	17.3
	GLB	25 (8)	**132(42)**	69 (22)	**73 (23)**	18 (6)	20.8

QUESTION 2 - PRELAB WORK (PLW)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
	HGR	-	**18 (58)**	7 (23)	6 (19)	-	38.7
1	SYS	2 (11)	**10 (53)**	6 (32)	1 (5)	-	57.9
	GLB	2 (3)	**34 (55)**	18 (29)	8 (13)	-	45.2
	HGR	1 (5)	2 (9)	4 (18)	**13 (59**	2 (9)	-54.5
2	SYS	1 (8)	1 (8)	4 (33)	**5 (42)**	1 (8)	-33.3
	GLB	2 (5)	4 (11)	10 (26)	**19 (50)**	3 (8)	-42.1
	HGR	-	1 (8)	5 (42)	**6 (50)**	-	-41.7
3	SYS	1 (8)	**5 (42)**	4 (33)	2 (17)	-	33.3
	GLB	1 (3)	8 (25)	**12 (38)**	11 (34)	-	-6.3
	HGR	-	**5 (50)**	4 (4)	1 (10)	-	40.0
4	SYS	1 (11)	**3 (33)**	**3 (33)**	2 (22)	-	22.2
	GLB	1 (5)	**9 (45)**	7 (35)	3 (15)	-	35.0
5	HGR	-	5 (29)	5 (29)	**7 (41)**	-	-11.8
&	SYS	1 (6)	4 (24)	**7 (41)**	4 (24)	1 (6)	0.0
6	GLB	2 (5)	13 (30)	**16 (36)**	11 (25)	2 (5)	4.5
	HGR	1 (1)	**31 (34)**	25 (27)	**33 (36)**	2 (2)	-3.3
PLW	SYS	6 (9)	23 (33)	**24 (35)**	14 (20)	2 (3)	18.8
	GLB	8 (4)	**68 (35)**	63 (32)	52 (27)	5 (3)	9.7

QUESTION 2 - MINI-PROJECTS (MP)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
	HGR	2 (11)	**7 (37)**	5 (26)	5 (26)	-	21.1
1	SYS	4 (21)	**10 (53)**	3 (16)	2 (11)	-	63.2
	GLB	6 (14)	**21 (50)**	8 (19)	7 (17)	-	47.6
	HGR	-	2 (14)	**5 (36)**	4 (19)	3 (21)	-35.7
2	SYS	-	1 (9)	3 (27)	**4 (36)**	3 (27)	-54.5
	GLB	-	3 (12)	**8 (32)**	**8 (32)**	6 (24)	-44.0
	HGR	-	3 (18)	6 (35)	**7 (41)**	1 (6)	-29.4
3	SYS	-	**3 (60)**	1 (20)	1 (20)	-	40.0
	GLB	-	6 (25)	8 (33)	**9 (38)**	1 (4)	-16.7
	HGR	1 (11)	3 (33)	2 (22)	3 (33)	-	11.1
4	SYS	-	2 (33)	2 (33)	2 (33)	-	0.0
	GLB	1 (6)	5 (29)	5 (29)	**6 (35)**	-	0
5	HGR	-	1 (25)	1 (25)	1 (25)	1 (25)	-25.0
&	SYS	-	-	1 (33)	1 (33)	1 (33)	-66.7
6	GLB	-	1 (14)	2 (29)	2 (29)	2 (29)	-42.9
	HGR	3 (5)	16 (25)	19 (30)	**20 (32)**	5 (8)	-9.5
MP	SYS	4 (9)	**16 (36)**	10 (23)	10 (23)	4 (9)	13.6
	GLB	7 (6)	**36 (31)**	31 (27)	32 (28)	9 (8)	1.7

QUESTION 2 - PRELAB WORK plus MINI-PROJECTS (P&P)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
	HGR	2 (9)	**9 (39)**	7 (30)	5 (22)	-	26.1
1	SYS	3 (19)	**7 (44)**	3 (19)	1 (6)	2 (13)	43.8
	GLB	7 (15)	**17 (37)**	11 (24)	8 (17)	3 (7)	28.3
	HGR	-	3 (15)	7 (35)	**10 (50)**	-	-35.0
2	SYS	1 (13)	**7 (88)**	-	-	-	100.0
	GLB	1 (3)	**12 (36)**	9 (27)	**10 (30)**	1 (3)	6.1
	HGR	-	**6 (46)**	2 (15)	3 (23)	2 (15)	7.7
3	SYS	1 (11)	**4 (44)**	2 (22)	2 (22)	-	33.3
	GLB	1 (4)	**11 (44)**	4 (16)	7 (28)	2 (8)	12.0
	HGR	1 (10)	-	**6 (60)**	2 (20)	1 (10)	-20.0
4	SYS	-	**3 (60)**	2 (40)	-	-	60.0
	GLB	1 (6)	4 (25)	**8 (50)**	2 (13)	1 (6)	12.5
5	HGR	-	**5 (63)**	2 (25)	1 (13)	-	50.0
&	SYS	1 (33)	-	**2 (67)**	-	-	33.3
6	GLB	1 (8)	**5 (42)**	4 (33)	2 (17)	-	33.3
	HGR	3 (4)	23 (31)	**24 (32)**	21 (28)	5 (4)	2.7
P&P	SYS	6 (15)	**21 (51)**	9 (22)	3 (7)	2 (5)	53.7
	GLB	11 (8)	**49 (37)**	36 (27)	29 (22)	7 (5)	18.2

SA=Strongly Agree A=Agree N=Neutral D=Disagree SD=Strongly Disagree DIF=(1+2)-(4+5)

APPENDIX C - 1 / (3/15)

QUESTION 3 - CONTROL (CTRL)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	9 (17)	**30 (57)**	11 (21)	3 (6)	-	67.9
	SYS	3 (9)	15 (44)	**16 (47)**	-	-	52.9
	GLB	14 (14)	**54 (52)**	33 (32)	3 (3)	-	62.5
2	HGR	4 (13)	10 (32)	**15 (48)**	2 (7)	-	38.7
	SYS	1 (4)	**12 (50)**	11 (46)	-	-	54.2
	GLB	5 (8)	26 (39)	**33 (49)**	3 (5)	-	41.8
3	HGR	4 (12)	**16 (47)**	12 (35)	2 (6)	-	52.9
	SYS	1 (5)	7 (35)	**11 (55)**	1 (5)	-	35.0
	GLB	6 (10)	24 (41)	**25 (43)**	3 (5)	-	46.6
4	HGR	3 (15)	8 (40)	**9 (45)**	-	-	55.0
	SYS	2 (11)	8 (42)	**9 (47)**	-	-	52.6
	GLB	5 (10)	20 (41)	**22 (45)**	2 (4)	-	46.9
5 & 6	HGR	-	**14 (67)**	6 (29)	1 (5)	-	61.9
	SYS	-	**9 (75)**	3 (25)	-	-	75.0
	GLB	-	**24 (63)**	12 (32)	2 (5)	-	57.9
CTR	HGR	20 (13)	**78 (49)**	53 (33)	8 (5)	-	56.6
	SYS	7 (6)	**51 (46)**	**51 (46)**	1 (1)	-	51.8
	GLB	30 (10)	**148 (47)**	126 (40)	13 (4)	-	52.1

QUESTION 3 - PRELAB WORK (PLW)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	2 (7)	13 (42)	**15 (48)**	1 (3)	-	45.2
	SYS	2 (11)	**10 (53)**	6 (32)	1 (5)	-	57.9
	GLB	5 (8)	25 (40)	**30 (48)**	2 (3)	-	45.2
2	HGR	1 (5)	**10 (46)**	9 (41)	2 (9)	-	40.9
	SYS	-	5 (42)	**6 (50)**	1 (8)		33.3
	GLB	1 (3)	**18 (47)**	16 (42)	3 (8)	-	42.1
3	HGR	1 (8)	**7 (58)**	4 (33)	-	-	66.7
	SYS	-	**8 (67)**	4 (33)	-	-	66.7
	GLB	2 (6)	**18 (56)**	12 (38)	-	-	62.5
4	HGR	2 (20)	3 (30)	**5 (50)**	-	-	50.0
	SYS	-	4 (44)	**4 (44)**	1 (11)		33.3
	GLB	2 (10)	7 (35)	**10 (50)**	1 (5)	-	40.0
5 & 6	HGR	1 (6)	5 (29)	**11 (65)**	-	-	35.3
	SYS	3 (18)	5 (29)	**8 (47)**	1 (6)	-	41.2
	GLB	5 (11)	17 (39)	**21 (48)**	1 (2)	-	47.7
PLW	HGR	7 (8)	38 (41)	**44 (48)**	3 (3)	-	45.7
	SYS	5 (7)	**32 (46)**	28 (41)	4 (6)	-	47.8
	GLB	15 (8)	85 (43)	**89 (45)**	7 (4)	-	47.4

QUESTION 3 - MINI-PROJECTS (MP)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	2 (11)	**16 (84)**	1 (5)	-	-	94.7
	SYS	6 (32)	**8 (42)**	4 (21)	1 (5)	-	68.4
	GLB	8 (19)	**27 (64)**	6 (14)	1 (2)	-	81.0
2	HGR	3 (21)	**6 (43)**	4 (29)	1 (7)	-	57.1
	SYS	3 (27)	**4 (36)**	4 (36)	-	-	63.6
	GLB	6 (24)	**10 (40)**	8 (32)	1 (4)	-	60.0
3	HGR	2 (12)	**9 (53)**	6 (35)	-	-	64.7
	SYS	-	**3 (60)**	2 (40)	-	-	60.0
	GLB	2 (8)	**14 (58)**	8 (33)	-	-	66.7
4	HGR	-	**8 (89)**	1 (11)	-	-	88.9
	SYS	1 (17)	1 (17)	**3 (50)**	1 (17)	-	16.7
	GLB	1 (6)	**11 (65)**	4 (24)	1 (6)	-	64.7
5 & 6	HGR	-	1 (25)	**2 (50)**	1 (25)	-	0.0
	SYS	-	**2 (67)**	1 (33)	-	-	66.7
	GLB	-	**3 (43)**	**3 (43)**	1 (14)	-	28.5
MP	HGR	7 (11)	**40 (64)**	14 (22)	2 (3)	-	71.4
	SYS	10 (23)	**18 (41)**	14 (32)	2 (5)	-	59.1
	GLB	17 (15)	**65 (57)**	29 (25)	4 (4)	-	67.8

QUESTION 3 - PRELAB WORK plus MINI-PROJECTS (P&P)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	4 (17)	8 (35)	**11 (48)**	-	-	52.2
	SYS	3 (19)	**8 (50)**	4 (25)	-	-	68.8
	GLB	9 (20)	17 (37)	**19 (41)**	-	-	56.5
2	HGR	3 (15)	**10 (50)**	5 (25)	2 (10)	-	55.0
	SYS	1 (13)	**6 (75)**	1 (13)	-	-	87.5
	GLB	5 (15)	**19 (58)**	7 (21)	2 (6)	-	66.7
3	HGR	2 (15)	**6 (46)**	5 (39)	-	-	61.5
	SYS	2 (22)	**4 (44)**	3 (33)	-	-	66.7
	GLB	4 (16)	**12 (48)**	8 (32)	1 (4)	-	60.0
4	HGR	-	**7 (70)**	2 (20)	1 (10)	-	60.0
	SYS	**2 (40)**	1 (20)	**2 (40)**	-	-	60.0
	GLB	2 (13)	**9 (56)**	4 (25)	1 (6)	-	62.5
5 & 6	HGR	-	**5 (63)**	3 (38)	-	-	62.5
	SYS	-	**2 (67)**	1 (33)	-	-	66.7
	GLB	-	**8 (67)**	4 (33)	-	-	66.7
P&P	HGR	9 (12)	**36 (49)**	26 (35)	3 (4)	-	56.8
	SYS	8 (20)	**21 (51)**	11 (27)	-	-	70.7
	GLB	20 (15)	**65 (49)**	42 (32)	4 (3)	-	61.4

SA=Strongly Agree A=Agree N=Neutral D=Disagree SD=Strongly Disagree DIF=(1+2)-(4+5)

APPENDIX C - 1 / (4/15)

QUESTION - 4 CONTROL (CTRL)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	6 (11)	34 (64)	7 (13)	5 (9)	1 (2)	64.2
	SYS	4 (12	21 (62)	7 (21)	2 (6)	-	67.6
	GLB	13 (13)	65 (63)	16 (15)	9 (9)	1 (1)	65.4
2	HGR	-	18 (58)	9 (29)	4 (13)	-	45.2
	SYS	4 (17)	17 (71)	2 (8)	1 (4)	-	83.3
	GLB	5 (8)	38 (57)	14 (21)	8 (12)	2 (3)	49.3
3	HGR	2 (6)	22 (65)	5 (15)	5 (15)	-	55.9
	SYS	4 (20)	10 (50)	3 (15)	2 (10)	1 (5)	55.0
	GLB	7 (12)	35 (60)	8 (14)	7 (12)	1 (2)	58.6
4	HGR	3 (15)	7 (35)	5 (25)	5 (25)	-	25.0
	SYS	2 (11)	10 (53)	4 (21)	2 (11)	1 (5)	47.4
	GLB	7 (14)	22 (45)	11 (22)	7 (14)	2 (4)	40.8
5 & 6	HGR	1 (5)	11 (52)	5 (24)	4 (19)	-	38.1
	SYS	1 (8)	5 (42)	2 (17)	3 (25)	1 (8)	16.7
	GLB	3 (8)	18 (47)	8 (21)	8 (21)	1 (3)	31.6
CTR	HGR	12 (8)	92 (58)	31 (20)	23 (15)	1 (.6)	50.3
	SYS	15 (14)	63 (57)	18 (16)	11 (10)	3 (3)	58.2
	GLB	35 (11)	178 (56)	57 (18)	40 (13)	7 (2)	52.4

QUESTION 4 - MINI-PROJECTS (MP)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	-	12 (63)	4 (21)	2 (11)	1 (5)	47.4
	SYS	6 (32)	10 (53)	3 (16)	-	-	84.2
	GLB	6 (14)	23 (55)	9 (21)	3 (7)	1 (2)	59.5
2	HGR	1 (7)	4 (29)	4 (29)	5 (36)	-	0.0
	SYS	-	4 (36)	4 (36)	1 (9)	2 (18)	9.1
	GLB	1 (4)	8 (32)	8 (32)	6 (24)	2 (8)	4.0
3	HGR	2 (12)	11 (65)	2 (12)	2 (12)	-	64.7
	SYS	-	5 (100)	-	-	-	100.0
	GLB	2 (8)	17 (71)	3 (13)	2 (8)	-	70.8
4	HGR	2 (22)	4 (44)	1 (11)	2 (22)	-	44.4
	SYS	-	5 (83)	-	1 (17)	-	66.7
	GLB	2 (12)	11 (65)	1 (6)	3 (18)	-	58.8
5 & 6	HGR	1 (25)	1 (25)	2 (50)	-	-	50.0
	SYS	-	1 (33)	2 (67)	-	-	33.3
	GLB	1 (14)	2 (29)	4 (57)	-	-	42.9
MP	HGR	6 (10)	32 (51)	13 (21)	11 (18)	1 (2)	41.3
	SYS	6 (14)	25 (57)	9 (21)	2 (5)	2 (5)	61.4
	GLB	12 (10)	61 (53)	25 (22)	14 (12)	3 (3)	48.7

QUESTION 4 - PRELAB WORK (PLW)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	3 (10)	13 (42)	11 (36)	3 (10)	1 (3)	38.7
	SYS	1 (5)	7 (37)	5 (23)	6 (32)	-	10.5
	GLB	7 (11)	27 (44)	16 (26)	11 (18)	1 (2)	35.5
2	HGR	2 (9)	10 (46)	9 (41)	1 (5)	-	50.0
	SYS	-	6 (50)	4 (33)	1 (8)	1 (8)	33.3
	GLB	2 (5)	19 (50)	13 (34)	3 (8)	1 (3)	44.7
3	HGR	1 (8)	7 (58)	2 (17)	2 (17)		50.0
	SYS	1 (8)	8 (67)	2 (17)	1 (8)	-	66.7
	GLB	2 (6)	17 (53)	7 (22)	6 (19)	-	40.6
4	HGR	1 (10)	4 (40)	3 (30)	1 (10)	1 (10)	30.0
	SYS	1 (11)	5 (56)	2 (22)	1 (11)	-	55.6
	GLB	2 (10)	9 (45)	6 (30)	2 (10)	1 (5)	40.0
5 & 6	HGR	1 (6)	12 (71)	1 (6)	2 (12)	1 (6)	58.8
	SYS	2 (12)	5 (29)	5 (29)	4 (24)	1 (6)	11.8
	GLB	5 (11)	21 (48)	9 (21)	7 (16)	2 (5)	38.6
PLW	HGR	8 (9)	46 (50)	26 (28)	9 (10)	3 (3)	45.7
	SYS	5 (7)	31 (45)	18 (26)	13 (19)	2 (3)	30.4
	GLB	18 (9)	93 (47)	51 (26)	29 (15)	5 (3)	39.3

QUESTION 4 - PRELAB WORK plus MINI-PORJECTS (P&P)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	2 (9)	8 (35)	7 (30)	6 (26)	-	17.4
	SYS	2 (13)	9 (56)	4 (25)	-	1 (6)	62.5
	GLB	6 (13)	19 (41)	11 (24)	8 (17)	2 (4)	32.6
2	HGR	3 (15)	10 (50)	3 (15)	3 (15)	1 (5)	45.0
	SYS	1 (13)	4 (50)	1 (13)	2 (25)	-	37.5
	GLB	4 (12)	16 (49)	6 (18)	6 (18)	1 (3)	39.4
3	HGR	-	7 (54)	3 (23)	1 (8)	2 (15)	30.8
	SYS	2 (22)	5 (56)	2 (22)	-	-	77.8
	GLB	2 (8)	15 (60)	5 (20)	1 (4)	2 (8)	56.0
4	HGR	-	4 (40)	2 (20)	4 (40)	-	0.0
	SYS	-	5 (100)	-	-	-	100.0
	GLB	-	10 (63)	2 (13)	4 (25)	-	37.5
5 & 6	HGR	1 (13)	4 (50)	2 (25)	1 (13)	-	50.0
	SYS	1 (33)	-	2 (67)	-	-	33.3
	GLB	2 (17)	4 (33)	5 (42)	1 (8)	-	41.7
P&P	HGR	6 (8)	33 (45)	17 (23)	15 (20)	3 (4)	28.4
	SYS	6 (15)	23 (56)	9 (22)	2 (5)	1 (2)	63.4
	GLB	14 (11)	64 (49)	29 (22)	20 (15)	5 (4)	40.2

SA=Strongly Agree A=Agree N=Neutral D=Disagree SD=Strongly Disagree DIF=(1+2)-(4+5)

APPENDIX C - 1 / (5/15)

QUESTION 5 - CONTROL (CTRL)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	2 (4)	14 (26)	**18 (34)**	16 (30)	3 (6)	-5.7
	SYS	4 (12)	3 (9)	**14 (41)**	12 (35)	1 (3)	-17.6
	GLB	7 (7)	18 (17)	**41 (39)**	32 (31)	6 (6)	-12.5
2	HGR	2 (7)	10 (32)	**13 (42)**	6 (19)	-	19.4
	SYS	2 (8)	7 (29)	**9 (38)**	5 (21)	-	16.7
	GLB	6 (9)	18 (27)	**28 (42)**	13 (19)	1 (2)	14.9
3	HGR	5 (15)	9 (27)	**12 (35)**	7 (21)	1 (3)	17.6
	SYS	1 (5)	1 (5)	**9 (45)**	8 (40)	1 (5)	-35.0
	GLB	6 (10)	11 (19)	**23 (40)**	16 (28)	2 (3)	-1.7
4	HGR	2 (10)	5 (25)	**7 (35)**	5 (25)	1 (5)	5.0
	SYS	1 (5)	6 (32)	**6 (32)**	5 (26)	-	10.5
	GLB	4 (8)	13 (27)	**15 (31)**	14 (29)	2 (4)	2.0
5	HGR	4 (19)	3 (14)	**7 (33)**	**7 (33)**	-	0
&	SYS	1 (8)	**4 (33)**	2 (17)	**4 (33)**	1 (8)	0
6	GLB	5 (13)	8 (21)	10 (26)	**13 (34)**	2 (5)	-5.3
CTR	HGR	15 (9)	41 (26)	**57 (36)**	41 (26)	5 (3)	6.3
	SYS	9 (8)	21 (19)	**41 (37)**	34 (31)	3 (3)	-6.4
	GLB	28 (9)	68 (22)	**118(37)**	88 (28)	13 (4)	-1.6

QUESTION 5 - MINI-PROJECTS (MP)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	1 (5)	5 (26)	**9 (47)**	3 (16)	-	15.8
	SYS	-	4 (21)	4 (21)	**10 (53)**	-	-31.6
	GLB	1 (2)	10 (24)	**15 (36)**	14 (33)	-	-7.1
2	HGR	1 (7)	4 (29)	**8 (57)**	1 (7)	-	28.6
	SYS	1 (9)	3 (27)	**5 (46)**	2 (18)	-	18.2
	GLB	2 (8)	7 (28)	**13 (52)**	3 (12)	-	24.0
3	HGR	3 (18)	**5 (29)**	4 (24)	4 (24)	1 (6)	17.6
	SYS	-	1 (20)	**2 (40)**	**2 (40)**	-	-20.0
	GLB	3 (13)	**7 (29)**	6 (25)	**7 (29)**	1 (4)	8.3
4	HGR	4 (44)	1 (11)	**4 (44)**	-	-	55.6
	SYS	-	1 (17)	**4 (67)**	1 (17)	-	0.0
	GLB	4 (24)	2 (12)	**10 (59)**	1 (6)	-	29.4
5	HGR	1 (25)	**1 (25)**	-	1 (25)	1 (25)	0.0
&	SYS	-	**2 (67)**	-	1 (33)	-	33.3
6	GLB	1 (14)	**3 (43)**	-	2 (29)	1 (14)	14.3
MP	HGR	10 (16)	16 (25)	**25 (40)**	9 (14)	2 (3)	23.8
	SYS	1 (2)	11 (25)	**15 (34)**	16 (36)	-	-9.1
	GLB	11 (10)	29 (25)	**44 (38)**	27 (24)	2 (2)	9.6

SA=Strongly Agree A=Agree N=Neutral

QUESTION 5 - PRELAB WORK (PLW)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	3 (10)	9 (29)	8 (26)	**10 (32)**	1 (3)	3.2
	SYS	-	3 (16)	**8 (42)**	7 (37)	1 (5)	-26.3
	GLB	3 (5)	13 (21)	21 (34)	**23 (37)**	2 (3)	-14.5
2	HGR	-	4 (18)	**8 (36)**	**8 (36)**	2 (9)	-27.3
	SYS	-	1 (8)	**5 (42)**	4 (33)	1 (8)	-33.3
	GLB	-	6 (16)	**15 (40)**	13 (34)	3 (8)	-26.3
3	HGR	2 (17)	3 (25)	**3 (25)**	3 (25)	1 (8)	8.3
	SYS	-	2 (17)	4 (33)	**5 (42)**	1 (8)	-33.3
.	GLB	2 (6)	6 (19)	**12 (38)**	9 (28)	3 (9)	-12.5
4	HGR	1 (10)	**4 (40)**	**4 (40)**	1 (10)	-	40.0
	SYS	1 (11)	**3 (33)**	2 (22)	**3 (33)**	-	11.1
	GLB	2 (10)	**7 (35)**	**7 (35)**	4 (20)	-	25.0
5	HGR	2 (12)	**9 (53)**	5 (29)	1 (6)	-	58.8
&	SYS	1 (6)	4 (24)	5 (29)	**6 (35)**	1 (6)	-11.8
6	GLB	3 (7)	**15 (34)**	**15 (34)**	9 (21)	2 (5)	15.9
PLW	HGR	8 (9)	**29 (32)**	28 (30)	23 (25)	4 (4)	10.9
	SYS	2 (3)	13 (19)	24 (35)	**25 (36)**	4 (6)	-20.3
	GLB	10 (5)	47 (24)	**70 (36)**	58 (30)	10 (5)	-5.6

QUESTION 5 - PRELAB WORK plus MINI-PROJECT (P&P)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	1 (4)	3 (13)	8 (35)	**9 (39)**	1 (4)	-26.1
	SYS	1 (6)	1 (6)	5 (31)	**8 (50)**	1 (6)	-43.8
	GLB	3 (7)	5 (11)	14 (30)	**18 (39)**	5 (11)	-32.6
2	HGR	2 (10)	4 (20)	**9 (45)**	4 (20)	-	10.0
	SYS	-	-	**4 (50)**	3 (38)	1 (13)	-50.0
	GLB	2 (6)	5 (15)	**14 (42)**	10 (30)	1 (3)	-12.
3	HGR	1 (8)	3 (23)	**5 (39)**	4 (31)	-	0.0
	SYS	-	-	**5 (56)**	3 (33)	1 (11)	44.4
	GLB	1 (4)	3 (12)	**12 (48)**	7 (28)	2 (8)	-20.0
4	HGR	2 (20)	3 (30)	**4 (40)**	1 (10)	-	40.0
	SYS	-	1 (20)	**2 (40)**	2 (40)	-	-20.0
	GLB	2 (13)	4 (25)	**7 (44)**	3 (19)	-	18.8
5	HGR	1 (13)	**4 (50)**	3 (38)	-	-	62.5
&	SYS	-	-	1 (33)	1 (33)	1 (33)	-66.7
6	GLB	1 (8)	**5 (42)**	4 (33)	1 (8)	1 (8)	33.3
P&P	HGR	7 (10)	17 (23)	**29 (39)**	18 (24)	1 (1)	6.8
	SYS	1 (2)	2 (5)	**17 (42)**	17 (42)	4 (10)	-43.9
	GLB	9 (7)	22 (17)	**51 (39)**	39 (30)	9 (7)	-12.9

D=Disagree SD=Strongly Disagree DIF=(1+2)-(4+5)

APPENDIX C - 1 / (6/15)

QUESTION 6 - CONTROL (CTRL)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	11 (21)	**25 (47)**	14 (26)	1 (2)	1 (2)	64.2
	SYS	-	15 (44)	**17 (50)**	2 (6)	-	38.2
	GLB	12 (12)	**47 (45)**	40 (39)	3 (3)	1 (1)	52.9
2	HGR	2 (7)	**15 (48)**	13 (42)	1 (3)	-	51.6
	SYS	1 (4)	7 (29)	**14 (58)**	2 (8)	-	25.0
	GLB	3 (5)	26 (39)	**34 (51)**	4 (6)	-	37.3
3	HGR	7 (21)	**22 (65)**	5 (15)	-	-	85.3
	SYS	4 (20)	**9 (45)**	4 (20)	3 (15)	-	50.0
	GLB	11 (19)	**33 (57)**	11 (19)	3 (5)	-	70.7
4	HGR	3 (15)	**12 (60)**	4 (20)	1 (5)	-	70.0
	SYS	1 (5)	**12 (63)**	6 (32)	-	-	68.4
	GLB	4 (8)	**31 (63)**	13 (27)	1 (2)	-	69.4
5 & 6	HGR	2 (10)	**12 (57)**	5 (24)	2 (10)	-	57.1
	SYS	1 (8)	4 (33)	**6 (50)**	1 (8)	-	33.3
	GLB	4 (11)	**18 (47)**	13 (34)	3 (8)	-	50.0
CTR	HGR	25 (16)	**86 (54)**	41 (26)	5 (3)	1 (.6)	66.0
	SYS	7 (6)	47 (43)	**48 (44)**	8 (7)	-	41.8
	GLB	34 (11)	**155(49)**	112(35)	14 (4)	1 (.3)	54.9

QUESTION 6 - PRELAB WORK (PLW)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	2 (6)	13 (42)	**16 (52)**	-	-	48.4
	SYS	-	**9 (47)**	**9 (47)**	-	1 (5)	42.1
	GLB	2 (3)	26 (42)	**32 (52)**	1 (2)	1 (2)	41.9
2	HGR	-	**11 (50)**	10 (46)	1 (5)	-	45.5
	SYS	-	**6 (50)**	4 (33)	1 (8)	-	41.7
	GLB	-	**19 (50)**	16 (42)	1 (3)	1 (3)	44.7
3	HGR	3 (25)	**7 (58)**	2 (17)	-	-	83.3
	SYS	-	**7 (58)**	5 (42)	-	-	58.3
	GLB	3 (9)	**17 (53)**	12 (38)	-	-	62.5
4	HGR	1 (10)	4 (40)	**5 (50)**	-	-	50.0
	SYS	-	**5 (56)**	3 (33)	1 (11)	-	44.4
	GLB	1 (5)	**9 (45)**	**9 (45)**	1 (5)	-	45.0
5 & 6	HGR	2 (12)	**8 (47)**	6 (35)	1 (6)	-	52.9
	SYS	-	3 (18)	**12 (71)**	2 (12)	-	5.9
	GLB	2 (5)	15 (34)	**23 (52)**	4 (9)	-	29.5
PLW	HGR	8 (9)	**43 (47)**	39 (42)	2 (2)	-	53.3
	SYS	-	30 (44)	**33 (48)**	3 (4)	2 (3)	36.2
	GLB	8 (4)	86 (44)	**92 (47)**	7 (4)	2 (1)	43.4

QUESTION 6 - MINI-PROJECTS

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	1 (5)	**11 (58)**	6 (32)	1 (5)	-	57.9
	SYS	1 (5)	**10 (53)**	8 (42)	-	-	57.9
	GLB	2 (5)	**23 (55)**	16 (38)	1 (2)	-	57.1
2	HGR	1 (7)	**7 (50)**	6 (43)	-	-	57.1
	SYS	-	4 (36)	**6 (55)**	1 (9)	-	27.3
	GLB	1 (4)	11 (44)	**12 (48)**	-	1 (4)	44.0
3	HGR	3 (18)	**10 (59)**	4 (24)	-	-	76.5
	SYS	-	**4 (80)**	1 (20)	-	-	80.0
	GLB	3 (13)	**15 (63)**	6 (25)	-	-	75.0
4	HGR	**4 (44)**	2 (22)	2 (22)	-	-	66.7
	SYS	1 (17)	**2 (33)**	1 (17)	2 (33)	-	16.7
	GLB	5 (29)	**6 (35)**	3 (18)	2 (12)	-	52.9
5 & 6	HGR	**2 (50)**	-	1 (25)	-	-	50.0
	SYS	-	1 (33)	**2 (67)**	-	-	33.3
	GLB	2 (29)	1 (14)	**3 (43)**	-	-	42.9
MP	HGR	11 (18)	**30 (48)**	19 (30)	1 (2)	-	63.5
	SYS	2 (5)	**21 (48)**	18 (41)	2 (5)	1 (2)	45.5
	GLB	13 (11)	**56 (49)**	40 (35)	3 (3)	1 (1)	56.5

QUESTION 6 - PRELAB WORK plus MINI-PROJECTS (P&P)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	%DIF
1	HGR	2 (9)	9 (39)	**11 (48)**	-	-	47.8
	SYS	6 (38)	**6 (38)**	3 (19)	-	-	75.0
	GLB	10 (22)	**15 (33)**	18 (39)	1 (2)	-	52.2
2	HGR	5 (25)	**10 (50)**	5 (25)	-	-	75.0
	SYS	-	**8(100)**	-	-	-	100.0
	GLB	5 (15)	**22 (67)**	6 (18)	-	-	81.8
3	HGR	3 (23)	**7 (54)**	3 (23)	-	-	76.9
	SYS	-	**6 (67)**	2 (22)	1 (11)	-	55.6
	GLB	3 (12)	**14 (56)**	7 (28)	1 (4)	-	64.0
4	HGR	2 (20)	**6 (60)**	2 (20)	-	-	80.0
	SYS	2 (40)	**2 (40)**	-	1 (20)	-	60.0
	GLB	4 (25)	**8 (50)**	3 (19)	1 (6)	-	68.8
5 & 6	HGR	-	**4 (50)**	4 (50)	-	-	50.0
	SYS	-	**1 (33)**	1 (33)	-	-	33.3
	GLB	-	**5 (42)**	6 (50)	-	-	41.7
P&P	HGR	12 (16)	**36 (49)**	25 (34)	-	-	64.9
	SYS	8 (20)	**23 (56)**	6 (15)	2 (5)	-	70.7
	GLB	22 (17)	**64 (49)**	40 (30)	3 (2)	-	62.9

SA= Strongly Agree   A=Agree   N=Neutral   D=Disagree   SD=Strongly Disagree   DIF=(1+2)-(4+5)

APPENDIX C - 1 / (7/15)

QUESTION 7 - CONTROL (CTRL)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
	HGR	13 (25)	33 (62)	4 (8)	1 (2)	-	84.9
1	SYS	10 (29)	19 (56)	3 (9)	-	-	85.3
	GLB	30 (29)	61 (59)	8 (8)	1 (1)	-	86.5
	HGR	3 (10)	17 (55)	9 (29)	1 (3)	-	61.3
2	SYS	3 (13)	15 (63)	5 (21)	1 (4)	-	70.8
	GLB	7 (10)	38 (57)	18 (27)	3 (5)	-	62.7
	HGR	6 (18)	23 (68)	3 (9)	1 (3)	-	82.4
3	SYS	4 (20)	15 (75)	1 (5)	-	-	95.0
	GLB	10 (17)	40 (69)	5 (9)	2 (3)	-	82.8
	HGR	1 (5)	11 (55)	7 (35)	1 (5)	-	55.0
4	SYS	4 (21)	8 (42)	5 (26)	1 (5)	-	57.9
	GLB	7 (14)	23 (47)	13 (27)	5 (10)	-	51.0
5	HGR	3 (14)	12 (57)	6 (29)	-	-	71.4
&	SYS	1 (8)	7 (58)	2 (17)	2 (17)	-	50.0
6	GLB	4 (11)	22 (58)	9 (24)	2 (5)	-	63.2
	HGR	26 (16)	96 (60)	29 (18)	4 (3)	-	74.2
CTR	SYS	22 (20)	64 (58)	16 (15)	5 (5)	-	73.6
	GLB	58 (18)	184 (58)	53 (17)	14 (4)	-	71.9

QUESTION 7 - PRELAB WORK (PLW)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
	HGR	3 (10)	24 (77)	2 (7)	1 (3)	-	83.9
1	SYS	4 (21)	13 (68)	1 (5)	1 (5)	-	84.2
	GLB	8 (13)	46 (74)	5 (8)	2 (3)	-	83.9
	HGR	2 (9)	18 (82)	2 (9)	-	-	90.9
2	SYS	2 (17)	7 (58)	2 (25)	-	-	75.0
	GLB	4 (11)	29 (76)	5 (13)	-	-	86.8
	HGR	1 (8)	6 (50)	4 (33)	-	-	58.3
3	SYS	3 (25)	9 (75)	-	-	-	100.0
	GLB	5 (16)	21 (66)	4 (13)	1 (3)	-	78.1
	HGR	1 (10)	7 (70)	2 (20)	-	-	80.0
4	SYS	6 (67)	3 (33)	-	-	-	100.0
	GLB	7 (35)	11 (55)	2 (10)	-	-	90.0
5	HGR	1 (6)	10 (59)	4 (24)	2 (12)	-	52.9
&	SYS	3 (18)	10 (59)	3 (18)	1 (6)	-	70.6
6	GLB	7 (16)	24 (55)	9 (21)	4 (9)	-	61.4
	HGR	8 (9)	65 (71)	14 (15)	3 (3)	-	76.1
PLW	SYS	18 (26)	42 (61)	7 (10)	2 (3)	-	84.1
	GLB	31 (16)	131 (67)	25 (13)	7 (4)	-	79.1

QUESTION 7 - MINI-PROJECTS (MP)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
	HGR	1 (5)	15 (79)	3 (16)	-	-	84.2
1	SYS	7 (37)	12 (63)	-	-	-	100.0
	GLB	9 (21)	30 (71)	3 (7)	-	-	92.8
	HGR	2 (14)	6 (43)	4 (29)	-	1 (7)	50.0
2	SYS	2 (18)	9 (82)	-	-	-	100.0
	GLB	4 (16)	15 (60)	4 (16)	-	1 (4)	72.0
	HGR	1 (6)	11 (65)	4 (24)	1 (5)	-	64.7
3	SYS	2 (40)	1 (20)	2 (40)	-	-	60.0
	GLB	3 (13)	12 (50)	7 (29)	1 (4)	-	58.3
	HGR	2 (22)	4 (44)	2 (22)	1 (11)	-	55.6
4	SYS	4 (67)	2 (33)	-	-	-	100.0
	GLB	7 (41)	7 (41)	2 (12)	1 (6)	-	76.5
5	HGR	1 (25)	3 (75)	-	-	-	100.0
&	SYS	-	2 (67)	1 (33)	-	-	66.7
6	GLB	1 (14)	5 (71)	1 (14)	-	-	85.7
	HGR	7 (11)	39 (62)	13 (21)	2 (3)	1 (2)	68.3
MP	SYS	15 (34)	26 (59)	3 (7)	-	-	93.2
	GLB	24 (21)	69 (60)	17 (15)	2 (2)	1 (1)	78.3

QUESTION 7 - PRELAB WORK plus MINI-PROJECTS (P&P)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
	HGR	4 (17)	14 (61)	2 (9)	2 (9)	-	69.6
1	SYS	4 (25)	10 (63)	1 (6)	1 (6)	-	81.3
	GLB	9 (20)	28 (61)	4 (9)	4 (9)	-	71.7
	HGR	4 (20)	11 (55)	3 (15)	2 (10)	-	65.0
2	SYS	2 (25)	6 (75)	-	-	-	100.0
	GLB	6 (18)	21 (64)	3 (9)	3 (9)	-	72.7
	HGR	3 (23)	8 (62)	2 (15)	-	-	84.6
3	SYS	3 (33)	5 (56)	-	1 (11)	-	77.8
	GLB	7 (28)	14 (56)	2 (8)	2 (8)	-	76.0
	HGR	4 (40)	4 (40)	2 (20)	-	-	80.0
4	SYS	2 (40)	2 (40)	1 (20)	-	-	80.0
	GLB	6 (38)	6 (38)	4 (25)	-	-	75.0
5	HGR	-	6 (75)	1 (13)	1 (13)	-	62.5
&	SYS	1 (33)	1 (33)	1 (33)	-	-	66.7
6	GLB	1 (8)	7 (58)	3 (25)	1 (8)	-	58.3
	HGR	15 (20)	43 (58)	10 (14)	5 (7)	-	71.6
P&P	SYS	12 (29)	24 (59)	3 (7)	2 (5)	-	82.9
	GLB	29 (22)	76 (58)	16 (12)	10 (8)	-	72.0

SA= Strongly Agree A=Agree N=Neutral D=Disagree SD=Strongly Disagree DIF=(1+2)-(4+5)

APPENDIX C - 1 / (8/15)

QUESTION 8 - CONTROL (CTRL)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	9 (17)	**21 (40)**	18 (34)	4 (8)	1 (2)	47.2
	SYS	4 (12)	10 (29)	**17 (50)**	2 (60)	1 (3)	32.4
	GLB	14 (14)	**39 (38)**	**40 (39)**	7 (7)	4 (4)	40.4
2	HGR	3 (10)	10 (32)	**14 (45)**	4 (13)	-	29.0
	SYS	3 (13)	7 (29)	**9 (38)**	3 (13)	2 (8)	20.8
	GLB	7 (10)	20 (30)	**30 (45)**	8 (12)	2 (3)	25.4
3	HGR	12 (35)	**19 (56)**	2 (6)	1 (3)	-	88.2
	SYS	6 (30)	**11 (55)**	2 (10)	1 (5)	-	80.0
	GLB	18 (31)	**33 (57)**	4 (7)	2 (3)	-	84.5
4	HGR	4 (20)	**11 (55)**	3 (15)	2 (10)	-	65.0
	SYS	2 (11)	**11 (58)**	4 (21)	1 (5)	-	63.2
	GLB	7 (14)	**26 (53)**	11 (22)	4 (8)	-	59.2
5	HGR	2 (10)	**17 (81)**	2 (10)	-	-	90.5
&	SYS	-	**8 (67)**	3 (25)	-	-	66.7
6	GLB	2 (5)	**28 (74)**	6 (16)	1 (3)	-	76.3
CTR	HGR	30 (19)	**78 (49)**	39 (25)	11 (7)	1 (.6)	60.4
	SYS	15 (14)	**47 (43)**	36 (33)	7 (6)	3 (3)	47.3
	GLB	48 (15)	**146(46)**	92 (29)	22 (7)	6 (2)	52.4

QUESTION 8 - MINI-PROJECTS (MP)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	1 (5)	**11 (58)**	7 (37)	-	-	63.2
	SYS	2 (11)	7 (37)	**8 (42)**	1 (5)	-	42.1
	GLB	3 (7)	**20 (48)**	16 (38)	1 (2)	-	52.4
2	HGR	1 (7)	**5 (36)**	**5 (36)**	-	1 (7)	28.6
	SYS	-	1 (9)	**8 (73)**	1 (9)	1 (4)	0.0
	GLB	1 (4)	6 (24)	**13 (52)**	2 (8)		16.0
3	HGR	4 (24)	**6 (35)**	**6 (35)**	1 (6)	-	52.9
	SYS	**3 (60)**	-	2 (40)	-	-	60.0
	GLB	7 (29)	7 (29)	**8 (33)**	2 (8)	-	50.0
4	HGR	**6 (67)**	1 (11)	2 (22)	-	-	77.8
	SYS	2 (33)	2 (33)	2 (33)	-	-	66.7
	GLB	**9 (53)**	3 (18)	4 (24)	-	-	70.6
5	HGR	**2 (50)**	-	1 (25)	-	-	50.0
&	SYS	-	**2 (67)**	-	-	-	66.7
6	GLB	**2 (29)**	2 (29)	1 (14)	-	-	57.1
MP	HGR	14 (22)	**23 (37)**	21 (33)	2 (3)	1 (2)	54.0
	SYS	7 (16)	**12 (27)**	20 (46)	2 (5)	-	38.6
	GLB	22 (19)	**38 (33)**	42 (37)	5 (4)	1 (1)	47.0

QUESTION 8 - PRELAB WORK (PLW)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	5 (16)	**11 (36)**	11 (36)	2 (7)	1 (3)	41.9
	SYS	1 (5)	**11 (58)**	7 (37)	-	-	63.2
	GLB	8 (13)	**27 (44)**	22 (36)	3 (5)	1 (2)	50.0
2	HGR	-	**12 (55)**	8 (36)	1 (5)	1 (5)	45.5
	SYS	-	**7 (58)**	2 (17)	2 (17)	-	41.7
	GLB	2 (5)	**21 (55)**	10 (26)	3 (8)	1 (3)	50.0
3	HGR	3 (25)	**8 (67)**	-	1 (8)	-	83.3
	SYS	2 (17)	**5 (42)**	5 (42)	-	-	58.3
	GLB	5 (16)	**17 (53)**	6 (19)	3 (9)	-	59.4
4	HGR	-	3 (30)	**7 (70)**	-	-	30.0
	SYS	2 (22)	**4 (44)**	2 (22)	1 (11)	-	55.6
	GLB	2 (10)	7 (35)	**10 (50)**	1 (5)	-	40.0
5	HGR	1 (6)	7 (41)	**8 (47)**	1 (6)	-	41.2
&	SYS	2 (12)	**9 (53)**	5 (29)	1 (6)	-	58.8
6	GLB	5 (11)	**21 (48)**	16 (36)	2 (5)	-	54.5
PLW	HGR	9 (9)	**41 (45)**	34 (37)	5 (5)	2 (2)	46.7
	SYS	7 (10)	**36 (52)**	21 (30)	4 (6)	-	56.5
	GLB	22 (11)	**93 (47)**	64 (33)	12 (6)	2 (1)	51.5

QUESTION 8 - PRELAB WORK plus MINI-PROJECT (P&P)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	2 (9)	**13 (57)**	6 (26)	1 (4)	-	60.9
	SYS	3 (19)	**9 (56)**	3 (19)	-	-	75.0
	GLB	6 (13)	**23 (50)**	14 (30)	-	1 (2)	60.9
2	HGR	2 (10)	**10 (50)**	7 (35)	1 (5)	-	55.0
	SYS	1 (13)	**5 (63)**	2 (25)	-	-	75.0
	GLB	3 (9)	**19 (58)**	10 (30)	1 (3)	-	63.6
3	HGR	**7 (54)**	5 (39)	1 (8)	-	-	92.3
	SYS	3 (33)	**4 (44)**	2 (22)	-	-	77.8
	GLB	**11 (44)**	**11 (44)**	3 (12)	-	-	88.0
4	HGR	2 (20)	**5 (50)**	3 (30)	-	-	70.0
	SYS	2 (40)	**3 (60)**	-	-	-	100.0
	GLB	4 (25)	**9 (56)**	3 (19)	-	-	81.3
5	HGR	2 (25)	**3 (38)**	3 (38)	-	-	62.5
&	SYS	-	**3(100)**	-	-	-	100.0
6	GLB	2 (17)	**7 (58)**	3 (25)	-	-	75.0
P&P	HGR	15 (20)	**36 (49)**	20 (27)	1 (1)	1 (1)	66.2
	SYS	9 (22)	**24 (59)**	7 (17)	-	-	80.5
	GLB	26 (20)	**69 (52)**	33 (25)	1 (1)	1 (1)	70.5

SA=Strongly Agree A=Agree N=Neutral D=Disagree SD=Strongly Disagree DIF=(1+2)-(4+5)

APPENDIX C - 1 / (9/15)

QUESTION 9 - CONTROL (CTRL)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	5 (9)	**33 (62)**	11 (21)	4 (8)	-	64.2
	SYS	2 (6)	**12 (35)**	8 (24)	7 (21)	4 (12)	8.8
	GLB	7 (7)	**56 (54)**	24 (23)	12 (12)	4 (4)	45.2
2	HGR	-	**13 (42)**	12 (39)	3 (10)	2 (7)	25.8
	SYS	3 (13)	**10 (42)**	6 (25)	4 (17)	1 (4)	33.3
	GLB	3 (5)	**26 (39)**	22 (33)	10 (15)	5 (8)	20.9
3	HGR	1 (3)	10 (29)	**18 (53)**	3 (9)	-	23.5
	SYS	2 (10)	**8 (40)**	7 (35)	2 (10)	-	40.0
	GLB	3 (5)	20 (35)	**26 (45)**	5 (9)	1 (2)	29.3
4	HGR	2 (10)	7 (35)	**9 (45)**	2 (10)	-	35.0
	SYS	2 (11)	**10 (53)**	3 (16)	2 (11)	2 (11)	42.1
	GLB	6 (12)	**20 (41)**	14 (29)	6 (12)	3 (6)	34.7
5	HGR	3 (14)	**10 (48)**	5 (24)	1 (5)	-	57.1
&	SYS	-	**7 (58)**	2 (17)	3 (25)	-	33.3
6	GLB	5 (13)	**18 (47)**	9 (24)	4 (11)	-	50.0
	HGR	11 (7)	**73 (46)**	55 (35)	13 (8)	2 (1)	43.4
CTR	SYS	9 (8)	**47 (43)**	27 (25)	18 (16)	7 (6)	28.2
	GLB	24 (8)	**140(44)**	96 (30)	37 (12)	13 (4)	36.0

QUESTION 9 - PRELAB WORK (PLW)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	-	10 (32)	**16 (52)**	5 (16)	-	16.1
	SYS	1 (5)	**11 (58)**	6 (32)	1 (5)	-	57.9
	GLB	3 (5)	**26 (42)**	**26 (42)**	7 (11)	-	35.5
2	HGR	1 (5)	**9 (41)**	5 (23)	7 (32)	-	13.6
	SYS	2 (17)	**5 (42)**	1 (8)	2 (17)	1 (8)	33.3
	GLB	3 (8)	**15 (40)**	8 (21)	10 (26)	1 (3)	18.4
3	HGR	-	3 (25)	**8 (67)**	1 (8)	-	16.7
	SYS	1 (8)	4 (33)	**7 (58)**	-	-	41.7
	GLB	1 (3)	9 (28)	**18 (56)**	3 (9)	1 (3)	18.8
4	HGR	1 (10)	1 (10)	**6 (60)**	2 (20)	-	0
	SYS	1 (11)	2 (22)	**5 (56)**	1 (11)	-	22.2
	GLB	2 (10)	3 (15)	**11 (55)**	4 (20)	-	5.0
5	HGR	1 (6)	**7 (41)**	6 (35)	2 (12)	1 (6)	29.4
&	SYS	2 (12)	**7 (41)**	5 (29)	3 (18)	-	35.3
6	GLB	3 (7)	**19 (43)**	15 (34)	5 (11)	1 (2)	36.4
	HGR	3 (3)	30 (33)	**41 (45)**	17 (19)	1 (1)	16.3
PLW	SYS	7 (10)	**29 (42)**	24 (35)	7 (10)	1 (1)	40.6
	GLB	12 (6)	72 (37)	**78 (40)**	29 (15)	3 (2)	26.5

QUESTION 9 - MINI-PROJECTS (MP)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	1 (5)	**7 (37)**	6 (32)	3 (16)	1 (5)	21.1
	SYS	4 (21)	**9 (47)**	5 (26)	1 (5)	-	63.2
	GLB	5 (12)	**19 (45)**	12 (29)	4 (10)	1 (2)	45.2
2	HGR	-	**4 (29)**	3 (21)	**4 (29)**	3 (21)	-21.4
	SYS	-	3 (27)	2 (18)	**5 (46)**	1 (9)	-27.3
	GLB	-	7 (28)	5 (20)	**9 (36)**	4 (16)	-24.0
3	HGR	2 (12)	**6 (35)**	**6 (35)**	1 (6)	1 (6)	35.3
	SYS	-	-	**3 (60)**	2 (40)	-	-40.0
	GLB	2 (8)	7 (29)	**10 (42)**	3 (13)	1 (4)	20.8
4	HGR	1 (11)	2 (22)	**4 (44)**	1 (11)	1 (11)	11.1
	SYS	1 (17)	**3 (50)**	1 (17)	1 (17)	-	50.0
	GLB	2 (12)	**6 (35)**	**6 (35)**	2 (12)	1 (6)	29.4
5	HGR	1 (25)	**2 (50)**	-	1 (25)	-	50.0
&	SYS	-	1 (33)	**2 (67)**	-	-	33.3
6	GLB	1 (14)	**3 (43)**	2 (29)	1 (14)	-	42.9
	HGR	5 (8)	**21 (33)**	19 (30)	10 (16)	6 (10)	15.9
MP	SYS	5 (11)	**16 (36)**	13 (30)	9 (21)	1 (2)	25.0
	GLB	10 (9)	**42 (37)**	35 (30)	19 (17)	7 (6)	22.6

QUESTION 9 - PRELAB WORK plus MINI-PROJECTS (P&P)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	1 (4)	**10 (44)**	7 (30)	5 (22)	-	26.1
	SYS	2 (13)	6 (38)	**7 (44)**	1 (6)	-	43.8
	GLB	4 (9)	**17 (37)**	16 (35)	9 (20)	-	26.1
2	HGR	1 (5)	**9 (45)**	2 (10)	7 (35)	-	15.0
	SYS	1 (13)	**4 (50)**	3 (38)	-	-	62.5
	GLB	2 (6)	**15 (46)**	5 (15)	10 (30)	-	21.2
3	HGR	1 (8)	5 (38)	**6 (46)**	1 (8)	-	38.5
	SYS	2 (22)	2 (22)	**2 (22)**	2 (22)	-	22.2
	GLB	3 (12)	8 (32)	**10 (40)**	3 (12)	-	32.0
4	HGR	-	2 (20)	**5 (50)**	3 (30)	-	-10.0
	SYS	-	**5(100)**	-	-	-	100.0
	GLB	-	**8 (50)**	5 (31)	3 (19)	-	31.3
5	HGR	-	**4 (50)**	3 (38)	1 (13)	-	37.5
&	SYS	-	**2 (67)**	1 (33)	-	-	66.7
6	GLB	-	**6 (50)**	4 (33)	2 (17)	-	33.3
	HGR	3 (4)	**30 (41)**	23 (31)	17 (23)	-	21.6
P&P	SYS	5 (12)	**19 (46)**	12 (29)	4 (10)	-	48.8
	GLB	9 (7)	**54 (41)**	40 (30)	27 (21)	-	27.3

SA=Strongly Agree A=Agree N=Neutral D=Desagree SD=Strongly Desagree DIF=(1+2)-(4+5)

APPENDIX C - 1 / (10/15)

QUESTION 10 - CONTROL (CTRL)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	10 (19)	33 (62)	9 (17)	-	-	81.1
	SYS	3 (9)	24 (71)	7 (21)	-	-	79.4
	GLB	18 (17)	64 (62)	21 (20)	-	-	78.8
2	HGR	3 (10)	21 (68)	6 (19)	1 (3)	-	74.2
	SYS	4 (17)	16 (67)	4 (17)	-	-	83.3
	GLB	9 (13)	42 (63)	13 (19)	3 (5)	-	71.6
3	HGR	6 (18)	21 (62)	7 (21)	-	-	79.4
	SYS	1 (5)	17 (85)	2 (10)	-	-	90.0
	GLB	7 (12)	41 (71)	9 (16)	1 (2)	-	81.0
4	HGR	1 (5)	8 (40)	9 (45)	2 (10)	-	35.0
	SYS	4 (21)	12 (63)	3 (16)	-	-	84.2
	GLB	7 (14)	25 (51)	14 (29)	3 (6)	-	59.2
5	HGR	-	13 (62)	6 (29)	2 (10)	-	52.4
&	SYS	3 (25)	3 (25)	6 (50)	-	-	50.0
6	GLB	4 (11)	16 (42)	16 (42)	2 (5)	-	47.4
	HGR	20 (13)	96 (60)	37 (23)	5 (3)	-	69.8
CTR	SYS	15 (14)	72 (66)	23 (21)	-	-	79.1
	GLB	45 (14)	188 (59)	74 (23)	9 (3)	-	70.7

QUESTION 10 - MINI-PROJECTS (MP)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	4 (21)	11 (58)	4 (21)	-	-	78.9
	SYS	8 (42)	9 (47)	2 (11)	-	-	89.5
	GLB	14 (33)	21 (50)	6 (14)	-	-	83.3
2	HGR	1 (7)	5 (36)	7 (50)	1 (7)	-	35.7
	SYS	1 (9)	6 (55)	3 (27)	1 (9)	-	54.5
	GLB	2 (8)	11 (44)	10 (40)	2 (8)	-	44.0
3	HGR	2 (12)	11 (65)	4 (24)	-	-	76.5
	SYS	2 (40)	3 (60)	-	-	-	100.0
	GLB	4 (17)	16 (67)	4 (17)	-	-	83.3
4	HGR	-	7 (78)	2 (22)	-	-	77.8
	SYS	1 (17)	4 (67)	1 (17)	-	-	83.3
	GLB	1 (6)	12 (71)	4 (24)	-	-	76.5
5	HGR	1 (25)	2 (50)	1 (25)	-	-	75.0
&	SYS	-	1 (33)	1 (33)	-	-	33.3
6	GLB	1 (14)	3 (43)	2 (29)	-	-	57.1
	HGR	8 (13)	36 (57)	18 (29)	1 (2)	-	68.3
MP	SYS	12 (27)	23 (53)	7 (16)	1 (2)	-	77.3
	GLB	22 (19)	63 (55)	26 (23)	2 (2)	-	72.2

QUESTION 10 - PRELAB WORK (PLW)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	4 (13)	21 (68)	5 (16)	-	-	80.6
	SYS	2 (11)	13 (68)	2 (11)	2 (11)	-	68.4
	GLB	8 (13)	40 (65)	10 (16)	3 (5)	-	72.6
2	HGR	1 (5)	16 (73)	5 (23)	-	-	77.3
	SYS	1 (8)	7 (58)	2 (17)	2 (17)	-	50.0
	GLB	2 (5)	27 (71)	7 (18)	2 (5)	-	71.1
3	HGR	-	8 (67)	4 (33)	-	-	66.7
	SYS	5 (48)	4 (33)	3 (25)	-	-	75.0
	GLB	5 (16)	20 (63)	7 (22)	-	-	78.1
4	HGR	1 (10)	7 (70)	2 (20)	-	-	80.0
	SYS	1 (11)	6 (67)	2 (22)	-	-	77.8
	GLB	2 (10)	14 (70)	4 (20)	-	-	80.0
5	HGR	1 (6)	10 (59)	5 (29)	1 (6)	-	58.8
&	SYS	2 (12)	12 (71)	3 (18)	-	-	82.4
6	GLB	3 (7)	27 (61)	11 (25)	2 (5)	-	63.6
	HGR	7 (8)	62 (67)	21 (23)	1 (1)	-	73.9
PLW	SYS	11 (16)	42 (61)	12 (17)	4 (6)	-	71.0
	GLB	20 (10)	128 (65)	39 (20)	7 (4)	-	71.9

QUESTION 10 - PRELAB WORK plus MINI-PROJECTS (P&P)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	4 (17)	15 (65)	3 (13)	1 (4)	-	78.3
	SYS	5 (31)	8 (50)	2 (13)	1 (6)	-	75.0
	GLB	10 (22)	28 (61)	6 (13)	1 (2)	1 (2)	78.3
2	HGR	1 (5)	12 (60)	5 (25)	1 (5)	-	60.0
	SYS	3 (38)	4 (50)	-	1 (13)	-	75.0
	GLB	4 (12)	20 (61)	6 (18)	2 (6)	-	66.7
3	HGR	2 (15)	9 (69)	2 (15)	-	-	84.6
	SYS	4 (44)	3 (33)	2 (22)	-	-	77.8
	GLB	6 (24)	15 (60)	4 (16)	-	-	84.0
4	HGR	2 (20)	6 (60)	2 (20)	-	-	80.0
	SYS	2 (40)	3 (60)	-	-	-	100.0
	GLB	4 (25)	9 (56)	3 (19)	-	-	81.3
5	HGR	1 (13)	4 (50)	3 (38)	-	-	62.5
&	SYS	-	1 (33)	2 (67)	-	-	33.3
6	GLB	1 (8)	5 (42)	6 (50)	-	-	50.0
	HGR	10 (14)	46 (62)	15 (20)	2 (3)	-	73.0
P&P	SYS	14 (34)	19 (46)	6 (15)	1 (2)	1 (2)	75.6
	GLB	25 (19)	77 (58)	25 (19)	3 (2)	1 (1)	75.0

SA=Strongly Agree A=Agree N=Neutral D=Desagree SD=Strongly Desagree DIF=(1+2)-(4+5)

APPENDIX C - 1 / (11/15)

QUESTION 11 - CONTROL (CTRL)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	-	1 (2)	10 (19)	**31 (59)**	10 (19)	-75.5
	SYS	-	-	10 (29)	**18 (53)**	6 (18)	-70.6
	GLB	-	2 (4)	20 (19)	**58 (56)**	21 (20)	-74.0
2	HGR	-	4 (13)	6 (19)	**17 (55)**	4 (13)	-54.8
	SYS	-	4 (17)	9 (38)	**9 (38)**	2 (8)	-29.2
	GLB	1 (2)	10 (15)	18 (27)	**30 (45)**	8 (12)	-40.3
3	HGR	-	1 (3)	9 (27)	**21 (62)**	3 (9)	-67.6
	SYS	1 (5)	1 (5)	-	**16 (80)**	2 (10)	-80.0
	GLB	2 (3)	2 (3)	11 (19)	**38 (66)**	5 (9)	-67.2
4	HGR	-	3 (15)	**9 (45)**	6 (30)	1 (5)	-20.0
	SYS	-	-	**8 (42)**	7 (37)	3 (16)	-52.6
	GLB	-	4 (8)	17 (35)	**18 (37)**	8 (16)	-44.9
5 & 6	HGR	-	3 (14)	**8 (38)**	8 (38)	-	-23.8
	SYS	-	1 (8)	**4 (33)**	4 (33)	3 (25)	-50.0
	GLB	-	5 (13)	**15 (40)**	12 (32)	4 (11)	-28.9
CTR	HGR	-	12 (8)	42 (26)	**83 (52)**	18 (11)	-56.0
	SYS	1 (1)	6 (6)	31 (28)	**55 (50)**	16 (15)	-58.2
	GLB	3 (1)	25 (8)	81 (26)	**157 (50)**	46 (15)	-55.2

QUESTION 11 - MINI-PROJECTS (MP)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	-	1 (5)	4 (21)	**13 (68)**	1 (5)	-68.4
	SYS	-	-	1 (5)	**12 (63)**	6 (32)	-94.7
	GLB	-	1 (2)		**28 (67)**	8 (19)	-83.3
2	HGR	2 (14)	2 (14)	**5 (36)**	4 (29)	1 (7)	-7.1
	SYS	-	2 (28)	-	**9 (82)**	-	-63.6
	GLB	2 (8)	4 (16)	5 (20)	**13 (52)**	1 (4)	-32.0
3	HGR	1 (6)	1 (6)	3 (18)	**9 (53)**	3 (18)	-58.8
	SYS	-	1 (20)	-	**3 (60)**	1 (20)	-60.0
	GLB	1 (4)	2 (8)	4 (17)	**12 (50)**	5 (21)	-58.3
4	HGR	1 (11)	-	3 (33)	**5 (56)**	-	-44.4
	SYS	-	1 (17)	-	**4 (67)**	1 (17)	-66.7
	GLB	1 (6)	1 (6)	3 (18)	**11 (65)**	1 (6)	-58.8
5 & 6	HGR	1 (25)	-	**2 (50)**	-	1 (25)	0.0
	SYS	-	-	1 (33)	**2 (67)**	-	-66.7
	GLB	1 (14)	-	3 (43)	**2 (29)**	1 (14)	-28.6
MP	HGR	5 (8)	4 (6)	17 (27)	**31 (49)**	6 (10)	-44.4
	SYS	-	4 (9)	2 (5)	**30 (68)**	8 (18)	-77.3
	GLB	5 (4)	8 (7)	20 (17)	**66 (57)**	16 (14)	-60.0

QUESTION 11 - PRELAB WORK (PLW)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	-	2 (7)	5 (16)	**21 (68)**	2 (7)	-67.7
	SYS	-	-	2 (11)	**10 (53)**	7 (37)	-89.5
	GLB	-	3 (5)	8 (13)	**36 (58)**	13 (21)	-74.2
2	HGR	-	2 (9)	6 (27)	**12 (55)**	2 (9)	-54.5
	SYS	-	2 (17)	2 (17)	**6 (50)**	2 (17)	-50.0
	GLB	-	4 (11)	11 (29)	**19 (50)**	4 (11)	-50.0
3	HGR	1 (8)	2 (17)	1 (8)	**6 (50)**	2 (17)	-41.7
	SYS	-	-	-	**7 (58)**	5 (42)	-100
	GLB	1 (3)	2 (6)	4 (13)	**15 (47)**	10 (31)	-68.8
4	HGR	-	1 (10)	-	**7 (70)**	2 (20)	-80.0
	SYS	-	1 (11)	2 (22)	**4 (44)**	2 (22)	-55.6
	GLB	-	2 (10)	3 (15)	**11 (55)**	4 (20)	-65.0
5 & 6	HGR	1 (6)	2 (12)	6 (35)	**8 (47)**	-	-29.4
	SYS	-	-	7 (41)	**8 (47)**	2 (12)	-58.8
	GLB	1 (2)	3 (7)	14 (32)	**21 (48)**	4 (9)	-47.7
PLW	HGR	2 (2)	9 (10)	18 (20)	**54 (59)**	8 (9)	-55.4
	SYS	-	3 (4)	13 (19)	**35 (51)**	18 (26)	-72.5
	GLB	2 (1)	14 (7)	40 (20)	**102 (52)**	35 (18)	-61.7

QUESTION 11 - PRELAB WORK plus MINI-PROJECTS (P&P)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	-	1 (4)	6 (26)	**9 (39)**	7 (30)	-65.2
	SYS	-	-	1 (6)	**9 (56)**	6 (38)	-93.8
	GLB	-	3 (7)	7 (15)	**21 (46)**	14 (30)	-69.6
2	HGR	-	4 (20)	8 (40)	**8 (40)**	-	-20.0
	SYS	-	-	1 (13)	**4 (50)**	3 (38)	-87.5
	GLB	-	4 (12)	9 (27)	**16 (49)**	3 (9)	-45.5
3	HGR	1 (8)	1 (8)	3 (23)	**6 (46)**	2 (15)	-46.2
	SYS	-	1 (11)	2 (22)	**3 (33)**	3 (33)	-55.6
	GLB	1 (4)	2 (8)	7 (28)	**10 (40)**	5 (20)	-48.0
4	HGR	-	3 (30)	3 (30)	**3 (30)**	1 (10)	-10.0
	SYS	-	-	1 (20)	**4 (80)**	-	-80.0
	GLB	-	3 (19)	4 (25)	**8 (50)**	1 (6)	-37.5
5 & 6	HGR	-	2 (25)	**3 (38)**	3 (38)	-	-12.5
	SYS	-	1 (33)	**1 (33)**	-	1 (33)	0.0
	GLB	-	4 (33)	**4 (33)**	3 (25)	1 (8)	0.0
P&P	HGR	1 (1)	11 (15)	23 (31)	**29 (39)**	10 (14)	-36.5
	SYS	-	2 (5)	6 (15)	**20 (49)**	13 (32)	-75.6
	GLB	1 (1)	16 (12)	31 (24)	**58 (44)**	24 (18)	-49.2

SA=Strongly Agree A=Agree N=Neutral D=Disagree SD=Strongly Disagree DIF=(1+2)-(4+5)

APPENDIX C - 1 / (12/15)

QUESTION 12 - CONTROL (CTRL)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	5 (9)	27 (51)	14 (26)	3 (6)	-	54.7
	SYS	4 (12)	15 (44)	10 (29)	4 (12)	-	44.1
	GLB	11 (11)	49 (47)	28 (27)	11 (11)	-	47.1
2	HGR	-	18 (58)	7 (23)	2 (7)	-	51.6
	SYS	2 (8)	11 (46)	9 (38)	1 (4)	1 (4)	45.8
	GLB	3 (5)	35 (52)	19 (28)	4 (6)	2 (3)	47.8
3	HGR	4 (12)	19 (56)	6 (18)	4 (12)	1 (3)	52.9
	SYS	1 (5)	15 (75)	3 (15)	-	-	80.0
	GLB	6 (10)	34 (59)	9 (16)	7 (12)	1 (2)	55.2
4	HGR	2 (10)	5 (25)	5 (25)	7 (35)	-	0.0
	SYS	3 (16)	7 (37)	6 (32)	2 (11)	-	42.1
	GLB	7 (14)	16 (33)	12 (25)	11 (22)	-	24.5
5 & 6	HGR	1 (5)	8 (38)	5 (24)	5 (24)	1 (5)	14.3
	SYS	-	7 (58)	5 (42)	-	-	58.3
	GLB	2 (5)	15 (40)	12 (32)	6 (16)	1 (3)	26.3
CTR	HGR	12 (75)	77 (48)	37 (23)	21 (13)	2 (1)	41.5
	SYS	10 (9)	56 (51)	33 (30)	7 (6)	1 (1)	52.7
	GLB	29 (9)	150 (47)	80 (25)	39 (12)	4 (1)	42.9

QUESTION 12 - PRELAB WORK (PLW)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	-	11 (36)	13 (42)	4 (13)	-	22.6
	SYS	1 (5)	9 (47)	7 (37)	1 (5)	-	47.4
	GLB	1 (2)	29 (47)	21 (34)	5 (8)	1 (2)	38.7
2	HGR	1 (5)	9 (41)	8 (36)	3 (14)	-	31.8
	SYS	1 (8)	7 (58)	4 (33)	-	-	66.7
	GLB	2 (5)	19 (50)	13 (34)	3 (8)	-	47.4
3	HGR	2 (17)	5 (42)	1 (8)	4 (33)	-	25.0
	SYS	4 (33)	7 (58)	1 (8)	-	-	91.7
	GLB	6 (19)	19 (59)	2 (6)	5 (16)	-	62.5
4	HGR	-	1 (10)	7 (70)	1 (10)	-	0.0
	SYS	1 (11)	6 (67)	2 (22)	-	-	77.8
	GLB	1 (5)	7 (35)	10 (50)	1 (5)	-	35.0
5 & 6	HGR	-	7 (41)	3 (18)	4 (24)	-	17.6
	SYS	2 (12)	10 (59)	2 (12)	2 (12)	1 (6)	52.9
	GLB	2 (5)	23 (52)	7 (16)	7 (16)	1 (2)	38.6
PLW	HGR	3 (3)	33 (36)	32 (35)	16 (17)	-	21.7
	SYS	9 (13)	39 (57)	16 (23)	3 (4)	1 (1)	63.8
	GLB	12 (6)	97 (50)	53 (27)	21 (11)	2 (1)	43.9

QUESTION 12 - MINI-PROJECTS (MP)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	-	10 (53)	7 (37)	2 (11)	-	42.1
	SYS	2 (11)	15 (79)	2 (11)	-	-	89.5
	GLB	2 (5)	28 (67)	10 (24)	2 (5)	-	66.7
2	HGR	1 (7)	5 (36)	3 (21)	4 (29)	-	14.3
	SYS	-	8 (73)	2 (18)	1 (9)	-	63.6
	GLB	1 (4)	13 (52)	5 (20)	5 (20)	-	36.0
3	HGR	2 (12)	10 (59)	4 (24)	1 (6)	-	64.7
	SYS	2 (40)	2 (40)	-	1 (20)	-	60.0
	GLB	4 (17)	14 (58)	4 (17)	2 (8)	-	66.7
4	HGR	-	6 (67)	1 (11)	2 (22)	-	44.4
	SYS	-	6 (100)	-	-	-	100.0
	GLB	-	14 (82)	1 (6)	2 (12)	-	70.6
5 & 6	HGR	-	3 (75)	-	1 (25)	-	50.0
	SYS	-	-	2 (67)	1 (33)	-	-33.3
	GLB	-	3 (43)	2 (29)	2 (29)	-	14.3
MP	HGR	3 (5)	34 (54)	15 (24)	10 (16)	-	23.5
	SYS	4 (9)	31 (71)	6 (14)	3 (7)	-	72.7
	GLB	7 (6)	72 (63)	22 (19)	13 (11)	-	57.4

QUESTION 12 - PRELAB WORK plus MINI-PROJECTS (P&P)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	1 (4)	7 (30)	7 (30)	7 (30)	1 (4)	0.0
	SYS	4 (25)	6 (38)	5 (31)	-	1 (6)	56.3
	GLB	6 (13)	16 (35)	14 (30)	7 (15)	3 (7)	26.1
2	HGR	1 (5)	5 (25)	-	6 (30)	1 (5)	-5.0
	SYS	1 (13)	4 (50)	3 (38)	-	-	62.5
	GLB	2 (6)	12 (36)	11 (33)	6 (18)	1 (3)	21.2
3	HGR	2 (15)	10 (77)	-	1 (8)	-	84.6
	SYS	3 (33)	4 (44)	1 (11)	1 (11)	-	66.7
	GLB	5 (20)	16 (64)	1 (4)	3 (12)	-	72.0
4	HGR	1 (10)	2 (20)	4 (40)	3 (30)	-	0.0
	SYS	-	3 (60)	2 (40)	-	-	60.0
	GLB	1 (6)	6 (38)	6 (38)	3 (19)	-	25.0
5 & 6	HGR	-	2 (25)	3 (38)	2 (25)	-	0.0
	SYS	1 (33)	-	1 (33)	1 (33)	-	0.0
	GLB	1 (8)	2 (17)	4 (33)	4 (33)	-	-8.3
P&P	HGR	5 (7)	26 (35)	20 (27)	19 (26)	2 (3)	13.5
	SYS	9 (22)	17 (42)	12 (29)	2 (5)	1 (2)	56.1
	GLB	15 (11)	52 (39)	36 (27)	23 (17)	4 (3)	30.3

SA=Strongly Agree A=Agree N=Neutral D=Disagree SD=Strongly Disagree DIF=(1+2)-(4+5)

APPENDIX C - 1 / (13/15)

QUESTION 13 - CONTROL (CTRL)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	6 (11)	25 (47)	16 (30)	5 (9)	1 (2)	47.2
	SYS	5 (15)	15 (44)	7 (21)	5 (15)	1 (3)	41.2
	GLB	12 (12)	52 (50)	27 (26)	10 (10)	2 (2)	50.0
2	HGR	1 (3)	12 (39)	14 (45)	3 (10)	1 (3)	29.0
	SYS	1 (4)	9 (38)	7 (29)	5 (21)	2 (8)	12.5
	GLB	2 (3)	28 (42)	23 (34)	10 (15)	4 (6)	23.9
3	HGR	3 (9)	17 (50)	10 (29)	4 (12)	-	47.1
	SYS	1 (5)	8 (40)	8 (40)	2 (10)	1 (5)	30.0
	GLB	4 (7)	28 (48)	19 (33)	6 (10)	1 (2)	43.1
4	HGR	3 (15)	11 (55)	5 (25)	1 (5)	-	65.0
	SYS	2 (11)	11 (58)	2 (11)	3 (16)	1 (5)	47.4
	GLB	6 (12)	25 (51)	10 (20)	7 (14)	1 (2)	46.9
5 & 6	HGR	-	15 (71)	3 (14)	1 (5)	-	66.7
	SYS	-	7 (58)	4 (33)	1 (8)	-	50.0
	GLB	-	23 (61)	9 (24)	4 (11)	-	50.0
CTR	HGR	13 (8)	80 (50)	48 (30)	14 (9)	2 (1)	48.4
	SYS	9 (8)	50 (46)	28 (26)	17 (16)	5 (5)	33.6
	GLB	24 (8)	156(49)	88 (28)	38 (12)	8 (2)	42.3

QUESTION 13 - PRELAB WORK (PLW)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	1 (3)	24 (77)	4 (13)	2 (7)	-	74.2
	SYS	1 (5)	9 (47)	7 (37)	2 (11)	-	42.1
	GLB	3 (5)	39 (63)	16 (26)	4 (7)	-	61.3
2	HGR	2 (9)	11 (50)	7 (31)	2 (9)	-	50.0
	SYS	2 (17)	6 (50)	3 (25)	-	-	66.7
	GLB	4 (11)	21 (55)	10 (26)	2 (5)	-	60.5
3	HGR	-	4 (33)	7 (58)	1 (8)	-	25.0
	SYS	2 (17)	4 (33)	4 (33)	2 (17)	-	33.3
	GLB	2 (6)	14 (44)	12 (38)	4 (13)	-	37.5
4	HGR	1 (10)	6 (60)	2 (20)	1 (10)	-	60.0
	SYS	2 (22)	4 (44)	3 (33)	-	-	66.7
	GLB	3 (15)	10 (50)	5 (25)	1 (5)	1 (5)	55.0
5 & 6	HGR	-	11 (65)	6 (35)	-	-	64.7
	SYS	1 (6)	12 (71)	4 (24)	-	-	76.5
	GLB	1 (2)	32 (73)	11 (25)	-	-	75.0
PLW	HGR	4 (4)	56 (61)	26 (28)	6 (7)	-	58.7
	SYS	8 (12)	35 (51)	21 (30)	4 (6)	-	56.5
	GLB	13 (7)	116(59)	54 (28)	11 (6)	1 (.5)	59.7

QUESTION 13 - MINI-RPOJECTS (MP)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	2 (11)	11 (58)	4 (21)	2 (11)	-	57.9
	SYS	4 (21)	10 (53)	2 (11)	3 (16)	-	57.9
	GLB	7 (17)	22 (52)	7 (17)	6 (14)	-	54.8
2	HGR	1 (7)	2 (14)	8 (57)	3 (21)	-	0.0
	SYS	1 (9)	6 (55)	3 (27)	-	-	63.6
	GLB	2 (8)	8 (32)	11 (44)	3 (12)	-	28.0
3	HGR	1 (6)	8 (47)	7 (41)	1 (6)	-	47.1
	SYS	-	3 (60)	-	1 (20)	1 (20)	20.0
	GLB	1 (4)	12 (50)	8 (33)	2 (8)	1 (4)	41.7
4	HGR	1 (11)	2 (22)	4 (44)	2 (22)	-	11.1
	SYS	-	4 (67)	1 (17)	1 (17)	-	50.0
	GLB	2 (12)	7 (41)	5 (29)	3 (18)	-	35.3
5 & 6	HGR	-	1 (25)	2 (50)	1 (25)	-	0.0
	SYS	-	1 (33)	1 (33)	1 (33)	-	0.0
	GLB	-	2 (29)	3 (43)	1 (14)	1 (14)	0.0
MP	HGR	5 (8)	24 (38)	25 (40)	8 (13)	1 (2)	31.7
	SYS	5 (11)	24 (55)	7 (16)	6 (14)	1 (2)	50.0
	GLB	12 (10)	51 (44)	34 (30)	15 (13)	2 (2)	40.0

QUESTION 13 - PRELAB WORK plus MINI-PROJECTS (P&P)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	1 (4)	12 (52)	5 (22)	3 (13)	2 (9)	34.8
	SYS	3 (19)	8 (50)	3 (19)	2 (13)	-	56.3
	GLB	5 (11)	24 (52)	8 (17)	6 (13)	3 (7)	43.5
2	HGR	2 (10)	7 (35)	7 (35)	3 (15)	-	30.0
	SYS	-	7 (88)	1 (13)	-	-	87.5
	GLB	2 (6)	18 (55)	8 (24)	4 (12)	-	48.5
3	HGR	2 (15)	8 (62)	2 (15)	1 (8)	-	69.2
	SYS	2 (22)	4 (44)	1 (11)	2 (22)	-	44.4
	GLB	5 (20)	13 (52)	3 (12)	4 (16)	-	56.0
4	HGR	-	4 (40)	5 (50)	1 (10)	-	30.0
	SYS	1 (20)	3 (60)	1 (20)	-	-	80.0
	GLB	1 (6)	8 (50)	6 (38)	1 (6)	-	50.0
5 & 6	HGR	1 (13)	4 (50)	1 (13)	2 (25)	-	37.5
	SYS	-	3(100)	-	-	-	100.0
	GLB	1 (8)	7 (58)	1 (8)	3 (25)	-	41.7
P&P	HGR	6 (8)	35 (47)	20 (27)	10 (14)	2 (3)	39.2
	SYS	6 (15)	25 (61)	6 (15)	4 (10)	-	65.9
	GLB	14 (11)	70 (53)	26 (20)	18 (14)	3 (2)	47.7

SA=Strongly Agree A=Agree N=Neutral D=Disagree SD=Strongly Disagree DIF=(1+2)-(4+5)

APPENDIX C - 1 / (14/15)

QUESTION 14 - CONTROL (CTRL)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	-	9 (17)	**22 (42)**	21 (40)	1 (2)	-24.5
	SYS	-	2 (6)	**18 (53)**	11 (32)	3 (9)	-35.3
	GLB	1 (1)	14 (14)	**43 (41)**	40 (39)	6 (6)	-29.8
2	HGR	-	8 (26)	**12 (39)**	11 (36)	-	-9.7
	SYS	3 (13)	7 (29)	**7 (29)**	7 (29)	-	12.5
	GLB	4 (6)	16 (24)	**26 (39)**	21 (31)	-	-1.5
3	HGR	-	4 (12)	**14 (41)**	16 (47)	-	-35.3
	SYS	-	3 (15)	2 (10)	**13 (65)**	2 (10)	-60.0
	GLB	-	8 (14)	18 (31)	**30 (52)**	2 (3)	-41.4
4	HGR	1 (5)	**6 (30)**	6 (30)	6 (30)	1 (5)	0.0
	SYS	1 (5)	**6 (32)**	5 (26)	5 (26)	2 (11)	0.0
	GLB	2 (4)	13 (27)	14 (29)	**15 (31)**	5 (10)	-10.2
5 & 6	HGR	3 (14)	7 (33)	**8 (38)**	2 (10)	1 (5)	33.3
	SYS	-	1 (8)	5 (42)	**6 (50)**	-	-41.7
	GLB	3 (8)	9 (24)	**15 (40)**	9 (24)	2 (5)	2.6
CTR	HGR	4 (3)	34 (21)	**62 (39)**	56 (35)	3 (2)	-13.2
	SYS	4 (4)	19 (17)	37 (34)	**43 (39)**	7 (6)	-24.5
	GLB	10 (3)	60 (19)	**116(37)**	116(37)	15 (5)	-19.2

QUESTION 14 - PRELAB WORK (PLW)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	-	6 (19)	**13 (42)**	11 (36)	1 (3)	-19.4
	SYS	-	3 (16)	**8 (42)**	7 (37)	1 (5)	-26.3
	GLB	-	10 (16)	**25 (40)**	24 (39)	3 (5)	-27.4
2	HGR	-	**11 (50)**	6 (27)	5 (23)	-	27.3
	SYS	-	3 (25)	**5(42)**	3 (25)	-	0.0
	GLB	-	**16 (42)**	13 (34)	8 (21)	-	21.1
3	HGR	-	2 (17)	**9 (75)**	1 (8)	-	8.3
	SYS	-	-	4 (33)	**6 (50)**	2 (17)	-66.7
	GLB	-	3 (9)	**16 (50)**	10 (31)	3 (9)	-31.3
4	HGR	1 (10)	**4 (40)**	3 (30)	2 (20)	-	30.0
	SYS	-	2 (22)	**4 (44)**	2 (22)	1 (11)	-11.1
	GLB	1 (5)	6 (30)	**8 (40)**	4 (20)	1 (5)	10.0
5 & 6	HGR	-	5 (29)	**8 (47)**	4 (24)	-	5.9
	SYS	-	3 (18)	5 (29)	**8 (47)**	1 (6)	-35.3
	GLB	-	10 (23)	**18 (41)**	14 (32)	2 (5)	-13.6
PLW	HGR	1 (1)	28 (30)	**39 (42)**	23 (25)	1 (1)	5.4
	SYS	-	11 (16)	**26 (38)**	26 (38)	5 (7)	-29.0
	GLB	1 (.5)	45 (23)	**80 (41)**	60 (31)	9 (5)	-11.7

QUESTION 14 - MINI-RPOJECTS (MP)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	-	6 (32)	**9 (47)**	4 (21)	-	10.5
	SYS		4 (21)	2 (11)	**11 (58)**	2 (11)	-47.4
	GLB	-	11 (26)	12 (29)	**17 (41)**	2 (5)	-19.0
2	HGR	3 (21)	4 (29)	**5 (36)**	2 (14)	-	35.7
	SYS	-	1 (9)	4 (36)	**6 (55)**	-	-45.5
	GLB	3 (12)	5 (20)	**9 (36)**	8 (32)	-	0
3	HGR	1 (6)	1 (6)	6 (35)	**8 (47)**	1 (6)	-41.2
	SYS	1 (20)	1 (20)	1 (20)	**2 (40)**	-	0.0
	GLB	2 (8)	2 (8)	7 (29)	**12 (50)**	1 (4)	-37.5
4	HGR	2 (22)	1 (11)	**4 (44)**	2 (22)	-	11.1
	SYS	-	**3 (50)**	1 (17)	2 (33)	-	16.7
	GLB	2 (12)	5 (29)	**6 (35)**	4 (24)	-	17.6
5 & 6	HGR	1 (25)	1 (25)	**1 (25)**	1 (25)	-	25.0
	SYS	-	1 (33)	**2 (67)**	-	-	33.3
	GLB	1 (14)	2 (29)	**3 (43)**	1 (14)	-	28.6
MP	HGR	7 (11)	13 (21)	**25 (40)**	17 (27)	1 (2)	3.2
	SYS	1 (2)	10 (23)	10 (23)	**21 (48)**	2 (5)	-27.3
	GLB	8 (7)	25 (22)	37 (32)	**42 (37)**	3 (3)	-10.4

QUESTION 14 - PRELAB WORK plus MINI-PROJECTS (P&P)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	-	4 (17)	7 (30)	**10 (44)**	2 (9)	-34.8
	SYS	1 (6)	1 (6)	4 (25)	**10 (63)**	-	-50.0
	GLB	1 (2)	9 (20)	12 (26)	**21 (46)**	3 (7)	-30.4
2	HGR	-	5 (25)	**9 (45)**	6 (30)	-	-5.0
	SYS	-	-	2 (25)	**5 (63)**	1 (13)	-75.0
	GLB	-	6 (18)	13 (39)	**13 (39)**	1 (3)	-24.2
3	HGR	-	4 (31)	3 (23)	**6 (46)**	-	-15.4
	SYS	-	1 (11)	1 (11)	**6 (67)**	1 (11)	-66.7
	GLB	-	7 (28)	5 (20)	**12 (48)**	1 (4)	-24.0
4	HGR	-	**5 (50)**	3 (30)	2 (20)	-	30.0
	SYS	-	-	**5(100)**	-	-	0.0
	GLB	-	5 (31)	**8 (50)**	3 (19)	-	12.5
5 & 6	HGR	-	**5 (63)**	1 (13)	2 (25)	-	37.5
	SYS	-	1 (33)	-	**2 (67)**	-	-33.3
	GLB	-	**6 (50)**	2 (17)	4 (33)	-	16.7
P&P	HGR	-	23 (31)	23 (31)	**26 (35)**	2 (3)	-6.8
	SYS	1 (2)	3 (7)	12 (29)	**23 (56)**	2 (5)	-51.2
	GLB	1 (1)	33 (25)	40 (30)	**53 (40)**	5 (4)	-18.2

SA=Strongly Agree A=Agree N=Neutral D=Disagree SD=Strongly Disagree DIF=(1+2)-(4+5)

APPENDIX C - 1 / (15/15)

QUESTION 15 - CONTROL (CTRL)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	-	17 (32)	**24 (45)**	9 (17)	2 (4)	11.3
	SYS	1 (3)	13 (38)	**17 (50)**	3 (9)	-	32.4
	GLB	5 (5)	36 (35)	**44 (42)**	16 (15)	2 (2)	22.1
2	HGR	-	10 (32)	**11 (36)**	9 (29)	1 (3)	0
	SYS	-	**12 (50)**	9 (38)	2 (8)	1 (4)	37.5
	GLB	1 (2)	**26 (39)**	25 (37)	13 (19)	2 (3)	17.9
3	HGR	-	11 (32)	**15 (44)**	8 (24)	-	8.8
	SYS	1 (5)	**9 (45)**	8 (40)	2 (10)	-	40.0
	GLB	1 (2)	20 (35)	**25 (43)**	12 (21)	-	15.5
4	HGR	1 (5)	6 (30)	3 (15)	**9 (45)**	1 (5)	-15.0
	SYS	1 (5)	5 (26)	**11 (58)**	2 (11)	-	21.1
	GLB	5 (10)	**17 (35)**	14 (29)	12 (25)	1 (2)	18.4
5 & 6	HGR	2 (10)	5 (24)	**8 (38)**	5 (24)	1 (5)	4.8
	SYS	-	4 (33)	**6 (50)**	2 (17)	-	16.7
	GLB	3 (8)	11 (29)	**15 (40)**	8 (21)	1 (3)	13.2
CTR	HGR	3 (2)	49 (31)	**61 (38)**	40 (25)	5 (3)	4.4
	SYS	3 (3)	44 (40)	**51 (46)**	11 (10)	1 (1)	31.8
	GLB	15 (5)	111 (35)	**123 (39)**	61 (19)	6 (2)	18.6

QUESTION 15 - PRELAB WORK (PLW)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	-	9 (29)	**18 (51)**	4 (13)	-	16.1
	SYS	-	**9 (47)**	7 (37)	3 (16)	-	31.6
	GLB	1 (2)	22 (36)	**31 (50)**	8 (13)	-	24.2
2	HGR	-	5 (23)	7 (32)	**10 (46)**	-	-22.7
	SYS	-	**6 (50)**	4 (33)	2 (17)	-	33.3
	GLB	-	11 (29)	13 (34)	**14 (37)**	-	-7.9
3	HGR	-	-	4 (33)	**7 (58)**	1 (8)	-66.7
	SYS	3 (25)	**4 (33)**	4 (33)	1 (8)	-	50.0
	GLB	3 (9)	**10 (31)**	9 (28)	9 (28)	1 (3)	9.4
4	HGR	-	1 (10)	**8 (80)**	1 (10)	-	0.0
	SYS	2 (22)	**4 (44)**	3 (33)	-	-	66.7
	GLB	2 (10)	5 (25)	**12 (60)**	1 (5)	-	30.0
5 & 6	HGR	-	3 (18)	6 (35)	**7 (41)**	1 (6)	-29.4
	SYS	3 (18)	5 (29)	**7 (41)**	2 (12)	-	35.3
	GLB	4 (9)	12 (27)	**17 (39)**	10 (23)	1 (2)	11.4
PLW	HGR	-	18 (20)	**43 (47)**	29 (32)	2 (2)	-14.1
	SYS	8 (12)	**28 (41)**	25 (36)	8 (12)	-	40.6
	GLB	10 (5)	60 (31)	**82 (42)**	42 (21)	2 (1)	13.3

QUESTION 15 - MINI-RPOJECTS (MP)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	-	5 (26)	**10 (53)**	4 (21)	-	5.3
	SYS	2 (11)	**11 (58)**	5 (26)	1 (5)	-	63.2
	GLB	2 (5)	**18 (43)**	17 (41)	5 (12)	-	35.7
2	HGR	1 (7)	-	4 (29)	**8 (57)**	1 (7)	-57.1
	SYS	-	**7 (64)**	2 (18)	2 (18)	-	45.5
	GLB	1 (4)	7 (28)	6 (24)	**10 (40)**	1 (4)	-12.0
3	HGR	-	6 (35)	**10 (59)**	1 (6)	-	29.4
	SYS	-	**4 (80)**	-	1 (20)	-	60.0
	GLB	-	10 (42)	**11 (46)**	3 (13)	-	29.2
4	HGR	1 (11)	2 (22)	**3 (33)**	2 (22)	1 (11)	0.0
	SYS	-	3 (50)	**3 (50)**	-	-	50.0
	GLB	1 (6)	5 (29)	**7 (41)**	3 (18)	1 (6)	11.8
5 & 6	HGR	1 (25)	-	1 (25)	**2 (50)**	-	-25.0
	SYS	-	1 (33)	**2 (67)**	-	-	33.3
	GLB	1 (14)	1 (14)	**3 (43)**	2 (29)	-	0.0
MP	HGR	3 (5)	13 (21)	**28 (44)**	17 (27)	2 (3)	-4.8
	SYS	2 (5)	**26 (59)**	12 (27)	4 (9)	-	54.5
	GLB	5 (4)	41 (36)	**44 (38)**	23 (20)	2 (2)	18.3

QUESTION 15 - PRELAB WORK plus MINI-PROJECTS (P&M)

EXP	DEG	1 (SA)	2 (A)	3 (N)	4 (D)	5 (SD)	% DIF
1	HGR	2 (9)	7 (30)	**10 (44)**	3 (13)	1 (4)	21.7
	SYS	2 (13)	**8 (50)**	6 (38)	-	-	62.5
	GLB	5 (11)	17 (37)	**19 (41)**	4 (9)	1 (2)	37.0
2	HGR	1 (5)	4 (20)	4 (20)	**11 (55)**	-	-30.0
	SYS	-	**5 (63)**	2 (25)	1 (13)	-	50.0
	GLB	1 (3)	11 (33)	8 (24)	**13 (39)**	-	-3.0
3	HGR	1 (8)	3 (23)	**7 (54)**	1 (8)	1 (8)	15.4
	SYS	3 (33)	**5 (57)**	-	1 (11)	-	77.8
	GLB	4 (16)	**9 (36)**	8 (32)	2 (8)	2 (8)	36.0
4	HGR	-	1 (10)	**4 (40)**	3 (30)	2 (20)	-40.0
	SYS	-	2 (40)	**3 (60)**	-	-	40.0
	GLB	-	3 (19)	**8 (50)**	3 (19)	2 (13)	-12.5
5 & 6	HGR	-	3 (38)	**4 (50)**	1 (13)	-	25.0
	SYS	1 (33)	-	**2 (67)**	-	-	33.3
	GLB	1 (8)	3 (25)	**7 (58)**	1 (8)	-	25.0
P&P	HGR	4 (5)	18 (24)	**29 (39)**	19 (26)	4 (5)	-1.4
	SYS	6 (15)	**20 (49)**	13 (32)	2 (5)	-	58.5
	GLB	11 (8)	43 (33)	**50 (38)**	23 (17)	5 (4)	19.7

SA=Strongly Agree A=Agree N=Neutral D=Disagree SD=Strongly Disagree DIF=(1+2)-(4+5)

APPENDICES D

CHAPTER 6

(From PAGE 330 to 336)

APPENDIX D - 1
(CHAPTER 6)

"FINAL" LAB MANUAL

VERSION 5
(INSIDE BACK COVER)

APPENDIX D - 2 - MINI-PROJECTS (FORM)

PRACTICAL PROBLEM - 5

NAME____Bench n°_________

This is a problem to be solved by practical means using some of the chemistry and techniques you have experienced in this practical course.

PROBLEM:

Write down here any ideas you have about how you can solve this practical problem. You should plan how to solve it and list the chemicals and apparatus you need to do it.

NOW ASK A STAFF MEMBER TO CHECK YOUR IDEAS BEFORE STARTING

APPENDIX D - 3 - PRE QUESTIONNAIRE

FIRST YEAR LABORATORY SURVEY

NAME____Bench №____________

We are carrying out a survey of laboratory work in the First Year. To help us, we would like to know what you think of any <u>previous</u> laboratory work you did before coming to the university. Your sincere opinions will be valued and they will have no bearing whatsoever on your laboratory performance or mark in this laboratory course.
First, we would like to know some information about your <u>previous</u> experience in chemistry.

1) What is your **HIGHEST** qualification in chemistry?

HIGHER GRADE **SIXTH YEAR STUDIES** **OTHER**

If OTHER could you please specify____

The grid below is for you to make judgements on a series of scales. If you have found previous laboratory work very boring you tick the box as follows.

INTERESTING						BORING

If you have found previous laboratory work fairly interesting you would tick the box as follow:

INTERESTING						BORING

Please tick <u>one</u> of the boxes in each line, according to your opinion of any <u>previous</u> laboratory work you have experienced.

EASY						DIFFICULT
WASTE OF TIME						USEFUL
INTERESTING						BORING
CONFUSING						UNDERSTANDABLE
SATISFYING						FRUSTRATING
UNENJOYABLE						ENJOYABLE
ADEQUATE WRITTEN INSTRUCTIONS						INADEQUATE WRITTEN INSTRUCTIONS
LEARNT A LOT						LEARNT A LITTLE
DISORGANISED						WELL-ORGANISED

<u>WHAT WOULD YOU LIKE TO LEARN FROM THIS LABORATORY COURSE</u>?

THANK YOU FOR YOUR CO-OPERATION

APPENDIX D - 4 - POST QUESTIONNAIRE

FIRST YEAR LABORATORY SURVEY

NAME________________________________ Bench Nº__________

Continuing our survey of laboratory work in the First Year, we would like to know what you thought of the practical work you have experienced during this term.
Your frank opinions will be valued and they will be treated in strict **CONFIDENCE** and will not be used in any way to assess your performance or mark in this laboratory course.
The grid below is for you to make judgements on a series of scales. If you have found the laboratory work very boring you would tick the box as follows:

INTERESTING						BORING

If you have found the laboratory work fairly interesting you would tick the box as follows:

INTERESTING						BORING

Please tick one of the boxes in each line, according to your opinion of the laboratory work you have experienced this term:

EASY						DIFFICULT
WASTE OF TIME						USEFUL
INTERESTING						BORING
CONFUSING						UNDERSTANDABLE
SATISFYING						FRUSTRATING
UNENJOYABLE						ENJOYABLE
ADEQUATE WRITTEN INSTRUCTIONS						INADEQUATE WRITTEN INSTRUCTIONS
LEARNT A LOT						LEARNT A LITTLE
DISORGANISED						WELL-ORGANISED

1. Which experiment or experiments did you enjoy most of all?______________________
   Could you please tell us why you found it (them) the most enjoyable?

2. Which experiment or experiments did you find most difficult?______________________
   Could you please tell us why you found it (them) the most difficult?

3. Which experiment or experiments did you find most useful?______________________
   Could you please tell us why you found it (them) the most useful?

4. What do you think were the good points about the lab-course?

5. What do you think were the worst features of the lab-course?

6. What changes do you think should be made to improve the lab-course?

7. What would you like to learn next time you do a lab course?

IF FOUND, PLEASE RETURN TO ROOM 157 OR LAB 170 - CHEMISTRY DEPT.

THANK YOU FOR YOUR CO-OPERATION

APPENDIX D - 5 - DIARY FOR EXPERIMENTS

DIARY for EXPERIMENT Nº____

NAME____Bench Nº____________

You are asked to rate statements about your experience in doing this **EXPERIMENT** on a '1 to 5' scale. Please indicate the extent to which you agree or disagree with each of the following statements by circling an appropriate number.
Your replies will be treated in strict **CONFIDENCE** and in no way will it affect your assessment or mark for this laboratory course.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. I had enough time in the laboratory to think about the chemistry involved in the experiment	1	2	3	4	5
2. It was clear to me what was expected in writing up my lab report	1	2	3	4	5
3. I would have liked more help with the calculations in this experiment	1	2	3	4	5
4. The prelab introduction to the balances and volumetric techniques helped me when I came to use those techniques in this experiment.	1	2	3	4	5
5. I had enough help in writing the chemical equations in this experiment	1	2	3	4	5
6. I was so confused in the laboratory that I ended up following the manual without really understanding what I was doing	1	2	3	4	5
7. I only understood what I had been doing in this experiment when I tried to write the lab-report	1	2	3	4	5
8. I was confident enough with the lab techniques to be able to concentrate on the chemistry involved in the experiment	1	2	3	4	5
9. The objective of this experiment was clear to me	1	2	3	4	5

IF FOUND, PLEASE RETURN TO ROOM 157 or LAB 170 - CHEMISTRY DEPT.

THANK YOU FOR YOUR CO-OPERATION

APPENDIX D - 6 - PRELAB WORK QUESTIONNAIRE

PRELAB - QUESTIONNAIRE

NAME____BENCH №____________

You are asked to rate statements about your experience in doing **PRELAB WORK** on a '1 to 5' scale. Please indicate the extent to which you agree or disagree with each of the following statements by circling an appropriate number.
Your replies will be treated in strict **CONFIDENCE** and in no way will they affect your assessment or mark for this laboratory course.

	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
1. I THINK THAT DOING THE **PRELAB WORK**					
a) helped me to understand the experiments before I attempted them in the laboratory	**1**	**2**	**3**	**4**	**5**
b) gave me more confidence when a I came to do the experiments in the laboratory	**1**	**2**	**3**	**4**	**5**
c) forced me to think about the experiments before I attempted them in the laboratory	**1**	**2**	**3**	**4**	**5**
d) meant that I was able to follow the manual in the laboratory with a greater understanding of what I was doing	**1**	**2**	**3**	**4**	**5**
2. I THINK THAT **PRELAB WORK** SHOULD ALWAYS BE INCLUDED BEFORE DOING AN EXPERIMENT	**1**	**2**	**3**	**4**	**5**

3. IN WHICH EXPERIMENT or EXPERIMENTS WAS (WERE) THE **PRELAB WORK** DIFFICULT?____
COULD YOU PLEASE TELL US WHY YOU FOUND IT (THEM) DIFFICULT?

4. IN WHICH EXPERIMENT or EXPERIMENTS WAS (WERE) THE **PRELAB WORK** USEFUL ?____
COULD YOU PLEASE TELL US WHY YOU FOUND IT (THEM) USEFUL?

THANK YOU FOR YOUR CO-OPERATION

APPENDIX D - 7 - MINI-PROJECTS QUESTIONNAIRE

PRACTICAL-PROBLEM QUESTIONNAIRE

NAME____BENCH №__________

You are asked to rate statements about your experience in solving the **PRACTICAL PROBLEMS** on a '1 to 5' scale. Please indicate the extent to which you agree or disagree with each of the following statements by circling an appropriate number.
Your replies will be treated in strict **CONFIDENCE** and in no way will they affect your assessment or mark for this laboratory course.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. I THINK THAT SOLVING THE **PRACTICAL PROBLEMS**					
a) forced me to design and plan my own experiments	**1**	**2**	**3**	**4**	**5**
b) illustrated practical applications of the laboratory	**1**	**2**	**3**	**4**	**5**
c) gave me confidence in my practical work	**1**	**2**	**3**	**4**	**5**
d) allowed me to use my knowledge of chemistry to investigate the problems	**1**	**2**	**3**	**4**	**5**
2. I THINK THAT MORE **PRACTICAL PROBLEMS** LIKE THESE SHOULD BE INCLUDED IN THIS COURSE	**1**	**2**	**3**	**4**	**5**
3. I THINK THAT SOLVING THE **PRACTICAL PROBLEM** AT THE END OF THE COURSE HELPED ME TO UNDERSTAND THE EXPERIMENT WHICH HADCOME BEFORE	**1**	**2**	**3**	**4**	**5**

IF FOUND, PLEASE RETURN TO ROOM 157 or LAB 170 - CHEMISTRY DEPT.

THANK YOU FOR YOUR CO-OPERATION

APPENDIX B - 1

"IMPROVED" LAB MANUAL

VERSION 3

CONTENTS

1. SAFETY AND LABORATORY PRACTICE

Experiments involving the use of glass apparatus and chemicals should always be regarded as potentially hazardous. Some of the compounds you will work with are corrosive, poisonous or flammable; therefore you should always exercise extreme care in the laboratory and:

a- **AT ALL TIMES IN THE LABORATORY YOU MUST WEAR SAFETY SPECTACLES**. This is to protect you from your neighbours' mistakes as well as your own. Follow instructions closely.

b- Avoid spillage on skin and clothing. Report any accident immediately even if it does not involve personal injury as e.g. spillage of chemicals or breakage of glassware.

c- Some of the equipment necessary for the experiments is both delicate and expensive and will have to be used by your fellow students in this and subsequent years. Extreme care should be exercised at all times when handling equipment. If you are in any doubt at all as to how a piece of equipment should be operated then **ASK A DEMONSTRATOR**.

d- Ensure that all glass apparatus used by you is cleaned before you leave the laboratory and replaced in the drawer in which you found it. Replace empty reagent bottles on the shelves where you found them at the beginning of the laboratory period.

e- DO NOT return used reagents into the reagent bottles on the benches but where appropriate (e.g. with silver nitrate solutions) pour into the residue bottles provided.

2. FIRE REGULATIONS

FIRE is a serious hazard in any laboratory and is usually caused by the careless handling of organic solvents. These must NOT be heated using a Bunsen flame, nor used in the near vicinity of a flame.

PLEASE MAKE A POINT OF READING THE NOTICES RELATING TO FIRE EVACUATION PROCEDURE.

WHEN THE ALARM SOUNDS

1. Do not stay to collect personal belongings.
2. Follow the instructions of members of staff and **WALK** via the nearest emergency exit to your assembly point in **UNIVERSITY PLACE.**
3. Those in toilets and lifts must leave without delay and make for the nearest emergency exit

IMPORTANT: **If smoke or other obstacles are found, make for the nearest clear exit.**

3. LABORATORY NOTEBOOKS

You will require a hard-backed notebook in A4 size for the laboratory. We require you to keep an up-to-date written account of your laboratory work including all measurements and observations made and all rough working. Ancillary notebooks, loose pieces of paper, etc. are **NOT** allowed as they are a fire hazard. For the purposes of the CHEMISTRY ordinary laboratory course your manual contains most of the necessary background work and details of the experimental procedure. There is no need for you to copy this into your notebook. Your report should include:

1. all results and observations; 2. calculations where appropriate;
3. interpretations of results and observations including equations where appropriate; and
4. conclusions.

Drawing and Using Graphs

In some of the experiments in this manual, you will be asked to display your results in graphical form. Presenting experimental data in this way has several advantages over a simple tabulation of results.

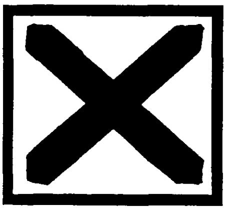
1. A graph shows clearly the functional relationship between the variables concerned. For example, a straight line (a linear relationship between variables) is usually obvious.
2. Any points which have been seriously mis-measured or incorrectly calculated, are also immediately obvious.
3. The deviation of the points from the line drawn through them gives a good idea of the accuracy of the results, or possibly, the adequacy of the theory that predicted the functional relationship.

In order to realise these advantages to the full, it is important that several basic principles are followed when drawing graphs:

1. Work exclusively in pencil, using a sharp, fairly hard (1H, 2H) pencil.
2. Use the fullest possible extent of the graph paper. If the graph will not fit one way round try the other - a sheet of graph paper is not usually square. Do not, for example, plot 3 x 3 inches on paper measuring 12 x 9 inches.
3. Label the axes clearly, stating the physical property represented and its units.
4. Mark each experimental result clearly by using a point, or ⊙ ; ⊡ ; △ etc.
5. Give the graph a title stating the variables which are being plotted against each other.
6. Draw straight lines with a ruler in such a way that the deviations of the experimental points from the line are minimised.
7. Draw curves neatly, again minimising the deviations of the experimental points from the line. With curves, it is often helpful to sketch the curve lightly in pencil at first to get the smoothest possible line, and subsequently draw over the sketch more heavily.The light sketch lines can then be erased.
8. Some graphs have linear and curved regions.Use a ruler for the former and merge it into the latter.
9. For maximum accuracy, the gradients of straight lines should be derived using the entire linear portion of the graph, and not just a small portion of it.

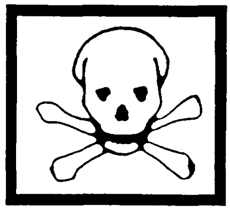
4. KEY TO SYMBOLS

Pay attention to these symbols in the right margin. They indicate the hazards of the substances used.



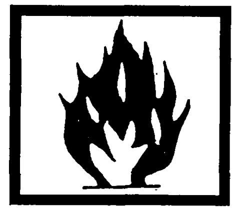
IRRITANT/ HARMFUL

Take care in handling



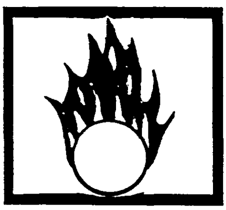
TOXIC

Be careful not to absorb or ingest



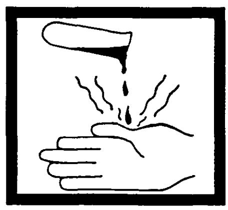
FLAMMABLE

Keep away from naked flames



OXIDISING

Keep away from Flammable substances

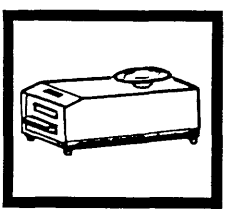


CORROSIVE

Take care in handling.

EXPLOSIVE

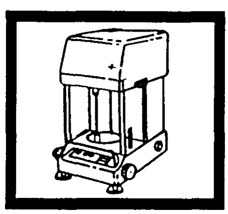
Must be conducted in fume cupboard



ROUGH BALANCE

Only rough weighings required.

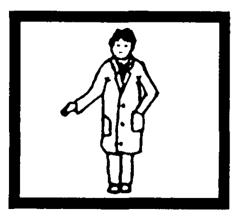
Use rough balances on benches A or B (*)



ANALYTICAL BALANCE

Accurate weighings required.

Use analytical balances in Balance room or on benches 10 and 16(*)

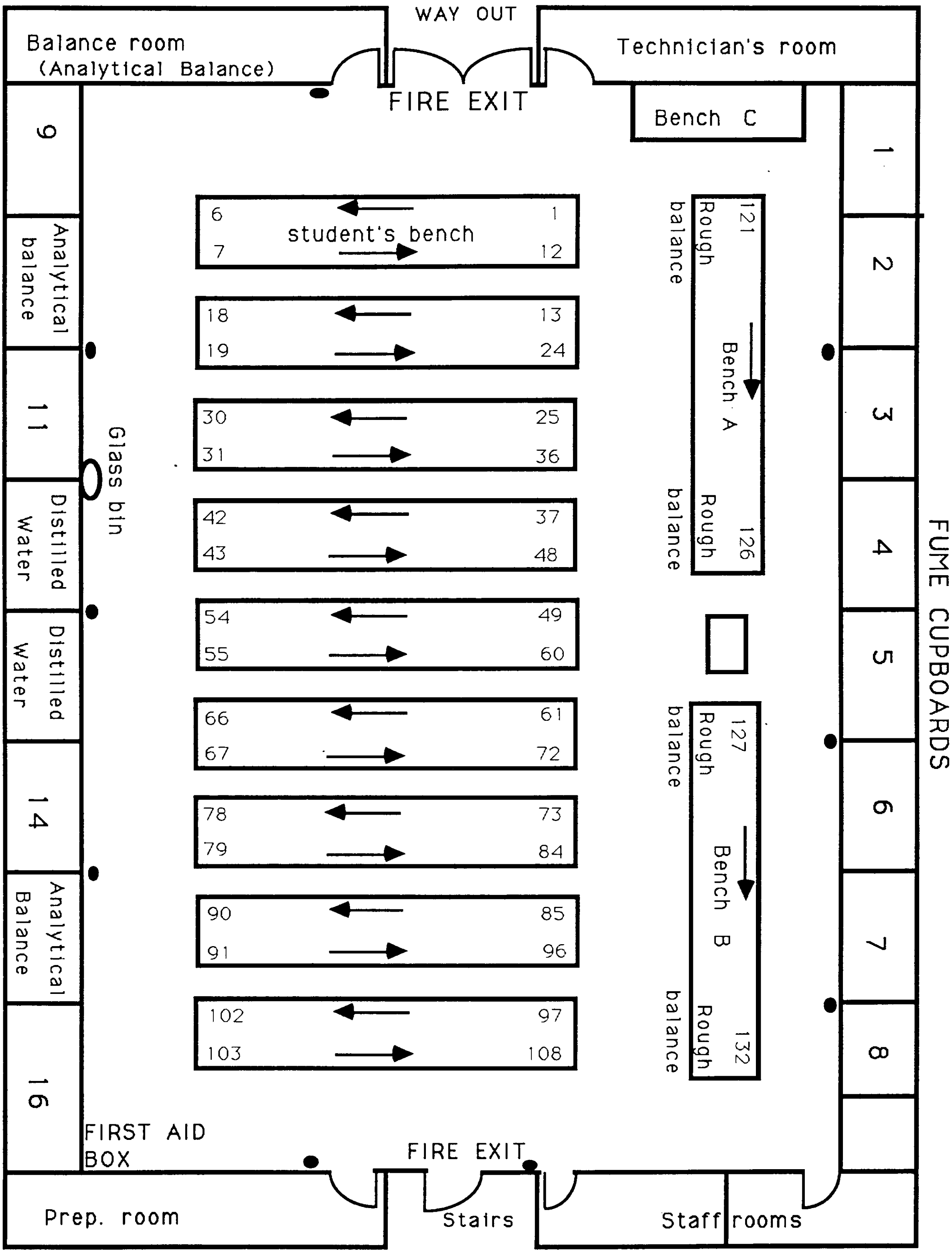


DEMONSTRATOR

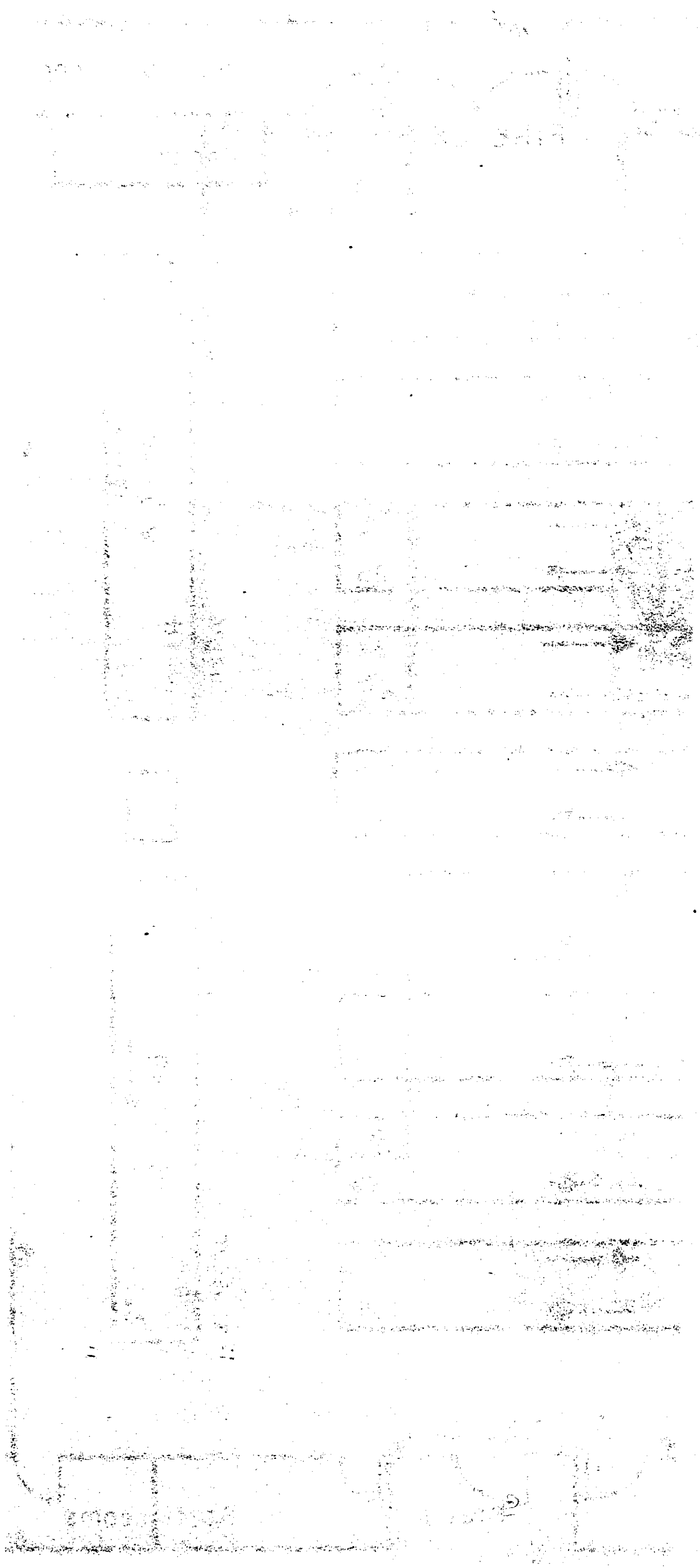
Contact your demonstrator at this stage in the experiment

(*) Refer to map of lab (page 5) for location of rough and analytical balance

5. MAP OF LABORATORY - room 170



● Fire extinguisher $-CO_2$ and fire blanket



EXPERIMENT - 1

INORGANIC PYROTECHNICS

Purpose
The purpose of this experiment is to illustrate a solid state oxidation-reduction reactions and how to calculate the % yield of the reaction.

Safety Precautions

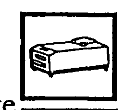
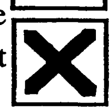

Chromium salts are toxic, particularly by skin absorption.
Both of these reactions are exothermic and involve toxic materials. They must be carried out in the fume cupboard.
The thermite reaction (part B) is so vigorous and exothermic that you must be supervised by a demonstrator when it is performed.
Pay attention to the symbols in the right margin. They indicate the hazards of the substances used.

The Experimental Report should contain:
the balanced equations for the reactions which occur in the experiment;
the calculations of the % yield of the reactions;
answers to questions in these written instructions.

Outline of the Experiment
A. The decomposition of ammonium dichromate (ammonium dichromate volcano) to produce chromium(III) oxide.
B. The reduction of this chromium(III) oxide and chromium(VI) oxide with aluminium (thermite reaction) to produce chromium metal.

THE EXPERIMENTS

The Experimental procedure
Chemicals for this experiment are on benches 'A' or 'B'.
Refer to map of lab (page 5) for location of apparatus and equipment.

A. The Ammonium dichromate 'Volcano'



Using a rough balance (appendix-1) weigh out about 3 grams of ammonium dichromate $(NH_4)_2Cr_2O_7$. Also weigh a 100 ml beaker and record its weight. It will be used to collect and weigh the product of the reaction.

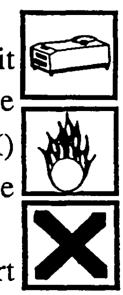
Place a large filter paper (bench 'C') on the bench in the fume cupboard (2;4 or 7) and on top of this your "asbestos" centered wire gauze. Pour the ammonium dichromate on to the gauze so that it forms a cone shaped pile in the centre.

Light the apex of the cone with a match. It may take two or three attempts, but once the reaction has started it will continue by itself. Record your observations in your own lab notebook. The solid product is chromium(III) oxide. There are also gaseous products. What do you think they are?

Collect and weigh the chromium (III) oxide product and save it for part B.

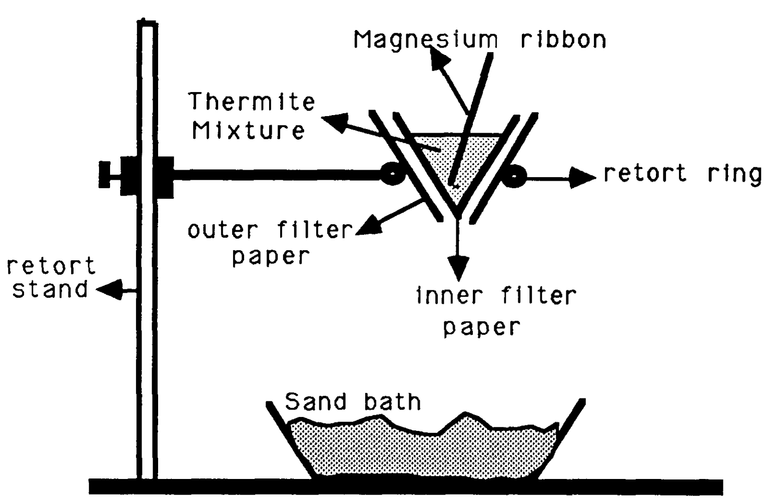
Write a balanced equation for the reaction.

B. The Thermite Reaction.



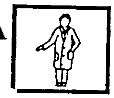
Crush the chromium(III) oxide product from part A in a beaker with a glass rod to make it as compact as possible. Add enough additional chromium(III) oxide (Cr_2O_3) to make the total weight up to 7 g. Now add 5.5 g of aluminium powder and 3 g of chromium(VI) oxide (CrO_3). Mix the ingredients thoroughly using a glass rod. This is the thermite mixture.

Prepare the apparatus for the thermite reaction as shown in the diagram below. (The retort ring, stand and sand bath arrangement can be found already set up in the fume cupboards 5 or 8).



Fold (appendix-3 item B-1) two 15-20 cm filter papers; tear the apex off one of them and place them one inside the other, the intact one to the inside. Fill it with all the prepared thermite mixture. Support the filter paper cone in a retort ring, with a sand bath beneath it, as shown in the diagram. When the apparatus is complete, insert about 4 inches of magnesium ribbon (bench 'C') into the centre of the thermite mixture to act as a fuse.

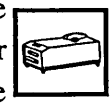
FROM THIS POINT ON YOU MUST BE SUPERVISED BY A DEMONSTRATOR.



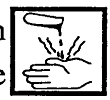
Remove the inner cone of filter paper containing the thermite mixture and then moisten the outer cone with water from a wash bottle. Replace the inner filter paper cone. Light the top of the magnesium ribbon with a Bunsen burner. **AS SOON AS** the magnesium begins to burn put down the burner, close the fume cupboard and retire at least 3 to 4 feet. **DO NOT** look directly at the burning magnesium. Focus on the bottom of the filter paper cone and the sand bath. Molten metal should be observed.

Which metal is it? How could you verify this?

When the metal in the sand bath appears cool, (take care; appearances can be deceiving) use tongs to remove the metal and quench it in cold water. Break off any encrusted sand or fused oxide surrounding the metal. Weigh the metal and calculate % yield based on the amount of Cr_2O_3 and CrO_3 used.



Place the metal in a test tube and observe what happens when the metal is covered with 2 mol l^{-1} HCl. It may be necessary to warm the test tube to initiate any reaction. Remove the metal from the acid. Wash and dry it.



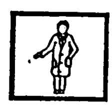
Calculation

Use the following data to calculate the enthalpy (heat) of reduction of Cr_2O_3 to Cr by aluminium.

$$Cr_2O_3\,(s) \longrightarrow 2\,Cr + {}^3/_2\,O_2 \qquad \Delta H^o = +1041\ kJmol^{-1}$$
$$2\,Al + {}^3/_2\,O_2 \longrightarrow Al_2O_3\,(s) \qquad \Delta H^o = -1668\ kJmol^{-1}$$

Is the value you calculated consistent with your observations of the experiment?

ASK YOUR DEMONSTRATOR TO CHECK YOUR RESULTS.



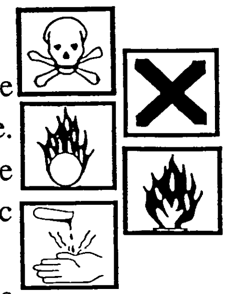
EXPERIMENT - 2

CHEMISTRY OF THE HALOGENS

Purpose

The purpose of this experiment is to do five series of reactions on halogen compounds and to compare the reactions within each series.

Safety Precautions

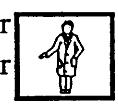


Unlike sodium chloride, the sodium salts of the other halides are poisonous and should be handled with care. Many of the other chemicals in this experiment are toxic and corrosive. Hydrogen fluoride, formed when covalent fluorides undergo hydrolysis, and from the reaction of fluoride ion with acid, causes severe burns. CCl_4 and $CHCl_3$ give toxic vapours.

Pay attention to symbols in the right margin. They indicate the hazards of the substances used.

The Experimental Report

For your own benefit, draw up a table of comparisons in your own lab notebook while doing the following experiments and make a note of each observation. (examples of the tables are include in the instructions).



The balanced equations for the reactions should be reported along with the tabular comparison that you make. Check with your demonstrator that you have interpreted your observations correctly.

Answers to the questions in these written instructions should be given.

Outline of the Experiment

The five series of reactions are;

A. reaction of covalent chlorides with water.

B. reaction of ionic halides with sulphuric acid.

C. redox reactions of halides.

D. replacement of one halide by another.

E. reaction of halides with silver nitrate.

THE EXPERIMENTS

The experimental procedure

Chemicals for this experiment are in fume cupboards 3 or 6.

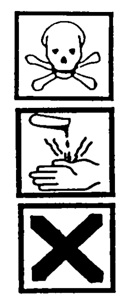
Refer to map of lab (page 5) for location of apparatus and equipment.

A. Reaction of Covalent Chlorides with water

<u>**This experiment should be carried out in the fume cupboard.**</u>

In the following experiments you are going to observe how some **COVALENT CHLORIDE** compounds react when water is added to them drop by drop.
Before you start - think what might happen. Will a gas be evolved?
If so - what is it likely to be? What will the other products of the reaction be?
If you mix **XCl** + **HOH**, there is a possibility that you will get **HCl** + **XOH**, BUT it does not happen in every case.

See what happens in the following cases and record your observations in a table in your own lab notebook (similar to table 1).
Take small samples of the following covalent chlorides in four clean dry test tubes (either 1 cm of a liquid in a test tube or the amount of a solid that will fit on the tip of a spatula). Carefully add water drop by drop.



1. Aluminum chloride ($AlCl_3$)
2. Carbon Tetrachloride (CCl_4)
3. Silicon Tetrachloride ($SiCl_4$)
4. Phosphorus Pentachloride (PCl_5)

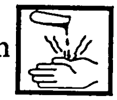
When any reaction has ceased, add more water - up to about 5 ml.

Are any reaction products soluble? What effect do these solutions have on litmus paper? Why do CCl_4 and $SiCl_4$ behave differently from one another? Write a balanced equation for each reaction.

TABLE 1- REACTIONS WITH WATER

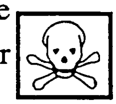
COVALENT HALIDES	LITMUS	OBSERVATIONS	PRODUCTS OF THE REACTION
$AlCl_3$			
CCl_4			
$SiCl_4$			
PCl_5			

B. Reaction of halides with sulphuric acid.



You are going to compare the reactions of conc. sulphuric acid on a few crystals of sodium fluoride, sodium chloride, sodium bromide and sodium iodide.

Consider for a moment, before beginning the experiment, what possible reactions could occur? $\mathbf{H_2SO_4 + NaX \longrightarrow ?}$



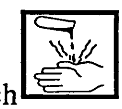
The obvious result is HX, but HX might, itself, be attacked by H_2SO_4 so you could have any of the following gases HX, X_2 or reduction products of H_2SO_4 such as SO_2, H_2S or even sulphur. How will you recognise these products if they should be produced?

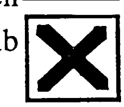
Think this through before you begin the experiment.How would you expect each of the possible gaseous products - HX, X_2, SO_2, or H_2S to react with litmus paper?

Record all your observations in your own lab notebook (similar to table 2). Note the evidence for the occurrence of a chemical reaction such as colour changes, gas evolution or the production of heat.

Write a balanced equation for each reaction that occurs.

<u>This experiment should be carried out in the fume cupboard.</u>





Have some wet litmus paper ready to use.

Line up 4 test tubes, one for each of the halide compounds. Use a few crystals of each.

Carefully add about 2 ml of concentrated H_2SO_4 to each test tube. If necessary warm each test tube gently. Observe what happens. Note your observations in your own lab notebook.

Test each gas evolved for its reaction with litmus paper by holding a piece of moist litmus paper in the mouth of the test tube

Note: In the case of sodium fluoride the gas evolved may react with glass.

Rinse out that test tube with water and look for evidence of this on the walls of the test tube. What is happening in this reaction? Remember that glass is a chemical substance. This reaction is one of the methods used for etching glass.

TABLE 2 - REACTIONS WITH H_2SO_4

IONIC HALIDES	LITMUS PAPER	GAS(ES) EVOLVED	OBSERVATIONS	OTHER PRODUCTS
$NaF + H_2SO_4$				
$NaCl + H_2SO_4$				
$NaBr + H_2SO_4$				
$NaI + H_2SO_4$				

C. Redox reactions of halides

The experiment should be carried out in the fume cupboard.



In a test tube mix a few crystals of sodium chloride with a small sample of MnO_2 (a good oxidizing agent), then add about 2 ml of concentrated H_2SO_4 and gently warm the test tube. Compare this result with that in the previous section in which sodium chloride by itself was allowed to react with H_2SO_4. What gas has been evolved? What made the difference? Why? Write a balanced equation for this reaction

	Gas evolved, other products and observations
$NaCl + H_2SO_4 + MnO_2$	

D. Replacement of One Halogen By Another

In this section you are going to use dilute aqueous solutions of the ionic halides. Prepare about 10 ml of each solution by dissolving a few crystals (about the amount on the tip of a spatula) of each in water in test tubes. Take about 2 cm depth of each solution in test tubes for the following reactions and keep the remaining solutions to use in part E.


Prepare a chlorine water solution by diluting approximately 2 ml of sodium hypochlorite with 10 ml of water, then acidifying it with a small amount of 1 molar sulphuric acid (test with litmus paper).

Add a few drops of the chlorine solution to your samples of dilute sodium fluoride, sodium chloride, sodium bromide, and sodium iodide, in test tubes, and note what you see. Record your observations in your own lab notebook (similar to table 3).

Add 1 ml of chloroform (trichloromethane) to each of the solutions. It will form a lower layer. Shake the test tubes (appendix 3) and observe the colour of the chloroform layer. Halogens are more soluble in chloroform than they are in water, so any free halogen is removed from the water and ends up in the chloroform layer giving a distinctive colour.

Add more chlorine water drop by drop and shake. Continue adding the chlorine water gradually and observe the colour of the chloroform and any changes that occur. Record your observations in your own lab notebook (similar to table 3).

TABLE 3 - REACTION WITH Cl_2

HALIDES + Cl_2	INITIALLY	WITH CHLOROFORM	CHLORINE WATER IN EXCESS	OTHER PRODUCTS
$NaF + Cl_2$				
$NaCl + Cl_2$				
$NaBr + Cl_2$				
$NaI + Cl_2$				

How do you explain these observations? Try to write balanced equations to explain the reactions that took place.
To show what a sensitive test this is for iodide, empty out your iodide test tube, add water and repeat the chloroform test. Can you still detect the traces of iodine left?

E. Reaction of halides with silver nitrate.



You are going to study the reaction of silver nitrate with your remaining solutions of sodium fluoride, sodium chloride, sodium bromide, and sodium iodide.
Take about 2 cm depth of each halide solution (prepared previously) in test tubes, and to each add a few drops of aqueous silver nitrate (obtainable from the bench 'A' - it is expensive!). Record your observations in your own lab notebook (similar to table 4).

<u>In the fume cupboard</u> add a few drops of concentrated ammonia (ammonium hydroxide) to any of the silver halides which are precipitated, and shake the tube. Does the halide solid disappear?

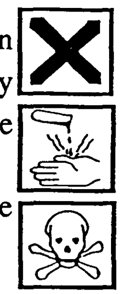
TABLE 4 - REACTION WITH SILVER NITRATE

HALIDES	$AgNO_3$	OBSERVATIONS	PRODUCTS OF REACTION
NaF			
NaCl			
NaBr			
NaI			

EXPERIMENT - 3

ACID-BASE TITRATIONS

Purpose
The purpose of this experiment is to standardise solutions of NaOH and HCl.

Safety Precautions


Sodium hydroxide pellets are extremely corrosive and will cause burns if they come in contact with your skin. The pellets also absorb enough moisture to form an extremely corrosive solution. The acids are dilute and therefore not as hazardous but should still be handled with care.
Pay attention to the symbols in the right margin. They indicate the hazards of the substances used.

The Experimental Report should contain:
the balanced equations for the reactions used in the experiment;
the calculation for the molarities;
the actual readings obtained in the titrations;
answers to questions in these written instructions.

Outline of the Experiment
A. Preparation of an approximately M/10 (0.1 mol per litre) solution of NaOH.
B. Standardisation of the NaOH against a solid acid, potassium hydrogen phthalate ($KHC_8H_4O_4$).
C. Use of the standardised NaOH solution to standardise an approximately M/10 solution of hydrochloric acid.

THE EXPERIMENTS

Basic Ideas Behind the Experiment
For a lot of chemical work, solutions of accurately known concentrations are required. The process of measuring the accurate molarity (i.e. number of moles per litre) of a solution is called **STANDARDISATION.**

The preparation of these accurate solutions may not be easy for a variety of reasons. For example, concentrated hydrochloric acid comes in to the department as a solution of about 11 molar. Even when it has been diluted <u>accurately</u> 11 times it is still only <u>approximately</u> 1 molar.

Sodium hydroxide has a formula weight of 40. It would seem to be an easy matter to weigh out 40 grams of pellets, dissolve them in water and make up to one litre. However, NaOH pellets absorb moisture and CO_2 from the air. With CO_2 they undergo a chemical reaction.

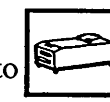
$$2\,NaOH + CO_2 \longrightarrow Na_2CO_3 + H_2O$$

It is therefore impossible to weigh out exactly 40 g of pure NaOH.
The point of this experiment is to show you how these problems are overcome by standardising the NaOH and HCl solutions.

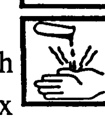
The experimental Procedure

Chemicals for this experiment are on bench 'A' or 'B'.
Refer to map of lab (page 5) for location of apparatus and equipment.

A. Preparation of a M/10 Sodium Hydroxide Solution.



Using a rough balance (appendix 1) weigh out approximately 1 g of NaOH (3 pellets) into a beaker.



Dissolve the NaOH in a few ml of distilled water and transfer the solution carefully, with washings to a 250 ml volumetric flask. Make up to the mark with distilled water and mix thoroughly by inverting the flask several times.

Calculate the approximate molarity of the solution and transfer it to your own labelled reagent bottle.

B. Standardisation of a Sodium Hydroxide Solution

Using an analytical balance (weighing procedure - appendix 1) weigh out about 0.6 g of potassium hydrogen phthalate ($KHC_8H_4O_4$) accurately and transfer it to a 250 ml conical flask. Calculate the number of moles of $KHC_8H_4O_4$ in the flask.
To the flask add about 75 ml (measuring cylinder) of distilled water to dissolve the $KHC_8H_4O_4$, and a few drops of phenolphthalein indicator.

Titrate the sample of potassium hydrogen phthalate solution with the sodium hydroxide, following the procedure as in appendix 2:

1. As you near the end point, the pink colour at the point of entry persists for longer.
2. The end point is reached when one drop provides a permanent pink colour. Stop the titration and read the level of the solution in the burette accurately.

Write the equation for the titration reaction. How many moles of NaOH have reacted with the sample of $KHC_8H_4O_4$? Calculate the molarity of the NaOH solution.

3. Repeat with a further portion of phthalate until two values of the molarity of NaOH agree to within 1%. If you are unable to obtain this agreement see your demonstrator.

C. Titration of Hydrochloric Acid with Standardized Sodium Hydroxide

1. Transfer exactly 25 ml of given hydrochloric acid (bench 'A') by pipette into a conical flask;
2. Add a few drops of phenolphthalein.
2. Add about 50 ml (measuring cylinder) of distilled water.
3. Titrate in the same way as in part B.

Repeat this with other 25 ml samples of HCl until two titrations agree to within 1%.

Write a balanced equation for the reaction.

Calculate the molarity of the HCl. Report your answer to your **demonstrator.**

EXPERIMENT - 4

IODIMETRY

Purpose

The purpose of this experiment is to standardise a solution of sodium thiosulphate by titration with iodine.

Safety Precautions

There are no special precautions for this experiment except for the fact that some of the chemicals are moderately toxic.

Pay attention to the symbols in the right margin. They indicate the hazards of the substances used.

The experimental report should contain:

the balanced equations for the reactions which occur in the experiment;
the calculations of the molarities of the solutions;
the actual readings obtained in the titrations;
answers to questions in these written instructions.

Outline of the Experiment

A. Writing the balanced equation for the reaction of the oxidising agent KIO_3 (potassium iodate) with iodide ion.
B. Preparation of a KIO_3 solution of known concentration.
C. Titration of the iodine (liberated by a known amount of iodate solution) with the thiosulphate solution.
D. Calculation of the molarity of the thiosulphate solution.

THE EXPERIMENT

Basic Ideas Behind the Experiment

Pure samples of sodium thiosulphate are not readily obtainable. Hence it is not possible to prepare a thiosulphate solution of accurate molarity simply by weighing the compound and dissolving it in a known volume. Instead its molarity must be determined by a procedure called standardisation (see experiment 3).

The standardisation involves a titration between the thiosulphate ion ($S_2O_3^{2-}$), and iodine (I_2). The titration reaction is;

$$I_2 + 2\,S_2O_3^{2-} \longrightarrow 2\,I^- + S_4O_6^{2-}$$

The iodine in the titration is obtainable from the reaction of the iodide ion (I^-), from KI, with a suitable oxidising agent. In this experiment potassium iodate (KIO_3) is used as the oxidising agent and iodide ion is added in excess, so that the amount of I_2 formed is limited by the known amount of iodate ion used to oxidise it.

The Experimental procedure

Chemicals for this experiment are on bench 'A' or 'B'.
Refer to map of lab (page 5) for location of apparatus and equipment.

A - Writing the equation

Write a balanced equation for the reaction of iodate ion with iodide ion.

Note: I_2 is the only iodine containing product. If you have a problem producing the equation for this reaction consult your demonstrator.

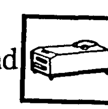
B - Preparation of Standard Potassium Iodate (KIO_3) solution

Using an analytical balance (weighing procedure - appendix 1), weigh out approximately 0.9 g of Analar (analytically pure) KIO_3 accurately into a weighing bottle. Transfer the iodate to a beaker and take your second weighing of the weighing bottle. Dissolve the iodate in a few ml of distilled water and transfer the solution carefully, with washings, to a 250 ml volumetric flask. Make up to the mark with distilled water.

Calculate the molarity of the solution and transfer it to your own labelled reagent bottle.

C - Titration of iodine (liberated by a known amount of iodate solution) with thiosulphate solution.

Note: A sodium thiosulphate solution of approximately 0.1 mol l^{-1} is available in the laboratory on bench 'A'. Obtain a 100 ml sample of this solution to use for the analysis.



1. The titration must be carried out following the procedure of appendix 2.
2. Using a rough balance weigh out approximately 1 gram of potassium iodide (KI) and measure out about 5 ml of 1 molar sulphuric acid. These will be used shortly.
3. Use a pipette to transfer 25 ml of potassium iodate solution to a clean 250 ml conical flask.
4. Add the 1 gram of KI to the conical flask. What do you expect to happen?
5. Add 5 ml of 1 molar sulphuric acid. What is the explanation for what you observe?
6. Titrate the iodine released with the sodium thiosulphate solution. At first the solution will be intense red-brown. As the titration proceeds the colour will lighten to a pale yellow. At this point add a few drops of starch indicator. This produces an intense blue-black starch iodine complex. Continue adding sodium thiosulphate solution drop by drop until the blue colour just disappears.

Repeat the titration until two reproducible titres are obtained (difference < 0.1 ml).

Note: Do not throw your solutions away. Save your remaining standardised potassium iodate and sodium thiosulphate solutions for experiment 5.

D - Calculations

Calculate the molarity of the sodium thiosulphate solution and consult your **demonstrator** to see if your result agree with the stated molarity of the solution.

EXPERIMENT - 5

PREPARATION AND ANALYSIS OF A THIOUREA COPPER (I) COMPLEX - $\{Cu[SC(NH_2)_2]_3\}_2.SO_4.2H_2O$

Purpose

The purpose of this experiment is to prepare a copper(I) complex and then to analyse it by iodimetry (see experiment 4)

Safety Precautions

Thiourea should be used with care since it is toxic and may cause cancer. Copper compounds are also toxic. Concentrated nitric acid will be used during the analysis of the complex and should be treated with care and caution. The preparation of the complex for analysis must be carried out in a fume cupboard.

Pay attention to the symbols in the right margin. They indicate the hazards of the substances used.

The Experimental Report should contain:

calculations for the formula weight of the complex and the theoretical % Cu in the complex;
calculations for the actual % Cu in the complex you have prepared and analysed;
a comparison of the actual % Cu with the theoretical % Cu;
answers to questions in these written instructions.

Outline of the Experiment

A. Preparation of the Copper Complex.
B. Analysing for the % of Cu in the Complex.

THE EXPERIMENTS

Basic Ideas Behind the Experiment

1. Metal ions readily accept electrons from electron pair donors. Substances which are electron pair donors are classified as bases. In Inorganic Chemistry such bases are called ligands. A combination of a metal ion and a ligand (or group of ligands) is called a **COMPLEX.** In this experiment the metal ion is Cu^+ and the ligand is thiourea $[:SC(NH_2)_2]$.

2. Metals in the middle block (d-block) of the Periodic Table have the ability to form ions in several oxidation states. For example you already know that iron ions exist as Fe^{2+} and Fe^{3+} and that copper ions exist as Cu^+ and Cu^{2+}. The Cu^{2+} in water gives the familiar blue of $CuSO_{4\,(aq)}$. The Cu^+ ion is much less common and its compounds are usually either insoluble in water, or decompose in it. You will prepare a copper(I) compound in which the Cu^+ is protected from water by forming a stable complex with thiourea.
3. In preparations of Cu^+ complexes it is usual to begin with a Cu^{2+} compound so that we can make use of a solution of it in water. However, to make the complex it will have to be reduced to Cu^+. The thiourea is both a reducing agent and a ligand and so it can do both jobs.

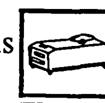
The Experimental Procedure

Chemicals for this experiment are on bench 'A' or 'B'.

A. Preparation of the Copper(I) Complex

Preparing the solutions:

1. Using a rough balance weigh out about 2.5 g of blue copper(II) sulphate crystals ($CuSO_4$ 5 H_2O) and dissolve them in about 15 ml of water.



2. Make a solution of about 5 g of thiourea in 30 ml of water. (You may have to warm the solution gently to get all the thiourea to dissolve: do not heat strongly). Cool and divide this solution into two roughly equal portions.

Making the complex

Slowly add the copper(II) sulphate solution to one of the portions of the thiourea solution while stirring continuously. A white crystalline substance (the complex) should form. If a sticky material results, rub it firmly against the side of the beaker with a glass rod and soon the white crystals will form. Let the solution stand for five minutes to allow the crystallization to be completed.

The formula of the complex is $\{Cu[SC(NH_2)_2]_3\}_2SO_4.2H_2O$

If the solution above the crystal layer is still blue add some of the other portion of thiourea (1 ml at a time) until the blue colour disappears.

Filtration and Purification

Filter the crystals through a filter paper in a Buchner funnel and flask attached to a water pump. (see vacuum filtration - appendix 3).

When the filtration is completed, scrape the crystals off the paper and transfer them to a 250 ml beaker. Add about 5 ml of your remaining thiourea solution and 50 ml of water plus 2-3 drops of dilute sulphuric acid. Warm the solution and stir until the crystals dissolve.

DO NOT allow the temperature of the solution to exceed 70°C (about as hot as you can bear on the palm of your hand) or you will be destroying the complex.
Allow the solution to cool. Crystals of the complex will reappear. Filter through a fresh piece of paper using the Buchner apparatus. Wash the crystals with a few ml of cold water and then with about 10 ml of ethanol. Continue to draw air through the crystals until the ethanol has evaporated and the crystals are dry. Weigh your crystals on a rough balance and record your yield. The preparation of the complex has been completed.

Basic Ideas Behind the Analysis Method.

1. By heating the complex with an oxidising acid like nitric acid we can do two things at once:
   a. destroy the thiourea ligands and
   b. oxidise the Cu^+ to Cu^{2+}.
2. Having obtained a Cu^{2+} solution, we can analyse for copper ion in solution by a method similar to that in experiment 4. When iodide ions (from KI) are added to $Cu^{2+}(aq)$ solutions the Cu^{2+} is reduced to Cu^+ and some of the iodide ions are oxidised to I_2.

$$2\,Cu^{2+} + 4\,I^- \longrightarrow 2\,CuI + I_2$$

   The equation shows that 2 moles of Cu^{2+} $\equiv$ 1 mole of I_2
3. The I_2 which is released can be titrated with thiosulphate as in experiment 4.

$$2\,S_2O_3^{2-} \longrightarrow S_4O_6^{2-} + 2\,e$$

$$I_2 + 2\,e \longrightarrow 2\,I^-$$

$$\text{hence:}\quad 2\,S_2O_3^{2-} + I_2 \longrightarrow S_4O_6^{2-} + 2\,I^-$$

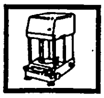
$$2 \text{ moles thiosulphate} \equiv 1 \text{ mole } I_2 \equiv 2 \text{ moles } Cu^{2+}$$

B. Analysis of Copper Complex

Method of Analysis

Preparing the sample for analysis:

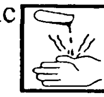
Using an analytical balance (weighing procedure - appendix 1) weigh out about 0.6 g of your complex accurately and tip it into a 100 ml beaker.



Caution: carry out the next part of the analysis in a fume cupboard.

Throughout this section, take care not to lose any of your sample by splashing. Take 10 ml of concentrated nitric acid (located in the fume cupboard) and add it to 10 ml of water. Add this diluted acid to the sample of the complex and cover the beaker with a watch glass.
After a few minutes a vigorous reaction will take place.

From your observations how do you know that $Cu^{2+}(aq)$ is being made and that the nitric acid is being reduced?



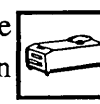
After the reaction subsides, gently boil the solution until it has evaporated almost to dryness. This gets rid of most of the unused nitric acid and also removes the decomposition products from the thiourea.

The Analysis:

When the beaker has cooled, add about 20 ml of water(measuring cylinder) to dissolve the Cu^{2+} compound. Transfer this to a conical flask and rinse the beaker twice with distilled water and add the rinsings to the conical flask. The pH of this solution will be too low for the next part of the analysis so it is adjusted as follows:

Add 4 M ammonium solution (ammonium hydroxide) drop by drop to the blue solution until a faint cloudiness remains even after shaking. Now add 4 M ethanoic(acetic) acid drop by drop until the cloudiness just disappears and a transparent blue solution is left.

Now add about 2 g of KI. This will react with the Cu^{2+} to give a brown solution of iodine and a white milky suspension of CuI. Titrate this with standardised thiosulphate solution (from experiment 4) until the brown almost disappears. Add a few drops of starch solution and continue the titration until the blue colour disappears and the milky white liquid (CuI in suspension) is left.



Calculate the theoretical and practical (actual) % Cu in your complex and compare them.

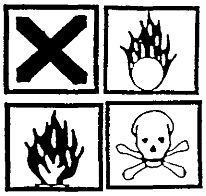
Give to your **demonstrator** any of your complex which is left over.

PREPARATION AND ANALYSIS OF $K_3[Cr(C_2O_4)_3].3H_2O$

Purpose

The purpose of this experiment is to prepare a chromium(III) complex and then to analyse it by titration.

Safety Precautions



Oxalate salts are toxic and should be handled with care. Chromium compounds are potential skin irritants and can cause cancer.

Pay attention to the symbols in the right margin. They indicate the hazards of the substances used.

The Experimental Report should contain:

the balanced equations for the reactions in the experiment;

the calculation for the actual % Cr in the complex you have prepared and analysed;

a comparison of the actual % Cr with the theoretical % Cr;

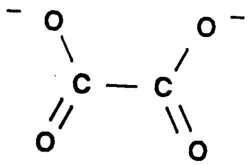
answers to questions in these written instructions.

Outline of the Experiment

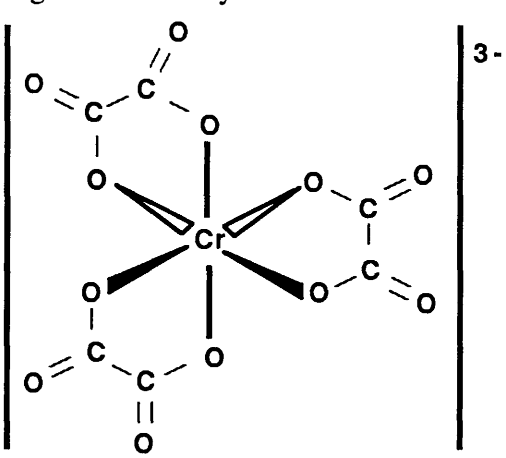
A. Preparation of the complex. B. Analysis of the complex.

THE EXPERIMENTS

Basic ideas behind the formation of the complex



Metal ions can accept electrons from electron pair donors. These donors are molecules or ions called **LIGANDS.** An example is the oxalate (ethanedioate) ion.The oxygen atom at each end of the ion has a lone pair of electrons which it can donate.The oxalate ions are arranged octahedrally around the chromium(III) ion.



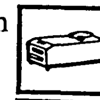
The new complex ion has an all over charge of 3^- since the Cr^{3+} ion is surrounded by three oxalate ions each of which has a 2^- charge.

The Experimental Procedure

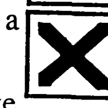
Chemicals for this experiment are on bench 'A' or 'B'.

A. Preparation of the complex:

1. Dissolve about 4.5 g of oxalic acid dihydrate[$(COOH)_2.2H_2O$] in 10 ml of warm water.



2. Using a rough balance weigh out 1.5 g of potassium dichromate and then add it, a little at a time, to the oxalic acid solution. There will be a fairly vigorous reaction.



3. While the reaction is subsiding, weigh out about 1.75 g of potassium oxalate ($K_2C_2O_4.H_2O$). Gently heat the reaction mixture (from part 2) until it is just beginning to boil and add the potassium oxalate and allow it to dissolve.

Note: We have now completed two operations.
  (a) The chromium in the dichromate ion was in the 6+ oxidation state and the oxalic acid has reduced it to the 3+ oxidation state.
  (b) The excess of the oxalate and potassium ions have now been added to complete the formation of the complex $K_3[Cr(C_2O_4)_3].3H_2O$.

4. Cool the solution and add 2 ml of ethanol. Blue-green crystals of the complex now grow in the nearly black solution.

5. Filter off the crystals on a paper in a Buchner apparatus. (See appendix-3).
6. Wash the crystals (which are still on the filter) with a mixture of 5 ml of ethanol and 5 ml of water. Finally wash the crystals with 5 ml of pure ethanol. Continue to draw air through the filter to dry the crystals, but finally dry them by pressing them between two sheets of filter paper.

Note: To be clear in your mind about what has been done so far, write and balance the equations for:

Dichromate $\longrightarrow$ Chromium(III) (reduction)
Oxalic acid $\longrightarrow$ Carbon dioxide (oxidation)
Oxalate ion + Chromium(III) $\longrightarrow$ complex ion

Basic ideas behind the analysis of the complex

How pure is the complex you have made? This can be found out by analysis, but we need to stop for a bit of theory before beginning the analysis.

The oxalate ions in the complex can be released by adding a strong base, which removes the chromium(III) as its hydroxide.

$$\textbf{Complex} \xrightarrow{\text{base}} \mathbf{Cr(OH)_3} + \textbf{oxalate ions} \quad \text{(unbalanced equation)}$$

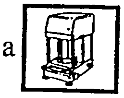
These free oxalate ions can be oxidised to CO_2 by a suitable oxidising agent such as MnO_4^-

In the presence of acid the MnO_4^- is reduced to Mn^{2+}. However, the reaction between oxalate and permanganate is so slow that we have to operate at about 70°C to speed things up.

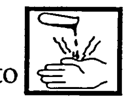
$$\mathbf{MnO_4^- + Oxalate\ ions \longrightarrow CO_2 + Mn^{2+}} \quad \text{(unbalanced equation)}$$

As MnO_4^- is intensely purple and Mn^{2+}(aq) is nearly colourless we have a built-in indicator of when the reaction is complete.One drop extra of MnO_4^- will make the solution pale pink.

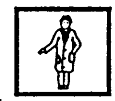
B. Method of Analysis



1. Using an analytical balance (weighing procedure-appendix 1) weigh out accurately a sample of your complex (in the region of 0.3 g) and transfer it to a 100 ml beaker.



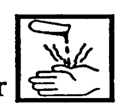
2. Use a measuring cylinder to add 10 ml of water followed by 10 ml of 4 M KOH.
3. Cover the beaker with a watch glass and gently bring to a boil. Allow the solution to boil gently until no more green $Cr(OH)_3$ is precipitated.



DO NOT LET THIS SOLUTION BOIL DRY.

4. This has now released the oxalate. The $Cr(OH)_3$ is a sticky substance which is difficult to filter. Filter with a fluted filter paper into a 250 ml conical flask (see appendix 3).
5. The liquid which comes through the paper contains the oxalate which is needed for analysis. Wash the precipitate with 25 ml of hot distilled water and collect these washings also in the conical flask.

Note: For the MnO_4^- to go to Mn^{2+} the solution must be acid, whereas the solution collected above is very alkaline.



6. Add 4 M sulphuric acid until the solution is distinctly acid (test with litmus paper).
7. Heat the solution to 70°C (the temperature you can just bear on the palm of your hand) and titrate with the standard potassium permanganate (bench 'A').

Note: You may have to raise the temperature several times during the titration to keep it near 70°C. The end point is a pale pink colour which lasts even when warmed up.

How pure was your complex?

$$\begin{array}{ccc} \mathbf{K_3[Cr(C_2O_4)_3].3H_2O} & \longrightarrow & \mathbf{3\,(C_2O_4)^{2-}} \\ \text{1mole} & & \text{3mole} \end{array}$$

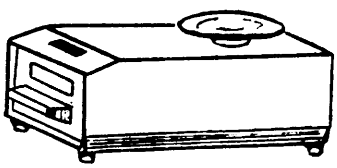
Work out the ion electron half equations for the oxidation of oxalate to CO_2 and for the reduction of MnO_4^- to Mn^{2+} and hence establish how many moles of oxalate are equivalent to 1 mole of MnO_4^- (see appendix 4).

How many moles of complex are equivalent therefore to 1 mole of MnO_4^-?

Now calculate the actual % Cr in your complex from your analysis and compare this value with the theoretical % Cr calculated from the formula of the complex.

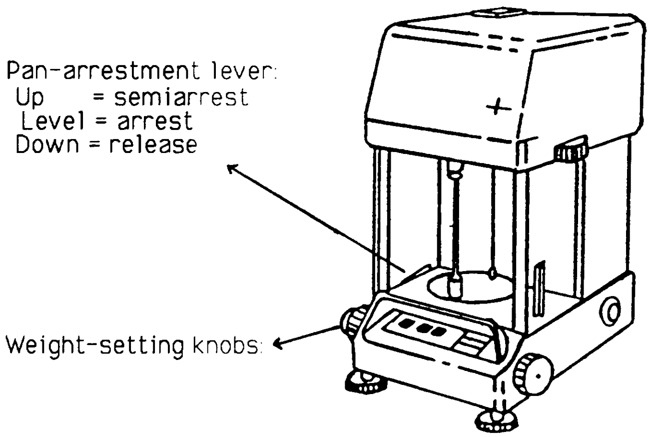
APPENDIX - 1 - BALANCES - OPERATING INSTRUCTIONS

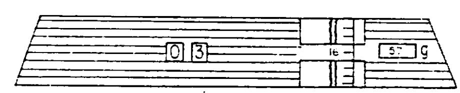
A - USE OF ROUGH BALANCES - a Stanton D20T, or D40T or a Sartorius 1106 top loading balance.



These are of lower precision (0.01 g) than the analytical balances but are perfectly adequate for weighing reagents and products in preparative work. Solids must be weighed on a watch glass or in a small beaker. Liquids must be weighed in a beaker or weighing bottle. The vessel used for weighing is tared, i.e. its weight is subtracted from the total by rotating the illuminated scale back to zero or pressing the button **T**, then the reagent is added until desired weight appears on the scale.

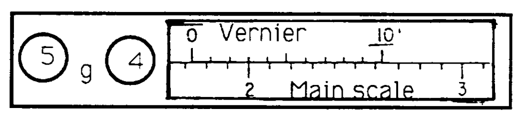
B - USE OF ANALYTICAL BALANCES - a Stanton CL41 or an Oertling R40 balance - both analytical balances are capable of weighing to 0.0001 g.





WEIGHT = 3.1657 g

Oertling R 40 DIGITAL SCALE



WEIGHT = 5.4173

Stanton CL 41 VERNIER SCALE

The Stanton CL41 has the following controls:

(i) off / partial release / full release;

(ii) zero adjustment;

(iii) levelling;

(iv) weight change 100 g / Tare (grey knob, not normally required), tens g (red), units g (yellow), $^1/_{10}$ ths g (blue).

The balance point is shown on an illuminated scale, 0-100 mg, equipped with a vernier scale for the range 0.1 - 0.9 mg. The vernier scale is used to measure accurately a fraction of the finest division on the main scale of a measuring instrument as in the example above:

a - the zero mark in the vernier scale indicates that the reading is between 1.7 and 1.8 (0.017 and 0.018 g);

b - the division of the vernier scale which coincides with a division of the main scale indicates the exact reading. The vernier division which coincides is 3, which is exactly 0.0003. The accurate reading is the sum of all readings (5.0 + 0.4 + 0.017 + 0.0003) and gives 5.4173 g.

The Oertling R40 has the following controls:

(i) off / pre-weigh / full release;
(ii) zero adjustment;
(iii) levelling;
(iv) weight change tens g (front left knob), Units g (front middle), $^{1}/_{1000}$ths and $^{1}/_{10000}$ths g (front right).
Readout is completely digital.

The following points must be observed when using the analytical balance:

1. Keep the balance scrupulously clean;
2. Work in front of the balance in order to see the scale clearly;
3. Weight changes > 1 g **must** be made with the pre-weigh / full release control **OFF**;
4. Weight changes < 1 g may be made with the partial release control on but **NEVER** with the full release control **ON**;
5. All weighing must be performed with samples contained in capped weighing bottles;
6. Return all weight control knobs to their zero positions after use;
7. **DO NOT** overload the balance.

Weighing procedure

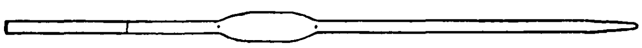
In many experiments the instructions state 'Weigh accurately about 0.X g of ...'. At first sight this is a contradiction but it means that the mass of the sample does not need to be exactly 0.X000 g. However its mass is required to four decimal places of grams.

Use the following procedure to ensure accuracy and cleanliness of the balance pan and case.

1. On a top loading balance transfer a suitable (approximate) quantity of the substance to be weighed to a clean dry weighing bottle. Take the weighing bottle, a clean beaker (conical flask in case of titration) tongs, and your lab book to the analytical balance;
2. Transfer the weighing bottle to the balance pan. This and all subsequent manipulations involving the weighing bottle must be carried out using the tongs;
3. Determine the weight of the bottle plus sample and record this in your lab notebook;
4. Transfer the substance into the beaker;
5. Reweigh the bottle. Record the weight of bottle plus residue and hence obtain the mass of the sample transferred to the beaker;
6. Any material remaining in the bottle must **NOT** be returned to the reagent bottle but should be deposited in the jar provided.

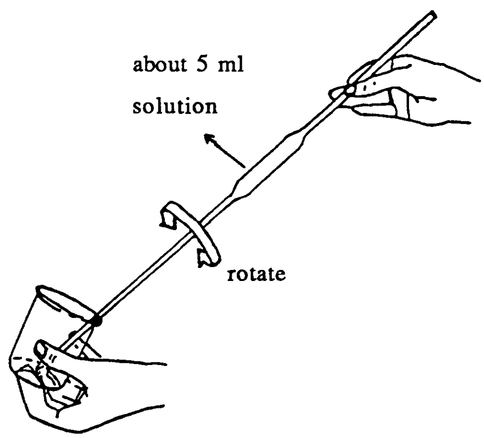
APPENDIX - 2 - VOLUMETRIC TECHNIQUES

A - VOLUMETRIC PIPETTE - often has a bulb in the centre and has only one calibration marking on the upper part of the tube. These are calibrated to deliver a fixed and exact volume: 10 ml ±0.04; 25 ml ±0.06 and so on.



1. Selecting

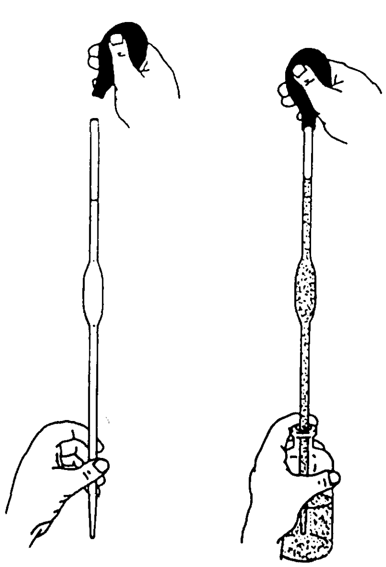
The top and tip must be undamaged;
Use a volumetric pipette only if a precise volume is required otherwise use a measuring cylinder.



2. Cleaning

Fill the bulb of pipette to about one third of its capacity with water. While holding it nearly horizontal carefully rotate the pipette so that the interior surfaces are covered. Drain inverted, and rinse with distilled water. Repeat the first step to rinse with a little of the solution to be measured and let it flow out of the tip.

3. Fitting and filling

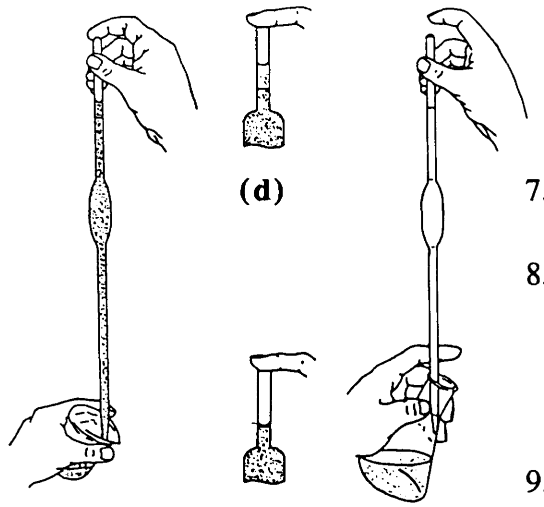


(a) (b)

1. The top end of the pipette should be moistened slightly and placed into the bulb;
2. Place solution into rinsed beaker before filling the pipette;
3. The bulb should be squeezed to expel air and the point end (tip) inserted into the liquid to be measured;

NOTE: <u>At all times</u>, the pipette should be held in one hand, and the bulb in the other.

4. By releasing the pressure in the bulb the liquid is sucked into the pipette till it is 2-3 cm above the mark on the upper stem (b). Be careful not to jam the bulb too tightly on the pipette you must be able to remove it easily;
5. Hold the pipette in your right hand and ease the bulb off the top with your left hand (vice-versa if you are a left handed);

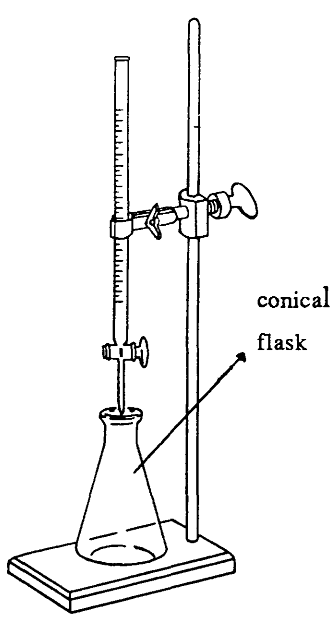


(d)

(c) (e) (f)

6. As the bulb comes off, cover the top of the pipette with the index finger of the right hand (not a thumb which gives less control over the liquid level). This changeover must be done rapidly.If the liquid level falls beneath the mark you will have to start all over again;
7. The outside of pipette should be dried removing any drops adhering to it with a towel paper;
8. The liquid level is carefully allowed to fall until it is at the calibration mark. This is best done by rotating the pipette slowly, to release the pressure of your finger on the top of the pipette (remember to read the bottom of the meniscus);
9. Then the liquid should be drained into the receiver vessel as shown in figure (f);
10. The pipette should be held vertically when readings are taken and when it is being drained;
11. While draining, the tip of the pipette should be held against the inside wall of the receiver vessel.

B - THE BURETTE



(a)

1. The burette - a typical set up for a burette is shown in figure (a). A standard 50 ml burette, when used properly, is capable of delivering volumes accurate to ±0.02ml. To reach this level of accuracy, certain important points must be adhered to. The tap must be well (but not over) greased and leak free. When turning the tap apply pressure to push it into the barrel. If the stopcock barrel is streaked, it must be regreased otherwise the tap will leak.

2. Cleaning - before making any measurements the burette must be thoroughly cleaned:

a - rinse out the burette with detergent solution;

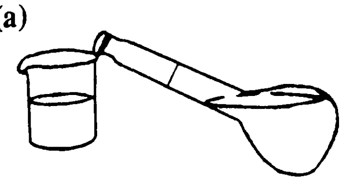
b - wash with tap water;

c - wash with distilled water;

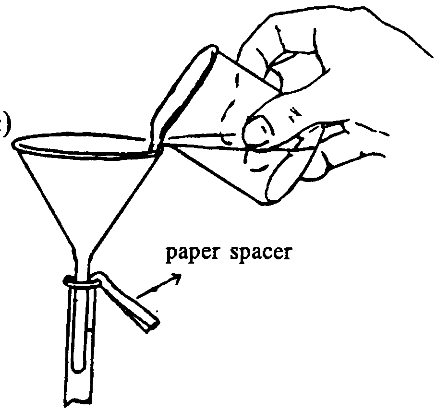
d - rinse with the solution to be used. This is done by pouring 5 to 10ml of the solution into the burette (with the stopcock closed) then tilting the burette to an almost horizontal position and turning it so that the entire inner surface comes into contact with the liquid. The rinsings are then allowed to run out.

Place solution into rinsed beaker
before filling burette

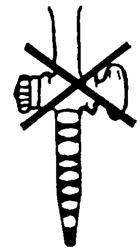
(a)



(c)

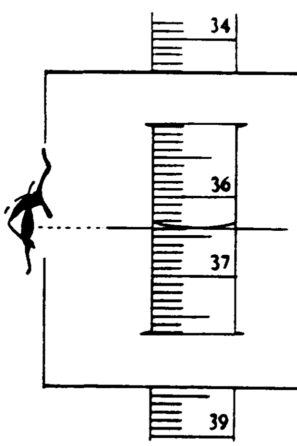


(d)



no trapped
air bubbles

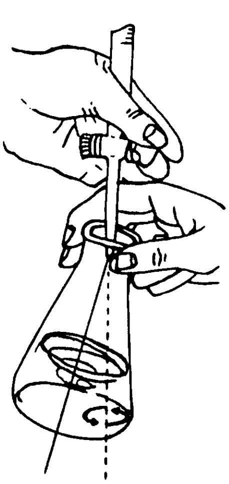
3. Filling - fill the burette to any mark near the top of the scale. Ensure that there are no air traps or bubbles in the burette, particularly around the tap and the tip (figure d) by opening the tap to discard some of the titrant.



(e)

Read the burette at the bottom of the meniscus (figure e) which will show up as a thin dark line if outlined by a white background. The scale will give a value to 0.1 ml and you must estimate the second decimal place to 0.02 ml.

C - THE TITRATION PROCEDURE



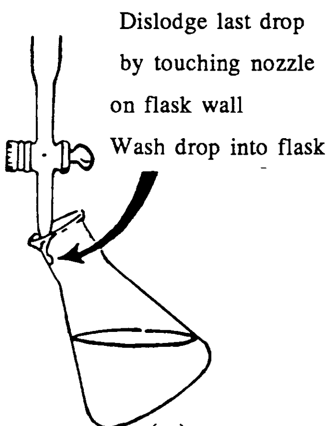
(f)

By pipette, place the solution to be titrated into a clean 250 ml conical flask. Alternatively, weigh out the required weight of solid into a clean 250 ml conical flask and dissolve this in distilled water. Remember to add indicator when told in the experimental written instructions. Add the titrant slowly from the burette, while swirling the flask with the right hand as shown in figure (f) until you are close to the end point. Always push the stopcock into the barrel while rotating the stopcock during a titration. A right handed person holds the handle of the stopcock with the left hand as shown in figure (f).

Near the end point, add the titrant drop by drop opening the tap just enough to allow a single drop to appear at the tip of the burette and then transfer the drop to the flask. Remember to continue to swirl the contents of the flask throughout the titration.

When the first permanent change in colour appears, note the burette readings. Repeat accurate titrations until good agreement is obtained.

Note: For precision work, volumes of less than one drop can be rinsed from the tip of the burette with distilled water from a wash bottle.



(g)

Set out your results as follows:

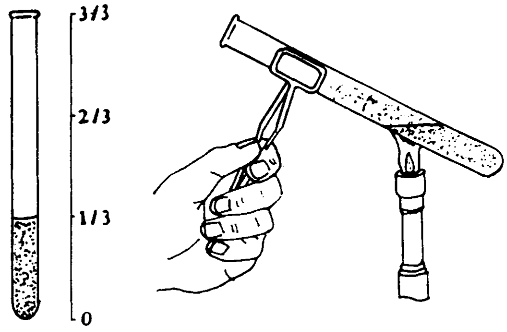
Final burette reading	=	ml
Initial burette reading	=	ml
Titre	=	ml

Each reading, and the titre, should be recorded to two decimal places. If the second figure after the point is zero it must be shown as such and not omitted.

Note: WASH THE BURETTE OUT THOROUGHLY BEFORE STORAGE IN AN INVERTED POSITION WITH THE TAP OPEN.

APPENDIX - 3 - GENERAL LABORATORY TECHNIQUES

A - TEST TUBE



(a) (b)

A - Filling a test tube

The test tube is a vessel used to do reactions with a small sample of chemicals. Never fill it more than one-third full.(see figure a).

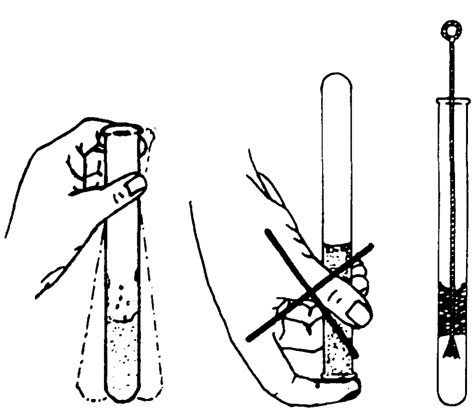
B - Heating a test tube

Hold the test tube with a wooden holder at an angle of approximately 45-degrees as it is shown in figure (b).

CARE must always be taken when heating:

Be sure that the tube is heated slowly. Place the surface of the contents of the the tube in the flame (not the base of the test tube), and always move the tube in the flame constantly.

The mouth of the tube is **NEVER** pointed at anyone during the heating process.



DO NOT

(c) (d) (e)

C - Shaking a test tube

When you use a small volume you can shake moving the bottom of the tube as it is shown in figure (c).

DO NOT close the mouth of the tube with your finger for shaking (figure d).

D - Cleaning a test tube

Wash with detergent and use a proper brush as shown in figure (e).

Rinse with tap water to remove the soap.

B - FILTRATION

There are two general methods of filtration: GRAVITY and VACUUM FILTRATION.

GRAVITY FILTRATION is a procedure in which the filtrate passes through the filter medium under the force of gravity and capillary attraction between the liquids and the funnel stem.

Folding a filter paper:

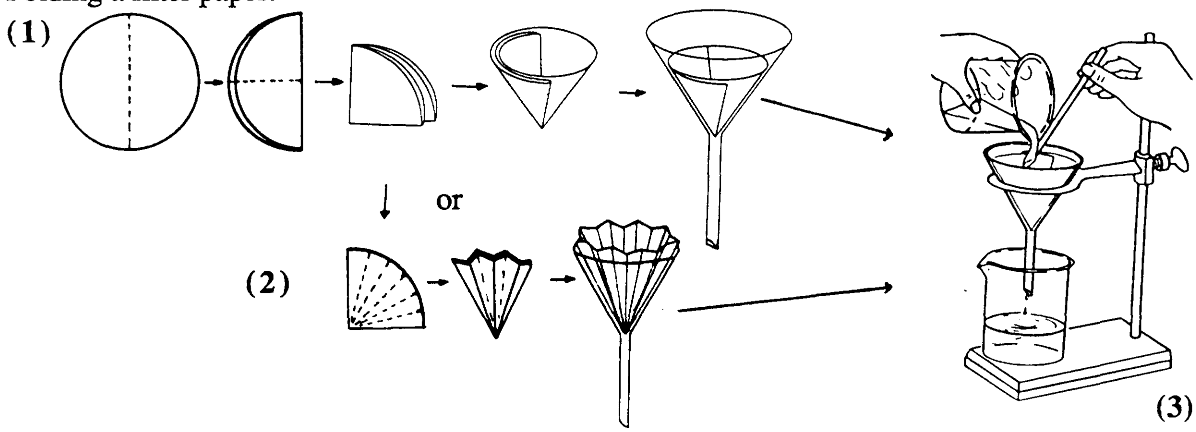


Figure 1 - Normal filter - the filter paper is first folded exactly in half then the second fold is made so that one corner is about 3 mm inside the other. The paper is then opened into a cone so that the shorter edge will be pressed against the funnel wall and covered by the longer edge of paper.

Figure 2 - Fluted filter - fold the filter paper in half and than fold this half into eight equal sections. The fluted filter paper is then opened and placed into a funnel.

The filtration is performed by assembling the apparatus as shown in figure (3), moistening the filter paper with a small amount of water then pouring the mixture to be filtered through the paper. To guide the mixture into the funnel use a glass stirring rod.

CARE must be taken not to fill the paper more than two thirds full.

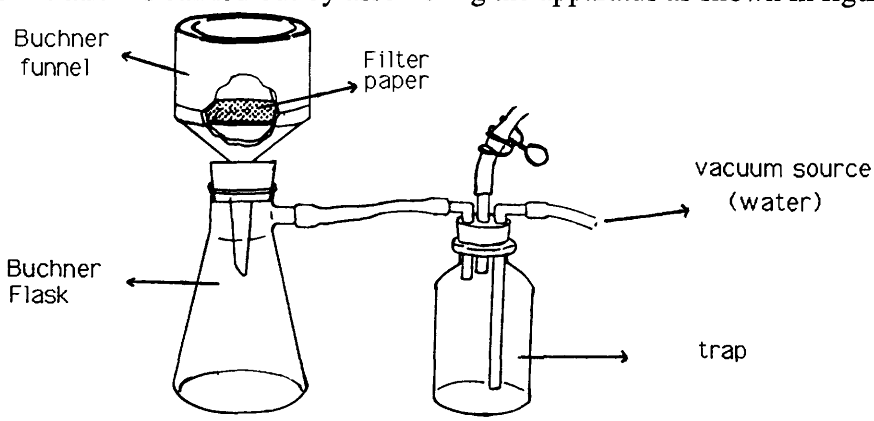
To remove the solid that remains in the original vessel use water to wash all the solid into the funnel.

TAKE CARE: wet filter paper tears very easily.

VACUUM FILTRATION - (Buchner funnel) - is a procedure in which a pressure differential is maintained across a filter medium by evacuating the air below the filter paper. This provides a force on the solution in addition to that of gravity and increases the rate of filtration.

The filter paper should be chosen so that it exactly fits the funnel.

The funnel is fitted to a suction flask with a rubber collar so that the filter flask will be vacuum tight. The side arm of the flask is connected to a pump such as a tap water aspirator with a trap placed between them. This trap helps prevent the suck back of unwanted material into the system. The filtration is carried out by assembling the apparatus as shown in figure below.



APPENDIX - 4 - PROCEDURE FOR BALANCING REDOX EQUATIONS

Although there is no single 'correct' method of balancing a redox reaction, the following systematic procedure (appropriate for reactions taking place in aqueous solution) is recommended.

Building up the equations by the following systematic procedure is recommended.

1. Begin the equation by writing the formula of one of the reactants on the left hand side, and on the right the formula of the product to which it is converted.
2. Balance the equation with respect to the principal atom.
3. Balance the oxygen atoms (if any) by adding the appropriate number of H_2O molecules to the oxygen deficient side of the equation.
4. Balance the hydrogen atoms by adding H^+ ions to the appropriate side of the equation.
5. Balance ion charges by adding electrons to the appropriate side of the equation. Call this equation (A).

Repeat steps 1- 5 for the other reactant, to obtain another equation (equation - B).

6. Multiply equations (A) and (B) by suitable factors such that the number of electrons on the left of one of the equations is equal to the number on the right of the other.
7. Add the equations together to obtain the required overall equation for the reaction.

This approach is appropriate for reactions in acidic or neutral solutions. For reactions taking place in alkaline solution, it is unrealistic to write an equation involving H^+ ions.
To balance an equation for an alkaline solution reaction we need proceed by applying the series of steps 1 - 8, then add one further step:

8. Note the number of H^+ ions which appear in your equation, add the same number of OH^- ions to each side of the equation, then write H_2O in place of each H^+, OH^- pair.

You might sometimes have to face problems in which the reactive species are not specified, but rather the names of compounds are given. For example, if one of the compounds is iron(III) chloride you will have to decide if the reactant species is Fe^{3+} or Cl^-. This can be done rigorously using information about redox potentials, but without having recourse to this, some rough working rules may be useful.

1. If the compound is a salt of a metal in columns 1 or 2 of the Periodic Table the reactant will be the associated <u>anion</u>, because the metal ion cannot change its oxidation state to anything else which would be stable in aqueous solution.

2. If it is a salt of any other non-transition metal the reactant is likely to be the anion, unless it is a reaction in which the metal ion is reduced to the free metal.

3. In a transition metal compound it is likely that the ion which contains the transition metal will be the reactant. In some instances this will be a cation (e.g. Mn^{2+}) and in others an anion (e.g. MnO_4^-).

4. If there is still doubt, this can often be resolved by considering whether the other reactant is likely to be an oxidising agent or a reducing agent, e.g. iron(III) chloride will react with a reducing agent:

$$Fe^{3+} + e \longrightarrow Fe^{2+}$$

and with an oxidising agent:

$$2\,Cl^- \longrightarrow Cl_2 + 2\,e$$

APPENDIX - 5 - GUIDE TO THE WATER-SOLUBILITY OF THE COMMON INORGANIC COMPOUNDS

SOLUBLE

A. All column I metal salts (Na^+; K^+; Rb^+ and Cs^+)

B. All ammonium salts (NH_4^+)

C. All strong acids (H^+)

D. All nitrates (NO_3^-)

E. Sulphates (SO_4^{2-}) except Pb^{2+}; Ba^{2+};Sr^{2+} and Ca^{2+}

F. Chlorides (Cl^-) except Pb^{2+}; Ag^+ and Hg_2^{2+}.

INSOLUBLE

G. Carbonates and sulphides except those of groups A and B above.

H. Hydroxides except those in group A above and $Ba(OH)_2$.

BORDERLINE CASES

$Ca(OH)_2$; $Sr(OH)_2$ and Ag_2SO_4 are sparingly soluble.
$PbCl_2$ is soluble in hot water.

APPENDIX - 6 - GUIDE TO THE COLOUR OF COMMON INORGANIC IONIC COMPOUNDS

A. Coloured compounds The following cations and anions give hydrated crystalline solids or solutions in water with the following colours:

BLUE	Cu^{2+}
GREEN	Cr^{3+}; Ni^{2+}; Fe^{2+}(pale green)
YELLOW	Fe^{3+}; CrO_4^{2-} (yellow-brown)
ORANGE	$Cr_2O_7^{2-}$
RED/PINK	Co^{2+} (purple-red), Mn^{2+} (pale pink - almost colourless)
PURPLE	MnO_4^-

B. Colourless compounds The following cations and anions form colourless compounds except when in compounds with a coloured anion or cation:

Alkali metals	Na^+; K^+ etc.
Alkaline earth metals	Mg^{2+}; Ca^{2+} etc
Ammonium salts	NH_4^+
Other ions	Ag^+; Al^{3+}; Pb^{2+}; Zn^{2+}; Sn^{2+}; Hg_2^{2+}; Hg^{2+}; SO_4^{2-}; NO_3^-; CO_3^{2-}; OH^-; Cl^-.

C. **Oxides and sulphides** Those which are insoluble generally do not show the characteristic colour of the metal ion, and are often black.

APPENDIX - 7 - QUALITATIVE TESTS FOR OXYGEN AND CHLORINE

1. Oxygen (O_2)

A colourless and odourless gas. Best detected by its ability to support combustion, i.e. it will ignite a glowing wood splinter.

2. Chlorine (Cl_2)

A greenish, toxic gas which is more dense than air. If chlorine is suspected to be present, it must not be sniffed. Best detected by its action on moist litmus paper: colour change blue $\longrightarrow$ red (formation of HCl as a product from the reaction of Cl_2 and H_2O) then paper becomes bleached.

APPENDIX B - 2

"PRELAB WORK" LAB MANUAL

VERSION 4

CONTENTS

GENERAL LABORATORY INFORMATION

1. SAFETY AND LABORATORY PRACTICE

Experiments involving the use of glass apparatus and chemicals should always be regarded as potentially hazardous. Some of the compounds you will work with are corrosive, poisonous or flammable; therefore you should always exercise extreme care in the laboratory and:

a- AT ALL TIMES IN THE LABORATORY YOU MUST WEAR SAFETY SPECTACLES. This is to protect you from your neighbours' mistakes as well as your own. Follow instructions closely.

b- Avoid spillage on skin and clothing. Report any accident immediately even if it does not involve personal injury as e.g. spillage of chemicals or breakage of glassware.

c- Some of the equipment necessary for the experiments is both delicate and expensive and will have to be used by your fellow students in this and subsequent years. Extreme care should be exercised at all times when handling equipment. If you are in any doubt at all as to how a piece of equipment should be operated then ASK A DEMONSTRATOR.

d- Ensure that all glass apparatus used by you is cleaned before you leave the laboratory and replaced in the drawer in which you found it. Replace empty reagent bottles on the shelves where you found them at the beginning of the laboratory period.

e- DO NOT return used reagents into the reagent bottles on the benches but where appropriate (e.g. with silver nitrate solutions) pour into the residue bottles provided.

2. FIRE REGULATIONS

FIRE is a serious hazard in any laboratory and is usually caused by the careless handling of organic solvents. These must NOT be heated using a Bunsen flame, nor used in the near vicinity of a flame.

PLEASE MAKE A POINT OF READING THE NOTICES RELATING TO FIRE EVACUATION PROCEDURE.

WHEN THE ALARM SOUNDS

1. Do not stay to collect personal belongings.
2. Follow the instructions of members of staff and **WALK** via the nearest emergency exit to your assembly point in **UNIVERSITY PLACE.**
3. Those in toilets and lifts must leave without delay and make for the nearest emergency exit

IMPORTANT: **If smoke or other obstacles are found, make for the nearest clear exit.**

3. LABORATORY NOTEBOOKS

You will require a hard-backed notebook in A4 size for the laboratory. We require you to keep an up-to-date written account of your laboratory work including all measurements and observations made and all rough working. Ancillary notebooks, loose pieces of paper, etc. are NOT allowed as they are a fire hazard. For the purposes of the CHEMISTRY ordinary laboratory course your manual contains most of the necessary background work and details of the experimental procedure. There is no need for you to copy this into your notebook. Your report should include:

1. all results and observations; 2. calculations where appropriate;
3. interpretations of results and observations including equations where appropriate; and
4. conclusions.

Drawing and Using Graphs

In some of the experiments in this manual, you will be asked to display your results in graphical form. Presenting experimental data in this way has several advantages over a simple tabulation of results.

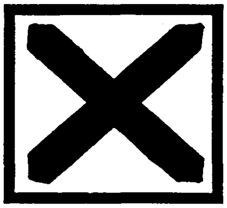
1. A graph shows clearly the functional relationship between the variables concerned. For example, a straight line (a linear relationship between variables) is usually obvious.
2. Any points which have been seriously mis-measured or incorrectly calculated, are also immediately obvious.
3. The deviation of the points from the line drawn through them gives a good idea of the accuracy of the results, or possibly, the adequacy of the theory that predicted the functional relationship.

In order to realise these advantages to the full, it is important that several basic principles are followed when drawing graphs:

1. Work exclusively in pencil, using a sharp, fairly hard (1H, 2H) pencil.
2. Use the fullest possible extent of the graph paper. If the graph will not fit one way round try the other - a sheet of graph paper is not usually square. Do not, for example, plot 3 x 3 inches on paper measuring 12 x 9 inches.
3. Label the axes clearly, stating the physical property represented and its units.
4. Mark each experimental result clearly by using a point, or ⊙ ; ⊡ ; △ etc.
5. Give the graph a title stating the variables which are being plotted against each other.
6. Draw straight lines with a ruler in such a way that the deviations of the experimental points from the line are minimised.
7. Draw curves neatly, again minimising the deviations of the experimental points from the line. With curves, it is often helpful to sketch the curve lightly in pencil at first to get the smoothest possible line, and subsequently draw over the sketch more heavily.The light sketch lines can then be erased.
8. Some graphs have linear and curved regions.Use a ruler for the former and merge it into the latter.
9. For maximum accuracy, the gradients of straight lines should be derived using the entire linear portion of the graph, and not just a small portion of it.

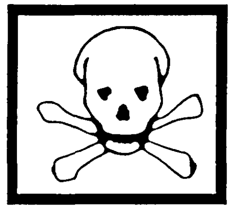
4. KEY TO SYMBOLS

Pay attention to these symbols in the right margin. They indicate the hazards of the substances used.



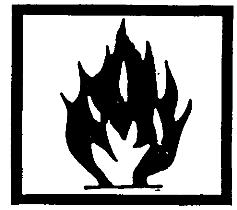
IRRITANT/
HARMFUL

Take care in handling



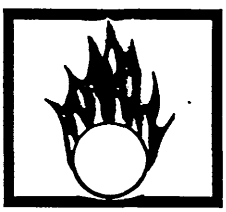
TOXIC

Be careful not to absorb or ingest



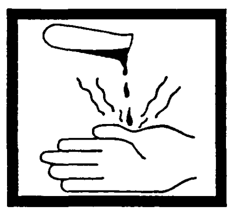
FLAMMABLE

Keep away from naked flames



OXIDISING

Keep away from Flammable substances

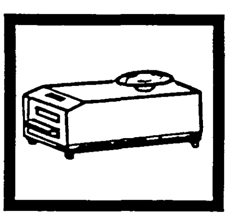


CORROSIVE

Take care in handling.

EXPLOSIVE

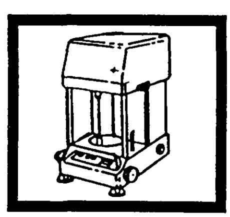
Must be conducted in fume cupboard



ROUGH
BALANCE

Only rough weighings required.

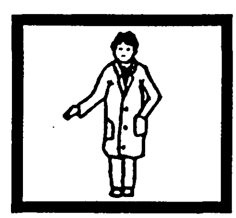
Use rough balances on benches A or B (*)



ANALYTICAL
BALANCE

Accurate weighings required.

Use analytical balances in Balance room or on benches 10 and 16(*)

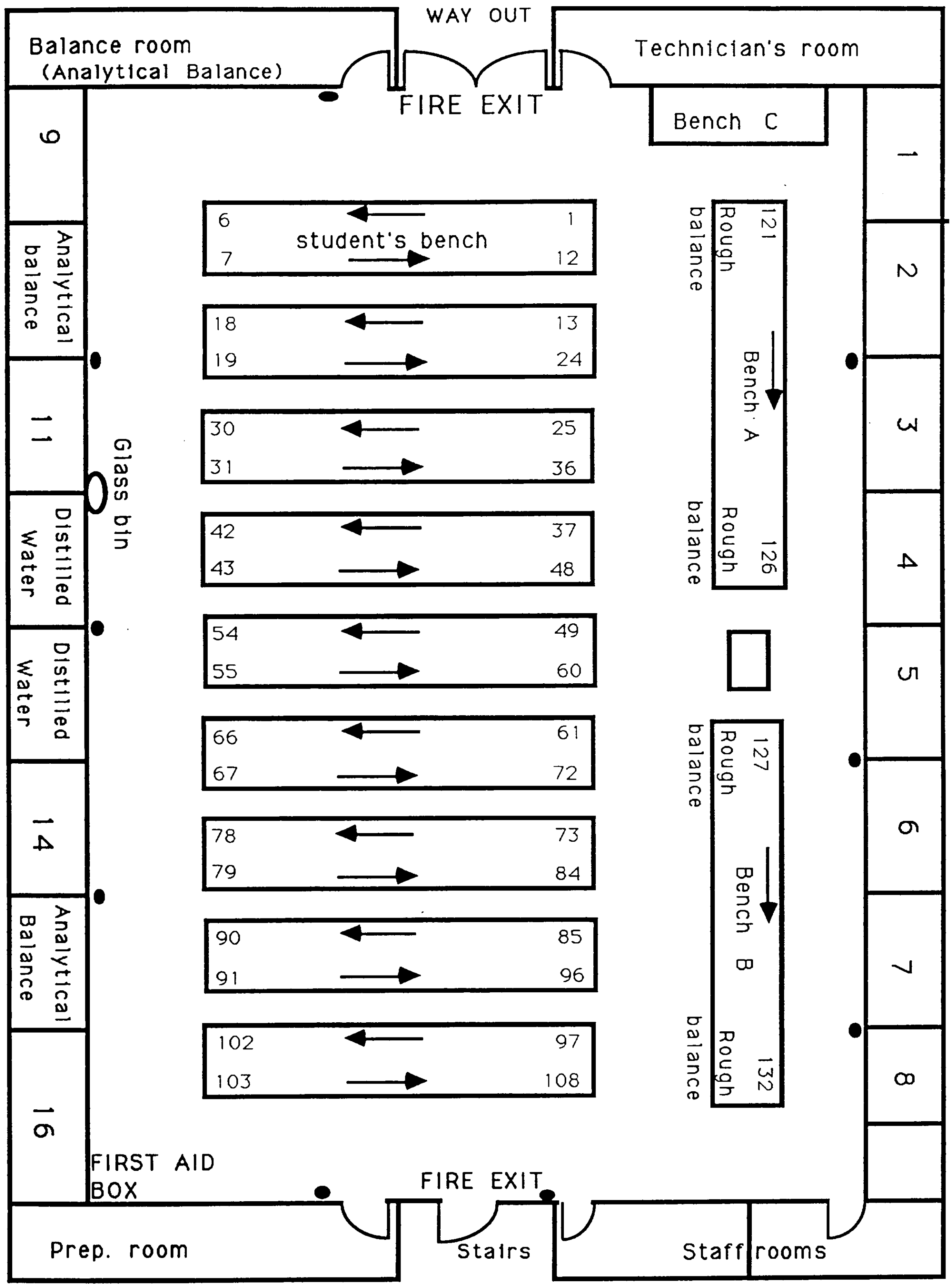


DEMONSTRATOR

Contact your demonstrator at this stage in the experiment

(*) Refer to map of lab (page 5) for location of rough and analytical balance

5. MAP OF LABORATORY - room 170



● Fire extinguisher $-CO_2$ and fire blanket

PRELAB WORK INSTRUCTIONS

You are expected to do some prelab work for each experiment. This work must be completed before you come to the laboratory to do the experiment. It does not matter if you discuss the work with other students but it is essential that you understand and can do the prelab work before entering the laboratory. The prelab work has been included to help you obtain a better understanding of the experiment before doing it in the laboratory. **You should read the experiment carefully and see how the prelab work is related to it**.

When you enter the laboratory you should show your completed prelab work to your **DEMONSTRATOR** who will check it.

PRELAB WORK for EXPERIMENT - 1

NAME____**Bench №**________

PART A - Balance the equation for the decomposition of ammonium dichromate [$(NH_4)_2Cr_2O_7$] to chromium(III) oxide(Cr_2O_3). Hence calculate the mass of $(NH_4)_2Cr_2O_7$ required to make 2.0 g of Cr_2O_3.

$$(NH_4)_2Cr_2O_7 \longrightarrow Cr_2O_3 + N_2 + H_2O$$

PART - B - Write the balanced equations for both the reduction of Cr_2O_3 and CrO_3 with Al to produce Cr Metal (thermite reaction). Hence calculate the theoretical yield of Cr metal from the complete reduction of 7.0 g of Cr_2O_3 and 3.0 g of CrO_3.

ASK YOUR DEMONSTRATOR TO CHECK YOUR WORK

EXPERIMENT - 1

INORGANIC PYROTECHNICS

Purpose

The purpose of this experiment is to illustrate a solid state oxidation-reduction reactions and how to calculate the % yield of the reaction.

Safety Precautions

Chromium salts are toxic, particularly by skin absorption.
Both of these reactions are exothermic and involve toxic materials. They must be carried out in the fume cupboard.
The thermite reaction (part B) is so vigorous and exothermic that you must be supervised by a demonstrator when it is performed.
Pay attention to the symbols in the right margin. They indicate the hazards of the substances used.

The Experimental Report should contain:

the balanced equations for the reactions which occur in the experiment;
the calculations of the % yield of the reactions;
answers to questions in these written instructions.

Outline of the Experiment

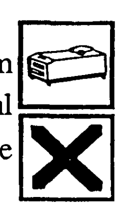
A. The decomposition of ammonium dichromate (ammonium dichromate volcano) to produce chromium(III) oxide.
B. The reduction of this chromium(III) oxide and chromium(VI) oxide with aluminium (thermite reaction) to produce chromium metal.

THE EXPERIMENTS

The Experimental procedure

Chemicals for this experiment are on benches 'A' or 'B'.
Refer to map of lab (page 5) for location of apparatus and equipment.

A. The Ammonium dichromate 'Volcano'



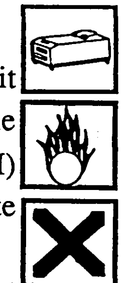
Using a rough balance (appendix-1) weigh out approximately the mass of ammonium dichromate $(NH_4)_2Cr_2O_7$ calculated in your **PRELAB WORK**. Also weigh a 100 ml beaker and record its weight. It will be used to collect and weigh the product of the reaction.

Place a large filter paper (bench 'C') on the bench in the fume cupboard (2;4 or 7) and on top of this your "asbestos" centered wire gauze. Pour the ammonium dichromate on to the gauze so that it forms a cone shaped pile in the centre.

Light the apex of the cone with a match. It may take two or three attempts, but once the reaction has started it will continue by itself. Record your observations in your own lab notebook. The solid product is chromium(III) oxide. There are also gaseous products. What do you think they are?

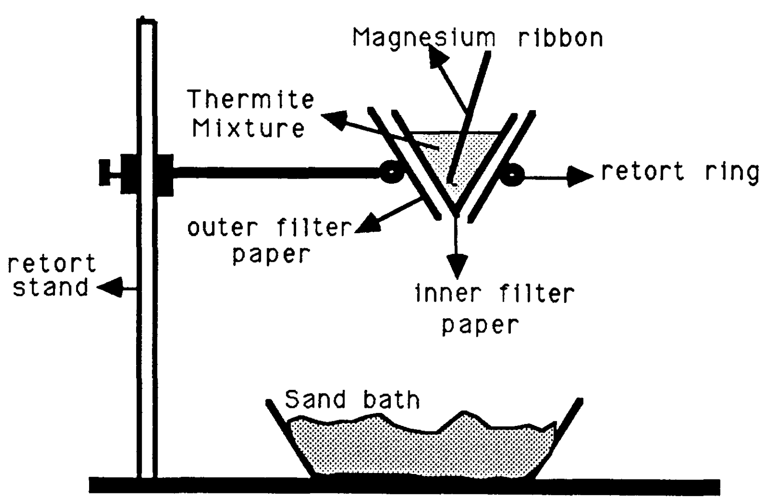
Collect and weigh the chromium (III) oxide product and save it for part B.

B. The Thermite Reaction.



Crush the chromium(III) oxide product from part A in a beaker with a glass rod to make it as compact as possible. Add enough additional chromium(III) oxide (Cr_2O_3) to make the total weight up to 7 g. Now add 5.5 g of aluminium powder and 3 g of chromium(VI) oxide (CrO_3). Mix the ingredients thoroughly using a glass rod. This is the thermite mixture.

Prepare the apparatus for the thermite reaction as shown in the diagram below. (The retort ring, stand and sand bath arrangement can be found already set up in the fume cupboards 5 or 8).

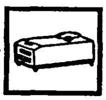


Fold (appendix-3 item B-1) two 15-20 cm filter papers; tear the apex off one of them and place them one inside the other, the intact one to the inside. Fill it with all the prepared thermite mixture. Support the filter paper cone in a retort ring, with a sand bath beneath it, as shown in the diagram. When the apparatus is complete, insert about 4 inches of magnesium ribbon(bench 'C') into the centre of the thermite mixture to act as a fuse.

FROM THIS POINT ON YOU MUST BE SUPERVISED BY A DEMONSTRATOR. 

Remove the inner cone of filter paper containing the thermite mixture and then moisten the outer cone with water from a wash bottle. Replace the inner filter paper cone. Light the top of the magnesium ribbon with a Bunsen burner. **AS SOON AS** the magnesium begins to burn put down the burner, close the fume cupboard and retire at least 3 to 4 feet. **DO NOT** look directly at the burning magnesium. Focus on the bottom of the filter paper cone and the sand bath. Molten metal should be observed. 

Which metal is it? How could you verify this?

When the metal in the sand bath appears cool, (take care; appearances can be deceiving) use tongs to remove the metal and quench it in cold water. Break off any encrusted sand or fused oxide surrounding the metal. Weigh the metal and calculate % yield based on the amount of Cr_2O_3 and CrO_3 used. 

Place the metal in a test tube and observe what happens when the metal is covered with 2 mol l^{-1} HCl. It may be necessary to warm the test tube to initiate any reaction. Remove the metal from the acid. Wash and dry it. 

Calculation

Use the following data to calculate the enthalpy (heat) of reduction of Cr_2O_3 to Cr by aluminium.

$$Cr_2O_3\,(s) \longrightarrow 2\,Cr + {}^3/_2\,O_2 \qquad \Delta H^o = +1041\ kJmol^{-1}$$
$$2\,Al + {}^3/_2\,O_2 \longrightarrow Al_2O_3\,(s) \qquad \Delta H^o = -1668\ kJmol^{-1}$$

Is the value you calculated consistent with your observations of the experiment?

ASK YOUR DEMONSTRATOR TO CHECK YOUR RESULTS. 

PRELAB WORK for EXPERIMENT - 2

NAME____Bench Nº_______

Write equations for the following reactions:

PART - A - PCl_5 with water
PART - B - H_2SO_4(conc.) with NaCl
PART - C - NaCl + H_2SO_4(conc.) + MnO_2
PART - D - Cl_2 / H_2O (solution of chlorine in water) with NaCl and NaI.
PART - E - $AgNO_3$ with NaCl and NaI.

ASK YOUR DEMONSTRATOR TO CHECK YOUR WORK

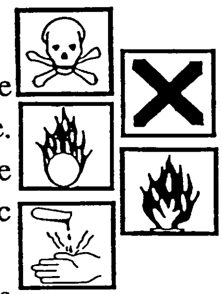
EXPERIMENT - 2

CHEMISTRY OF THE HALOGENS

Purpose

The purpose of this experiment is to do five series of reactions on halogen compounds and to compare the reactions within each series.

Safety Precautions



Unlike sodium chloride, the sodium salts of the other halides are poisonous and should be handled with care. Many of the other chemicals in this experiment are toxic and corrosive. Hydrogen fluoride, formed when covalent fluorides undergo hydrolysis, and from the reaction of fluoride ion with acid, causes severe burns. CCl_4 and $CHCl_3$ give toxic vapours.

Pay attention to symbols in the right margin. They indicate the hazards of the substances used.

The Experimental Report

For your own benefit, draw up a table of comparisons in your own lab notebook while doing the following experiments and make a note of each observation. (examples of the tables are include in the instructions).

The balanced equations for the reactions should be reported along with the tabular comparison that you make. Check with your demonstrator that you have interpreted your observations correctly.

Answers to the questions in these written instructions should be given.

Outline of the Experiment

The five series of reactions are;

A. reaction of covalent chlorides with water.

B. reaction of ionic halides with sulphuric acid.

C. redox reactions of halides.

D. replacement of one halide by another.

E. reaction of halides with silver nitrate.

THE EXPERIMENTS

The experimental procedure

Chemicals for this experiment are in fume cupboards 3 or 6.

Refer to map of lab (page 5) for location of apparatus and equipment.

A. **Reaction of Covalent Chlorides with water**

<u>This experiment should be carried out in the fume cupboard.</u>
In the following experiments you are going to observe how some **COVALENT CHLORIDE** compounds react when water is added to them drop by drop.
Before you start - think what might happen. Will a gas be evolved?
If so - what is it likely to be? What will the other products of the reaction be?
If you mix **XCl** + **HOH**, there is a possibility that you will get **HCl** + **XOH**, **BUT** it does not happen in every case.

See what happens in the following cases and record your observations in a table in your own lab notebook (similar to table 1).
Take small samples of the following covalent chlorides in four clean dry test tubes (either 1 cm of a liquid in a test tube or the amount of a solid that will fit on the tip of a spatula).
Carefully add water drop by drop.

1. Aluminum chloride ($AlCl_3$)
2. Carbon Tetrachloride (CCl_4)
3. Silicon Tetrachloride ($SiCl_4$)
4. Phosphorus Pentachloride (PCl_5)

When any reaction has ceased, add more water - up to about 5 ml.

Are any reaction products soluble? What effect do these solutions have on litmus paper? Why do CCl_4 and $SiCl_4$ behave differently from one another? Write a balanced equation for each reaction.

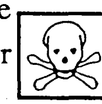
TABLE 1- REACTIONS WITH WATER

COVALENT HALIDES	LITMUS	OBSERVATIONS	PRODUCTS OF THE REACTION
$AlCl_3$			
CCl_4			
$SiCl_4$			
PCl_5			

B. Reaction of halides with sulphuric acid.

You are going to compare the reactions of conc. sulphuric acid on a few crystals of sodium fluoride, sodium chloride, sodium bromide and sodium iodide.

Consider for a moment, before beginning the experiment, what possible reactions could occur? $H_2SO_4 + NaX \longrightarrow ?$



The obvious result is HX, but HX might, itself, be attacked by H_2SO_4 so you could have any of the following gases HX, X_2 or reduction products of H_2SO_4 such as SO_2, H_2S or even sulphur. How will you recognise these products if they should be produced?

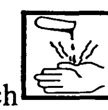
Think this through before you begin the experiment.How would you expect each of the possible gaseous products - HX, X_2, SO_2, or H_2S to react with litmus paper?

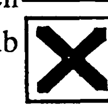
Record all your observations in your own lab notebook (similar to table 2). Note the evidence for the occurrence of a chemical reaction such as colour changes, gas evolution or the production of heat.

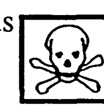
Write a balanced equation for each reaction that occurs.

<u>This experiment should be carried out in the fume cupboard.</u>

Have some wet litmus paper ready to use.







Line up 4 test tubes, one for each of the halide compounds. Use a few crystals of each. Carefully add about 2 ml of concentrated H_2SO_4 to each test tube. If necessary warm each test tube gently. Observe what happens. Note your observations in your own lab notebook.

Test each gas evolved for its reaction with litmus paper by holding a piece of moist litmus paper in the mouth of the test tube

Note: In the case of sodium fluoride the gas evolved may react with glass.

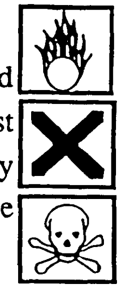
Rinse out that test tube with water and look for evidence of this on the walls of the test tube. What is happening in this reaction? Remember that glass is a chemical substance. This reaction is one of the methods used for etching glass.

TABLE 2 - REACTIONS WITH H_2SO_4

IONIC HALIDES	LITMUS PAPER	GAS(ES) EVOLVED	OBSERVATIONS	OTHER PRODUCTS
$NaF + H_2SO_4$				
$NaCl + H_2SO_4$				
$NaBr + H_2SO_4$				
$NaI + H_2SO_4$				

C. Redox reactions of halides

The experiment should be carried out in the fume cupboard.

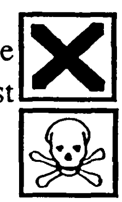


In a test tube mix a few crystals of sodium chloride with a small sample of MnO_2 (a good oxidizing agent), then add about 2 ml of concentrated H_2SO_4 and gently warm the test tube. Compare this result with that in the previous section in which sodium chloride by itself was allowed to react with H_2SO_4. What gas has been evolved? What made the difference? Why? Write a balanced equation for this reaction

	Gas evolved, other products and observations
$NaCl + H_2SO_4 + MnO_2$	

D. Replacement of One Halogen By Another

In this section you are going to use dilute aqueous solutions of the ionic halides. Prepare about 10 ml of each solution by dissolving a few crystals (about the amount on the tip of a spatula) of each in water in test tubes. Take about 2 cm depth of each solution in test tubes for the following reactions and keep the remaining solutions to use in part E.



Prepare a chlorine water solution by diluting approximately 2 ml of sodium hypochlorite with 10 ml of water, then acidifying it with a small amount of 1 molar sulphuric acid (test with litmus paper).

Add a few drops of the chlorine solution to your samples of dilute sodium fluoride, sodium chloride, sodium bromide, and sodium iodide, in test tubes, and note what you see. Record your observations in your own lab notebook (similar to table 3).

Add 1 ml of chloroform (trichloromethane) to each of the solutions. It will form a lower layer. Shake the test tubes (appendix 3) and observe the colour of the chloroform layer. Halogens are more soluble in chloroform than they are in water, so any free halogen is removed from the water and ends up in the chloroform layer giving a distinctive colour.

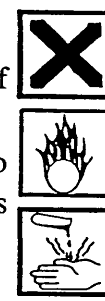
Add more chlorine water drop by drop and shake. Continue adding the chlorine water gradually and observe the colour of the chloroform and any changes that occur. Record your observations in your own lab notebook (similar to table 3).

TABLE 3 - REACTION WITH Cl_2

HALIDES + Cl_2	INITIALLY	WITH CHLOROFORM	CHLORINE WATER IN EXCESS	OTHER PRODUCTS
$NaF + Cl_2$				
$NaCl + Cl_2$				
$NaBr + Cl_2$				
$NaI + Cl_2$				

How do you explain these observations? Try to write balanced equations to explain the reactions that took place.
To show what a sensitive test this is for iodide, empty out your iodide test tube, add water and repeat the chloroform test. Can you still detect the traces of iodine left?

E. Reaction of halides with silver nitrate.



You are going to study the reaction of silver nitrate with your remaining solutions of sodium fluoride, sodium chloride, sodium bromide, and sodium iodide.
Take about 2 cm depth of each halide solution (prepared previously) in test tubes, and to each add a few drops of aqueous silver nitrate (obtainable from the bench 'A' - it is expensive!). Record your observations in your own lab notebook (similar to table 4).

<u>In the fume cupboard</u> add a few drops of concentrated ammonia (ammonium hydroxide) to any of the silver halides which are precipitated, and shake the tube. Does the halide solid disappear?

TABLE 4 - REACTION WITH SILVER NITRATE

HALIDES	$AgNO_3$	OBSERVATIONS	PRODUCTS OF REACTION
NaF			
NaCl			
NaBr			
NaI			

PRELAB WORK OF EXPERIMENT - 3

NAME____Bench Nº______

PART A - Calculate the mass of NaOH required to prepare 250 ml of an 0.10 M NaOH solution.

PART - B - Calculate the mass of $KHC_8H_4O_4$ required to react with 25.00 ml of 0.10 M NaOH. The equation for the reaction is:

$$NaOH + KHC_8H_4O_4 \longrightarrow KNaC_8H_4O_4 + H_2O$$

Note: In this reaction $KHC_8H_4O_4$ is behaving as an acid in which the first hydrogen can be replaced by sodium. It is therefore a monoprotic acid.

PART - C - It was found by titration that 22.50 ml of 0.120 M NaOH was required for complete reaction with 25.00 ml of a HCl solution. Calculate the molarity of the HCl solution.

ASK YOUR DEMONSTRATOR TO CHECK YOUR WORK

EXPERIMENT - 3

ACID-BASE TITRATIONS

Purpose

The purpose of this experiment is to standardise solutions of NaOH and HCl.

Safety Precautions

Sodium hydroxide pellets are extremely corrosive and will cause burns if they come in contact with your skin. The pellets also absorb enough moisture to form an extremely corrosive solution. The acids are dilute and therefore not as hazardous but should still be handled with care.

Pay attention to the symbols in the right margin. They indicate the hazards of the substances used.

The Experimental Report should contain:

the balanced equations for the reactions used in the experiment;

the calculation for the molarities;

the actual readings obtained in the titrations;

answers to questions in these written instructions.

Outline of the Experiment

A. Preparation of an approximately M/10 (0.1 mol per litre) solution of NaOH.

B. Standardisation of the NaOH against a solid acid, potassium hydrogen phthalate ($KHC_8H_4O_4$).

C. Use of the standardised NaOH solution to standardise an approximately M/10 solution of hydrochloric acid.

THE EXPERIMENTS

Basic Ideas Behind the Experiment

For a lot of chemical work, solutions of accurately known concentrations are required. The process of measuring the accurate molarity (i.e. number of moles per litre) of a solution is called **STANDARDISATION.**

The preparation of these accurate solutions may not be easy for a variety of reasons. For example, concentrated hydrochloric acid comes in to the department as a solution of about 11 molar. Even when it has been diluted <u>accurately</u> 11 times it is still only <u>approximately</u> 1 molar.

Sodium hydroxide has a formula weight of 40. It would seem to be an easy matter to weigh out 40 grams of pellets, dissolve them in water and make up to one litre. However, NaOH pellets absorb moisture and CO_2 from the air. With CO_2 they undergo a chemical reaction.

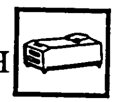
$$2\,NaOH + CO_2 \longrightarrow Na_2CO_3 + H_2O$$

It is therefore impossible to weigh out exactly 40 g of pure NaOH.
The point of this experiment is to show you how these problems are overcome by standardising the NaOH and HCl solutions.

The experimental Procedure

Chemicals for this experiment are on bench 'A' or 'B'.
Refer to map of lab (page 5) for location of apparatus and equipment.

A. Preparation of a M/10 Sodium Hydroxide Solution.



Using a rough balance (appendix 1) weigh in a beaker approximately the mass of NaOH calculated in your **PRELAB WORK**.

Dissolve the NaOH in a few ml of distilled water and transfer the solution carefully, with washings to a 250 ml volumetric flask. Make up to the mark with distilled water and mix thoroughly by inverting the flask several times.

Calculate the approximate molarity of the solution and transfer it to your own labelled reagent bottle.

B. Standardisation of a Sodium Hydroxide Solution

Using an analytical balance (weighing procedure - appendix 1) weigh in a weighing bottle an amount of potassium hydrogen phthalate ($KHC_8H_4O_4$) approximately equal to the mass calculated in your **PRELAB WORK**. Transfer the $KHC_8H_4O_4$ to a 250 ml conical flask and take your second weighing of the weighing bottle.
Calculate the number of moles of $KHC_8H_4O_4$ in the conical flask.
To the conical flask add about 75 ml (measuring cylinder) of distilled water to dissolve the $KHC_8H_4O_4$, and a few drops of phenolphthalein indicator.

Titrate the sample of potassium hydrogen phthalate solution with the sodium hydroxide, following the procedure as in appendix 2:

1. As you near the end point, the pink colour at the point of entry persists for longer.
2. The end point is reached when one drop provides a permanent pink colour. Stop the titration and read the level of the solution in the burette accurately.

Write the equation for the titration reaction. How many moles of NaOH have reacted with the sample of $KHC_8H_4O_4$? Calculate the molarity of the NaOH solution.

3. Repeat with a further portion of phthalate until two values of the molarity of NaOH agree to within 1%. If you are unable to obtain this agreement see your demonstrator.

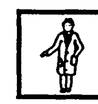
C. Titration of Hydrochloric Acid with Standardized Sodium Hydroxide

1. Transfer exactly 25 ml of given hydrochloric acid (bench 'A') by pipette into a conical flask;
2. Add a few drops of phenolphthalein.
2. Add about 50 ml (measuring cylinder) of distilled water.
3. Titrate in the same way as in part B.

Repeat this with other 25 ml samples of HCl until two titrations agree to within 1%.

Write a balanced equation for the reaction.

Calculate the molarity of the HCl. Report your answer to your **demonstrator**.



PRELAB WORK for EXPERIMENT - 4

NAME____ **Bench Nº**______

PART - A - Calculate the mass of KIO_3 required to prepare 250 ml of an 0.015 M KIO_3 solution.

PARTS - B and C

1 - Write the balanced equation for the reaction of the oxidising agent potassium iodate (KIO_3) with iodide ion in an acidic solution. The IO_3^- ion is reduced to I_2 and I^- is oxidised to I_2.(refer to appendix 4)

$IO_3^- + I^- + H^+ \longrightarrow I_2$ (unbalanced equation 1)

2- The I_2 obtained from the equation 1 reacts with thiosulphate ion ($S_2O_3^{2-}$) according to the balanced equation,

$I_2 + 2\,S_2O_3^{2-} \longrightarrow 2\,I^- + S_4O_6^{2-}$ (balanced equation 2)

3- Compare equation 2 with the equation you have written for the oxidation of I^- by IO_3^- in an acidic solution (equation 1), and decide the number of moles of $S_2O_3^{2-}$ which are equivalent to 1 mole of IO_3^-.

Using this relationship do the following titration calculation.

The molarity of a thiosulphate solution was determined by titration with a standard KIO_3 solution. In the titration excess KI was added to 25.00 ml of a 0.0155 M KIO_3 solution which had been acidified with a few millilitres of sulphuric acid. The I_2 formed from this reaction was titrated with a thiosulphate solution. It was found that 22.42 ml of the thiosulphate solution was required for complete reaction with the I_2. Calculate the molarity of the thiosulphate solution.

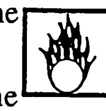
ASK YOUR DEMONSTRATOR TO CHECK YOUR WORK

EXPERIMENT - 4

IODIMETRY

Purpose
The purpose of this experiment is to standardise a solution of sodium thiosulphate by titration with iodine.

Safety Precautions
There are no special precautions for this experiment except for the fact that some of the chemicals are moderately toxic.
Pay attention to the symbols in the right margin. They indicate the hazards of the substances used.



The experimental report should contain:
the balanced equations for the reactions which occur in the experiment;
the calculations of the molarities of the solutions;
the actual readings obtained in the titrations;
answers to questions in these written instructions.

Outline of the Experiment
A. Preparation of a KIO_3 solution of known concentration.
B. Titration of the iodine (liberated by a known amount of iodate solution) with the thiosulphate solution.
C. Calculation of the molarity of the thiosulphate solution.

THE EXPERIMENT

Basic Ideas Behind the Experiment
Pure samples of sodium thiosulphate are not readily obtainable. Hence it is not possible to prepare a thiosulphate solution of accurate molarity simply by weighing the compound and dissolving it in a known volume. Instead its molarity must be determined by a procedure called standardisation (see experiment 3).
The standardisation involves a titration between the thiosulphate ion ($S_2O_3^{2-}$), and iodine (I_2). The titration reaction is;

$$I_2 + 2\,S_2O_3^{2-} \longrightarrow 2\,I^- + S_4O_6^{2-}$$

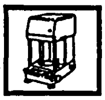
The iodine in the titration is obtainable from the reaction of the iodide ion (I^-), from KI, with a suitable oxidising agent. In this experiment potassium iodate (KIO_3) is used as the oxidising agent and iodide ion is added in excess, so that the amount of I_2 formed is limited by the known amount of iodate ion used to oxidise it.

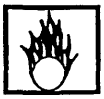
The Experimental procedure

Chemicals for this experiment are on bench 'A' or 'B'.

Refer to map of lab (page 5) for location of apparatus and equipment.

A - Preparation of Standard Potassium Iodate (KIO_3) solution





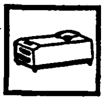
Using an analytical balance (weighing procedure - appendix 1), weigh in a weighing bottle an amount of Analar (analytically pure) KIO_3 approximately equal to the mass calculated in your **PRELAB WORK**. Transfer the iodate to a beaker and take your second weighing of the weighing bottle. Dissolve the iodate in a few ml of distilled water and transfer the solution carefully, with washings, to a 250 ml volumetric flask. Make up to the mark with distilled water and mix thoroughly by inverting the flask several times.

Calculate the molarity of the solution and transfer it to your own labelled reagent bottle.

B - Titration of iodine (liberated by a known amount of iodate solution) with thiosulphate solution.

Note: A sodium thiosulphate solution of approximately 0.1 mol l^{-1} is available in the laboratory on bench "A'. Obtain a 100 ml sample of this solution to use for the analysis.

1. The titration must be carried out following the procedure of appendix 2.
2. Using a rough balance weigh out approximately 1 gram of potassium iodide (KI) and measure out about 5 ml of 1 molar sulphuric acid. These will be used shortly.



3. Use a pipette to transfer 25 ml of potassium iodate solution to a clean 250 ml conical flask.
4. Add the 1 gram of KI to the conical flask. What do you expect to happen?
5. Add 5 ml of 1 molar sulphuric acid. What is the explanation for what you observe?
6. Titrate the iodine released with the sodium thiosulphate solution. At first the solution will be intense red-brown. As the titration proceeds the colour will lighten to a pale yellow. At this point add a few drops of starch indicator. This produces an intense blue-black starch iodine complex. Continue adding sodium thiosulphate solution drop by drop until the blue colour just disappears.

Repeat the titration until two reproducible titres are obtained (difference < 0.1 ml).

Note: Do not throw your solutions away. Save your remaining standardised potassium iodate and sodium thiosulphate solutions for experiment 5.

C - Calculations

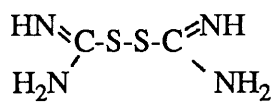
Calculate the molarity of the sodium thiosulphate solution and consult your **demonstrator** to see if your result agree with the stated molarity of the solution.

PRELAB WORK for EXPERIMENT - 5

NAME____ **Bench Nº**________

PART - A - Calculate the mass of $CuSO_4.5H_2O$ required to prepare 3.5 g of copper(I) complex. The balanced equation for the reaction is:

$2\ CuSO_4.5H_2O\ +\ 8\ SC(NH_2)_2 \longrightarrow$

$\{Cu[SC(NH_2)_2]_3\}_2SO_4\ 2H_2O\ +$  $+\ H_2SO_4\ +\ 8\ H_20$

PART - B - Calculate the % Cu in the pure complex($\{Cu[SC(NH_2)_2]_3\}_2SO_4\ 2H_2O$).

ASK YOUR DEMONSTRATOR TO CHECK YOUR WORK

EXPERIMENT - 5

PREPARATION AND ANALYSIS OF A THIOUREA COPPER (I) COMPLEX - $\{Cu[SC(NH_2)_2]_3\}_2SO_4 \cdot 2H_2O$

Purpose

The purpose of this experiment is to prepare a copper(I) complex and then to analyse it by iodimetry (see experiment 4)

Safety Precautions

Thiourea should be used with care since it is toxic and may cause cancer. Copper compounds are also toxic. Concentrated nitric acid will be used during the analysis of the complex and should be treated with care and caution. The preparation of the complex for analysis must be carried out in a fume cupboard.
Pay attention to the symbols in the right margin. They indicate the hazards of the substances used.

The Experimental Report should contain:

calculations for the formula weight of the complex and the theoretical % Cu in the complex;
calculations for the actual % Cu in the complex you have prepared and analysed;
a comparison of the actual % Cu with the theoretical % Cu;
answers to questions in these written instructions.

Outline of the Experiment

A. Preparation of the Copper Complex.
B. Analysing for the % of Cu in the Complex.

THE EXPERIMENTS

Basic Ideas Behind the Experiment

1. Metal ions readily accept electrons from electron pair donors. Substances which are electron pair donors are classified as bases. In Inorganic Chemistry such bases are called ligands. A combination of a metal ion and a ligand (or group of ligands) is called a **COMPLEX.** In this experiment the metal ion is Cu^+ and the ligand is thiourea $[:SC(NH_2)_2]$.

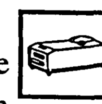
2. Metals in the middle block (d-block) of the Periodic Table have the ability to form ions in several oxidation states. For example you already know that iron ions exist as Fe^{2+} and Fe^{3+} and that copper ions exist as Cu^{+} and Cu^{2+}. The Cu^{2+} in water gives the familiar blue of $CuSO_{4\,(aq)}$. The Cu^{+} ion is much less common and its compounds are usually either insoluble in water, or decompose in it. You will prepare a copper(I) compound in which the Cu^{+} is protected from water by forming a stable complex with thiourea.
3. In preparations of Cu^{+} complexes it is usual to begin with a Cu^{2+} compound so that we can make use of a solution of it in water. However, to make the complex it will have to be reduced to Cu^{+}. The thiourea is both a reducing agent and a ligand and so it can do both jobs.

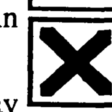
The Experimental Procedure

Chemicals for this experiment are on bench 'A' or 'B'.

A. Preparation of the Copper(I) Complex

Preparing the solutions:





1. Using a rough balance weigh out approximately the mass of blue copper(II) sulphate crystals($CuSO_4\ 5\ H_2O$) calculated in your **PRELAB WORK** and dissolve them in about 15 ml of water.
2. Make a solution of about 5.0 g of thiourea calculated in 30 ml of water. (You may have to warm the solution gently to get all the thiourea to dissolve: do not heat strongly). Cool and divide this solution into two roughly equal portions.

Making the complex

Slowly add the copper(II) sulphate solution to one of the portions of the thiourea solution while stirring continuously. A white crystalline substance (the complex) should form. If a sticky material results, rub it firmly against the side of the beaker with a glass rod and soon the white crystals will form. Let the solution stand for five minutes to allow the crystallization to be completed.
The formula of the complex is $\{Cu[SC(NH_2)_2]_3\}_2SO_4.2H_2O$.

If the solution above the crystal layer is still blue add some of the other portion of thiourea (1 ml at a time) until the blue colour disappears.

Filtration and Purification

Filter the crystals through a filter paper in a Buchner funnel and flask attached to a water pump. (see vacuum filtration - appendix 3).

When the filtration is completed, scrape the crystals off the paper and transfer them to a 250 ml beaker. Add about 5 ml of your remaining thiourea solution and 50 ml of water plus 2-3 drops of dilute sulphuric acid. Warm the solution and stir until the crystals dissolve. **DO NOT** allow the temperature of the solution to exceed 70°C (about as hot as you can bear on the palm of your hand) or you will be destroying the complex.

Allow the solution to cool. Crystals of the complex will reappear. Filter through a fresh piece of paper using the Buchner apparatus. Wash the crystals with a few ml of cold water and then with about 10 ml of ethanol. Continue to draw air through the crystals until the ethanol has evaporated and the crystals are dry. Weigh your crystals on a rough balance and record your yield. The preparation of the complex has been completed.

Basic Ideas Behind the Analysis Method.

1. By heating the complex with an oxidising acid like nitric acid we can do two things at once:
   a. destroy the thiourea ligands and
   b. oxidise the Cu^+ to Cu^{2+}.
2. Having obtained a Cu^{2+} solution, we can analyse for copper ion in solution by a method similar to that in experiment 4. When iodide ions (from KI) are added to $Cu^{2+}(aq)$ solutions the Cu^{2+} is reduced to Cu^+ and some of the iodide ions are oxidised to I_2.
   $$2\,Cu^{2+} + 4\,I^- \longrightarrow 2\,CuI + I_2$$
   The equation shows that 2 moles of $Cu^{2+} \equiv$ 1 mole of I_2
3. The I_2 which is released can be titrated with thiosulphate as in experiment 4.
   $$2\,S_2O_3^{2-} \longrightarrow S_4O_6^{2-} + 2\,e$$
   $$I_2 + 2\,e \longrightarrow 2\,I^-$$
   $$\text{hence: } 2\,S_2O_3^{2-} + I_2 \longrightarrow S_4O_6^{2-} + 2\,I^-$$

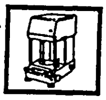
   $$2 \text{ moles thiosulphate} \equiv 1 \text{ mole } I_2 \equiv 2 \text{ moles } Cu^{2+}$$

B. Analysis of Copper Complex

Method of Analysis

Preparing the sample for analysis:

Using an analytical balance (weighing procedure - appendix 1) weigh out about 0.6 g of your complex accurately and tip it into a 100 ml beaker.

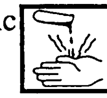


Caution: carry out the next part of the analysis in a fume cupboard.

Throughout this section, take care not to lose any of your sample by splashing. Take 10 ml of concentrated nitric acid (located in the fume cupboard) and add it to 10 ml of water. Add this diluted acid to the sample of the complex and cover the beaker with a watch glass.

After a few minutes a vigorous reaction will take place.

From your observations how do you know that $Cu^{2+}(aq)$ is being made and that the nitric acid is being reduced?

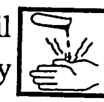


After the reaction subsides, gently boil the solution until it has evaporated almost to dryness. This gets rid of most of the unused nitric acid and also removes the decomposition products from the thiourea.

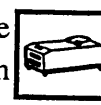
The Analysis:

When the beaker has cooled, add about 20 ml of water(measuring cylinder) to dissolve the Cu^{2+} compound. Transfer this to a conical flask and rinse the beaker twice with distilled water and add the rinsings to the conical flask. The pH of this solution will be too low for the next part of the analysis so it is adjusted as follows:

Add 4 M ammonia solution (ammonium hydroxide) drop by drop to the blue solution until a faint cloudiness remains even after shaking. Now add 4 M ethanoic (acetic) acid drop by drop until the cloudiness just disappears and a transparent blue solution is left.



Now add about 2 g of KI. This will react with the Cu^{2+} to give a brown solution of iodine and a white milky suspension of CuI. Titrate this with standardised thiosulphate solution (from experiment 4) until the brown almost disappears. Add a few drops of starch solution and continue the titration until the blue colour disappears and the milky white liquid (CuI in suspension) is left.



Calculate the actual % Cu in your complex and compare with the % Cu calculated in your **PRELAB WORK** (theoretical).

Give to your **demonstrator** any of your complex which is left over.

PRELAB WORK for EXPERIMENT - 6

NAME____**Bench Nº**________

PART - A - In step 2 of the preparation of the complex the oxalic acid($H_2C_2O_4$) is oxidised to carbon dioxide(CO_2) by potassium dichromate($K_2Cr_2O_7$). Write the ion electron half-equations for the oxidation of $H_2C_2O_4$ to CO_2 and for the reduction of $Cr_2O_7^{2-}$ to Cr^{3+}. Hence write the balanced ionic equation for the oxidation-reduction reaction.

Calculate the mass of potassium dichromate($K_2Cr_2O_7$) required to prepare 5.0 g of $K_3[Cr(C_2O_4)_3].3H_2O$

PART - B - Calculate the % Cr in the pure complex ($K_3[Cr(C_2O_4)_3].3H_2O$).

ASK YOUR DEMONSTRATOR TO CHECK YOUR WORK

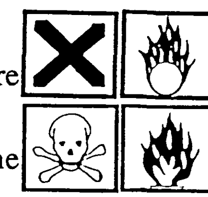
EXPERIMENT - 6

PREPARATION AND ANALYSIS OF $K_3[Cr(C_2O_4)_3].3H_2O$

Purpose

The purpose of this experiment is to prepare a chromium(III) complex and then to analyse it by titration.

Safety Precautions



Oxalate salts are toxic and should be handled with care. Chromium compounds are potential skin irritants and can cause cancer.
Pay attention to the symbols in the right margin. They indicate the hazards of the substances used.

The Experimental Report should contain:

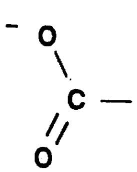
the balanced equations for the reactions in the experiment;
the calculation for the actual % Cr in the complex you have prepared and analysed;
a comparison of the actual % Cr with the theoretical % Cr;
answers to questions in these written instructions.

Outline of the Experiment

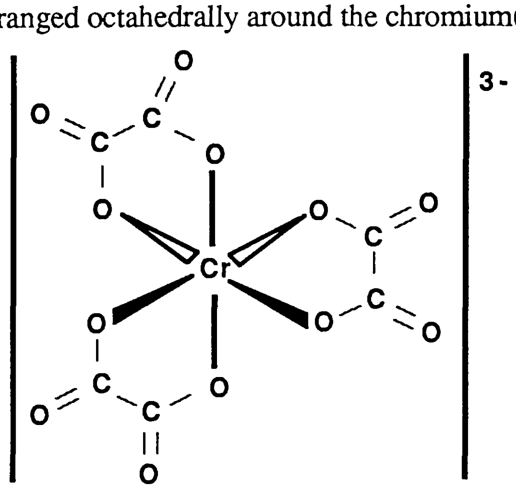
A. Preparation of the complex. B. Analysis of the complex.

THE EXPERIMENTS

Basic ideas behind the formation of the complex



Metal ions can accept electrons from electron pair donors. These donors are molecules or ions called **LIGANDS.** An example is the oxalate (ethanedioate) ion.The oxygen atom at each end of the ion has a lone pair of electrons which it can donate.The oxalate ions are arranged octahedrally around the chromium(III) ion.

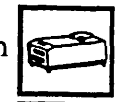


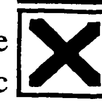
The new complex ion has an all over charge of 3^- since the Cr^{3+} ion is surrounded by three oxalate ions each of which has a 2^- charge.

The Experimental Procedure

Chemicals for this experiment are on bench 'A' or 'B'.

A. Preparation of the complex:





1. Dissolve about 4.5 g of oxalic acid dihydrate[$(COOH)_2.2H_2O$] in 10 ml of warm water.
2. Using a rough balance weigh out approximately the mass of potassium dichromate calculated in your **PRELAB WORK** and then add it, a little at a time, to the oxalic acid solution. There will be a fairly vigorous reaction.
3. While the reaction is subsiding, weigh out about 1.75 g of potassium oxalate ($K_2C_2O_4.H_2O$). Gently heat the reaction mixture (from part 2) until it is just beginning to boil and add the potassium oxalate and allow it to dissolve.

Note: We have now completed two operations.

(a) The chromium in the dichromate ion was in the 6+ oxidation state and the oxalic acid has reduced it to the 3+ oxidation state.

(b) The excess of the oxalate and potassium ions have now been added to complete the formation of the complex $K_3[Cr(C_2O_4)_3].3H_2O$.

4. Cool the solution and add 2 ml of ethanol. Blue-green crystals of the complex now grow in the nearly black solution.
5. Filter off the crystals on a paper in a Buchner apparatus. (See appendix-3).
6. Wash the crystals (which are still on the filter) with a mixture of 5 ml of ethanol and 5 ml of water. Finally wash the crystals with 5 ml of pure ethanol. Continue to draw air through the filter to dry the crystals, but finally dry them by pressing them between two sheets of filter paper.

Basic ideas behind the analysis of the complex

How pure is the complex you have made? This can be found out by analysis, but we need to stop for a bit of theory before beginning the analysis.

The oxalate ions in the complex can be released by adding a strong base, which removes the chromium(III) as its hydroxide.

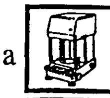
$$\textbf{Complex} \xrightarrow{\text{base}} \mathbf{Cr(OH)_3} + \textbf{oxalate ions} \quad \text{(unbalanced equation)}$$

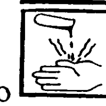
These free oxalate ions can be oxidised to CO_2 by a suitable oxidising agent such as MnO_4^- In the presence of acid the MnO_4^- is reduced to Mn^{2+}. However, the reaction between oxalate and permanganate is so slow that we have to operate at about 70°C to speed things up.

$$\mathbf{MnO_4^-} + \textbf{Oxalate ions} \longrightarrow \mathbf{CO_2} + \mathbf{Mn^{2+}} \quad \text{(unbalanced equation)}$$

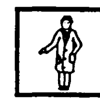
As MnO_4^- is intensely purple and $Mn^{2+}_{(aq)}$ is nearly colourless we have a built-in indicator of when the reaction is complete.One drop extra of MnO_4^- will make the solution pale pink.

B. Method of Analysis





1. Using an analytical balance (weighing procedure-appendix 1) weigh out accurately a sample of your complex (in the region of 0.3 g) and transfer it to a 100 ml beaker.
2. Use a measuring cylinder to add 10 ml of water followed by 10 ml of 4 M KOH.
3. Cover the beaker with a watch glass and gently bring to a boil. Allow the solution to boil gently until no more green $Cr(OH)_3$ is precipitated.



DO NOT LET THIS SOLUTION BOIL DRY.

4. This has now released the oxalate. The $Cr(OH)_3$ is a sticky substance which is difficult to filter. Filter with a fluted filter paper into a 250 ml conical flask (see appendix 3).
5. The liquid which comes through the paper contains the oxalate which is needed for analysis. Wash the precipitate with 25 ml of hot distilled water and collect these washings also in the conical flask.

Note: For the MnO_4^- to go to Mn^{2+} the solution must be acid, whereas the solution collected above is very alkaline.

6. Add 4 M sulphuric acid until the solution is distinctly acid (test with litmus paper).
7. Heat the solution to 70°C (the temperature you can just bear on the palm of your hand) and titrate with the standard potassium permanganate (bench 'A').

Note: You may have to raise the temperature several times during the titration to keep it near 70°C. The end point is a pale pink colour which lasts even when warmed up.

How pure was your complex?

$$\underset{\text{1 mole}}{K_3[Cr(C_2O_4)_3].3H_2O} \longrightarrow \underset{\text{3 mole}}{3\,(C_2O_4)^{2-}}$$

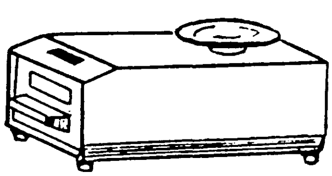
Work out the ion electron half equations for the oxidation of oxalate to CO_2 and for the reduction of MnO_4^- to Mn^{2+} and hence establish how many moles of oxalate are equivalent to 1 mole of MnO_4^- (see appendix 4).

How many moles of complex are equivalent therefore to 1 mole of MnO_4^-?

Now calculate the actual % Cr in your complex from your analysis and compare with % Cr calculated in your **PRELAB WORK** (theoretical).

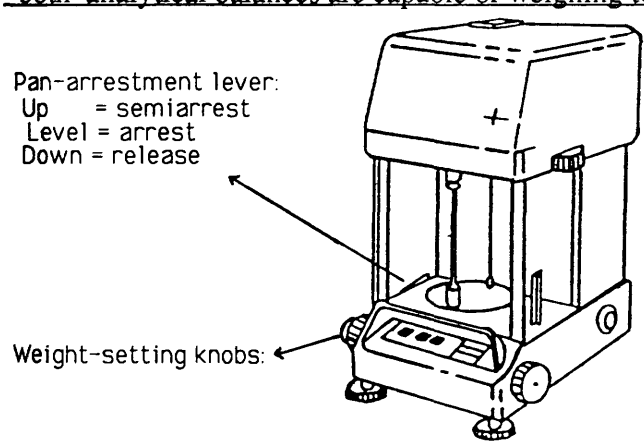
APPENDIX - 1 - BALANCES - OPERATING INSTRUCTIONS

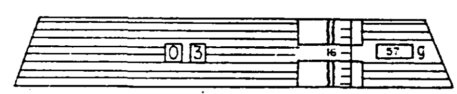
A - USE OF ROUGH BALANCES - a Stanton D20T, or D40T or a Sartorius 1106 top loading balance.



These are of lower precision (0.01 g) than the analytical balances but are perfectly adequate for weighing reagents and products in preparative work. Solids must be weighed on a watch glass or in a small beaker. Liquids must be weighed in a beaker or weighing bottle. The vessel used for weighing is tared, i.e. its weight is subtracted from the total by rotating the illuminated scale back to zero or pressing the button T, then the reagent is added until desired weight appears on the scale.

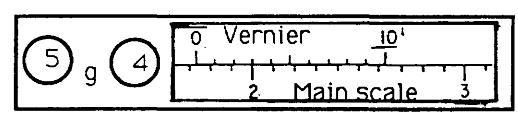
B - USE OF ANALYTICAL BALANCES - a Stanton CL41 or an Oertling R40 balance - both analytical balances are capable of weighing to 0.0001 g.





WEIGHT = 3.1657 g

Oertling R 40 DIGITAL SCALE



WEIGHT = 5.4173

Stanton CL 41 VERNIER SCALE

The Stanton CL41 has the following controls:

(i) off / partial release / full release;

(ii) zero adjustment;

(iii) levelling;

(iv) weight change 100 g / Tare (grey knob, not normally required), tens g (red), units g (yellow), $^{1}/_{10}$ ths g (blue).

The balance point is shown on an illuminated scale, 0-100 mg, equipped with a vernier scale for the range 0.1 - 0.9 mg. The vernier scale is used to measure accurately a fraction of the finest division on the main scale of a measuring instrument as in the example above:

a - the zero mark in the vernier scale indicates that the reading is between 1.7 and 1.8 (0.017 and 0.018 g);

b - the division of the vernier scale which coincides with a division of the main scale indicates the exact reading. The vernier division which coincides is 3, which is exactly 0.0003. The accurate reading is the sum of all readings (5.0 + 0.4 + 0.017 + 0.0003) and gives 5.4173 g.

The Oertling R40 has the following controls:

(i) off / pre-weigh / full release;
(ii) zero adjustment;
(iii) levelling;
(iv) weight change tens g (front left knob), Units g (front middle), $^{1}/_{1000}$ths and $^{1}/_{10000}$ths g (front right).
Readout is completely digital.

The following points must be observed when using the analytical balance:

1. Keep the balance scrupulously clean;
2. Work in front of the balance in order to see the scale clearly;
3. Weight changes > 1 g **must** be made with the pre-weigh / full release control **OFF**;
4. Weight changes < 1 g may be made with the partial release control on but **NEVER** with the full release control **ON**;
5. All weighing must be performed with samples contained in capped weighing bottles;
6. Return all weight control knobs to their zero positions after use;
7. **DO NOT** overload the balance.

Weighing procedure

In many experiments the instructions state 'Weigh accurately about 0.X g of ...'. At first sight this is a contradiction but it means that the mass of the sample does not need to be exactly 0.X000 g. However its mass is required to four decimal places of grams.

Use the following procedure to ensure accuracy and cleanliness of the balance pan and case.

1. On a top loading balance transfer a suitable (approximate) quantity of the substance to be weighed to a clean dry weighing bottle. Take the weighing bottle, a clean beaker (conical flask in case of titration) tongs, and your lab book to the analytical balance;
2. Transfer the weighing bottle to the balance pan. This and all subsequent manipulations involving the weighing bottle must be carried out using the tongs;
3. Determine the weight of the bottle plus sample and record this in your lab notebook;
4. Transfer the substance into the beaker;
5. Reweigh the bottle. Record the weight of bottle plus residue and hence obtain the mass of the sample transferred to the beaker;
6. Any material remaining in the bottle must **NOT** be returned to the reagent bottle but should be deposited in the jar provided.

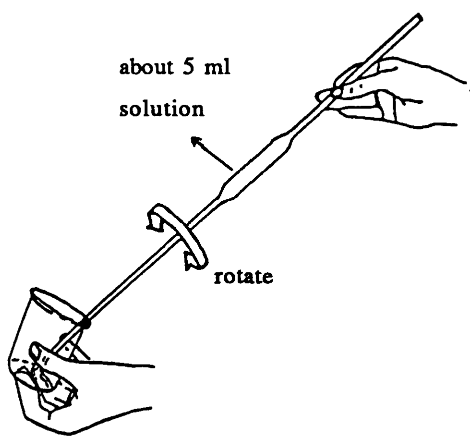
APPENDIX - 2 - VOLUMETRIC TECHNIQUES

A - VOLUMETRIC PIPETTE - often has a bulb in the centre and has only one calibration marking on the upper part of the tube. These are calibrated to deliver a fixed and exact volume: 10 ml ±0.04; 25 ml ±0.06 and so on.

1. Selecting

The top and tip must be undamaged;

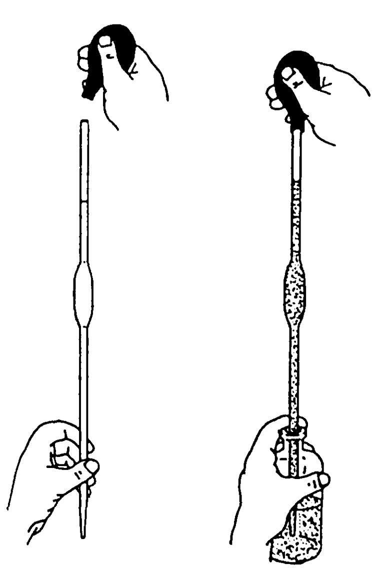
Use a volumetric pipette only if a precise volume is required otherwise use a measuring cylinder.



2. Cleaning

Fill the bulb of pipette to about one third of its capacity with water. While holding it nearly horizontal carefully rotate the pipette so that the interior surfaces are covered. Drain inverted, and rinse with distilled water. Repeat the first step to rinse with a little of the solution to be measured and let it flow out of the tip.

3. Fitting and filling

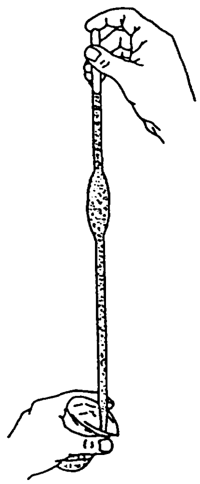


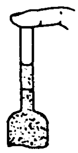
(a) (b)

1. The top end of the pipette should be moistened slightly and placed into the bulb;
2. Place solution into rinsed beaker before filling the pipette;
3. The bulb should be squeezed to expel air and the point end (tip) inserted into the liquid to be measured;

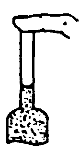
NOTE: <u>At all times</u>, the pipette should be held in one hand, and the bulb in the other.

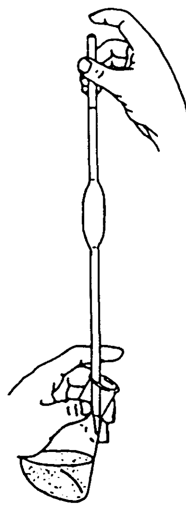
4. By releasing the pressure in the bulb the liquid is sucked into the pipette till it is 2-3 cm above the mark on the upper stem (b). Be careful not to jam the bulb too tightly on the pipette you must be able to remove it easily;
5. Hold the pipette in your right hand and ease the bulb off the top with your left hand (vice-versa if you are a left handed);





(d)

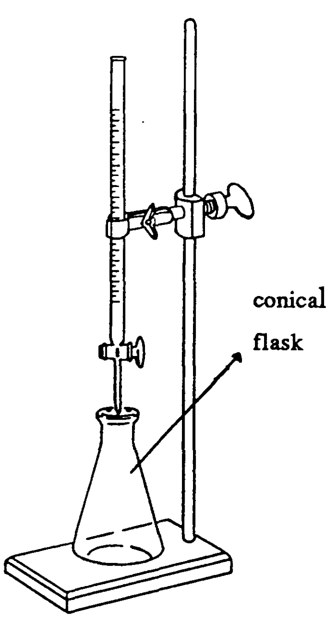




(c) (e) (f)

6. As the bulb comes off, cover the top of the pipette with the index finger of the right hand (not a thumb which gives less control over the liquid level). This changeover must be done rapidly.If the liquid level falls beneath the mark you will have to start all over again;
7. The outside of pipette should be dried removing any drops adhering to it with a towel paper;
8. The liquid level is carefully allowed to fall until it is at the calibration mark. This is best done by rotating the pipette slowly, to release the pressure of your finger on the top of the pipette (remember to read the bottom of the meniscus);
9. Then the liquid should be drained into the receiver vessel as shown in figure (f);
10. The pipette should be held vertically when readings are taken and when it is being drained;
11. While draining, the tip of the pipette should be held against the inside wall of the receiver vessel.

B - THE BURETTE



(a)

1. The burette - a typical set up for a burette is shown in figure (a). A standard 50 ml burette, when used properly, is capable of delivering volumes accurate to ±0.02ml. To reach this level of accuracy, certain important points must be adhered to. The tap must be well (but not over) greased and leak free. When turning the tap apply pressure to push it into the barrel. If the stopcock barrel is streaked, it must be regreased otherwise the tap will leak.

2. Cleaning - before making any measurements the burette must be thoroughly cleaned:

a - rinse out the burette with detergent solution;

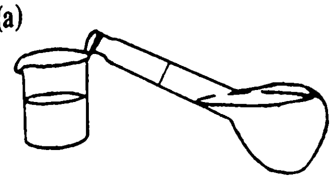
b - wash with tap water;

c - wash with distilled water;

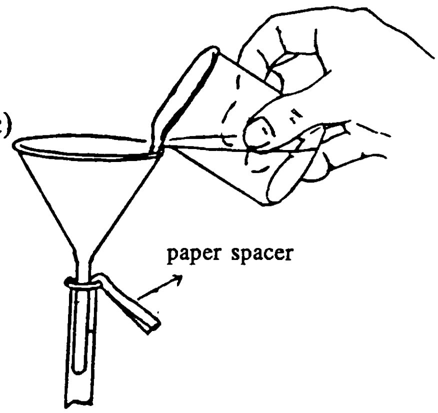
d - rinse with the solution to be used. This is done by pouring 5 to 10ml of the solution into the burette (with the stopcock closed) then tilting the burette to an almost horizontal position and turning it so that the entire inner surface comes into contact with the liquid. The rinsings are then allowed to run out.

Place solution into rinsed beaker
before filling burette

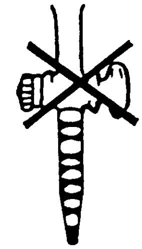
(a)



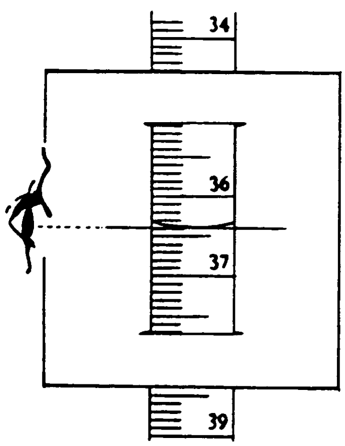
(c)



(d)



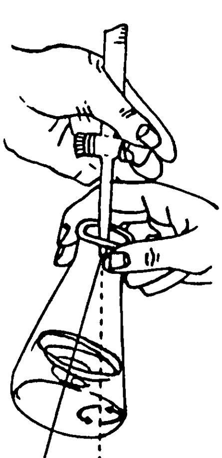
3. **Filling** - fill the burette to any mark near the top of the scale. Ensure that there are no air traps or bubbles in the burette, particularly around the tap and the tip (figure d) by opening the tap to discard some of the titrant.



(e)

Read the burette at the bottom of the meniscus (figure e) which will show up as a thin dark line if outlined by a white background. The scale will give a value to 0.1 ml and you must <u>estimate the second decimal place to 0.02 ml</u>.

C - THE TITRATION PROCEDURE



(f)

By pipette, place the solution to be titrated into a clean 250 ml conical flask. Alternatively, weigh out the required weight of solid into a clean 250 ml conical flask and dissolve this in distilled water. Remember to add indicator when told in the experimental written instructions. Add the titrant slowly from the burette, while swirling the flask with the right hand as shown in figure (f) until you are close to the end point. Always push the stopcock into the barrel while rotating the stopcock during a titration. A right handed person holds the handle of the stopcock with the left hand as shown in figure (f).