Exploring Attitudes and Difficulties in School Chemistry in the Emirates

by

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A Thesis submitted for the degree of Doctor of Philosophy

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To my wife and sons

Ibtihal, Mustafa and Ammen

Abstract

Chemistry teaching and learning face many problems in the Emirates. This study seeks to explore the nature of these problems and to identify possible ways forward.

A review of studies on learning difficulties in chemistry is provided seeking to establish the reasons why students find chemistry difficult to learn, with likely explanations for the difficulties observed. Information processing is discussed in some detail, this approach being seen as offering a good rationalisation of what has been observed in the learning of a subject like chemistry. There is also a brief overview of what attitudes are, along with the relationship between attitudes and behaviour, and how to measure attitudes.

The overall aim of this study is to explore the problems and then to develop and test ways by which the situation might be improved.

In the first stage of this project, the areas of difficulty for students were identified, using a sample of 490 students aged between 15-17 years. The main areas of difficulty for year 10 were: *chemical formula, quantum number, periodic table of elements, lanthanides and actinides and chemical equations. For year 11, the main areas of difficulty were: mole calculation, chemical equation balance, homologous series, isomerism, alkyl groups and pH & pOH calculation.*

In the second stage, students were then asked for comments on the areas of difficulty and, later, took a short test using structural communication grids, these offering insights into areas of confusion and misconceptions. For the third stage of this project, attitudes relating to chemistry were measured using questionnaires, this being conducted with 225 students aged 15-17 years. The surveys and questionnaires revealed a clear picture of the situation in chemistry in the Emirates showing fairly negative attitudes, probably mainly as a result of an overcrowded and largely irrelevant curriculum taught by very didactic approaches which took little account of the psychology of learning.

The core of the study involved the development of four units of paper-based teaching material. These were designed specifically to meet two sets of criteria. Firstly, the predictions from information processing determined the way the material was presented so that student learning was likely to be enhanced. Secondly, the evidence from attitude development informed the design with the aim that positive attitudes towards studies in chemistry would be encouraged. The way the units were used and the way they were tested is described, this work also being carried out with students in years 10 and 11 (age 16-17 approximately) in typical schools in the Emirates. For this stage, a total sample of 800 students boys and girls aged between 16-17 years in Emirates secondary schools

participated. Each unit of work lasted for about 6-8 weeks.

The testing involved a number of approaches including structural communication grids, open-ended questions and, with one unit, the development of a concept map. Attitudes to numerous aspects of the processes involved in learning chemistry were also explored. The performance of the students was found to be markedly better than control groups, the t-test values being significant at around $p < 0.001$. Numerous attitude comparisons were made using the chi-square statistic. Here, extremely high values were obtained, indicating quite massive attitude changes had taken place.

The insights offered by the study are summarised and the possibilities for future work are also outlined. The whole study arose from a concern that students in the Emirates often seemed to have poor attitudes towards their studies in chemistry and that many were rejecting chemistry as a subject to pursue. This study has provided illumination on the problem and, on the basis of the evidence obtained, suggests possible ways forward to a better approach to the study of what is an important school discipline, the outcomes being widely applicable in many countries.

Acknowledgements

I would particularly like to express my warm thanks to my supervisor Dr. Norman Reid for his kind assistance, patience, unfailing support, expert guidance and much valued advice throughout my project.

I am especially grateful to the Head teacher, Mr. Ibrahem Barakh, and his staff and pupils of Emirates schools for their involvement in the study, making the investigation possible.

Meanwhile, I am grateful to Professor Rex Whitehead and my friends in the centre for science education who give me encouragement whenever I need it. Also, I would like to thank Ms. Liz Greenway for her help.

Last, but not the least, I would like to express my love to my wife Ibtihal, my sons Mustafa and Ameen for their caring support, patience and unending encouragement.

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Chapter One

Chemistry Teaching and Learning in the Emirates

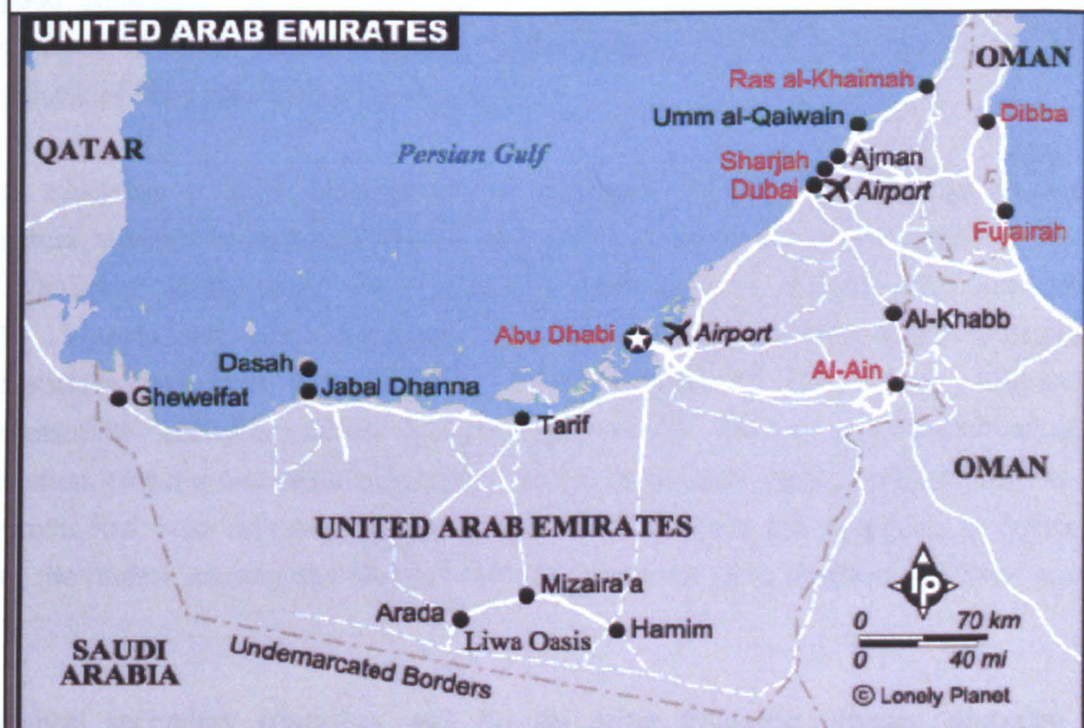
1.1 Introduction

Chemistry teaching and learning face many problems in the Emirates. This thesis seeks to explore the nature of these problems and to identify possible ways forward. However, chemistry education has to be seen in the context of the overall education system and this chapter offers the reader a brief overview of the United Arab Emirates and an outline of its education system. The type of problems related to chemistry teaching and learning are then outlined and the aims of this project are described.

1.2 The United Arab Emirates

The United Arab Emirates (U.A.E.) is a federation of seven emirates or states each with its own unique character and personality but yet united with a common goal and destiny. The seven emirates are: Abu Dhabi, Dubai, Sharjah, Ajman, Umm Al-Qaiwain, Ras Al-Khaimah, and Fujairah. (Figure 1.1.)

Figure 1.1: United Arab Emirates Map



The official language of the U.A.E. is Arabic. Other languages spoken are English, Hindi, and Farsi. The U.A.E. has capitalised on its convenient location on the trade routes between Asia and Europe while its more recent oil wealth has offered huge resources for development. The area of the U.A.E. is 83,600 sq.km. The population of the U.A.E. is around 3 million.

1.3 The Emirates Educational System

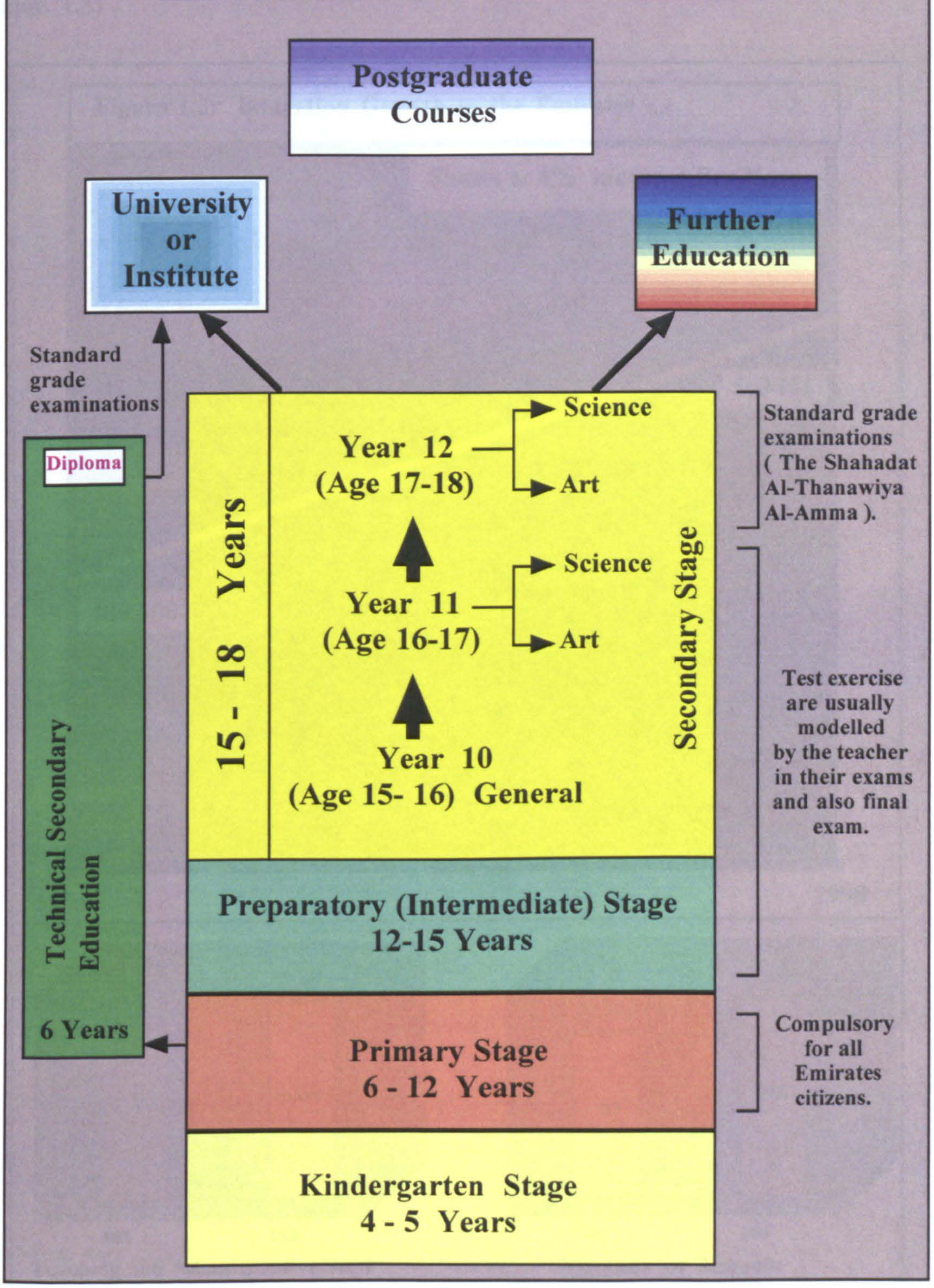
Before the discovery of oil, there was very little development in the Arabian peninsula, and certainly no proper educational system. In 1962, when oil production started in Abu Dhabi, the country had just 20 schools providing for less than 4,000 students, most of them boys. The country lacked the necessary infrastructure for development (hospitals, housing, airports, etc.) as well as qualified human resources. The discovery of oil provided the necessary finances to improve the educational system. This was a high priority for Sheik Zayed bin Sultan Al Nahyan, the UAE President, who declared: "Youth is the real wealth of the nation". His aim was to use the oil revenue to develop academically and technically qualified citizens - men and women - able to serve their country in its future progress.

When the U.A.E. was established in 1971, education was still largely confined to urban areas, and there were less than 28,000 students in the country. Any student wishing to go beyond secondary education was financed by the government and had to go abroad, sometimes to other Arabic countries, but mainly to the UK and the United States. (Ministry of Information and Culture, 2001).

Free education is now provided for all Emirates citizens. The existing educational structure, which was established in the early 1970s, is a four tier system covering 14 years of education: kindergarten (4 - 5 years old); primary (6 - 12 years old); intermediate (12 - 15 years old); and secondary (15 - 18 years old). Primary school education is compulsory and lasts for six years. It is followed by three years' preparatory (intermediate) education which qualifies students for *general* or *technical* secondary education. General secondary education lasts for three years (ages 15-18). It consists of a common first year followed by two years where students can specialise in Science or Arts, the student making this choice when they pass year 10 (a common first year, age 15-16).

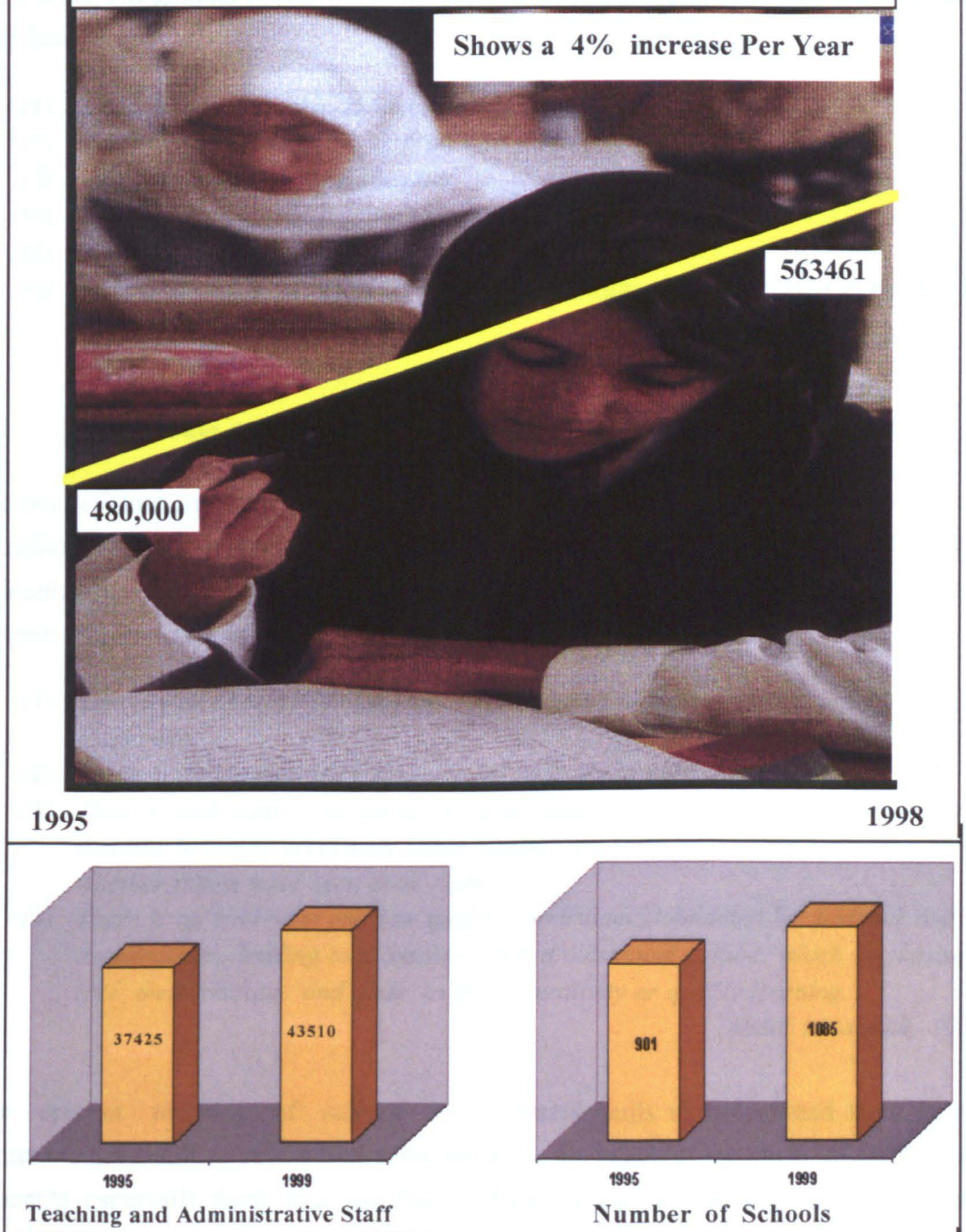
Technical secondary education lasts for six years following primary education and comprises three main streams: technical, agricultural and commercial. It offers both preparatory and secondary cycles. The preparatory cycles offers an Engineering course for the acquisition of basic skills leading to the Intermediate Certificate. At the end of the secondary cycle, a Technical Secondary Diploma is awarded. Secondary education is also offered in religious institutions. Courses lead to '*The Shahadat Al-Thanawiya Al-Amma*' (See Figure 1.2).

Figure 1.2 The U.A.E. Educational System



The government policy is to provide staff/student ratios of 1:20 at kindergarten and primary level and 1:15 at intermediate and secondary level. The total number of students at primary and secondary level in public and private schools reached 563,461 in 1998 from 480,973 in 1995, an increase of 4 percent year. Teaching and administrative staff rose to 43,510 (1999) from 37,425 in 1995, while the number of schools increased from 901 to 1085 for the same period (Ministry of Information and Culture, 2002). (See Figure 1.3)

Figure 1.3: Education Growth in the Emirates



Throughout schooling, students have no choice over subjects taken although, in year 11 (age 16-17), students can opt for a science-based curriculum or an arts-based curriculum. However, the subjects taken in each curriculum are fixed. Teachers set class tests themselves but these are based on the style of testing of the national examinations. Year 12 students have to sit Standard Grade Examinations named '*The Shahadat Al-Thanawiya Al-Amma*' (*Secondary School Leaving Certificate*) and this is prepared by the Ministry of Education. All of the students obtain the Secondary School Leaving Certificate and the scores achieved on this exam settle criteria for continuing education at University or Institute level. All teachers have a "Teacher's Guide Book", designed by Ministry of Education. The general objectives of teaching science in general education were designed to help learner to:

(1) Understand, functionally, the basic scientific facts and concepts.
(2) Acquire, functionally, the appropriate values and traditions.
(3) Acquire appropriate mental skill.
(4) Acquire appropriate manual skill.
(5) Acquire appropriate scientific interests and inclinations.
(6) Deepen the taste for science, appreciate scientific efforts and belief in values.

(Ministry of Education & Youth, 2002)

1.4 Major Issues and Problems in Emirates Educational System

Various evaluation studies and sector analyses reports indicate that the Emirates educational system currently faces problems, which result in a lack of overall system efficiency and effectiveness. The major issues and problems facing the Emirates Educational system are:

(1) There is an absence of systematic and strategic planning, making any attempt piecemeal.
(2) There is an absence of clear, coherent policies to guide decision making.
(3) There is ambiguity of objectives at policy and operational levels, leading to an inability to assess accurately either whether the right things have been done or whether things have been done right.
(4) There is an irrelevant and low quality curriculum, dominated by textbook and examinations, leading to a teacher-centred classroom culture, which emphasises rote memorisation and fails to foster creativity or quality learning.

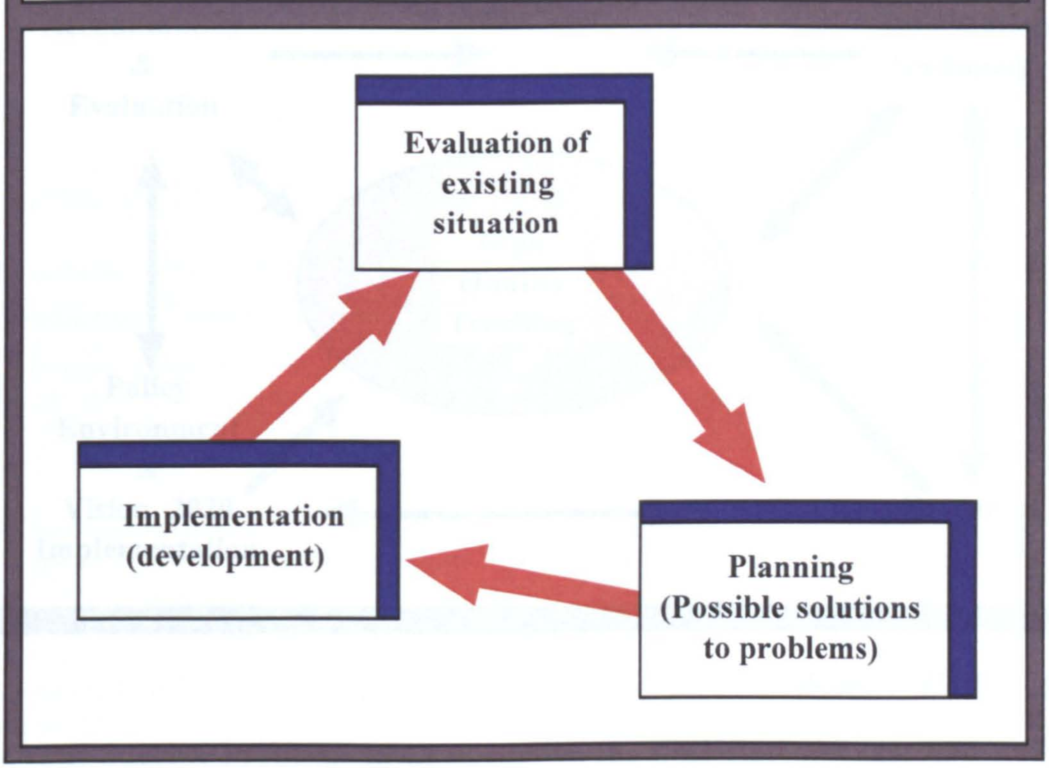
(Abdul Mawgood, 1999)

The present teaching of science in Emirates tends to be isolated from its social context. As a result, it seems that some students are rejecting the study of certain science concepts especially those that contradict their values, beliefs, and conventional beliefs (Haidar, 2002).

1.5 Emirates Education 'Vision 2020'

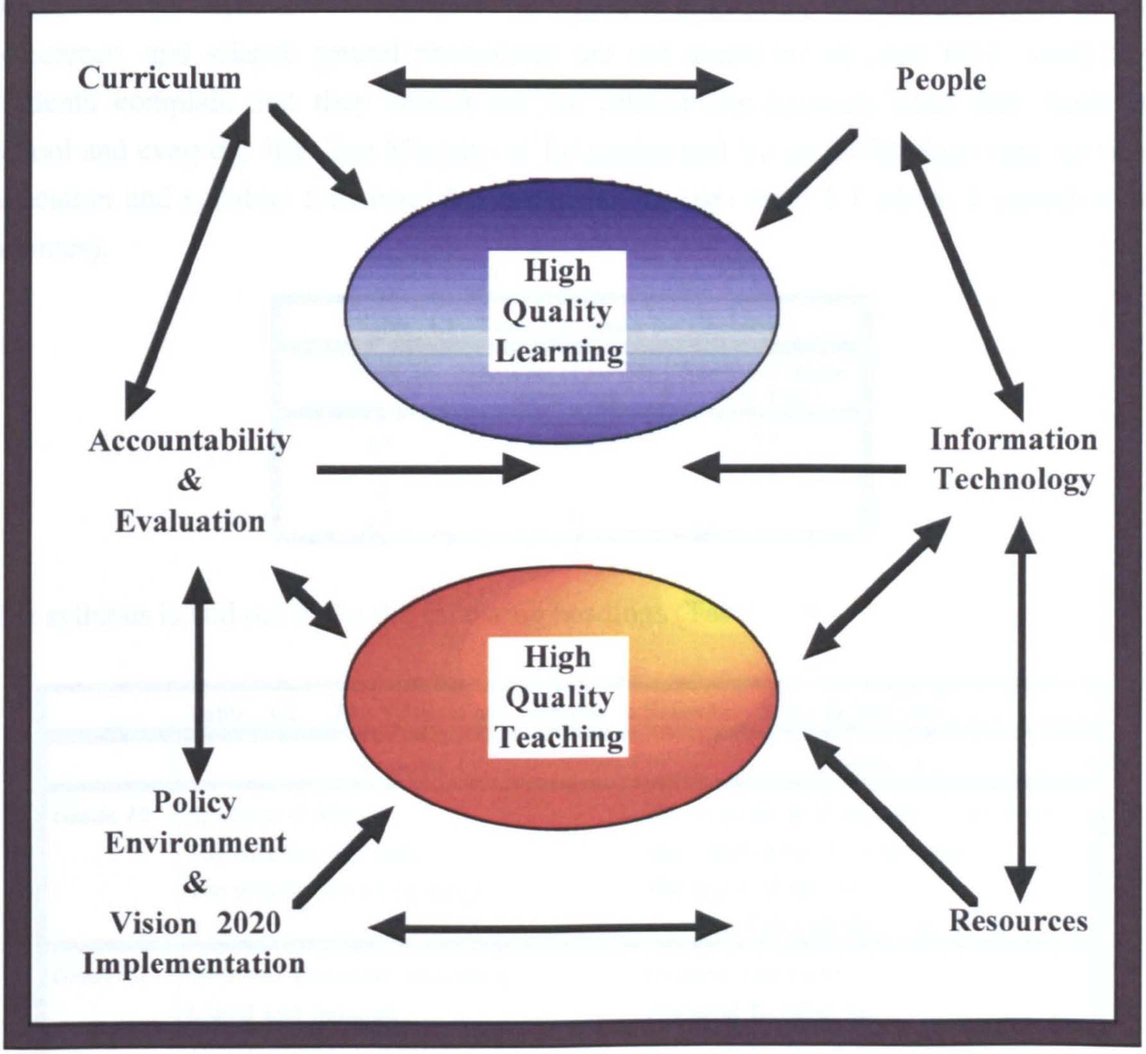
The vision is a comprehensive and cohesive plan for the development of education in Emirates to meet the national development requirements of the 21st century. Vision 2020 is not only a cohesive and comprehensive plan of educational development but it is also a continuous and cyclical process moving from evaluation of existing situations to planning, to implementation and then to further evaluation and so on. Each of the components of vision 2020 requires a simple exposition (figure 1.4). *(Abdul Mawgood, 1999)*

Figure 1.4 The Components of Emirates Education Vision 2020



Vision 2020 implementation will facilitate the achievement of the objectives of the change projects contained under each of the implementation elements. These interrelationships are illustrated as follows in figure 1.5.

Figure 1.5 : ***The Implementation Elements Interrelationships***



(Source: Haidar, 1999).

1.6 The Specific Problems in Chemistry in the Emirates

Chemistry is mainly taught in the three stages of general education in Emirates. In both the primary and the intermediate stages, it is actually taught through teaching general science (integrated curriculum). However, at the secondary stage, it is taught separately as a major subject. Thus, chemistry only exists as a discrete discipline for the final three years at school.

The secondary stage is considered as a preparation stage where students are prepared for their roles in society as well as, where appropriate, for higher education. Chemistry, therefore, is one of the basic subjects in science curricula at the secondary stage (Haidar, 1999).

Johnstone (1991) points out that the difficulties of learning science are related to the nature of science itself and to the methods by which science to customarily taught without regard to what is known about children's learning. Haidar (1999) notes that the present science education curriculum in the Emirates ignores the social aspect of the nature of science, and science natural phenomena are not accessible in class time. Secondary students complain that they cannot see the relationship between what they study in school and everyday life. The Ministry of Education and Youth (2002) determine the time allocation and syllabus for chemistry for each year (see table 1.1 where 1 period is 40 minutes).

Table 1.1 Time Allocation for Chemistry

Year	Number of Periods each Week	Number of Hours each Year
10	2	37
11	3	56
12	4	75

The syllabus is laid out under the following headings (Table 1.2).

Table 1.2 The Syllabus of Chemistry in Secondary Stage in Emirates

	Semester 1	Semester 2
Grade 10	Structure of Matter The structure of Atoms The periodic law of elements	The structure and reactions of compounds Ionic and covalent compounds The chemical reaction Elements and compounds in life
Grade 11	Mole and Chemical calculation Liquid and Solution Thermochemistry Organic Chemistry	Dynamic Chemistry Chemical Equilibrium Acids, Bases and Salts
Grade 12	Chemical Solutions Organic Chemistry Biochemistry Oil and gas industries	Oxidation and Reduction Electrochemistry Metals Nuclear Chemistry

Emirates society has a great concern about complaints from parents and teachers that a significant percentage of students do not select the science stream in the secondary school. Furthermore, low morale and low expectations for student's achievement in science among science teachers are characteristics of science teaching. There have been some complaints that the secondary school graduates are poorly equipped to do the kind of academic work required by higher education institutions in the country, arising from poor preparation of students in the sciences.

The secondary schools have science laboratories for each branch in science, but there is a little laboratory work. While most schools have libraries, their quality varies from school to another. Also, there appear to be no major effort to integrate computers in instruction (Haidar, 1999).

In the Emirates, most chemistry teachers originally are from other Middle East countries, and have been trained to use a very direct teaching style with limited opportunity for student-centred learning (McNally *et. al.*, 2002). They face many frustrations and discouragement in the teaching field. In addition, they do not have much knowledge about modern methods of teaching chemistry and are unaware of the findings from research on teaching.

Some goals of teaching chemistry in the secondary school in Emirates are:

(1) To provide learners with enough knowledge about the chemical concepts.
(2) To provide learners with a full preparation which enables them to continue their university studies in different scientific sectors.
(3) To help learners to acquire an appropriate amount of chemical information and experiences in a functional way.
(4) To bring up an Arab generation which shows values and admirable attitudes and behaviours, such as: a full respect of science and scientists.
(5) To give learners the opportunity of acquiring suitable scientific, skills, such as: analysis, practising experiments, finding out conclusions, answering exercises and questions, using books, references and scientific magazines.

(Ministry of Education and Youth, 2002).

1.7 The Purpose of This Project

The overall aim of this project is explore the situation relating to the teaching and learning of chemistry in the secondary schools in the Emirates, to offer strategies and approaches which will reduce pupil difficulties in chemistry, these being based on the accepted understandings of psychological reasons which bring about difficulties for students. Using established models of learning and research evidence about learning in the sciences, the aim is to test some ways forward which are likely to improve the situation in the learning of chemistry in the Emirates. This testing will involve not only the investigation of student performance in chemistry tests but will also seek to explore the ways attitudes are affected by the new approaches.

1.8 The Thesis Presentation

This thesis gives an account of this work. Early chapters will offer a review of studies on learning difficulties in chemistry and science education literature seeking to establish the reasons that students find chemistry difficult to learn, with likely explanations for the difficulties observed. Several models of learning will be outlined and these can offer a useful framework for research in science education. In particular, information processing is discussed in some detail, this approach being seen as offering a good rationalisation of what has been observed in the learning of a subject like chemistry.

Of course, attitudes towards studying chemistry are vitally important and chapter four gives brief overview of what attitudes are, along with the relationship between attitudes and behaviour, and how to measure attitudes.

Chapter five describes the first exploratory study which had the aim of identifying the main areas of student difficulties at years 10 and 11 (ages 16-17 approximately) in typical schools in the Emirates. The approaches used are described along with details about the sample of students chosen. The results obtained are then discussed.

The core of the study involved the development of four units of teaching material. These were designed specifically to meet two sets of criteria. Firstly, the predictions from information processing determined the way the material was presented so that student learning was likely to be enhanced. Secondly, the evidence from attitude development informed the design with the aim that positive attitudes towards studies in chemistry would be encouraged. The way the units were used and the way they were tested is described, this work also being carried out with students in years 10 and 11 (age 16-17 approximately) in typical schools in the Emirates.

The testing involved a number of approaches including structural communication grids, open-ended questions and, with one unit, the development of a concept map. Attitudes to numerous aspects of the processes involved in learning chemistry were also explored. The insights offered by the study are summarised and the possibilities for future work are also outlined.

The whole study arose from a concern that students in the Emirates often seemed to have poor attitudes towards their studies in chemistry and that many were rejecting chemistry as a subject to pursue. It is hoped that this study will offer illumination on the problem and give possible ways forward to a better approach to the study of what is an important school discipline, the outcomes being widely applicable in many countries.

Chapter Two

Difficulties in Learning Chemistry

2.1 Introduction

This chapter looks into difficulties in learning chemistry. Much work has been carried out in this area and an attempt is made to draw together some of the main findings and to offer insight into the patterns which have been found.

2.2 Areas of Difficulties and Understanding in Chemistry

The fact is that many students claim that science is hard to learn (Johnstone, 1991) and they view chemistry as one of the most difficult subjects to study. Learning chemistry places demands on students and teachers that can seem insurmountable (Stiff & Wilensky, 2002). In many countries, the understanding of scientific ideas of the majority of students is thought to be very poor (Gott & Johnson, 1999). There are numerous studies in science education which have looked at school and university students' difficulties and understandings of scientific phenomena and chemistry concepts.

In 1971, Johnstone *et al.* and, in 1973, Duncan and Johnstone found numerous themes to be causing problems in the context of Scottish chemical education. These included: ion-electron half equations, cracking hydrocarbons, calculations arising from the chemical equations, equation balancing, bonding, Hess's law, calculation involving the molarity of a solution, redox reactions, addition and condensation polymerisation, saponification and ester formation. In addition, a very large number of students in Scotland had difficulty in understanding the mole and using it in chemical calculations.

In 1977, Johnstone *et al.*, reported that some students failed to perceive a chemical equilibrium mixture as a single entity, and considered the two sides of a chemical equation as if they were independent. Also, the students seem to see chemical equilibrium being characterised as a static, balanced condition. Such students clearly have an inadequate conception of the processes occurring at a particulate level in chemical systems.

Students' understanding of chemical formulas and equations are two other areas important in chemistry. Studies by Ben-Zvi, Eylon, and Silberstein (1982), Maloney and Friedel (1991) indicate that high school and college chemistry students do not associate chemical formulas with the appropriate representation at the particle level. Students in all of these studies had difficulty in relating the subscript of the formula to the appropriate number of atoms when given particle drawings. Yarroch (1985) showed that students do not make distinctions, in terms of particles involved, between the coefficients preceding the formula in an equation and the subscripts of the formula. Moreover, among the high school students interviewed who had balanced equations correctly, more than 50% did not understand this relationship. Also, Niaz and Lawson (1985) found that non-major college students enrolled in chemistry find balancing equations difficult and that equation balancing skill was related to their formal reasoning ability and mental capacity.

In 1984, Yager & Yager examined student's knowledge of key concepts in science and chemistry textbooks by using multiple-choice tests to determine students' definitions of eight science concepts (volume, organism, motion, energy, molecule, cell, enzyme, and fossil). They concluded that there was a general decline in students' understanding of the meaning of concepts from seventh to eleventh grade. In a similar study in Belgium, deBuerger-Van der Borght and Mabille (1989) examined students' understanding of 20 topics and ideas (carbon, three-dimensional, unit, capillary, element, energy, equilibrium, to identify, nucleus, mineral, unstable, organism, oxidise, mole, structure, synthesis, system, acid, combustion, periodic). Using a more open-ended procedure, students were given a list of concepts and asked to write down all the meanings they associated with them. The authors concluded that, although there was no regression in knowledge between 12 and 18 year old students, new information given each year in the curriculum has a short life span and students generally did not link what was learned in science one year with what was learned the next.

In 1985, Hackling & Garnett indicated that students often seemed unable to consider the forward and reverse reaction separately, and had a limited understanding of the particulate bases of chemical reactions. Yarroch (1985) found that students were often unable to draw diagrammatic representations of chemical equations and that many students showed a lack of understanding of the different use of subscripts in formulae and coefficients in chemical equations. This is consistent with Johnstone's (1991) observation that attention to the submicroscopic level is often inadequate. However, care must be taken to distinguish between molecules and network structures so that students do not visualise ionic substances as simple molecules. Cros *et al.*, (1986) found that certain concepts, such as the Bohr model of the atom, were extremely difficult to dislodge.

Chemistry problems involving solutions (usually aqueous) are difficult. These problems involve an understanding of the solution process, molarity, and, frequently, acids and bases. Gabel & Samuel (1986) set out to determine whether students' difficulties in solving molarity problems were related to their misconceptions concerning solutions in general or to their inability to understand the mole concept. They indicated that the students' difficulties were related more to not understanding solutions than to lack of understanding of the mole concept. Cros *et al.*, (1986) have studied the understanding of acids, bases, mole and solution concepts of first-year university students in France. They found that students could name several acids but were less adept at naming bases. Although students were somewhat familiar with the technical definitions of pH, they had little idea of the meaning as applied to everyday life.

Ross & Munby (1991) reported similar findings with advanced twelfth-grade students in Ontario, Canada, by using multiple-choice tests to construct concept maps and interviews. Schmidt (1991) also used multiple-choice tests to identify students' conceptions of neutralisation. Tests were administered to 1500 German students (grades 11 to 13) to test their understanding of neutralisation. He found that many students applied the neutralisation concept only for strong acids and bases and believed that most neutralisation reactions went to completion.

Nakhleh & Krajcik (1991) found that high school students' conceptions of acids and bases were more successfully modified when they used microcomputer-based laboratory experiments rather than laboratory exercises involving chemical indicators or pH meters. Prietio *et al.*, (1989) explored Spanish students' ideas of basic chemical aspects of solutions in grades 6 to 8. They concluded:

(1) About three quarters of students believe in homogeneity of solutions;
(2) About one-half of the students depicted solutions as continuous;
(3) Students generally use familiar rather than scientific terminology to describe the dissolution process even though they have had instruction using more scientific terms;
(4) Examples of solutions generally refer only to solids dissolving in liquids.

Longden *et al.* (1991) explored 11-12 and 13-14 year old English students' notions of dissolving. They found that only 20 percent of year 11-12 year old and 30 percent of the 13-14 year old students understood dissolving at both macro and microscopic levels. They also found that fewer students understood dissolving on the everyday (macro) level than on the particle (micro) level and concluded that many students do not connect the two levels. These studies on acids and bases indicate that students have only a rudimentary knowledge of acids and bases. This lack of understanding is coupled with their lack knowledge about solutions and molarity.

A study of the differences in how undergraduate students, graduate students, and chemistry faculty members view certain science concepts was reported by Kleinman *et al* (1987). They asked 10, 8, and 3 persons from the three groups respectively to tell them what images they had for each of key concepts found in standard chemistry texts (bond energy, equilibrium, functional group, mole, orbital, resonance, solubility, and spontaneous process). The authors indicated that there was an increase in both the level of abstraction and the number of images per person from undergraduate to faculty. Undergraduate students' primary mode of thinking was associative, whereas that of faculty involved using models. In 1989, in a study by Peterson *et al.*, they showed that students have difficulties understanding the particulate nature of matters, atom, molecule, covalent bonding, and structure.

Mass, volume, and density are three concepts in chemistry which are considered important. Students' understanding of these is also linked to their knowledge of the particulate nature of matter. Mullet & Gervais (1990) explored students' understanding of mass. Mullet & Gervais sought to determine whether French high school students (13-15 year olds) understood the difference between the concepts of weight and mass. They concluded that students have an intuitive concept of mass that is distinct from that of weight. Enochs & Gabel (1984) showed that a large percentage of students did not understand the concept of volume and were unable to distinguish surface from volume. Hewson (1986) studied the conceptions of mass, volume, particles, and density of 40 high school students in the Qwa Qwa region of South Africa using interviews. She found that the scientific conception of volume was missing in most students, that the particle mass-weight concept was missing in all students, and that most students used alternative conceptions for mass-weight, volume, and density. She attributed this to their use of the terminology in everyday experiences and to the structure of their home language. Overall, these studies indicate that many students lack sufficient understanding of the very concepts that form the basis for the study of matter (mass, volume, and density).

Students' lack of a scientific conception of mass and volume undoubtedly affects their understanding of the concept of mole. The mole is one of the most important concepts in chemistry. Most chemistry teachers and students complain that mole is difficult to teach and difficult to learn (Herron, 1996). Duncan & Johnstone (1973) obtained 14-15 years old Scottish students' conception of the mole by administering multiple-choice tests. They concluded that some of the major misunderstandings were: balancing equations; and the concentration of solutions. In a study by Novick & Menis (1976), they indicated three major erroneous conceptions held by the students:

(1) A mole is a certain mass and not a certain number;
(2) A mole is a certain number of particles of gas;
(3) A mole is a property of a molecule.

Cervellati *et al.* (1982), using a multiple - choice test to determine how secondary school students (ages 15-17) in Bologna perceived the mole, showed that students' understanding improved with age but was generally low at all ages. Findings include that:

(1) *Students were not familiar with the mole as amount rather than mass;*
(2) *22.4 litres, although well known as a number, was not linked to pressure, temperature, or condition of state;*
(3) *Most students were familiar with the magnitude of Avogadro's number;*
(4) *Students found solving stoichiometric problems difficult.*

Ma (1986) showed that most Malaysian students did not have a coherent understanding and have several difficulties and misconception connected with the mole concept and its applications. In a study by Furib and Guisasola (2000), it was shown that most chemistry teachers in Spain do not hold an updated meaning of quantity (as an 'amount of substance') and of the 'mole'. Thus, it is not surprising that students in Spain have not learned the 'mole' concept in a meaningful way even though they do use it in an operative form.

Chemistry problems frequently contain terms such as "substance", or "solid", or "liquid", or "gas". Research studies in this area have focused on student's lack of ability to classify substances as solids, liquids, and gases (Jones *et al.* 1989; Stavy, 1991). Shepherd & Renner (1982) found that none of the high school students in grades 10 and 12 used a completely correct explanation of differences among solids, liquids, and gases using particles.

Studies by Gabel (1990) and Hesse & Anderson (1992) indicate that chemistry students do not have satisfactory knowledge of the kinetic molecular theory either before or after taking an introductory chemistry course. Tsaparlis (1994a, 1994b) found that students who had finished the lower secondary school in Greece have problems in chemical notation, atomic and molecular structure, chemical equations, and simple stoichiometric calculations.

Many students from secondary level to university struggle to learn chemistry and many do not succeed (Nakleh, 1992). Garnet & Treagust (1992) reported that students have a poor response in electrolytic cells and attributed this to a lack of knowledge about the operation of these cells. Davies (1992) found that the understanding of oxidation and reduction (redox) concepts by chemistry students is limited.

In 1993, Nakhleh & Krajcik indicated that students have limited or confused definitions of 'strong' and 'weak' when applied to acids and bases. Also, the students think of pH in terms of acidity rather than providing information about the H^+ and OH^- concentration. Ayas (1993) indicated that the most often practised teaching-learning method in Turkey in chemistry classrooms was lecturing. The lack of theoretical understanding and implementation of teaching strategies and methodologies, the lack of chemistry teaching aids, the lack of chemical equipment , the size of laboratories and classroom over-crowding were shortcomings in the General Lycees of the Region in Turkey.

The concept of chemical equilibrium depends on numerous other chemical concepts. Problems involving chemical equilibrium are generally quite complex and depend on students' understanding of stoichiometric relationships, solubility, and concentration. The studies on the understanding of chemical equilibrium reported by Wheeler & Kass (1987), Rahal (1986), Crosby (1988), Camacho & Good (1989), Maskill & Cachapuz (1989), and Banerjee & Power (1991) have revealed that many students lack the conceptual understanding of fundamental concepts (such as concentration) on which the conceptual framework of equilibrium is based.

Many high school and university students experience difficulties with fundamental thermodynamic ideas in chemistry (Banerjee, 1995a). Despite the importance of thermodynamics as a foundation of chemistry, most students emerge from introductory courses with only very limited understanding of this subject (Ochs,1996). Heat, temperature, and thermodynamics concepts are important for understanding science and constitute a fundamental knowledge domain. Albert (1978), Erickson (1979, 1980), Shayer & Wylam (1981), Frenkel & Strauss (1985), and Appleton (1985) all examined students' conceptions of heat, temperature, and more advanced thermodynamic topics. They found that students' conceptions generally improved with age, although some misconceptions were more prevalent among older subjects.

Carson & Watson (1999) showed that students come to the University with a very limited understanding of enthalpy change. In a recent study by Sirhan (2000), he found that many Scottish chemistry students have some difficulty with chemistry topics such as enthalpy, entropy, free energy changes, pH calculations, isomerism, and mole calculations.

In the Emirates, the result of an investigation carried by Al-Marashda (2002) with secondary schools students in the department of Al-Ain Education Zone indicated major problems. In his study of difficulties in learning chemistry in secondary school in Al-Ain, he drew the conclusion that secondary students have difficulties in learning chemical concepts such as: writing chemical formula, periodic table, chemical bonds, writing chemical equation, mole and chemical calculations, liquids and solutions specialities, organic chemistry, solubility product, titration, Faraday sums, and metals. This seems to encompass almost all the curriculum - a frightening thought!

Stiff & Wilensky (2002) pointed out that mathematical formulae, chemical symbols, and scientific measurements all seek to describe phenomena that are not visible to the students.

The above section has listed a range of studies from many countries with widely different educational structures and teaching approaches. The problems seem widespread and must be related to the fundamental nature of the chemistry to be learned and the way that students function in the learning process. While considerable research has developed an overall picture of the extent of the problems, only a small amount of research has asked serious questions about the fundamental nature of the problems and how they can be solved. Useful reviews of the problems have been offered by Gabel in the USA and Sirhan in the UK .

The fundamental nature of the problems has been explored in depth in a long series of empirical studies led by Johnstone. This has led him to develop new approaches to teaching these topics, some of which have been tested and found to be highly effective. His early work led to a new style of textbook (Johnstone *et al.*, 1981) while his general approach was outlined in his paper of 1997 (Johnstone, 1997) and will be discussed in much more detail later. Sadly, his findings have not been applied widely and the difficulties in learning chemistry still persist in many countries.

His work raises a fundamental and interesting question. Based on a long series of carefully conducted experiments, he has been able to demonstrate the fundamental nature of the problem and has been able to offer practical solutions. In the light of this, it is very strange that curriculum planners and textbook writers have failed to apply his ideas and reduce the difficulties students experience.

2.3 Difficulties in Teaching Chemical Concepts

Many chemistry concepts that are taught are abstract and have few features that are easily derived from direct experience. Indeed, it is difficult to illustrate these ideas without using analogies, and these analogies themselves may lead to more confusion. Fundamentally, the molecular level is abstract and unrelated to learner experience. The way chemistry is taught in most school syllabuses demands the introduction of the molecular at an early stage, tending to reduce chemistry to an intellectual exercise in abstraction. The struggling learner reverts to rote memorisation and understanding is the casualty.

Many uses of scientific concepts at higher levels of abstraction develop naturally from basic level categories. Teachers need to consider the constructs in a formal way for the same reasons. If they do not, they may be not sufficiently able to construct concepts for the benefit of students (Herron, 1996). Also, Reid (2000) pointed out that chemistry contains many abstract ideas and students may well perceive chemistry as abstract discipline with limited connection to day-to-day living.

Students are hindered in learning some chemistry topics because they see little use for them. For example, the topics of atoms and molecules have little perceived value. Most topics develop naturally as a result of informal experience and the process has limitations. Science topics such as: atom, molecule, mass, acceleration, mathematical limit, square root, and probability have features that are undetected through experience. Such topics cannot develop naturally. They must be invented and formally taught.

The difficulty of learning the science concepts is often determined by whether the pattern of events that define the conceptual category can be derived directly from sensory perception or only indirectly through complex elaboration of perception. Table 2.1 shows a classification of chemistry concepts (Herron, 1996).

Table 2.1 Classification of Chemical Concepts

Class	Characteristics	Example
Concrete Concepts	Perceptible example, perceptible attribute	Arrhenius Acid
Invisible Examples	No perceptible instances	Atom, molecule, photon
Invisible Attributes	Critical attributes are not perceptible	Element, compound
Dual Concepts	Learned at two levels	Element, compound
Principle Concepts	Classification requires knowledge of principle used in test substances	Mole, mixture
Properties Concepts	Name properties	Oxidation Number
Symbolic Concepts	Names from of symbolic expression; symbolic form governed by explicit rules	Formula, chemical symbol, chemical equation
Processes	Concept is a process rather than an object	Melting, oxidation, distillation, dissociation

Johnstone (1999a , 2000) points out that chemistry is regarded as a difficult subject by students. The difficulties may lie in human learning *and* in the intrinsic nature of the subject. The former will be considered in chapter 3 while the latter will be discussed below. Chemical concepts form from our senses by noticing common factors and regularities and by establishing 'example' and 'non-example'. This direct concept formation is possible in recognising, for example, metals or flammable substances, but quite impossible for concepts like 'element' or 'compound', bonding types, internal crystal structures and family groupings such as alcohols, ketones or carbohydrates. The psychology for the formation of most chemical concepts is quite different from that of the 'normal' world.

2.4 The Complexity of the Chemistry

Many of the students have difficulties in understanding fundamental concepts (Kavanaugh and Moomaw, 1981). Research on students' understanding of chemistry concepts has revealed that students have many misconceptions. The concepts examined include equilibrium (Banerjee, 1991), phase changes (Bar & Travis., 1991), chemical reaction (Barker & Millar, 1999), gases (Benson, *et al.*, 1993), stoichiometry (BouJaoude & Barakat , 2000), atoms and molecules (Griffiths & Preston, 1992) , acids and bases (Ross & Mumby, 1991), and covalent bonding (Peterson *et al.*,1986). Many of the topics about which students hold misconceptions are basic to chemistry knowledge and are interrelated.

"Chemistry is a complex and ill-defined field that requires considerable skill and effort to teach and learn, and requires the joint efforts of chemistry education specialists and content specialists in all fields working together to analyse the demands of learning chemistry to find better ways forward" (Bucat, 2002).

From his observations, Johnstone (1991) offered a helpful insight when he concluded that chemistry can be taught at three levels:

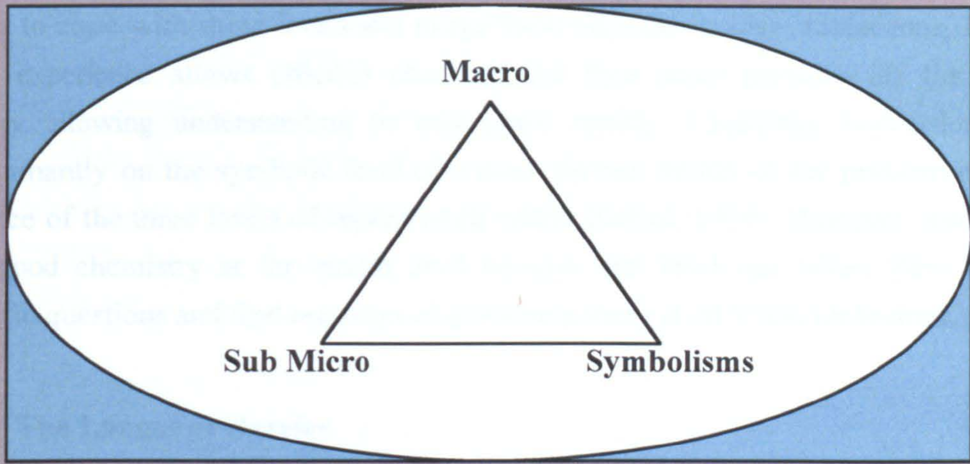
(1) The macroscopic level: is sensory and deals with tangible and visible phenomena, what can be seen, touched and smelled.
(eg. salt dissolving in water)

(2) The submicroscopic level: provides explanations at a particulate level.
(eg. disruption of the ionic lattice and ions, structures, surround by water molecule, moving into solution)

(3) The symbolic level: represents processes in terms of formulae and equations symbols, molarity, mathematical manipulation and graphs.
(eg. diagrams and representations of bonds, hydrogen bonds, lattices etc)

Johnstone (1993) called the above three levels as the basic components of new chemistry (See Figure 2.1).

Figure 2.1 : ***The Basic Components of New Chemistry***



There is considerable evidence that such multiple representations may be causing problems. Researchers have begun to explore pedagogical difficulties with representation of chemical phenomena on multiple levels. Kozma & Russell (1997) suggest that, due to the submicroscopic level of molecular interactions, chemists must use symbols to refer to the atomic objects and processes within their domain which they cannot observe directly. Moreover, aggregations of molecules result in phenomena on a macroscopic level such as when water freezes or ice melts. On the symbolic level, where most teaching and learning take place in the traditional chemistry classroom, instructors use multiple representations for the same phenomena. Thinking of the laboratory, Banerjee (1995b) found that students are further expected to connect the symbolic representations in texts to the actual physical substances they use in an experiment and the numerical measurements they take from laboratory instruments. Although chemists may easily discern the relationships between chemical phenomena at the submicroscopic, microscopic, and macroscopic levels and fluidly move between various symbolic representations of the phenomena, students have considerably more difficulty. Johnstone has offered helpful explanations of this problem and these are now discussed.

To understand chemistry fully, it is necessary to experience all the above three levels. Information processing models suggest this will pose problems because the working memory has a limited capacity. For the learner, the use of all three levels simultaneously is likely to bringing about an information overload, with the working memory unable to cope. It has been shown repeatedly that information overload of this sort brings about a dramatic drop in performance (eg Johnstone and El-Banna, 1986). The only way the learner can cope is to resort to memorisation and understanding becomes more or less impossible.

Chemistry teachers have considerable experience of chemistry and they can group ideas together. This process is known as 'chunking'. These efficient chunking skills enable the teacher to cope with these levels and merge them into one 'reality' (Johnstone, 1993). In effect, experience allows efficient chunking and thus takes pressure off the working memory allowing understanding to take place readily. Chemistry instruction occurs predominantly on the symbolic level (the most abstract level), so the problem is not the existence of the three levels of representing matter (Gabel, 1999). However, students can learn good chemistry at the macro level because this level can 'allow them to frame scientific questions and find out ways of answering them at all levels (Johnstone, 1991).

2.5 The Language Barrier

Chemistry in common with all science has a distinctive vocabulary of words which have very specific meanings for a chemist. A major part of teaching and learning chemistry is approaching this language in a way which assists students in the development of their understanding of chemical concepts (Loeffler, 1989).

Several studies disclosed language-related difficulties of chemistry student. These difficulties can be listed :

(1) Lack of understanding of *familiar* words used to convey meaning in chemistry;
(2) Lack of understanding of *technical* terms introduced in the study of chemistry;
(3) Ascribing a *familiar* meaning to a common word used in a *technical* sense;
(4) Using everyday meaning to draw *incorrect inferences* about chemical events;
(5) Failing to learn the *conventions* applied to specialised chemical language to the level of automatisation required to "read chemistry" fluently (Herron, 1996).

Ver Beek and Louters (1991) state that, "Chemistry is a complex discipline that requires multiple skills to master." They note that chemistry students must be competent in areas such as mathematics, problem solving, conceptualisation, handling theories (they probably mean models) and *chemical language*, among others. Also, they found that the difficulties experienced by beginning college chemistry students are caused by a lack of chemical language skill rather than a lack of reasoning and/or mathematical skills. Consistent with these findings, Markow (1988) advocates first teaching students how to speak the language of chemistry, followed by the mathematics and other skills needed to master chemistry successfully.

Many words used in science have different meanings in everyday language. According to a study by Gilbert *et al.* (1982), there were numerous occasions when students' interpretations of language differed from the intended meaning. Some of these misinterpretations, and their likely origins are presented in the following three examples.

Each example is derived from a description from Gilbert's study in 1982.

(1) '*The salt bridge completes the circuit*' has different meanings to students from those anticipated by teachers. The concise Oxford Dictionary defines 'complete' to mean 'finish', make whole or 'perfect', and 'make up the amount of'. The students thought that the salt bridge completed the circuit by 'supplying, or making up for the electrons which were accepted by reduced species at the cathode, and incorrectly concluded that electrons emerged, or came out of, the salt bridge.'

(2) '*Ions carry the charge*' many students implied that ions conduct charge in the same way that a suitcase is carried. They interpreted 'carry' to mean that the electron is 'picked up, transported, and then deposited.'

(3) '*The basic principles for the operation of electrochemical cells are reversed for electrolytic cells'*. Teachers sometimes use this statement because in a electrochemical cell a chemical reaction produces an electric current, while in an electrolytic cell, an electric current is used to produce a chemical reaction. However, many students applied the idea of 'opposite' or 'reversed' inappropriately. Some students correctly thought that in an electrochemical cell, the anions and cations are respectively positively and negatively charged. In contrast, some students thought that the processes of oxidation and reduction took place at the anode and cathode, respectively, in an electrochemical cell but that the reverse occurred in an electrolytic cell.

Hillman *et al.* (1981) note that *vocabulary* poses difficulty for school students and teachers in training. In this study, less than 20 percent understood the meaning of the words 'converse' and 'postulate'. Many concepts in electrochemistry are most important but most difficult, and there is a complex technical language with words like molecular, intermolecular, ionic, anode, anion, Faraday, and ionic formulae. The use of the word 'intramolecular' clearly provided the more able students with considerable difficulty and the phrase 'atoms in a molecule' proved much clearer to them.

Special problems occur when chemical language such as formulas, equations, and other symbolic representations are used in chemistry. Because of the events and their description are unfamiliar to students, the problem is compounded. Teaching chemical language is like teaching a foreign language and limiting discussion to the culture in which that is spoken. Using a new language to talk about familiar events is difficult enough; when the language and events are both unfamiliar, little opportunity exists to do more then process symbols on the surface (Herron, 1996).

Arshad (1994) found that chemical formulae, chemical equations, elements, compound, and mixtures concepts were not influenced by using local language and culture and caused difficulty for Malaysian secondary school students.

A lack of chemical language skill can limit the students' ability to solve problems. Johnstone (1980) observed a threshold response in chemical problem solving: students were able to solve problems of increasing difficulty until they were required to work with that one additional language item that they did not understand. Johnstone (1986) suggested that in order first to understand a problem, apart from solving it, the capacity of the working short term memory cannot be overloaded. The average capacity of the working memory for an adult (a person 16 years old or older) is known to be 7 and most adults have working memory capacities lying between 5 and 9. Thus, the adult learner can only cope with 7 ± 2 pieces of information. A "piece" of information is determined by the individual's existing knowledge of language. For example, to a chemist, $CH_3CH_2CH_3$ is one piece of information, propane. To a non-chemist, each letter and number may represent a separate "piece" of information. Thus, learning the language associated with chemistry is imperative for success in the discipline.

Johnstone (1991) also suggested that the language barrier seems to be a very obvious source of difficulty since chemistry has many unfamiliar technical words. However, he showed that most of the problems occur with *non-technical* terms which students think they understand. For example, a pipette is a pipette, but, in the chemistry laboratory, the word 'clear' means 'colourless' and does not mean ' transparent', and a 'volatile-compound' can mean at least four things to students: a 'flammable, explosive, unstable, and dangerous compound'. All of these are derived from normal English usage. Bucat, (2002) suggested there is also a technical jargon used only in chemistry, as well as everyday terms that have not the same meanings when used in the chemistry context, such as: spontaneous, saturated, property, and dispersion .

In the Emirates, the language barrier plays a central role in difficulties of understanding chemistry. Using two words or phrases to describe the same idea can also be a source of confusion, eg. galvanic cell + voltaic cell; cathode pole + negative pole; anode pole + positive pole; cathode ray + negative pole ray; anode ray + positive pole ray, amphoteric oxide + hesitate oxide. Using local language when translating chemical concepts into Arabic language can cause problems, eg. quantum numbers, amphoteric oxide, the co-ordinate bond, alkali metal, pH & pOH, pig iron, ligands, groups and complex ions. All these can cause difficulty for Emirates secondary school students.

2.6 The Chemistry Curriculum

In the Emirates, the school chemistry curriculum has been changed three time within three years. This instability produces many problems for teachers and reflects uncertainty on the part of curriculum designers.

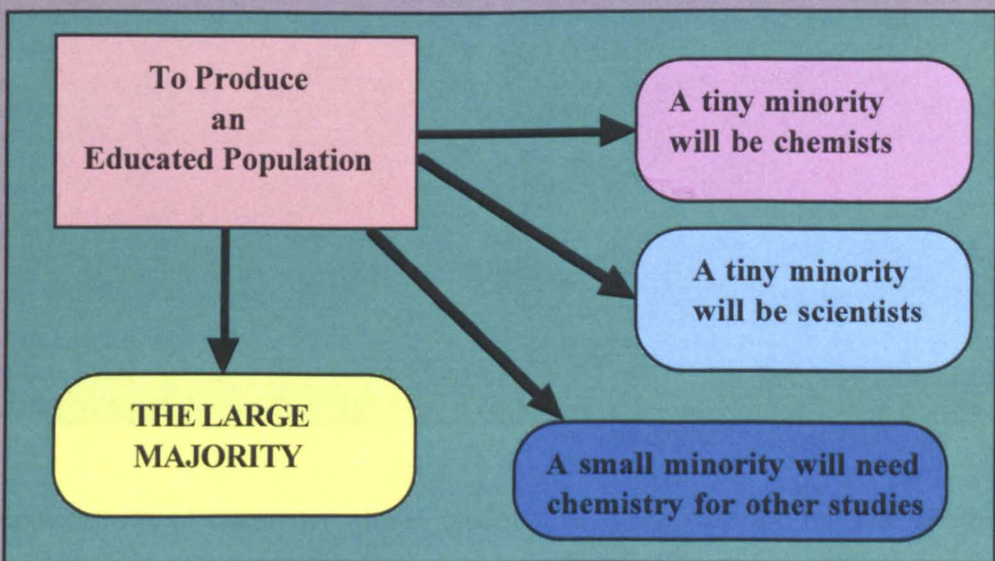
There are many principles which could be used to develop a chemistry curriculum. Many of these reflect the logic of chemistry as a discipline and the assumption that any chemistry course must be constructed to meet the needs of the following course. The ultimate logic of the latter approach is to develop all chemistry courses to meet the needs of that tiny minority who will be research chemists!

Reid (2000) posed important questions when he argued that there are three important questions which must be addressed in planning any chemistry course:

> (1) *What are the questions that chemistry asks?*
> (2) *How does chemistry obtain its answers?*
> (3) *How does the chemistry relate to the lifestyle of the learner?*

In looking at school chemistry, he argues that the production of an educated population is the fundamental aim (see Figure 2.2).

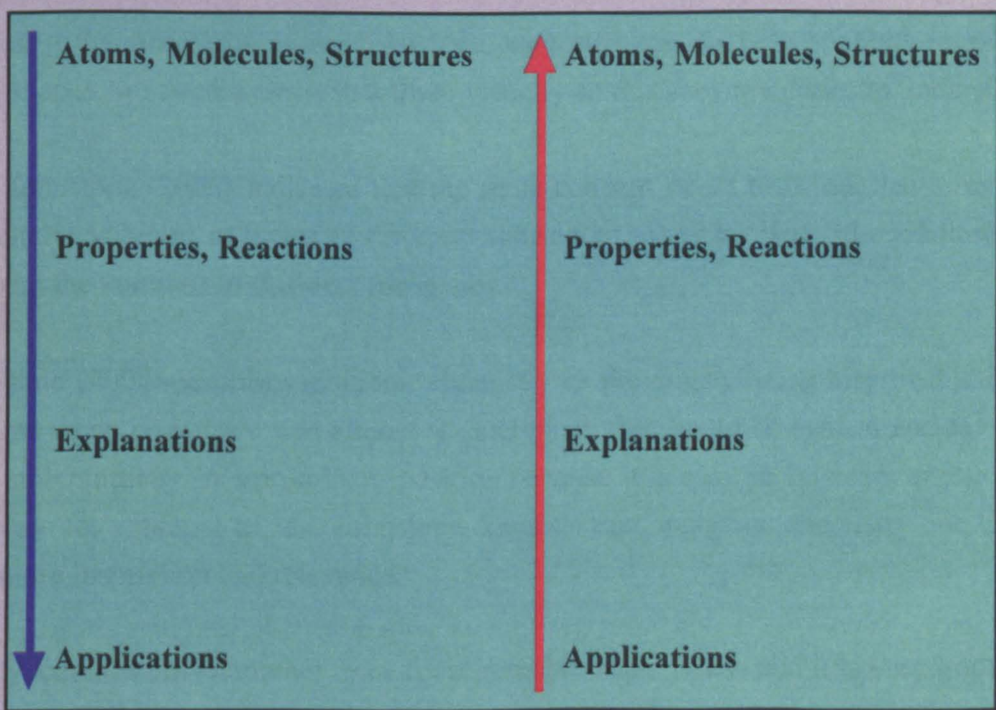
Figure 2.2 : ***Why Study Chemistry at School***



However, the structure of the chemistry curriculum in the Emirates is based on a logical order. The chemistry textbook of year 10 start with elements, atomic, and chemical bonds, and in year 11 start with the mole, chemical calculation, liquids and solutions. These are best explained on the microscopic level first, before presenting descriptive chemistry at the macroscopic level.

In looking widely at approaches to curriculum construction, Reid (2000) defined an applications-led approach in terms of the chemistry to be taught being selected in order to able the learners to make sense of applications which are drawn from their own experience and life style. Later, he discussed teaching materials which had been developed on this basis (Reid, 2002). He describes a physics curriculum which has been designed in this way (Reid, 2000) and shows the power of this course not only to retain students in physics studies but also as a very sound basis for further studies. In essence, the chemistry curriculum could be designed starting with applications from life and developing the chemical understandings required to make sense of these and not by the logic of the chemistry discipline (Figure 2.3).

Figure 2.3 : ***A change of Direction***



Using applications of chemistry allows students to work with the relevant chemistry to understand and move towards a solution - an understanding of how chemistry can make sense of the world around. The new way is illustrated by the upward vertical line in figure 2.3.

In order to design an established chemistry syllabus, Reid (2000) drew on much earlier research (Reid, 1978) to pinpoint five areas which might assist to define a chemistry curriculum:

(1) The historical dimension of chemistry
(2) The social impact of chemistry on our life style study.
(3) The industrial implications of chemistry in our society.
(4) The economic implications of chemistry activity in our society.
(5) The socio-moral implications of chemistry.

Johnstone (2000) identified five issues related to the way the chemistry curriculum is planned: syllabus order, structures, the mole, moving towards inorganic chemistry, and equilibrium.

When considering syllabus order, Johnstone considered the most relevant starting point for students. For example, do we begin in the traditional way with salt, sodium carbonate, silver nitrate and barium chloride or do we begin with petrol, camping gas, plastics and foods? This is very similar to the applications-led ideas of Reid (1999).

Regarding the structures issue, Johnstone suggested that to help students to rationalise these shapes, we need to represent them visually so that they are easier to understand.

Also Johnstone (2000) indicated that the mole concept needs to be applied to molecules, the relative volumes of moles of different substances allow to ''see'' the relationship and compare the volumes of different molecules.

Johnstone (2000) describes inorganic chemistry as previously being historical artefacts of the time when chemistry was almost all analytical. One could be cynical and say that we keep stoichiometry in a prominent position because it is easy to set exam questions on it and easy for students to fail. Johnstone suggests that inorganic chemistry can be taught with more inspiration and relevance.

Finally, equilibrium is another issue for alternative frameworks and it is very important to present the following features which are relative to equilibrium in everyday life:

- *Equal masses on each side.*
- *Addition to the left makes the system tilt to the left.*

Students will recognise this from shopping, riding bicycles, carrying suitcases or walking along a mountain ridge. However, Johnstone (2000) also describes how there are quite good analogies available to make this visualisable, but most of them suffer from being 'two-sided' and so can perpetuate a wrong idea in which students forget that reactants and product exist in the same vessel at equilibrium .

Al-Marashda (2002) has indicated that the chemistry curriculum in the Emirates needs to be redesigned to decide the priorities for what should be taught in order to avoid the difficulties in learning and teaching chemistry.

2.7 Conclusions

There are two fundamental sources of difficulty for the learning of chemistry. The first is the nature of chemistry itself. Its subject matter is the nature of matter and the way matter changes. The Johnstone model (figure 2.1) illustrates the three levels required in learning chemistry. Evidence shows clearly that the learner cannot work confidently and successfully at all three levels. It is important, therefore, to concentrate on the macro level at the outset.

However, the chemistry to be taught must relate to the experience of the learner. Often, this is simply not the case and abstract ideas are introduced which are not obviously connected to the real world experience of the learner. This emphasises the importance of knowing what the learner knows and the kind of ideas which are real at a given stage of learning.

This leads on the learner. The curriculum must make sense to the learner and be perceived as meaningful. However, what is taught must be presented in such a way that is consistent with the way the person can learn new material. The limitations of working memory are critical in this. This affects all aspects of learning and will be discussed in more detail in the next chapter.

Overall, there are clear messages for determining what is to be taught and the order of teaching. There are also clear messages for the actual way the material is taught.

In the specific context of the Emirates, it is self evident that the features of the learners' mind cannot be changed while it is difficult to change the curriculum programme. It is hoped to have better results if the 'transmission system' is modified to bring it into line with the best evidence about the way the learner understands new material. How this will be attempted is part of this study.

In the experience of teachers in the Emirates, many students in Emirates come to the class with wrong and confused ideas or even a complete lack of background knowledge and this will be explored later. Learning experiences need to be offered to prepare students to grasp new material by clarifying or correcting previously held concepts or by providing fundamental instruction on such concepts.

Chapter Three

Learning Models

3.1 Introduction

Having looked at the record of the difficulties associated with the learning of chemistry, this chapter looks in particular at these models which relate to observations on difficulties in the field of science education: Piaget's intellectual development, Ausubel's meaningful learning model, Novak's model of elements, Ashcraft and Baddeley's model, and the information processing model of Johnstone.

3.2 Piaget

Jean Piaget, the Swiss psychologist, was a scholar who studied extensively the intellectual development of the child. During his school years, Piaget became a keen student of zoology, while, in adolescence and early adulthood, he became drawn to epistemology (Lovell, 1971). Piaget spent more than 50 years observing children from birth to adolescence to see how they responded to a variety of tasks (Novak, 1978).

From Piaget's point of view, the child is growing in an environment that affects his development. He is adapting to surroundings and absorbing what is required for growth and necessarily changing his behaviour at the same time. Piaget describes the thought processes that bring about this adaptation as schemata (Piaget, 1962). Schemata mean that the child builds up sequences of actions, or patterns of behaviour which have definite structure (Lovell, 1971). The child may also have to modify his internal schema to fit reality. This latter process is called accommodation (Piaget & Inhelder, 1969), and accommodation is a modification of a schema as a result of new experiences (Beard, 1969). By contrast, assimilation is the complementary process of interpreting experience (individual instances of general concepts) in terms of current cognitive schemes and the goal of each thinker between accommodation and assimilation is equilibrium (Goswami, 1998).

Piaget (1962) observed that cognitive development is a group of logical successive equilibrations (a constant adjustment of balance between assimilation and accommodation) of cognitive structure, each structure deriving from the previous one. Donaldson (1998) also noted that self-regulation happens when living organisms can maintain or repair their own structures in case of threat of damage. Piaget used self-regulation, equilibrium, assimilation, and accommodation as features of biological adaptation to explain the human intellectual development .

Piaget's theory deals with the development of cognitive operational capacities. Piaget proposed that children undergo four major intellectual development stages:

Stage	Age	Description
Sensory-motor	Ages 0-2	During the sensimotor stage, the child comes to recognise, among others things the objects do not disappear when they are moved out of sight. The cognitive ability to recognise the permanence of objects is a key characteristic of the end of this stage. Also, true concept learning would not be expected.
Pre-operational	Ages 2-7	This stage is characteristic by the child's egocentric view of objects and events in the world and their inability to see an object or an event from a perspective other than their own. The child can perform certain set-theoretic operations (Novak, 1988).
Concrete Operational	Ages 7-11	In this stage, the child can see an object or an event from a perspective other than their own. Also, a child always starts with experience and makes limited interpolation and extrapolation from the data available to his senses (Phillips, 1968).
Formal Operational	Ages 12 on	In this stage, the child (or adult) can make inferences or predictions in hypothetical cases as well as or concrete or observed events (Novak, 1988). A child develops the reasoning and logic to solve all classes of problems. There is a "freeing" of thought from direct experience. The child's cognitive structures reach maturity during this stage. (Wadsworth, 1984).

The last two of these stages are important at secondary and tertiary levels (Piaget, 1962). Johnstone (1987) described the last two stages in the context of science. The concrete operational is characterised by :

- *Thinking about or doing things with physical objects.*
- *Ordering, classifying and arranging.*
- *Manipulating things in the mind.*
- *Limited exploration of possibilities.*

At this stage, the learner is able to solve problems but his solutions are characteristically in terms of direct experiences. By contrast, the formal operational stage is characterised by:

- *Logical reasoning, drawing conclusions from premises.*
- *Testing hypotheses.*
- *Planning experiments.*
- *Formulating general rules.*
- *Manipulating propositions in the mind.*
- *Exploring many possibilities.*

These characteristic are important in a scientist and teachers would hope to find these in their students when progressing from secondary to higher education.

3.3 Learning and Teaching Concepts According to Piaget

In looking at science teaching at school level, some practical observations may be made.

(a) When beginning a new topic, learning should be based on concrete experiences or on the children's (or adolescents') own experiences, even in the case of the most able students.

(b) The capacity for thinking in formal operations does not start to develop until children attain a mental age of about thirteen years and is initiated by problems raised in attempting to reconcile different viewpoints in discussion and co-operative tasks. Normally, these skills are more fully achieved by sixteen years.

(c) Methods of teaching for the majority of students in the first two years in secondary school (and even later for those who are slower) should be suited to children who think in concrete terms.

(Beard, 1969).

Karplus (1977) suggested three phases for teaching formal concepts:

(1) Exploration: *In this phase, the students explore new materials and new ideas with minimal guidance. Where the students gain experience with the environment and they learn through their own actions and reactions in a new situation.*

(2) Concept introduction: *In this phase, the students provide social transmission and it starts with the definition of a new concept. The concept may introduced by the teacher, a textbook, or medium such as a film.*

(3) Concept application: *In this third phase, familiarisation takes place as students apply the new concept and / or reasoning pattern to additional situations. This last phase provides additional time and experiences for self-regulation. Also, it aids the students whose conceptual reorganisation takes place more slowly than average. This stage is necessary to extend the range of applicability of the new concept.*

According to Piaget (1970), there are three major principles guiding intellectual growth and biological development. These are outlined in turn and their possible significance for the teaching of chemistry in the Emirates is discussed briefly.

(1) Cognitive development is facilitated by providing activities or situations that engage learners and require adaptation (i.e. assimilation and accommodation).

The Emirates is a rich country and the facilities in the secondary schools are adequate. The schools have laboratories. However, there is no evidence that these facilities are frequently used. This means that activities are more limited than is necessary so the cognitive development of students is also limited.

(2) Learning materials and activities should involve the appropriate level of motor or mental operations for a child of a given developmental stage; teachers should avoid asking students to perform tasks that are beyond their current cognitive capabilities.

In the Emirates, there are both insufficient learning materials and teaching equipment. Furthermore, the structure of the school day is such that there is insufficient time for experiments, demonstrations or full use of the laboratories. Consequently, students are not involved in a appropriate levels of motor or mental operations for their development stages. There is no time for capabilities of students to unfold at their own pace.

(3) Use teaching methods that actively involve students and present challenges.

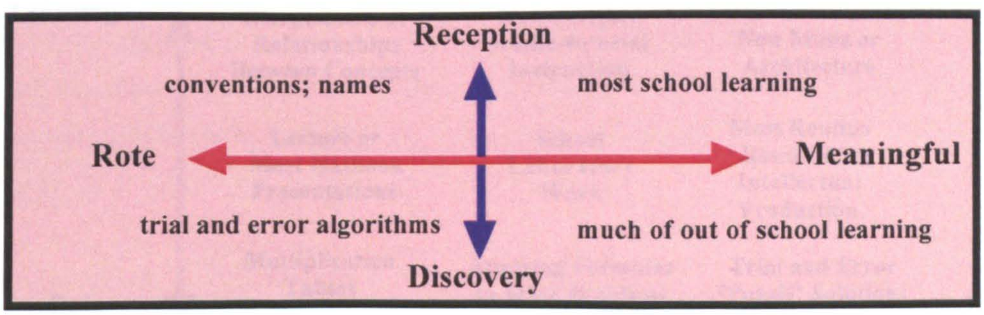
In the Emirates, the chemistry education program is based on a teacher-centred model. Thus, the methods of teaching chemistry (and science) is not student-centred and this situation makes the students less actively involved in their studies.

3.4 Ausubel's Model of Meaningful Learning

The most important factor in Ausubel's model is his emphasis on the prior knowledge of the learner. Ausubel started with this premise: "The most important single factor influencing learning is what the learner already knows, ascertain this and teach him accordingly." (Ausubel, 1968).

Ausubel's meaningful learning model focussed on both the presentational methods of teaching and the acquisition of knowledge (Ausubel, 1968). In 1961, Ausubel split the methods of learning into two groups: reception and discovery. He also offered a clear separation of these methods of learning from learning which he described as rote or as meaningful learning (see figure 3.1).

Figure 3.1 Type of learning according to Ausubel's model.



Reception learning in school is usually related to didactic forms of teaching. Ausubel claimed that most people learn primarily through reception learning rather than discovery learning (Ausubel *et al*, 1978). In reception learning, concepts and propositions are presented to the learner by an independent agent (eg.. a teacher, book, computer, film) whereas, in discovery learning, the goal is for the learner to infer the most important concepts and to construct significant propositions independently. It is important to note that reception and discovery learning may be accomplished through either meaningful or rote processes (Wandersee & Novak, 1998) and discovery learning is based on a learner rather than a teacher-oriented view of the teaching and learning process (Larochelle *et al*, 1998).

Thinking of the long term memory, Johnstone (1997) described meaningful learning as "good, well-integrated, branched, retrievable, and usable learning" while rote learning is "at best, isolated and boxed learning that relates to nothing else in the mind of the learner". Also, Novak (1998) suggested that rote learning occurs when the learner memorises new information without relating it to prior knowledge, or when learning material that has no relationship to prior knowledge.

According to Ausubel *et. al,* (1978) meaningful learning has three requirements:

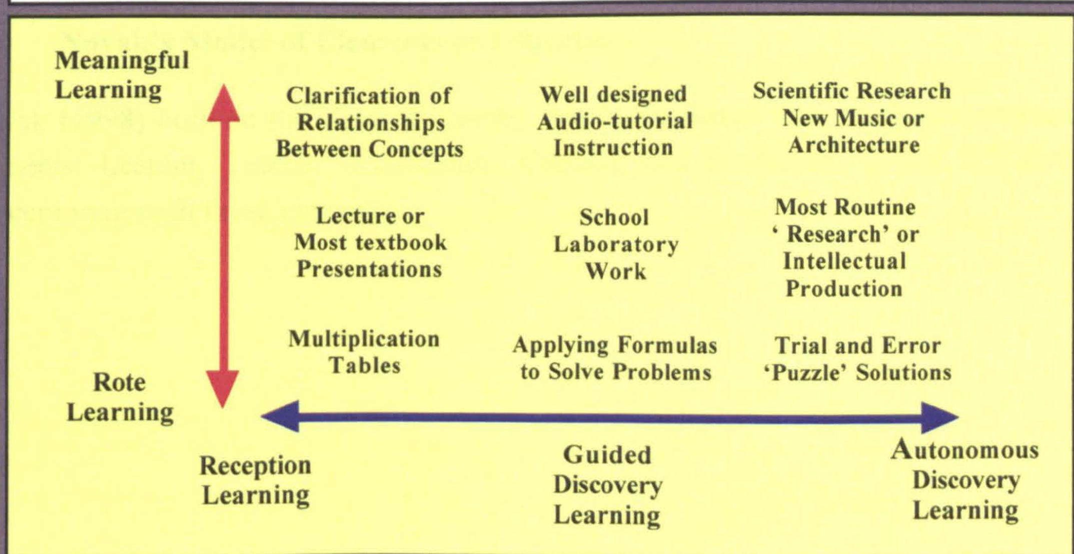
(1) *Relevant prior knowledge*: The learner must know some information that relates to the new information to be learned in some nontrivial way.

(2) *Meaningful material*: The knowledge to be learned must be relevant to other knowledge and must contain significant concept and propositions.

(3) *The learner must choose to learn meaningfully:* The learner must consciously and deliberately choose to relate new knowledge the learner already knows in some nontrivial way (Novak & Gowin, 1984).

Figure 3.2 shows how the two dimensions of learning, as specified by Ausubel, can be illustrated with respect to practical learning.

Figure 3.2 : ***Reception Learning & Discovery Learning*** **(Wandersee & Novak, 1998)**



In looking at the teaching of chemistry in the Emirates, while it is desirable that learning should be meaningful (looking at the top line in figure 3.2), in practice only the clarification of relationships between concepts has any possibility of being observed. It is, however, probable that much learning is done in rote fashion with information simply being stored in long term memory in a not-very-meaningful way. Even laboratory work might be reduced to rote learning as students observe routine experiments designed to give 'right' answers.

3.5 Concept Learning According to Ausubel

Learning in the sciences requires much concept learning and Ausubel's model has much to offer in looking at the ways by which concepts develop.

(a) Ausubel believes that, in acquiring new concepts, the new pieces of knowledge are linked to specifically relevant concepts or propositions which are already known.

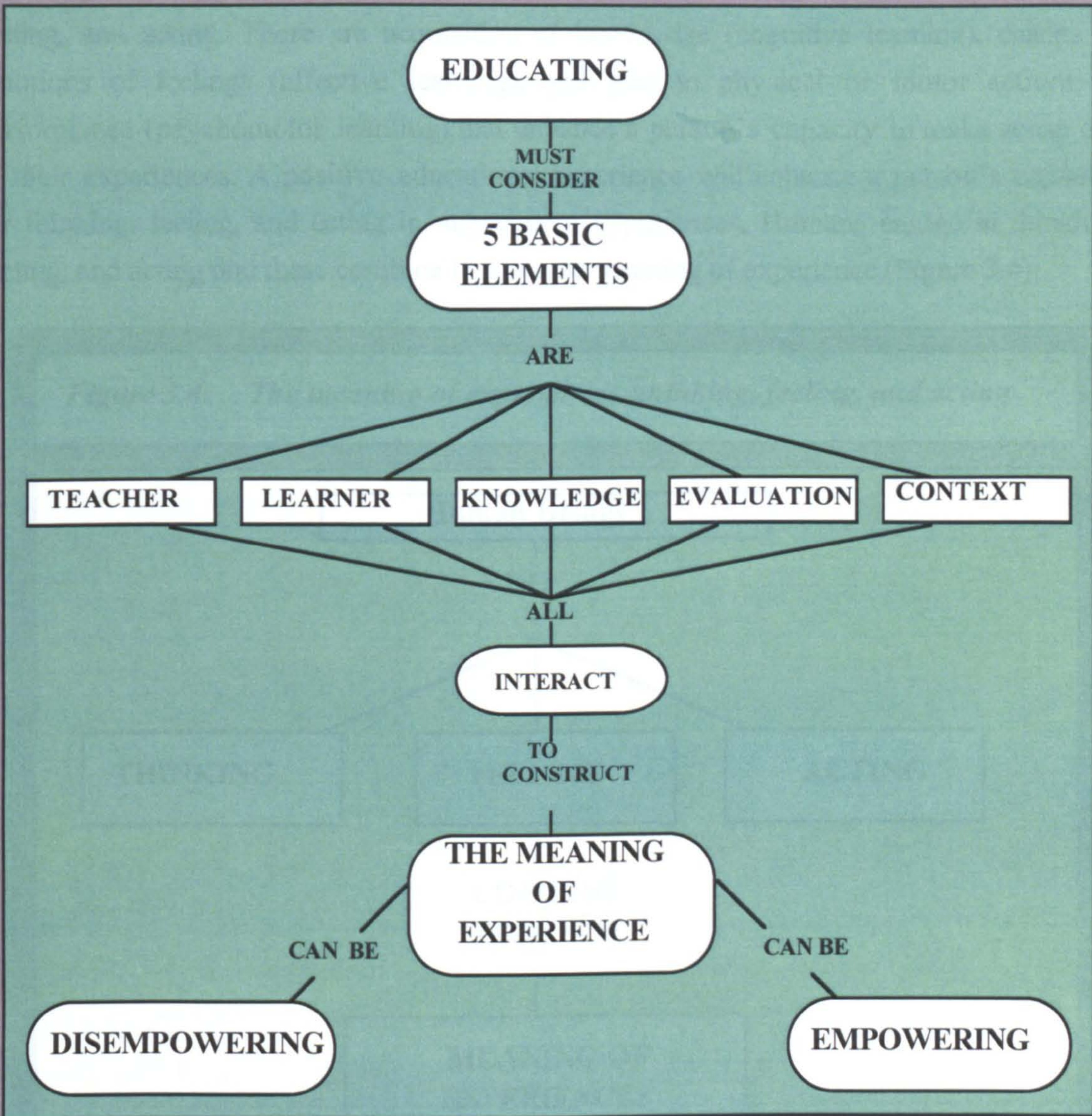
(b) The changes in the quality of meaningful learning acquired by the growing individual happen gradually, not as a result of general stages of cognitive development or as a result of merely being older, but rather because of the growing differentiation and integration of specifically relevant concepts in cognitive structure (Novak, 1978).

These principles have direct application to the learning of chemistry. Directed teaching must seek to make these links and allow knowledge to be integrated meaningfully. In addition, the learner needs time to think through ideas and to allow connections to be made. In the typical overloaded syllabuses in chemistry, there is a real danger that neither of these will be possible.

3.6 Novak's Model of Elements of Education

Novak (1998) built on the ideas of Ausubel and he proposed that education involved five elements: Learner, Teacher, Knowledge, Context, and Evaluation. Figure 3.3 shows a concept map with these elements.

Figure 3.3 : ***The Concept Map of the Five Elements According to Novak's Model***



Nevertheless, Novak sees evaluation as an additional key element in education. Two additional factors operate in education: money and time but they are not specific to education. Haidar (1999) looked at present status of the Emirates science education programme using Novak's model of the five elements of education:

(a) Learner

Novak (1998) has argued that the learner constructs meaning of his/her experiences in three ways: thinking, feeling, and acting. The teachers complain there is a lack of motivation in the part of the learners in Emirates: they study only if they have to. To sum up, it is obvious that the process of learning is ignored in favour of teaching (Ministry of

Education & Youth, 1997).

Novak (1998) suggested that successful education must focus on the learner's thinking, feeling, and acting. There are acquisition of knowledge (cognitive learning), change in emotions of feelings (affective learning), and gain in physical or motor actions or performance (psychomotor learning) that enhance a person's capacity to make sense out of their experiences. A positive educational experience will enhance a person's capacity for thinking, feeling, and acting in subsequent experiences. Humans engage in thinking, feeling, and acting and these combine to form the meaning of experience (Figure 3.4)

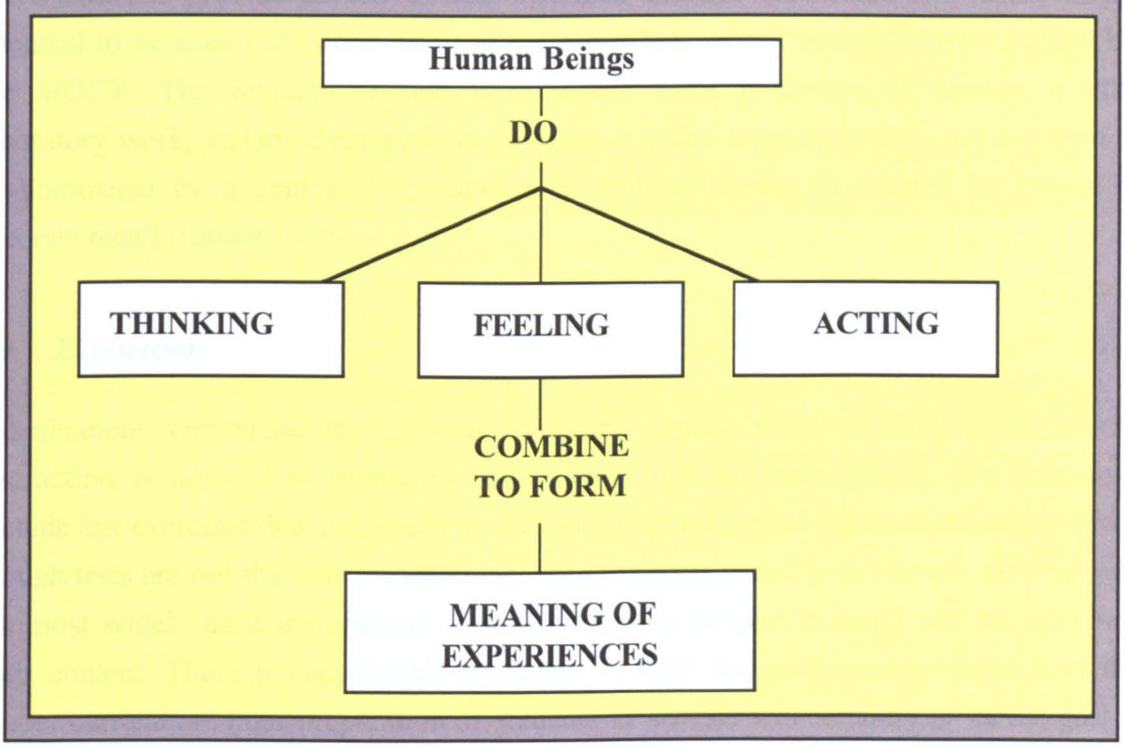


Figure 3.4: The meaning of experiences :thinking, feeling, and acting

(b) *Teacher*

The learning process in the present science education programme is based on the teacher - centred model (teachers represent the authority of knowledge in this model) in the Emirates. Instruction is, mostly, dominated by oral presentation of information from teacher to the students. In his study, Haidar (2002) identified that Emirates' secondary school science teachers lack an understanding of the social component of science and the ability to distinguish between science and technology.

(c) Knowledge (The Science Education Curriculum)

The science education curriculum at the Emirates is product of GASERC (The Gulf Arab States Educational Research Centre). The programme includes curriculum guides, subject matter textbooks, and accompanying teacher's guides. The curriculum is highly structured and directs the teacher about what and when to teach. Science textbooks were prepared to include condensed content knowledge, while both the processes and the nature of science are neglected. Nevertheless, there have been recent calls to incorporate the processes of science in the science curriculum The present curriculum ignores the social aspect and encourages students to adopt the traditional view about science, which is consistent with the positivist approach to science. This could, probably, explain why students see school science as irrelevant to their daily lives. The MOEY (Ministry Of Education & Youth) exerts effort to provide attractive, well-organized and free textbooks. The textbooks are intended to be used only once. Some of the secondary school textbooks were revised by the MOEY. The revision process incorporated some processes of science, a little laboratory work, and more engagement of students in the learning process but still tend to be dominated by a content laden approach, with emphasis on success by means of accurate recall (Haidar,1999).

(d) Evaluation

Examinations emphasise the process of giving regular tests. In fact, much of the instruction is devoted to preparing the students for the examinations. The textbooks include test exercises that are usually modelled by the teacher on these examinations. Even though tests are not the only measurement used to assess learning in schools, they are still the most widely used instruments. The curriculum is defined in major part by tests and their content. There is considerable emphasis on tests and examinations throughout the school curriculum. Poor preparation of students in science will certainly block the goal of the country's leadership to build a modern nation.

(e) Context

Context relates to the classroom environment, culture, and facilities. In the Emirates, science is taught in a way that does not encourage students to feel at ease in science classes. The learning environment is threatening. Although there is no empirical evidence for this issue, experience indicates that students' attitudes towards science are not positive. This can be seen by comparing the number of students enrolled in both science and art streams in secondary school. The facilities in the secondary school are adequate. The schools have science laboratories for each branch of science. The laboratories have student work stations so that student can engage in scientific inquiry. However, there appears to be a little evidence that these facilities are frequently used. Sometime the shortage of equipment and materials forces the teachers to do demonstrations rather than make the students work individually or in groups (Haidar, 1999).

Novak (1998) presented six fundamental principles that should be considered if learning is to occur properly:

(a) Motivate students to learn. No learning will take place unless the learner chooses to learn.

(b) Understand and engage the learner's existing relevant knowledge, both valid and invalid ideas.

(c) Organise the conceptual knowledge you want to teach.

(d) Consider what will be a facilitative context for educating - learning takes place in a context.

(e) Be sensitive (knowledge teachers) to the learner's ideas and feelings.

(f) Assess students' progress and further motivate the learner through this.

Novak's six principles need to be compared with the ten principles proposed by Johnstone. Based on empirical observation over more than 30 years, Johnstone developed the ten principles (sometimes known as the Ten Commandments - Gray, 1997) and used them to develop a new first year university chemistry course. The outcomes from research on this course showed the effectiveness of many of his ideas (Sirhan *et al*, 1999, Sirhan and Reid, 2001). Johnstone's ten principles (Johnstone, 1997) are summarised:

- *What you learn is controlled by what you already know and understand.*
- *How you learn is controlled by how you have learned successfully in the past.*
- *If learning is to be meaningful it has to link on to existing knowledge and skills enriching and extending both.*
- *The amount of material to be processed in unit time is limited.*
- *Feedback and reassurance are necessary for comfortable learning and assessment should be humane.*
- *Cognisance should be taken of learning style and motivation.*
- *Students should consolidate their learning by asking themselves about what is going on in their own heads.*
- *There should be room for problem solving in its fullest sense to exercise and strengthen linkages.*
- *There should be room to create, defend, try out, and hypothesise.*
- *There should be opportunity given to teach (You do not really learn until you teach).*

Johnstone based most of his work on an information model of learning and various models of this kind are now considered.

3.7 Information Processing Models

One of the characteristics of all information processing models is that they track the way information moves through the cognitive system. Making sense of conceptual material often demands that many ideas have to be held at once and information processing approaches have been found to be very useful in understanding the problems associated with such learning.

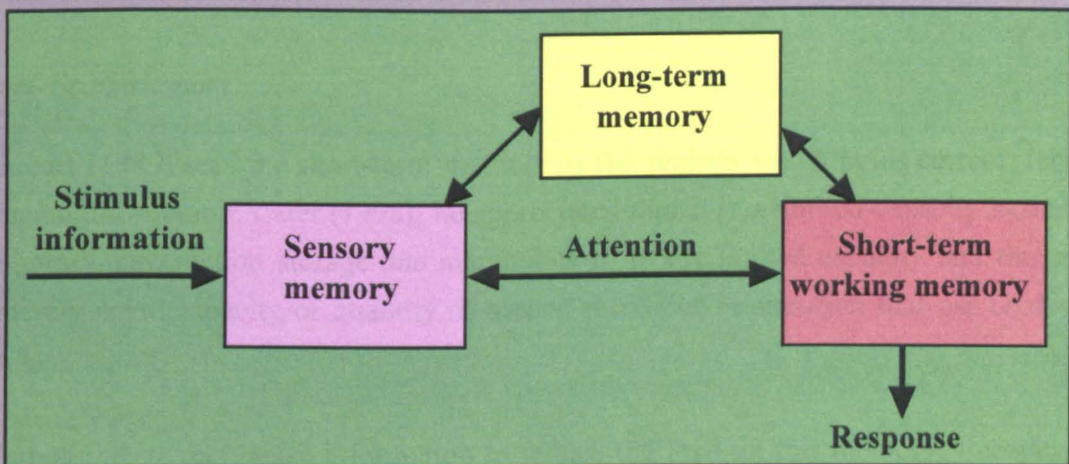
3.7.1 The Ashcraft Model

According to Ashcraft (1994), the modal model of human memory is divided into three types of information storage:

(1) *The Sensory Memory.*
(2) *The Short-Term Memory.*
(3) *The Long-Term Memory.*

Figure 3.5 shows the human information processing system according to Ashcraft (1998).

Figure 3.5 : ***The Human Information Processing System According to Ashcraft***



The Sensory Memory

In this model, Ashcraft (1998) indicates that:

(a) From the outside world information comes into the system through sensory memory, which is actually a bank of very brief memories, one for every sensory input system; they hold information briefly for further processing.

(b) Attention is the mental process that transfers these brief memories into short-term memory.

Alatzky (1975) has shown that our sensory memory consists of our sensory registers which are linked to the senses of sight, hearing, touch, smell, and taste. Psychologists have described the two types of sensory registers:

(1) The sensory register for vision, called the *icon*. For Neisser (1967), it is the system designed to receive and hold visual stimulation. About one quarter to one half of a second time duration of information is held in iconic memory.

(2) The sensory register for hearing (auditory), is called the *echo*. Neisser (1967) indicates that it is the memory component that receives auditory stimulation from the external environment. The time period during which information in auditory sensory memory is available is probably no more than 2 to 3 seconds.

Biggs & Moore (1993) have shown that, in any situation, we experience a huge variety of sensations and our five senses simultaneously deliver a massive amount of information, this being much more than we could possibly handle at any one time. The sensory register is where we pay attention by *selecting* information that is important to the individual. The sensory register functions to sort input information into important categories: what to attend to and what to ignore. In teaching, the teacher focusses on encouraging students consciously to want to attend, by using variability: in teaching approach, content, media and student-teacher interaction; and presentation of concepts is facilitated by using overviews and adjunct questions.

Short-Term Memory

Ashcraft (1989) sees the short-term memory as the register which holds current, recently attended information. Later (1998), he appreciated that it is a limited-capacity system for temporary information storage *and* manipulation. It has limited capacity and this is the relatively small capacity or quantity of mental resources or attention that can be devoted to a task.

It is possible to reorganise information to reduce the load on this memory. Recoding is a powerful device for overcoming the limitation in capacity. Short-term memory receives its information from the internal, mental world (the long-term memory) as well as from the external world (from the sensory registers). Information is encoded from sensory memory and from long-term memory. The trace duration of short-term memory information is about 15 to 20 seconds, longer if there is rehearsal.

The term working memory is used as a better description of the space formerly called short term memory. If the space is being used merely to hold information, then the term 'short term memory' is sufficient. However, most of the time, a person uses the space not only to hold information but also to process it in some way. The term 'working memory space' captures this dual function better. In his famous experiment of 1956, Miller has shown that the average capacity of the working memory space for an adult (over 16 years of age) is 7 and that most adults have working memory spaces between 5 and 9. His paper describes what he calls the "magic number of 7 ± 2" (Miller, 1956).

Long-Term Memory

According to the Ashcraft (1989), long-term memory is the ultimate destination for information we want to learn and remember: the memory system responsible for storing information on a relatively permanent basis.

A useful summary of the commonly accepted features of the three memory stores has been provided, in cases where the material to be remembered is verbal (Craik & Lockhart, 1972) - Table 3.1.

Table 3.1: Commonly Accepted Differences Between the three Storages of Verbal Memory.

Feature	Sensory register	Short term store	Long term store
Entry of Information	Pre-attentive	Requires attention	Rehearsal
Maintenance of Information	Not possible	Continued attention, rehearsal	Repetition organisation
Format of Information	Literal copy of input	Phonemic, probably visual, possible semantic	Largely semantic, some auditory
Capacity	Large	Small	No known limit
Information Loss	Decay	Displacement, possible loss	Deletion, loss of accessibility or interference
Trace Duration	0.25 to 2 seconds	Up to 30 seconds	Minutes to years
Retrieval	Readout	Proabably automatic, Consciousness Temporal, phonemic	Retrieval item cues, possible search process

3.7.2 The Johnstone Model

Johnstone (1999 b) has carried out a very large amount of work on learning in the sciences and much of his research has been based around two models. The first, *information processing* and the second, the *chemistry triangle*. The latter has already been presented in second chapter.

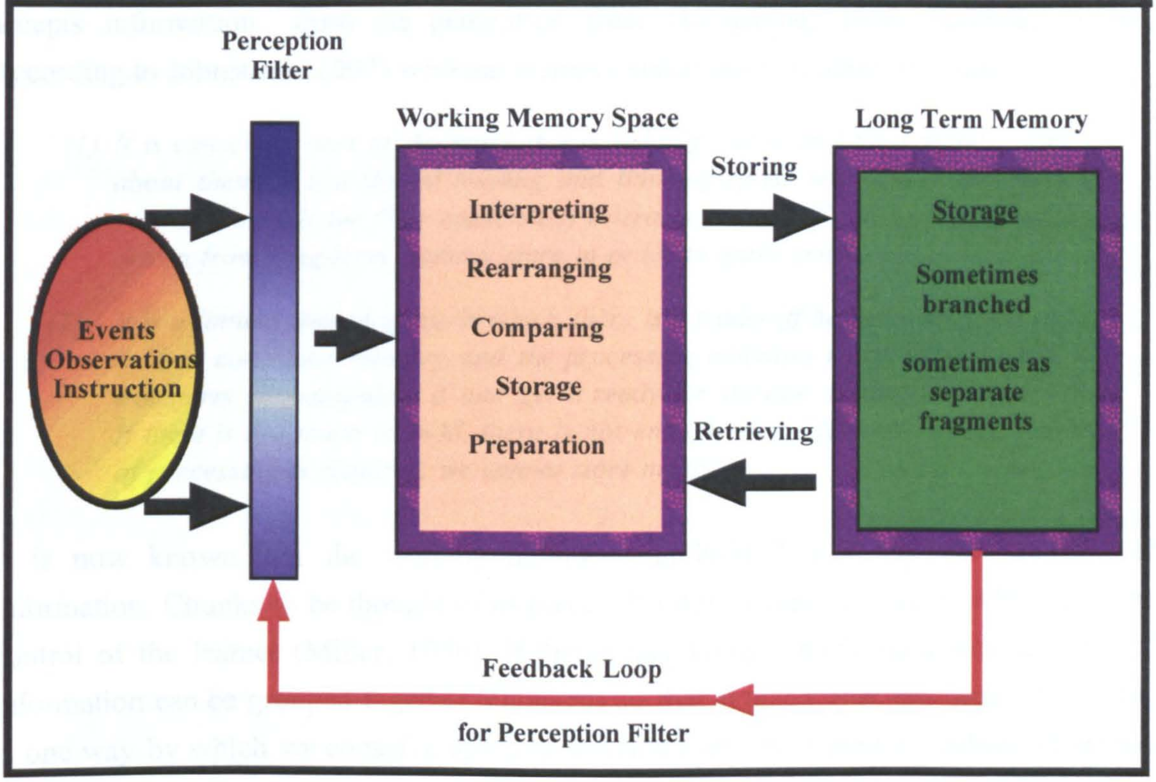
The information processing model is a model for learning which looks at how the learner takes information in and stores it (Johnstone, 1993). Johnstone developed his model from evidence from a very long series of experiments. The model often uses words derived from the way computers operate. Indeed, computer systems have offered insights into the way information can be handled as well as a language to describe what is happening. The model offers very useful insights into all learning but, unusually for educational models, it also offers predictions about what will happen if certain conditions are changed.

The model is described in terms of three 'parts' of memory, along the same lines as the modal model.

(a) *The Perception Filter*
(b) *The Working Memory Space*
(c) *The Long-term Memory*

The model (Johnstone, 1993) is shown in Figure 3.6 and then each feature is described in turn.

Figure 3.6 : *Information Processing Model According to Johnstone*



The Perception Filter

In figure 3.6, the sensory memory is renamed the perception filter. The perception filter receives signals from the outside world and admits some of them to the working memory. Clearly the perception filter is constantly bombarded by stimuli but an individual is able to select or filter out certain signals for further considerations. This filtering process is influenced or perhaps controlled by what is already held in the long term memory (LTM). This is consistent with what Ausubel had observed when he emphasised the importance of knowing what the learner knows already and how that learning was gained. Previous learning and experience control the perception filter and, hence, control what will be selected and then learned. White (1988) discusses the aspects of previous learning which will influence new learning and stresses that more than the cognitive is involved - interest, attitudes and abilities will also be involved.

Learning involves all areas of the information processing model and, as learning occurs, attitudes will be adjusted and so the perception filter will vary as part of the on-going development of the learner (Kempa and Nicholls, 1983).

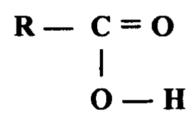
Working Memory Space

Working memory is of limited capacity and is where conscious thinking takes place, rather than in the long-term memory (Biggs & Moore, 1993). Also, it is the area which then accepts information from the perception filter (Johnstone, 1988; Baddeley, 1986). According to Johnstone (1997) working memory space has two main function:

> *"(1) It is conscious part of the mind that is holding ideas and facts while it thinks about them. It is a shared holding and thinking space where new information coming through the filter consciously interacts with itself and with information drawn from long-term memory store in order to make sense.*
>
> *(2) It is a limited shared space in which there is a trade-off between what has to be held in conscious memory and the processing activities required to handle it, transform it, manipulate it and get it ready for storage in long-term memory. If there is too much to hold, there is not enough space for processing; if a lot of processing is required, we cannot store much."*

It is now known that the working memory can hold 7 ± 2 separate 'chunks' of information. Chunks to be thought of as pieces of information, the size of which is in the control of the learner (Miller, 1956). If the learner knows much, then several items of information can be grouped together (chunked) so that it takes only one space. Chunking is one way by which we conserve space in working memory. Chunking subsumes several pieces of information under a single idea.

Johnstone's example (1974) of the functional group in organic chemistry is an excellent example of chunking. Before one learns the carboxylic acid (alkanoic acid) group, the information in the formula:



must be stored as a series of separate items:

> "R" connected to a carbon atom bonded to two oxygen atoms, one of the oxygen connected by a double bond and the other oxygen connected to the carbon and a hydrogen atom by single bonds.

However, the experienced chemist sees the carboxylic (alkanoic) acid group as one entity and describes the molecule as "R" connected to the carboxylic group. This illustrates how previous knowledge aids chunking and takes pressure of a limited working memory space. Indeed, it was Kellett's study on the way school students 'see' organic structures which offered the first clues about the basis of difficulties in chemistry. This led Johnstone to the Information Processing Model (Johnstone and Kellett, 1974 and 1980) and has offered a sound basis for understanding why a subject like chemistry can be difficult as well as ways by which the difficulties can be reduced.

When a person is working in a familiar problem area, much of the information used is likely to exist in chunks, and more space is available in working memory to deal with logical relationships and conditions that are unique to the problem at hand. However, when a person works in a unfamiliar area, less information is chunked, and the demands on working memory are increased (Herron, 1996), again emphasising the importance of the ideas of Ausubel.

In addition, chunking is important in communication, and therefore, in learning. When the teacher says: 'Concentrated Sulphuric acid is a powerful dehydrating agent', a student may think of the communication, and have constructed it as a small number of chunks. Thus: (Concentrated Sulphuric acid) (is a) (powerful) (dehydrating agent). The students, who have not learned as much may hear it is as rather more chunks: (Concentrated) (Sulphuric) (acid) (is a) (powerful) (dehydrating) (agent). It is likely that the latter student would experience working memory overload and would fail to register the full message (White, 1988). Biggs & Moore (1993) describe processes in working memory as Figure 3.7.

Figure 3.7 Processes in Working Memory

(1) ***Use imagery***: This method is suitable if it is only necessary to hold the material for 30 seconds, but, if you are distracted, the material will be dislodged from your working memory and it will be impossible to retrieve from long-term memory. For example, if you look up a phone number in the directory and then momentarily think of something else.

(2) ***Recycle***: Repeat the number for as long as necessary to finish dialling it, but not long enough to lodge the number in long-term memory.

(3) ***Rehearse***: Repeat the number until it is fixed in long-term memory.

(3) ***Code***: Link the number to another number. We already know our car registration number, or a telephone number, or the old-even code.

Long-Term Memory

Long - term memory or long-term store is a vast store where information inter-linked in huge association networks (Johnstone, 1997). The store contains information of two kinds; *Semantic* knowledge which is shared by most people, and is usually second-hand. Examples would be "Rome is the capital of Italy", "The boiling point of water is 100°C". The other material which is stored is *Episodic* and is made up of personal knowledge and experience. It is personal and may differ widely from person to person. It contains likes and dislikes, beliefs and prejudices, interests and aversions.

Long-term memory is a memory system that stores information over intervals longer than a few seconds (Green, 1996). It is a permanent repository of information which is accumulated over periods of days, weeks, months and years (Bruning *et al.*, 1995) and it is where information is stored on a permanent basis. From the beginning of life, learners are able to store associative information in long-term memory. Creating associations between events is part of the innate capabilities of the cognitive system. Long-term memory is not purely an associative system. However, association is simply part of the organisational foundation on which more complex types of information structures are built (Dockrell & McShane, 1992).

Biggs & Moore (1993) suggested three processes of long-term memory: *trace decay, interference and structural integration.* The most important determinant of what is remembered is what is already known. Information is dismembered and reconstructed along one or more of seven dimension *enactive, sensory, affective, temporal, spatial, semantic, and logical yielding variously procedural, episodic, and semantic memory.* Frequently school experiences isolate memory of the context from memory of content. Encoding is a process that the most critical transformation of the information occurs when it leaves the short-term memory and enters the long-term memory.

Johnstone's model indicates that, at a simple level, one could compare storage and recall to a filing system in which new information is related to existing files and placed there. If an incoming letter does not fit the system, a new file is created and cross-referenced or indexed in some way to facilitate its retrieval. It is very difficult to take over someone else's filing system and find things again. "Learning is not the transfer of material from the head of the teacher to the head of the student intact." (Johnstone, 1979).

Learning is, therefore, the *reconstruction* of material, provided by the teacher, in the mind of the student. It is an idiosyncratic reconstruction of what the student understands, or is thought to be understood, of the new material provided, tempered by existing knowledge, beliefs, biases, and misunderstandings in the mind of student. Storage refers to the holding of information that has been received by the individual (Hall, 1982). In addition, Johnstone (1997) indicates that storage can take place in at least four ways:

(1) "The new knowledge finds a good fit to existing knowledge and is merged to enrich the existing knowledge and understanding (correctly filed).

(2) The new knowledge seems to find (or at least a reasonable fit) with existing knowledge and is attached and stored, but this may, in fact, be a misfit (a misfiling). These misfits often have a semantic origin.

(3) Storage can often have a linear sequence built into, and that may be sequence in which things were taught.

(4) The last type of memorisation is that occurs when the learner can find no connection on which to attach the new knowledge".

Ausubel has grouped these types of learning between two ends of a spectrum. The first, described above, in which new learning links correctly to old knowledge and under standing, is called meaningful learning. Whereas, the last types, mentioned above, is called rote learning. The second is the basis of alternative conceptions or misconceptions.

Waugh and Norman (1965) used the term "*secondary memory*" to refer to long term memory and Eysenck (1977) indicates that the capacity of long term memory is essentially unlimited, with forgetting being determined by interference (Gagne, 1977) between newer and older memories which may block the accessibility of stored information. The phenomenon of forgetting may be due to the ineffectiveness of retrieval processes.

In the Emirates, one of the educational zones has conducted some research to know how much knowledge is left in students 'long-term memory'. At the beginning of the school year, the zone contacted parents of first ranked students in all secondary schools classes. They informed parents that their sons would retake exams on materials they learned last year. The exams were administered and graded. The results were surprisingly low: as reported first students failed to pass the repeated exams. This confirmed concerns about the quality of the science education program in Emirates (Haidar, 1999).

3.8 Conclusions

- The Piagetian model adopted an 'age-stage' approach in its attempt to explain how children attain concepts of different levels of abstraction. It assumes that all individuals pass through the same successive stages, however overlapping they are. These stages are characterised by the ability to perform at certain level of mental operations. An individual cannot deal with a relatively higher level of learning tasks until his growth reaches the corresponding stage. It becomes clear, however, that neither the mental nor the chronological age seems to be more important than the other. This reveals that it is pointless to try to teach abstract conceptual material at too young an age.
- Because science involves making discoveries, there is a temptation to think of discovery learning being the best way to teach the sciences. This confuses two separate issues and it has to be recognised that reception-learning is not as inferior as it is sometime thought to be. One of Ausubel's most useful insights was the distinction between the rote-meaningful continuum for learning and the reception-discovery continuum for presentation of school subject material.
- A concept can be taught effectively through a reception learning approach, provided

that it is made meaningful to the learner. However, it is important to emphasise *meaningful* learning. This means that ideas have to be linked carefully and time must be offered for meaning to be established. It is also essential that assessment tests for understanding and not just for recall skills.

- The Emirates science education programme uses Novak's model of the five elements of education: Learner, Teacher, Knowledge, Context, and Evaluation. This model may be useful for pinpointing five key aspects of the teaching and learning situation. It does not offer clear guidelines on its own for the best way forward.

- Long-term memory controls the perception filter. In the learning process, the learner responds and then attends to information which has some positive connection with what is already known. Thus, the starting point of learning should be what students already know. Johnstone (1997) stated ' You may be the provider of stimuli during teaching, but how does the student filter what you provide? If essential previous knowledge or concepts or language is missing, how will this affect what your students take out of what you say?'.

- Johnstone (1997) stated that, 'giving more may mean learning less' . Because the working space has limited capacity, it can be overloaded easily. There are strategies for using working memory more efficiently but these are not easily taught. One of the ways is to be able to chunk information. It is important that teachers seek ways by which information can be chunked and to present materials using such ways. However, what is held is long term memory (knowledge and experience) offers the most powerful tools for chunking, another reason why knowledge of what the learner knows already is so important.

- Consolidation is very important to avoid forgetting. It is achieved through confirmation, correction, classification, differential practice and review in the course of repeated exposures with feedback, to learning material. The teacher should encourage the learner to understand and not to memorise concepts by using linkage between the symbolic and representation level of teaching material. There must be enough time allowed for thought, discussion, expressing ideas.

- It is important to help students to activate and use their relevant knowledge in new learning material. These provide more and stronger links with existing networks' knowledge as is supported by the theories of "meaningful learning" and "conceptual learning" by Ausubel *et al* (1978). Thus, students learn more effectively when they already know something about a content area and when concepts in that area mean something to them and to their particular background or culture. When teachers link new information to the students' prior knowledge, they activate the students' interest and curiosity, and infuse instruction with a sense of purpose.

Chapter Four

Attitudes to Chemistry

4.1 Introduction

The concept of 'attitudes' has long since been one of the most generally applied concepts, used widely by psychologists and sociologists (Allport, 1935; Ajzen, 2000). Shared understandings are common to all interpretations (Ajzen & Fishbein, 1980).

This chapter provides an overview of what attitudes are, attitude change and development, attitude towards science and chemistry, attitude and behaviour, and how to measure attitudes.

4.2 What are attitudes?

The concept of attitude has played an outstanding role throughout the history of social psychology. Many early theorists virtually defined the field of social psychology as the scientific study of attitudes (Ajzen & Fishbein, 1980). Amajor issue when considering the term "attitude", is its definition and this has been used differently by various researchers (Johnstone & Reid, 1981).

One of the first researchers to employ the term "attitude" was Herbert Spencer (1862, quoted by Ajzen & Fishbein, 1980), who argued that ''arriving at correct judgements on disputed questions much depends on the attitude of mind we preserve while listening to, or taking part in, the controversy". This definition is the most widely quoted one although new ideas have emerged later.

In 1901, Baldwin defined an attitude as "readiness for attention or action of a definite sort". In 1918, Thomas and Znaniecki were the first to use the attitude concept to explain social behaviour. However, they viewed attitudes as individual mental processes that determine a person's actual and potential responses. The 20s and 30s saw a new change in definition.

In 1928, Thurstone described an attitude as ''the affect for or against a psychological object'', while, three years later, Likert (1932) used a much less precise definition, referring to a "certain range within which responses move". Allport (1935) gave a definition which combines both of these ideas when he talked about "a mental and neural state of readiness to respond, organised through experience, exerting a directive and / or dynamic influence on behaviour". His definition has stood the test of time and has influenced many future thinkers and researchers. By the mid-century the debate had erupted with new definitions.

In 1943, Newcomb used an attitude as "a readiness for motive arousal". In 1946, Krech took a new approach suggesting that attitudes are to be regarded as aspects of learning - in particular, of problem solving: attitudes are "attempts at solution". Doob (1947) pursued this viewpoint further by suggesting that theories of learning apply also to attitude development. Three other definitions stressed the affective nature of attitudes. In 1954, Katz and Sarnoff talked about a, "stable or fairly stable organisation of cognitive and affective processes". In 1958, Rhine referred to an attitude as a "concept with an evaluative dimension", and Triandis in 1971, spoke of an attitude as "an idea charged with emotion". In 1948, Krech & Crutchfield described aspects of attitudes as ''motivational, emotional, perceptual and cognitive''.

These contributions have stressed that attitudes involve more than the cognitive and, in particular, the "evaluative dimension" proposed by Rhine has assumed greater importance in later work. In some ways, this is what distinguishes an attitude from other latent constructs. A person may know, may have feelings or may experience. However, it is possible that these may lead to *evaluation* and this may lead to subsequent decisions. Thus, for example, a school student may have studied some chemistry. In doing this, he gains knowledge of chemistry and of the learning of chemistry. He may come to have negative feelings towards chemistry and the acquisition of chemical ideas. Indeed, the behaviour demanded of him in such studies may be objectionable in his eyes. Overall, he has developed a negative attitude towards chemistry and study in chemistry, such an attitude being expressed in negative evaluations of aspects of chemistry learning. In turn, such an attitude may lead him to reject further studies.

Osgood *et al.* (1957), referred to attitudes as "tendencies of approach or avoidance", or as "favourable or unfavourable". In 1959, Katz and Stotland saw an attitude as "a tendency or predisposition to evaluate an object or symbol of that in a certain way", and an attitude as necessarily having both an affective component and a cognitive component, and behavioural component only if a person engaged in action vis-a-vis the attitude object. This brought together many previous ideas. This left the second half of the century open to analysis of the definition.

In 1962, Fishbein and Raven referred to an attitude as "an implicit evaluative response", again picking up the 'evaluative' idea. Defleur and Westie (1963) expressed disquiet against the dominant theme that attitudes are latent constructs. Instead, they argued for precise attitudes to specific social objects in specific situations, as defined by a particular measuring technique. Cook and Selltiz (1964) appreciated that attitudes, on their own, do not control behaviour.

Rokeach (1968) define an attitude as "a relatively enduring organisation of beliefs around an object or situation predisposing one to respond in some preferential manner". According to Klausmeier (1977), the word attitude is used not only to describe the variegated emotional states of individuals, as well as identifiable public, which are used to communicate significance among individuals that speak the same language. In 1984, Roediger *et al.*, defined attitude as "a relatively stable tendency to respond consistently to a particular object". These contributions emphasised the fact that attitudes tend to have features of some stability. They tend to lead to certain relatively consistent patterns of behaviour.

In reviewing the literature, Reid (1978) noted that attitudes have three components:

(1) A knowledge about the object, the beliefs, ideas components (Cognitive).
(2) A feeling about the object, like or dislike component (Affective).
(3) A tendency-towards-action the object component (Behavioural).

Taking a similar line, Bagozzi and Burnkrant (1979) described attitude as the interplay of affect and cognition, with tendency to behave as a secondary consequence. Ajzen & Fishbein (1980) imply that a complete description of attitude requires all three components:

(1) The affective component is the emotional (like-dislike) component of an attitude.
(2) The behavioural component is the overt behaviour attached to our internal attitude.
(3) The cognitive component is the storage component where we organise information about an attitude object.

McGuire (1985) also noted that an attitude has three dimensions as follows: cognitive, affective, and cognitive.

Judd *et al.*, (1991) viewed attitude as "evaluations of various objects that are stored in memory". According to Thurstone (1928) quoted by Goncalez (1995), attitude is "the total sum of inclinations and human feeling, prejudices or distortions and preconceived notions, ideas, fears and convictions regarding a certain matter". In 1996, Brito defined an attitude as a "personal inclination, idiosyncratic, present in all individuals, directed to objects, events or people, that takes on a different direction and intensity according to the experiences each individual has had".

The various definitions of attitude reflect the psychological backgrounds of the writers.

Although they refer latent constructs, cognitive processes, or behavioural as bases for definitions.

4.3 Attitude Change and Development

As understandings developed through social psychological research, attitudes were seen as being related to the cognitive, affective and behavioural and offering some kind of reasonably stable evaluation of events, situations and people. More recent work has explored the idea of attitude strength. Krosnick and Petty (1995) define attitude strength in terms of two parameters: stability and crystallisation. In their view, strong attitudes should be stable and should have a strong impact on judgements and behaviour. Krosnick and Abelson (1976), however, argue that a group of variables are treated as indicators of attitude strength. It is accordingly of general importance that Bizer, Visser, Berent, and Krosnick (2003) show that these different variables do not measure the same attribute. It follows that they cannot be equivalent indicators of attitude strength. Bizer and his colleagues then make an argument that these variables should instead be viewed as possible causes of crystallisation or stability and, thus, as indirect causes of attitude strength. In a set of analyses the authors look at possible causal relationships among the different variables in the set. In doing so they show, for example, that the variables "importance of an issue" and "knowledge of the issue" have different causes and have different effects on other variables.

Despite the tendency to be consistent, attitudes are open to development and change. Much work looked at the processes which allowed attitude change to occur. Developmental change means doing something the same way, but better, using a technique such as process reengineering. Transitional change means finding a new way to do the same thing, such as automating a process. It also means doing something different by creating new structures and new processes to fit new objectives. There are three elements to be considered in developing a successful change strategy: people, process, and structure. Thought should be given to both the skills and the attitude of people involved. The process should take into account the stake holders, time frame, context, and outcome. The formalised relationships and organisational imperatives through which work gets done the structure should be flexible enough to be reconfigured and reshaped as needed with changing circumstances (Jurow, 1999).

The two extreme processes creating attitude change are:

Internal:	*attitude change occurs through motivation, desire and control of the individual.*
External:	*attitude change arises through outside pressure, forcing a change in attitude and is not always under the control of the individual.*

When the internal process is not in agreement with the external process, there is conflict and so dissonance occurs within the individual. Dissonance is a psychological state arising when new contradictory information disrupts the existing equilibrium amongst elements of the cognitive system: leading to internal inconsistencies. This is an uncomfortable state. A little more than 40 years ago, Leon Festinger (1957) published "A Theory of Cognitive Dissonance" . Festinger's theory of cognitive dissonance has been one of the most influential theories in social psychology (Jones, 1985). It has generated hundreds and hundreds of studies, from which much has been learned about the determinants of attitudes and beliefs, the internalisation of values, the consequences of decisions, the effects of disagreement among persons, and other important psychological processes.

As presented by Festinger in 1957, dissonance theory began by postulating that pairs of cognition (elements of knowledge) can be relevant or irrelevant to one another. If two cognition are relevant to one another, they are either consonant or dissonant. Two cognitions are consonant if one follows from the other, and they are dissonant if the obverse (opposite) of one cognition follows from the other. The existence of dissonance, being psychologically uncomfortable, motivates the person to reduce the dissonance and leads to avoidance of information likely to increase the dissonance. The greater the magnitude of the dissonance, the greater is the pressure to reduce dissonance.

There are three ways to reduce dissonance:

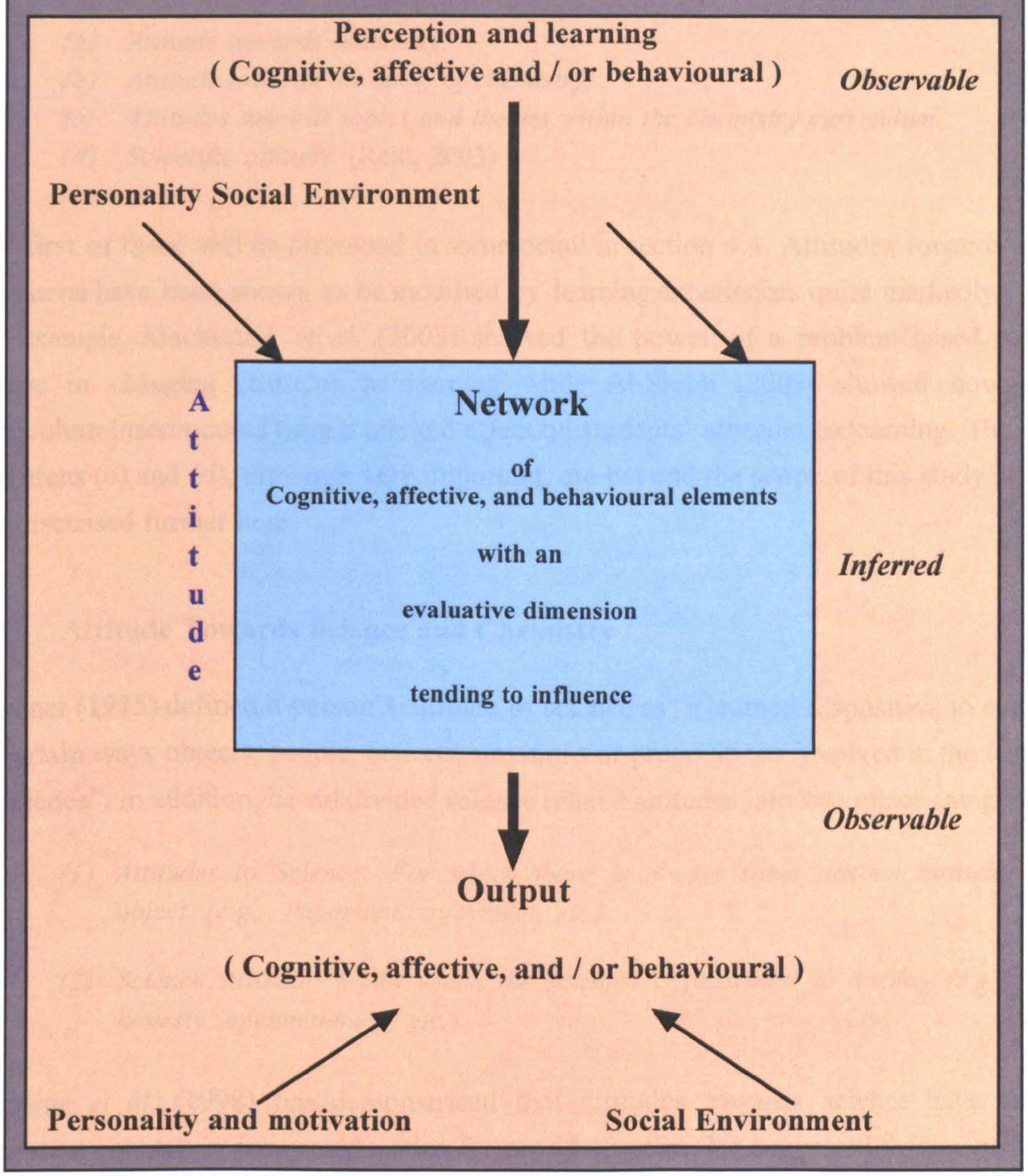
(1) *Change existing elements of knowledge to make the earlier cognitive system, and newly obtained knowledge, consistent. Many lead to change in both attitude and behaviour.*

(2) *Find, and accept, the consistent elements from the source of dissonance: does not, in general, lead to attitude change.*

(3) *Deny the importance of the new cognition. Attitude is not changed but earlier attitude becomes even stronger (Festinger, 1957).*

Using what was known in 1978, Reid attempted to define an attitude pictorially (Reid, 1978). Many years later, he adjusted his definition slightly to take into account further contributions from the research literature (Reid 2000). This is shown in figure 4.1

Figure 4.1 : Model of Attitudes



An attitude is defined by what is in the box but the model shows the influences on attitudes and the effects of attitudes. Figure 4.1 takes into account the cognitive influences in attitude development, the construct nature of attitudes, and the readiness to respond to outcomes. It also warns against deducing an attitude from behaviour patterns: attitudes have a functional purpose, but circumstances of personality and social environment may so alter behaviour (by, for example, suppressing behaviour or bringing about compartmentalisation of attitudes) that behaviour may have little connection with any real, underlying attitudes.

It is important to recognise that there has to be an object for each attitude. In other words, a person has an attitude to 'something'. In the context of chemistry education, there are four possible attitude objects:

(a) Attitude towards chemistry;
(b) Attitude towards the study of chemistry;
(c) Attitudes towards topics and themes within the chemistry curriculum.
(d) Scientific attitude. (Reid, 2003)

The first of these will be discussed in some detail in section 4.4. Attitudes towards study in general have been shown to be modified by learning experiences quite markedly. Thus, for example, Mackenzie *et al.* (2003) showed the power of a problem based medical course in changing attitudes to learning while Al-Shibli (2003) showed how small curriculum inserts could have a marked effect on students' attitudes to learning. The other two areas (c) and (d), although very important, are beyond the scope of this study and are not discussed further here.

4.4 Attitude Towards Science and Chemistry

Gardner (1975) defined a person's attitude to science as "a learned disposition to evaluate in certain ways objects, people, actions, situations or propositions involved in the learning in science". In addition, he subdivided science related attitudes into two major categories:

(1) Attitudes to Science: For which there is always some distinct attitude object. (e.g.., important, enjoyment, etc.).

(2) Science Attitude: Styles which the scientist is presumed to display (e.g., honesty, openmindness, etc.).

Osborne *et al*, (1998) has demonstrated that attitudes towards science have been a persistent concern in science education for nearly 40 years. He suggested three aspects:

(a) Attitude to science in society.
(b) Attitudes to school science.
(c) Attitude to scientific careers.

Various studies have looked at potential factors which might be thought to influence student attitudes towards the sciences.

(1) Gender

There is much evidence to suggest that there are gender differences in attitudes towards science. Wood (1990) discusses the effects of gender on subject choice. Gender is a complex issue as there are also interactions with race and social class. Sekwao (1992) found that boys in all schools in Tanzania had more positive attitude towards science than the girls. Colley *et al.*, (1994) found that boys preferred science but girls preferred English and the Humanities in England and Wales. However, Barber (1994) reports evidence that girls in England and Wales now are achieving better results at GCSE and A level than boys even in science.

In Scotland, a major study was conducted by Skryabina on attitudes to physics. In this, she also explored gender (Reid and Skryabina, 2002 a, b). She found that, in the context of the Scottish situation, the differences in attitude were not all that common and that, although the areas of interest of boys and girls did differ, the overall attitudes tended to be somewhat similar. This may reflect a school curriculum structure where serious attempts were made to make it gender neutral. However, she did not explore attitudes towards chemistry.

In Switzerland, Roten (2004) found that men have more positive attitudes toward science and greater levels of scientific knowledge than women, gender differences are non significant once the sociodemographic variables are included in the multiple regression models. More specifically, scientific knowledge and education have an independent effect on attitudes toward science.

(2) Perceived difficulty

Several studies in England and Wales conducted over last 20 years have discovered that "science is perceived as difficult by young students and suggested that chemistry and physics [at school] are only taken by students who do well and are not taken as incidental or additional subjects" (Osborne *et al*, 1998). Judging by the Skryabina study in Scotland, the situation there is very different. Chemistry and Physics are popular subjects taken by many students at all levels. This suggests that difficulty and positive attitudes are not so easily correlated.

(3) Effective teaching

Woolnough (1994) identified that good teaching was characterised by teachers being enthusiastic about their subject, setting it in everyday contexts and running well ordered and stimulating science lessons. Good science teaching is a formative influence on attitudes towards school science. Wood (1990) has investigated the characteristics of teachers valued by students, and he found that, for both sexes, dislike of a teacher led to dislike of the subject "at least temporarily". Reid and Skryabina (2002 a, b) found that the teacher was a very important factor in encouraging positive attitudes towards physics, especially for the girls.

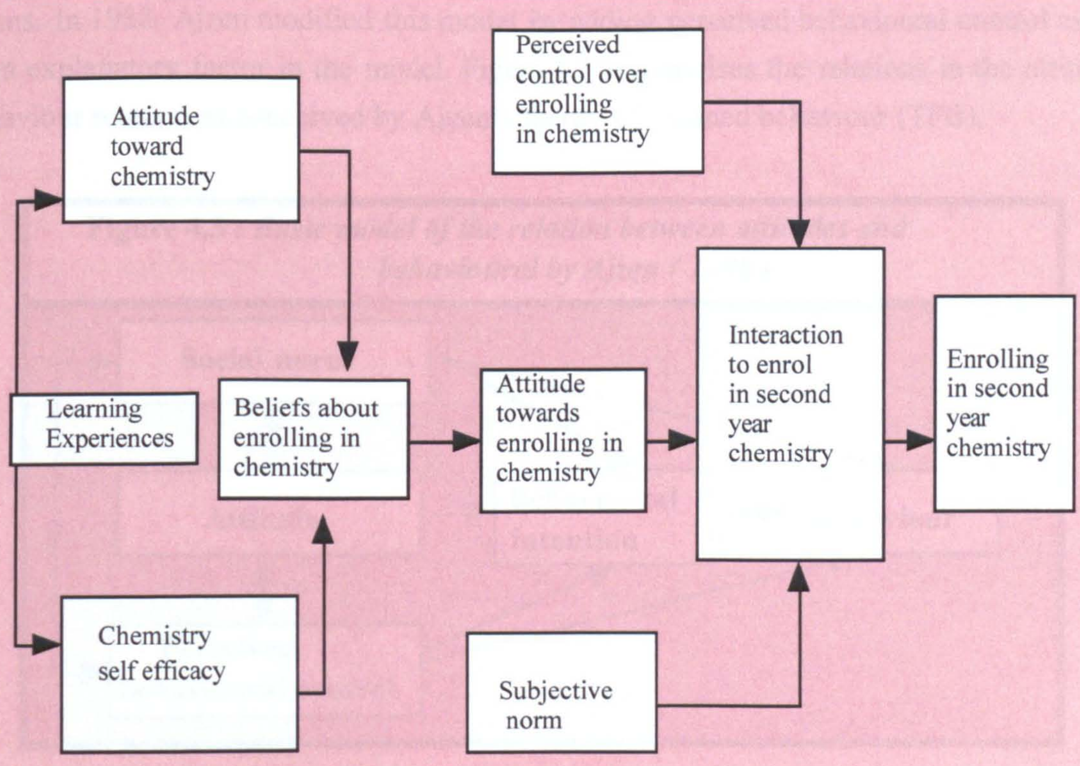
Overall, it is reasonable to suggest that effective teaching in chemistry means: (a) students should be given opportunities to experience and explore chemistry ; (b) Students should be encouraged to think and reflect about their chemistry understanding ; and (c) Students should be given opportunities to exchange their ideas.

(4) Students' background

The influence of ethnic and home background seems to have some effect on students' attitudes to science. Asian students (including Emirates students) have a clear preference to study engineering, mathematics or medicine related subjects. Asian parents have a particularly important influence on students career choice (Osborne *et al*, 1998).

Coll *et al.* (2002) described and developed the Chemistry Attitudes and Experiences Questionnaire (CAEQ). The focus of the CAEQ is on the antecedents of attitude towards enrolling in chemistry: namely, their learning experiences, attitudes towards chemistry and self efficacy in chemistry. Figure 4.2 shows the theoretical framework used in the development of the CAEQ.

Figure 4.2 : *Theoretical framework used in the development of the CAEQ*



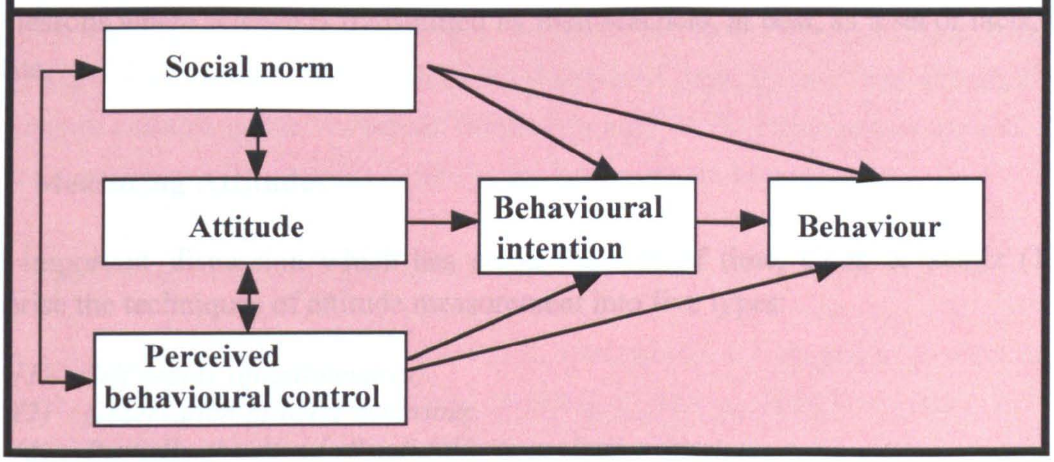
The approach adopted by Coll reflects the psychological tradition of attitude scaling. This method is highly suspect when applied to educational situations where a clearly defined latent construct is not usually relevant. The method has been criticised thoughtfully by Johnstone (1984) and, briefly, by Reid (2004). Quite apart from the suspect methodology, the outcomes from such scales tend to obscure important detail and, frequently, such approaches yield little of importance.

It is interesting to note that Reid and Skryabina (2002 a, b) did not use such an approach and her study yielded a large range of highly useful and applicable insights. For example, in her study, she found that there were three major factors which influenced school students to continue with physics: their school experience in physics, their school teacher, and the perceived potential for careers. This outcome confirmed a much earlier study in Scotland where the first two factors were clearly observed, the social context at that time making careers in the sciences less problematic (Hadden and Johnstone, 1983).

4.5 Attitudes and Behaviour

One of the main discussion topics in the long history of attitude theory has been the relation between attitudes and behaviour. Also, one of the most generally accepted models of the relation between attitudes and behaviour was drawn by Fishbein & Ajzen (1975). They found that behaviour is rather well predicted from behavioural intentions. These behaviour intentions were in turn explainable and predictable from attitude and social norms. In 1988, Ajzen modified this model by adding perceived behavioural control as an extra explanatory factor in the model. Figure 4.3 summarises the relations in the attitude behaviour relation as conceived by Ajzen's theory of planned behaviour (TPB).

Figure 4.3 : ***Basic model of the relation between attitudes and behavioural by Ajzen (1988)***



Thus. according to the Theory of Planned Behaviour, an individual's behaviour is influenced by their attitude toward that particular behaviour, their associate's (e.g. peers, family and mentors) attitude toward the behaviour, and the individual's control over the behaviour (Ajzen, 1989).

Wood (1990) found that attitudes are not fixed and student's behaviour in relation to certain aspects of school may influence the formation of their subsequent attitudes. This results in a complex relationship between attitudes and behaviour where the intersection is not in one direction. He suggests that students attitudes are responses to environmental features yet students participate in shaping the environment as they endeavour to cope with school. Schunk (1992) supports this view when he states that students "affect classroom events as much as they are affected by them".

Thus, students' attitudes to chemistry will affect their ability to learn in the classroom and will contribute to the learning environment favourably or adversely depending on their relative positive or negative states of mind. Similarly, the quality of provision including teaching methods and standard of laboratory will affect students. The students and their learning environment interact culminating in a successful or poor learning outcome.

Thus, overall, attitudes to chemistry is one component - an important component - in determining whether students will choose to study chemistry at some stage. Difficulties in chemistry are not neatly related to attitudes although, where the chemistry experience is found very difficult, positive attitudes will fall. A satisfactory and meaningful experience of chemistry seems to be a major factor in developing positive attitudes and the role of the teacher is an important element in this. There are some teachers whose attitudes are positive towards the promotion of good science teaching-learning situations, for most students, in many countries. However, there are others teachers who have negative attitudes towards teaching science, so that the reality of the school classroom consists of many lessons where science is transmitted by their teachers, at best, as a set of facts, laws and data.

4.6 Measuring Attitudes

In an important discussion which has stood the test of time, Cook & Selltiz (1964) categorise the techniques of attitude measurement into five types:

(1) Self report (questionnaires).
(2) Observation of overt behaviour.
(3) Partially structured stimuli (akin to projective tests).
(4) Performance of tasks (congenial material learned rapidly).
(5) Physiological tests.

In the context of education, questionnaires and interviews (both essentially self report measures) are the most important methods of attitude measurement. The major questionnaire approaches are:

(a) Thurstone's Method Of Equal-Appearing Intervals

Thurstone was born in 1887 and started his academic studies in electrical engineering at Cornell University and he continued his studies at University of Chicago in social psychology. His innovations in design and development of motion picture equipment led to an offer to work with Thomas Edison (Thurstone, 1931). The first major technique of attitude measurement was developed by Thurstone, in 1929, and he was the first to make extensive use of attitude questionnaires. Thurstone's scaling was constructed in these steps:

(1) Specification of the attitude variable to be measured.
(2) Collection of a wide variety of opinions relating to the specified attitude variable.
(3) Editing this material for a list of about 100 statements of opinion.
(4) Sorting the statements into an imaginary scale representing the attitude variable. This should be done by about 300 readers (judges).
(5) Calculation of the scale value of each statement.
(6) Elimination of some statements by the criterion of ambiguity.
(7) Elimination of some statements by the criterion irrelevance.
(8) Selection of a shorter list of about 20 statements evenly graduated along the scale. (Thurstone, 1928)

A few psychologists, including Likert, had criticisms of Thurstone's Method. They argued that method was laborious and time-consuming and that the scale values of the statements were independent of the attitude distribution of the readers who sort the statements (Likert, 1932). In general, this scale is rarely used in current advertising and marketing research due to cost and time considerations. However, its historical value and influence on other methods is immeasurable. Thurstone demonstrated that attitudes could be measured and this started to break down the views of the behaviourist psychologists who had long argued against the possibility of measuring latent constructs.

(2) Likert's Method Of Summated Ratings

Rensis Likert (1932) was born in 1903 and received an AB degree in economics and sociology in 1922. After that he studied psychology at Columbia University, where he received his PhD in 1932.

The Likert technique is one of the most popular attitude measuring tools. The technique involved assigning values from 1 to 5 to each of the five different positions on the five point system. The 1 end was always assigned to the negative end of the scale and the 5 end to the positive end of the scale. The subject is given a statement that is a judgement of value rather than a judgement of fact. Theses statements have to do with wants, desires, cognitive dispositions of the subjects, not with their opinions regarding matters of fact. After each of these value statements were five responses typically follow patterns like:

Strongly Agree ...... Agree ...... Uncertain ...... Disagree ...... Strongly Disagree

Originally, (Likert, 1932) allocated a scoring system (on a 7 point scale for a positive statements) as follows:

+3	Strong agreement
+2	Agreement
+1	Mild agreement
0	Nor disagreement
-1	Mild disagreement
-2	Disagreement
-3	Strong disagreement

(Reid, 1978) outlined some of the main problems with the Likert scale approach. The method makes numerous assumptions, some of which are not sustainable. It assumes that the spacing between the points on the scale in each question are the same and that it is valid to add up scores between items simply on the basis of correlation. It is possible (indeed highly likely) to have two items which are highly correlated but which are asking completely different questions. In addition, it is not appropriate to use Person correlation in that this method is based on an assumption of an approximation to normality. A simple inspection of distributions reveals that this is often not true.

Finally, two candidates may obtain the same score by entirely different combinations of item scores - their attitudes cannot be said to be the same and yet they have the same score. This is part of the fundamental weakness of using the Likert method as the basis of an attitude scale in that important detail is lost in an adding process.

However, it is possible to use the method without adding up the scores on items. Each item is analysed separately. In modern times, many marketing researchers use the Likert scale to test attitudes without using his summated rating method. Nevertheless, the scaling method has been used in the field of attitudes to science. Brown & Davis (1973) used this technique to construct five sub scales each relating to an attitudinal objective laid down for students in the first two years of secondary education in Scotland. Interestingly, they came up with few significant results. Almost certainly, important detail was lost in the adding process.

(3) Guttman's Scalogram (Cumulative Scales)

Guttman's scaling was developed in the 1940 and is a technique of mixing questions up in the sequence. It is based on the assumption that a single, unidimensional trait can be measured by a set of statements that are order along a continuum of "difficulty of acceptance". The statements range from those that are easy for most people to accept to those that few persons would endorse (Zimbardo *et al.*, 1965). Guttman's technique is one of the so-called interlocking methods: if statements and persons who score on them vary jointly according to some attitude and we can measure a person on that attitude based on the person's measure on the statement then we have a scalogram. Guttman's scale measures one attitude through a set attitude statements (unidimensional).

Person / response pattern (row) x item (column) matrix
Perfect scale = perfect triangular pattern

Overall, this method is summarised as follows:

1- Collect statements .
2- Obtain responses (100 or more per sample).
3- Order (measure) statements by free (20% trim on each end).
4- Person x item.
5- Count errors and calculate coefficient of reproducibility R, if R >= 0.9, reduce statement (~ 10) to make a scale. *(Dawes, 1972)*

In particular he has developed new theories and applications for social attitudes, intelligence tests, and other aspects of human behaviour. Surprising as it may sound Guttman's main interest was in theory rather than method. In fact, he saw the two inseparable arguing that 'the form of data analysis is part of the hypotheses'. His method is rarely used today.

(4) Osgood's Method Of Semantic Differential

The psychologist and communications scholar Charles E. Osgood developed work in the measurement of meaning connotation . His concern was with semantics and he devised a method to plot the differences between individual's connotations for words and thus map the psychological 'distance' between words. Osgood's method is known as the 'Semantic differential'. Osgood wanted to create a scale that accurately mapped identification and localisation of attitudes in a subject's process. He said "Our work in semantic measurement appears to suggest such as identification: if attitudes is, indeed, some portion of the internal meditational activity, it is, by inference from our theoretical model, part of the semantic structure of an individual, and may be correspondingly indexed" (Osgood *et al.*, 1957). The Semantic Differential was not originally developed for attitude measurement but has been proved to be a useful measure of attitudes.

Reid (1978) used phrase pairs that are opposite in meaning and these phrase pairs are evaluative comments on the attitude object. A series of unlabelled boxes (anything from 3 to 7 in number) is placed between the word pairs and responses are made by ticking the box that most fits the subject's opinion. This method is more limited than the Likert approach because words or short phrases only are used but it is faster for students to respond.

Here is an example from Reid's (2004) evaluative phrase pairs below:

What are your opinions about your laboratory experiences in chemistry ?
Tick ONE box on each line.

Useful	☐ ☐ ☐ ☐ ☐ ☐	Useless
Not helpful	☐ ☐ ☐ ☐ ☐ ☐	Helpful
Understandable	☐ ☐ ☐ ☐ ☐ ☐	Not understandable
Satisfying	☐ ☐ ☐ ☐ ☐ ☐	Not satisfying
Boring	☐ ☐ ☐ ☐ ☐ ☐	Interesting
Well organised	☐ ☐ ☐ ☐ ☐ ☐	Not well organised
The best part of chemistry	☐ ☐ ☐ ☐ ☐ ☐	The worst part of chemistry
Not enjoyable	☐ ☐ ☐ ☐ ☐ ☐	Enjoyable

Osgood *et al.*, (1957) has indicated that three major factors of dominant, independent dimensions that people use in judging concepts. He refers to these dimensions as:

Evaluative factors: These consist of evaluation statements such as: good- bad, hot cold, smooth -rough.

Power factors: These measure power and potency of judgmental connotation such as: strong-weak.

Activity factors: These measure judgements such as: active-passive, tense-relaxed.

Reid (1978) used this method based on 4 to 7 point scales, with bipolar pairs placed at opposite ends of the scale. Here is an example of the instructions he used with students.

quick	☑ ☐ ☐ ☐ ☐ ☐	slow
important	☐ ☐ ☑ ☐ ☐ ☐	unimportant
safe	☐ ☐ ☐ ☐ ☑ ☐	dangerous

The positions of the ticks between the word pairs show that you consider it as <u>very</u> quick, slightly more important than unimportant and <u>quite</u> dangerous.

Osgood's technique has been found to be reliable (Osgood *et al.* 1969). Also, it has been claimed by Brunton (1961) that this technique's validity appears to be high, based on its high correlation with scores obtained by traditional Thurstone, Likert and Guttman type of scale.

This method has many of the same problems as the Likert method when used as a scaling technique. However, like the Likert method, it can be used in such a way that each bipolar line is treated separately and, here, it gives fascinating and detailed insights into attitudes. It is used in the attitude exploration in this study because of its known high validity and reliability, ease of construction and the fact that students can answer large number of questions very rapidly, giving useful quantities of data.

4.7 Conclusions

In thinking about learning in chemistry, attitudes towards chemistry are clearly very important. This chapter has offered a brief summary of the nature of attitudes and the ways by which they can be measured. This has determined the way attitudes towards chemistry are to be measured in this study. The overall pattern is:

(1) Attitudes express our evaluation of something or someone. They may be based on our knowledge, our feelings and our actions. In the context of studies in science, attitudes are evaluations, which may influence thinking and behaviour. Positive attitudes towards chemistry may well influence whether a person will choose to study chemistry as an elective subject.

(2) Attitudes are important to us because they cannot be neatly separated from study. It is a relatively quick series of steps for a student with difficulty in a topic to move from that to a belief that they cannot succeed in that topic. They then may consider that it is beyond them totally and they, therefore, will no longer attempt to learn in that area. A bad experience has led to a perception which led to an evaluation and further learning is effectively blocked (Reid, 2003).

(3) Previous studies have identified a number of factors generally that influence attitudes towards science. These can be broadly defined as: gender, perceived difficulty, effective teaching, students' backgrounds, and environmental factors (structural, classroom, and curriculum variables). These is no doubt that these factors plays a central role in Emirates students' attitudes towards chemistry.

(4) There are many methods of measuring attitudes such as: Thurstone's method of equal-appearing intervals, Likert's method of summated ratings, Guttman's

scalogram, and Osgood's method of semantic differential. Osgood's technique has been found to be reliable (Osgood *et al.*, 1969). Also, it has been claimed by Brunton (1961) that this technique has validity based on its higher correlation with scores obtained by the traditional methods of Thurstone, Likert, and Guttman.

Chapter Five

Surveys of Difficulties

5.1 Introduction

This chapter describes the first experiment which looked at the difficulties students saw in their chemistry studies. The approaches used are described along with details about the sample of students chosen. The results obtained are then discussed.

The survey looked at years 10 and 11 (ages 16-17 approximately) in typical schools in the Emirates.

5.2 Preparing the Survey

Many studies have looked at difficulties students at both school and university have in learning science subjects. There are two approaches which have been adopted. Student performance has been analysed and the difficulties analysed (e.g. Hackling & Garnett, 1985; Yaroch, 1985; Johnstone, 1991; Ma, 1986; Nakhleh & Krajqk, 1993; Furib *et al*, 2000; Carson & Watson, 1999; Stiff & Wilensky, 2002). The other approach is simply to ask students to identify, from a list, those topics or themes which they see causing problems for them (e.g., Johnstone *et al*, 1971; Duncan & Johnstone, 1973; Johnstone *et al*, 1977; Tsaparlis, 1991, 1994; Sirhan, 2000; Al-Marashda, 2002).

In the first approach, it is not always easy to be sure that diagnostic tests of the appropriate standard have been used. Nonetheless, major areas of difficulty have been identified fairly easily. The second approach relies on good student self awareness and the willingness to be honest. If the student thinks that an admission of difficulty has potentially unhelpful consequences, then honesty might be compromised.

In at least one study, both approaches have been adopted and it has been shown that student perceptions of difficulty match closely to their performance results (Sirhan, 2000). This is encouraging evidence that a survey of student perceptions is a valid approach. The advantage of this approach is speed and simplicity.

In this study described here, the survey approach was adopted and the format of the survey form was based very closely on that used by Sirhan (2000). Two survey forms were developed, one for year 10 and the other for year 11. The school syllabus and textbooks were analysed to identify the main topics being covered. Thirty topics were listed in each survey form appendix (A) and the survey forms are shown in full with the data obtained in Tables 5.1 and 5.2.

Students were asked to rate the various topics taught into one of four categories, described as: *easy*, *moderate*, *difficult* or *never studied*. Each description was defined for the students:

Easy	*"understood without difficulty"*
Moderate	*"had difficulties but I understand it now"*
Difficult	*"still do not understand it"*
Never studied	*"have never been taught this topic"*

If their answers were *difficult*, students were invited to say why they found the topic difficult. In this way the students were given an opportunity to comment freely about the reasons for difficulties.

For this stage, a total sample of 490 students was selected. There were 240 students (127 boys and 113 girls) for year 10 (aged between 15-16 years) and 250 students (129 boys and 121 girls) for year 11 (aged between 16-17 years). The students came from a large typical secondary schools in the United Arab Emirates. The surveys were completed in May 2002, towards the end of the year's teaching, with 20-30 minutes being found to be an adequate time.

5.3 Year 10 Students' Responses

Table 5.1 shows the percentages of year 10 students' responses to each topic. It has to be noted that the data must be interpreted in a relative way. The purpose of the survey is merely to identify those topics which appear to be ***most difficult*** for the students. For the year 10 students, most topics are recorded as *easy*. Some topics are rated as *moderately difficult*: oxidation number, and acidic and basic oxides. The real interest lies in the topics which have the highest rating as *difficult*. Five topics have the highest ratings here: Chemical formulae, Chemical equation, Quantum number, Lanthanides and Actinides, and Periodic table of elements. Oxyacetylene is the only topic never studied. Table 5.1 shows the pattern of results obtained, as percentage in each category, with the most difficult topics shaded. It is highly likely that the students would tend not to overemphasise difficulty in that they might well see this as an admission which would not prove acceptable if seen by their teachers. This is not a problem in that the data are interpreted relatively.

Table 5.1 Difficulties for Year 10 Students

Topic	Easy (%)	Moderate (%)	Difficult (%)	Not Studied (%)
Elements and compounds	81	17	2	0
Symbols of elements	79	17	4	0
Atoms and molecules	79	18	3	0
Oxidation Number	29	69	2	0
Chemical formulae	10	8	**82**	0
Atomic and molecular mass	65	35	0	0
Cathode ray	79	21	0	0
Proton, electron and neutron	83	17	0	0
Radioactivity	63	36	1	0
Alpha, beta and gamma radiation	77	23	0	0
Atomic number, mass number	86	14	0	0
Isotopes	80	20	0	0
Ground and excited state of electron	70	25	5	0
Quantum Number	13	16	**71**	0
Electron Clouds	71	29	0	0
Aufbau principle	75	25	0	0
Hund's rule and Pauli exclusion	78	21	0	1
Periodic Table	7	14	**79**	0
Halogens	72	28	0	0
Acidic and basic oxides	16	84	0	0
Lanthanides and actinides	10	19	**71**	0
Electronegativity	78	19	3	0
Type of chemical bonds	70	26	4	0
Chemical equation	13	12	**75**	0
Semi-conductors	67	30	3	0
Allotropy	86	14	0	0
Ozone	86	13	0	1
Chlorofluorocarbons	61	32	3	4
Oxy-acetylene flame	44	38	7	11
Ultraviolet	71	26	0	3

5.4 Year 11 Students' Responses

Table 5.2 shows the percentage of year 11 students' responses to each topic. As with year 10, most topics are rated as *easy*. Quite a number of topics are considered to be *moderately difficult*: Mass and Volume gas calculations, Molarity, Alkanes and Alkenes, Resonance, Polymerisation, Dynamic equilibrium, Normal salts, The ionic product of water, and Hydrocarbon compounds. Again, the real interest lies in those topics which have the highest difficulty ratings: Mole calculation, Chemical equation balance, Alkanes and Alkenes, Homologous series, Alkyl groups, and pH and pOH calculation. Enthalpy is the only topic never studied. Table 5.2 shows the data obtained.

Table 5.2 Difficulties for Year 11 Students

Topic	Easy (%)	Moderate (%)	Difficult (%)	Not Studied (%)
Mole calculation	28	20	**52**	0
Balancing chemical equations	23	23	**53**	1
Mass and volume gas calculation	40	43	13	4
Boyle's, Charles', Gay-Lussac's laws	58	24	14	4
Standard conditions	60	30	8	2
Vapour pressure	55	30	14	1
Saturated and supersaturated solutions	78	14	3	5
Molarity	58	39	2	1
Hess's law	64	18	15	3
Osmosis	61	36	1	2
Conservation of energy law	56	31	6	7
Endothermic and exothermic reactions	52	28	14	6
Enthalpy	2	6	0	92
Alkanes and alkenes	29	43	**25**	3
Homologous series	25	24	**50**	1
Alkyl groups	11	27	**51**	21
Isomerism	30	19	**50**	1
Resonance	15	60	6	19
Polymerisation	36	48	4	12
Catalyst factors	79	13	5	3
Forward and backward reaction	78	20	1	1
Dynamic equilibrium	35	40	10	15
Equilibrium law	60	38	1	1
Le Chatelier	55	31	4	10
Arrhenius	59	20	**20**	1
Acid rain	75	20	0	5
pH and pOH calculation	22	27	**50**	1
Normal salts	38	40	12	10
Ionic product of water	26	42	**27**	5
Hydrocarbon compounds	25	46	**22**	7

5.5 Students Comments on Reasons for Difficulties (year 10 and year 11)

In the free response space beside each topic, many students wrote more than one comment. These comments highlighted some of the sources of the difficulties. It is possible to group their comments under four headings, recognising that some comments do fit neatly under any one heading:

(a) *Curriculum Content.*

(b) *Overload of working memory space.*

(c) *Methods of teaching.*

(d) *Concept formation.*

Here are some typical comments:

1 *The presentation of the concept in text book is not clear.*
2 *Difficult to understand the concept.*
3 *The concept is complex.*
4 *There are a lot of mathematical laws.*
5 *We studied the concept at the end of course so the teacher didn't focus on it.*
6 *Teacher's method is bad.*
7 *Not enough time spent to explain the concept.*
8 *Not enough examples.*
9 *Similar names and too many to remember.*
10 *A lot of questions.*
11 *The concept is difficult to relate to the questions.*
12 *A lot of compounds.*
13 *No chance to practice.*
14 *Quickly taught in order to finish the curriculum.*
15 *A lot of homework so too busy and can't keep the idea in mind easily and became confused.*
16 *Too many steps and techniques.*
17 *Never done it before (have no idea about it).*
18 *Hard to remember how to do all calculations.*
19 *No clear definitions were provided for differences between types of isomers.*
20 *I can't visually imagine.*
21 *Never been able to.*

A full list of comments is in the appendix (B). However, it is useful to look at the comments which relate to those topics which students found particularly difficult.

In year 10,

(a) Chemical formulae

Students are taught balancing using oxidation number. 170 (71%) of them indicated that they were being confused in exchanging oxidation numbers. They wished more examples. Oxidation number is an extremely difficult concept to grasp and requires a mature understanding of valency, polarity, charge and atomic structure. It is asking the impossible to expect students at this stage to be able to apply the concept in writing and handling formulae. The amount of information to be held at one time vastly exceeds the working memory space of students, making this approach more or less impossible, as the pupil responses indicate.

(b) Quantum numbers

There were several common views expressed. 66 students indicated that they were confused, with many suggesting that it was difficult to distinguish the numbers. Quantum ideas are extremely abstract and are not intuitive. It requires considerable experience of the physical realities of chemical situations before the idea of energy quantisation being accessible to students. The idea of abstract numbers (which arise from the solution of very complex equations) representing quantum states is probably completely beyond a learner without considerable experience. It was interesting to note that some 20 students said that the topic was "not entertaining"!

(c) Periodic table

149 (62%) students indicated that there were too many elements, similar symbols were confusing, and they had never seen the table before. It has to be remembered that the students are taught in Arabic and are faced with symbols based mainly on English (or Greek) names. There is the potential for vast information overload. It is interesting to note that 41 said the topic was difficult to understand. This is sad in that the periodic table was designed to rationalise and make sense of a vast amount of data.

(d) Lanthanides and actinides

102 (43%) thought this topic complicated, with inadequate information to make sense of it. This is probably because the coverage in their textbook is very limited. Certainly, these elements are not usually covered at school level and their chemistry is complex.

(e) Chemical equations

This topic includes writing and balancing equations. 99 students (41%) wished more practice and more examples. Again, the use of English letters poses problems and the names of compounds have to be translated mentally from English to Arabic and vice versa. It is known that translation uses up working memory space, thus making this topic even more difficult (Johnstone and Selepeng, 2001). There is another problem for Arabic speaking students. By convention, equations are written from left to right. Reversing this inbuilt procedures will pose yet more demand on Arabic-writing students.

In year 11, similar patterns were observed with different topics.

(a) *Mole calculation*

76 students wished more practice and they have problem with mole mathematics method. Mole calculation is an area where students always seem to have problems. Also, students often lack the understanding of this concept. Mole calculations, by their very nature, are highly information intensive. Working memory space is very easy to overload with such problems.

(b) Chemical equation balance

More than 20 students wished more practice and examples. They indicated that they were missing the rules of balancing. Chemical equation balance will be an extremely difficult concept to grasp if it is taught involving ideas like polarity, charge and oxidation number, all at the same time. This is the way it is often presented in the Emirates. Information overload is almost guaranteed!

(c) Organic topics

There were several common views expressed. Many students indicated that organic chemistry is easy to receive, easy to forget. The amount of information to be held at one time vastly exceeds the working memory space of students and overload will be common. Kellett (Johnstone and Kellett, 1974) explored this problem many years ago and showed how students were 'seeing' organic structures.

The students indicated that they were confused over isomerism. The problem with isomerism is that three dimensional shapes have to be represented on two dimensional paper. This requires considerable practice and experience (Johnstone *et al.*, 1977) Again, the use of English names and letters poses additional problems and the names of compounds have to be translated mentally from English to Arabic and vice versa.

(d) *Lewis, Arrhenius, Bronsted-Lowry acids*
Many students wished more examples and practical work in laboratory. They have great difficulty in differentiating between these different ways of thinking of acids.

(e) *pH and pOH calculation*
43 students wished more practice and examples. This topic causes problems with university chemistry students (Sirhan, 2000). Although they have problems with mathematical methods, the fundamental problem is probably not mathematical. The difficulty may come from confusions in defining the meaning of representations and equations such as: $[H^+]$, $[OH^-]$, $pH = - \log [H^+]$, $pOH = \log [OH^-]$.

(f) *The ionic product of water*
Students wished more practice and information. This whole area is highly abstract and requires a confidence in using various representations. The key relationships have little tangible meaning:

$$pH + pOH = 14 \qquad [H+] [OH-] = 10^{-14}$$

Having pin-pointed some of the major areas of difficulty, some test material was developed to explore these areas in more detail. This is now described.

5.6 Exploring the Difficulties

In the survey described above, students were asked how they saw various topics in this studies in terms of difficulty. The approach now described looked at some of the topics which were perceived as most difficult in an attempt to gain further insights into the nature of the difficulties. Structural Communication Grids, as a diagnostic testing method, were used in this study.

The Structural Communication Grid (SCG) is an assessment technique which involves data being presented in the form of a numbered grid and students being asked to select appropriate boxes, and sometimes to put them into a logical sequence in response to a set question. It has been found that this technique gives an insight into sub-concepts and linkages between ideas held by students, so that understanding can be assessed at a deep level (Johnstone *et al*, 2000). Its introduction heralds a new resource to assist in the process of education and seems analogous to the invention of the various programmed instruction techniques (Egan, 1972).

Structural Communication Grids can be used for assessment and for diagnosis, and they provide an appropriate technique for the purpose of gaining insights into pupil difficulties in this study. Figure 5.1 shows the basic structure of a structural communication grid (SCG) (Johnstone *et al,* 2000).

Figure 5.1: The basic structure of the SCG

1	2	3	4
5	6	7	8
9	10	11	12

The SCG idea originates from Egan's (1972) work and since then it has been developed and used by many researchers (e.g., Duncan, 1974; Johnstone & Mughol, 1979; Johnstone & MacGuire, 1987; Scottish Examination Board, 1997). A modified form of SCGs was used by the new Scottish Qualification Authority (SQA) in 1998 in its science examinations (Johnstone *et al*, 2000). The boxes are of no significance other than to hold an array of information. The number of boxes used depends on the age of the students, but 9 to 12 boxes are appropriate for students towards the end of their school studies. Any kind of information can be placed in the boxes and it is possible to ask several questions, all relating to one grid. Students have no way of knowing how many right answers are present - it could be anything from 1 to 9 with a nine box grid. It is the pattern of correct and the pattern of wrong answers which can offer insights into understanding (Ambusaidi & Johnstone, 2000).

Johnstone described different styles of objective questions as alternatives to multiple-choice. This included SCG, Venn diagrams, linked true/false statements, mind maps and logic problems (Overton, 1998).

It is possible to list many strengths and advantages of the SCG technique:

(1) The contents of the boxes can be words, phrases, pictures, formulae, varied, or made suitable for visual thinkers.

(2) SCG completely eliminates the guessing problems, a criticism of multiple choice questions.

(3) The analysis of the results penalises wrong answers to discourage guessing.

(4) The reasoning chain (where answers are required in an order) gives an indication of the way the student's knowledge is inter-linked.

(5) Credit in SCG is given for partial or incomplete knowledge.

(6) The student's are able to handle SCG quickly after a little practice and the time required to answer these grid question is similar or less than that required to test the same objectives conventionally.

(7) **Often,** there is no factually wrong information displayed in grid questions. It may be irrelevant for answering one particular question but highly relevant for anther.

(8) The grid's boxes content may be necessary to answer two or more questions, so guessing by elimination is completely ruled out.

(9) Grid questions can be designed to assess the student's degree of understanding of the topic by using a computer work station and offered as a self assessment technique which could help students identify their weaknesses and strengths.

(10) In conclusion, the flexibility of the SCG as an assessment and diagnostic tool is enormous and would lend itself to the production of much shorter and less wordy levels of complexity (Johnstone *et al*, 2000).

(11) They are much easier to set it than multiple choice questions .

(12) The *correct* responses offered by a student reveal something of the grasp of the fundamental concept; for example, if there are 3 correct answers but many students have missed the same one of the three, clear evidence is gained of a knowledge gap.

(13) The *wrong* answers offered by the students reveal something of the misunderstandings and misconception; for example, if many students add a particular wrong answer, this can reveal a misconception or misunderstanding.

(14) It is possible to score it such a test and there are several ways. Here is one :

$$\text{Mark for each question} = \frac{\text{Number of correct answers selected}}{\text{Total number of correct answers}} - \frac{\text{Number of wrong answers selected}}{\text{Total number of wrong answers}}$$

(15) One grid test can be used to ask many questions, gaining useful insights into many aspects of some concept or area of interest.

(16) Clear patterns of responses can be highly informative (Reid, 2003).

Two grid tests were designed, one for year 10 and the other for year 11. The tests are now shown in full in figures 5.2 and 5.3.

Figure 5.2 Grid Test for Year 10

What do you understand?

This is an unusual test.
It is designed to find out what you have understood from your previous studies.
The results from this will assist in planning future courses.

Here is an example question:
Select all box (es) which contain names of capital cities.

A Vienna	**B** Glasgow	**C** Damascus
D Melbourne	**E** Paris	**F** Delhi

The correct answer is: A, C, E, and F.
(Glasgow is **not** the capital of Scotland and Melbourne is **not** the capital of Australia but Vienna is the capital of Austria, Damascus for Syria, Paris for France and Delhi for India).

Write down the letters for the answers to the following questions.
You should select **ALL** the correct answers.
Look at the boxes below and answer the questions, which follow:
(Boxes may be used as many times as you wish)

Question 1

A $_{2}He$	**B** $_{27}Al$	**C** $_{20}Ca$
D $_{17}Cl$	**E** $_{16}S$	**F** $_{15}P$

Select ***all*** the box (es) which contain:

(a) Atoms which can form three bonds? ....
(b) Atoms which can form two bonds? ....

Question 2

An atom is a nucleus surrounded by electrons **A**	Atoms only exist in elements **B**	Atoms are the smallest particles which can exist **C**
Atoms have more electrons than protons **D**	Atoms are only found linked to each other **E**	Atoms contain protons, neutrons and electrons **F**

Select ***all*** the box (es) which contain

Statements about atoms, which are **true** ....

Question 3 Look at boxes below and answer the questions, which follow:

Cu A	H_2S **B**	MgO **C**
SiO_4 **D**	K **E**	$NaBr_2$ **F**
AlP **G**	Br_2 **H**	Ar **I**

(a) Which of the following formulae should ***not*** exist? ....

(b) which contain formulae of elements? ....

(c) which contain formulae of compounds? ....

(d) Which are liquids at room temperature? ....

(e) Which are metals? ....

The same rubric was used at the start of the test for year 11 as that used in year 10. The actual questions are shown in figure 5.3.

Figure 5.3 Grid Test for Year 11

Question 1

Mass of a mole is 18g **A**	Mole of molecules of hydrogen **B**	Mass of a mole is 1g **C**
Mass of a mole is 17g **D**	Two hydrogen atoms linked together **E**	A mole of molecules of water **F**
A mole of atoms of hydrogen **G**	Two hydrogen atoms linked to one oxygen atom **H**	A mixture of hydrogen and oxygen atoms **I**

Select all the box (es) where there are statement which are:

(a) **True** about the formula: H_2O? ....

(b) **True** about the formulas: H_2? ....

Relative atomic mass of the elements are:
H= 1, O=16

Question 2

Copper **A**	Sodium phosphate **B**	Oxygen **C**
Potassium chloride **D**	Magnesium **E**	Water **F**
Nitrogen **G**	Hydrogen **H**	Magnesium oxide **I**
Aluminium **J**	Argon **K**	Ammonia **L**

Select all the box (es) which contain

(a) Elements, which can show a valency of 3 ....

(b) Elements, which can show an oxidation number of +2? ....

(c) Molecules in which there are covalent bonds? ....

(d) Molecules in which there are polar covalent bond? ....

(e) Molecules in which there are ionic bonds? ....

(f) Molecules in which there are hydrogen bonds? ....

Q3: Write in your answers:

(a) In ethane, the line between the two carbon atoms is a single bond.
What does this line represent? ....

(b) In ethene, the line between the two carbon atoms is a double bond.
What does this double line represent ....

Question 4

An atom is a nucleus surrounding by electrons **A**	Atoms only exist in elements **B**	Atoms are the smallest particles which can exist **C**
Atoms have more electrons than protons **D**	Atoms are only found linked to each other **E**	Atoms contain protons, neutrons and electrons **F**

Select all the box (es) which contain statements about atoms, which are **true** ....

For this stage, a total sample of 318 students was selected. There were 168 students (88 boys and 80 girls) for year 10 (aged 15-16 years) and 150 students (74 boys and 76 girls) from year 11 (aged between 16-17 years). The students came from a large typical secondary schools in the united Arab Emirates. The surveys were completed in October 2002, towards the end of the year's teaching, with 30-90 minutes being found to be an adequate time.

These grid tests aimed to test the grasp of underlying ideas in chemistry. This is the strength of structural communication grids in that they offer insights into the conceptual understanding of ideas tested.

5.7 Discussing the Results of the Grid Tests

While structural communication grids can be marked like any other test, the strength of these tests is in exploring incomplete answers and looking closely at patterns of wrong answers. To do this, the student performance in each part of each question is converted into a code. The codes may have to be adjusted in the light of what is observed. The aim of these codes is to count the numbers of students under each code and this will give a picture of how students performed in each question and where the problems lie. The codes were chosen to achieve these aims. Appendix (C)

In the following chapter, the results for each section of each question are discussed in turn, starting with the year 10 group of students. All data are shown as percentages for clarity.

Chapter Six

Analysis of Results

The results obtained from the diagnostic use of the structural communication grids tests with years 10 and 11 are now outlined and their meaning discussed. In each case, the data are presented as percentages, showing the proportion who chose various options.

6.1 Analysis of the Grid Test for year 10 students

Question 1

A $_{2}He$	**B** $_{27}Al$	**C** $_{20}Ca$
D $_{17}Cl$	**E** $_{16}S$	**F** $_{15}P$

Select ***all*** the box (es) which contain:

(a) Atoms which can form three bonds? ....

(b) Atoms which can form two bonds? ....

Table 6.1 Response of year 10 students to Item 1(a)

Table 6.1	
Q1(a): Select atoms which can form three bonds?	N = 168
Response (Correct = B and F)	**%**
Both correct answers	30
B chosen	14
F chosen	5
B chosen but one wrong answer also chosen	12
F chosen but one wrong answer also chosen	5
B and F chosen with one wrong answer also chosen	8
B chosen but two wrong answer also chosen	11
F chosen but two wrong answer also chosen	11
Others responses	4
Total	**100**

While 30% obtained both answers, it is interesting to note that, where only one right answer was chosen, it was usually F which was omitted. Perhaps, it is easier to see that Al has valency 3 but not so easy for P (Phosphorus).

Table 6.2 Response of year 10 students to Item 1(b)

Table 6.2	
Q 1(b): Select atoms which can form two bonds?	N = 168
Response (Correct = C and E)	%
Both correct answers chosen	21
C chosen	9
E chosen	8
C chosen but one wrong answer also chosen	8
E chosen but one wrong answer also chosen	8
C and E chosen with one wrong answer chosen	5
C and E chosen with two wrong (A and F)	20
C and E chosen with three wrong (A,D,and F)	15
Other response	4
Total	**98**

Note: rounding errors can make the total in this and other tables **not** add exactly to 100%

The most common wrong answers appear to be A and F. Clearly, there is the possibility of the 2 in $_2$He misleading the students. Again, there is uncertainty over P (35% think it has valency 2). This all suggests that students know certain answers by memory but do not really understand the principles underlying valency.

Question 2

An atom is a nucleus surrounded by electrons **A**	Atoms only exist in elements **B**	Atoms are the smallest particles which can exist **C**
Atoms have more electrons than protons **D**	Atoms are only found linked to each other **E**	Atoms contain protons, neutrons and electrons **F**

Select ***all*** the box (es) which contain

Statements about atoms, which are **true** ....

Table 6.3 Response of year 10 students to Item 2

Table 6.3	
Q 2: Select which box (es) contain statements about atoms are true?	N = 168
Response (Correct = A and F)	%
Both correct answers	39
A chosen	2
F chosen	3
A chosen with one wrong answer	5
F chosen with one wrong answer	2
A and F chosen with one wrong answer (C)	45
Other responses	5
Total	**101**

The most interesting result is that 45% think box C is correct (Atoms are the smallest particles which can exist). Clearly, there is a conceptual confusion. They do not seem to appreciate that sub-atomic particles can have a separate existence. There is a return to Daltonian ideas of atoms.

Question 3 Look at boxes below and answer the questions, which follow:

Cu A	H_2S **B**	MgO **C**
SiO_4 **D**	K **E**	$NaBr_2$ **F**
AlP **G**	Br_2 **H**	Ar **I**

(a) Which of the following formulae should ***not*** exist? ....

(b) which contain formulae of elements? ....

(c) which contain formulae of compounds? ....

(d) Which are liquids at room temperature? ....

(e) Which are metals? ....

Table 6.4 Response of year 10 students to Item 3(a)

Table 6.4	
Q 3(a): Which of the following formulae should not exist?	N = 168
Response (Correct = D and F)	%
Both correct answers chosen	1
D chosen	0
F chosen	4
D chosen along with G and I	27
D chosen along with G,I, and H	22
F chosen along with G and I	15
F chosen along with G,I, and H	21
D and F chosen with one wrong answer	3
D chosen with one wrong answer	1
F chosen with one wrong answer	3
Other responses	5
Total	**102**

The answers illustrate complete confusion. 85% think that G (AlP) and I (Ar) are correct answers to the questions while 43% think that H (Br_2) is a correct answer. Aluminium phosphide has an unfamiliar looking formula but it is difficult to see why they chose bromine and argon. It is of even greater concern that so many failed to pick out formulae which are impossible.

Table 6.5 Response of year 10 students to Item 3(b)

Table 6.5	
Q 3 (b): Which boxes contain formulae of elements?	N = 168
Response (Correct= A, E, H, and I)	%
All correct answers chosen	57
Three of four correct answers chosen	15
Two of four correct answers chosen	11
One of four correct answers chosen plus C	9
All correct answers chosen plus C	4
Two correct answers chosen plus one wrong answer	0
Other responses	5
Total	**101**

This reveals that the majority of students grasped the concept of elements in terms of their formulae, with 72% getting at least 3 correct.

Table 6.6 Response of year 10 students to Item 3(c)

Table 6.6	
Q 3(c): Which boxes contain formulae of compounds?	N = 168
Response (Correct = B, C, and G)	%
All three correct answers chosen	0
Two of three correct answers chosen	5
One of three correct answers chosen (C)	22
All three correct answers chosen plus H	8
Two correct answers chosen plus H	11
One of the three correct answers chosen plus H	50
Other responses	4
Total	**100**

A very interesting feature is that 69% think Br_2 is a compound. This reveals considerable conceptual confusion about the nature of compounds. A compound is not a molecule with 2 or more atoms but a molecule with 2 or more *different* atoms: this distinction seems to have been missed by many.

Table 6.7 Response of year 10 students to Item 3(d)

Table 6.7	
Q3(d): Which are liquids at room temperature?	N = 168
Response (Correct = H)	%
H chosen	23
H chosen plus one extra wrong	0
H chosen plus E and I	32
H chosen plus A, E, I	35
Others responses	10
Total	**100**

Only 23% identified bromine only as a liquid at room temperature although it was selected by 90% along with other answers. Of concern is the observation that E and I are thought to be correct by 67%. Thus, they think that potassium and argon are liquids at room temperature. Chemistry is taught in a very theoretical way in the Emirates with little reference to any laboratory work. Clearly, the students have no mental image arising from seeing potassium stored under oil or the fact that argon is a constituent of air and not easily liquefied.

Table 6.8 Response of year 10 students to Item 3(e)

Table 6.8	
Q 3(e): Which are metals?	N = 168
Response (Correct = A and E)	%
Both correct answers chosen	6
A chosen	4
E chosen	33
A chosen but one wrong answer	4
E chosen but one wrong answer	0
A and E chosen with one wrong	4
A chosen with H and I	20
E chosen with H and I	20
Other responses	10
Total	**101**

Surprisingly, many omitted A (Cu). Of even greater importance, a high proportion chose H (Br_2) and I (Ar). It appears that students do not have experience of these elements.

6.2 Analysis of the Grid Test for year 11 Students

The same method of presentation is used to outline the results for year 11.

Question 1

Mass of a mole is 18g **A**	Mole of molecules of hydrogen **B**	Mass of a mole is 1g **C**
Mass of a mole is 17g **D**	Two hydrogen atoms linked together **E**	A mole of molecules of water **F**
A mole of atoms of hydrogen **G**	Two hydrogen atoms linked to one oxygen atom **H**	A mixture of hydrogen and oxygen atoms **I**

Select all the box (es) where there are statement which are:

(a) **True** about the formula: H_2O? ....

(b) **True** about the formulas: H_2? ....

Table 6.9 Response of year 11 students to Item 1(a)

Table 6.9	
Q1(a): Select box(es) which are statement true about the formulae: H2O?	N = 150
Response (Correct = A, F and H)	%
Three correct answers chosen	10
F and H chosen	57
H chosen	20
Three correct answers plus one wrong answer	2
Two correct answers plus one wrong answer	3
One correct answers plus one wrong answer	2
Other responses	7
Total	**101**

The vast majority picked out H (two hydrogens linked to one oxygen). A (mass of a mole is 18g) is missed by 77% while F (a mole of molecules of water) is missed by 20%. Students have confusion about the mole. This has been observed in almost all studies (Furib & Goisasda, 2000; Johnstone, 2000, and Cervellati *et al.*,1982). The mole is not taught clearly. It is a counting system but students often see it as a mass (or weight). However, introducing the mole too early is the main source of the problem. Until students have a sound conceptual understanding of molecules and molecular size, the concept of the mole is simply beyond them, almost certainly because the number of ideas to make sense of the mole exceeds working memory space. Far too often, the mole, mass weight, volume, Avogadro's number are all introduced together or close together, causing total confusion.

Table 6.10 Response of year 11 students to Item 1(b)

Table 6.10	
Q 1(b): Select box(es) which are true statement about the formulae: H2?	N = 150
Response (Correct = B and E)	%
Two correct answers chosen	14
B only	23
E only chosen	50
B chosen with a wrong answer	0
E chosen with wrong answer	1
Band E chosen with a wrong answer	3
Other responses	9
Total	**100**

It is important to note that 50% of students do not see H_2 as representing a mole of molecules and this may demonstrate their confusion about or lack of understanding of the concept of 'moles'. This could be symptomatic of a problem in the teaching and/or learning of moles. E is missed by 23% (E is two hydrogen atoms linked together) which is surprising .

Question 2

Copper **A**	Sodium phosphate **B**	Oxygen **C**
Potassium chloride **D**	Magnesium **E**	Water **F**
Nitrogen **G**	Hydrogen **H**	Magnesium oxide **I**
Aluminium **J**	Argon **K**	Ammonia **L**

Select all the box (es) which contain

(a) Elements, which can show a valency of 3 ....

(b) Elements, which can show an oxidation number of +2? ....

(c) Molecules in which there are covalent bonds? ....

(d) Molecules in which there are polar covalent bond? ....

(e) Molecules in which there are ionic bonds? ....

(f) Molecules in which there are hydrogen bonds? ....

Table 6.11 Response of year 11 students to Item 2(a)

Table 6.11	
Q 2(a): Select box(es) which contain elements can show a valency of 3?	N = 150
Response (Correct = G and J)	%
Two correct answers chosen	38
G only chosen	19
J only chosen	17
G and J chosen along with H	6
G and J chosen along with I	3
G and J chosen along with K	4
G and J chosen along with L	3
G chosen with H	3
G chosen with I	3
Other responses	3
Total	**99**

While 38% get both correct answers, Aluminium is missed by 25% while Nitrogen is missed by 17%. It is fundamental that students at this stage know with confidence which common elements have valency 3. This need not be memorised but simply deduced form the Periodic Table. 16% of the students select the correct two answers but add a wrong answer (H, I, K or L). Clearly, valency is not handled with confidence at all.

Table 6.12 Response of year 11 students to Item 2(b)

Table 6.12	
Q 2(b): Select box(es) which contain elements which can show an oxidation number of +2?	N = 150
Response (Correct = A and E)	%
Two correct answers chosen	33
A only chosen	17
E only chosen	17
A and E chosen along with H	13
A and E chosen along with K	13
Other responses	7
Total	**100**

33% of students obtained both correct answers. Magnesium is missed by 17% and Copper is missed by 17% as well. Previous questions have shown that there are still many confusions abut valency. Oxidation state is a more complicated idea and it is not surprising that there are difficulties here. This is illustrated by the observation that 26% think Hydrogen and Argon have oxidation number: +2. This suggests a fundamental confusion over the idea of valency as well as the nature and meaning of oxidation number. Almost certainly, the concept of oxidation number should not be introduced until the more fundamental ideas of valency and bonding are fully established.

Table 6.13 Response of year 11 students to Item 2(c)

Table 6.13	
Q 2(c): Select box(es) which contain molecules in which there are covalent bonds?	N = 150
Response (Correct = C, F, G, H and L)	%
All five correct	27
Four of five correct	17
Three of five correct	19
Two of five correct	15
One of five correct	7
All five correct plus one extra	7
Four correct plus one extra	1
Other	9
Total	**102**

This should have been straightforward in that covalent bonds (in the examples shown) occur when two non-metal atoms are linked. Students missed molecules of elements: oxygen, nitrogen, hydrogen, as well as ammonia. The results of this question reveal a lack of confidence in fundamental (and apparently straightforward) ideas. It suggest that learning has been based on memory with little or no attempt to understanding the underlying ideas.

Table 6.14 Response of year 11 students to Item 2(d)

Table 6.14	
Q2(d): Select box(es) which contain molecules in which there are polar covalent bonds?	N = 150
Response (Correct = F and L)	%
Both correct chosen	44
F only chosen	22
L only chosen	21
Two correct answers plus G	3
Two correct answers plus I	3
Two correct answers plus J	3
Other responses	5
Total	**101**

The students did surprisingly well in this question, with 44% getting both correct answers. Ammonia was missed by 22% while water was missed by 21% . Encouragingly, very few students added extra (wrong) answers or suggested other molecules as polar. This suggest that water and ammonia were taught specifically as polar.

Table 6.15 Response of year 11 students to Item 2(e)

Table 6.15	
Q 2(e): Select box(es) which contain molecules in which there are ionic bonds?	N = 150
Response (Correct = B, D and I)	%
All three correct answers chosen	34
Two correct answers chosen	22
One correct answers chosen	15
All three correct chosen plus one extra	15
Two correct chosen plus one extra	5
Other responses	9
Total	**100**

While 34% obtained all three correct answers, 37% missed 1 to 2 correct answers. Students tended to miss sodium phosphate and magnesium oxide but they remembered potassium chloride. Where they added an extra choice, it often was argon. This seems strange at first sight but little is taught about argon and students may simply have been guessing from a position of ignorance. Nonetheless, it does reveal that the lack of reactivity of the noble gases is not grasped.

Table 6.16 Response of year 11 students to Item 2(f)

Table 6.16	
Q 2(f): Select box(es) which contain molecules in which there are hydrogen bonds?	N = 150
Response (Correct = F and L)	%
Both correct answers chosen	36
F only chosen	17
L only chosen	14
F chosen with H	13
L chosen with one wrong answer	7
F and L chosen with one wrong answer	6
F and L chosen with two wrong answers	4
Other responses	3
Total	**100**

36% obtained both correct answers but ammonia was missed by 17% and water was missed by 14% . It is a little surprising that 24% overall failed to identify water as having molecules which can form hydrogen bonds. However, of greater concern is the observation that 13% think hydrogen has hydrogen bonds.

Question 3 asked about students' interpretations of the lines linking atoms. 57% indicated that they understood that the single line represented a pair of electrons with a double line representing 4 electrons. A further 33% indicated that they understood the lines of term of electrons but they did not state or imply the number of electrons involved. 10% failed to respond. It is clear that the students were grasping that the line used indicated a bond representing electrons. Overall, the responses showed good understanding. The results are consistent with the high response rates obtained for a large group of first year university students (mainly Scottish) who were asked the same question before they started their lecture course in organic chemistry at university (Sirhan, 2000).

Question 4

An atom is a nucleus surrounding by electrons **A**	Atoms only exist in elements **B**	Atoms are the smallest particles which can exist **C**
Atoms have more electrons than protons **D**	Atoms are only found linked to each other **E**	Atoms contain protons, neutrons and electrons **F**

Select all the box (es) which contain statements about atoms, which are **true** ....

Table 6.17 Response of year 11 students to Item 4

Table 6.17	
Q 4: Select which box(es) contain true statements?	N = 150
Response (Correct = A and F)	%
Both correct answers chosen	45
A only chosen	6
F only chosen	7
A chosen with B	3
A chosen with C	5
F chosen with B	3
A and F chosen plus C	20
Other responses	10
Total	**99**

45% of students obtained both correct answers. However, 25% of students think that 'atom are smallest part which can exist' with one or both correct answers. This suggests that there is a conceptual confusion between atoms and molecules.

6.3 Attitudes Questionnaire

In this exploratory study looking at problems with the learning of chemistry in The Emirates, a difficulties survey has pinpointed the key problem themes while the tests based on structural communication grids has thrown considerable light on the nature of the problems. In the next stage of this project, two short questionnaires to explore attitudes towards chemistry were used, one for year 10 and the other for year 11. Overall, it aimed to see how they related to their experiences of difficulties. Each questionnaire involved ten questions:

Questions 1 and 2 asked for gender and school attended. Questions 3 and 4 explored student's views of their chemistry course and their perceptions of themselves in relation to their studies in chemistry. Question 5 considered which aspects of their chemistry learning they enjoyed most while question 6 related the importance of chemistry to that of other subjects.

Question 7 focusses on specific difficulties related to attitudes (for both years, but difficulty of chemical concept are different) while question 8 explored the influences that attract students to study chemistry in future years. Questions 9 and 10 were open questions and they aimed to discover what most and least attracts students to chemistry.

The attitudes questionnaires were given to two groups of year 10 and year 11 students. For this stage, a total sample of 225 students were involved: (115 students, 60 boys and 55 girls, for year 10, aged between 15 - 16 years and 110 students, 55 boys and 55 girls, for year 11, aged between 16 - 17 years). The questionnaires were distributed among year 10 and year 11 students in February 2003, with 10 minutes being found to be adequate time for each test inclusive of administration.

The questionnaires are shown in full in the appendix (D) but each question is now shown here and data obtained are discussed. For clarity, the data are presented as percentages . Where any statistical analysis was applied, this was applied to raw data. The raw data are shown in full in the appendix (E)

6.4 Analysis of Attitudes Questionnaire responses for year 10 students

The responses to the questions will now be discussed in turn.

Questions 1 and 2 asked for gender and school attended.

(3) What are your opinions about your school chemistry lessons in year 10 ?

The purpose of this question is to find out the attitudes of students during their year's study in chemistry. The percentages of responses were calculated as follows:

I like chemistry lessons	40	17	11	10	12	10	I hate chemistry lessons
Boring	17	9	11	14	20	29	Interesting
Easy	19	21	16	7	11	26	Difficult
Useless	8	4	5	8	13	62	Useful
Important	60	10	10	4	8	8	Unimportant
Enjoyable	18	17	18	16	8	2	Boring

It is encouraging to note that the students tend to see chemistry as useful and important. However, their perceptions on other aspects are less positive: indeed, some of the responses are *very* negative and this is a matter of concern. Views are divided on whether it is interesting, difficult and enjoyable, with some evidence of polarisation of views in the group surveyed. However, there is a tendency for this group to like chemistry lessons, which is encouraging.

In the context of most societies today, chemistry has an intrinsically important and useful place in terms of industry, employment and offering essential knowledge and experience for medical, paramedical and many other careers. Chemistry, by its very nature, has the potential to be exciting and this should lead to positive views of interest and enjoyment. However, if it is taught (no matter how well) with little recourse to the experimental, this will not be so evident to learners.

(4) How do you feel about the chemistry you have learned ?

The purpose of this question is to explore how the students see themselves in relation to their studies in chemistry. The percentages of responses were calculated as follows:

I am enjoying the subject	30	8	20	7	4	31	I am NOT enjoying the subject
I feel I am NOT coping well	23	8	13	6	9	41	I feel I am coping well
I find it very easy	19	21	17	8	12	23	I find it very hard
I am growing intellectually	41	12	9	7	10	21	I am NOT growing intellectually
I am NOT obtaining a lot of new skills	23	10	12	9	11	35	I am obtaining a lot of new skills
I hate practical work	46	10	10	2	6	26	I am enjoying practical work
I am getting better in the subject	33	14	11	13	7	22	I am getting worse in the subject
I do not like my teacher	30	3	14	21	7	25	I like my teacher
It is definitely 'my' subject	30	9	17	10	11	23	I t is definitely not 'my' subject

The most marked feature of the pattern of results is the extent of polarisation: their experiences in chemistry tend to be strongly negative or strongly positive. When compared to the patterns of results obtained by Skryabina in looking at perceptions of self in relation to physics in Scotland at various stages throughout secondary education (Reid and Skryabina, 2002 a), much greater polarisation is observed here and the attitudes here tend to be *much more negative*. The most marked feature here is the high proportion who dislike practical work and also those who dislike the teacher. In Scotland, practical work is rated highly in both physics (Reid and Skryabina, 2002 b) and chemistry (Shah, 2004) at all school levels while reactions towards teachers are usually highly positive. However, despite the many negative perceptions, it is encouraging to note that quite a good proportion see it as 'their' subject. Linked to the responses in previous question, it seems that students see the importance and significance of chemistry *despite* their poor experience in studying it.

(5) What do you enjoy in your <u>chemistry</u> lessons ?
Tick as many you wish.

The purpose of this question was to reflect on the students' opinions of chemistry lessons. The *percentages* of responses are as follows:

55	Studying the theory	30	Studying chemistry applications in life
60	Doing practical work	62	Studying about chemical reactions in the human body
30	Explaining natural phenomena	10	Setting up apparatus
50	Drawing shapes (atoms, molecules, etc)	59	Studying how chemistry can improve my life
45	Writing formulae and chemical equations	20	Solving every day problems
40	Balancing chemical equations	61	Studying how chemistry can make our lives healthier

The choices with the highest ratings include 'doing practical work', 'drawing shapes', 'chemical reactions in the human body', 'chemistry improving life', and 'making lives healthier'. The first two reflect the traditional pattern where practical activities are rated highly (for a review, see Shah, 2004). The latter three all are related to the desire for studies to be perceived as related to lifestyle and meaningful context (for a discussion of this issue, see Reid, 1999). However, 'studying theory' was also widely supported and it is interesting to note that relatively few students chose 'chemistry applications in life' or 'solving everyday problems'. This perhaps reflects a syllabus where neither seems to be a realistic possibility.

(6) Here are some school subjects:

A	Arabic	D	Biology	B	Chemistry	E	Geography
C	Geology	F	History	G	Mathematics	H	Physics

Using the letters, place these in order of importance to yourself:

Most important to me .... ***Least*** important to me

The purpose of this question is to help in rating chemistry with respect to other subjects about students' opinions. The percentages of responses for the three sciences and mathematics are as follows:

Chemistry

Most important to m 13 17 18 19 15 9 7 2 Least important to me

Physics

Most important to me 2 19 17 20 24 2 6 10 Least important to me

Biology

Most important to me 24 10 28 18 12 11 4 3 Least important to me

Mathematics

Most important to me 45 23 10 6 3 5 4 4 Least important to me

Overall, students tend to see these four subjects as important rather than unimportant. However, the relatively low ratings for chemistry and physics compared to biology and mathematics suggest that their experience in the former two is unsatisfactory.

(7) ***Show your opinion about the topics you have studied.***

The purpose of this question was to consider topics which students had previously described as difficult . The *percentages* of responses were calculated as follows:

%	Chemical Formulae	Quantum Numbers	Periodic Table	Lanthanides and Actinites	Chemical equations
Important to improve my life	66	12	69	18	64
Boring	55	90	44	92	40
Interesting	40	7	63	4	48
Complicated	62	85	70	87	73
Good basis for future study	68	5	59	3	51

It is important to note that a high proportion of students think all difficult topics in the above table are boring and complicated. However, more than 40% of students think that chemical formula, periodic table of elements, and chemical equation are important to improve their life, interesting, and are a good basis for future study. Thus, the students seem aware of the significance of some of the topics but still find them unattractive.

(8) Think about what might influence you to study chemistry in future years. Which of the following would attract you to further study in chemistry.

The purpose of this question was to determine which factors had influenced students to study chemistry in future years. The *percentages* of responses are as follows:

40	An interesting course
70	There are good possibilities of jobs
30	What my friends think
0	Television programmes
56	The wishes of my parents
45	Exciting experiments in class
35	An interesting textbook
51	A stimulating teacher
0	Anything else: ....

Previous work in physics in Scotland had found considerable evidence which suggested the importance of the teacher, the nature of the course, and the possibilities of careers as the most important factors (Reid and Skryabina, 2002). Here there is also some influence from parents and friends, perhaps reflecting the different cultural setting.

(9) Write one sentence to say what most attracts you to chemistry.

60% of students answered that "practical work" attracted them most to chemistry and 40% of students answered that they were attracted to chemistry by the fascinating descriptions of how elements were discovered. The latter is particularly encouraging in that this was specifically introduced the new materials.

(10) Write one sentence to say what least attracts you to chemistry.

60% of students found that theoretical study attracted them least to chemistry. Students named three further issues that they found least attracted them to chemistry: 55% named methods of teaching, 40% named teacher personality and 38% named their chemistry textbook. This is not an encouraging picture.

6.5 Analysis of Attitudes Questionnaire responses for year 11 students

The responses to the questions will now be discussed in turn.

(3) What are your opinions about your school chemistry lessons in year 11?

The purpose of this question is to find out the attitudes of students during their year's study in chemistry. The percentages of responses were as follows:

I like chemistry lessons	30	22	27	12	6	3	I hate chemistry lessons
Boring	6	13	18	27	21	15	Interesting
Easy	15	30	35	12	4	4	Difficult
Useless	3	5	9	10	29	44	Useful
Important	43	26	12	11	5	3	Unimportant
Enjoyable	14	15	27	23	13	8	Boring

As with year 10, it is encouraging to note that the students tend to see chemistry as useful and important. Views are divided on whether it is enjoyable but interest levels have risen from year 10, with students finding it easier.

(4) How do you feel about the chemistry you have learned ?

The purpose of this question is to explore how the students see themselves in relation to their studies in chemistry. The percentages of responses were calculated as follows:

I am enjoying the subject	15	24	13	25	9	14	I am NOT enjoying the subject
I feel I am NOT coping well	18	10	11	10	24	27	I feel I am coping well
I find it very easy	22	27	23	16	8	4	I find it very hard
I am growing intellectually	37	21	16	11	12	3	I am NOT growing intellectually
I am NOT obtaining a lot of new skills	6	12	12	12	24	34	I am obtaining a lot of new skills
I hate practical work	4	6	5	8	13	64	I am enjoying practical work
I am getting better in the subject	35	23	15	12	9	6	I am getting worse in the subject
I do not like my teacher	35	9	12	18	15	11	I like my teacher
It is definitely 'my' subject	15	23	29	18	10	5	It is definitely not 'my' subject

Polarisation is much less evident when compared to year 10. Views are much more positive overall. In particular, their views of laboratory work have changed quite dramatically. However, they are still not favourably disposed towards their teachers.

(5) What do you enjoy in your chemistry lessons ?

The purpose of this question was to reflect on the students' opinions of chemistry lessons. The *percentages* of responses were calculated as follows:

50 Studying the theory	60 Studying chemistry applications in life
70 Doing practical work	69 Studying about chemical reactions in the human body
54 Explaining natural phenomena	20 Setting up apparatus
55 Drawing shapes (atoms, molecules, etc)	65 Studying how chemistry can improve my life
58 Writing formulae and chemical equations	66 Solving every day problems
50 Balancing chemical equations	71 Studying how chemistry can make our lives healthier

Compared to the younger year group, most topics are rated more highly although the general pattern is similar. Anything related to practical work tends to gain a high rating while themes which make the chemistry related to their lifestyle and context are also rated highly. The general pattern is similar to that obtained in the studies conducted by Skryabina (Skryabina and Reid, 2002 a, b)

(6) Here are some school subjects:

A	Arabic	D	Biology	B	Chemistry	E	English
C	Geology	F	Mathematics	G	Physics	H	Religion

Using the letters, place these in order of importance to yourself:

Most important to me .... ***Least*** important to me

The purpose of this question is to help in rating chemistry with respect to other subjects about students' opinions. The percentages of responses are as follows:

Chemistry										
	Most important to me	2	10	16	21	21	13	11	6	Least important to me
Physics										
	Most important to me	9	25	20	15	15	7	3	6	Least important to me
Biology										
	Most important to me	6	11	14	26	12	6	16	9	Least important to me
Mathematics										
	Most important to me	38	19	7	9	10	7	4	6	Least important to me

While students still see them as important, their views of the three sciences are not so positive. Indeed, chemistry is perhaps less well rated than physics.

(7) Show your opinion about the topics you have studied.

The purpose of this question was to consider topics which students had previously described as difficult . The *percentages* of responses were calculated as follows:

%	Mole Calculation	Balancing Equations	Homologous Series	Isomerism	Alkyl Groups	pH and pOH Calculation
Important to improve my	40	45	61	54	20	70
Boring	70	53	38	50	33	57
Interesting	41	65	60	57	40	44
Complicated	80	56	49	66	30	79
Good basis for future	20	50	28	62	35	52

It is important to note that a high proportion of students think mole calculation, chemical equation balance, isomerism, and pH & pOH calculation are boring and complicated. However, more than 44% of students think that balancing equations, isomerism, and pH & pOH calculation are important to improve their life, interesting, and are a good basis for future study. Thus, the students seem aware of the significance of some of the topics but still find them unattractive.

(8) Think about what might influence you to study chemistry in future years.
Which of the following would attract you to further study in chemistry.

This question was seeking which factors had influenced students to study chemistry in future years. The percentages of responses were calculated as follows:

72	An interesting course
75	There are good possibilities of jobs
55	What my friends think
0	Television programmes
66	The wishes of my parents
55	Exciting experiments in class
40	An interesting textbook
70	A stimulating teacher
30	Anything else: ....

As with the younger group, the great importance of the course and the teacher are apparent along with a very strong perception of job possibilities as being important. Of the 30% who ticked the 'anything else' option, 'government encouragement' and 'shortage of chemistry teachers' are listed. In order to address the shortage of chemistry and science teachers in Emirates, the Emirates' government has started to encourage the students to select chemistry at undergraduate level by giving them grants and increasing the salaries of newly qualified teachers of chemistry or science by $2500 per month. Also, The Ministry of Education in Emirates has started to implement a structure which improves career prospects of teachers, enabling them to gain promotion as head teachers more quickly and, perhaps, thereafter as supervisors in the Zone of Education or Ministry. Naturally salaries would increase accordingly.

(9) Write one sentence to say what most attracts you to chemistry.

68% of students answered that 'practical work' attracted them most to chemistry and 35% of students answered that they were attracted to chemistry by the fascinating descriptions of how gases collected (such as Cl_2). This might merely reflect a recent experience.

(9) Write one sentence to say what least attracts you to chemistry.

75% of students found that the presentation of chemical knowledge attracted them least to chemistry. Also, 40% of students named methods of teaching the issue that they found least attracted them to chemistry.

6.6 Comparison of Year Groups

It is possible to compare the responses of the two year groups. Table 5.18 shows the comparisons for questions 3, 4, and 6 between year 10 and year 11 groups. It is important to recognise that year 11 is different from year 10 in that the year 11 students have elected to pursue a more science-based curriculum. Comparisons must be interpreted with caution.

Comparison are made using chi square as a test of 'goodness of fit' . In this, the question being asked is whether year 11 differs from year 10.

Table 6.18: The comparisons between year 10 and year 11 groups with comments

Year 11 Compared to Year 10 using Chi-Square as a 'goodness of fit' test				
Question	**Chi-Square**	**Degrees of Freedom**	**Significance**	**Comment**
I like chemistry lessons	49.1	4	$p < 0.001$	*Less polarised for year 11*
Interesting	28.1	4	$p < 0.001$	*Year 11 is more polarised*
Easy	40.6	3	$p < 0.001$	*Year 11 is greater difficulty*
Useful	4.6	2	n.s.	*Both see chemistry as useful*
Important	32.0	3	$p < 0.001$	*Year 11 is less polarised*
Enjoyable	13.2	4	$p < 0.05$	*Year 11 is less polarised*
I am enjoying the subject	11.3	3	$p < 0.05$	*Year 11 is less polarised*
I feel I am NOT coping well	32.5	5	$p < 0.001$	*Year 11 is less polarised*
I find it very easy	9.8	3	$p < 0.05$	*Year 11 find it easier*
I am growing intellectually	34.7	5	$p < 0.001$	*Year 11 is less polarised*
I am obtaining a lot of new skills	24.3	4	$p < 0.001$	*Year 11 is more positive*
I like practical work	109.4	2	$p < 0.001$	*Year 11 are dramatically more positive*
I am getting better in the subject	14.7	4	$p < 0.01$	*Year 11 is more positive*
I do like my teacher	5.6	2	n.s.	
It is definitely 'my' subject	55.2	4	$p < 0.01$	*Year 11 is less polarised*
Chemistry	27.1	5	$p < 0.001$	*Year 11 are less positive*
Physics	16.6	4	$p < 0.01$	*Year 11 are more positive*
Biology	27.4	4	$p < 0.001$	*Year 11 are less positive*
Mathematics	12.6	3	$p <0.01$	*Year 11 are less positive*

It is also possible to look at questions 5 and 8 to see how the two year groups have responded. The general pattern of responses to question 5 (which looked at areas of greatest interest) shows considerable similarities. Understandably, year 11 shows a much greater interest in natural phenomena and the applications of chemistry in life. Question 8 explored the influences attracting them to chemistry. Again, the two year groups often show similar response patterns although the older group, as might be expected, perceive a greater influence from an interesting course, a good teacher and supportive peer group.

6.7 Conclusion

The general impression left from the results of the two grid tests is that many students have not grasped some of the basic ideas of chemistry.

For year 10, the students have not really understood the ideas of valency, the nature of the atom, the meaning of chemical formulae and how to write them. Indeed, some are not even sure what elements are! The results leave an impression that students have memorised some things but do not really understand what it is all about. Chemistry is abstract and they have no 'feel' for the nature of chemicals.

For year 11, as might be expected, the concept of the mole is not understood. Even with this older group, valency is causing problems and again, as expected, oxidation state is an area of considerable confusion. Of greater concern is the observation that the nature of bonding and valency are poorly understood. If students have not mastered some of the basic skills, then it reduces chemistry to an abstract subject to be memorised. Perhaps it is little wonder that attitudes are not too positive.

With attitudes, with year 10, as might be expected, many questions show considerable polarisation. This year group contains those who will elected to follow a science based course along with those who will opt out of sciences. The general impression left from both year groups is that here there are students who are well aware of the importance and significance of chemistry but who find the whole learning experience highly unsatisfactory. Many find it boring, difficult and are not coping too well, sometimes perhaps blaming the teacher for experiences that are not good. The data tend to confirm the need to make a curriculum closely related to context and lifestyle of learners. The data also suggest strongly that the problems faced by chemistry in the Emirates are much less serious with cognate subjects.

Students views of specific topics are highly revealing. They often see importance (or lack of it (eg lanthanides) and are aware that some topics are important in the context of their lives. Nonetheless, they find much of the work boring and complicated. Comparisons between year groups must be treated with caution in that year 11 is a group following a science-based curriculum while the younger groups contains the whole age cohort. The observed differences are probably explainable in terms of this difference.

Chapter Seven

The New Teaching Material

7.1 Introduction

In the first experiment, areas of difficulty were identified and student attitudes were measured. This chapter describes the second experiment which looked to develop an instructional approach to improve student's conceptual understanding of four broad areas of the curriculum. These had been identified as problem areas. The four areas are: the periodic table of elements, chemical equations, organic chemistry, and acids and alkalis. The overall aim is to develop a teaching and learning approach which will reduce the problems as well as encouraging more positive attitudes. The new teaching materials will be based on established educational principles so that more effective learning can take place. The approaches used are described along with details about the sample of students chosen. The results obtained are then discussed in the following chapter.

The survey looked at years 10 and 11 (ages 16-17 approximately) in typical schools in the Emirates.

7.2 The Curriculum Programme

In the Emirates, chemistry is taught in all three stages of the general education programme. In both the primary and the intermediate stages it is actually taught through teaching general science (integrated curriculum). However, at the secondary stage (ages 16-18) it is separately taught as a major subject, aiming to meet the specific needs and abilities of the learners. The secondary stage is considered as a stage which seeks to prepare students to move into society. At this level, chemistry is one of the basic subjects among the science curricula (Haidar, 1999). The topics in the chemistry textbook that students are taught in the first semester and second semester of secondary school includes have been listed in chapter 1 (see table 1.2).

7.3 The New Teaching Material

Four booklets were designed (two for year 10 and two for year 11) for use with students in the Emirates. They were designed to be used by the students in the to replace the chemistry textbooks. To develop the new teaching material, a number of factors were considered:

(a) The booklets had to cover the material required by The Emirates curriculum;

(b) *They had to fit the time available in the curriculum;*

(c) *They should draw in useful approaches from previous research and development.*

Of greater importance, they had to be constructed in such a way that they were based on the evidence from previous research on learning, especially learning in highly conceptual areas like chemistry. This will be discussed later.

The themes covered by each booklet are now outlined. The booklets are shown in full in the appendix (F)

Year 10

First booklet The Periodic Table of Elements

History of the 'Periodic Table of Elements'	A Pattern of Sizes
The Importance of the Periodic Table of Elements	Electrons in Atoms
How Common are the Elements ?	Electronegativity
When were the Elements Discovered?	The Idea of Bond Polarity
Why Does the Periodic Table have such a strange shape ?	Patterns with the Elements
The Periodic Table and Reactivity	Groups and Valency
Atoms and Smaller Particles	Using the Periodic Table
Electrons, Shells, Energy and Spatial Arrangement.	Transition Metals
Some Consequences	What makes a metal like a metal ?

Second booklet Chemical Equations

Why do atoms form bonds between them?	The meaning of chemical equations
Other elements	Writing chemical equations
Valency with Roman numerals	Chemical equations and quantity
Valency is easy	How to balance equations
Writing chemical formulae	Equations and mass
More complicated molecules	Masses and units
Some things to remember	Final ideas

Year 11

First Booklet Organic Chemistry

Why Carbon?	The Products From Cracking
Fun with Balloons	The Alkenes in More Detail
Chains and Rings	Looking at Alkenes
Hydrocarbons	Uses for Alkenes
A Drawing Problem	So Many Hydrocarbons- So Many Names!!
Looking at the Alkanes	Different Shapes and Sizes
Oil	Another Homologous Series!

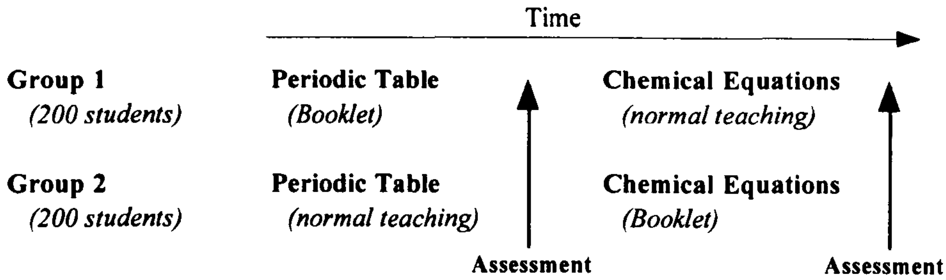
Second Booklet Acids and Alkalis

Where do the hydrogen ions come from?	Measuring PH
More about Hydrogen Ions	POH Scale
How many Hydrogen Ions?	Indicators and Titrations
How does Hydrogen Ion Concentration Vary?	Titrations
The PH Scale	

To assess the impact of the booklets in action, a total sample of 800 students was selected. There were 400 students (200 boys and 200 girls) from year 10 and 400 students (200 boys and 200 girls) from year 11. The students were aged between 16-17 years and came from a large typical secondary schools in the United Arab Emirates.

It was not possible to divide each of the samples of 400 into exactly matched groups so that the effect of the new materials could be compared to that of the teaching and learning materials currently in use. Because there were two booklets for each year group, it was possible to allow each group of 200 for each year to undertake one booklet, the other 200 acting as a control group. The experimental structure is shown in figure 7.1.

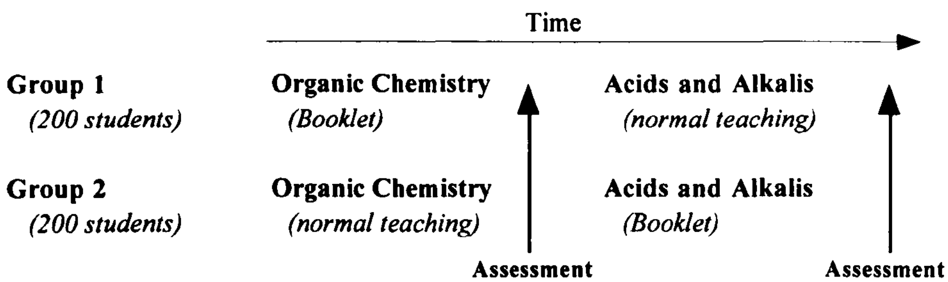
Figure 7.1 Experimental Structure for year 10



In this way, group 1 is the experimental group for the teaching on the Periodic Table while group 2 is the experimental group for the teaching on Chemical Equations. This experimental structure does not require exactly balanced groups and has the ethical advantage that both groups are having the experience of the new materials in one topic.

A similar experimental structure is used for year 11 (see figure 7.2)

Figure 7.2 Experimental Structure for year 11



There is one other advantage. It allows the booklet experiment to be repeated, using two age groups, although involving different topics.

7.4 The Purpose of this Experiment

The previous survey of understanding and of attitudes has shown that the students have major gaps in their understanding. They find many topics difficult and unattractive. They do not appear to be able to see the purpose, relevance and context of the work they are being asked to do. The new booklets seek to address these problems.

Previous work has shown that most of the difficulties in learning chemistry are caused by the learners being required to handle too much information at the same time. The working memory has a small and fixed capacity and it easy to overload the working memory space with highly conceptual subjects like chemistry. The booklets will aim to present the material in such a way that working memory overload is minimised. This will follow the pattern described by Danili in her work in Greece (Danili and Reid, 2004)

In a review, Reid (1999) suggested that the key to positive attitudes arising from many studies was that the material being learned was perceived by the learners as related to their current lifestyle, aspirations and interests. This led to the concept of the applications-led curriculum where the curriculum itself was designed around applications which made sense to the learners and were perceived as related to them. Examples of such curricula in physics were discussed and the very positive reactions of learners was noted. The effectiveness of such curricula in laying a sound basis for future study was also noted. The aim here is to re-structure the chemistry to be taught to make it more related to the learners. However, it has to be recognised that there are limits to this in that subject matter to be taught is laid down.

In order to make the curriculum accessible, the following teaching issues were considered: order, presentation, sequencing of ideas, applications and contexts. Very often, the aim was to start with the life examples which were likely to be meaningful and build from these. Great care was taken in, the way the material was presented so that working memory overload was minimised. This meant a step-by-step handling of some ideas.

Students are more likely to understand when they have opportunities to interact with the ideas being taught. The new teaching approach aimed to help students become active learners by providing them with material which involved discussion, considering issues, applying ideas and thinking through what was being presented to them.

Thus, the following aspects of the learning process were considered when designing the booklets:

(1) Working memory - avoiding overload .
(2) Encouraging use of relevant applications.
(3) Encouraging understanding not memorising.
(4) Linking new material to previously held material in a meaningful way.
(5) As a bonus, the aim was to make chemistry fun by the use of appropriate applications and illustrations.

The measurements were set against that background. The aim was to test to see if this new approach encouraged better understanding rather than a dependence on recall. The aim was also to assess student attitudes to see if they had become more positive towards their studies and the issues arising from them.

Some of this can be illustrated. In the first booklet (Organic chemistry) for year 11, students were offered a fun activity. This is described in using balloons to help students understand the concepts underpinning the stereochemistry around a carbon atom.

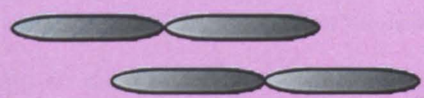
An example of this is shown in the figure 7.3

Figure 7.3: An Example of Chemistry Fun Approach of the Teaching Material

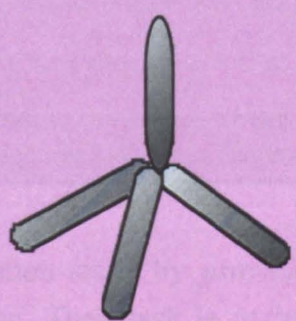
Try this for yourself:

Take two long modelling balloons:

Holding both ends of each balloon, twist each to form a narrow bit in the middle:



Now twist the two balloons together:



The four 'legs' move a part from each other and from a shape called a ***tetrahedral shape.***

The balloons show the geometry of the electron pairs and the position taken naturally by two balloons tied together at the centre. The balloons, like the electron pair clouds they represent, arrange themselves so as to be far from one another as possible.

Much of this can be described as an active approach. However, the activity was not the fundamental issue. The key thing is to teach in such a way that the working memory is not overloaded, the new ideas can be linked meaningfully to previously held ideas and that time is allowed for the learner to explore ideas in such a way that understandings can be checked. Active learning may well allow new ideas to be linked and checked but, of itself, it is not sufficient for efficient and effective understandings to be guaranteed. Thus, for example, laboratory work is often highly active but it may well not result in much learning (Johnstone and Wham, 1983).

In all booklets students were asked to work through and answer questions which are shown in the figure 7.4, 7.5, 7.6 and 7.7 .

Figure 7.4: An Example of Active learning Approach of the Teaching Material

Look at the periodic table. This shows the dates of discovery (the dates when the elements were obtained in a reasonably pure form (some were known to exist before that) for many of the elements and try to answer the follow questions:

(1) The dates of discovery for some elements are not given.
Can you suggest a reason why they are not shown?

(2) Look at the last column (the noble gases).
Where do most of these gases occur in the world?
Why do you think they were they all discovered at a similar time?

(3) Many of the metals in columns I and II were discovered near the start of the 19th century.
These are common metals.
Why were they discovered so late in the world's history?
What allowed them to be discovered at this time?

(4) Why were metals like copper, silver, gold, tin and lead discovered so early?

(5) Nitrogen, oxygen and chlorine were all discovered about the same time. Can you suggest a reason why? Why was fluorine discovered later?

This question starts by *providing* information rather than asking the students to recall information. Their task is to interpret and to offer explanations. The wording tries to encourage an approach where they do not think in terms of 'right' answers. By looking at groups of elements which fit each of the questions, working in a group, they try to see what these elements have in common and to relate the dates to their wider knowledge. The students have little experience of the periodic table and it is written in a foreign language for them. The set of questions offers them an experience of becoming more familiar with the table and seeing that there are patterns. The table must have some kind of meaning and purpose. This is their introduction to the table.

Figure 7.5: An Example of Active Learning Approach of the Teaching Material

(2) Try these - they are a bit more difficult !

(a) How much water would expect to obtain if you burned 4g of hydrogen in oxygen?

(b) Titanium metal can be obtained by reacting titanium (IV) oxide with magnesium metal which is converted to magnesium oxide. How much titanium (IV) oxide would you need to make 96g of titanium metal?

(1) Now try some yourself - balance the following equations.

□ H_2	+	□ N_2	→	□ NH_3		
□ C_3H_8	+	□ O_2	→	□ CO_2	+	□ H_2O
□ Al	+	□ CuO	→	□ Al_2O_3	+	□ Cu
□ K_2O	+	□ H_2O	→	□ KOH		
□ I_2	+	□ $Na_2S_2O_3$	→	□ NaI	+	□ $Na_2S_4O_6$

Question (2) is the last of a series of exercises and is presented as a challenge. Balancing equations requires students to apply previously learned rules. Part (b) uses unfamiliar chemicals but these are deliberately chosen in that the arithmetic is extremely easy, allowing the students to concentrate on the principles they have been taught, easing pressure on working memory. Question (1) is simply given to allow practice so that confidence and competence in a basic skill can develop.

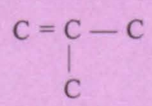
Figure 7.6: An Example of Active learning Approach of the Teaching Material

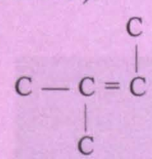
(1) Gives names for the following alkene molecules:

(a) C_4H_8 ....

(b) C_7H_{14} ....

(2) Give names for the following structures (the hydrogen are not shown):





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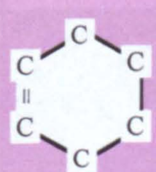
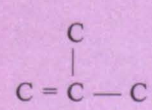




....

(3) Alkenes are never used in petrol or diesel fuel. Think of the conditions inside a car cylinder as petrol is burned explosively. Suggest what might happen if alkenes were used in car engines?

Question (1) and (2) are simply given to allow practice for naming in different ways: naming chemical formula and structural formula so that confidence and competence in a basic skill can develop. Question (3) requires students to apply previously knowledge and link it on to present problems.

Figure 7.7: An Example of Active learning Approach of the Teaching Material

(1) In practice, it often happens that three water molecules are group around one hydrogen ion in three dimensions. Try to draw this:

(2) Calculate the pH of 0.02 mol per litre hydrochloric acid solution?

(3) A solution contains 0.0001 mole per litre of hydrogen ions. What is the pH?

(4) What is the pH of a solution contains 0.035 moles per litre of hydrochloric acid?

One of the main problems in chemistry is that there is a need to visualise molecular situations and use imagination. Question (1) invites the students to attempt to draw what is happening with a hydrogen ion in water. It makes them, think about the way the water molecule might be attracted to the ion and raises questions about the three dimensional nature of molecular situations. The other three questions are designed to allow students to practice routine calculations, these starting very simply and becoming progressively more demanding.

Some examples of these models are described below:

In order to explain when were the elements discovered, a new periodic table with the date of discovery was designed and it is really different than the periodic table classic which is used in the chemistry textbook in Emirates (see Figure 7.8).

Figure 7.8 Showing the Date of Discovery of Elements

1776 $_{1}$H																	1895 $_{2}$He
1817 $_{3}$Li	1828 $_{4}$Be											1808 $_{5}$B	$_{6}$C	1772 $_{7}$N	1776 $_{8}$O	1886 $_{9}$F	1898 $_{10}$Ne
1807 $_{11}$Na	1808 $_{12}$Mg											1827 $_{13}$Al	1824 $_{14}$Si	1669 $_{15}$P	$_{16}$S	1774 $_{17}$Cl	1894 $_{18}$Ar
1807 $_{19}$K	1808 $_{20}$Ca	1876 $_{21}$Sc	1791 $_{22}$Ti	1801 $_{23}$V	1797 $_{24}$Cr	1774 $_{25}$Mn	$_{26}$Fe	1735 $_{27}$Co	1751 $_{28}$Ni	$_{29}$Cu	1746 $_{30}$Zn	1875 $_{31}$Ga	1886 $_{32}$Ge	1649 $_{33}$As	1817 $_{34}$Se	1826 $_{35}$Br	1898 $_{36}$Kr
1861 $_{37}$Rb	1808 $_{38}$Sr	1828 $_{39}$Y	1824 $_{40}$Zr	1801 $_{41}$Nb	1782 $_{42}$Mo	1937 $_{43}$Te	1844 $_{44}$Ru	1803 $_{45}$Rh	1803 $_{46}$Pd	$_{47}$Ag	1817 $_{48}$Cd	1863 $_{49}$In	$_{50}$Sn	1620 $_{51}$Sb	1782 $_{52}$Te	1811 $_{53}$I	1898 $_{54}$Xe
1860 $_{55}$Cs	1808 $_{56}$Ba	1839 $_{57}$La	1923 $_{72}$Hf	1903 $_{73}$Ta	1783 $_{74}$W	1925 $_{75}$Re	1803 $_{76}$Os	1803 $_{77}$Ir	1735 $_{78}$Pt	$_{79}$Au	$_{80}$Hg	1861 $_{81}$Tl	$_{82}$Pb	1753 $_{83}$Bi	1898 $_{84}$Po	1940 $_{85}$At	1900 $_{86}$Rn
1939 $_{87}$Fr	1898 $_{88}$Ra	1889 $_{89}$Ac															

Very often, Periodic Tables are introduced with too much information at the start. This Periodic Table simply offered the symbol and the date of discovery (where known). The students had to refer to other notes to find the names corresponding to symbols, giving them repeated practice in using the table. No attempt was made to justify its shape or the use of atomic numbers which were seen simply as the numbers of the elements in order. The aim was to avoid information overload and to allow the students to link new material (patterns of dates) to information they knew already or could work out.

In the chemistry textbook for year 10 in Emirates, the periodic table of elements starts first with the scientific attempts to divide the chemical elements in groups and the periodic idea, then moves through the work of Mendeleev and Lother Meyer to form groups, periods, links to atomic size, ionisation energy and electronegativity. This is far too much information all presented at once. An added complication is that it is all presented in a script foreign to the students and writing is from left to right, yet another added complication. Inevitably, these added language barriers will use up valuable working memory space as well as making the formation of links to familiar ideas more difficult.

In the new material, time was spend at the start to look simply at history of the periodic table of elements and the importance of it. Then, basic and simple ideas were developed: How common are the various elements? When were the elements discovered? Why does the periodic table have such a strange shape ? The periodic table and reactivity. This relates the table to what they students already know, and gives them time to practice using the table in unthreatening situations.

At that stage, the construction of atoms and the ideas of energy, electrons shells and spatial arrangement were developed. The consequences of sizes and shapes were introduced and this led naturally on to concepts like electronegativity and the idea of bond polarity. These ideas were then applied to rationalise the behaviour of elements, groups, valency, the nature and character of metal and so on.

Chemical calculations is another area which can cause great problems. In the Emirates chemistry textbook, the method of calculating the mass of a compound like $(NH_4)_2SO_4$ is:

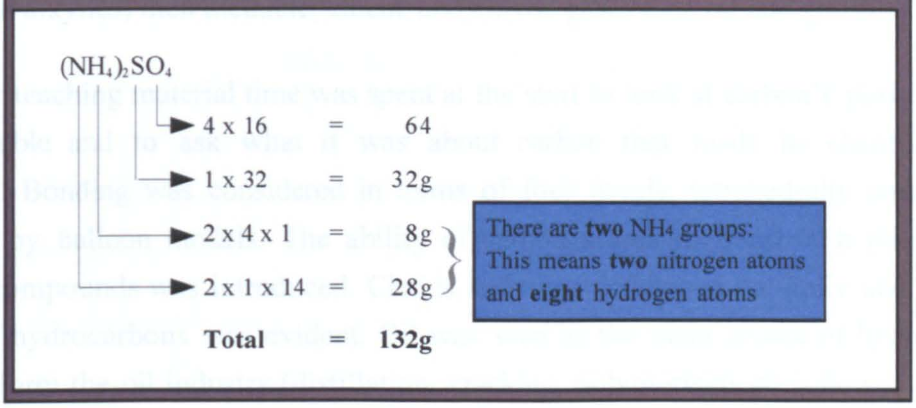
$$2\,(4\text{x}1 + 14) + 32 + (4\text{x}16) = 132\text{g}$$

Mistakes occur frequently, simply because the method assumes confidant understanding of the formula and the ability of use an algebraic formulation. Information overload is almost certainly guaranteed.

A simpler approach was adopted, in an attempt to reduce information overload.

An example of how to find the mass of a molecule of a compound is shown in figure 7.9.

Figure 7.9 Finding the Mass of a Compound.



The hidden aim was to try to introduce an element of enjoyment and, indeed, fun. Colour as used where appropriate, eg.

Indicators	Colour Change	pH Interval
Methyl Orange	Orange-Yellow	2.1 - 4.4
Methyl Red	Red-Yellow	4.2 - 6.3
Bromothymol Blue	Yellow-Blue	6.0 - 7.6
Phenolphthalein	Colourless-Red	8.3 - 10.0

The chemical equation in the chemistry textbook for year 10 in Emirates starts first with the meaning of chemical equation and the steps of balancing, with some examples. Types of chemical reactions are then described. In the new teaching material, time was spend at the start to represent why do atoms form bonds between them. This was presented in simple electrostatic terms, with electrons between atoms able to hold adjacent nuclei together.

Valency follows naturally and valency numbers were shown with Roman numerals. This seems to make the idea of valency straightforward and allows confidence in writing correct chemical formulae and being able to interpret what a formula means (at least at a molecular level). The equation is a means of representing the re-arrangement of chemical bonds now is developed and practice is given in writing such equations. With confidence in writing and balancing equations, the idea of quantity is now introduced.

Organic chemistry is introduced late in the Emirates syllabus (year 11) and is seen as difficult. This used to be case in the Scottish syllabus (Johnstone *et. at.* 1971). In the light of research evidence, the presentation of the organic was introduced much earlier and is a different way (Johnstone *et. at.* 1980). This influenced the presentation used here.

In the chemistry textbook for year 11 in Emirates, organic chemistry starts first with the bonds in organic compounds then carbon atom and the hydrocarbons compounds (alkanes, alkenes and alkynes) then methane, ethene and ethyne gases then oil and gasoline.

In the new teaching material time was spent at the start to look at carbon's position in the periodic table and to ask what it was about carbon that made its chemistry very interesting. Bonding was considered in terms of four bonds, tetrahedrally arranged and illustrated by balloon models. The ability of carbon atoms to bond with other carbon atoms in compounds was introduced. Chains and rings developed naturally and the sheer number of hydrocarbons was evident. Oil was seen as the main source of hydrocarbons and ideas form the oil industry (distillation, cracking, polymerisation) followed and were linked to structures and homologous series.

Again, the overall aims was to present the material in such a way that the students could link it on to previous knowledge. By developing ideas step by step, it was hoped that overload of working memory would be reduced, allowing the students to begin to understand ideas rather than simply memorise a mass of information.

The acids and alkalis topic in the chemistry textbook for year 11 in Emirates start first with the Arrhenius theory, then ionic product of water the meaning of pH and pOH and some examples to calculate the pH, pOH, $[H^+]$ and $[OH^-]$ and, finally, the importance of pH.

In the new teaching material, time was spend at the start to simply think about the hydrogen ion and the idea of acids and alkalis was developed slowly. Representations were introduced slowly and the hydrogen ion was continually brought into to focus as the key idea.

At this point, the more complicated ideas were developed; quantities of hydrogen ions and how hydrogen ion concentration varies. At this point the need for a logarithmic scale becomes evident and pH and pOH scales are introduced, with the use of indicators and titrations following.

The test materials are now described and their use in assessing student performance after using the materials is described. The test materials were given the heading: "**What do you Understand**" and the focus was on measuring understanding rather than recall. They were designed to be as unthreatening as possible.

7.5 Structural Communication Grids

Four tests were designed, one for each of the four topics. The tests are shown in full below.

What do you understand ?

This is an unusual test.

It is designed to find out what you have understood from the Periodic Table of Elements.

Here is an example question:

Select all box (es) which contain names of capital cities.

1 **Vienna**	2 **Glasgow**	3 **Damascus**
4 **Melbourne**	5 **Paris**	6 **Delhi**

The correct answer is 1, 3, 5, and 6.

(Glasgow is ***not*** the capital of Scotland and Melbourne is ***not*** the capital of Australia but Vienna is the capital of Austria, Damascus for Syria, Paris for France and Delhi for India)

Q1 Write down the number for the answers to the following questions.

Look at the boxes below and answer the question that follow:
(*Boxes may be used as many times as you wish*)

A Ne	**B** As	**C** Fe	**D** Li
E K	**F** Al	**G** Cl	**H** Ar
I F	**J** Mg	**K** Kr	**L** Na

Select the box(es) which contain elements which:

(a) Can show a valency of 2 ? ....

(b) Can show a valency of 3 ? ....

(c) Are non-metals? ....

(d) Are noble gases? ....

(e) Were known in ancient time? ....

(f) Are halogens? ....

Q2

A F > Cl > Br > I	**B** Cs > Rb > K > Na	**C** Sr > Ca > Mg > Be
D Be < Mg < Ca < Sr	**E** Li > Be > B > C	**F** Li < Be < B < C

Select the box(es) which contain elements:

(a) In a group in the right order of electronegativity ? ....

(b) In a period in the right order of electronegativity ? ....

(c) In a group in the right order of atom size ? ....

(d) In a period in the right order of atom size ? ....

Q3

A K	**B** Ne	**C** Al	**D** Sr
E Na	**F** Rb	**G** F	**H** Br
I Cl	**J** Ca	**K** Ar	**L** Mg

Select box (es) which contain:

(a) Elements which have 1 electron in the outer shell ? ....

(b) Elements which have 2 electrons in the outer shell ? ....

(c) Elements which have 7 electrons in the outer shell ? ....

(d) Electrons where the outer shell is completely full. ....

Q4 In ***one*** sentence explain why a:

(a) **Li** atom is smaller than a **Na** atom?

(b) **F** atom is smaller than **Cl** atom ?.

(c) **F** atom is smaller than a **Li** atom?

Q5 In ***two*** sentences explain why:

A Chlorine (Cl) atom is more electronegative than a Calcium (Ca) atom

What do you understand ?

Write in the answers to all questions

You can use the Periodic Table of Elements to help you.

(1) Write the correct chemical formulae for each of the following:

Sodium Chloride ....
Calcium Bromide ....
Aluminium Oxide ....
Magnesium Fluoride ....
Carbon Dioxide ....
Copper (I) Oxide ....
Potassium Nitrate ....
Ammonium Phosphate ....
Strontium Hydroxide ....

(2) Balance the following equations:

$K + O_2 \longrightarrow K_2O$

$Mg + HCl \longrightarrow MgCl_2 + H_2$

$Al + O_2 \longrightarrow Al_2O_3$

$H_2S + SO_2 \longrightarrow S + H_2O$

$I_2 + Na_2S_2O_3 \longrightarrow NaI + Na_2S_4O_6$

Use these values for questions 3 and 4
Some Relative Atomic Masses
H = 1, Cl = 35.5
O = 16, N = 14, S = 32

(3) Calculate the formula mass in grams for each of:

SO_2 ....

HCl ....

(4) Calculate:

(a) The mass of a mole of sulphuric acid (H_2SO_4)

(b) Number of moles of ammonia (NH_3) in 68g of ammonia

<u>What do you understand ?</u>

This is an unusual test.

It is designed to find out what you have understood from the periodic Table of Elements.

Here is an example question:

Select all box (es) which contain names of capital cities.

1 **Vienna**	**2** **Glasgow**	**3** **Damascus**
4 **Melbourne**	**5** **Paris**	**6** **Delhi**

The correct answer is 1, 3, 5, and 6.

(Glasgow is ***not*** the capital of Scotland and Melbourne is ***not*** the capital of Australia but Vienna is the capital of Austria, Damascus for Syria, Paris for France and Delhi for India)

Q1 Write down the number for the answers to the following questions.
Look at the boxes below and answer the question that follow:
(Boxes may be used as many times as you wish.)

A C_2H_2	**B** C_3H_8	**B** CH_4
D C_5H_{10}	**E** C_4H_8	**F** C_7H_{16}
G C_3H_4	**H** C_7H_{14}	**I** C_6H_6

Select the box(es) which contain:

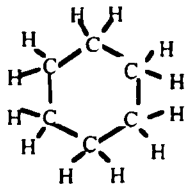
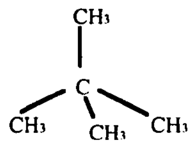
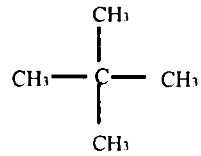
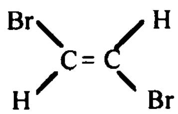
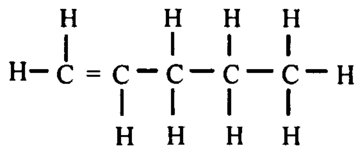
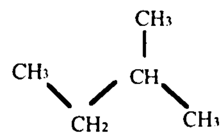
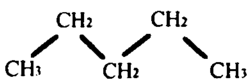
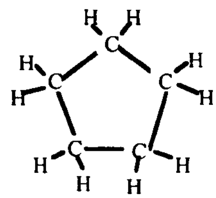
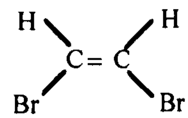
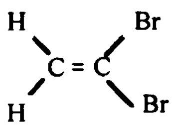
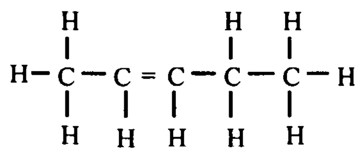
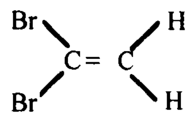
(a) Alkanes ....

(b) Alkenes ....

(c) Alkynes ....

(d) Cycloalkanes ....

Q2

 A	 B	 C
 D	 E	 F
 G	 H	 I
 J	 K	 L

Select the box(es) which contain:

(a) Isomers of the molecule shown in box **B** ....

(b) Isomers of the molecule shown in box **G** ....

(c) Isomers of the molecule shown in box **H** ....

(d) Isomers of the molecule shown in box **I** ....

(e) Isomers of the molecule shown in box **J** ....

Q3 (a) Explain in **three** sentences why cracking so important in oil industry?

(b) "Polymerisation is the opposite of cracking"

Write in **three** sentences how this is true?

What do you understand ?

Write in the answers to all questions

This test designed to find out what you have understand about Acids and Alkalis.

Q1 (a) Calculate the pH of 0.01 mole per litre hydrochloric acid solution.
(b) Calculate the $[H^+]$ concentration in moles per litre for some drinking water which has a pH of 6.

Q2 (a) The $[OH^-]$ concentration in moles per litre is 0.001. What is the pH of the solution?
(b) In some pure water at 25°C, the $[H^+]$ and $[OH^-]$ are both 10^{-7} moles per litre. What is the pH ?

Q3 (a) Water from an underground source is found to have a pH of 4.3. What is the concentration of hydrogen ion in moles per litre?
(b) A bottle of cleaning liquid has a pH of 10. What is the $[H^+]$ and $[OH^-]$?

Q4 (a) Some brands of liquid soap, for use in having a shower, state that they have a pH of 5.8. Suggest why 5.8 is chosen ?
(b) The pH value of Human blood is normally 7.4 . Suppose a very ill person's blood pH is found to have fallen to 6.4.
(i) What is the hydrogen ion concentration in the blood of a *normal* person?
(ii) What is the hydrogen ion concentration in the blood of the very *ill* person?
(iii) How much *more* hydrogen ion is present in the blood of the very sick person?

Q5 You have a litre of 0.1M HCl (pH = 1) and a litre of 0.01M NaOH (pH= 12). The two solutions are mixed. What is the likely pH of the final solution. (Do not attempt any calculation).

Tick one box

10.9	7	6.5	1.35	0.95

Q6 Look at the following table:

Indicators	Colour Change	pH Interval
Methyl Orange	Orange-Yellow	2.1 - 4.4
Methyl Red	Red-Yellow	4.2 - 6.3
Bromothymol Blue	Yellow-Blue	6.0 - 7.6
Phenolphthalein	Colourless-Red	8.3 - 10.0

(a) Choose the best indicator for a titration of sodium hydroxide and sulphuric acid, given that sodium sulphate has a pH of 7.
(b) Choose the best indicator for a titration of sodium hydroxide and ethanoic acid, given that sodium ethanoate has a pH of 9.

In chapter nine, the results for each test are discussed in turn, starting with the year 10 group of students.

Chapter Eight

Concept Mapping

8.1 Introduction

Concept maps are a very interesting technique which has been used to offer rich insights into the way a concept is 'mapped' in the student mind and drawings or diagrams showing connections between major concepts in a course or section of a course (Novak, 1991).

This chapter looks into the nature of concept mapping, concept maps and science, some advantages of concept mapping, kinds of concept maps, steps in making a concept maps, concept maps and curriculum design, concept mapping for meaningful learning, and concept map and mind map.

8.2 What is Concept Mapping?

Concept mapping is a technique for representing knowledge in graphical form. Knowledge graphs are networks consist of nodes (points/vertices/circles) and links (lines/arcs/edges). Nodes represent concepts and links represent the relations between concepts. Concepts and sometimes links are labelled. Links can be non-, uni- or bidirectional. Concept and links may be categorised, they can simply associative, specified or divided in categories such as: as causal or temporal relations (Berger, 1996). Stoddart *et al.* (2000) noted the basic element of concept maps consists of concept words or phrases that are connected together with linking words or phrases to from complete thoughts called 'propositions' For example,

concept ——► linking word ——► concept

Novak and Gowin (1984) suggested that, "propositions are two or more concept labels linked by words in a semantic unit". They also see concept and propositions composed of concepts as the central elements in the structure of knowledge and construction of meaning. They represent propositions in semantic networks called *Concept maps*. Many others have found concept maps (also called semantic networks, semantic maps, and knowledge map) useful in teaching propositions. Concept maps can aid learning the declarative knowledge of relationships among concepts. The value of concept maps depends on variables that change from one classroom to another. Teachers must experiment with such tools to learn how to use them in their own classroom. The concept mapping technique was first used and developed by Prof. Joseph D. Novak at Cornell University in the 1960. This work was based on the ideas of David Ausubel who stressed the importance of prior knowledge in being able to learn about new concepts. Novak concluded that, "Meaningful learning involves the assimilation of new concepts and propositions into existing cognitive structures" (Herron, 1996).

Berger (1996) asserted that concept mapping can be carried out for several purposes:

- *To generate ideas (brain storming, etc.).*
- *To design a complex structure (long texts, hypermedia, large web sites, etc.).*
- *To communicate complex ideas.*
- *To aid learning by explicitly integrating new and old knowledge.*
- *To assess understanding or diagnose misunderstand.*

8.3 Concept Maps and Science

Concept mapping is an active learning tool with numerous uses in the science classroom, including planning, teaching, revision and assessment (Edmondson, 2000, Kinchin, 2000). The concept map has been described as "the most important meta-cognitive tool in science education today" (Mintzes *et al.* 1998). However, that assertion remains to be vindicated by evidence.

Markow & Lonning (1998) suggest that concept maps have been demonstrated to be a powerful instructional tool which assists students in clarifying their understandings and makes connections between concept explicit. Educators have found concept maps useful to assess prior student knowledge, to identify gaps in student knowledge, to help teacher education students identify key concepts to target in their teaching and as an assessment tool to determine the extent and quality of new connections students are able to make after instruction (Mason, 1992).

Researchers have used concept maps in the field of chemistry (Stensvold & Wilson 1990, Markow & Lonning 1998), physics (Roth & Roycoudhury 1994), ecology and environmental education (Brody 1993, Heinze-Fry 1997), biology (Heinze-Fry & Novak 1990, Jegede *et al.*,1990, Songer & Mintzes 1993), astronomy (Zeilik *et al.* 1997), veterinary and medicine (Edmondson, 1995), engineering (Moreira & Greca, 1996), geology (Gonzalez, 1993), and mathematics (Khan 1993, Moreira & Motta, 1993). In addition, concept maps have been used in education, policy studies and the philosophy of science to provide a visual representation structures and argument forms (Gaines & Shaw, 1992).

Researchers also have used concept maps with elementary students (Eschenbrenner, 1994), middle school students (Sizmur & Osborne 1997; Coleman, 1998), high school students (Stensvold & Wilson 1990), and college students (Heinze-Fry & Novak 1990; Pearsall *et al.* 1997) including teacher education students (Mason, 1992).

8.4 Advantages of Concept Mapping

Gaines & Shaw (1992) claim that it is only through practice that the advantages of concept mapping become clear.

Concept maps,-

- *Clearly define the central idea, by positioning it in the centre of the page.*
- *Allow the learner to indicate clearly the relative importance of each idea.*
- *Allow the learner to figure out the links among the key ideas more easily. This is particularly important for creative work such as essay writing.*
- *Allow the learner to see all your basic information on one page.*
- *As a result of the above, and because each map will look different, it makes recall and review more efficient.*
- *Allow the learner to add in new information without messy scratching out or squeezing in.*
- *Make it easier for people to see information in different ways, from different viewpoints, because it does not lock it into specific positions.*
- *Allow the learner to see complex relationships among ideas, such as self-perpetuating systems with feedback loops, rather than forcing you to fit non-linear relationships to linear formats, before you have finished thinking about them.*
- *Allow the learner to see contradictions, paradoxes, and gaps in the material or in your own interpretation of it more easily and, in this way, provides a foundation for questioning, which in turn encourages discovery and creativity.*

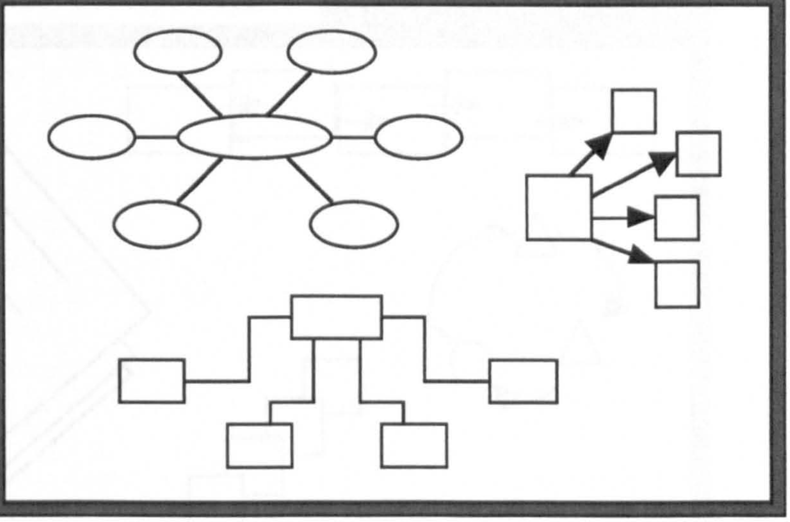
8.5 Kinds of Concept Maps

(Concept Maps Tutorial, Undated) four major basic types of concept maps have been described and these different types are presented in the next page:

(1) *Spider Concept Map*

The "spider" concept map is organised by placing the central theme in the middle and then having sub points radiate out from around the centre. (Figure 8.1)

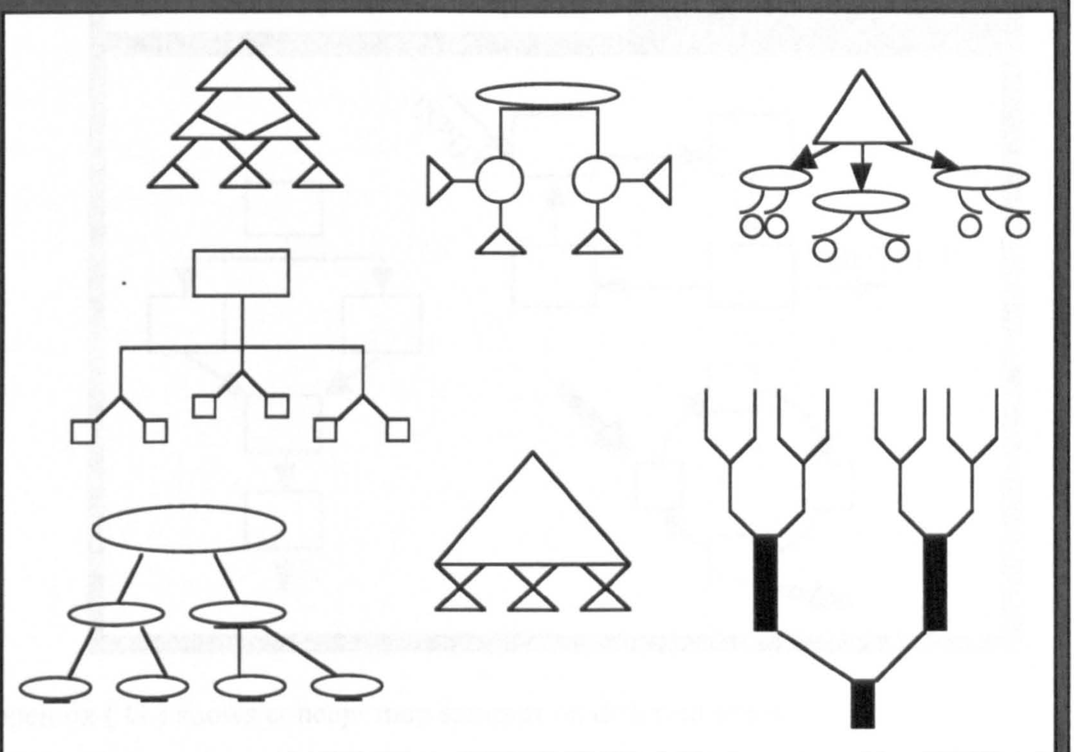
Figure 8.1 Spider Concept Maps



(2) *Hierarchy Concept Map*

The "hierarchy" concept map uses a descending order of importance with the most important item at the top and other item arranged as they relate. (Figure 8.2)

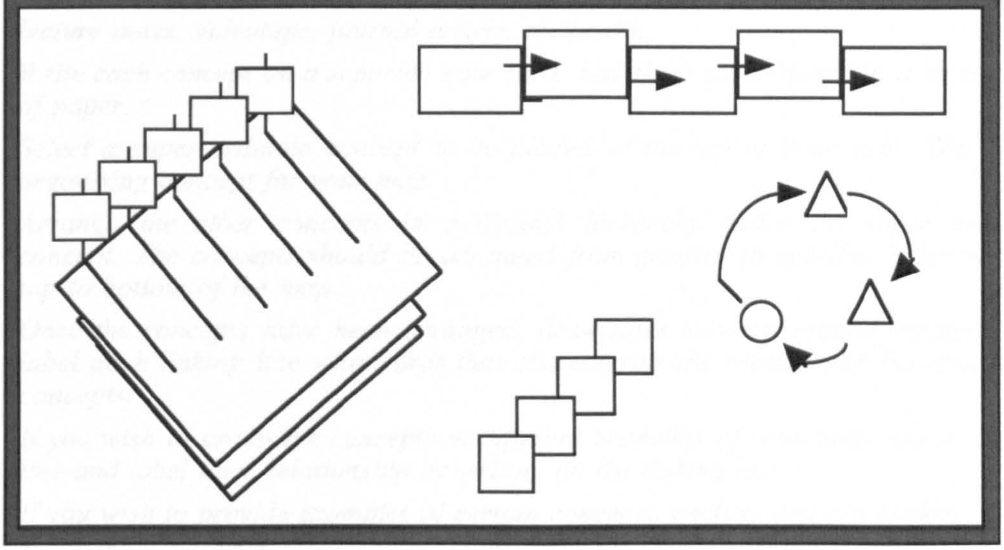
Figure 8.2 Hierarchy Concept Maps



(3) Flowchart Concept Map

The "flowchart" concept map uses a linear format to organise information. (Figure 8.3).

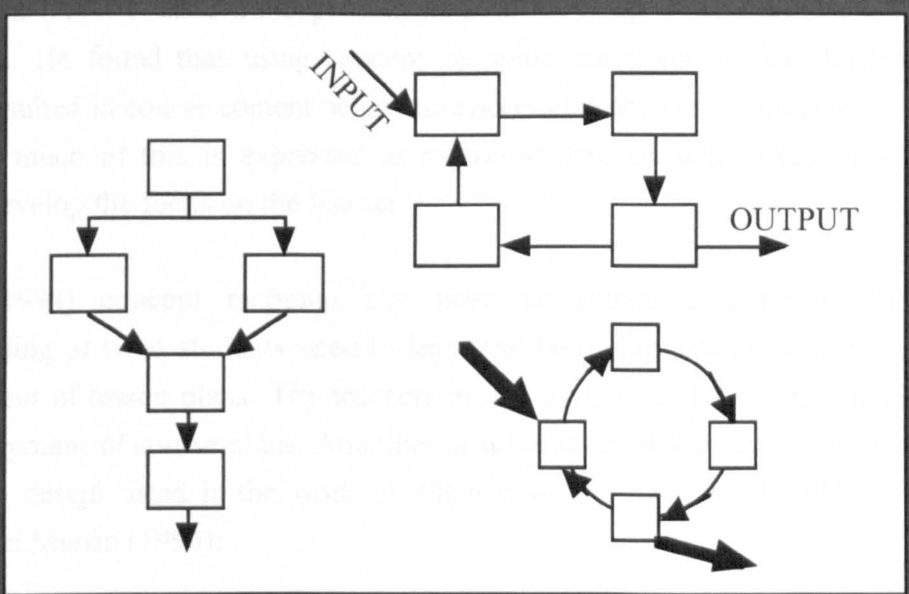
Figure 8.3 Flowchart Concept Maps



(4) *Systems Concept Map*

The ''systems'' concept map uses a flowchart like structure, with the addition of 'INPUTS' and 'OUTPUTS' (Figure 8.4).

Figure 8.4 Systems Concept Maps



Appendix (G) shows concept map samples on different areas.

8.6 Steps in Making a Concept Maps

Wandersee and Novak (1998) suggest that concept maps can be created by using straightforward steps:

(1) *Select 1-12 concepts from the science content material being considered (e.g. lecture notes, videotape, journal article, textbook).*

(2) *Write each concept on a separate note card. Lay these cards down on a large sheet of paper.*

(3) *Select a super ordinate concept to be placed at the top of your map. This is the organising concept for your map.*

(4) *Arrange the other concepts in a distinct hierarchy under the super ordinate concept. The concepts should be arranged from general to specific, in levels from top to bottom of the map.*

(5) *Once the concepts have been arranged, draw lines between related concepts and label each linking line with words that characterise the relationship between those concepts.*

(6) *If you wish to cross-link concepts in different branches of your map, use a dashed line and label their relationship by writing on the linking line.*

(7) *If you wish to provide examples of certain concepts, enclose these in broken ovals.*

(8) *Examples should be connected to their source concepts by an 'e.g.' labelled linking line.*

(9) *Review and reflect. Once you are satisfied with your concept map's revised arrangement, redraw the map in final form.*

8.7 Concept Maps and Curriculum Design

It is claimed that concept maps can be used as excellent planning devices for instruction. Edmondson (1995) used concept mapping to develop a problem-based veterinary curriculum. He found that using concept mapping principles in the curricula planning process resulted in course content being more accessible and easily integrated by students. However, much of this is expressed as aspiration and curriculum planners have other ways to develop the focus on the learner.

Martin (1994) concept mapping also provides educators a more comprehensive understanding of what students need to learn and help eliminate sequencing errors in the development of lesson plans. The teachers in the study found the maps quite useful for the development of course plans. Anumber of advantages of the use of concept maps for curriculum design listed in the work of Allen *et al.* (1992), Dyrud (1994), Edmondson (1995), and Martin (1994):

- *By constructing a concept map, you can see areas that appear trivial, that you may want to drop from the course.*
- *You can discover the themes you want emphasise.*
- *You can understand how students may see or organise knowledge differently from you, which will help you better relate to the students and to challenge their ways of thinking (Dyrud, 1994).*
- *The mapping process can help you identify concepts that are key to more than one discipline, which helps you move beyond traditional disciplinary boundaries.*
- *Concept maps help you select appropriate instructional materials. You can construct a map that incorporates teaching strategies as well as time and task allocations for various parts of the course (Edmondson, 1995).*
- *You can visually explain the conceptual relationships used for your objectives in any course.*
- *You can facilitate efforts to reconceptualise course content.*
- *You can use concept maps to provide a basis for discussion among students and to summarise general course concepts.*
- *Concept maps support a holistic style of learning.*
- *Mapping concepts can increase your ability to provide meaningfulness to students by integrating concept.*
- *Concept maps can increase your potential to see multiple ways of constructing meaning for students.*
- *Mapping the concepts can help you develop courses that well- integrated, logically sequenced, and have continuity.*
- *Concept maps help "teachers design units of study that are meaningful, relevant, pedagogically sound, and interesting to students" (Martin, 1994).*
- *Concept maps help "the teacher to explain why a particular concept is worth knowing and how it relates to theoretical issues both within the discipline and without" (Allen et al. 1993).*

In the Emirates, their is no evidence that the concept maps are being used in the chemistry curriculum and science curriculum to develop the curriculum and help the students in understanding the scientific concepts and also help the teachers in teaching processes.

8.8 Concept Mapping For Meaningful Learning

Novak (1998) asserted that concept maps can play a role in "teaching, learning, curriculum, and governance". For the learner, they help to make evident the key concepts or propositions to be learned and also suggest linkages between the new knowledge and what he or she already knows. For the teacher, concept maps can be used to determine pathways for organising meanings and for negotiating meanings with students, as well as to point out students' misconceptions. In curriculum planning and organisation, concept maps may be used for separating significant from trivial information and for choosing examples. With respect to governance, concept maps help students understand their role as learners; they also clarify the teacher's role and create a learning atmosphere of mutual respect.

Ausubel stressed three conditions for meaningful learning:

> *The material to be learned must be conceptually clear and presented with language and examples relatable to the learner's prior knowledge. Concept maps can be helpful to meet this condition, both by identifying large general concepts prior to instruction in more specific concepts, and by assisting in the sequencing of learning tasks though progressively more explicit knowledge that can anchored into developing conceptual frameworks.*
>
> *The learner must possess relevant prior knowledge. This condition is easily met after age 3 for virtually any domain of subject matter, but it is necessary to be careful and explicit in building concept frameworks if one hopes to present detailed specific knowledge in any field in subsequent lessons. We see, therefore, the conditions (1) and (2) are interrelated and both are important.*
>
> *The learner must choose to learn meaningfully. The one condition over which the teacher or mentor has only indirect control is the motivation of students to choose to learn by attempting to incorporate new meanings into their prior knowledge, rather than simply memorising concept definitions or propositional statements or computational procedures. The control over this choice is primarily in the evaluation strategies used, and typical objective tests seldom require more than rote learning* (Holden, 1992).

Several (Novak& Gowin, 1984; Novak, 1990, Mintzes *et al.* 1998) have suggested that concept mapping can be used in assessment. Indeed, Edwards & Fraser (1983) argued that they can be as effective as more time-consuming clinical interviews. However, the work of Otis (2000) has cast considerable doubt on the reliability of using concept maps in any form of assessment.

8.9 Mind Maps and Concept Maps

Novak (1998) offers guidelines for building a concept map. However, the term of mind map and concept map are sometimes used interchangeably. Nonetheless, there are differences and similarities between mind maps and concept maps. Table 8.1 Shows these differences and similarities:

Table 8.1 The differences and similarities between mind map and concept map.

Concept Map	Mind Map
Have several main concept.	Have only one main concept.
It is an educational tool used to: •Explore prior knowledge and misconceptions •Encourage meaningful learning to improve achievement •Measure concept understanding	It is a note taking technique for : •Generate ideas (brainstorming) •Making summaries from a book or a lecture •Meeting and in lectures, etc.
It is developed by J.Novak	It is developed by Tony Buzan
Top down hierarchy (from most inclusive at the top to less inclusive at the bottom).	Centre out hierarchy (most inclusive in the middle and more specific radiate out from centre).
Branching of ideas, and examples	Branching of ideas, and examples
Cross links, which indicate creative ability between ideas are important	Cross links are not emphasised or shown
Words should be at the end of the linking lines	Words should be on the linking lines

(Source: Bahar 1999)

In this study, it was decided to use concept map drawing in an attempt to explore the number of ideas which students had gained when studying the topic on the Periodic Table. Because of the doubts over the use of concept mapping for assessment, the only use made was to note the number of nodes and the number of links.

Chapter Nine

Analysis of Results

9.1 Analysis of the Grid Test Responses for Years 10 and 11 Students

While structural communication grids can be marked like any other test, the strength of these tests is in exploring incomplete answers and looking closely at patterns of wrong answers. To do this, the student performance in each part of each question is converted into a code. The codes may have to be adjusted in the light of what is observed. The aim of these codes is to count the numbers of students under each code and this will give a picture of how students performed in each question. The codes were chosen to achieve these aims. Table 9.1 shows the codes and scores which were used for 'The Periodic Table of Elements' and 'Organic Chemistry', the first two tests to be marked.

Table 9.1 Example Codes and Scores

Number of correct answers	Number of wrong answers	Codes	Scores
1	0	10	1
1	1	11	0.6
		other	0
2	0	20	1
2	1	21	0.67
2	2	22	0
1	0	10	0.5
		other	0
3	0	30	1
3	1	31	0.75
3	2	32	0.4
3	3	33	0
2	0	20	0.67
2	1	21	0.4
2	2	22	0
1	0	10	0.33
1	1	11	0
		other	0

The data were entered into a spreadsheet (full data in appendix H). The codes were converted into scores (table 9.1) and a total score was obtained for each student for each test. In order to compare between the groups, an independent t-test was used. Here, the overall performance is compared between groups who had used the new teaching materials or who had been taught in the traditional way.

9.2 Test Results

The main aim of this study is to explore the performance of senior school students when they have been taught in a way which is consistent with information processing predictions related to successful learning and also consistent with the evidence about the development of positive attitudes. For the first purpose, the total scores in the four tests and the responses to the attitude survey are analysed.

However, it is possible to analyse the detailed responses in every a part of every question, especially when structural communication grids are used, to pinpoint specific areas where learning has been achieved successfully and specific areas where the students are showing consistent confusions. Where the pattern of responses in each part of each question suggested some interesting features, the response pattern was considered in more detail. This offers insights into the specific ways in which the new materials assisted students towards better understanding.

The results for each test are now discussed in turn, comparing the performance of the groups who used the new teaching material or who were taught in the traditional style.

9.3 Test: The Periodic Table of Elements

Table 9.2 shows the comparison of the experimental group and control group in year 10 student achievement in the grid test on '*The Periodic Table of Elements*'.

Table 9.2 Experimental group and control group
'The Periodic Table of Elements'.

Periodic Table									
Experimental Group					*Control Group*				
N	*Mean*	*S.D.*	*Max*	*Min*	*N*	*Mean*	*S.D.*	*Max*	*Min*
200	79.2	4.84	95	60	200	61.0	8.6	85	43
t -test	t = 26.23		p < 0.001						

The data showed that there was a very significant difference in chemistry achievement with year 10 (on topic: 'The Periodic Table of Elements') between the mean scores achieved by the experiment group and the control group ($t = 26.23$, $p < 0.001$).

Interestingly, questions 1(a), 1(b), 2(b) and 2(d) test ideas which are taught similarly to both groups and the response patterns are virtually identical. The mean marks (as facility values) are now shown for each part of each question for the two groups.

Question 1

A	B	C	D
Ne	As	Fe	Li
E	**F**	**G**	**H**
K	Al	Cl	Ar
I	**J**	**K**	**L**
F	Mg	Kr	Na

Select the box(es) which contain elements which:

		Experimental Group	*Control Group*
(a)	Can show a valency of 2 ?	1.0	1.0
(b)	Can show a valency of 3 ?	0.9	0.9
(c)	Are non-metals?	0.7	0.1
(d)	Are noble gases?	0.6	0.3
(e)	Were known in ancient time?	0.8	0.1
(f)	Are halogens?	0.8	0.5

The new materials have clearly offered to the students a much better grasp of the periodic table: recognising groups of elements. However, the ability of the students to recognise valency is unaltered.

Question 2

A	B	C
F > Cl > Br > I	Cs > Rb > K > Na	Sr > Ca > Mg > Be
D	**E**	**F**
Be < Mg < Ca < Sr	Li > Be > B > C	Li < Be < B < C

Select the box(es) which contain elements:

		Experimental Group	*Control Group*
(a)	In a group in the right order of electronegativity ?	1.0	0.5
(b)	In a period in the right order of electronegativity ?	0.8	0.8
(c)	In a group in the right order of atom size ?	0.8	0.6
(d)	In a period in the right order of atom size ?	0.9	0.7

The new materials have brought abut consistent improvement. The most marked area of improvement is in grasping how electronegativity varies across a group.

Question 3

A	B	C	D
K	Ne	Al	Sr
E	**F**	**G**	**H**
Na	Rb	F	Br
I	**J**	**K**	**L**
Cl	Ca	Ar	Mg

Select box (es) which contain:

		Experimental Group	*Control Group*
(a)	Elements which have 1 electron in the outer shell ?	0.9	0.4
(b)	Elements which have 2 electrons in the outer shell ?	0.9	0.6
(c)	Elements which have 7 electrons in the outer shell ?	0.9	0.5
(d)	Electrons where the outer shell is completely full.	0.7	0.7

This question shows a dramatic difference in performance in three parts. The new materials have been successful in enabling the students to understand the electronic arrangement in atoms correctly. The octet was not emphasised in the new materials (it is misleading) and there is no difference between the two groups in part (d).

Question 4

In ***one*** sentence explain why a:

		Experimental Group	*Control Group*
(a)	**Li** atom is smaller than a **Na** atom?	0.9	0.9
(b)	**F** atom is smaller than **Cl** atom ?.	0.9	0.9
(c)	**F** atom is smaller than a **Li** atom?	1.0	0.9

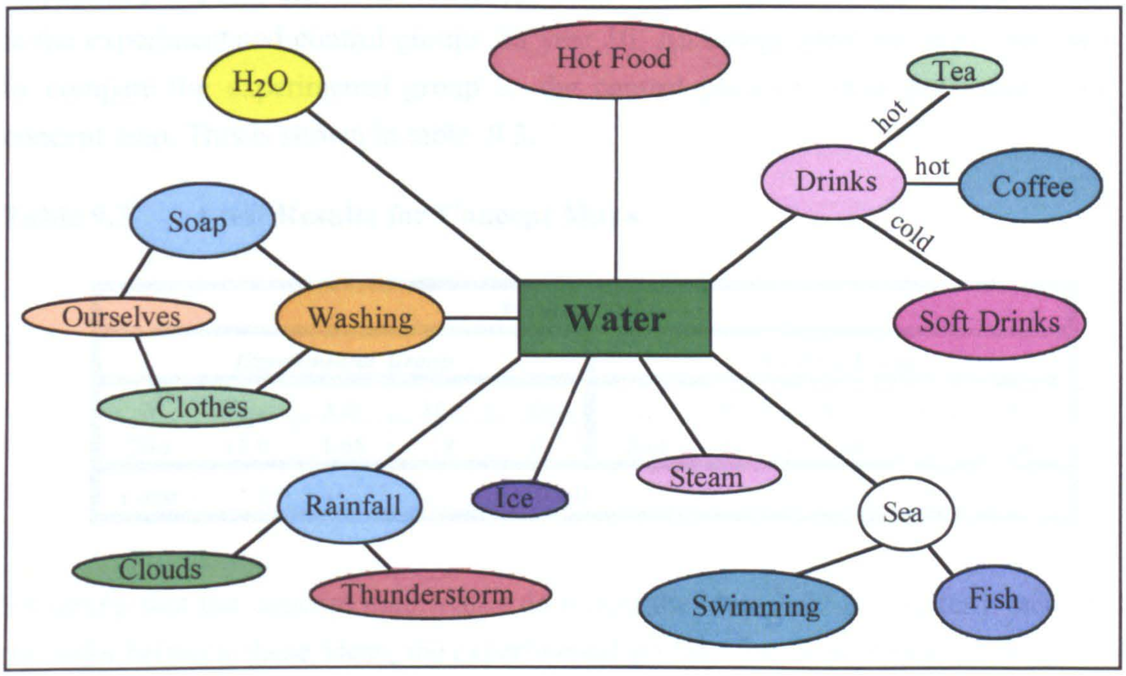
Question 5 In ***two*** sentences explain why a Chlorine (Cl) atom is more electronegative than a Calcium (Ca) atom

Experimental Group	*Control Group*
0.7	0.6

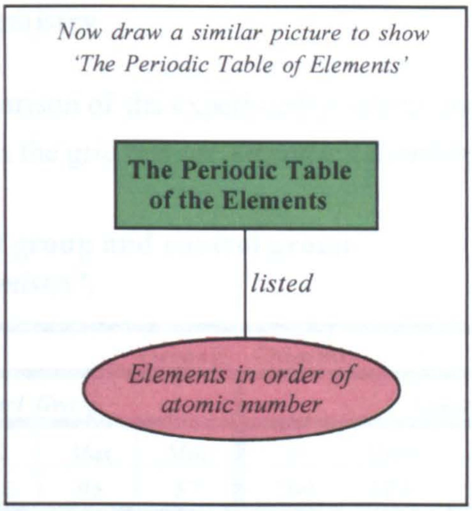
In questions 4 and 5, students are asked for explanations and the experimental group are only slightly better than the control group.

Year 10 students were also invited to construct a concept map on the topic of 'The Periodic Table of Elements' as a way to gain an insight into the students' ideas lodged in long term memory. They were given an example concept map (figure 9.1)

Figure 9.1 Example map



They were then given a sheet of paper with the information as shown below. They were invited to draw as much as they could in the same way to show what they knew about the Periodic Table. A total sample of 400 students of year 10 boys and girls age 15-16 years were involved.



The following approach was adopted in marking the concept map:

One mark was awarded for every correct 'node' (each title, topic, or point) - 'correct' being defined as chemically correct and related to 'The Periodic Table of Elements'.

One mark was awarded for every correct 'link', this being a word, phrase or sentence connecting two nodes - 'correct' being defined as a correct connection in chemical terms.

*There is **no maximum** mark.*

Appendix (H) also shows the 'Concept Map Marks' which were achieved by students in the experiment and control groups for year 10. An independent samples t-test was run to compare the experimental group to the control group in their performance on the concept map. This is shown in table 9.3.

Table 9.3 t-test Results for Concept Maps

Periodic Table									
Experimental Group					*Control Group*				
N	*Mean*	*S.D.*	*Max*	*Min*	*N*	*Mean*	*S.D.*	*Max*	*Min*
200	11.9	1.68	18	9	200	11.5	1.04	14	8
t -test	$t = 3.44$		$p < 0.001$						

Assuming that the concept map marks do reflect the ideas held in long term memory and the links between these ideas, the experimental group's better performance suggests that they hold more ideas relating to the periodic table.

The marks for the maps were included in the test marks when the overall performance of the two groups was compared.

9.4 Test: Organic Chemistry

Table 9.4 shows the comparison of the experimental group and control group in the year 11 students' achievement in the grid test on '***Organic Chemistry***'.

Table 9.4 Experimental group and control group '*Organic Chemistry*'.

Organic Chemistry									
Experimental Group					*Control Group*				
N	*Mean*	*S.D.*	*Max*	*Min*	*N*	*Mean*	*S.D.*	*Max*	*Min*
200	71.0	6.70	95	57	200	57.0	7.44	83	42
t -test	t= 19.65			p < 0.001					

The same situation occurs in the 'Organic Chemistry' grid test with year 11. There was a very significant difference between the mean scores achieved by the experiment group and the control group ($t = 19.65$, $p < 0.001$). Again, the experimental group performed significantly better than the control group in the 'Organic Chemistry' grid test. Each question is now discussed in turn.

Question 1

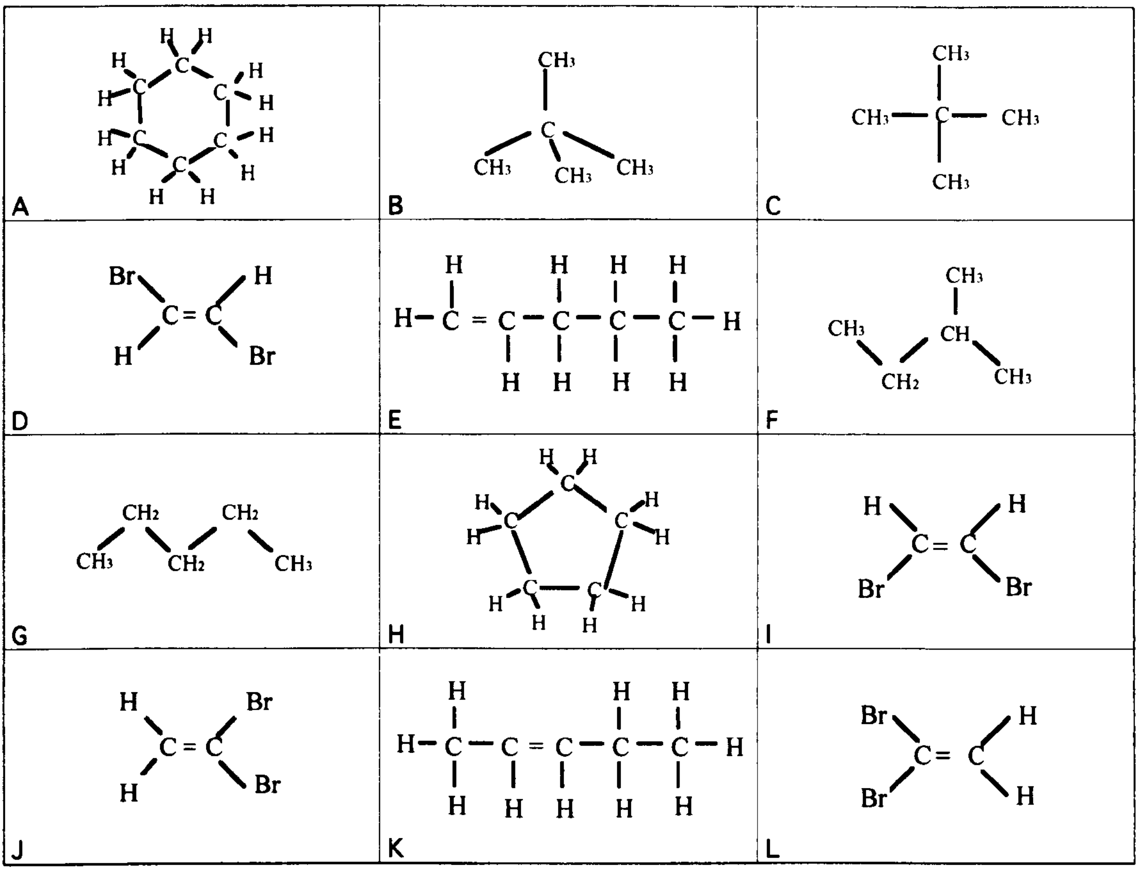
A C_2H_2	**B** C_3H_8	**B** CH_4
D C_5H_{10}	**E** C_4H_8	**F** C_7H_{16}
G C_3H_4	**H** C_7H_{14}	**I** C_6H_6

Select the box(es) which contain:

		Experimental Group	*Control Group*
(a)	Alkanes	0.70	0.65
(b)	Alkenes	0.56	0.54
(c)	Alkynes	0.76	0.77
(d)	Cycloalkanes	0.60	0.63

Large differences between the two groups are not observed. The new material has not really made any change to the recognition of hydrocarbon molecules

Question 2



Select the box(es) which contain:

		Experimental Group	*Control Group*
(a)	Isomers of the molecule shown in box **B**	0.78	0.81
(b)	Isomers of the molecule shown in box **G**	0.65	0.66
(c)	Isomers of the molecule shown in box **H**	0.67	0.70
(d)	Isomers of the molecule shown in box **I**	0.66	0.34
(e)	Isomers of the molecule shown in box **J**	0.73	0.56

In only two questions is there a major difference in performance. The control group clearly has difficulty in seeing isomerism around a double bond.

Question 3

(a) Explain in **three** sentences why cracking is so important in oil industry?

Experimental Group	*Control Group*
0.8	0.6

(b) "Polymerisation is the opposite of cracking"

Write in **three** sentences how this is true?

Experimental Group	*Control Group*
0.8	0.5

The experimental group has a much better grasp of the oil industry

9.5 Test: Chemical Equations

Table 9.5 shows the comparison of the experimental group and control group with year 10 students in the test on '***Chemical Equations***'.

Table 9.5 Experimental group and control group
'*Chemical Equations*'

Chemical : Equations									
Experimental Group					*Control Group*				
N	*Mean*	*S.D.*	*Max*	*Min*	*N*	*Mean*	*S.D.*	*Max*	*Min*
200	80.2	8.97	97	44	200	71.0	10.07	97	44
t -test	t= 9.66		p < 0.001						

The data showed that there was a very significant difference in chemistry achievement in the topic 'The Chemical Equation' between the mean scores achieved by the experiment group and the control group ($t = 9.66$, $p < 0.001$). Specific questions gave the following pattern.

Question 1 required the students to write formula for several compounds;

	Experimental. Group	*Control Group*
	0.8	0.7

Question 2 required the students to balance several equations:

	Experimental. Group	*Control Group*
	0.9	0.7

Question 3 required the students to calculate formula masses

	Experimental. Group	*Control Group*
	0.9	0.9

Question 4 involved calculations relating to mass and moles:

	Experimental. Group	*Control Group*
(a) The mass of a mole of sulphuric acid (H_2SO_4)	0.8	0.7
(b) Number of moles of ammonia (NH_3) in 68g of ammonia	0.7	0.5

In only questions 1 and 2 is there difference in performance. It is clear that the control group has more difficulty in writing formulae and balancing equation. The results reflect that the experimental group's better performance in calculations of mass and moles. The different approach adopted in the new material clearly has proved effective.

9.6 Test: Acids and alkalis

Table 9.6 shows the comparison of the experimental group and control group with year 10 students in the grid test on '***Acids and alkalis***'.

Table 9.6 Experimental group and control group
'Acids and alkalis'

Acids and : Alkalis									
Experimental Group					*Control Group*				
N	*Mean*	*S.D.*	*Max*	*Min*	*N*	*Mean*	*S.D.*	*Max*	*Min*
200	75.0	6.51	94	59	200	64.3	7.48	88	47
t -test	$t = 15.10$		$p < 0.001$						

The same situation occurs in the 'Acids and alkalis' grid test. There was a very significant difference between the mean scores achieved by the experiment group and the control group ($t = 15.1$, $p < 0.001$). Again, the experimental group performed significantly better than the control group in the 'Acids and alkalis' test.

Q1 (a) Calculate the pH of 0.01 mole per litre hydrochloric acid solution.

Experimental Group	*Control Group*
1.0	0.9

(b) Calculate the $[H^+]$ concentration in moles per litre for some drinking water which has a pH of 6.

Experimental Group	*Control Group*
0.9	0.9

Q2 (a) The $[OH^-]$ concentration in moles per litre is 0.001. What is the pH of the solution?

Experimental Group	*Control Group*
0.7	0.5

(b) In some pure water at 25°C, the $[H^+]$ and $[OH^-]$ are both 10^{-7} moles per litre. What is the pH ?

Experimental Group	*Control Group*
1.0	1.0

Only one question is there difference in performance. The control group has difficulty to get pH by using $[OH^-]$ concentration. This means there is difficulty in connecting pH and pOH laws together.

Q3 (a) Water from an underground source is found to have a pH of 4.3.
What is the concentration of hydrogen ion in moles per litre?

Experimental Group	*Control Group*
0.7	0.5

(b) A bottle of cleaning liquid has a pH of 10.
What is the $[H^+]$ and $[OH^-]$?

Experimental Group	*Control Group*
0.7	0.6

Large differences between the two groups are observed. The new material has really made change to the ability to relate pH to ion concentrations.

Q4 (a) Some brands of liquid soap, for use in having a shower, state that they have a pH of 5.8. Suggest why 5.8 is chosen ?

Experimental Group	*Control Group*
0.9	0.9

(b) The pH value of Human blood is normally 7.4 .
Suppose a very ill person's blood pH is found to have fallen to 6.4.

(i) What is the hydrogen ion concentration in the blood of a *normal* person?

(ii) What is the hydrogen ion concentration in the blood of the very *ill* person?

(iii) How much *more* hydrogen ion is present in the blood of the very sick person?

Experimental Group	*Control Group*
0.7	0.7

There is not any different performance between two groups in this question.

Q5 You have a litre of 0.1M HCl (pH = 1) and a litre of 0.01M NaOH (pH= 12).
The two solutions are mixed. What is the likely pH of the final solution.
(Do not attempt any calculation).

Tick one box

10.9	7	6.5	1.35	0.95

Experimental Group	*Control Group*
0.8	0.5

This question can be answered with more or less no calculation. It seeks to test if the students really can conceptualise neutralisation related to pH change. The new materials have made a quite enormous difference in performance. The students using these materials have now a much more intuitive grasp of the ideas involved.

Q6 Look at the following table:

Indicators	Colour Change	pH Interval
Methyl Orange	Orange-Yellow	2.1 - 4.4
Methyl Red	Red-Yellow	4.2 - 6.3
Bromothymol Blue	Yellow-Blue	6.0 - 7.6
Phenolphthalein	Colourless-Red	8.3 - 10.0

(a) Choose the best indicator for a titration of sodium hydroxide and sulphuric acid, given that sodium sulphate has a pH of 7.

Experimental Group	*Control Group*
0.9	0.8

(b) Choose the best indicator for a titration of sodium hydroxide and ethanoic acid, given that sodium ethanoate has a pH of 9.

Experimental Group	*Control Group*
0.9	0.9

There is no large differences in performance between two groups. Two groups cope with choosing indicators reasonably well.

9.7 Discussion

The t-values are very high and therefore the probability that the results happened by chance are extremely low. It is true that the experimental and control groups for each group were not matched as the researcher was restricted by the class organisation in schools. However, any variation resulting from this was eliminated as a factor, as each group acted as a control for one section of work and one test result only. Thus, the case for being confident of the results has been strengthened enormously.

The t-test data are summarised in table 9.7:

Table 9.7 t-test values and Differences in Means

t-test values and Differences in Means			
		t-test value	Difference in Means
Year 10			
	Periodic Table	26.33	18
	Equations	9.66	9
Year 11			
	Organic	19.65	14
	Acids and Alkalis	15.10	11

The improvements in the means scores obtained are very large. The effectiveness of the new teaching material has therefore been shown to bring about a very marked consistent improvement in the performance of students. There is a possibility that the material, being new and different, generated greater interest, simply on grounds of novelty. However, it is unlikely that this would have caused such a great improvement.

Two features were deliberately used to underpin the design of the new materials. Firstly, the materials aimed to be attractive, with diagrams, linked to everyday experience enabling students to build on existing knowledge and enabling them to assimilate and transfer new learning into long-term memory. An example includes the new design of the periodic table, simply offering the symbol and date of discovery (see figure 7.6) and then setting exploratory tasks preventing information overload and encouraging an investigative approach. This was the second factor: the reduction of information overload. By carefully sequencing the ideas introduced and presenting them step by step, the aim was to avoid situations where the amount of information to be handled at any one time exceeded the working memory capacity of the learners.

Previous work has shown again and again the influence of working memory on examination performance (see chapter 3). In this study, the teaching material was deliberately designed to reduce working memory overloading. The results are quite remarkable.

An example of the whole approach can be seen in the chemical calculations section (see figure 7.7). These new methodologies played a central role in the results. Indeed, using appropriate applications, illustrations and colours was aiming to make chemistry fun (see figure 7.3) and this may also have played an important role in the results.

Finally, the most important design feature to influence results was that questions in the materials often started by providing information rather than asking the students to recall information (see figure 7.4). The aim was to develop and test skills of understanding, interpretation and seeing things in context.

Care was taken in designing the test material to ensure that it covered the key elements of the syllabus and did not favour one group or the other.

9.8 Gender Issues

For each test and each of the experimental and control groups, comparisons of performance between genders were made using an independent samples t-test. Of the eight comparisons, in six cases, there were no significant differences. In two cases, significant differences were found:

Table 9.8 Gender Comparison 1

Experimental Group			Organic Chemistry						
Girls					*Boys*				
N	*Mean*	*S.D.*	*Max*	*Min*	*N*	*Mean*	*S.D.*	*Max*	*Min*
100	73.7	5.17	85	61	100	69.1	7.35	89	54
t -test	t = 5.09		p < 0.001						

There was very significant difference between boys and girls in the experiment group in 'organic chemistry test', ($t = 5.09$, $p < 0.001$). Girls performed significantly better than boys. It is not obvious why this is so.

Table 9.9 Gender Comparison 2

Control Group			Acids and Alkalis						
Girls					*Boys*				
N	*Mean*	*S.D.*	*Max*	*Min*	*N*	*Mean*	*S.D.*	*Max*	*Min*
100	65.5	7.27	86	53	100	63.3	7.56	88	47
t -test	t = 2.04		p < 0.043						

Boys and girls perform differently in the 'Acids and Alkalis' grid test although the effect is not large. Girls are better. Again, it is not obvious why this has happened.

Chapter Ten

Attitudes of Students

10.1 Attitudes Questionnaire

The same attitude questionnaires which had been used with the previous year group were used with year 10 and year 11. The full questionnaires are shown in appendix D. Items in the attitudes questionnaire were designed to measure students' attitudes towards the learning of chemistry. The goal of the new teaching material was for the students to hold more positive attitudes toward the learning of chemistry. The questionnaire had been used with the previous year groups and items in the attitudes questionnaire were designed to explore this.

With the previous year group, 115 year 10 and 110 year 11 pupils completed the questionnaire. The following year, after using the new teaching materials, 400 year 10 pupils (aged between 15 - 16 years) and 400 for year 11 (aged between 16 - 17 years) were involved. The two successive year groups were similar in other ways, being typical pupils in Emirates schools.

The attitudes towards chemistry questionnaires were distributed among year 10 and year 11 students in April 2005 *after* the booklets had been used to explore whether the new teaching materials had changed attitudes in any way.

First of all, the results from the questionnaires when applied to 400 pupils in each group in April 2005 are discussed. Then the results from each year group are compared to the results obtained with the previous year groups. In discussing the results obtained, each question is shown here in turn, with the data obtained expressed as percentages. All statistical analyses were conducted using actual frequencies (see appendix I)

10.2 Analysis of Attitudes Questionnaire Responses for Year 10 Students

Questions 1 and 2 merely asked for gender and school attended and are not discussed here. The sample of year 10 students was 400.

Question 3 ***What are your opinions about your school chemistry lessons in year 10 ?***

I like chemistry lessons	70	10	3	2	3	12	I hate chemistry lessons
Boring	20	1	1	2	5	71	Interesting
Easy	60	9	1	4	1	25	Difficult
Useless	10	8	2	2	5	73	Useful
Important	69	11	2	3	6	9	Unimportant
Enjoyable	66	12	1	1	3	17	Boring

There is a tendency for this group to like chemistry lessons which is very good and it is encouraging to note that over 60% of students tend to see chemistry as useful, interesting, enjoyable, easy and important. However, one very marked feature of the data obtained is the extent to which views are polarised: while the majority are positive, a sizeable minority are strongly negative in their responses: 25% see chemistry lessons as difficult, 20% as boring, for example.

Question 4 ***How do you feel about the chemistry you have learned ?***

I am enjoying the subject	63	8	1	1	7	15	I am NOT enjoying the subject
I feel I am NOT coping well	27	12	11	4	5	41	I feel I am coping well
I find it very easy	60	4	7	2	6	21	I find it very hard
I am growing intellectually	48	5	5	4	15	23	I am NOT growing intellectually
I am NOT obtaining a lot of new skills	18	7	5	8	9	53	I am obtaining a lot of new skills
I hate practical work	11	2	2	5	10	70	I am enjoying practical work
I am getting better in the subject	64	11	5	2	5	13	I am getting worse in the subject
I do not like my teacher	19	2	2	1	8	68	I like my teacher
It is definitely 'my' subject	30	8	2	13	2	45	It is definitely not 'my' subject

It is encouraging to note that the students tend to enjoy practical work, like their teacher, enjoy the subject and find chemistry an easy subject. However, as with the previous question, there is marked polarity in the response patterns. Indeed, some the response distributions seem almost be the inverse of a normal distribution. There are clearly two populations present, one fairly positive, and the other very negative.

The scale of some of the negative views are matters of considerable concern: the proportions who feel they are *not* coping well (39% - the two end categories added together) and *not* growing intellectually (38%). However, the feature of greatest concern is that such a large proportion are being driven to the view that chemistry is *not* their subject (47%).

Question 5 ***What do you enjoy in your chemistry lessons ?***

60	Studying the theory	38	Studying chemistry applications in life
71	Doing practical work	62	Studying about chemical reactions in the human body
30	Explaining natural phenomena	15	Setting up apparatus
69	Drawing shapes (atoms, molecules, etc)	62	Studying how chemistry can improve my life
65	Writing formulae and chemical equations	35	Solving every day problems
68	Balancing chemical equations	67	Studying how chemistry can make our lives healthier

The choices with the highest ratings include 'doing practical work', 'drawing shapes', 'writing formulae and chemical equations', 'balancing chemical equations', 'chemical reactions in the human body', 'chemistry improving life', and 'making lives healthier'. The first four choices of the left-hand column reflect the traditional pattern where practical activities are rated highly (Shah, 2004). The latter three all are related to the desire for studies to be perceived as related to lifestyle and meaningful context (Reid, 1999). However, 'studying theory' was also widely supported and it interesting to note that relatively few pupils chose 'chemistry applications in life' or 'solving everyday problems'. This perhaps reflects a syllabus where neither seems to be a realistic possibility.

Question 6

Chemistry									
Most important to me	52	9	6	5	1	2	2	25	Least important to me
Physics									
Most important to me	53	16	10	11	2	1	2	5	Least important to me
Biology									
Most important to me	50	11	12	14	8	4	1	2	Least important to me
Mathematics									
Most important to me	60	14	6	2	2	6	4	6	Least important to me

The first feature that stands out is the way mathematics outshines the sciences. Secondly, the polarisation of the chemistry responses is very different to the other three. This is consistent with the data from the previous questions where there is a large minority who are very negative in their views of chemistry. Indeed, the extent of this negativity is not shared by the other three subjects. This makes it clear that something is seriously wrong with the chemistry learning situations which is not shared by these three cognate subjects.

If the distribution of responses of chemistry and physics are compared using chi-square as a contingency test, a value of 63.5 (df5) is obtained. This is significant at $p < 0.001$, confirming that the response distributions are, indeed, very different.

Question 7

%	Chemical Formulae	Quantum Numbers	Periodic Table	Actinides	Chemical equations
Important to improve my life	72	2	70	1	74
Boring	35	92	25	95	20
Interesting	69	2	71	2	70
Complicated	37	89	30	89	36
Good basis for future study	74	3	69	3	68

It is important to note that a high proportion of students think 'Quantum numbers' and 'Lanthanides & Actinides' topics are boring and complicated. However, more than 68% of students think that chemical formula, periodic table of elements, and chemical equations are important to improve their life, interesting, and are a good basis for future study. Thus, the pupils seem aware of the significance of the last three topics and find them attractive.

Question 8

Think about what might influence you to study chemistry in future years.
Which of the following would attract you to further study in chemistry.

69	An interesting course
72	There are good possibilities of jobs
40	What my friends think
0	Television programmes
70	The wishes of my parents
45	Exciting experiments in class
60	An interesting textbook
50	A stimulating teacher
0	Anything else: ....

Previous work in physics in Scotland had found the importance of the teacher, the interesting course, and the possibilities of careers as the most important factors (Reid and Skryabina, 2002 a, b). The pattern here is somewhat similar for chemistry. Here there is also some influence from parents and friends, perhaps reflecting the different cultural setting, when compared to Scotland.

Question 9 ***Write one sentence to say what most attracts you to chemistry.***

70% of students answered that "practical work" attracted them most to chemistry. Students also answered that they were attracted to chemistry by the fascinating descriptions of how elements were discovered. The latter is particularly encouraging in that this was specifically introduced in the new materials. It is true that using meaningful questions in the periodic table booklet and a new design of the periodic table encouraged students to read and search the internet or science books. In so doing students were actively involved in learning by finding out more information about how elements have been discovered (when, where, how, why...etc) such as in questions 5, 6, 7, 8 ,9, and 10. Thus, it is very interesting that students mentioned this point as most attracting to chemistry.

Question 10 ***Write one sentence to say what least attracts you to chemistry.***

65% of students found that theoretical study attracted them least to chemistry. This reflects the curriculum content.

10.3 Analysis of Attitudes Questionnaire Responses for Year 11 Students

Question ***What are your opinions about your school chemistry lessons in year 10 ?***

I like chemistry lessons	72	8	5	4	1	10	I hate chemistry lessons
Boring	18	2	2	3	7	68	Interesting
Easy	66	10	2	1	1	20	Difficult
Useless	15	5	2	1	5	70	Useful
Important	73	8	4	2	3	10	Unimportant
Enjoyable	69	13	2	4	2	10	Boring

It is encouraging to note that the students tend to see chemistry lessons as interesting, enjoyable, easy, useful and important. Less than a quarter of students consider that chemistry is boring and difficult. However, as with year 10, polarisation of views is to be seen, although it does not seem quite as marked.

Question 4 ***How do you feel about the chemistry you have learned ?***

I am enjoying the subject	66	6	2	2	5	19	I am NOT enjoying the subject
I feel I am NOT coping well	30	10	11	3	7	39	I feel I am coping well
I find it very easy	67	4	3	2	2	22	I find it very hard
I am growing intellectually	33	5	9	2	20	31	I am NOT growing intellectually
I am NOT obtaining a lot of new skills	21	9	2	1	12	55	I am obtaining a lot of new skills
I hate practical work	14	4	1	1	12	68	I am enjoying practical work
I am getting better in the subject	68	6	2	1	7	16	I am getting worse in the subject
I do not like my teacher	17	3	2	2	6	70	I like my teacher
It is definitely 'my' subject	35	10	4	10	11	30	I t is definitely not 'my' subject

It is encouraging to note that the students tend to like their teacher, enjoy practical work, consider that they are getting better in the subject, find it easy, and enjoy their chemistry. However, there are some questions where there is marked polarity, with large proportions being very negative: lack of enjoyment (24%), not coping (40%), finding it very hard (24%), not obtaining new skills (30%). In some areas, there is a very range of perception. For example, seeing chemistry as 'their' subject shows some polarisation but the views are now widely spread. In some cases, there are interesting anomalies: while 40% are negative about coping well, only 24% find it hard. This might suggest that the pupils are aware that the subject is not intrinsically that difficult but, nonetheless, they do not feel they are coping, perhaps because of what they are being asked to do.

Question 5 ***What do you enjoy in your chemistry lessons ?***

62	Studying the theory	73	Studying chemistry applications in life
75	Doing practical work	66	Studying about chemical reactions in the human body
63	Explaining natural phenomena	11	Setting up apparatus
65	Drawing shapes (atoms, molecules, etc)	67	Studying how chemistry can improve my life
68	Writing formulae and chemical equations	69	Solving every day problems
70	Balancing chemical equations	69	Studying how chemistry can make our lives healthier

The choices with the highest ratings include 'doing practical work', 'balancing chemical equations', 'drawing shapes', 'chemical reactions in the human body', 'chemistry improving life', and 'making lives healthier'. The first three reflect the traditional pattern where practical activities are rated highly (Shah, 2004). The latter three all are related to the desire for studies to be perceived as related to lifestyle and meaningful context (Reid 1999). However, 'studying theory' was also widely supported and it interesting to note that relatively few pupils chose 'chemistry applications in life' or 'solving everyday problems'. As with year 10, this perhaps reflects a syllabus where neither seems to be a realistic possibility.

Question 6

Chemistry									
Most important to me	57	11	2	4	2	1	3	20	Least important to me
Physics									
Most important to me	59	12	3	5	4	3	6	8	Least important to me
Biology									
Most important to me	53	13	14	10	2	2	2	4	Least important to me
Mathematics									
Most important to me	64	12	8	3	1	3	5	4	Least important to me

As with year 10, the polarisation of views relating to chemistry stand out. Comparing the responses of chemistry and physics using chi-square as a contingency test gives a value of 32.7 (df5) which s significant at $p < 0.001$.

Question 7

%	Mole Calculation	Balancing Equations	Homologous Series	Isomerism	Alkyl Groups	pH and pOH Calculation
Important to improve my life	45	59	30	56	35	76
Boring	65	30	30	39	30	28
Interesting	46	70	64	60	63	70
Complicated	60	30	35	40	20	29
Good basis for future study	28	55	26	65	40	71

It is important to note that a high proportion of students consider the 'mole calculation' topic as boring and complicated. However, more than 55% of students think that balancing equations, isomerism, and pH & pOH calculation are important to improve their life, interesting, and are a good basis for future study. Thus, the pupils seem aware of the significance of some of the topics but still find them unattractive.

Question 8

80	An interesting course
81	There are good possibilities of jobs
62	What my friends think
0	Television programmes
73	The wishes of my parents
63	Exciting experiments in class
66	An interesting textbook
79	A stimulating teacher
46	Anything else: ....

Again, the importance of the teacher, the interesting course, and the possibilities of careers are important factors. Here there is some influence from parents and friends, perhaps reflecting the cultural setting. It can be seen that most of students in year 10 and 11 have similar responses to this question and this is because they are from the same society.

Question 9 ***Write one sentence to say what most attracts you to chemistry.***

Again, 70% of students answered that "practical work" attracted them most to chemistry, showing the same view as year 10.

Question 10 ***Write one sentence to say what least attracts you to chemistry.***

60% of students found that theoretical study attracted them least to chemistry.

10.4 Attitude Comparisons (Year 10)

400 year 10 pupils completed one teaching unit. In the survey described in chapter 6, 115 year 10 pupils completed the questionnaire to look at their attitudes towards chemistry. This same questionnaire was used here with the 400 pupils, one month after they had completed the material covered by the two new teaching units. Their responses were compared to the responses from the 115 pupils from the equivalent group from the previous year, at roughly the same time of year.

Each question is now discussed in turn. The data for the two samples are shown as percentages for clarity. Chi-square, used as a contingency test, was applied, the test being applied to the frequency data to see if the two sets of responses differed statistically. In many of the tables below, the top line shows the responses for original application of the questionnaire (traditional teaching followed) and the second line shows the the responses for second application of the questionnaire (after use of new teaching materials). The chi-square value is shown: *chi-square value (degrees of freedom) significance level.*

Table 10.1 Question 3

What are your opinions about your school chemistry lessons in year 10 ?

Top line N = 115 Traditional teaching
Lower line N = 400 New teaching materials

I like chemistry lessons	40	17	11	10	12	10	*I hate chemistry lessons*
	70	10	3	2	3	12	**36.7 (df3) $p < 0.001$**
Boring	17	9	11	14	20	29	*Interesting*
	20	1	1	2	5	71	**66.0 (df3) $p < 0.001$**
Easy	19	21	16	7	11	26	*Difficult*
	60	9	1	4	1	25	**47.1 (df3) $p < 0.001$**
Useless	8	4	5	8	13	62	*Useful*
	10	8	2	2	5	73	**14.1 (df3) $p < 0.001$**
Important	60	10	10	4	8	8	*Unimportant*
	69	11	2	3	6	9	**13.2 (df3) $p < 0.001$**
Enjoyable	18	17	18	16	8	2	*Boring*
	66	12	1	1	3	17	**104.1 (df3) $p < 0.001$**

In every case, the group who had experienced the new material have vastly improved attitudes. However, there are some interesting patterns which can be seen. In several questions, there is quite marked polarity with both groups: boring...interesting, easy.... difficult, useful....useless. The most marked differences occurred with: boring....interesting, easy....difficult, and enjoyable....boring. The new teaching materials were deliberately constructed to minimise demands of working memory and thus make the chemistry more accessible. In the views of this year 10 group, this seems to have been successful when compared to the views of the previous year group who had not experienced any of the new teaching materials. The materials were also designed to relate the chemistry more to life and, thus make it appeal more. This also seems to have occurred.

It has to be noted that the chi-square values are extremely high, indicating very large changes in response patterns.

Table 10.2 Question 4

How do you feel about the chemistry you have learned ?

Top line N = 115 Traditional teaching
Lower line N = 400 New teaching materials

I am enjoying the subject	30	8	20	7	4	31	*I am NOT enjoying the subject*	
	63	8	1	1	7	15		**50.6 (df2) $p < 0.001$**
I feel I am NOT coping well	23	8	13	6	9	41	*I feel I am coping well*	
	27	12	11	4	5	41		**3.1 (df2) n.s.**
I find it very easy	19	21	17	8	12	23	*find it very hard*	
	60	4	7	2	6	21		**77.6 (df3) $p < 0.001$**
I am growing intellectually	41	12	9	7	10	21	*I am NOT growing intellectually*	
	48	5	5	4	15	23		**17.1 (df5) $p < 0.01$**
I am NOT obtaining a lot of new skills	23	10	12	9	11	35	*I am obtaining a lot of new skills*	
	18	7	5	8	9	53		**16.7 (df5) $p < 0.01$**
I hate practical work	46	10	10	2	6	26	*I am enjoying practical work*	
	11	2	2	5	10	70		**106.0 (df2) $p < 0.001$**
I am getting better in the subject	33	14	11	13	7	22	*I am getting worse in the subject*	
	64	11	5	2	5	13		**38.2 (df3) $p < 0.001$**
I do not like my teacher	30	3	14	21	7	25	*I like my teacher*	
	19	2	2	1	8	68		**120.7 (df2) $p < 0.001$**
It is definitely 'my' subject	30	9	17	10	11	23	*It is definitely not 'my' subject*	
	30	8	2	13	2	45		**12.2 (df2) $p < 0.01$**

In only one question are the responses ***not*** different: the question about coping well. This is surprising, particularly in the light of their responses to the following question relating to difficulty. In one question, the the group who had undertaken the new material showed a less positive attitude: "it is definitely my subject'. This is very surprising. In every other case, the group who had undertaken the new material show more positive attitudes.

Question 5 ***What do you enjoy in your chemistry lessons ?***

Pupils could select or choose not to select each of these. The first number is the percentage of the original group (traditional teaching) while the second number is the percentage of the group who used the new teaching material, all shown as percentages.

(only significant values shown)

55/60	Studying the theory		
30/38	Studying chemistry applications in life		
60/71	Doing practical work		
62/72	Studying about chemical reactions in the human body		
30/30	Explaining natural phenomena		
10/15	Setting up apparatus		
50/69	Drawing shapes (atoms, molecules, etc)	13.7 (df1)	$p < 0.001$
59/62	Studying how chemistry can improve my life		
45/65	Writing formulae and chemical equations	14.6 (df1)	$p < 0.001$
20/35	Solving every day problems	9.3 (df1)	$p < 0.01$
40/68	Balancing chemical equations	29.7 (df1)	$p < 0.001$
61/67	Studying how chemistry can make our lives healthier		

In four areas, the two groups differed statistically in their selection. One unit of the new teaching materials specifically dealt with formulae, equations and structures. It is very clear that this had a positive impact on pupils. It is also encouraging that the pupils who had used the new materials were selecting 'solving everyday problems' more often in that the units tried to make chemistry relate more closely to real life.

Question 6 ***Order of School Subjects***

Chemistry									
Most important to me	13	17	18	19	15	9	7	2	*Least important to me*
	52	9	6	5	1	2	2	25	**101.8 (df5) p < 0.001**
Physics									
Most important to me	2	19	17	20	24	2	6	10	*Least important to me*
	53	16	10	11	2	1	2	5	**109.1 (df4) p < 0.001**
Biology									
Most important to me	24	10	28	18	12	11	4	3	*Least important to me*
	50	11	12	14	8	4	1	2	**29.8 (df5) p < 0.001**
Mathematics									
Most important to me	45	23	10	6	3	5	4	4	*Least important to me*
	60	14	6	2	2	6	4	6	**14.2 (df4) p < 0.001**

The large change in attitudes in physics may have been caused by a major change in the entire physics curriculum which was introduced between the two measurements. There has also been a major change in the biology curriculum. There has been no change in the mathematics or chemistry curriculum (other than the use on the new units from this project). This may account for the very large attitude change observed in chemistry.

Question 8

Think about what might influence you to study chemistry in future years.

Which of the following would attract you to further study in chemistry?

40/69	An interesting course	**32.1 (dfl) $p < 0.001$**
70/72	There are good possibilities of jobs	
30/40	What my friends think	
0/0	Television programmes	
56/70	The wishes of my parents	**8.3 (dfl) $p < 0.01$**
45/45	Exciting experiments in class	
35/60	An interesting textbook	**22.9 (dfl) $p < 0.001$**
51/50	A stimulating teacher	
0/0	Anything else:	

Students who had used the new materials founds that 'an interesting course' and 'an interesting textbook' are important. This clearly reflects the design of the chemistry booklets. Again there is some influence from parents perhaps reflecting the similar cultural setting for both groups because they are from same society.

10.5 Attitude Comparisons (Year 11)

400 pupils from year 11 completed one teaching unit. In the survey described in chapter 6, 110 pupils from year 11 completed a questionnaire to look at their attitudes towards chemistry. This same questionnaire was used with the 400 pupils after they had completed one unit of new teaching material. Their responses were compared to the original 110, an equivalent group of pupils from the previous year.

Each question is now discussed in turn. The data for the two samples are shown as percentages for clarity. Chi-square, used as a contingency test, was applied, the test being applied to the frequency data to see if the two sets of responses differed statistically. In each table below, the top line shows the responses for original application of the questionnaire (traditional teaching followed) and the second line shows the responses for second application of the questionnaire (after use of new teaching materials). The chi-square value is shown: *chi-square value (degrees of freedom) significance level.*

Table 10.3 Question 3

What are your opinions about your school chemistry lessons in year 10 ?

Top line N = 110 Traditional teaching
Lower line N = 400 New teaching materials

I like chemistry lessons	30	22	27	12	6	3	*I hate chemistry lessons*	
	72	8	5	4	1	10		**117.6 (df5) p < 0.001**
Boring	6	13	18	27	21	15	*Interesting*	
	18	2	2	3	7	68		**121.6 (df2) p < 0.001**
Easy	15	30	35	12	4	4	*Difficult*	
	66	10	2	1	1	20		**155.4 (df2) p < 0.001**
Useless	3	5	9	10	29	44	*Useful*	
	15	5	2	1	5	70		**28.3 (df2) p < 0.001**
Important	43	26	12	11	5	3	*Unimportant*	
	73	8	4	2	3	10		**46.4 (df3) p < 0.001**
Enjoyable	14	15	27	23	13	8	*Boring*	
	69	13	2	4	2	10		**147.0 (df2) p < 0.001**

In every case, the group who had experienced the new material have vastly improved attitudes. However, there are some interesting patterns which can be seen. In several questions, there is less polarity with both groups when compared to year 10: boring....interesting. Like year 10, the most marked differences occurred with: boring....interesting, easy....difficult, and enjoyable....boring. However, like...dislike is also very marked with year 11.

The new teaching materials were deliberately constructed to minimise demands of working memory and thus make the chemistry more accessible. In the views of this year 11 group, this seems to have been successful. The materials were also designed to relate the chemistry more to life and, thus make it appeal more. This also seems to have occurred.

Table 10.4 Question 4

How do you feel about the chemistry you have learned ?

Top line N = 115 Traditional teaching
Lower line N = 400 New teaching materials

I am enjoying the subject	15	24	13	25	9	14	*I am NOT enjoying the subject*	
	66	6	2	2	5	19		**104.2(df3) p < 0.001**
I feel I am NOT coping well	18	10	11	10	24	27	*I feel I am coping well*	
	30	10	11	3	7	39		**39.6 (df4) p < 0.001**
I find it very easy	22	27	23	16	8	4	*find it very hard*	
	67	4	3	2	2	22		**129.0 (df4) p < 0.001**
I am growing intellectually	37	21	16	11	12	3	*I am NOT growing intellectually*	
	40	5	7	2	20	26		**44.6 (df3) p < 0.01**
I am NOT obtaining a lot of new skills	6	12	12	12	24	34	*I am obtaining a lot of new skills*	
	5	9	10	9	12	55		**19.6 (df4) p < 0.001**
I hate practical work	4	6	5	8	13	64	*I am enjoying practical work*	
	2	4	7	7	12	68		**2.2 (df2) n.s.**
I am getting better in the subject	35	23	15	12	9	6	*I am getting worse in the subject*	
	68	6	2	1	7	16		**67.5 (df2) p < 0.001**
I do not like my teacher	35	9	12	18	15	11	*I like my teacher*	
	17	3	2	2	6	70		**12.5 (df2) p < 0.001**
It is definitely 'my' subject	15	23	29	18	10	5	*It is definitely not 'my' subject*	
	35	9	14	20	20	2		**31.1 (df4) p < 0.01**

In many of the questions, the difference between the responses of the two groups is quite enormous. Chi-square values are extremely high and the probability values quoted are misleading in that they underestimate the significance levels (chi-square tables do not quote figures beyond $p < 0.001$). Of interest is the lack of difference relating to laboratory work, this not being any part of the new materials at all. Also interesting is the low value of chi-square for liking the teacher. There was no attempt to influence teachers but, perhaps, the teachers who used the new materials might have been cast in a more positive light.

Question 5 ***What do you enjoy in your <u>chemistry</u> lessons ?***

Pupils could select or choose not to select each of these. The first number is the percentage of the original group (traditional teaching) while the second number is the percentage of the group who used the new teaching material.

(only significant values shown)

50/62	Studying the theory	23.0 (df1)	$p < 0.001$
60/73	Studying chemistry applications in life	7.0 (df1)	$p < 0.01$
70/78	Doing practical work	12.2 (df1)	$p < 0.001$
69/66	Studying about chemical reactions in the human body		
54/63	Explaining natural phenomena		
20/11	Setting up apparatus	6.2 (df1)	$p < 0.05$
55/65	Drawing shapes (atoms, molecules, etc)	14.8 (df1)	$p < 0.001$
65/67	Studying how chemistry can improve my life		
58/68	Writing formulae and chemical equations	15.9 (df1)	$p < 0.001$
66/69	Solving every day problems		
50/70	Balancing chemical equations	64.0 (df1)	$p < 0.001$
71/69	Studying how chemistry can make our lives healthier		

In many areas, the two groups different statistically in their selection.

Question 6 **Order of School Subjects**

Chemistry									
Most important to me	2	10	16	21	21	13	11	6	*Least important to me*
	57	11	2	4	2	1	3	20	**106.6 (df2) $p < 0.001$**
Physics									
Most important to me	9	25	20	15	15	7	3	6	*Least important to me*
	59	12	3	5	4	3	6	8	**124.8 (df5) $p < 0.001$**
Biology									
Most important to me	6	11	14	26	12	6	16	9	*Least important to me*
	53	13	14	10	2	2	2	4	**110.0 (df4) $p < 0.001$**
Mathematics									
Most important to me	38	19	7	9	10	7	4	6	*Least important to me*
	64	12	8	3	1		3	4	**28.4 (df4) $p < 0.001$**

The large change in attitudes in physics may have been caused by a major change in the entire physics curriculum which was introduced between the two measurements. There has also been a major change in the biology curriculum. There has been no change in the mathematics or chemistry curriculum (other than the use on the new units from this project). This may account for the very large attitude change observed in chemistry. The interesting observation is that the use of a single teaching unit in chemistry has had a similar impact in terms of attitudes to the complete overhaul of the physics and biology curricula.

Question 8

Think about what might influence you to study chemistry in future years.
Which of the following would attract you to further study in chemistry.

72/80	An interesting course	
75/81	There are good possibilities of jobs	
55/62	What my friends think	
0/0	Television programmes	
66/73	The wishes of my parents	
55/63	Exciting experiments in class	
40/66	An interesting textbook	**24.4 (df1) $p < 0.001$**
70/79	A stimulating teacher	**4.0 (df1) $p < 0.05$**
30/46	Anything else:	

'An interesting textbook' and 'a stimulating teacher' show different responses from the two groups. It appears the design of booklets has proved attractive and the role of teacher in the classroom has been enhanced.

10.6 Conclusions

Attitudes towards chemistry and, indeed, towards learning, are likely to be important factors influencing success. In almost every measurement made, the students who used the new materials have demonstrated more positive views when compared to the equivalent group from the previous years. Indeed, the size of many of the chi-square values has already been noted. The attitude changes, as evidenced by the questionnaire, have simply been enormous.

The size of the attitude change is all the more remarkable in that each group had only undertaken one chemistry teaching unit using the new materials. The themes covered by the four teaching units used varied considerably and yet the attitude changes have been consistently large. Thus, even a moderately sized curriculum insert seems to have had a massive effect. Inevitably, part of this may simply due to the very negative attitudes observed in the students in the Emirates with the previous year groups.

Many of the results are consistent with previous work, supporting the validity of questionnaire. Thus, for example, the power of the curriculum and the teacher in attracting students towards chemistry are seen while the universal popularity of practical activities is again strongly showing.

Year 10 students often showed marked polarisation. This year group contains students who will opt for a science-based course long with students who will opt out of science completely. Year 11 only contains those who have opted for a science based course.

Although the new materials have had a powerful impact, there is clearly more to be done. Chemistry still stands out poorly when compared to cognate disciplines. The curriculum in chemistry is very abstract and many of the topics are unrelated to student experiences (eg. quantum numbers and Lanthanides). These really have no place in a school syllabus and the students are clearly more perceptive than the curriculum planners! Typical examination questions (as evidenced by the end of chapter questions in the textbooks) test memory and lay no emphasis whatever in understanding concepts.

Looking at those areas where the differences between the groups who undertook the new materials and the previous year groups (the highest chi-square values), some interesting patterns are observed. Firstly, the effects on the year 11 group seem more marked in general than the year 10 group. Year 10 found chemistry lessons much easier and like them more.

Year 10 find chemistry, as a subject, easier and are enjoying practical work and have a better liking for their teachers when compared to the previous year groups. These is less effect on the view of the teacher or practical work for year 11 but they also are enjoying the subject much more. It appears that year 11 have opted for a science based course but, despite this, find the chemistry even less attractive.

A poor curriculum and teaching will tend to generate negative attitudes and this may lead to poor performance in tests and examinations. Good performance in tests and examinations will tend to generate better attitudes! Thus, attitudes and success are highly linked and each affects the other. The use of one new teaching unit has clearly generated better attitudes and improved performance. However, the teaching units were all developed based on the ideas of information processing and the findings from attitude development research. This reveals how well-attested educational models can have real benefits for the learner when applied consistently.

Chapter Eleven

General Conclusions

This study initially explored secondary students' difficulties in learning chemistry. The starting point of the investigation was to consider the difficulties of Emirates students in learning chemistry by carrying out surveys at the end of the academic year. This led on the more detailed surveys of difficulties and attitudes of the students.

In the light of what was found, new teaching materials were developed and their effectiveness were tested. There were two main aims in designing the new materials. The first aim was to seek to reduce the difficulties the students were experiencing. The second was to seek to develop more positive attitudes towards their studies in chemistry. An information processing model predicted that the difficulties were likely to be caused by working memory overload. A key design feature in the construction of the new materials was to re-structure the way the material was presented as that working memory overload was minimised.

Previous work on attitude development has shown that attitudes are more likely to develop if the learners interact mentally with the issues involved (Reid, 1978) while more recent work (Reid and Skryabina, 2002a) has shown that attitudes towards a subject are likely to be much more positive if the subject matter is presented in such a way that its context and significance are directly related to the learner. Given the limitations of written material, the aim was to design the materials in such a way that these two criteria were met, at least in part.

This chapter will review the experimental work and bring together the general conclusions from this study, suggesting some implications for the teaching and learning process.

11.1 A Review of the Study

In the first stage, two survey forms were developed, one for year 10 and the other for year 11, to identify the areas of greatest difficulty. A total sample of 490 students, boys and girls, were drawn from two large typical secondary schools in the United Arab Emirates, one a girls' school and one a boys' school. The surveys were completed in May 2002, towards the end of the year's teaching,.

In the second stage of this study, the areas of greatest difficulty were explored further using Structural Communication Grid questions, one for year 10 and the other for year 11. For this stage, a total sample of 318 students was selected again drawn from two secondary schools in the United Arab Emirates, one a girls' school and one a boys' school. The surveys were completed in October 2002.

For the third stage of this project, two questionnaires to explore attitudes towards chemistry were developed, one for year 10 and the other for year 11. Overall, they aimed to see how attitudes are related to their experiences of difficulties. For this stage, a total sample of 225 students in two typical Emirates schools were involved, one boys' and one girls' . The questionnaires were distributed among year 10 and year 11 students in February 2003. Together, these surveys gave an overall picture, with large samples, of the situation in chemistry in the Emirates and provided clear guidance for the next stage of the work.

In the fourth study new teaching material were designed (four booklets). For this stage, a total sample of 800 students boys and girls was selected. Each pupil completed one section of the syllabus using the new material. It was thus possible to use half the students in each year group as an experimental group and half as a control for each new material booklet, thus ensuring that there was no possible bias in the groups which had to be selected to meet the actual classes being taught.

The work was carried out over two terms. Two booklets were used in November-December 2004, one entitled 'The Periodic Table of Elements' (for one half of year 10), the others entitled 'Organic Chemistry' (for one half of year 11). The other two booklets were used in March-April 2005: 'Chemical Equation' for year 10 and 'Acids & Alkalis' for year 11, these being used with the other half of each year group respectively. This meant that the experimental group which worked with the booklets in November-December 2004 , became the control group in March-April 2005 for both year groups.

Chemistry tests were applied after completing the various sections of the syllabus and the results compared, for each topic, to see if the groups who had used the new materials were performing better than those who had been taught in the traditional way The attitudes of the students were also measured using the same questionnaire which had been used in February 2003, with the previous year groups. This was completed in April 2004.

From the t-test results, there was a quite marked improvement in performance with the use of all four booklets ($p < 0.001$) while the students attitudes also had become more positive, the effect being extremely marked (chi-square values sometimes were more than 100 which is very unusual).

11.2 Specific Findings

The results from the two grid tests in experiment 1 suggest that many students have not grasped some of the basic ideas of chemistry. The results leave an impression that students have memorised some things but do not really understand what it is all about. Chemistry is abstract and they have no 'feel' for the nature of chemicals. If students have not mastered some of the basic skills, then it reduces chemistry to an abstract subject to be memorised. Perhaps it is little wonder that attitudes are not too positive.

The general impression left from both year groups is that here there are students who are well aware of the importance and significance of chemistry but who find the whole learning experience highly unsatisfactory. The data tend to confirm the need to make a curriculum closely related to context and lifestyle of learners.

The improvements in the means scores obtained after using the new teaching materials are very large. The effectiveness of the new teaching material has therefore been shown to bring about a very marked consistent improvement in the performance of students. Two features were deliberately used to underpin the design of the new materials: reducing the working memory load and relating new material to the experiences and previous knowledge of students

Attitudes towards chemistry and, indeed, towards learning, are likely to be important factors influencing success. In almost every measure made, the students who used the new materials have demonstrated more positive views when compared to the equivalent group from the previous year. The size of the attitude change is all the more remarkable in that each group had only undertaken one chemistry teaching unit using the new materials.

11.3 Strengths and Weakness of the Study

Over many years, a large body of evidence has developed which points very clearly to the reasons why parts of chemistry are found to be difficult for learners. The new materials were deliberately and carefully designed to incorporate the features predicted by information processing as essential features. The syllabus could not be altered and the total content was, therefore, more or less the same. However, the way the material was presented was very different. Specifically, new ideas were carefully linked on to previous knowledge which the students should have possessed. The material was presented so that working memory was unlikely to be overloaded. Multiple approaches were adopted (using tables, diagrams, pictures as well as text) to communicate key ideas. Language was kept simple and accessible. The students were taught in Arabic and this poses all kind of problems with the way equations are conventionally written and symbols and numbers are used. This alone will place demands on working memory and care was taken in presenting these areas.

Nonetheless, despite the care taken, there is no certainty that the criteria suggested by information processing were, in fact, the essential criteria in that so many features of the new materials were very different from conventional teaching. For example group work was sometimes used. This alone will have had its own impact although it is known that it does not bring benefits to all students (Yang, 2000)

With the attitude work, the picture is perhaps more clear cut. The evidence form past studies has pinpoint the two key important features which allow positive attitudes to develop. The material reflected these very specifically and the changes in attitudes observed were quite remarkable. It is likely that the deigns features can be linked tightly to the outcomes.

One other weakness has to be considered. The teaching of chemistry in the Emirates is based on a very overcrowded syllabus, taught by very traditional didactic methods, using a very rigid and information laden approach. students will inevitably respond positively to change and this must also have been a factor in the greater success noted and the attitude change observed.

11.4 Recommendations for Further Study

In the light of the findings of the present research, the following recommendations are made:

(a) The chemistry syllabus should be extensively revised. Less should be covered and topics which are completely unrelated to the needs and aspirations of the students should be removed (eg lanthanides and actinides);

(b) The curriculum could easily be made applications-led in design and be overtly constructed fro the general education of the students rather than just fore the preparation of specialist chemists.

(c) The methods of presentation should taken into account limits in working memory, the need to build on prior knowledge and the need to allow discussion and dialogue to reduce misconceptions and confusions.

(d) There needs to be an extensive programme of training for curriculum planners, and for teachers.

(e) Although not covered here, such changes will inevitably require a re-think of all assessment to bring it into line with the new approaches. Again, extensive and possibly prolonged training will be needed.

11.5 Suggestions for Future Work

This work concentrated on older students. There may be a great need to carry out parallel studies with yonger students to ensure that the right foundations of knowledge and attitude are developed earlier. The work also needs to be extended to year 12. This will be difficult in that there are many pressure in the final year of schooling. Issues of gender need explored, especially with an applications-led curriculum.

This study aimed to apply established models relating to effective and efficient learning as well as the development of positive attitudes. What it has shown is that both learning and attitude development can be developed together. This offers a powerful model not only for chemistry but for other cognate subjects. If there was a consistent development across many subject areas, following parallel; approcahes, then there would be the need for a major research project to measure the outcomes and to pin point further areas needing exploration and development.

It is hoped that this study will be able to contribute to the development of chemistry as a school discipline so that students will complete course s who are equipped and motivated to make future contributions based in chemistry as well as many other career options.

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List of Appendices

Appendix A

Chemistry Level of Difficulty for Year 10 and Year 11

Chemistry Level of Difficulty-*Year 10*

This is designed to find where you have difficulties in order to plan teaching to help.
Please tick an appropriate box which indicates your opinion about each of the chemistry topics
Please be completely honest!
This is NOT a test.

Please use the following:

Easy	**understood it without difficulties**
Moderate	**had difficulties but I understand it now**
Difficult	**still do not understand it**
Never studied	**have never been taught this topic**

Please tick one box ONE each line to show what you think

	Easy	Moderate	Difficult	Never Studied	If difficult, Please say why
Elements and compounds	☐	☐	☐	☐	....
Symbols of elements	☐	☐	☐	☐	....
Atomic and molecule	☐	☐	☐	☐	....
Oxidation number	☐	☐	☐	☐	....
Chemical formula	☐	☐	☐	☐	....
Atomic and molecule mass	☐	☐	☐	☐	....
Cathode rays	☐	☐	☐	☐	....
Proton-electron and neutron	☐	☐	☐	☐	....
Radioactivity	☐	☐	☐	☐	....
α,-β and γ radiation	☐	☐	☐	☐	....
Atomic number and mass number	☐	☐	☐	☐	....
Isotopes	☐	☐	☐	☐	....
Grounds and excited state of electron	☐	☐	☐	☐	....
Quantum number	☐	☐	☐	☐	....
Electron clouds	☐	☐	☐	☐	....
Aufbau principle	☐	☐	☐	☐	....
Hund's rule and Pauli's exclusion principle	☐	☐	☐	☐	....
Periodic table of elements	☐	☐	☐	☐	....
Halogens	☐	☐	☐	☐	....
Lanthanides and actinides	☐	☐	☐	☐	....
Acidic and basic oxide	☐	☐	☐	☐	....
Electronegativity	☐	☐	☐	☐	....
Types of chemical bonds	☐	☐	☐	☐	....
Chemical equation	☐	☐	☐	☐	....
Semi-conductors	☐	☐	☐	☐	....
Allotropy	☐	☐	☐	☐	....
Ozone	☐	☐	☐	☐	....
Chloroflorocarbons	☐	☐	☐	☐	....
Oxy-acetylene flames	☐	☐	☐	☐	....
Ultraviolet rays	☐	☐	☐	☐	....

Thank you for your help

Centre for Science Education, University of Glasgow, Scotland

Chemistry Level of Difficulty-*Year 11*

This is designed to find where you have difficulties in order to plan teaching to help.
Please tick an appropriate box which indicates your opinion about each of the chemistry topics
Please be completely honest!
This is NOT a test.

Please use the following:

Easy	**understood it without difficulties**
Moderate	**had difficulties but I understand it now**
Difficult	**still do not understand it**
Never studied	**have never been taught this topic**

Please tick one box** ONE **each line to show what you think

	Easy	Moderate	Difficult	Never Studied	If difficult, Please say why
Mole calculations	☐	☐	☐	☐	....
Chemical equation balances	☐	☐	☐	☐	....
Mass and volum gas calculations	☐	☐	☐	☐	....
Boyle's, Charle's and Gay-Lussac lawss	☐	☐	☐	☐	....
Standard conditions	☐	☐	☐	☐	....
The vapour pressure of a liquids	☐	☐	☐	☐	....
Standard and supersturated solutionss	☐	☐	☐	☐	....
Molaritys	☐	☐	☐	☐	....
Hess's laws	☐	☐	☐	☐	....
Osmosiss	☐	☐	☐	☐	....
Conservation of energy laws	☐	☐	☐	☐	....
Endothermic and exothermic reactionss	☐	☐	☐	☐	....
Enthalpys	☐	☐	☐	☐	....
Alkanes and alkeness	☐	☐	☐	☐	....
Homologous seriess	☐	☐	☐	☐	....
Alkyl groupss	☐	☐	☐	☐	....
Isomerisms	☐	☐	☐	☐	....
Resonances	☐	☐	☐	☐	....
Polymerisations	☐	☐	☐	☐	....
Catalyst factorss	☐	☐	☐	☐	....
Forward and backward (reverse) reactions	☐	☐	☐	☐	....
Dynamic equilibriums	☐	☐	☐	☐	....
Equilibrium laws	☐	☐	☐	☐	....
Le Chatelier's principles	☐	☐	☐	☐	....
Lewis, Arhenius, Bronsted-Lowry acidss	☐	☐	☐	☐	....
Acid rains	☐	☐	☐	☐	....
pH & pOH calculationss	☐	☐	☐	☐	....
Normal saltss	☐	☐	☐	☐	....
The ionic product of waters	☐	☐	☐	☐	....
Hydrocarbon compoundss	☐	☐	☐	☐	....

Thank you for your help

Centre for Science Education, University of Glasgow, Scotland

Appendix B

General Student's Comments/Reasons for Difficulty
Year 10 and Year 11

General Student's Comments/Reasons for Difficulty-*Year 10*

Concept / Number of students responses	***Reasons for Difficulty/Number of student responses***
Elements and compounds [5]	Too many to remember [5]
Symbols of element [10]	Similar [8] Difficult to write [2]
Atoms and molecules [6]	Difficult to define and draw [6]
Oxidation number [5]	Get confused easily and difficult to understand [5]
Chemical formula [195]	Difficult to write [25] Get confused in exchange oxidation number, not enough example, not enough pracyice [170]
Radioactivity [3]	Wasn't explained well [3]
Ground and excited state of electron [13]	Was not explained clearly enough [10] Complicated [3]
Quantum numbers [170]	Difficult to tell a part [30] Difficult to keep in mind [14] Not explained properly, extremely confusing [66] Not entertaining [20] Done quickly [20]
Periodic table of elements [190]	Difficult to understand [41] Too many elements, similar symbols confusing, never seen it before [149]
Acidic and basic oxides [31]	Difficult to distinguish [16] Not enough time spent, done quickly [15]
Lanthanides and actinides [170]	Difficult to study [33] Complicated, not enough information given about it, never seen before [102] Done quickly [35]
Electronegativity [7]	Difficult to keep in mind what high and low electronegativity are [7]
Types of chemical bonds [10]	Difficult to define and distinguish between them [10]
Chemical equation [182]	Difficult to understand [40] Have no previous idea [41] Not enough practice, not explained clearly, not enough examples [99]
Semi-conductors [9]	Too quickly explained, not enough examples [9]
Cloroflorocarbons [6]	I don't know what this is [6]

General Student's Comments/Reasons for Difficulty-*Year 11*

Concept / Number of students responses	*Reasons for Difficulty/Number of student responses*
Mole calculation[130]	Not enough example [33] Less practice, complicated maths involved, confused [76] Never been able to [15] Never know which methods to use [6]
Chemical equation balance [132]	Have no previous idea [22] Not enough practice [34] Not enough examples [20] Not explained well [23] Complicated rules, especially with compound reaction [24] Easily get confused [9]
Mass and volume gas calculation [32]	Too many mathematical laws [17] I don't understand relevance of equations [15]
Boyle's, Charles's and Gay-Lussac laws [35]	Difficult to distinguish between them [11] Too many steps involved [7] Too many mathematical laws [17]
Standard conditions [20]	Don't spend enough time on it [7] Not enough examples [13]
The vapour pressure of a liquid [35]	Complicated [19] Wasn't explained well, and the presentation in the textbook not clear [16]
Sturated and supersaturated solutions [6]	Not enough time spent on this area, and not enough information [6]
Molarity [2]	Was not explained clearly enough [10] Complicated [3]
Hess's law [37]	Confusing and complicated [11] Too many mathematical steps involved, and poor explanation in the textbook [26]
Osmosis [2]	Wasn't explained well [2]
Conservation of energy law [16]	Don't spend enough time on it[5] Not enough information [11]
Endothermic and exothermic reactions [35]	Can't differentiate them [19] Not enough examples [12] Difficult to undersatnd [4]

Alkanes and alkenes [108]	Organic chemistry id difficult, and easy to forget[65] Confused [11] Mach more compounds [25] Too quickly explained [7]
Homologous series [125]	Easy to forget [59] Difficult to picture chemical series [40] Not enough examples [12] Not explained well [14]
Alkyl groups [128]	Difficult to remember the table [38] Organic chemistry is difficult [49] Don't spend enough time on it [25] Too many alkyl groups [16]
Isomerism [125]	Lectures difficult [19] Difficult to draw chemical structures, and not explaind well [35] I can't find examples of isomerism or name them [56] Confused [15]
Resonance [150]	Not enough information given [105 Not enough time spend [21] Not explained well [24]
Polymerisation [10]	Not enough information [4] Not enough examples [6]
Catalyst factors [12]	Only encouraged to role learn [4] Not enough information [5]
Forward and backward reactions [2]	Not enough information[2]
Dynamic equilibrium [37]	Too mathematical, difficult to understand and to remember equations [16] Confusing couldn't relate lectures to labs [10]
Equilibrium law [10]	Not enough information [8] Too quickly explained [2]
Le Chatelier's principle [10]	Not enough information [7] The presentation in textbook not clear [3]
Lewis,Arhenius, Bronsted-Lowry acids [49]	Can't differentiate them [19]

	Couldn't relate lectures to labs [11] Lecture vague [8] Too fast [6] Not enough examples [5]
PH and POH calculation [125]	Quickly explained in order to finish curriculum [43] No chance to practise[39] Difficult calculations [30] I don't understand relevance of equations and confused [13]
Normal salts [30]	Just talking not teaching [9] Not enough information [13] Too quickly explained [8]
Isomerism [125]	Lectures difficult [19] Difficult to draw chemical structures, and not explained well [35] I can't find examples of isomerism or name them [56] Confused [15]
The ionic product of water [66]	Difficult calculations [26] Not enough information [11] No previous knowledge [20] No chance to practise [9]
Hydrocarbon compounds [55]	Similar names, too many compounds, and although easily learnt, also easily forgotten [38] Organic chemistry is difficult [17]

Appendix C

Codes for Year 10 and Year 11

Codes -*Year 10*

Q1:

a-The following answers are correct: *B and F*

[It could be argued that D is also correct but pupils will not know this]

Code 1	Both correct answers chosen
Code 2	Only B chosen
Code 3	Only F chosen
Code 4	B chosen but one wrong answer also chosen
Code 5	F chosen but one wrong answer also chosen
Code 6	B and F chosen with one wrong answer also chosen
Code 7	B chosen but two wrong answers also chosen
Code 8	F chosen but two wrong answers also chosen
Code 9	Anything else

b- T he following answers chosen: *C and E*

Code 1	Both correct answers chosen
Code 2	Only C chosen
Code 3	Only E chosen
Code 4	C chosen but one wrong answer also chosen
Code 5	E chosen but one wrong answer also chosen
Code 6	C and E chosen with one wrong answer also chosen
Code 7	C chosen but two wrong answers also chosen
Code 8	E chosen but two wrong answers also chosen
Code 9	Anything else

Q2: The following answers are correct: *A and F*

Code 1	Both correct answers chosen
Code 2	Only A chosen
Code 3	Only F chosen
Code 10	A chosen but B also chosen
Code 11	A chosen but C also chosen
Code 12	A chosen but D also chosen
Code 13	A chosen but E also chosen
Code 20	F chosen but B also chosen
Code 21	F chosen but C also chosen
Code 22	F chosen but D also chosen
Code 23	F chosen but E also chosen
Code 30	B and F chosen with one wrong answer also chosen (this may have to be spilt up)
Code 31	B and F chosen with two wrong answers also chosen
Code 9	Anything else

Q3: **a-The following answers are correct: *D and F***

Code 1	Both correct answers chosen
Code 2	Only D chosen
Code 3	Only F chosen
Code 4	D chosen along with two wrong answers
Code 5	D chosen along with three wrong answers
Code 6	F chosen along with two wrong answers
Code 7	F chosen along with three wrong answers
Code 10	D and F chosen along with G
Code 11	D and F chosen along with H
Code 12	D and F chosen along with I
Code 20	D chosen along with G
Code 21	D chosen along with H
Code 22	D chosen along with I
Code 30	F chosen along with G
Code 31	F chosen along with H
Code 32	F chosen along with I
Code 9	Anything else

b- The following answers are correct: *A,E,H and I*

Code 1	All four correct answers chosen
Code 2	Three of four correct answers chosen (this may have tosplit up)
Code 3	Two of fore correct answers chosen
Code 4	One of four correct answers chosen plus one extra answers
Code 5	All correct answer chosen plus one extra wrong answer
Code 6	Two correct answers chosen plus one extra answer
Code 9	Anything else

C- The following are correct answers: *B,C, and G*

Code 1	All three correct answers chosen
Code 2	Two of the three correct answers chosen (this may have split up)
Code 3	One of the three correct answers chosen
Code 10	All three correct answers chosen plus one extra answer
Code 11	Two correct answers chosen plus one extra answer
Code 12	One of the three correct answers chosen plus extra wrong answers
Code 9	Anything else

d- The following are correct answers: *H*

Code 1	H chosen
Code 2	H plus one extra answer chosen (may need to be split up)
Code 3	H plus two extra answers chosen
Code 4	H plus three extra answers chosen
Code 9	Anything else

e- The following are correct answers: *A and E*

Code 1	Both correct answers chosen
Code 2	Only A chosen
Code 3	Only E chosen
Code 4	A chosen but one wrong answer also chosen
Code 5	E chosen but one wrong answer also chosen
Code 6	A and E chosen with one wrong answer also chosen
Code 7	A chosen but two wrong answers also chosen
Code 8	E chosen but two wrong answers also chosen
Code 9	Anything else

Codes -*Year 11*

Q1: a- The following answers are correct: ***A, F, and H***

Code 1	All three correct answers chosen
Code 2	Two of three correct answers chosen (This may have to be split up)
Code 3	One of the three correct answers chosen
Code 10	All three correct answers chosen plus one extra answer
Code 11	Two correct answers chosen plus on extra answer
Code 9	Anything else

b- The following are correct answers: ***B and E***

Code 1	Both correct answers chosen
Code 2	Only B chosen
Code 3	Only E chosen
Code 4	B chosen but one wrong answer also chosen
Code 5	E chosen but one wrong also chosen
Code 6	B and E chosen with one wrong answer also chosen
Code 9	Anything else

Q2: a-The following are correct answers: ***G and J***

Code 1	Both correct answers chosen
Code 2	Only G chosen
Code 3	Only J chosen
Code 10	G and J chosen along with H
Code 11	G and J chosen along with I
Code 12	G and J chosen along with K
Code 13	G and J chosen along with L
Code 21	G chosen along with H
Code 22	G chosen along with I
Code 23	G chosen along with K
Code 24	G chosen along with L
Code 32	J chosen along with K
Code 33	J chosen along with L
Code 9	Anything else

b- The following are correct answers: ***A and E***

Code 1	Both correct answers chosen
Code 2	Only A chosen
Code 3	Only E chosen
Code 4	A and E chosen along with F
Code 5	A and E chosen along with G
Code 6	A and E chosen along with H

Code 7	A and E chosen along with J
Code 10	A and E chosen along with K
Code 11	A and E chosen along with L
Code 12	A chosen along with B
Code 13	A chosen along with C
Code 14	A chosen along with D
Code 15	A chosen along with F
Code 16	A chosen along with G
Code 17	A chosen along with H
Code 18	A chosen along with I
Code 21	A chosen along with J
Code 22	A chosen along with K
Code 23	A chosen along with L

c- The following are correct answers: *C,F,G,H, and L*

Code 1	All five correct answers chosen
Code 2	Four of five correct answers chosen
Code 3	Three of five correct answers chosen
Code 4	Two of five correct answers chosen
Code 5	One of five correct answers chosen
Code 6	All five correct answers chosen plus one extra wrong answer
Code 7	Four correct answer chosen plus one extra wrong answer
Code 8	Three correct answer chosen plus one extra wrong answer
Code 10	Two correct answer chosen plus one extra wrong answer
Code 11	One correct answer chosen plus one extra wrong answer
Code 9	Anything else

d- The following are correct answers: *F and L*

Code 1	Both correct answers chosen
Code 2	Only F chosen
Code 3	Only L chosen
Code 4	F and L chosen along with G
Code 5	F and L chosen along with H
Code 6	F and L chosen along with I
Code 10	F and L chosen along with J
Code 11	F and L chosen along with K
Code 9	Anything else

e- The following are correct answers: *B, D, and I*

Code 1	All three correct answers chosen
Code 2	Two of the three correct answers chosen (This may have to be split up)
Code 3	One of the three correct answers chosen

Code 10	All three correct answers chosen plus one extra answer
Code 11	Two correct answers chosen plus on extra answer
Code 12	One correct answer chosen plus one extra answer
Code 9	Anything else

f- The following are correct answers: *F and L*

Code 1	Both correct answers chosen
Code 2	Only F chosen
Code 3	Only L chosen
Code 4	F chosen but one wrong answer also chosen
Code 5	L chosen but one wrong answer also chosen
Code 6	F and L chosen with one wrong answer also chosen
Code 7	F and L chosen with two wrong answers also chosen
Code 9	Anything else

Q3: a, b-following are correct answers: *Two electrons* and *Four electrons*

Code 1	If the pupil has the idea of 2 and 4 electrons respectively, stated or implied
Code 2	If the pupil has the idea of electrons
Code 9	Anything else

Q4: The following are correct answers: *A and F*

Code 1	Both correct answers chosen
Code 2	Only A chosen
Code 3	Only F chosen
Code 10	A chosen but B also chosen
Code 11	A chosen but C also chosen
Code 12	A chosen but D also chosen
Code13	A chosen but E also chosen
Code 20	F chosen but B also chosen
Code 21	F chosen but C also chosen
Code 22	F chosen but D also chosen
Code 23	F chosen but E also chosen
Code 30	A and F chosen with one wrong answer also chosen (this may have to be split up)
Code 31	A and F chosen with two wrong answers also chosen
Code 32	A and F chosen with three wrong answers also chosen
Code 9	Anything else

d- The following are correct answers: *F and L*

Code 1	Both correct answers chosen
Code 2	Only F chosen
Code 3	Only L chosen
Code 4	F and L chosen along with G
Code 5	F and L chosen along with H
Code 6	F and L chosen along with I
Code 10	F and L chosen along with J
Code 11	F and L chosen along with K
Code 9	Anything else

e- The following are correct answers: *B, D, and I*

Code 1	All three correct answers chosen
Code 2	Two of the three correct answers chosen (This may have to be split up)
Code 3	One of the three correct answers chosen
Code 10	All three correct answers chosen plus one extra answer
Code 11	Two correct answers chosen plus on extra answer
Code 12	One correct answer chosen plus one extra answer
Code 9	Anything else

f- The following are correct answers: *F and L*

Code 1	Both correct answers chosen
Code 2	Only F chosen
Code 3	Only L chosen
Code 4	F chosen but one wrong answer also chosen
Code 5	L chosen but one wrong answer also chosen
Code 6	F and L chosen with one wrong answer also chosen
Code 7	F and L chosen with two wrong answers also chosen
Code 9	Anything else

Q3: a, b-following are correct answers: *Two electrons* and *Four electrons*

Code 1	If the pupil has the idea of 2 and 4 electrons respectively, stated or implied
Code 2	If the pupil has the idea of electrons
Code 9	Anything else

Q4: The following are correct answers: *A and F*

Code 1	Both correct answers chosen
Code 2	Only A chosen
Code 3	Only F chosen
Code 10	A chosen but B also chosen
Code 11	A chosen but C also chosen
Code 12	A chosen but D also chosen
Code13	A chosen but E also chosen

Appendix D

You and Chemistry for Year 10 and Year 11

You and Chemistry/ Year 10

Please answer the questions below carefully.
Your answers will help in future planning.

(1) Are you: ☐ Girl ☐ Boy

(2) What secondary school do you attend at the moment? ....

This is an example. *If you had to describe "a racing car" you could do it like this:*

quick	☑ ☐ ☐ ☐ ☐ ☐	slow	The positions of the ticks between the word pairs show that you consider it as ***very*** quick, slightly more important than unimportant and ***quite*** dangerous.
important	☐ ☐ ☑ ☐ ☐ ☐	unimportant	
safe	☐ ☐ ☐ ☐ ☑ ☐	dangerous	

Use the same method of ticking to answer questions 3 and 4.

(3) What are your opinions about your **school chemistry** lessons in year 10?

I like chemistry lessons	☐ ☐ ☐ ☐ ☐ ☐	I hate chemistry lessons
Boring	☐ ☐ ☐ ☐ ☐ ☐	Interesting
Easy	☐ ☐ ☐ ☐ ☐ ☐	Difficult
Useless	☐ ☐ ☐ ☐ ☐ ☐	Useful
Important	☐ ☐ ☐ ☐ ☐ ☐	Unimportant
Enjoyable	☐ ☐ ☐ ☐ ☐ ☐	Boring

(4) How do you feel about the **chemistry you have learned** in year 11?

I am enjoying the subject	☐ ☐ ☐ ☐ ☐ ☐	I am NOT enjoying the subject
I feel I am NOT coping well	☐ ☐ ☐ ☐ ☐ ☐	I feel I am coping well
I find it very easy	☐ ☐ ☐ ☐ ☐ ☐	I find it very hard
I am growing intellectually	☐ ☐ ☐ ☐ ☐ ☐	I am NOT growing intellectually
I am NOT obtaining a lot of new skills	☐ ☐ ☐ ☐ ☐ ☐	I am obtaining a lot of new skills
I hate practical work	☐ ☐ ☐ ☐ ☐ ☐	I am enjoying practical work
I am getting better in the subject	☐ ☐ ☐ ☐ ☐ ☐	I am getting worse in the subject
I do not like my teacher	☐ ☐ ☐ ☐ ☐ ☐	I like my teacher
It is definitely "my" subject	☐ ☐ ☐ ☐ ☐ ☐	It is definitely NOT "my" subject

(5) What do you enjoy in your **chemistry** lessons?
Tick as many as you like.

- ☐ Studying the theory
- ☐ Doing practical work
- ☐ Explaining natural phenomena
- ☐ Drawing shapes (atoms, molecules etc)
- ☐ Writing formulae and chemical equations
- ☐ Balancing chemical equations
- ☐ Studying chemistry applications in life
- ☐ Studying about chemical reactions in the human body
- ☐ Setting up apparatus
- ☐ Studying how chemistry can improve my life
- ☐ Solving every day problems
- ☐ Studying how chemistry can make our lives healthier

(6) Here are some school subjects:

A Arabic	D Biology	B Chemistry	E Geography
C Geology	F History	G Mathematics	H Physics

Using the letters, place these in order of importance to yourself:

Most important to me .... ***Least*** important to me

(7) Show your opinion about the topics you have studied

Tick as many boxes as you like for each topic

	Chemical formula	**Quantum number**	**Periodic table of elements**	**Lanthanides and actinides**	**Chemical equation**
Important to improve my life					
Boring					
Interesting					
Complicated					
It is a good basis future study					

(8) Think about what might influence you to study chemistry in future years.
Which of the following would attract you to further study in chemistry
Tick as many boxes as you like

- ☐ An interesting course
- ☐ There are good possibilities of jobs
- ☐ What my friends think
- ☐ Television programmes
- ☐ The wishes of my parents
- ☐ Exciting experiments in class
- ☐ An interesting textbook
- ☐ A stimulating teacher
- ☐ Any thing else: ....

(9) Write one sentence to say what most attracts you to chemistry

....

....

(10) Write one sentence to say what least attracts you to chemistry

....

....

Thank You for Your Help

You and Chemistry/ Year 11

Please answer the questions below carefully.
Your answers will help in future planning.

(1) Are you: ☐ Girl ☐ Boy

(2) What secondary school do you attend at the moment? ....

This is an example. *If you had to describe "a racing car" you could do it like this:*

quick	☑ ☐ ☐ ☐ ☐ ☐	slow	The positions of the ticks between the word pairs show that you consider it as ***very*** quick, slightly more important than unimportant and ***quite*** dangerous.
important	☐ ☐ ☑ ☐ ☐ ☐	unimportant	
safe	☐ ☐ ☐ ☐ ☑ ☐	dangerous	

Use the same method of ticking to answer questions 3 and 4.

(3) What are your opinions about your **school chemistry** lessons in year 11?

I like chemistry lessons	☐ ☐ ☐ ☐ ☐ ☐	I hate chemistry lessons
Boring	☐ ☐ ☐ ☐ ☐ ☐	Interesting
Easy	☐ ☐ ☐ ☐ ☐ ☐	Difficult
Useless	☐ ☐ ☐ ☐ ☐ ☐	Useful
Important	☐ ☐ ☐ ☐ ☐ ☐	Unimportant
Enjoyable	☐ ☐ ☐ ☐ ☐ ☐	Boring

(4) How do you feel about the **chemistry you have learned** in year 11?

I am enjoying the subject	☐ ☐ ☐ ☐ ☐ ☐	I am NOT enjoying the subject
I feel I am NOT coping well	☐ ☐ ☐ ☐ ☐ ☐	I feel I am coping well
I find it very easy	☐ ☐ ☐ ☐ ☐ ☐	I find it very hard
I am growing intellectually	☐ ☐ ☐ ☐ ☐ ☐	I am NOT growing intellectually
I am NOT obtaining a lot of new skills	☐ ☐ ☐ ☐ ☐ ☐	I am obtaining a lot of new skills
I hate practical work	☐ ☐ ☐ ☐ ☐ ☐	I am enjoying practical work
I am getting better in the subject	☐ ☐ ☐ ☐ ☐ ☐	I am getting worse in the subject
I do not like my teacher	☐ ☐ ☐ ☐ ☐ ☐	I like my teacher
It is definitely "my" subject	☐ ☐ ☐ ☐ ☐ ☐	It is definitely NOT "my" subject

(5) What do you enjoy in your **chemistry** lessons?
Tick as many as you like.

- ☐ Studying the theory
- ☐ Doing practical work
- ☐ Explaining natural phenomena
- ☐ Drawing shapes (atoms, molecules etc)
- ☐ Writing formulae and chemical equations
- ☐ Balancing chemical equations
- ☐ Studying chemistry applications in life
- ☐ Studying about chemical reactions in the human body
- ☐ Setting up apparatus
- ☐ Studying how chemistry can improve my life
- ☐ Solving every day problems
- ☐ Studying how chemistry can make our lives healthier

(6) Here are some school subjects:

A Arabic	D Biology	B Chemistry	E English
C Geology	F Mathematics	G Physics	H Religion

Using the letters, place these in order of importance to yourself:

Most important to me .... ***Least*** important to me

(7)Show your opinion about the topics you have studied

Tick as many boxes as you like for each topic

	Mole calculation	Chemical Equation balance	Homologous Series	Isomerism	Alkyl groups	PH&POH Calculation
Important to improve my life						
Boring						
Interesting						
Complicated						
It is a good basis future study						

(8) Think about what might influence you to study chemistry in future years.
Which of the following would attract you to further study in chemistry
Tick as many boxes as you like

- ☐ An interesting course
- ☐ There are good possibilities of jobs
- ☐ What my friends think
- ☐ Television programmes
- ☐ The wishes of my parents
- ☐ Exciting experiments in class
- ☐ An interesting textbook
- ☐ A stimulating teacher
- ☐ Any thing else: ....

(9) Write one sentence to say what most attracts you to chemistry

....

....

(10) Write one sentence to say what least attracts you to chemistry

....

....

Thank You for Your Help

Appendix E

The Raw Data of Attitudes Questionnaires / Year 10 and Year 11 (Experiment 1)

Attitudes Towards Chemistry/ Year 10- Experiment.1

Number Of Students 115

Q3

I like chemistry lessones	46	20	11	12	14	12	I hate chemistry lessones
Boring	20	10	13	16	23	33	Interesting
Easy	22	24	18	8	13	30	Difficult
Useless	9	5	6	9	15	71	Useful
Important	68	12	12	5	9	9	Unimportant
Enjoyable	21	20	21	18	9	26	Boring

Q4

I am enjoying the subject	35	9	22	8	5	36	I am NOT enjoying the subject
I feel I am NOT coping well	26	9	15	7	11	47	I feel I am coping well
I find it very easy	22	24	20	9	14	26	I find it very hard
I am growing intellectually	47	14	10	8	12	24	I am NOT growing intellecually
I am NOT obtaining a lot of new skills	26	12	14	10	13	40	I am obtaining a lot of new skills
I hate practical work	53	12	11	2	7	30	I am enjoying practical work
I am getting better in the subject	38	16	13	15	8	25	I am getting worse in the subject
I do not like my teacher	35	3	16	24	8	29	I like my teacher
I t is definitely "my" subject	35	10	20	12	13	25	It is definitely NOT "my" subject

Q5

63	Studying the theory	35	Studying chemistry applications in life
69	Doing practical work	71	Studying about chemical reactions in the human body
35	Explaining natural phenomena	12	Setting up apparatus
58	Drawing shapes (atoms, molecules, etc)	68	Studying how chemistry can improve my life
52	Writing formulae and chemical equations	23	Solving every day problems
46	Balancing chemical equations	70	Studying how chemistry can make our lives healthier

Q6

Most importan to me (Chemistry)	15	20	21	22	17	10	8	2	***Least*** important to me
Most important to me (Physics)	2	22	20	23	28	2	7	12	***Least*** important to me
Most important to me (Biology)	28	12	23	21	12	13	5	3	***Least*** important to me
Most important to me (Mathematics)	52	26	12	7	3	6	5	5	***Least*** important to me

Q8

46 An interesting course
81 There are good possibilities of jobs
35 What my friends think
0 Television programmes
64 The wishes of my parents
52 Exciting experiments in class
40 An interesting textbook
59 A stimulating teacher
0 Anything else: ....

Attitudes Towards Chemistry/ Year 11- Experiment.1

Number Of Students 110

Q3

I like chemistry lessones	33	24	30	13	7	3	I hate chemistry lessones
Boring	7	14	20	30	23	17	Interesting
Easy	17	33	39	13	4	4	Difficult
Useless	3	6	10	11	32	48	Useful
Important	47	29	13	12	6	3	Unimportant
Enjoyable	15	17	30	25	14	9	Boring

Q4

I am enjoying the subject	17	26	14	28	10	15	I am NOT enjoying the subject
I feel I am NOT coping well	20	11	12	11	26	30	I feel I am coping well
I find it very easy	24	30	25	18	9	4	I find it very hard
I am growing intellectually	41	23	18	12	13	3	I am NOT growing intellecually
I am NOT obtaining a lot of new skills	7	13	13	13	26	35	I am obtaining a lot of new skills
I hate practical work	4	7	6	9	14	70	I am enjoying practical work
I am getting better in the subject	38	25	17	13	10	7	I am getting worse in the subject
I do not like my teacher	38	10	13	20	17	12	I like my teacher
I t is definitely "my" subject	17	24	32	20	11	6	It is definitely NOT "my" subject

Q5

55	Studying the theory	66	Studying chemistry applications in life
77	Doing practical work	76	Studying about chemical reactions in the human body
59	Explaining natural phenomena	22	Setting up apparatus
61	Drawing shapes (atoms, molecules, etc)	72	Studying how chemistry can improve my life
64	Writing formulae and chemical equations	73	Solving every day problems
55	Balancing chemical equations	78	Studying how chemistry can make our lives healthier

Q6

Most importan to me (Chemistry)	2	11	18	23	23	14	12	7	***Least*** important to me
Most important to me (Physics)	10	28	22	16	16	8	3	7	***Least*** important to me
Most important to me (Biology)	7	12	15	29	13	7	18	10	***Least*** important to me
Most important to me (Mathematics)	42	20	8	10	11	8	4	7	***Least*** important to me

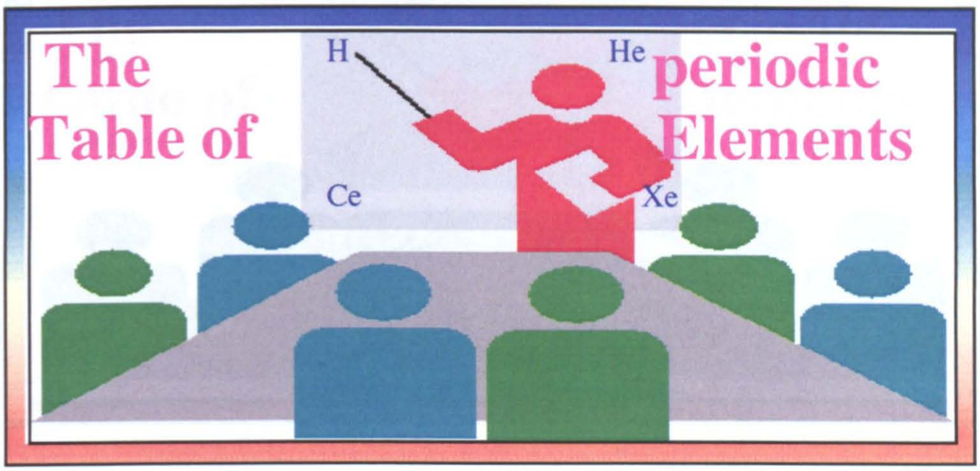
Q8

79	An interesting course
83	There are good possibilities of jobs
61	What my friends think
0	Television programmes
73	The wishes of my parents
61	Exciting experiments in class
44	An interesting textbook
77	A stimulating teacher
33	Anything else: ....

Appendix F

The New Teaching Material

The periodic Table of Elements booklet. **Chemical Equation booklet.**	**Year 10**
Organic Chemistry booklet. **Acids and Alkalis booklet.**	**Year 11**



This small booklet is designed to help you understand the periodic table of the elements.

The periodic table can be used to summarise and simplify what we know about the elements and their compounds.

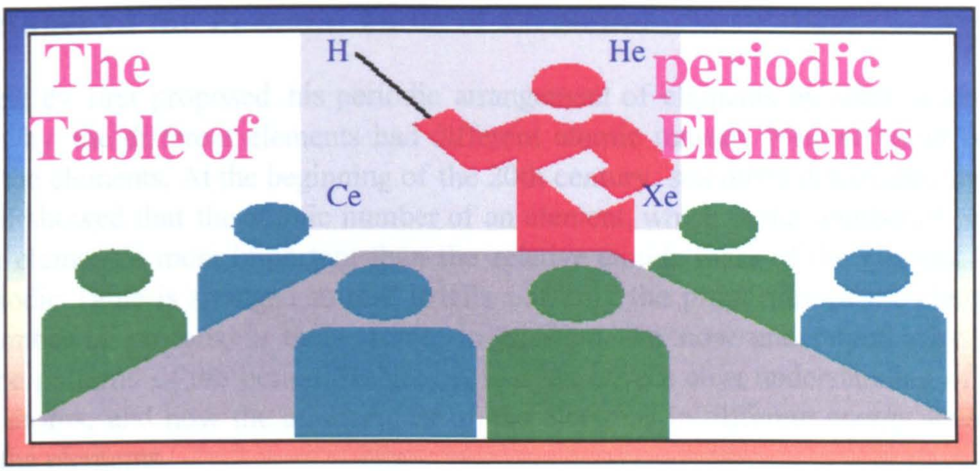
Read the booklet carefully.

Stop at the questions and fill in the best answers possible.

You may need to look up books or search the world-wide web using a computer.

Answers to the questions are provided at the end. Only use these *after* you have tried your best to find the answers.

The Centre for Science Education, University of Glasgow, Scotland
Web Site: http://www.gla.ac.uk/centres/scienceeducation



History of the 'Periodic Table of Elements'

By the early nineteenth century, the idea of comparing the masses of the elements was well known. John Dalton in Britain and Jons Jacob Berzelius in Sweden firmly established the idea of relative atomic mass. One problem related to uncertainties about certain chemical formulae: for example, was water HO or was it H_2O? Of course, at this time, many elements were as yet undiscovered and some published values of atomic mass were wrong.

In 1829, Wolfgang Dobereiner of Germany noticed that, in some groups of three chemically similar elements (for example, Cl, Br, I; Ca, Sr, Ba; S, Se, Te), the relative atomic mass of the middle is nearly midway between those of the first and last, and its properties are also roughly 'in the middle'. These 'triads' were probably the first attempt at looking for patterns among the elements.

In order to try to sort things out, Friedrick Kekule organised the First International Chemical Congress in Germany in 1860. This was the first ever international gathering of scientists. The most important lecture was given by an Italian, Stanislao Cannizzaro, who persuaded his listeners of the importance of accurate values of atomic masses.

In the next few years, several chemists to began to list the known elements in the order of their relative atomic masses. A few of them noticed that, certainly to begin with, every eighth element had similar properties. First to publish his results in 1862 was a Frenchman, Alexandre-Emil Beguyer de Chancourtois, but his argument was not well presented. Next was a Londoner, Alexander Newlands, who proposed his ideas at a meeting of The Chemical Society in 1863.

The great breakthrough came in 1969. The Russian chemist, Dmitri Mendele'ev (followed by Lother Mayer the following year), suggested that the properties of the elements can be represented as periodic functions of their atomic masses. Mendele'ev summarised this by publishing the first version of what we now call the periodic table. The word 'periodic' was used because he found that there was a repeat pattern after 8 elements. His original table is shown below - our modern table looks very different from this first design.

The Importance of the Periodic Table of Elements

When Mendele'ev first proposed his periodic arrangement of elements by their atomic masses, he had no idea why the different elements had different atomic masses. Neither could he explain the behaviour of the elements. At the beginning of the 20th century, scientists discovered the structure of the atoms and showed that the atomic number of an element, which is the number of protons in one atom of each element,is more important than the relative atomic mass of the element. Thus, in our days the Periodic Table is arranged so that it tells not only the properties of the elements but also about the number of protons in their atoms. In addition, we now understand why elements are arranged in the patterns of the periodic table, because we have a clear understanding of the structure of individual atoms, and how the arrangement of the electrons in different energy levels affects the reactivity of the elements.

Do you Know that ?

Element 101 was named Mendelevium (Md),
Asteroid 2769 was named after Mendele'ev.
The Russian Scientific Ship is called the *Dmitriy Mendeleev*

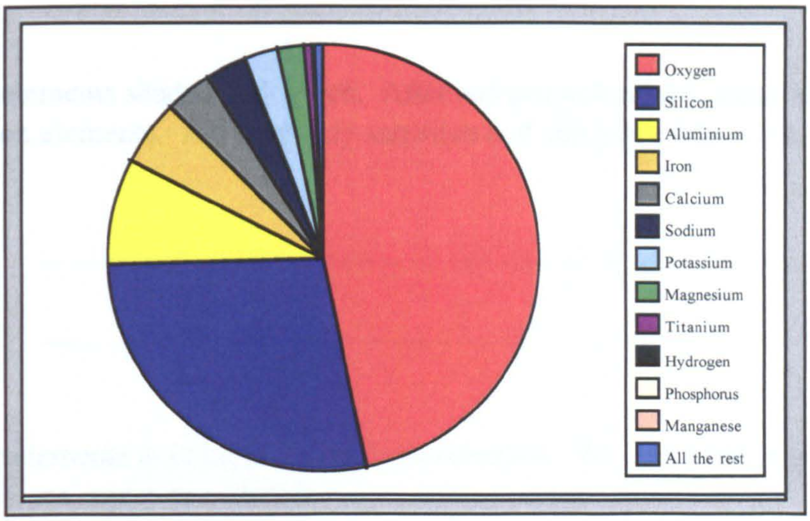
One way to make our life easier is to put things with similar behaviour into groups. For example, in supermarkets, the milk products are grouped together in the same place while the cleaning products are grouped together in a different place. The usefulness of this classification is to help customers find the kind of products they want easily.

There are over 100 elements. Can you remember the behaviour of all of these elements? That's more or less an impossibility!! The Periodic Table sorts the elements into families (they are called groups) and each group lies in a column. However, there are many patterns and trends which are found to exist in both the groups and also in the rows of the elements. Today, we can often understand why these patterns exist. However, the periodic table was first formed simply by placing the elements in order of the atomic mass of the elements by Mendele'ev. Today's periodic table has the elements in order of atomic number (which gives almost the same order as that obtained using atomic mass).

Let's now look at some simple patterns in the periodic table.

How Common are the Elements ?

Amazingly, most of the earth's crust (the air, the sea and water, the rocks to a depth of about 5 miles) is made up of only 12 of the elements:



The Periodic Table shows most of the elements, with colours to show how common they are.

$_{1}$H																	$_{2}$He
$_{3}$Li	$_{4}$Be											$_{5}$B	$_{6}$C	$_{7}$N	$_{8}$O	$_{9}$F	$_{10}$Ne
$_{11}$Na	$_{12}$Mg											$_{13}$Al	$_{14}$Si	$_{15}$P	$_{16}$S	$_{17}$Cl	$_{18}$Ar
$_{19}$K	$_{20}$Ca	$_{21}$Sc	$_{22}$Ti	$_{23}$V	$_{24}$Cr	$_{25}$Mn	$_{26}$Fe	$_{27}$Co	$_{28}$Ni	$_{29}$Cu	$_{30}$Zn	$_{31}$Ga	$_{32}$Ge	$_{33}$As	$_{34}$Se	$_{35}$Br	$_{36}$Kr
$_{37}$Rb	$_{38}$Sr	$_{39}$Y	$_{40}$Zr	$_{41}$Nb	$_{42}$Mo	$_{43}$Te	$_{44}$Ru	$_{45}$Rh	$_{46}$Pd	$_{47}$Ag	$_{48}$Cd	$_{49}$In	$_{50}$Sn	$_{51}$Sb	$_{52}$Te	$_{53}$I	$_{54}$Xe
$_{55}$Cs	$_{56}$Ba	$_{57}$La*	$_{72}$Hf	$_{73}$Ta	$_{74}$W	$_{75}$Re	$_{76}$Os	$_{77}$Ir	$_{78}$Pt	$_{79}$Au	$_{80}$Hg	$_{81}$Tl	$_{82}$Pb	$_{83}$Bi	$_{84}$Po	$_{85}$At	$_{86}$Rn
$_{87}$Fr	$_{88}$Ra	$_{89}$Ac**															

Colour	Elements
	Oxygen and silicon - about 75% of Earth's crust
	The next 10 - the really common elements
	Quite common
	Well known elements
	Not so common
	Rare enough to be highly valuable
	The rare elements
	The very rare elements

To Discuss

(1) Almost 75% of the Earth's crust is made up of the elements oxygen and silicon. Where (air, sea, water or rocks?) might you find these elements in the earth's crust?

....

(2) Look at the elements shaded dark green. After oxygen and silicon, these are the top ten most common elements. Are there any surprises and can you explain why they are there?

Surprises: ....

Reasons: ....

(3) Many of the elements in columns I and II are common. Where would you find these elements (air, sea, water or rocks?)?

....

(4) Why are ***rare*** elements like silver, gold, platinum, helium and neon so well known?

....

....

(5) Look at element 38 - Strontium. Use the internet or books to find as much as you can about this element. In what country was it discovered? After what was it named? Has it any uses?

....

....

....

....

....

....

When were the Elements Discovered ?

Look at the periodic table below. This shows the dates of discovery (the dates when the elements were obtained in a reasonably pure form - some were known to exist before that) for many of the elements:

1776 $_{1}$H																	1895 $_{2}$He
1817 $_{3}$Li	1828 $_{4}$Be											1808 $_{5}$B	$_{6}$C	1772 $_{7}$N	1776 $_{8}$O	1886 $_{9}$F	1898 $_{10}$Ne
1807 $_{11}$Na	1808 $_{12}$Mg											1827 $_{13}$Al	1824 $_{14}$Si	1669 $_{15}$P	$_{16}$S	1774 $_{17}$Cl	1894 $_{18}$Ar
1807 $_{19}$K	1808 $_{20}$Ca	1876 $_{21}$Sc	1791 $_{22}$Ti	1801 $_{23}$V	1797 $_{24}$Cr	1774 $_{25}$Mn	$_{26}$Fe	1735 $_{27}$Co	1751 $_{28}$Ni	$_{29}$Cu	1746 $_{30}$Zn	1875 $_{31}$Ga	1886 $_{32}$Ge	1649 $_{33}$As	1817 $_{34}$Se	1826 $_{35}$Br	1898 $_{36}$Kr
1861 $_{37}$Rb	1808 $_{38}$Sr	1828 $_{39}$Y	1824 $_{40}$Zr	1801 $_{41}$Nb	1782 $_{42}$Mo	1937 $_{43}$Te	1844 $_{44}$Ru	1803 $_{45}$Rh	1803 $_{46}$Pd	$_{47}$Ag	1817 $_{48}$Cd	1863 $_{49}$In	$_{50}$Sn	1620 $_{51}$Sb	1782 $_{52}$Te	1811 $_{53}$I	1898 $_{54}$Xe
1860 $_{55}$Cs	1808 $_{56}$Ba	1839 $_{57}$La*	1923 $_{72}$Hf	1903 $_{73}$Ta	1783 $_{74}$W	1925 $_{75}$Re	1803 $_{76}$Os	1803 $_{77}$Ir	1735 $_{78}$Pt	$_{79}$Au	$_{80}$Hg	1861 $_{81}$Tl	$_{82}$Pb	1753 $_{83}$Bi	1898 $_{84}$Po	1940 $_{85}$At	1900 $_{86}$Rn
1939 $_{87}$Fr	1898 $_{88}$Ra	1889 $_{89}$Ac**															

To Discuss

(6) The dates of discovery for some elements are ***not*** given. Can you suggest a reason why they are not shown?

....

(7) Look at the last column (the noble gases). Where do most of these gases occur in the world? Why do you think they were they all discovered at a similar time?

....

(8) Many of the metals in columns I and II were discovered near the start of the 19th century. These are common metals. Why were they discovered so late in the world's history? What allowed them to be discovered at this time?

....

(9) Why were metals like copper, silver, gold, tin and lead discovered so early?

....

(10) Nitrogen, oxygen and chlorine were all discovered about the same time. Can you suggest a reason why? Why was fluorine discovered later?

....

....

Why Does the Periodic Table have such a strange shape ?

$_{1}$H																	$_{2}$He
$_{3}$Li	$_{4}$Be											$_{5}$B	$_{6}$C	$_{7}$N	$_{8}$O	$_{9}$F	$_{10}$Ne
$_{11}$Na	$_{12}$Mg											$_{13}$Al	$_{14}$Si	$_{15}$P	$_{16}$S	$_{17}$Cl	$_{18}$Ar
$_{19}$K	$_{20}$Ca	$_{21}$Sc	$_{22}$Ti	$_{23}$V	$_{24}$Cr	$_{25}$Mn	$_{26}$Fe	$_{27}$Co	$_{28}$Ni	$_{29}$Cu	$_{30}$Zn	$_{31}$Ga	$_{32}$Ge	$_{33}$As	$_{34}$Se	$_{35}$Br	$_{36}$Kr
$_{37}$Rb	$_{38}$Sr	$_{39}$Y	$_{40}$Zr	$_{41}$Nb	$_{42}$Mo	$_{43}$Te	$_{44}$Ru	$_{45}$Rh	$_{46}$Pd	$_{47}$Ag	$_{48}$Cd	$_{49}$In	$_{50}$Sn	$_{51}$Sb	$_{52}$Te	$_{53}$I	$_{54}$Xe
$_{55}$Cs	$_{56}$Ba	$_{57}$La*	$_{72}$Hf	$_{73}$Ta	$_{74}$W	$_{75}$Re	$_{76}$Os	$_{77}$Ir	$_{78}$Pt	$_{79}$Au	$_{80}$Hg	$_{81}$Tl	$_{82}$Pb	$_{83}$Bi	$_{84}$Po	$_{85}$At	$_{86}$Rn
$_{87}$Fr	$_{88}$Ra	$_{89}$Ac**															

It is not quite as straightforward as first suggested. The first ***row*** has only two elements, the next two have ***eight*** elements while the next two rows have ***eighteen*** elements. The next two rows, if completed fully would have ***thirty two*** elements.

Look at the numbers: 2, 8, 18, 32
Divide each number by two and we get: 1, 4, 9, 16

Do you see the pattern: $1^2, 2^2, 3^2, 4^2$

There is ***some kind of logic***, it would appear....!
The horizontal rows are known as ***periods*** and the vertical columns are known as ***groups***.

Elements in any group (column) tend to be very similar while elements in adjacent columns are fairly similar.

There are far more metals (coloured blue) than non-metals (coloured pink). The elements near the dividing line between metals and non-metals often show a kind of mixed behaviour, sometimes like metals, sometimes like non-metals.

Metals **Non-metals**

$_{1}$H																	$_{2}$He
$_{3}$Li	$_{4}$Be											$_{5}$B	$_{6}$C	$_{7}$N	$_{8}$O	$_{9}$F	$_{10}$Ne
$_{11}$Na	$_{12}$Mg											$_{13}$Al	$_{14}$Si	$_{15}$P	$_{16}$S	$_{17}$Cl	$_{18}$Ar
$_{19}$K	$_{20}$Ca	$_{21}$Sc	$_{22}$Ti	$_{23}$V	$_{24}$Cr	$_{25}$Mn	$_{26}$Fe	$_{27}$Co	$_{28}$Ni	$_{29}$Cu	$_{30}$Zn	$_{31}$Ga	$_{32}$Ge	$_{33}$As	$_{34}$Se	$_{35}$Br	$_{36}$Kr
$_{37}$Rb	$_{38}$Sr	$_{39}$Y	$_{40}$Zr	$_{41}$Nb	$_{42}$Mo	$_{43}$Te	$_{44}$Ru	$_{45}$Rh	$_{46}$Pd	$_{47}$Ag	$_{48}$Cd	$_{49}$In	$_{50}$Sn	$_{51}$Sb	$_{52}$Te	$_{53}$I	$_{54}$Xe
$_{55}$Cs	$_{56}$Ba	$_{57}$La*	$_{72}$Hf	$_{73}$Ta	$_{74}$W	$_{75}$Re	$_{76}$Os	$_{77}$Ir	$_{78}$Pt	$_{79}$Au	$_{80}$Hg	$_{81}$Tl	$_{82}$Pb	$_{83}$Bi	$_{84}$Po	$_{85}$At	$_{86}$Rn
$_{87}$Fr	$_{88}$Ra	$_{89}$Ac**															

The Periodic Table and Reactivity

The most reactive metals are at the bottom left and most reactive non metals are at the top right.

> Metal reactivity is a complicated idea. What we are observing is the *speed* at which metals react. This depends on many factors and the pattern is not always simple

Thus, metal reactivity is, very roughly:

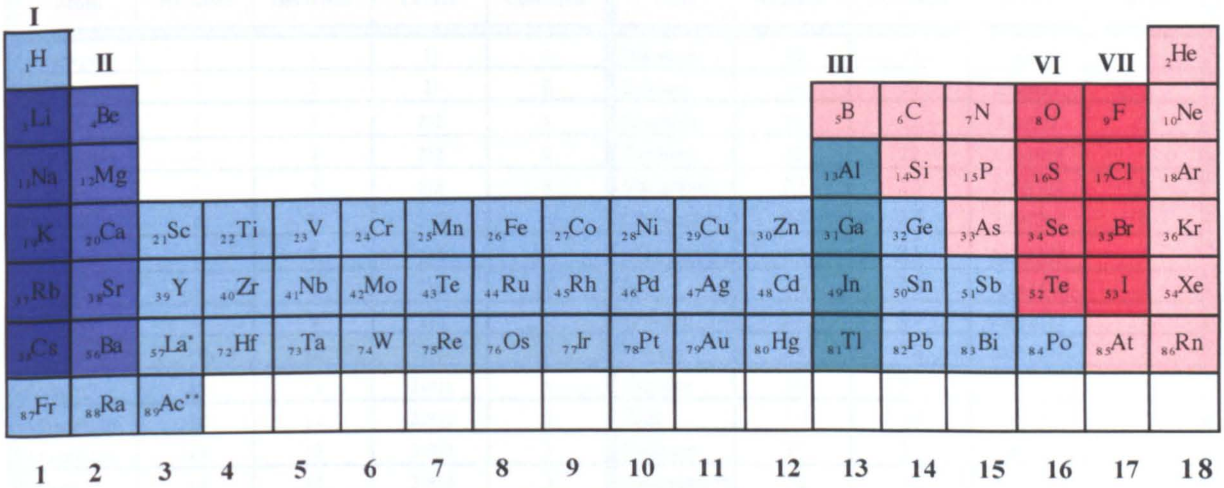
Cs > Rb > K > Na > Li	Column I is more reactive than Column II
Ba > Sr > Ca > Mg > Be	Column II is more reactive than Column III
Tl > In > Ga > Al	Column III is more reactive than Column IV

Non-metals are similar but everything is reversed. The order of reactivity is, very roughly:

F > Cl > Br > I	Column VII (column 17) is more reactive than Column VI
O > S > Se > Te	Column VI (column 16) is more reactive than Column V

Unfortunately, for other reasons, nitrogen does not fit the pattern and is very unreactive.

If we look at the middle 10 columns (from Scandium to Zinc), there are some patterns of reactivity but it is more complicated. The first column tends to be more reactive than the second and so on but the column starting with zinc is the exception - reactivity has become larger again.



For a simple rule:

Metal reactivity:	Column I (bottom to top)
	Column II (bottom to top)
MAZIT metals:	Mg, Al, Zn, Fe, Sn
Expensive metals:	Pb, Cu, Ag, Hg, Au, Pt

But, why is this the order of reactivity? Can the periodic table help us again?
We need to look at the way atoms are constructed.

Atoms and Smaller Particles

Atoms are made up of protons, neutrons and electrons. Here is a reminder of their properties. All the measurements are relative. Thus, we ***call*** the mass of a proton to be equal to 1 unit and the other two are compared to this.

	Mass	Charge
Protons	1	positive
Neutrons	1	neutral
Electrons	1/1850	negative

The elements are in order of their atomic number in the periodic table. However, the protons (and neutrons) are at the centre of the atom (known as the nucleus) and it is the electrons which are nearer the edge. Electrons do ***not*** orbit the nucleus (as some books suggest) but they move in quite complex ways. The main things to note is that, when atoms are electrically neutral, then they must have equal number of electrons and protons. The electrons can be thought of in terms of *energy and the way they move*.

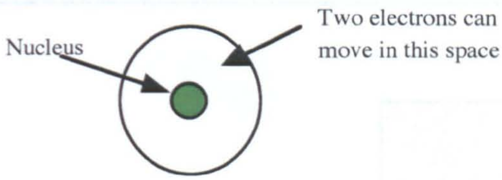
In simple terms, the electrons are organised in layers (called ***'shells'***). Here are the patterns of electrons (*electronic configurations*) for the first 36 elements:

Neutral atom	Atomic Number	Number of electrons	Electrons Levels	Most Common	Neutral atom	Atomic Number	Number of electrons	Electrons Levels	Most Common
Hydrogen	1	1	1)	1	Potassium	19	19	2)8)8)1	1
Helium	2	2	2)	0	Calcium	20	20	2)8)8)2	2
Lithium	3	3	2)1	1	Scandium	21	21	2)8)9)2	3
Beryllium	4	4	2)2	2	Titanium	22	22	2)8)10)2	4
Boron	5	5	2)3	3	Vanadium	23	23	2)8)11)2	5
Carbon	6	6	2)4	4	Chromium	24	24	2)8)12)2	6
Nitrogen	7	7	2)5	3	Manganese	25	25	2)8)13)2	7
Oxygen	8	8	2)6	2	Iron	26	26	2)8)14)2	2
Fluorine	9	9	2)7	1	Cobalt	27	27	2)8)15)2	2
Neon	10	10	2)8	0	Nickel	28	28	2)8)16)2	2
Sodium	11	11	2)8)1	1	Copper	29	29	2)8)17)2	2
Magnesium	12	12	2)8)2	2	Zinc	30	30	2)8)18)2	2
Aluminium	13	13	2)8)3	3	Gallium	31	31	2)8)18)3	3
Silicon	14	14	2)8)4	4	Germanium	32	32	2)8)18)4	4
Phosphorus	15	15	2)8)5	3	Arsenic	33	33	2)8)18)5	3
Sulphur	16	16	2)8)6	2	Selenium	34	34	2)8)18)6	2
Chlorine	17	17	2)8)7	1	Bromine	35	35	2)8)18)7	1
Argon	18	18	2)8)8	0	Krypton	36	36	2)8)18)8	0

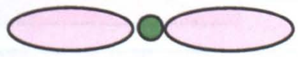
Notice how the valency relates to the number of electrons in the outer shell (or layer). These electrons tend to be nearer the edge of the atom and are involved in forming bonds with other atoms. We now need to look at this in more detail.

Electrons, Shells, Energy and Spatial Arrangement

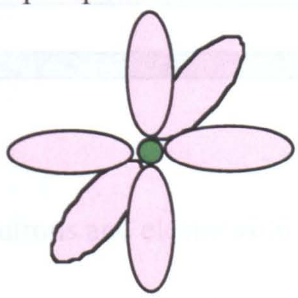
The ***first two*** electrons in any shell tend to move in space shaped like an sphere.



The ***next six*** electrons tend to move in space in pairs, each pair at right angles to the other pairs. One pair of electrons will move around the space shown in light purple:



Six electrons will move around in the purple spaces:



The first two electrons have been given a name: s electrons
The next six have been called: p electrons

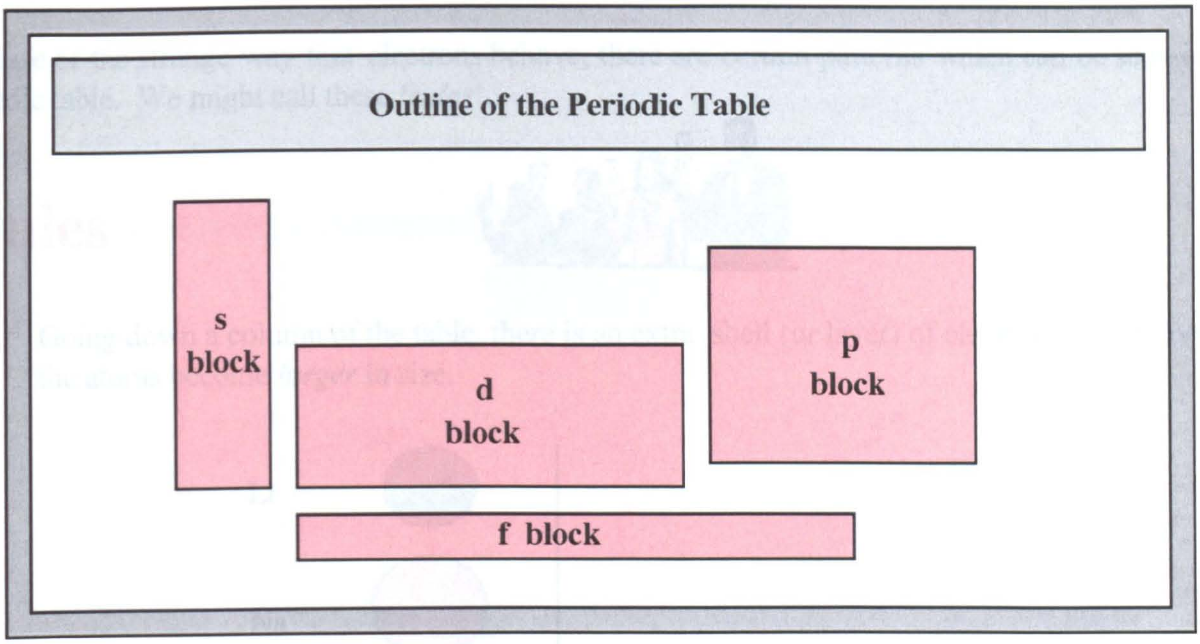
Together, they make up the eight electrons seen in the outer shell (layer) of the noble gas atoms (neon, argon, krypton and xenon). Remember, all electrons are identical - they can only differ in energy and the way they move.

> s electron and P electrons are all electron and are ***all identical.*** The letters 's' and 'p' merely show something about how the way the electrons move and their energy.

When there are 18 electrons in a shell, 2 will be **s electrons**, 6 will be **p electrons** and the remaining 10 are known as **d electrons**. With very large atoms, there can be 32 electrons in a shell, the final 14 being known as **f electrons**. This allows us to divide up the periodic table. In columns I and II, all the atoms have either 1 or 2 electrons in their outer shell. They are highly reactive metals.

Columns II to VIII (columns 13-18) all have p electrons in their outer shell and are known as the p block of elements. Most are non-metals.

The middle block all involve the growth of an inner shell, with d electrons being added. They are known as the d block of elements. They are all metals, show a wide variation in valency (most atoms can show more than one valency) and often give coloured compounds.
The f elements are all pushed together into the space for element 57 or 89.
Here is the pattern. Hydrogen is really unique, as it only has one electron and it is not shown.



For Practice

(11) Give the number of protons, neutrons and electrons in each of:

(a) $^{24}_{11}Na$

(b) $^{55}_{25}Mn$

(c) $^{19}_{9}F^{-}$

(d) $^{23}_{11}Na$

(12) Why is the relative atomic mass of manganese not a whole number? It is, in fact: 54.94

....

(13) What is the electronic configuration of each of:

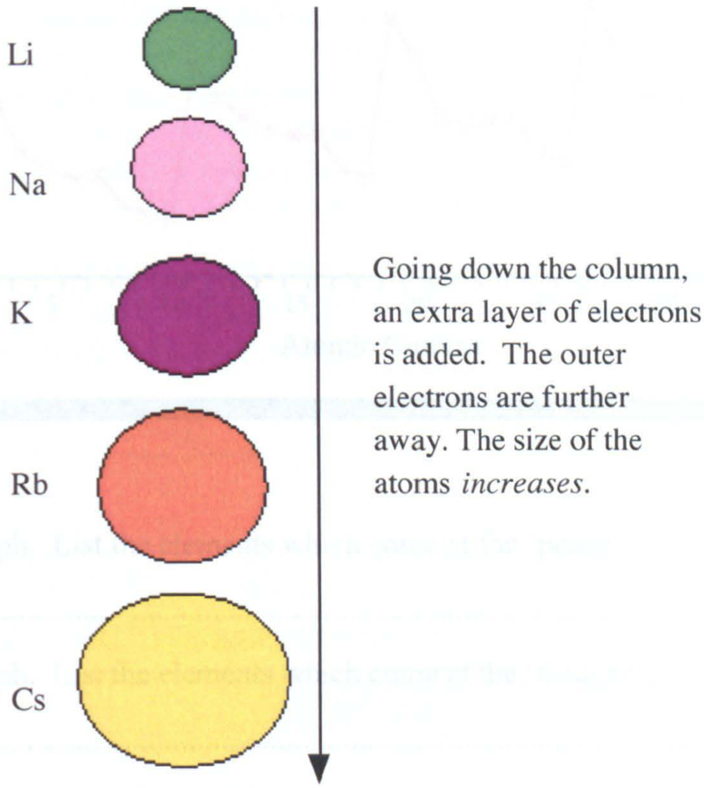
(a) Nitrogen
(b) Sulphur
(c) Manganese
(d) Bromine

Some Consequences

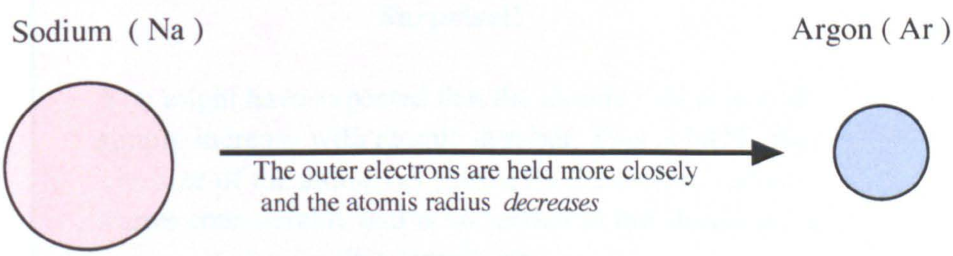
Because of the strange way that electrons behave, there are certain patterns which can be seen in the periodic table. We might call these ***'rules'***.

Rules

(1) Going down a column of the table, there is an extra shell (or layer) of electrons. Therefore the atoms become ***larger*** in size.

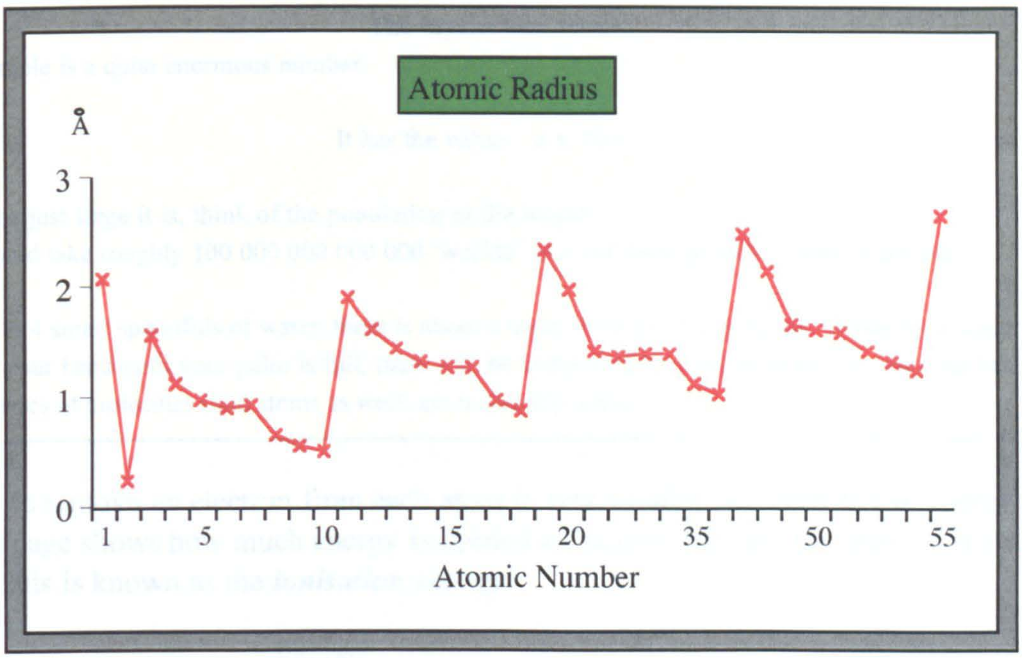


(2) Going across a group, the atoms have the same number of shells (layers) but the nucleus increase in number of protons. These protons attract the electrons more tightly and the sizes of the atom gets smaller.



A Pattern of Sizes

It is possible to draw a graph showing how the size of atoms varies as we increase the atomic number. The graph is shown below. Here, the radius of each element (from 1 to 56) is plotted against the atomic number. The radii are shown in Angstrom units (Å) where 1Å = 10^{-10} metres.



To Discuss

(14) Look at the graph. List the elements which come at the 'peaks'.

....

(15) Look at the graph. List the elements which come at the 'troughs'.

....

(16) Why do the ***metals*** which have a larger atomic radius tend to be more reactive than the metals which have a smaller radius?

....

Surprise!!

You might have expected that the atomic radius would simply increase with atomic number. This is NOT true. The size of the atoms (as shown by the atomic radius) varies considerably and is no related to the atomic number in a simple way.

Electrons in Atoms

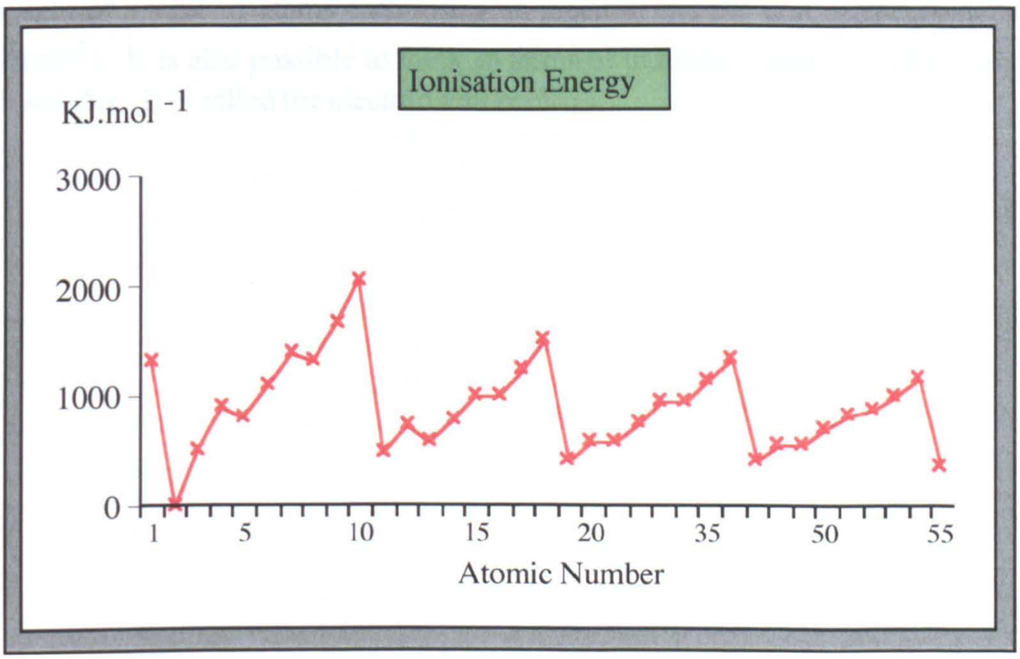
We have now looked at the way electrons are arranged in atoms and we have also looked at the size of atoms. Let us now look at the way atoms hold on to their electrons. Let us take a large number of atoms - in fact we shall take a mole of atoms (600,000,000,000,000,000,000,000 atoms !!).

> **The Mysterious Mole!!**
>
> The mole is a quite enormous number.
>
> It has the value: 6×10^{23}
>
> To see just large it is, think of the population of the world.
> It would take roughly 100 000 000 000 000 'worlds' like our own to hold a mole of people!
>
> Yet, in 4 small spoonfuls of water, there is about a mole of molecules of water. If you pour sugar onto your hand until your palm is full, there will be about a mole of sugar molecules on your hand. The sizes of molecules (and atoms as well) are incredibly small!!

If we want to remove an electron from each atom in this number, we need to ***use*** energy. The graph on the next page shows how much energy is needed to remove one electron from each atom of a mole of atoms. This is known as the ***ionisation energy***.

$$\text{Atom on its own} \xrightarrow{\text{Energy}} \text{Positive} \quad + \quad \text{electron}$$

$$X(g) \xrightarrow{\text{Energy}} X^{+}(g) \; + \; e^{-}$$



(17) Look at the graph. List the elements which come at the 'peaks'.

....

(18) Look at the graph. List the elements which come at the 'troughs'.

....

It is also possible to use more energy and remove a second electron from each atom on its own. The energy required is known as the second ionisation energy:

$$X^{+}(g) \xrightarrow{\text{Energy}} X^{2+}(g) \quad + \quad e^{-}$$

The second ionisation is always larger than the first ionisation.

(19) Why do you think the second ionisation is always larger than the first ionisation?

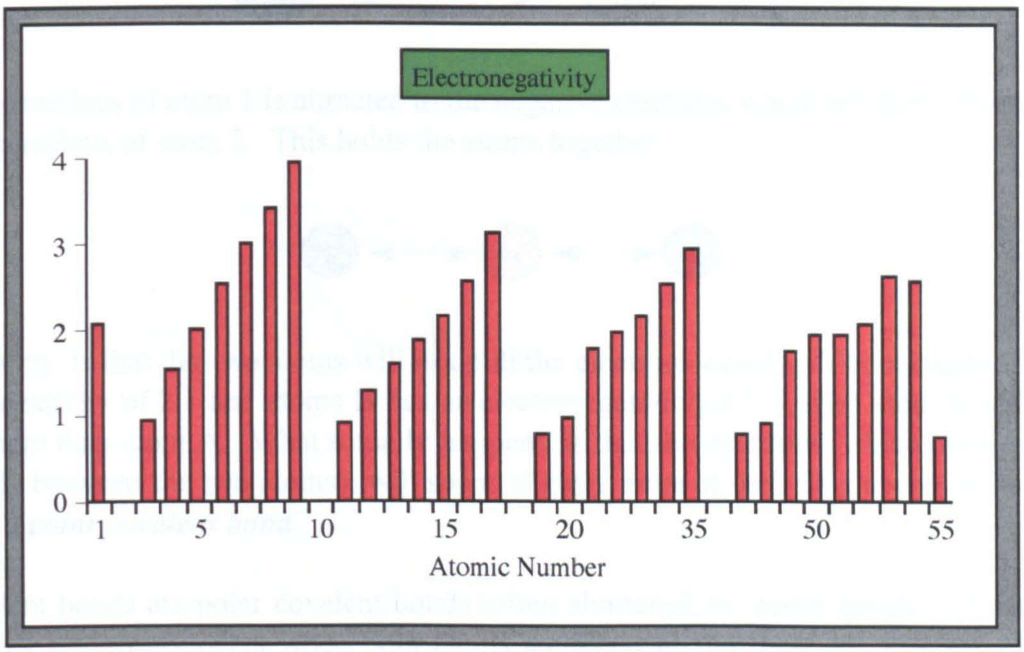
....

....

We have thought of a mole of atoms each losing an electron and the unit of energy is the kilo Joule per mole ($kJmol^{-1}$). It is also possible to think in terms of individual atoms and the energy unit used here is much smaller. It is called the electron volt (ev).

Electronegativity

It is possible to look at the energy involved in removing electrons from atoms and to look at the energy involved when electrons are added to atoms. This has given rise to what are called ***electronegativity numbers***. This indicates the tendency for atoms to gain or lose electrons. Again, we can plot the electronegativity value against atomic number to see the trends for the elements. The actual electronegativity value has no meaning but we can compare atoms to each other. Thus, for example, if two elements (eg. carbon and hydrogen) have atoms with approximately the same electronegativity, then we can say that the two atoms tend to hold electrons equally tightly. It is not possible to measure values for the noble gases and they are omitted.



To Discuss

(20) Look at the graph and name the group of elements which have the lowest electronegativities? Can you explain why?

....

....

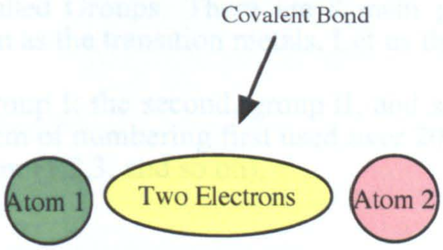
(21) Look at the graph and name the elements which have the highest electronegativities . Can you explain why?

....

....

The Idea of Bond Polarity

Imagine two atoms forming a covalent bond between them. A covalent bond involves two electrons between two adjacent nuclei:



The positive nucleus of atom 1 is attracted to the negative electrons which are themselves attracted to the positive nucleus of atom 2. This holds the atoms together:

The probability is that the two atoms will not pull the electrons equally. For example, if atom 1 has an electronegativity of 2.1 and atoms B has an electronegativity of 3.5, then atom B will attract the electrons more than atom A. What actually happens is that the electrons (which are moving around continuously between the two atoms), will spend slightly more of their time nearer atom B. We say the bond is a ***polar covalent bond***.

Most covalent bonds are polar covalent bonds (often shortened to ***'polar bonds'***). Covalent bonds which are not polar only occur when both atoms are identical and there are no other effects in the molecule which can attract electrons.

If the difference between the 'pulling power' of the two atoms is very great, then the electrons spend all their time on one atom and we have the ionic bond. Suppose atom A has an electronegativity of 0.9 and atom B has an electronegativity of 3.5, the chances are that an ***ionic bond*** will form, giving an A^+ ion and a B^- ion.

We show bond polarity using the Greek letter 'delta': d

Here are some common examples. The hydrogen chloride molecule is linked by a polar covalent bond, the electrons spending more of their time nearer the chlorine (shown by: d-). In water, there are two polar covalent bonds, with the electrons from both spending more of their time nearer the oxygen atom (which has a higher electronegativity).

$\delta+$ $\delta-$
H - Cl

$\delta+$ $\delta-$
H - O
H
$\delta+$

Patterns with the Elements

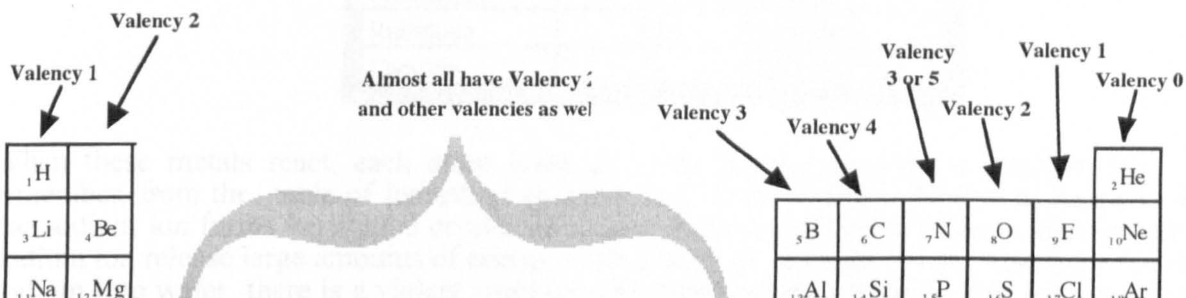
There are about 90 known elements. To pass your chemistry examination, imagine you had to remember all the details of every element.This would be completely impossible, no matter how clever you are!! The periodic table offers us a way to make life easier.

The vertical columns are called Groups. There are 8 main groups of elements and there are ten columns in the middle known as the transition metals. Let us think only of the 8 main groups.

The first column is called group I; the second, group II, and so on up group VIII. The numbers are based on a very ancient system of numbering first used over 2000 years ago! You can use this system or the usual numbering system (1,2,3, and so on).

Groups and Valency

The number of the group is related to the valency of the elements in that column.



$_{1}$H																	$_{2}$He
$_{3}$Li	$_{4}$Be											$_{5}$B	$_{6}$C	$_{7}$N	$_{8}$O	$_{9}$F	$_{10}$Ne
$_{11}$Na	$_{12}$Mg											$_{13}$Al	$_{14}$Si	$_{15}$P	$_{16}$S	$_{17}$Cl	$_{18}$Ar
$_{19}$K	$_{20}$Ca	$_{21}$Sc	$_{22}$Ti	$_{23}$V	$_{24}$Cr	$_{25}$Mn	$_{26}$Fe	$_{27}$Co	$_{28}$Ni	$_{29}$Cu	$_{30}$Zn	$_{31}$Ga	$_{32}$Ge	$_{33}$As	$_{34}$Se	$_{35}$Br	$_{36}$Kr
$_{37}$Rb	$_{38}$Sr	$_{39}$Y	$_{40}$Zr	$_{41}$Nb	$_{42}$Mo	$_{43}$Te	$_{44}$Ru	$_{45}$Rh	$_{46}$Pd	$_{47}$Ag	$_{48}$Cd	$_{49}$In	$_{50}$Sn	$_{51}$Sb	$_{52}$Te	$_{53}$I	$_{54}$Xe
$_{55}$Cs	$_{56}$Ba	$_{57}$La*	$_{72}$Hf	$_{73}$Ta	$_{74}$W	$_{75}$Re	$_{76}$Os	$_{77}$Ir	$_{78}$Pt	$_{79}$Au	$_{80}$Hg	$_{81}$Tl	$_{82}$Pb	$_{83}$Bi	$_{84}$Po	$_{85}$At	$_{86}$Rn
$_{87}$Fr	$_{88}$Ra	$_{89}$Ac**															

* There are 14 elements here - known as the Lanthanides
** There are 14 elements here - known as the Actinides
This saves us having to remember all the valency numbers !

Using the Periodic Table

The periodic table can be used to help us remember many things about the elements.

Let us look firstly at group I (column 1). These elements are known as the ***alkali metals***. This is because they form oxides and hydroxides which dissolve easily in water giving strong alkalis.

There are six metals in the group: lithium, sodium, potassium, rubidium, caesium and francium (which is radioactive). Many of these elements are quite common in the earth's crust. However, because they are highly reactive, we always find them bonded to other elements. Lithium, sodium and potassium are commonly available in school. Because they are all very reactive metals, they are stored under oil to prevent them coming into contact with water or air (oxygen). These metals have the following properties:

(1) They are good conductors of electricity and heat (like other metals).
(2) They are soft metals (so soft, they can cut with a knife!)
(3) They are metals with low densities (they float on water).
(4) They have shiny surfaces when freshly cut with a knife.
(5) They burn in oxygen or air, with wonderful coloured flames, to from white, solid oxides.

Metal	Flame Colour
Li	Crimson
Na	Strong yellow
K	Lilac
Rb	Green ?
Cs	Pink

The table below shows the electron structure of the first five elements of group 1.

Metal	Symbol	Configuratio
Lithium	Li	2)1
Sodium	Na	2)8)1
Potassium	K	2)8)8)1
Rubidium	Rb	2)8)18)8)1
Caesium	Cs	2)8)18)18)8)1

When these metals react, each atom loses an outer electron to form a positive ion. You will remember, from the table of ionisation energies. that it takes energy for this to happen. However, the sodium ion forms very good crystal structures and the formation of these releases energy. The sodium ion release large amounts of energy when dissolved in water. Thus, when you drop a piece of sodium into water, there is a violent reaction with much energy released. It is NOT true to say that sodium 'wants' to lose an electron. It requires energy to make a sodium atom lose an electron. However, the sodium ion reacts with water to release a large amount of energy.

Potassium is more reactive than sodium or lithium because less energy is required to remove the outer electron from its atom than for either lithium or sodium. This is because as you go down the group, the size of the atoms increases and the outer electron gets further away from the nucleus, hence becoming easier to remove.

Group II

Let us look secondly at group II (column I1). These elements are known as the alkaline earth metals. This is because the compounds of some of these elements can readily be seen in the countryside, such as calcium carbonate is found as chalk, limestone and marble is very large quantities. Limestone rock, being basic, is attacked by the natural acidity of rain and this can result in spectacular underground rivers and caves.

Group II also consists of six metals: beryllium, magnesium, calcium, strontium, barium and radium (which is radioactive). Magnesium and calcium are generally available in school. These metals have the following properties:

(1) They are harder than those in group I, but still not very hard.

(2) They are all reactive but less reactive than metals in Group I.

(3) They are silvery-grey coloured when pure and clean. However, they rapidly form white metal oxides when left in air.

(4) They are good conductors of heat and electricity (like all metals)

(5) Burn in oxygen or air, sometimes with characteristic flame colours, to form solid white oxides. For example,

$$2Mg\ (s) \quad + \quad O_2\ (g) \longrightarrow 2MgO\ (s)$$

Metal	Flame Colour
Be	No colour
Mg	No colour
Ca	Brick-red
Sr	Red
Ba	Green

(6) They react with water to form metal hydroxides. For example.

$$2Ca\ (s) \quad + \quad H_2O\ (l) \longrightarrow 2Ca(OH)_2\ (aq) \quad + \quad H_2\ (g)$$

The table below shows the electron structure of the first five elements of group I1.

Metal	Symbol	Configuratio
Beryllium	Be	2)2
Magnesium	Mg	2)8)2
Calcium	Ca	2)8)8)2
Strontium	Sr	2)8)18)8)2
Barium	Ba	2)8)18)18)8)2

Each atom has two electrons in its outer shell and all these metals always show a valency of 2.

Transition Metals

Between groups II and III is the ***block*** of elements known as the ***Transition Metals***.

Here are the ten metals which form the first row. Many of these metals will be well-known to you. Try to name each one.

Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn

Here is a summary of how these metals behave.

(1) They are harder and stronger than the metals in groups 1 and 2.
(2) They have much higher densities than the metals in groups 1 and 2.
(3) They vary in reactivity but they are not as reactive as the metals in columns 1 and 2
(4) Many of their compounds are coloured.
(5) They are often used on their own or in compounds as catalysts (speeding up other reactions)
(6) They are often able to show several valencies:

Metal	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
Observed Valencies	Always 3	2, 3 or 4	2, 3, 4 or 5	2, 3 or 6	2, 3, 4, 5. 6 or 7	2 or 3	2 or 3	Always 2	1 or 2	Always 2

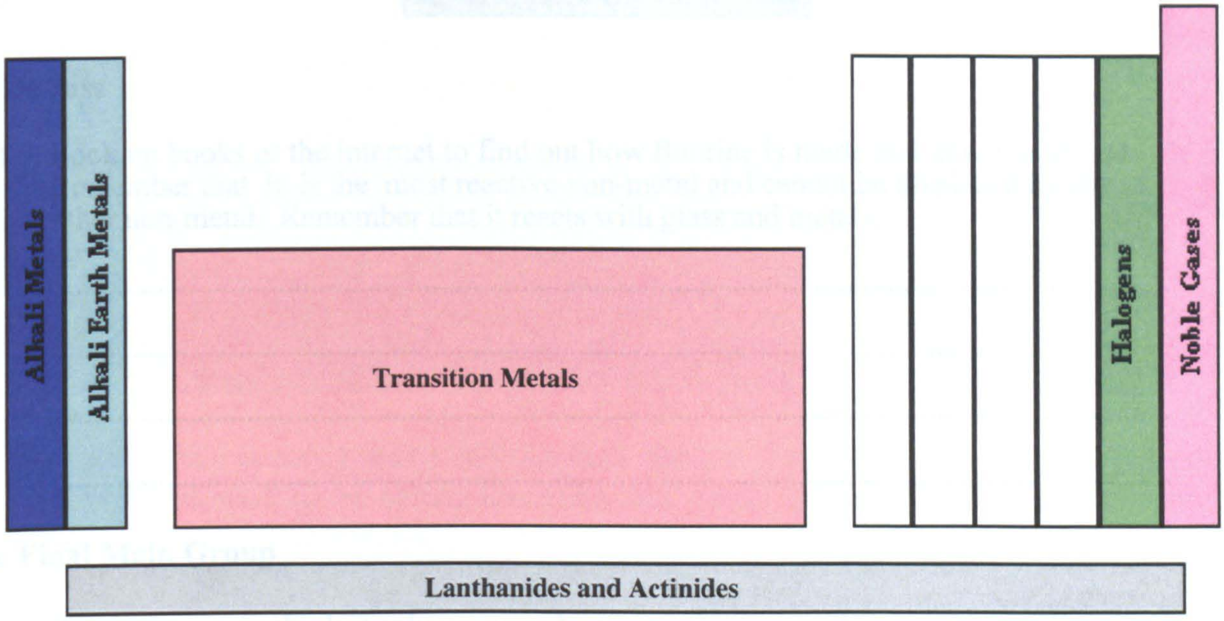
Look at Manganese. It has the remarkable ability of forming compounds where it shows a valency anything from 2 to 7. Life for manganese is complicated! When it forms these compounds, each valency gives compounds of different colours. Use textbooks or the internet to try to find the colours of as many of compounds as you can.

(22)

Compounds of Manganese	
Valency	**Colour**
2	
3	
4	
5	
6	
7	

Groups in the Periodic Table

We have now looked at Group 1 (the alkali metals) and group 2 (the alkaline earth metals). Here is a summary of some of the groups.



Let us look thirdly at group VII (column VI1). These elements are known as the halogens. The word halogen comes from a Greek word meaning 'salt producing' and was used because halogens were known to occur in compounds in the sea which are known as salts.

There are five elements in group VII: fluorine, chlorine, bromine, iodine and the astatine (which is radioactive). Chlorine, bromine, and iodine are generally available in school. The table below shows the electron structure of the five elements of group VII.

Metal	Symbol	Configuration
Fluorine	F	2)7
Chlorine	Cl	2)8)7
Bromine	Br	2)8)18)7
Iodine	I	2)8)18)18)7
Astatine	At	2)8)18)32)18)7

You can see that each atom of each element has seven electrons in its outer shell. They all show a valency of 1 although other valencies occur for chlorine, bromine and iodine (valencies 3,5,7) .
Here is what the halogen are like:

(1) They are all coloured although the colour of fluorine and chlorine are so faint that the they tend to be clear.
(2) They all exist as diatomic molecules: F_2, Cl_2, Br_2, and I_2.
(3) They show a gradual change from a gas (F_2 and Cl_2), liquid (Br_2) to solid (I_2).
(4) They are all reactive. Indeed, fluorine is so reactive that it reacts rapidly with glass, most metals and water.

Halogen	Colour
F	Yellow
Cl	Pale green
Br	Red/brown
I	Purple/black

To Discuss

(23) Look up books or the internet to find out how fluorine is made and how it is stored. Remember that it is the most reactive non-metal and cannot be displaced by any other non-metal. Remember that it reacts with glass and metals.

....

....

....

....

The Final Main Group

Originally, the group in the last column were known as inert gases because it was thought that they formed no compounds at all (they were named group 0, suggesting a valency of 0). It was later found that they could form compounds and the group is now called the ***noble gases*** and given the group number of 8.

There are six non-metal gases in the group: helium, neon, argon, krypton, xenon and radon (which is radioactive).

(1) They are all colourless gases - they cannot be seen.
(2) They all exist as monatomic molecules: He, Ne, Ar, Kr, Xe, Rn.
(3) They are very unreactive.

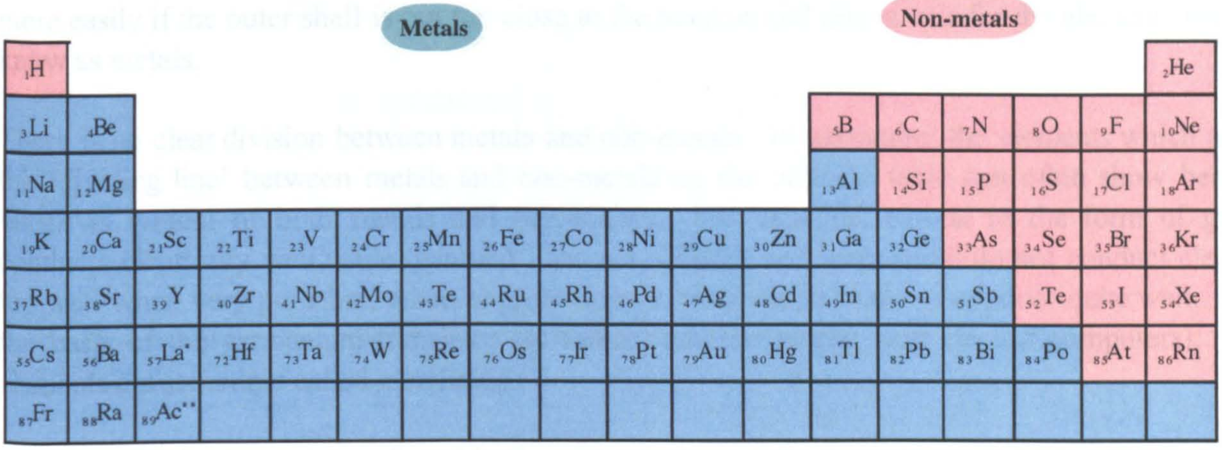
Many compounds of xenon and krypton have now been made, usually with oxygen and fluorine. The table below shows the electron structure of the first five elements of this group.

Noble gas	Symbol	Configuration
Helium	He	2
Neon	Ne	2)8
Argon	Ar	2)8)8
Krypton	Kr	2)8)18)8
Xenon	Xe	2)8)18)18)8

You can see that each atom of each element has eight electrons in its outer shell (except helium which has only 2 electrons) Because these atoms are small, these electrons are held tightly and this partly explains their difficulty in reacting with other elements.

Metals and Non-Metals

You will remember that most of the elements are metals.



We recognise metals usually because they are hard and shiny and they conduct heat and electricity well. Non-metals tend to be softer, less shiny and rarely conduct electricity or heat so well. However, there are many exceptions.

To Discuss

(24) Can you think of a well known non-metal which conducts electricity reality well?

....

(25) There are only two elements which are liquid at room temperature. One is very definitely a metal and one is very definitely a non-metal. Can you name them.

....

(26) Can you think of a non-metal which is shiny in appearance, like a metal ?

....

(27) Can you list several metals which are soft?

....

What makes a metal like a metal ?

For all atoms which show the behaviour which we describe as metallic (shiny, electrical conduction, hard), the atoms have a small number of electrons in their outer shell. If these electrons can be made to move, then conduction is likely and the appearance may be shiny. Electrons are able to move more easily if the outer shell is not too close to the nucleus and this is true for the elements which we know as metals.

There is no clear division between metals and non-metals. In particular, the elements which are near the 'dividing line' between metals and non-metals on the periodic table can often show behaviour which is typical of both metals and non-metals. For example, carbon in the form of graphite conducts electricity well while diamond does not. Silicon and germanium do not conduct electricity too well when very pure but, when slightly impure, they can be made to conduct quite well. This is the basis of the germanium transistor (in radios) and the silicon chip (in our computers). These elements are sometime called metalloids.

The non-metals elements are found in the p-block part of the periodic table. These atoms tend to smaller and hold their outer electrons more tightly. Conduction is, therefore, difficult and they often are less hard and less shiny than metals.

Hydrogen is often placed by itself in the periodic table. It is a gas and shows many properties typical of non-metals. However, it does not really fit into any of the columns of the periodic table. It has a valency of 1 and might seem to belong to column 1 or column 7. In terms of behaviour and reactivity, it is rather like carbon. Like the metals in column 1, it can form a positive ion (H^+) but it is not a metal. Like the non-metals in column 7, it can form a negative ion (H^-) but the positive ion is much more common. Like carbon, it forms strong covalent (or polar covalent) bonds Hydrogen is unique and does not really belong completely in any group.

Now Check Your Answers

How many did you get correct ?

Appendix

Discoverers of the Elements

Element	Name of scientist discovered	Element	Name of scientist discovered	Element	Name of scientist discovered
H	Henry Gavendish	N	Daniel Rutherford	Y	Johann Gadolin
Li	Johann Arfvedson	P	Hennig Brand	Zr	Martin Klaproth
Na	Sir Humphrey Davy	As	Unknown	Nb	Charles Hatchet
K	Sir Humphrey Davy	Sb	Unkown	Mo	Carl Scheele
Rb	R. Bunsen	Bi	Unkown	Tc	Carlo Perrier
Cs	Fusrov Kirchoff			Ru	Karl Klaus
Fr	Marguerite			Rh	William Wollaston
				Pd	William Wollaston
Be	Fredeich Wohler	O	Joseph Priestly	Ag	Unknown
Mg	Sir Humphery Davy	S	Unkown	Cd	Fredrick Stromeyer
Ca	Sir Humphery Davy	Se	Jons Berzelius		
Sr	A . Crawford	Te	Reichenstein	La	Carl Mosander
Ba	Sir Humphrey Davy	Po	Pierre & Mari Curie	Hf	Dirk Coster
Ra	Pierre& Marie Curie			Ta	Anders Ekeberg
				W	Fausthso&Juan Elhuyar
B	Sir Humphrey Davy	F	Jeseph Moissan	Re	Walter Noddack
Al	Hans Christian Oersted	Cl	Carl Scheele	Os	Smithson Tenant
Ga	Boisbaudran	Br	Antoine J. Balard	Ir	Smithson Tenant
In	Ferdinand Reich	I	Bernard Courtois	Au	Unknown
Ti	Sir William Crookes	At	D.R. Corson	Hg	Unknown
				Ac	Andre Debierne
C	Unknown			Rf	Albert Ghiorso
Si	Jons Berzelius	Sc	Lars Nilso	Db	Albert Ghiorso
Ge	Clemens Winkler	Ti	William Gregor	Sg	Albert Ghiorso
Sn	Unknown	V	Nils Sefstrom	Bh	Armbruster, Munzenber & others
Pb	Unkown	Cr	Louis Vauquelin		
		Mn	Johann Gahn	Hs	Ambruster, Munzenber & others
Ce	W. von Hisinger	Fe	Unknown		
Pr	C.F. Welsback	Co	George Brandt	Mt	Hearvy Ion research laboratory
Nd	C.F. Welsback	Ni	Alex Cronstedt		
Pm	J.A.Marinsky	Cu	Unknown		
Sm	Bosibaudran	Zn	Andreas Marggraf		
Eu	Eugene Demarcay				
Gd	Jean de Marignac	Th	Jons Berzelius	Cf	G.T.Seaborg
Tb	Carl Mosander	Pa	Fredrich Soddy	Es	Argonne,Alamos
Dy	Bosibaudran	U	Martin Klaproth	Fm	Argonne, Alamos
Ho	J.L.Soret	Np	E.M.McMillan	Md	G.T.Seaborg
Er	Carl Mosander	Pu	G.T.Seaborg	No	Nobel Institute of Physics
Tm	Per Theodor Cleve	Am	G.T.Seaborg		
Yb	Jenade Marignac	Cm	G.T.Seaborg	Lr	Albert Ghiorso
Lu	Georges Urbain	Bk	G.H.Seaborg		

Answers

(1) *Almost 75% of the Earth's crust is made up of the elements oxygen and silicon. Where (air, sea, water or rocks?) might you find these elements in the earth's crust?*

Oxygen is found in the air, and in water (including, of course, the sea). It is also found in most rocks (the most common rocks are silicates). Silicon occurs in silicate rocks and also as silicon dioxide (sand is silicon dioxide and some other rocks also are mainly silicon dioxide eg. quartz, agates).

(2) *Look at the elements shaded dark green. After oxygen and silicon, these are the top ten most common elements. Are there any surprises and can you explain why they are there?*

Perhaps the most surprising one is titanium. This is extremely common, occurring as the dioxide (TiO_2). Titanium oxide, when pure, is the whitest substance known and is used in all brilliant white paint. It is very difficult to convert the titanium dioxide to titanium metal as this takes an enormous amount of energy. Therefore, titanium metal is quite rare. However, it is incredibly useful, being as strong as steel, with half the density of steel. It also does not rust and it can be dyed to give colour effects. It is used in expensive parts in aircraft, in Olympic bicycles and in making very attractive jewellery.

(3) *Many of the elements in columns I and II are common. Where would you find these elements (air, sea, water or rocks?)?*

Most of the metals are found combined with other elements in rocks and in the sea. Lithium, sodium, potassium, rubidium and caesium are mainly in the sea, while strontium and barium are mainly in rocks. Magnesium and calcium occur in both the sea and in rocks. Beryllium is rare and occurs in rocks. Have you ever thought why these metals are found mainly in the sea? Elements are only found in the sea if their compounds are soluble in water and can be washed off the land. Column 1 metal compounds tend to be very water soluble so are found mainly in the sea.

(4) *Why are rare elements like silver, gold, platinum, helium and neon so well known?*

They are all very unreactive and, therefore, are more obvious to us as they are found uncombined with other elements or are easily produced from their compounds.

(5) *Look at element 38 - Strontium. Use the internet or books to find as much as you can about this element. In what country was it discovered? After what was it named? Has it any uses?*

Strontium was first discovered in Scotland. It was found in an old mine which was digging for compounds of silver and lead. The miners found large quantities of a dull grey-white rock which they called strontianite because the mine was very close to a tiny village called Strontian. The rock was later found to be strontium carbonate and the element was named after the village. Rocks containing strontium are quite common but there are few uses for the metal or its compounds. One use is the production of fireworks because strontium compounds give a very strong red colour to any flame. The next time you see red colours in fireworks, it may well be produced by small quantities of strontium compounds.

(6) *The dates of discovery for some elements are not given. Can you suggest a reason why they are not shown?*

The date of discovery for some elements such as iron, carbon, silver and gold are not given because they were discovered in prehistory and have been known since ancient times.

(7) *Look at the last column (the noble gases). Where do most of these gases occur in the world? Why do you think they were they all discovered at a similar time?*

Did you think of any good reasons? It took time for chemists to develop ways to handle gases. Once they knew this, research on gases was possible. For a long time, air was thought to be entirely nitrogen and oxygen. It was not until they did accurate measurements on the density of gases in the air that they realised that air must contain other gases. William Ramsay then started to look for these gases and he found five of them one after the other.

(8) *Many of the metals in columns I and II were discovered near the start of the 19th century. These are common*

metals. Why were they discovered so late in the world's history? What allowed them to be discovered at this time?

They were discovered so late because of their reactivity. They are always found linked strongly with one or more other elements. They do not occur in nature on their own. The only was to obtain these metals is by means of electrical energy (electrolysis). This could not happen until electricity was discovered and developed enough to be used. Amazingly, electricity was only used for experiments at the start of the nineteenth century and it took nearly 100 years before it was developed enough to use in homes.

(9) Why were metals like copper, silver, gold, tin and lead discovered so early?

They are rare elements and they are very unreactive. Despite their rarity, they could be obtained easily from their compounds (they do not form strong bonds with other elements).

(10) Nitrogen, oxygen and chlorine were all discovered about the same time. Can you suggest a reason why? Why was fluorine discovered later?

Scientists found it difficult to do experiments with gases. They had to learn ways to handle gases: how to keep them in containers, how to move them from one container to another, how to store, how to stop them being mixed up with air and so. Once this was achieved, the elements which are gases could be studied.
Think about fluorine? Have you ever seen any? It is so reactive that it reacts with most metals (often violently) and even with glass and water. It is so reactive that it can only be obtained by electrolysis, with no water present at all. It took a long time to overcome these problems. In passing, it is extremely dangerous because it reacts with the human body as well and therefore will destroy any experimenter if it escapes!!

(11) Give the number of protons, neutrons and electrons in each of:

		Electron	***Proton***	***Neutron***
(a)	$^{24}_{11}Na$	11	11	13
(b)	$^{55}_{25}Mn$	25	25	30
(c)	$^{19}_{9}F^-$	10	9	10
(d)	$^{23}_{11}Na$	11	11	12

(12) Why is the relative atomic mass of manganese not a whole number? It is, in fact: 54.94?

Like most elements, manganese contains isotopes. These are atoms with the same number of protons, but the neutron content varies. The isotopes of manganese are identical in every way other than the neutron content and this makes some atoms heavier than others. The relative atomic mass of manganese is the 'average' mass, taking into account the isotopes.

(13) What is the electronic configuration of each of:

(a)	Nitrogen	7 electrons:	2)5	or	$1s^2\ 2s^2\ 2p^3$
(b)	Sulphur	16 electrons	2)8)6	or	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$
(c)	Manganese	25 electrons	2)8)13)2	or	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6 3d^5 4s^2$
(d)	Bromine	35 electrons	2)8)18)7	or	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6 3d^{10} 4s^2 4p^5$

(14) Look at the graph. List the elements which come at the 'peaks'.
Lithium, sodium, potassium, rubidium and caesium.

(15) Look at the graph. List the elements which come at the 'troughs'.
Fluorine, chlorine, bromine and iodine.

(16) *Why do the metals which have a larger atomic radius tend to be more reactive than the metals which have a smaller radius?*

Metals react by losing one or more electrons to non-metal atoms. Metal atoms tend to be quite large (compared to non-metal atoms). The larger the atom, the less well the electron will be held. It takes energy to remove an electron from isolated metal atoms (look at the ionisation energies) but, with large atoms, the amount of energy is less and therefore, they will react more easily.

(17) *Look at the graph. List the elements which come at the 'peaks'.*

Helium, neon, argon, krypton and xenon.

(18) *Look at the graph. List the elements which come at the 'troughs'.*

Lithium, sodium, potassium, rubidium and caesium.

(19) *Why do you think the second ionisation is always larger than the first ionisation?*

The s econd ionisation energy is the energy required to remove the second electron from the positive ion after the first electron has already been removed from atom. Because the atom is already positive, it will be even more difficult to remove a negative electron from it.

(20) *Look at the graph and name the group of elements which have the lowest electronegativities? Can you explain why?*

The alkali metals have the lowest electronegativities. This is simply because the atoms are larger and the outer electron is quite a distance from the nucleus and is, therefore, held less tightly.

(21) *Look at the graph and name the elements which have the highest electronegativities . Can you explain why?*

Fluorine, chlorine, bromine and iodine have the highest electronegativities.
These atoms are smaller and the outer electrons are, therefore, closer to the nucleus. They are held all the more tightly by the nucleus and much energy is needed to pull them away.

(22) *Look at Manganese. It has the remarkable ability of forming compounds where it shows a valency anything from 2 to 7. Life for manganese is complicated! When it forms these compounds, each valency gives compounds of different colours. Use textbooks or the internet to try to find the colours of as many of compounds as you can?*

Compoundsof Manganese	
Valency	**Colour**
2	Pale pink
3	Dirty white
4	Black
5	Blue
6	Green
7	Dark purple

(23) *Look up books or the internet to find out how fluorine is made and how it is stored. Remember that it is the most reactive non-metal and cannot be displaced by any other non-metal. Remember that it reacts with glass and metals.*

What did you find? Here is some of the information:

The French chemist Henri Moissan first obtained fluorine in 1886 by electrolysis of pure, dry hydrogen fluoride (HF), in which potassium hydrogen fluoride (KHF_2) had been dissolved to make it conduct a current. Hydrogen fluoride is a liquid at temperatures below 21°C but will not conduct electricity easily on its own. Hydrogen is formed at the cathode and fluorine at the anode. It is essential to keep these two gases separate aa mixture explodes immediately! Today, fluorine is made in industry by the same method.

Fluorine reacts with almost everything. However, it can be stored in certain plastic containers and also in containers made of copper. Fluorine reacts with copper to form copper(II) fluoride. This forms a skin on the surface of the copper and the reaction then stops. Containers of fluorine must be stored with great care because, if any fluorine escapes, it is dangerous: it will react with almost anything and it will also kill humans.

(24) Can you think of a well known non-metal which conducts electricity really well?

Carbon in the form of graphite (the most common form). The other form of carbon (diamond) does not conduct at all.

(25) There are only two elements which are liquid at room temperature. One is very definitely a metal and one is very definitely a non-metal. Can you name them.

Mercury is a metal liquid at room temperature.
Bromine is a non-metal liquid at room temperature

(26) Can you think of a non-metal which is shiny in appearance, like a metal ?

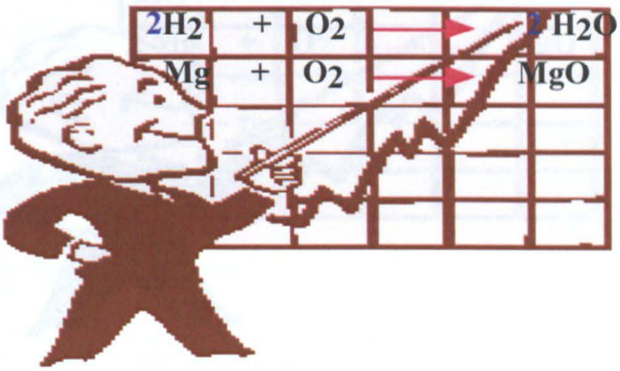
Iodine and silicon are perhaps the best known

(27) Can you list several metals which are soft?

Lithium, sodium, and potassium. Also, rubidium and caesium.

The Centre for Science Education, University of Glasgow, Scotland

Chemical Equation



This small booklet is designed to help you understand the Chemical equation and how to balance it.

Chemical equation can be used to summarise and simplify the chemical reaction .

Read the booklet carefully.

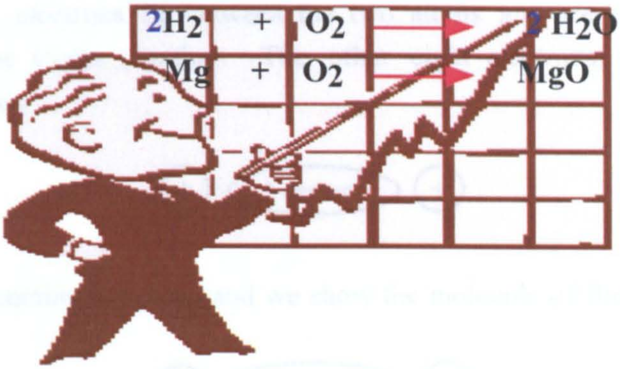
Stop at the questions and fill in the best answers possible.

You may need to look up books or search the world-wide web using a computer.

Answers to the questions are provided at the end. Only use these ***after*** you have tried your best to find the answers.

The Centre for Science Education, University of Glasgow, Scotland
Web Site: http://www.gla.ac.uk/centres/scienceeducation

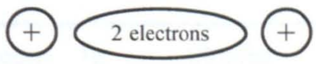
Chemical Equations



Why do atoms form bonds between them?

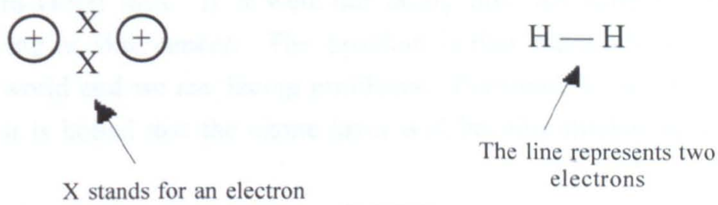
The nucleus of an atom (being positive) attracts the electrons (which are negative) and this holds an individual atom together. However, the positive nucleus of one atom can also attract the electrons of *another* atom. The electrons are then attracted to two nuclei and this holds the two atoms together. This is how atoms attract each other.

Look at two atoms of hydrogen. Each has one electron. If the nucleus of one hydrogen atom is attracted to the electron of the other hydrogen atom, then we could draw the situation like:



Each nucleus is positive and the two electrons are held between the two atoms, moving around, and being attracted to both nuclei. The two electrons hold the two nuclei together and we have a molecule of hydrogen.

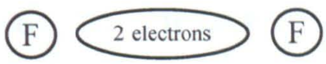
This can be shown in many ways:



A hydrogen molecule is shown as H_2. This means that two hydrogen atoms are held together by a chemical bond. In this case, the chemical bond is a *pair of electrons attracted to both nuclei.* It is very common for two atoms to be held together by a pair of electrons. Such a bond is known as a **COVALENT** Bond.

Let us look at two atoms of the element fluorine. Fluorine is element number 9. It is more complicated than hydrogen because each fluorine atoms has nine electrons. However, the same principle applies. Two electrons lie between the two atoms and are attracted to both nuclei, holding the two fluorine atoms together. The other eight electrons are not involved in the bonding in this direct way.

Each fluorine nucleus contains 9 protons and we show the molecule of fluorine like this:



This can also shown:

Most of the non-metal atoms form covalent bonds between two atoms like this. However, it is not always the case that only two atoms are involved. With Phosphorus, four atoms are linked together to give the molecule P_4. With sulphur, eight atoms are involved, linked in a ring which is shaped like a royal crown. Here is a list of some of the common molecules formed with non-metal elements.

Hydrogen	H_2	Chlorine	Cl_2
Oxygen	O_2	Bromine	Br_2
Nitrogen	N_2	Iodine	I_2
Fluorine	F_2	Phosphorus	P_4
Sulphur	S_8		

Have you ever heard of ozone? This gas is formed in the upper atmosphere in our plant and it absorbs harmful ultra-violet rays. If it were not doing this, the ultra-violet rays would cause us terrible damage, giving us skin cancer. The problem is that mankind has destroyed part of this ozone layer in our world and we are facing problems. Fortunately, we have learned how to stop the destruction and it is hoped that the ozone layer will become thicker in the near future.

What is ozone? It is a molecule containing **THREE** oxygen atoms linked together by covalent bonds. Its formula is O_3 and it is made by the effect of certain kinds of radiation on oxygen. Ozone is completely different from oxygen in its behaviour. It is harmful except in very tiny amounts but it has the wonderful ability of absorbing harmful ultra-violet radiation and making life possible on this plant!!

Other Elements

Metal atoms do not hold electrons quite so tightly and they tend not to form covalent bonds in this way. The non-metals in the last column of the periodic table also do not form such bonds easily either. They do not possess any single electrons, they hold electrons very tightly indeed and they usually manage to exist quite happily, with each atom with its own electrons.

What happens when the two atoms are different?

If the elements are non-metals, exactly the same kind of things often happens. Let us look at one hydrogen atom and one fluorine atom:

or H — F or HF

When the two atoms are different, we have a compound. We can obtain the same kind of molecules with many other atoms. Here are some of the common compounds with such non-metal atoms:

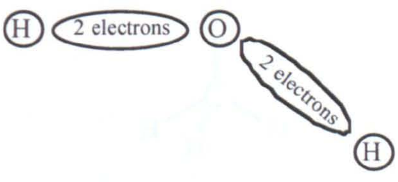
Hydrogen Fluoride	HF	Hydrogen chloride	HCl
Hydrogen bromide	HBr	Iodine Chloride	ICl

For simplicity, we do not show the electrons which hold the atoms together. In fact, the formulae we obtained are much easier to write than the names of the compounds!

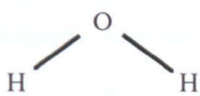
In every case above, the atoms each only had an odd number of electrons. This allows one electron from each atom to become part of the chemical bond holding the atoms together. However, some atoms are more versatile.

Other Atoms

Consider oxygen It has 8 electrons, and it can use two of them to form ***TWO*** bonds. If it links to hydrogen atoms, then it can link to **TWO** hydrogen atoms at the same time. It forms a molecule shaped like:



You will recognise this as water! It can be drawn in many ways but the simplest is: H_2O. Another useful way to show a water molecule is:

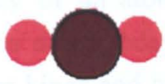


The water molecule has in fact, a shape like this, with the two hydrogen held on to the oxygen atom, creating an angle of 105°. The reason for the angle is that there are other electrons around the oxygen atom and these repel the electrons in each covalent bond, forcing them to this angle. Remember that each line represents a pair of electrons holding two nuclei together - a covalent bond.

Molecules can have all kinds of shapes. Some atoms can form two bonds (four electrons) between the atoms. Carbon is good at this. Nitrogen can even form three bonds between two nitrogen atoms in nitrogen gas.

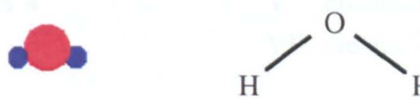
Here are some pictures of some molecules:

(1) Carbon dioxide has the atoms in a straight line



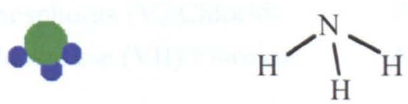
O = C = O CO_2

(2) Water is bent to an angle of about 105°.



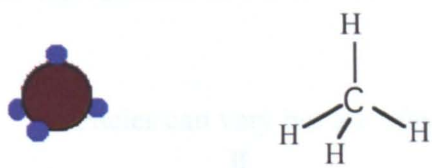
H_2O

(3) Ammonia (nitrogen hydride) is like a pyramid



NH_3

(4) Methane (carbon hydride) is like a tetrahedron (four faces)



CH_4

Note: A tetrahedron is a a word from geometry. It comes from Greek and means: 'four faces'. A tetrahedron is a pyramid built on a triangle. Can you see the four faces?

There are also four corners. It is a very common shape for many molecules in chemistry.

Valency with Roman numerals

Some atoms can form one bond only while others can form two, three four or even more. The number of bonds an atom can form is known as its VALENCY. In chemistry, valency is the power of an atom of an element to combine with other atoms. The valency of an atom is controlled by the number of unpaired electrons an atom can use to form the bond between the atom.

To show the valency of an atom, we use **Roman numerals**. Although the Roman language (Latin) is not spoken at all today, their numbering system is still used widely. The numbers are used to name ships or kings and queens (eg. Queen Elizabeth II). You can still find the numbers on some books to show the date of publication and in other places.

Here is the system:

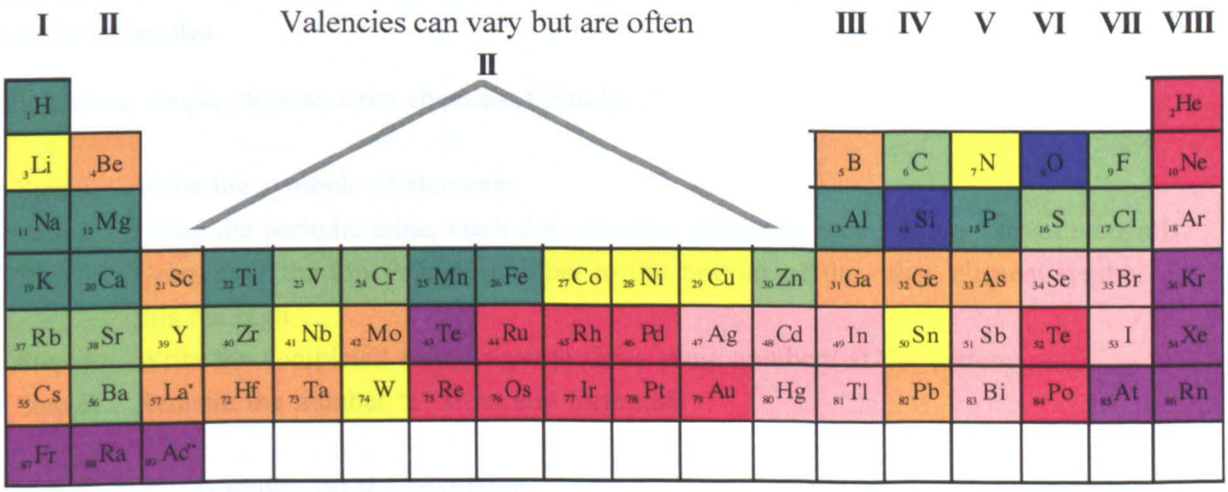
I means 1	II means 2	III means 3
IV means 4	V means 5	VI means 6
	VII means 7	

We use this system to show valency simply because the numbers do not become confused with the numbers in the chemical formula. Here are some examples:

Iodine (III) Chloride	ICl_3
Sulphur (IV) oxide	SO_2
Phosphorus (V) Chloride	PCl_5
Manganese (VII) Fluoride	MnF_7

Valency is EASY!!

Do not try to remember the valencies of the elements. Use the Periodic Table.



What about the metals in the middle. Most of them have a valency of II but many also show other valencies.

In fact, many of the elements can show more than one valency. It depends on how the atom uses its electrons to form bonds.

A simple way forward:

(a) For the main columns, the valency is found from the group number (the column number):

Group I	**Valency I**
Group II	**Valency II**
Group III	**Valency III**
Group IV	**Valency IV**
Group V	**Valency III (sometimes V)**
Group VI	**Valency II**
Group VII	**Valency I**
Group VIII	**Valency 0 (they rarely form bonds)**

(b) Assume that the metals in the middle have a valency of **II** unless told otherwise.

(c) You will be told if you meet any exceptions - you cannot work it out!!

Example:

Phosphorus is in Column V and would be expected to have a valency of III
Assume it is III unless told otherwise.

Thus: PCl_3 is Phosphorus (III) Chloride — what you expect
and PCl_5 is Phosphorus (V) Chloride — when phosphorus uses a higher valency of five.

Writing Chemical Formulae

Chemical formulas (or more correctly: formulae) show the numbers of the different types of atoms in molecules.

Follow these simple steps to write chemical formulas :

Step 1: Write the symbols of elements.
Step 2: Using the periodic table, mark the valencies above the atoms using Roman numerals.
Step 3: Cross-over the top valency number to the bottom of the other element symbol. Do this for both.
Step 4: Write the completed formulae with those same numbers at the bottom.
Step 5: Remove the number '1' from any formulae.

Now look at the examples on the next page.

Example 1:

Suppose you need to write the formula for sodium oxide

Step 1:	Write the symbols of elements:	Na O
Step 2:	Mark the valencies above the atoms:	$Na^{I}\ O^{II}$
Step 3:	Cross-over the valency numbers:	$Na_2\ O_1$
Step 4:	Write the completed formulae	Na_2O

This formula means:

***TWO** sodium atoms, each with a valency of one (I), link to **ONE** oxygen atom, with its valency of two (II).*

***Example 2**:*

Write the formula for aluminium sulphide

Step 1:	Write the symbols of elements:	Al S
Step 2:	Mark the valencies above the atoms:	$Al^{III}\ S^{II}$
Step 3:	Cross-over the valency numbers:	$Al_2\ S_3$
Step 4:	Write the completed formulae	Al_2S_3

Further Examples

(a)	Calcium Chloride:	$Ca^{II}\ Cl^{I}$	gives	$CaCl_2$	
(b)	Magnesium Oxide	$Mg^{II}\ O^{II}$	gives	Mg_2O_2	which simplifies to MgO
(c)	Carbon Oxide	$C^{IV}\ O^{II}$	gives	C_2O_4	which simplifies to CO_2 *(carbon dioxide - 'di' means two)*
(d)	Copper(II) Bromide	$Cu^{II}\ Br^{I}$	gives	$CuBr_2$	*(you are told the valency of copper)*
(e)	Iron(III) fluoride	$Fe^{III}\ F^{I}$	gives	FeF_3	*(you are told the valency of iron)*
(f)	Sulphur(VI) oxide	$S^{VI}\ O^{II}$	gives	S_2O_6	which simplifies to SO_3

*(sulphur often has a valency of two. Here, you are **told** it has a higher valency - six)*
(this is sulphur trioxide - 'tri' means three)

SELF ASSESSMENT QUESTIONS

Q1 Write formulae for the following compounds:

(a) Hydrogen fluoride

(b) Calcium chloride

(c) Aluminium oxide

(d) Copper(II) chloride

(e) Iron (II) sulphide

(f) Zinc bromide

More Complicated Molecules

What about molecules which contain three or more different kinds of atoms?

Fortunately, our method can be adapted to make writing these formulae easy as well. However, this depends on a simple idea:

Certain groups of atoms occur very frequently and it is possible to give the group of atoms a **GROUP Valency**. Here is a list of the eight common groups you will need. It is best to memorise these:

Valency 1		*Valency 2*		*Valency 3*	
Hydroxide	OH^{I}	Carbonate	CO_3^{II}	Phosphate	PO_4^{III}
Nitrate	NO_3^{I}	Sulphate	SO_4^{II}		
Ammonium	NH_4^{I}	Sulphite	SO_3^{II}		
Permanganate	MnO_4^{I}				

You can use exactly the same method as before. Here is an example: Sodium sulphate

Step 1: Write the symbols of groups: $Na \ SO_4$

Step 2: Mark the valencies above the groups: $Na^{I} \ SO_4^{II}$

Step 3: Cross-over the valency numbers: $Na_2 \ SO_4$

Step 4: Write the completed formulae Na_2SO_4

Here are more examples:

(a) ***Copper (II) Nitrate***

Step 1: Write the symbols of groups: $Cu \quad NO_3$

Step 2: Mark the valencies above the groups: $Cu^{II} \quad NO_3^{I}$

Step 3: Cross-over the valency numbers: $Cu \quad (NO_3)_2$ Use brackets - there are two nitrate *groups*

Step 4: Write the completed formulae $Cu(NO_3)_2$

(b) ***Aluminium Hydroxide***

Step 1: Write the symbols of groups: $Al \quad OH$

Step 2: Mark the valencies above the groups: $Al^{III} \quad OH^{I}$

Step 3: Cross-over the valency numbers: $Al \quad (OH)_3$ Brackets - there are three hydroxide *groups*

Step 4: Write the completed formulae $Al(OH)_3$

(c) ***Calcium Carbonate***

Step 1: Write the symbols of groups: $Ca \quad CO_3$

Step 2: Mark the valencies above the groups: $Ca^{II} \quad CO_3^{II}$

Step 3: Cross-over the valency numbers: $Ca_2 \quad (CO_3)_2$

Step 4: Write the completed formulae $CaCO_3$ The '2s' are removed: brackets not now needed

(d) ***Ammonium Phosphate***

Step 1: Write the symbols of groups: $NH_4 \quad PO_4$

Step 2: Mark the valencies above the groups: $NH_4^{I} \quad PO_4^{III}$

Step 3: Cross-over the valency numbers: $(NH_4)_3 \quad PO_4$

Step 4: Write the completed formulae $(NH_4)_3PO_4$ Brackets - three ammonium *groups*

Some things to remember:

(a) Always write the valencies in Roman numerals - it avoids confusions.

(b) When a group is to be 'multiplied', you must use brackets.

(c) Check at the end to see if numbers will cancel out.

However, only numbers common to **ALL** groups can be cancelled.

You **cannot** cancel Na_2SO_4. This formula means that there are *two* sodiums, *one* sulphur and *four* oxygens.

SELF ASSESSMENT
QUESTIONS

Q2 Now try the following. Write the formulae for:

(a) Sodium hydroxide?

(b) Iron (III) chloride?

(c) Potassium permanganate

(d) Chromium (III) sulphate

(e) Potassium carbonate

(f) Calcium hydroxide

The Meaning of Chemical Equations

When two are more materials react in some way to produce new products, we can summarise in words or using formulae. For example, suppose carbon burns in oxygen and carbon dioxide is formed. We can write this down:

$$\text{Carbon} \quad + \quad \text{Oxygen} \quad \xrightarrow{\text{burned}} \quad \text{Carbon Dioxide}$$

This is known as a chemical equation and is merely a summary of what is happening. It can also be written using symbols:

$$C \quad + \quad O_2 \quad \xrightarrow{\text{burned}} \quad CO_2$$

Thus, a chemical equation is a shorthand way of describing what goes on when we change chemical materials.

Of course, the symbols and formulae represent atoms and molcules. In practice, they represent *very large numbers* of atoms and molecules, because atoms and molcules are so incredibly tiny. Remember that a handful of carbon contains about: 1 000 000 000 000 000 000 000 000 atoms of carbon!!

Thus, when representing chemical changes using equations, the symbol for an element stands for two things:

(a) *An atom of the element.*
(b) *A mole of atoms of the element.*

We can go further with equations:

$$C(s) \quad + \quad O_2(g) \quad \xrightarrow{\text{burned}} \quad CO_2(g)$$

This equation tells us that:

(1) One *atom* of carbon reacts with one *molecule* of oxygen to produce one *molecule* of carbon dioxide.

(2) One *mole* of *atoms* of carbon react with one *mole* of *molecules* of oxygen to produce one *mole* of *molecules* of carbon dioxide.

(3) The equation also tells us the **state** of the products and reactants: the carbon was a solid while oxygen and carbon dioxide are gases.

The following symbols are used:

(g) means gas ***(l) means liquid*** ***(s) means solid*** ***(aq) means dissolved in water***

An equation can provide a very large amount of information in a summary form. However, we must know how to write formulae and use them in forming equations.

Writing Chemical Equations

When a chemical reaction occurs, it can be described by an equation. This shows the chemicals that react (called the ***reactants***) on the left-hand side, and the chemicals that they produce (called the ***products***) on the right-hand side. The chemicals can be represented by their names or by their chemical symbols.

$$\text{reactants} \longrightarrow \text{products}$$

The arrow between the reactants and products indicates that the reactants form the products and not the other way round. The only reason that the arrow goes from left to right is that most chemistry was developed in Germany and the United Kingdom and writing in these countries is from left to right!

Example 1. When magnesium burns with a very bright flare, it is just the reaction of magnesium and oxygen.

$$\text{magnesium} + \text{oxygen} \longrightarrow \text{magnesium oxide}$$

It is possible to write the chemical equation by using words from the right to left but convention is that they are always written from left to right.

$$\text{oxidemagnesium oxide} \longleftarrow \text{magnesium} + \text{oxygen}$$

Example 2. The reaction between hydrogen gas and oxygen gas to form water.

$$\text{hydrogen} + \text{oxygen} \longrightarrow \text{Water}$$

SELF ASSESSMENT QUESTIONS

(3) Write chemical equations, in symbols, for the following reactions

(a) Potassium burning in oxygen to form potassium oxide

(b) Aluminium reacting with iodine to form aluminium iodide

(c) Calcium oxide dissolving in water to give calcium hydroxide

(d) Copper(II) sulphate reacting with barium chloride to from barium sulphate and copper (II) chloride

Chemical Equations and Quantity

Chemical equations can tell us even more! We can use them to show the quantities of reactant and products. We cannot create or destroy atoms. Therefore, all the atoms we start with must end up in products. None are lost; none are gained!

Let us look at an example:

Hydrogen gas reacts with oxygen gas to form water. In fact, if you mix hydrogen and oxygen gases and then light the mixture, we get an incredibly loud explosion as the water forms. But ... how much hydrogen is to be mixed with the oxygen to get the best explosion? The equation can tell us.

$$\text{Hydrogen} + \text{Oxygen} \xrightarrow{\text{burned}} \text{Water}$$

$$H_2 + O_2 \xrightarrow{\text{burned}} H_2O$$

Look at the equation in symbols: This says that one molecule of hydrogen reacts with a molecule sof oxygen to form a molcule of water. However, there are TWO oxygen atoms on the left of the equation and only one on the right. Somehow, we have lost an atom of oxygen and that is impossible!

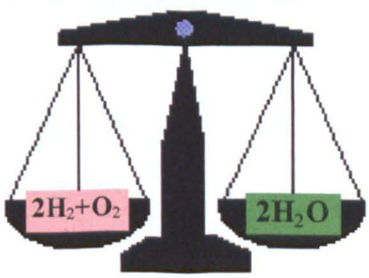
If we start with **TWO** molecules of hydrogen, then **TWO** water molcules are formed:

$$\mathbf{2}H_2 + O_2 \xrightarrow{\text{burned}} \mathbf{2}H_2O$$

Look at this equation now. **FOUR** hydrogen atoms are present at the start and **FOUR** are present in the two water molecules. **TWO** oxygen atoms are present at the start and **TWO** oxygen atoms are present in two water molecules.

This procedure is known as ***balancing an equation***. A balanced equation tells us the quantities of all reactants and products. The same number of each atom are present before and after the reaction. All that happens in a reaction is that that the atoms are linked in different ways.

In this case, it tells us that, for the best explosion, we need **TWICE** as much hydrogen as oxygen at the start.



How to Balance Equations

In general, we can balance a chemical equation by the following steps:

(1) Write down the correct formulae on the left side and right side of the equation.

(2) Start with the *most* complicated compound. Add numbers which are written before the formulae to try to obtain the same number of each atoms at each side of the equation.

(3) Repeat with the other compounds and do any elements last.

(4) Remember: you cannot change a formula
you can only add numbers BEFORE the compounds and elements.

(5) When you think you have the answer, check your balanced equation to be sure that you have the same total number of each type of atom on both sides of the equation arrow.

(6) It sounds complicated but, with practice, it becomes quite a straightforward process.
You need practice to become an expert!!

Here are some examples to help you:

(a) *Sodium reacting with oxygen to give sodium oxide*

$$Na + O_2 \longrightarrow Na_2O$$

Look at sodium oxide

There are two sodium atoms and one oxygen atom

Putting a 2 in front gives two oxygen atoms on the right

$$Na + O_2 \longrightarrow \mathbf{2}Na_2O$$

Look at sodium oxide again:

There are now four sodium atoms but only one on the left

Putting in a four on the left balances the equation

$$\mathbf{4}Na + O_2 \longrightarrow \mathbf{2}Na_2O$$

(b) *Calcium reacting with water to give calcium hydroxide*

$$Ca + H_2O \longrightarrow Ca(OH)_2 + H_2$$

Look at the calcium hydroxide

There are two oxygen atoms but only one oxygen atom on the left hand side

Putting a 2 in front of the water gives two oxygen atoms on both sides

$$Ca + \mathbf{2}H_2O \longrightarrow Ca(OH)_2 + H_2$$

Count each type of atom

You will find that the equation is now balanced.

(c) Potassium chlorate decomposes on heating to give potassium chloride and oxygen

$$KClO_3 \longrightarrow KCl + O_2$$

Look at the potassium chlorate

It contains 3 oxygen atoms but, on the right hand side, oxygen contains only 2.

The only way to balance the oxygen is to ***double*** the potassium chlorate and produce ***three*** molecules of oxygen.

$$\mathbf{2}KClO_3 \longrightarrow KCl + \mathbf{3}O_2$$

That gets the oxygen right!

What about the potassium or the chlorine?

Doubling the potassium chloride formed solves the problem.

$$\mathbf{2}KClO_3 \longrightarrow \mathbf{2}KCl + \mathbf{3}O_2$$

SELF ASSESSMENT QUESTIONS

Q4 Now try some yourself - balance the following equations.

□ H_2	+	□ N_2	$\longrightarrow$	□ NH_3		
□ C_3H_8	+	□ O_2	$\longrightarrow$	□ CO_2	+	□ H_2O
□ Al	+	□ CuO	$\longrightarrow$	□ Al_2O_3	+	□ Cu
□ K_2O	+	□ H_2O	$\longrightarrow$	□ KOH		
□ I_2	+	□ $Na_2S_2O_3$	$\longrightarrow$	□ NaI	+	□ $Na_2S_4O_6$

SELF ASSESSMENT QUESTIONS

Q5 Zinc metal reacts with hydrochloric acid (HCl) to produce zinc (II) chloride and hydrogen gas.

What is the balanced equation for the reaction?

Equations and Mass

Chemical equations give us a summary of what is happening in a chemical reaction. They tell us how many molecules react with each other and how many molecules are formed. Atoms cannot be created or destroyed. Therefore, the mass of all the products must be the same as all the mass of all the reactants.

We can calculate the mass of individual atoms and molecules, using the data in a periodic table. The table gives the atomic mass of each element. To find the mass of a molcule of a compound, all we need to do is to add up the masses of the atoms.

Example: the mass of a molecule of ammonia (NH_3)

NH_3

H_3 →	3 x 1	=	3
N →	1 x 14	=	14
	Total	=	**17**

Example: the mass of a molecule of sulphuric acid (H_2SO_4)

H_2SO_4

O_4 →	4 x 16	=	64
S →	1 x 32	=	32
H_2 →	2 x 1	=	2
	Total	=	**98**

SELF ASSESSMENT QUESTIONS

Q6 Work out the mass of a molecule of:

(a) Sulphur dioxide: SO_2

(b) Phosphoric acid H_3PO_4

(c) Iodine (VII) fluoride IF_7

Masses and Units

When we work out the mass of a molecule, the unit is simply called an *atomic mass unit.* However, molecules are tiny and the atomic mass unit is incredibly small. We usually work with huge numbers of molecules. Yet again, the mole is the unit we use.

Remember: ***A mole is approximately:*** 6×10^{23}

When we work with a mole of molecules, the unit changes to the gram.

We can work out the mass of a mole of molecules simply by doing the same process but changing the unit to grams - it's that easy!!

Example: the mass of a mole of molecules of silicon dioxide (SiO_2)

SiO_2

2×16	=	32g
1×28	=	28g
Total	=	**60g**

The mass of a mole of any substance is known as the ***gram formula mass.***

Example: the gram formula mass of calcium chloride ($CaCl_2$)

$CaCl_2$

2×35.5	=	71g
1×40	=	40g
Total	=	**111g**

Example: the gram formula mass of ammonium sulphate $(NH_4)_2SO_4$

$(NH_4)_2SO_4$

4×16	=	64
1×32	=	32
$2 \times 4 \times 1$	=	8
$2 \times 1 \times 14$	=	28
Total	=	**132**

There are **two** NH_4 groups:
This means **two** nitrogen atoms and **eight** hydrogen atoms

SELF ASSESSMENT QUESTIONS

Q7 Work out the gram formula mass of the following:

(a) Carbon dioxide: CO_2

(b) Nitric Acid: HNO_3

(c) Copper (II) Sulphate $CuSO_4$

(d) Potassium Phosphate K_3PO_4

(e) Water

Final Ideas

We can use equations to predict how much product we will obtain or how much reactant we should use.

Here is an example:

If 32g of sulphur is burned in air, what mass of sulphur (IV) oxide will we obtain ?

Firstly, we need to write and balance the equation:

$$S + O_2 \longrightarrow SO_2$$

Then, we work out the gram formula masses

S	+	O_2	$\longrightarrow$	SO_2
32g		(2 x 16) g = 32g		32 + (2 x 16) g = 64g

This tells us right away that, if we burn 32g of sulphur, we shall obtain 64 g of sulphur dioxide.

Another example:

Suppose we heat calcium carbonate strongly. It forms calcium oxide and carbon dioxide. How much calcium oxide and carbon dioxide will we expect to obtain when we heat 500 g of calcium carbonate (chalk) ?

Firstly, we write the balanced equation:

$$CaCO_3 \xrightarrow{\text{Heated}} CaO + CO_2$$

Then, we work out the gram formula masses of each compound:

$$CaCO_3 \xrightarrow{\text{Heated}} CaO + CO_2$$

$CaCO_3$	CaO	CO_2
= 40 + 12 + (3 x 16) g	= 40 + 16 g	= 12 + (2 x 16) g
= 100 g	= 56 g	= 44 g

This tells us that heating 100g of calcium carbonate gives us 56g of calcium oxide and 44g of carbon dioxide. However, we have 500g of calcium carbonate. This is five times as much and, therefore, we expect to obtain five times as much of each product:

Mass of calcium oxide expected:	5 x 56g	= 280g
Mass of carbon dioxide expected:	5 x 44g	= 220g

Notice we obtain 500g of total product. This has to be so - we started with 500g of calcium carbonate!

You can test this experimentally by simply weighing a small piece of chalk, placing it carefully on a gauze on a tripod stand and then roasting it very strongly for at least 15 minutes. The heat must be very intense. After cooling the solid product (which is calcium oxide), the mass of calcium oxide obtained should be 56% of the original mass of chalk. Try it and see.

Q

SELF ASSESSMENT QUESTIONS

(8) Try these - they are a bit more difficult !

(a) How much water would expect to obtain if you burned 4g of hydrogen in oxygen ?

(b) Titanium metal can be obtained by reacting titanium (IV) oxide with magnesium metal whihc is converted to magnesium oxide. How much titanium (IV) oxide would you need to make 96g of titanium metal?

Chemical Equations

Answers to Questions

Q1 Write formulae for the following compounds:

(a)	Hydrogen fluoride:	HF	
(b)	Calcium chloride:	$CaCl_2$	
(c)	Aluminium oxide:	Al_2O_3	
(d)	Copper(II) chloride	$CuCl_2$	
(e)	Iron (II) sulphide	FeS	(Did you remember to cancel?)
(f)	Zinc bromide	$ZnBr_2$	(Did you remember to use valency II for Zinc?)

Q2 Write the formulae for:

(a)	Sodium hydroxide?	$NaOH$	
(b)	Iron (III) chloride?	$FeCl_3$	
(c)	Potassium permanganate	$KMnO_4$	
(d)	Chromium (III) sulphate	$Cr_2(SO_4)_3$	
(e)	Potassium carbonate	K_2CO_3	
(f)	Calcium hydroxide	$Ca(OH)_2$	(Did you remember the brackets?)

(3) Write chemical equations, in symbols, for the following reactions

(a) Potassium burning in oxygen to form potassium oxide

$$K + O_2 \longrightarrow K_2O$$

(b) Aluminium reacting with iodine to form aluminium iodide

$$Al + I_2 \longrightarrow AlI_3$$

(c) Calcium oxide dissolving in water to give calcium hydroxide

$$CaO + H_2O \longrightarrow Ca(OH)_2$$

(d) Copper(II) sulphate reacting with barium chloride to from barium sulphate and copper (II) chloride

$$CuSO_4 + BaCl_2 \longrightarrow CuCl_2 + BaSO_4$$

Q4 Balance the following equations.

$$\mathbf{3}\,H_2 + N_2 \longrightarrow \mathbf{2}\,NH_3$$

$$C_3H_8 + \mathbf{5}\,O_2 \longrightarrow \mathbf{3}\,CO_2 + \mathbf{4}\,H_2O$$

$$\mathbf{2}\,Al + \mathbf{3}\,CuO \longrightarrow Al_2O_3 + \mathbf{3}\,Cu$$

$$K_2O + H_2O \longrightarrow \mathbf{2}\,KOH$$

$$I_2 + \mathbf{2}\,Na_2S_2O_3 \longrightarrow \mathbf{2}\,NaI + Na_2S_4O_6$$

Q5 Zinc metal reacts with hydrochloric acid (HCl) to produce zinc (II) chloride and hydrogen gas. What is the balanced equation for the reaction?

$$Zn + 2\,HCl \longrightarrow ZnCl_2 + H2$$

Q6 Work out the mass of a molecule of:

(a)	Sulphur dioxide:	SO_2	32 + (2 x 16) = 64
(b)	Phosphoric acid	H_3PO_4	(3 x 1) + 31 + (4 x 16) = 98
(c)	Iodine (VII) fluoride	IF_7	127 + (7 x 19) = 260

Q7 Work out the gram formula mass of the following:

(a)	Carbon dioxide:	CO_2	12 + (2 x 16) = 44g
(b)	Nitric Acid:	HNO_3	1 + 14 + (3 x 16) = 63g
(c)	Copper (II) Sulphate	$CuSO_4$	64 + 32 + (4 x 16) = 160g
(d)	Potassium Phosphate	K_3PO_4	(3 x 39) + 31 + (4 x 16) = 212g
(e)	Water	H_2O	(2 x 1) + 16 = 18g

(8) (a) How much water would expect to obtain if you burned 4g of hydrogen in oxygen ?

$2H_2$	+	O_2	$\longrightarrow$	$2H_2O$
= 2 x (2 x 1) g		= (2 x 16) g		= 2 x (2 x 1) +(2 x 16) g
= 4 g		= 32 g		= 36 g

The equation tells us immediately that 4g of hydrogen would give 36 g of water.

(b) Titanium metal can be obtained by reacting titanium(IV) oxide with magnesium metal which is converted to magnesium oxide. How much titanium(IV) oxide would you need to make 96g of titanium metal ?

TiO_2	+	$2Mg$	$\longrightarrow$	Ti	+	$2MgO$
= 48 + (2 x 16) g		= (2 x 24) g		= 48 g		= 2 x (24 + 16)
= 80 g		= 48 g				= 80g

The equation tell us 48g of titanium metal come from 80g titanium(IV) oxide. We wanted 96g. This is twice as much and, therefore, we need to use 160g of titanium(IV) oxide

This small booklet is designed to help you understand the organic chemistry.

Organic chemistry can be used to summarise and simplify what we know about the carbon element and its compounds.

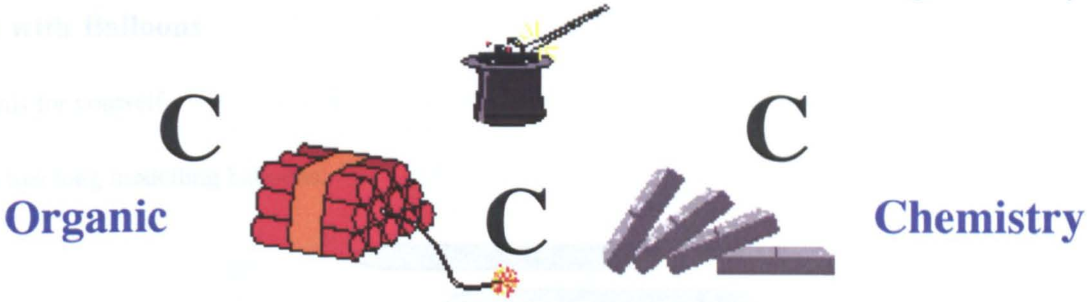
Read the booklet carefully.

Stop at the questions and fill in the best answers possible.

You may need to look up books or search the world-wide web using a computer.

Answers to the questions are provided at the end. Only use these ***after*** you have tried your best to find the answers.

The Centre for Science Education, University of Glasgow, Scotland
Web Site: http://www.gla.ac.uk/centres/scienceeducation



Why Carbon?

Inorganic chemistry looks at the compounds of the 91 naturally occurring elements and their reactions with each other. Organic chemistry simply considers the compounds of carbon.

Have you ever thought why carbon is so important? The reason is that the number containing carbon is quite awesome - in the region of seven million. This is far more than the number of compounds of ***all*** of the other elements added together. Most carbon compounds are called organic compounds.They were named 'organic' because the early chemists found that most plants and animals are made up of carbon compounds - organic meant 'made by living things'. In fact, almost all plastics, fibres (such as polyester, wool and cotton), dyes, drugs, pesticides, flavourings and foodstuffs consist largely of organic compounds. Indeed, you are a complex factory which makes thousands of carbon compounds all the time!!

Why so Many Compounds?

Carbon can be thought of as in the middle of the first period of eight elements in the periodic table.

Group>>	Group I	Group II	Group III	Group IV	Group V	Group VI	Group VII	Group VIII
Symbol >>	Li	Be	B	C	N	O	F	Ne
Valency >>	1	2	3	4	3	2	1	0

Carbon is element 6 and has four electrons in its outer shell.

The arrangement of the electrons is: 2)4

Carbon always has a valency of **FOUR**

It is very difficult for carbon to form ionic bonds.When it links to other atoms, it usually forms polar covalent bonds. Carbon forms such bonds very easily with non-metal atoms like oxygen, hydrogen and nitrogen although it can link to almost any element.

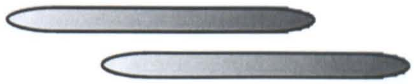
One carbon atom can link to another carbon atom very easily and this can lead to chains of carbon atoms or rings of carbon atoms. The chains can be ***extremely*** long (tens of thousands of atoms), making it possible for carbon to form very large numbers of carbon compounds. At this stage, we shall concentrate on short chains and small rings. Other atoms do not form such long chains easily although the element under carbon (silicon) can do the same. However, silicon chains tend to be alternating silicon-oxygen chains.They are the basis of most solid materials on this planet and are known as silicates. Most rocks are silicates.

Another reason for carbon's great power in forming such long chains lies in geometry. When carbon forms four bonds, the four bonds try to keep as far apart form each other as possible. This is understandable because a covalent bond (or polar covalent bond) is made up of a pair of electrons. We have to depend on the rules of geometry to find out how far apart they are and what shape will be formed.

Fun with Balloons

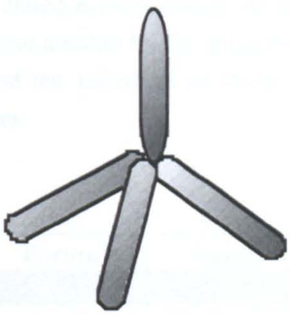
Try this for yourself:

Take two long modelling balloons:

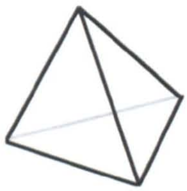


Holding each end on one balloon, twist each to form a narrow bit in the middle:

Now twist the two balloons together:



The four 'legs' move apart from each other and form a shape called a ***tetrahedral shape***.



Let us look at this a little more. Imagine a pyramid built on a triangle. There are four corners. This shape is known as a tetrahedron - which comes from the Greek language and means four faces: can you see the four faces of the shape?

If the carbon atom is in the middle of this shape, this carbon links to four other atoms, each at one corner of the tetrahedron:

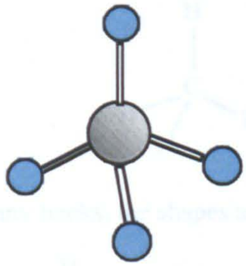
Because carbon forms bonds in three dimensions, the shapes of organic molecules can be extremely complicated but there are simple ways to sort this out for us.

Chains and Rings

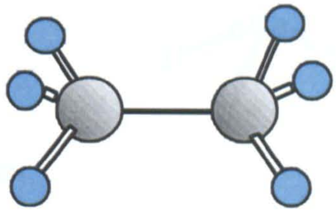
A carbon atom has four electrons which can be used to form bonds with other atoms. Each of the two atoms joined by one bond gives one electron to the shared pair. Carbon atoms link easily to each other, or to hydrogen, oxygen, nitrogens and one or two other elements.Carbon atoms are not so keen to link to metals. When carbon atoms link to each other, they can form chains and rings. We shall look at some these.

Hydrocarbons

If a carbon atom is joined to hydrogen atoms only, the molecule formed is called a hydrocarbon. The simplest hydrocarbon, which is called methane, is shown below.Because one carbon atom can link easily to another carbon atom, there is a whole series hydrocarbons. The first two are now shown:



Model of methane, CH_4



Model of ethane, C_2H_6

Compounds of carbon and hydrogen are called *hydrocarbons*. A series of compounds with similar chemical properties, in which members differ from one another by the possession of an additional CH_2 group, is called a *homologous series*. The names of the first ten members of these unbranched alkanes are given in the table below. This group are known as the ***alkanes***:

Name	Formula	Name	Formula
Methane	CH_4	Hexane	C_6H_{14}
Ethane	C_2H_6	Heptane	C_7H_{16}
Propane	C_3H_8	Octane	C_8H_{18}
Butane	C_4H_{10}	Nonane	C_9H_{20}
Pentane	C_5H_{12}	Decane	$C_{10}H_{22}$

Q

SELF ASSESSMENT QUESTIONS

(1) Look at the formulae for the first ten alkanes. If the number of carbons is n, work out the number of hydrogen in the alkane molecule. The formula will be:

C_nH____

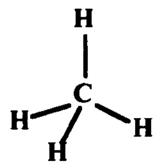
(2) Draw the structure of butane and pentane, showing all the hydrogen:

(3) What is main use for: (a) Butane: ....

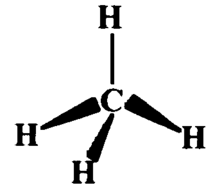
(b) Octane: ....

A Drawing Problem

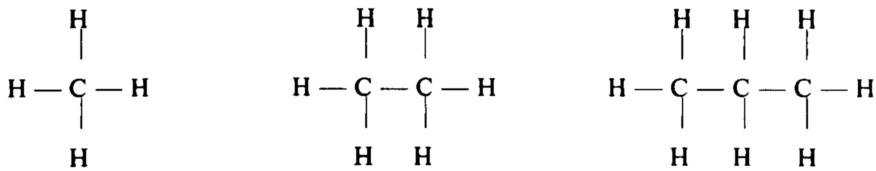
There is a real problem drawing molecules of the alkane hydrocarbons. It is fine for the first few but, then, it becomes almost impossible to draw them three-dimensionally. Methane can be drawn easily:



or



However, in many books, the shapes are 'flattened out" onto the page:

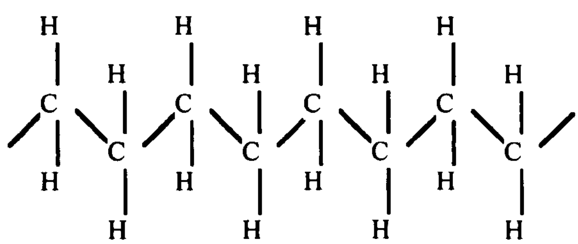


Methane Ethane Propane

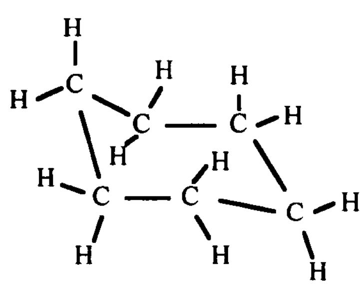
You must remember that the molecule is really three dimensional and not looking 'square'. However, you will find the 'square' drawings in many textbooks because it is so difficult to draw the three dimensional shapes.

Remember that each line is a polar covalent bond. This is a pair of electrons between the carbon nucleus and the hydrogen nucleus, these electrons attracting the protons in the two nuclei and holding the whole molecule together.

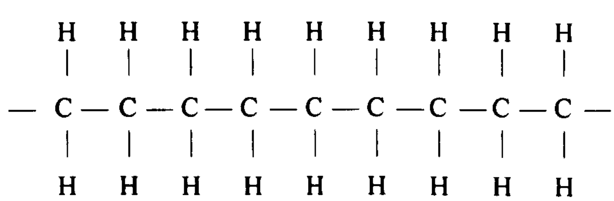
Here is a bit of a chain from an alkane, reminding us that the molecule is not flat:



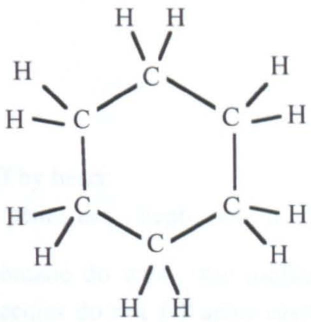
It is possible for the end of a chain to join (like a snake biting its tail) and form a ring.



Once again it is more convenient to fatten out the three-dimensional structure. Chains of carbon atoms are usually represented as:



Rings, which commonly contain six carbon atoms joined together, are represented as:



SELF ASSESSMENT QUESTIONS

(4) The alkane homologous series has a general formula of C_nH_{2n+2}, this means that, for every carbon, we have twice as many hydrogen plus two extra. Work out the general formula for the cycloalkanes: C_nH..........

(5) Draw a molecule of cyclopentane.

Looking at the Alkanes

Alkanes and the cycloalkanes are very common in the world. Crude oil is a mixture of about 2000 hydrocarbons, mostly alkanes and cycloalkanes. We shall look in a minute at how we can sort this mixture out a bit.

The various alkanes and cycloalkanes are very similar. The smallest molecules are light and are gases at room temperature, while the next group are liquids. The heavier molecules are solids with low melting points.

Alkane	Melting point (C)	Boiling point (C)
Methane	- 182	-164
Ethane	-183	-87
Propane	-190	-42
Butane	-138	0
Pentane	-129	36
Hexane	-95	69

Both alkanes and cycloalkanes are said to be ***saturated***. This word is used to indicate that they contain the *maximum number of hydrogen possible* in the molecules. We shall see in a moment that there are hydrocarbons which can react with hydrogen. All the alkanes and cycloalkanes have names ending in -ane. The cyclo- is added to the front of the name when the molecule is in a ring.

SELF ASSESSMENT QUESTIONS

(6) Learn the names for the first ten off by heart:

meth-, eth- prop-, but-, pent-, hex-, hept-, oct-, non-, dec-.

(7) Although cyclopropane and cyclobutane do exist, the molecules tend to fall apart very easily while cyclopentane and cyclohexane molecules do not fall apart easily. Think of their three-dimensional shape and suggest a reason for this:

....

Summary

The alkanes are a family of compounds known as a homologous series. They are all very similar. They all burn easily in air to give carbon dioxide and water. This is what comes from a car engine as the petrol burns. Alkanes have the ***general formula:***

$$C_nH_{(2n+2)}$$ where *n* is the number of carbon atoms present.

For example, if $n = 2$ then the formula of the alkane is: $C_2H_{(2x2)+2} = C_2H_6$ (ethane).

Strictly speaking a group of compounds with a general formula is known as a **homologous series** (homologous = same name).

Cycloalkanes are another homologous series, with the general formula: C_nH_{2n}

Cycloalkanes behave very similarly to the other alkanes, but they tend to have higher melting and boiling points.They have the same name as the corresponding straight-chain molecule, but with the prefix ***cyclo-*** (cyclo = circle or ring).

SELF ASSESSMENT QUESTIONS

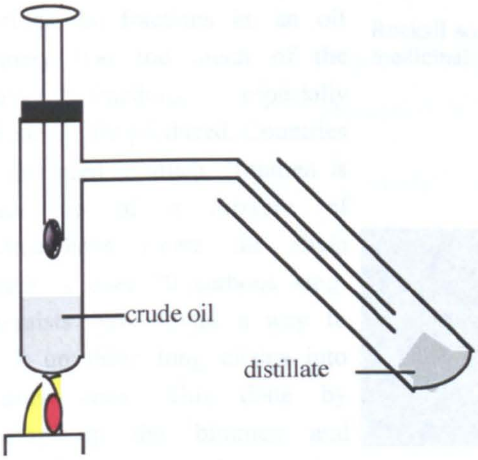
(8) Write the structural formulae of:

(a) Hexane (b) Cyclohexane

(9) It is found that there are two alkanes which both have the same formula: C_4H_{10}

Try to draw two different structures for this formula:

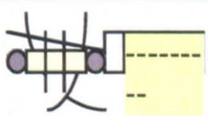
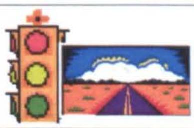
Oil

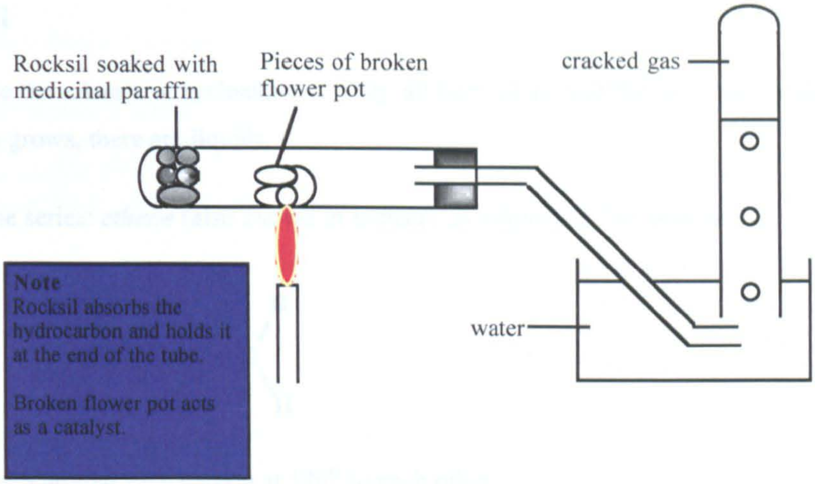


Oil is found widely below the Earth's surface. It may be necessary to drill down six or seven kilometres before the oil is reached. Oil was formed many millions of years ago from dead sea animals and plants which collected on the floor of the ocean and were covered by layers of rock fragments, silt, and mud. Oil and gas were formed as they decayed under pressure. Oil is a mixture of about 2000 hydrocarbons.

Oil can be separated using the fact that different hydrocarbons boil at different temperatures. Distillation sorts out the mixture of hydrocarbons into collections (called fractions) of hydrocarbons. In the laboratory, you may have carried out a small scale distillation of oil, using the apparatus alongside.You were probably able to obtain three or four different fractions as the temperature was altered.

The table below shows some of the substances which are obtained from oil by distillation in a refinery, together with the approximate number of carbon atoms in the molecules of each.

Fraction	Use	Number of carbon atoms per molecule
Gases		**1-4**
Petrol		**4-12**
Kerosine (Paraffin)		**9-16**
Diesel		**15-25**
Fuel Oil		**10-25**
Lubricating Oil		**20-70**
Bitumen (tar)		**>70**



There is a problem when oil is distilled in fractions in an oil refinery. Far too much of the heavy fractions, especially bitumen, are produced. Countries do not need so much. Bitumen is made up of a mixture of hydrocarbons where the chain length is over 70 carbons long. Chemists have found a way to break up these long chains into smaller ones. This done by heating up the bitumen and allowing it to come into contact with a hot surface (which acts as a catalyst). The long chains readily break up to give hydrocarbons with smaller chains. The process is known as ***catalytic cracking*** (often called: 'cat-cracking'). However, the hydrocarbons produced are not quite the same as the alkanes we start with. We shall look at that in a minute. A suitable arrangement for carrying out this experiment is shown alongside:

The Products From Cracking

Imagine an alkane with only 20 carbons being cracked.

```
    H   H   H   H   H   H   H   H   H   H   H   H   H   H   H   H   H   H   H   H
    '   '   '   '   '   '   '   '   '   '   '   '   '   '   '   '   '   '   '   '
H - C - C - C - C - C - C - C - C - C - C - C - C - C - C - C - C - C - C - C - C - H
    '   '   '   '   '   '   '   '   '   '   '   '   '   '   '   '   '   '   '   '
    H   H   H   H   H   H   H   H   H   H   H   H   H   H   H   H   H   H   H   H
```

This has the formula: $C_{20}H_{42}$

Imagine this breaks into two unequal parts on cracking, one part with 7 carbons, the other with 13 carbons. There is now not enough hydrogen to enable every carbon to have a valency of four.

```
    H   H   H   H   H   H   H | H   H   H   H   H   H   H   H   H   H   H   H   H
    '   '   '   '   '   '   ' | '   '   '   '   '   '   '   '   '   '   '   '   '
H - C - C - C - C - C - C - C | C - C - C - C - C - C - C - C - C - C - C - C - C - H
    '   '   '   '   '   '   ' | '   '   '   '   '   '   '   '   '   '   '   '   '
    H   H   H   H   H   H   H | H   H   H   H   H   H   H   H   H   H   H   H   H
```

What happens is that the carbons at the break point form a ***double bond*** with the next carbon:

```
    H   H   H   H   H       H        H       H   H   H   H   H   H   H   H   H   H   H
    '   '   '   '   '       '        '       '   '   '   '   '   '   '   '   '   '   '
H - C - C - C - C - C - C = C        C = C - C - C - C - C - C - C - C - C - C - C - C - H
    '   '   '   '   '   '   '        '   '   '   '   '   '   '   '   '   '   '   '   '
    H   H   H   H   H   H   H        H   H   H   H   H   H   H   H   H   H   H   H   H
```

The overall equation might be:

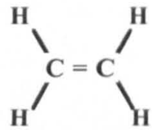
$$C_{20}H_{42} \xrightarrow{\text{catalytic cracking}} C_7H_{14} + C_{13}H_{26} + H_2$$

Each of the hydrocarbons formed contains one double bond between two carbons at the end of the chain and a little hydrogen is also produced. This has given us another homologous series and this group is called the ***Alkenes***. They have a general formula: C_nH_{2n} where n is the number of carbon atoms present.

The Alkenes in More Detail

In many ways, they behave just like the alkanes or cycloalkanes. They all burn in air and the small molecules give gases, then, as the chain length grows, there are liquids.

Let us look at the first member of the series: ***ethene*** (also known in industry as ***ethylene***). The structure is:



This molecules lies flat with the angles around each carbon at 120^{O} to each other.

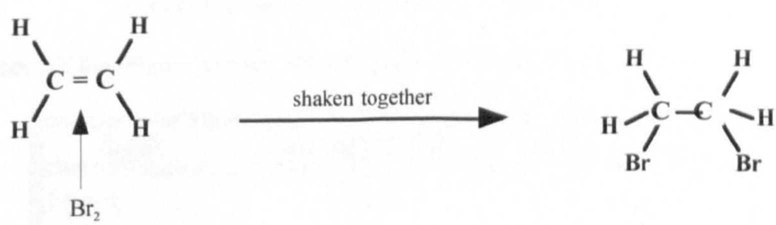
A double bond involves four electrons between the two carbon nuclei. The extra attraction of the electrons on the positive nuclei pulls the two carbons closer together (1 nanometre (nm) = 10^{-9} m):

		Distance between the two carbon atoms
Carbon-carbon double bond	C = C	0.134 nm
Carbon-carbon single bond	C — C	0.154 nm

This high concentration of negative charge (4 electrons) between the two carbon atoms in a double bond can attract atoms which have a high electronegativities (like the halogens - the elements in column 7). This gives us a test for alkenes.

Bromine dissolved in water is used because of its brown colour. If pure bromine is used, bromine is so attracted towards electrons that it can even link with the electrons in a carbon-carbon single bond. Bromine water contains only about 3% bromine diluted in water and this reacts with the double bond but does **not** react with a single bond. When it reacts, the brown colour disappears.

The test for a double bond is, therefore, to shake the hydrocarbon up with a small amount of bromine water. The brown colour rapidly disappears. Alkenes do this but alkanes (and cycloalkanes) do not. The reaction, for ethene, is:



In other words, any alkene will react with bromine water to give a dibromoalkane. The equation for ethene can be made more simple:

$$C_2H_4 \quad + \quad Br_2 \xrightarrow{\text{shaken}} C_2H_4Br_2$$

Reminder: Catalysts

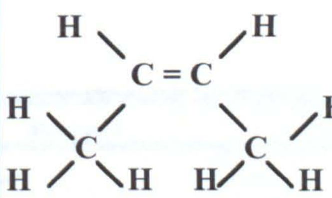
These are substances which allow a chemical reaction to go faster but the catalyst is not itself used up. Catalysts work in similar ways. For example, molecules of a reacting gas can stick on to the surface of the catalyst solid and the surface alters the reacting gas molecules in such a way that they can react faster. This is what happens in the catalytic cracking of alkanes to give alkenes.

Looking at Alkenes

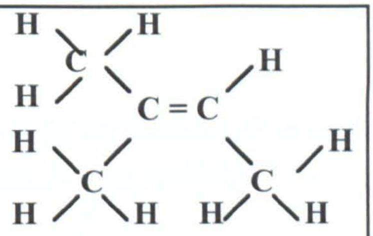
Alkene are named in the same way as alkanes. You do not have to remember another set of names!!

The first member is ethene, then propene, butene, pentene and so on. The "-ene" is used to show the presence of one double bond. You should note that all the other carbon-carbon bonds are single. In this homologous series (with general formula: C_nH_{2n}), there is only ***ONE*** carbon-carbon double bond in each molecule.

There is, unfortunately, a further complication. Although alkenes made by cracking always have the double bond at the end of the chain, it is quite easy to make molecules where the double bond is ***anywhere*** in the carbon chain. We have to find a way to show where it is and give it a name which indicates ***where*** the double bond is.



But-2-ene, C_4H_8



2-methylbut-2-ene, C_5H_{10}

The position of the double bond is shown by placing a number 'inside' the name:

but-2-ene shows that the double bond is between the second and the third carbon atom.

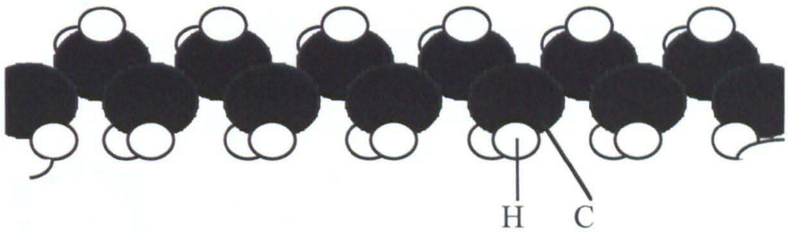
The first three members of the alkene family and their physical properties are shown:

Alkene	Melting point (C)	Boiling point (C)
Ethene	-169	-104
Propene	-185	-47
Butene	-184	-4

Alkenes are rarely found in nature and most are obtained by breaking up larger, less useful alkane molecules (catalytic cracking using a mixture of aluminium and chromium oxides heated to about 500°C).However, the alkenes are incredibly useful in making many other compounds.

Uses for Alkenes

In 1933, ethene was ***not*** thought to be useful and, during an experiment, some ethene gas gas was compressed to an enormously high pressure.When the apparatus was opened up, they found a white, waxy solid. Under conditions of very high pressure, thousands of ethene molecules are able to be linked together to form a very long chain of an alkane. The substance is known as **polythene (poly-ethene)**. This led to a whole range of new materials called plastics.Plastics contain molecules with very very long chains.Very soon other alkenes were polymerised to give all kinds of plastics, this group of plastics being known as ***addition polymers*** since the molecules were just 'added' together and there were no other products. Here is a picture showing what a part of a polyethene molecules might look like:



When we cause small molecules to link together to form huge chains, the small molecules are known as monomers and the long chains as polymers.Here are some common addition polymers based on alkenes.

Monomer	Polymer	Some Uses
Ethene	Polythene	Anything from bags to buckets
Propene	Polypropylene	Pipes and ropes
Chloroethene	Polyvinyl chloride (PVC)	From furniture to cars
Styrene	Polystyrene	Plastic cups, ceiling tiles
Tetrafluoroethene	Polytetrafluoroethene (PTFE)	Non-stick plastic

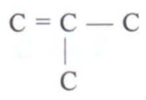
SELF ASSESSMENT QUESTIONS

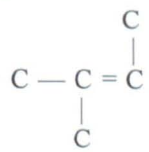
(10) Gives names for the following alkene molecules:

(a) C_4H_8 ....

(b) C_7H_{14} ....

(11) Give names for the following structures (the hydrogen are not shown):





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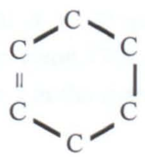
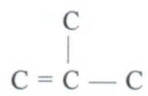




....

(12) Alkenes are never used in petrol or diesel fuel.Think of the conditions inside a car cylinder as petrol is burned explosively. Suggest what might happen if alkenes were used in car engines?

....

....

So Many Hydrocarbons - So Many Names!!

There are so many hydrocarbons that it seems impossible to remember how to name them.However, here is an easy way to name hydrocarbons:

Firstly, you need to ***remember*** the ten words to show the number of carbons from 1 to 10:

meth-, eth- prop-, but-, pent-, hex-, hept-, oct-, non-, dec-.

Now follow the procedure:

(1) Considering only chains of carbons, look at the structure and pick the longest chain. If there is a double bond, this longest chain should contain the double bond.

(2) Number the carbons on this chain, to give the *lowest* number to the double bond (if there is one), and then the *lowest* numbers to any side chains (if there are any).

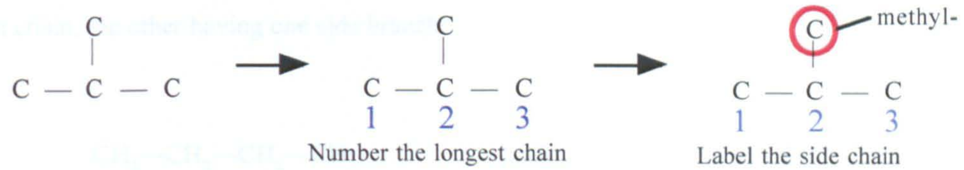
(3) The main chain is then named as an alkane or alkene with the prefix showing the number of carbons.

(4) The position of the double bond (if there is one) is shown using a number in the middle of the name.

(5) The positions of all side chains are shown, with that positions of attachment shown by numbers.

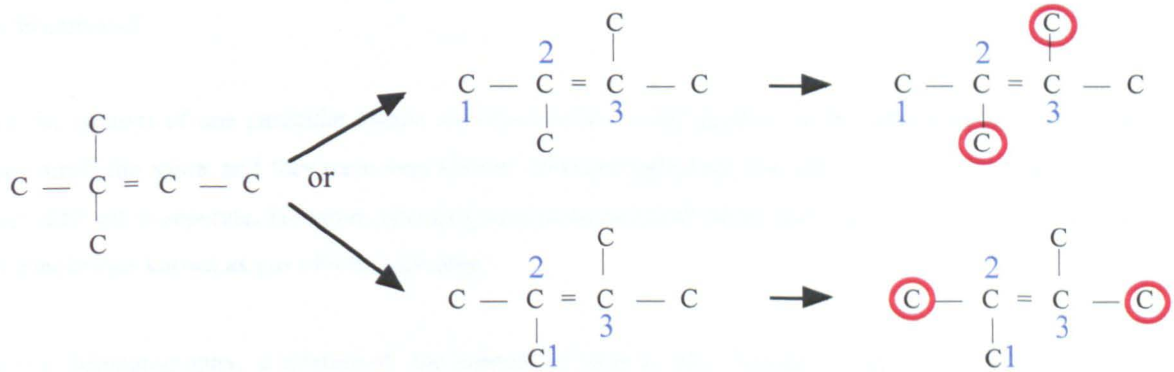
Some Examples *(with the hydrogen not shown for clarity)*

(a)



There are three carbons in the longest chain, numbered 1, 2, 3. This gives us the name **prop-**. With no double bonds in this chain, it is **propane**.There is one side-chain, containing one carbon, attached to the second position of the main chain.This gains its name **meth-**. This is adjusted to **methyl-**. The overall name is: **2-methylpropane**, the 2 at the start showing where the side chain is attached.

(b)



The longest chain is four carbons but there are several ways of selecting this. Two ways are shown. In this case, it does not matter which you choose but, in some cases, there will be differences. Always go for the chain which gives the *lowest* numbers for the double bond and side chains. This gives a **butene** and, to show where the double bond is, we call it **but-2-ene.** The double bond lies between carbons 2 and 3 and the lower number is always used to show the position. The side chains are now shown. There are two methyl- groups (**di-** shows two) in positions 2 and 3 also.

This gives: **2,3-dimethylbut-2-ene**.

Different Shapes and Sizes

Because carbon atoms can link to each other so easily, they can form not only chains and rings but also branches.This makes things appear to be very complicated because it is possible to have several molecules which have exactly the same molecular formula but have different structures. These are known as isomers (iso = **equal**; *meros* = **part**). In fact, the idea of isomers is quite straightforward, the real problem being to draw the three dimensional shapes on paper.

Let us look at butane: C_4H_{10}. Imagine the molecules 'squashed flat" on the page.There are two structures, one being a straight chain, the other having one side branch:

$CH_3—CH_2—CH_2—CH_3$ and $CH_3—CH_2(—CH_3)—CH_3$

Butane 2-methylpropane

As the length of an alkane chain increases, the number of isomers increases. In butane there are only two ways of arranging the four carbon atoms and the ten hydrogen atoms. Pentane, however, has three isomers, hexane has five, and octane, the eighth member of the alkane series, has eighteen. It is easy to see why there are so many hydrocarbons!!

All the isomers of one particular alkane are very similar to one another. In the laboratory they look the same, they smell the same, and they have very similar chemical behaviour.The isomers of a compound are, therefore, very difficult to separate. However, chemists have devised a very clever method of doing this which makes use of a technique known as *gas chromatography.*

In gas chromatography, a mixture of the isomers is made to pass through a long narrow tube which is packed with a dry powder. Because the different isomers have different shapes, they tend to move through the powder at different speeds and they come out at the end separated from each other.

SELF ASSESSMENT QUESTIONS

(13) Draw and name all the possible structural formula for

(a) C_5H_{12}

(b) C_5H_{10}

Another Homologous Series !

Carbon atoms can linked to each other form chains and rings, they can form branches in chains and it is possible for carbon atoms to be linked to each other by a double bond. It is also possible for two carbon atoms to be linked by a ***triple*** bond. This involves six electrons between the two carbon nuclei, holding the nuclei together. This brings the carbon atoms even closer together:

		Distance between the two carbon atoms
Carbon-carbon triple bond	$C\equiv C$	0.120 nm
Carbon-carbon double bond	$C=C$	0.134 nm
Carbon-carbon single bond	$C—C$	0.154 nm

This homologous series is known as the **alkynes**. The ***general formula*** of alkynes is:

$$C_nH_{2n-2}$$

where ***n*** is the number of carbon atoms present.

The simplest alkyne is known as ethyne but it is often called by its old name (which is, very confusingly, acetylene). Ethyne is a gas which burns with a flame which is so hot that it can cut through steel. Ethyne is used for cutting metal and welding.

$$C_2H_{(2x2)-2} = C_2H_2 \text{ (ethyne)}$$

Ethyne is a straight molecule, with all the atoms in a straight line:

$$H — C \equiv C — H$$

Ethynes also react with bromine water but the reaction is slow. Alkynes do not occur in large quantities in nature but some of them occur in small amounts in plants, giving the beautiful yellow colours to some flowers.

Ethyne itself is made in an unusual way.If certain calcium compounds are heated very strongly with carbon, a strange compound called calcium carbide forms easily. This has the formula CaC_2. The compound is ionic: Ca^{2+} C_2^{2-}

In fact, the carbide ion has the structure:

$$^-C \equiv C^-$$

When calcium carbide reacts with cold water, the carbide ion (which has two carbon atoms linked together by a triple bond) is immediately converted into ethyne (acetylene) gas. This is how ethyne is made for use in cutting and welding.It is also used as a starting material to make many other carbon compounds.

Remember

Alkanes	only contain single carbon-carbon bonds:	C_nH_{2n+2}
Alkenes	contain ONE carbon-carbon double bond and the rest are single:	C_nH_{2n}
Alkynes	contain ONE carbon-carbon triple bond and the rest are single:	C_nH_{2n-2}
Cycloalkanes	are rings with only single carbon-carbon bonds:	C_nH_{2n}
Cycloalkenes	are rings with ONE carbon-carbon double bond and the rest are single:	C_nH_{2n-2}

Q

SELF ASSESSMENT QUESTIONS

(1) The ***BIG*** Challenge: Molecules with six carbon atoms are very common. See how many different structures you can draw. You are allowed to have ***one*** double and triple bond in any molecule As you draw each one, try to name the molecule.

Now Check Your Answers

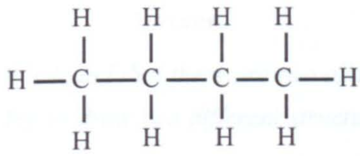
How many did you get correct?

Answers

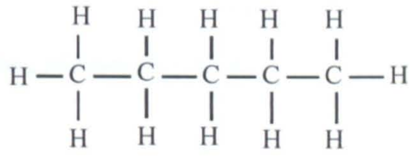
(1) *Look at the formulae for the first ten alkanes. If the number of carbons is n, work out the number of hydrogen in the alkane molecule. The formula will be:*

$$C_nH_{\underline{(2n+2)}}$$

(2) *Draw the structure of butane and pentane, showing all the hydrogen:*



Butane



Pentane

(3) *What is main use for:* (a) *Butane:* Calor gas and Camping gas. Sometimes mixed with propane, is used in portable blow lamps and for gas lighters.

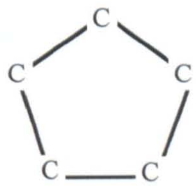
(b) *Octane:* Petrol .

(4) *The alkane homologous series has a general formula of* C_nH_{2n+2} *, this means that, for every carbon, we have twice as many hydrogen plus two extra. Work out the general formula for the cycloalkanes:*

$$C_nH_{\underline{2n}}$$

(5) *Draw a molecule of cyclopentane.*

Each carbon is attached to two hydrogen atoms.



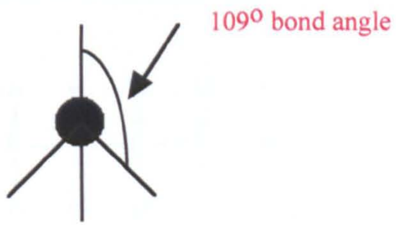
cyclopentane

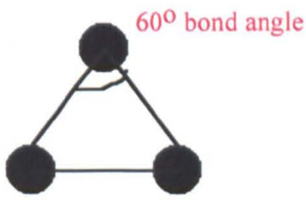
(6) *Learn the names for the first ten off by heart:*

meth-, eth- prop-, but-, pent-, hex-, hept-, oct-, non-, dec-.

(7) *Although cyclopropane and cyclobutane do exist, the molecules tend to fall apart very easily while cyclopentane and cyclohexane molecules do not fall apart easily. Think of their three-dimensional shape and suggest a reason for this:*

Cyclopropane is a triangular structure, with angles of 60° between the carbon-carbon bonds.The normal angle is that of tetrahedron which gives 109°. The molecule is somewhat strained to form the triangular stucture.

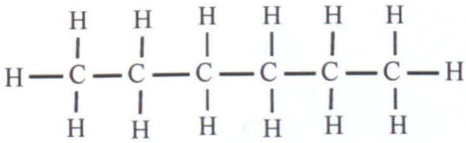




Cyclobutane is a square structure; with 90° angles. This is closer to the preferred 109° but it is still somewhat strained.

(8) Write the structural formulae of:

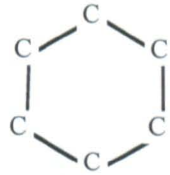
(a) Hexane



Hexane

(b) Cyclohexane

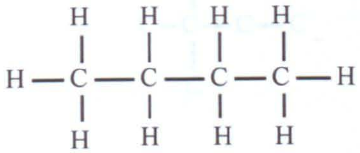
Each carbon is attached to two hydrogen atoms.



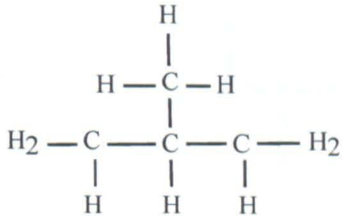
Cyclohexane

(9) It is found that there are two alkanes which both have the same formula: C_4H_{10}

Try to draw two different structures for this formula:



Butane



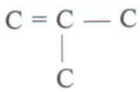
2-methyl propane

(10) Gives names for the following alkene molecules:

(a) C_4H_8 **Butene**

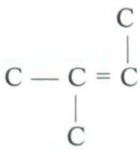
(b) C_7H_{14} **Hepten**

(11) Give names for the following structures (the hydrogen are not shown):

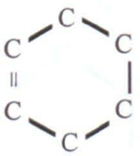


2- methylpropene

The double bond needs no number as it has to be between carbon 1 and 2.

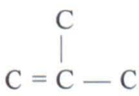


2- methyl but -2- ene



Cyclohexene

No number is needed as the ring is completely symmetrical



2- methypropene

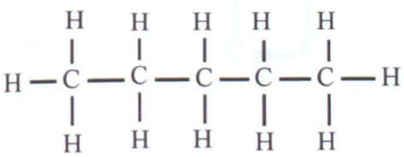
The same as the first molecule but turned over.

(12) Alkenes are never used in petrol or diesel fuel. Think of the conditions inside a car cylinder as petrol is burned explosively. Suggest what might happen if alkenes were used in car engines?

Alkenes can polymerise when placed under pressure, especially if there are possible catalysts present.

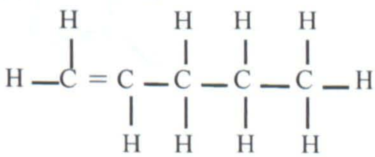
(13) Draw and name all the possible structural formula for

(a) C_5H_{12}



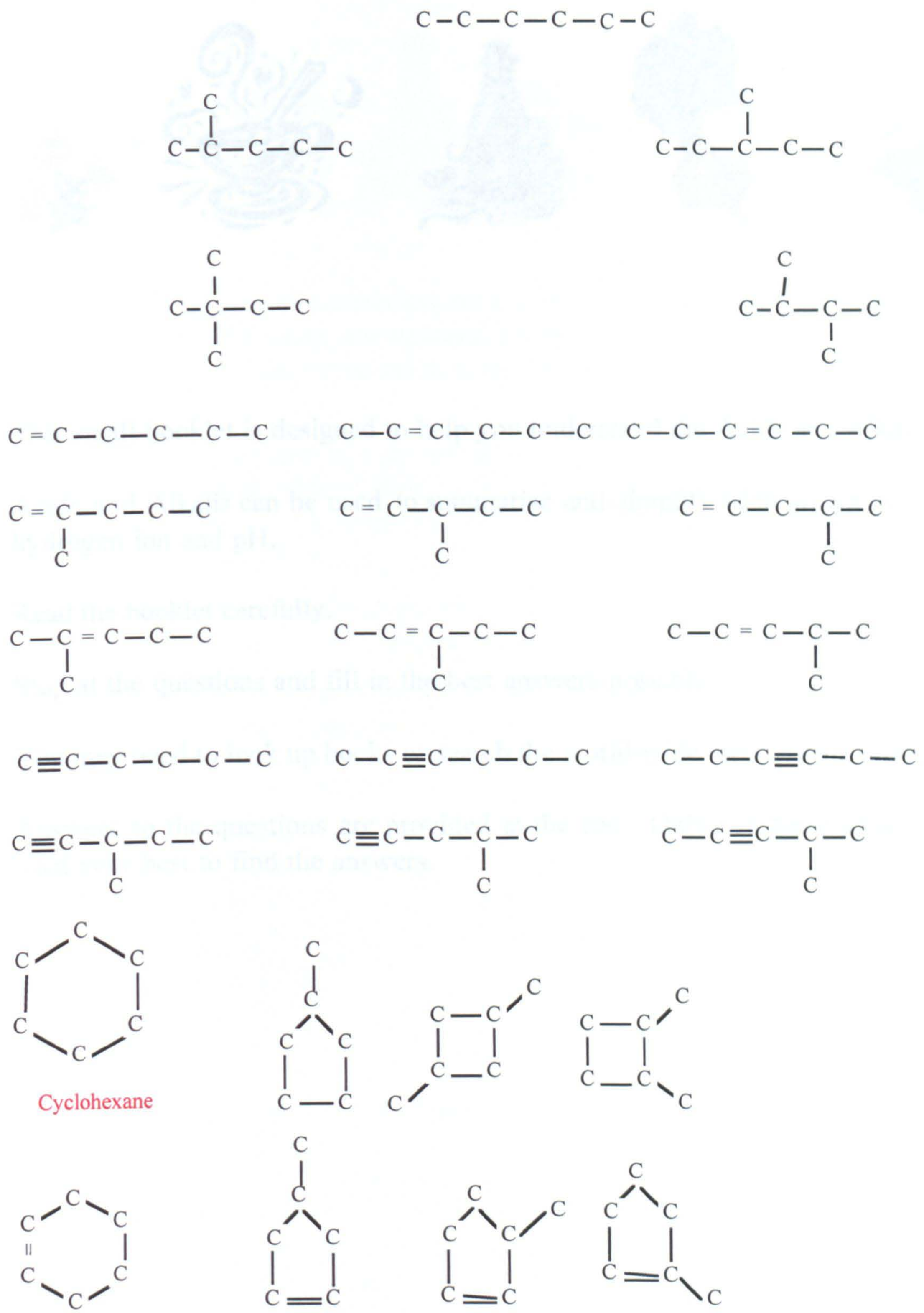
Pentane

(b) C_5H_{10}



pent-1-ene

*(14) The **BIG** Challenge: Molecules with six carbon atoms are very common. See how many different structures you can draw. You are allowed to have **one** double and triple bond in any molecule As you draw each one (without hydrogen atoms), try to name the molecule.*



Acids and Alkalis

This small booklet is designed to help you understand the Acids and Alkalis.

Acids and Alkalis can be used to summarise and simplify what we know about the hydrogen ion and pH.

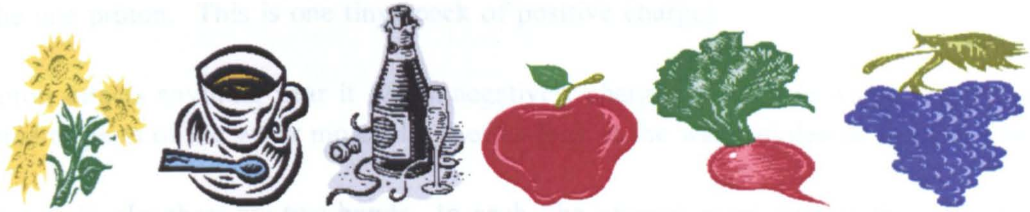
Read the booklet carefully.

Stop at the questions and fill in the best answers possible.

You may need to look up books or search the world-wide web using a computer.

Answers to the questions are provided at the end. Only use these ***after*** you have tried your best to find the answers.

Acids and Alkalis



You will have heard some substances being called acids and others which are called alkalis. Vinegar is an acid, while bicarbonate of soda and ammonia are alkalis. There is acid (sulphuric acid) in a car battery while many fruits we eat can be acidic: lemons are the most acidic of the fruits you will have eaten.

It took until 1884 for our ideas of acids and alkalis to become clearer. A famous Swedish chemist, called Svante Arrhenius, proposed that, when acids, alkalis or salts dissolved in water, charged particles were released into the water. He called these ions. These charged particles allowed the solution to conduct electricity.

In an acid, there is an excess of hydrogen ions. The symbol is H^+. Any substance which dissolves in water to release hydrogen ions is called an ***acid***.

In an alkali, there is an excess of hydroxide ions. The symbol is OH^-. Any substance which dissolves in water to release hydroxide ions is called an ***alkali***.

In pure water, there are equal numbers of hydrogen and hydroxide ions and we call this ***neutral.***

Where do the hydrogen ions come from?

In water, a very small number of the water molecules split to form hydrogen ions and hydroxide ions. At any time, only 0.00055% of the water molecules have split to give ions but there is continual process with water molcules splitting up and ions coming together to form water, all happening at a very fast rate. There is a lot of activity in water, all the time!! The continual splutting and re-linking is shown like this:

$$H_2O \rightleftharpoons H^+ + OH^-$$

Various substances, when added to water, increase the concentration of hydrogen ions, giving acids. Other substances decrease the concentrations of hydrogen ions, giving alkalis.

More About Hydrogen Ions

Hydrogen ions are strange particles!! A hydrogen atom has one proton in its nucleus and one electron outside the nucleus. When it forms a positive ion, it has lost the one electron. All that is left is the one proton. This is one tiny speck of positive charge!

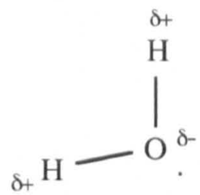
This proton attacts anything near it which negatively charged. When in water, the hydrogen ion is attracted to parts of the water molecule. Let us look at the water molecule in more detail.

In a water molecule, there are two bonds. In each, the oxygen atom attracts the pair of electrons more strongly and the bond is said to be ***polar covalent***. This means that the oxygen is slightly negative and is, therefore, attracted to the positive hydrogen ion quite strongly. The symbol "δ" is the Greek letter "d" and is called 'delta'. This symbol is used in mathematics to show "a very, very small bit of....". It is used here to show very small amounts of electrical charge. The water molecule can be drawn to show this:

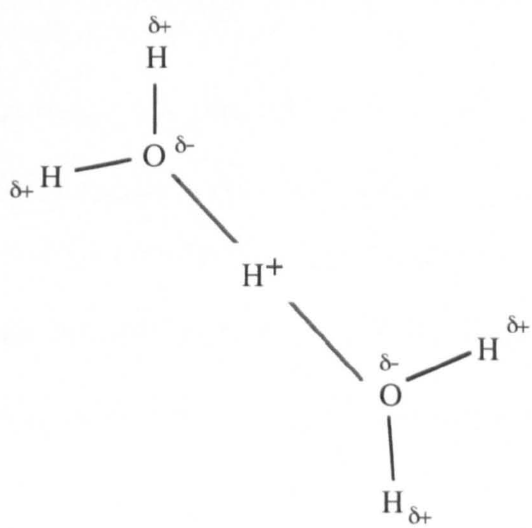
δ^+ means a small amount of positive charge

δ^- means a small amount of negative charge

The water molecule is bent with an angle of about 105°



Imagine two water molcules attracted to one hydrogen ion. It could look like this:



SELF ASSESSMENT QUESTIONS

Q1: In practice, it often happens that three water molecules are group around one hydrogen ion in three dimensions. Try to draw this:

How Many Hydrogen Ions?

Because hydrogen ions are so tiny, a solution can contain a huge number of hydrogen ions. For example, it is possible for ***ONE SMALL DROP*** of a dilute solution of an acid like hydrochloric acid to contain:

10,000,000,000,000,000,000 hydrogen ions !!!!

We need some easy way to handle such huge numbers. This is achieved using a scale called the **pH scale**, but first we have to think of the mole again.

How many moles of hydrogen ions are in dilute hydrochloric acid?

In fact, ***ONE SMALL DROP*** of a dilute solution of an acid like hydrochloric acid might contain:

1.6×10^{-5} moles of hydrogen ions !!!!

However, this is about 10^{16} hydrogen ions!!

The numbers are impossible to understand. With moles, the numbers are ***too small***. With ions, the numbers are ***too large***.

This is where pH helps.
Let us think of common solutions of acids and alkalis.

Concentration *(molarity)*	**Concentration of hydrogen ions** *(moles per litre)*	**Concentration of hydrogen ions** *(moles per litre)*
1 M HCl	1	10^{0}
0.1M HCl	0.1	10^{-1}
0.01M HCl	0.01	10^{-2}
0.001M HCl	0.001	10^{-3}
0.001M NaOH	0.00000000001	10^{-11}
0.01M NaOH	0.000000000001	10^{-12}
0.1M NaOH	0.0000000000001	10^{-13}
1 M NaOH	0.00000000000001	10^{-14}

The range of numbers is enormous! However, look at the right hand column.

It would be a great idea if we could use the index numbers because these are nice and small. However, most of them are negative.

The logarithm gives us the indices on their own and a negative sign makes everthing positive.

Concentration *(molarity)*	**Concentration of hydrogen ions** *(moles per litre)*	**Logarithm of Concentration**	**Negative Logarithm of Concentration**
1 M HCl	10^{0}	0	0
0.1M HCl	10^{-1}	-1	1
0.01M HCl	10^{-2}	-2	2
0.001M HCl	10^{-3}	-3	3
0.001M NaOH	10^{-11}	-11	11
0.01M NaOH	10^{-12}	-12	12
0.1M NaOH	10^{-13}	-13	13
1 M NaOH	10^{-14}	-14	14

The numbers in the right hand column are easy to handle. This gives us a way of making a scale for the concentration of hydrogen ions in solutions of acids and alkalis. It is known as the pH scale.

The formal definition is:

pH = the negative logarithm of the hydrogen ion concentration

$$pH = -\log [\ H^{+}(aq)\ ]$$

logarithm **concentration of hydrogen ions**

Remember: It may look complicated but it is designed to give nice small numbers

How does hydrogen ion concentration vary?

Here is a table showing the hydrogen ion concentration of some common substances

Substance	Hydrogen Ion Concentration
Pure water	0.0000001
Vinegar	0.002
Canned soft drink	0.00005
Dilute hydrochloric acid	1.00000000
Household ammonia	0.0000000001
Bicarbonate of soda	0.00000001
Rain water	0.0000016

Let us now expand the table to how how pH works

Substance	Hydrogen Ion Concentration (moles per litre)	Hydrogen ion Concentration in scientific notation	logarithm of hydrogen ion concentration	negative logarithm of hydrogen ion concentration
Pure water	0.0000001	1×10^{-7}	-7.0	7.0
Vinegar	0.002	2×10^{-3}	-2.7	2.7
Canned soft drink	0.00005	5×10^{-5}	-4.3	4.3
Dilute hydrochloric acid	1.00000000	1×10^{0}	0.0	0.0
Household ammonia	0.0000000001	1×10^{-10}	-10.0	10.0
Bicarbonate of soda	0.00000001	1×10^{-8}	-8.0	8.0
Rain water	0.0000016	1.6×10^{-6}	-5.8	5.8

Look at the table closely.

- In pure water, the hydrogen ion concentraton is 10^{-7} moles per litre.
- The logarithm of this value is -7.
- Changing the sign (which is what taking the negative value means) gives 7.

Notice that rain water does not have the same pH as pure water. As water falls out of the sky, it absorbs small amounts of carbon dioxide which makes the water very slightly acidic (a pH of 5.8).

The pH Scale

In pure water, the concentration of hydrogen ions is the same as the concentration of hydroxide ion.

In pure water:

Concentration of hydroegn ions = concentration of hydroxide ions = 10^{-7} moles per litre

We write this:

$$[H^+] = [OH^-] = 10^{-7}$$

The square bracket is used in chemistry to mean "the concentration of..."

This saves a lot of writing!!

Pure water is said to have a pH of 7

$$\text{pH (pure water)} = -\log [H^+] = -\log (10^{-7}) = 7$$

Look at some values for pH

	pH	
Acidic	0	Hydrochloric acid
	1	Acid in your stomach
	2	Lemon juice
	3	Cola drinks
	4	Tomatoes
	5	Black coffee
	6	Urine
Neutral	7	Pure water
	8	Sea water
	9	Baking sodia
	10	Great Salt lake
	11	Household ammonia
	12	Household bleach
	13	Overn cleaner
Alkaline	14	Sodium hydroxide

pH paper is paper which has various vegetable dyes soaked into it. It changes colour with solutions of different pHs. The colours are rather like those shown in the table above - in the middle column.

Measuring pH

We can use pH paper to find the pH of a solution. It is also possible to use various dyes which change colour when the pH changes. One of the best is called bromothymol blue and it changes from yellow in acid solutions to blue in alkaline solutions, It changes colour around pH 7. These dyes are known as ***indicators*** and are very useful to show specific pH changes. Here are four of these indicators. The colour changes across the pH range shown. We shall look at the use of indicators more later.

Indicators	Colour change	pH interval
Methyl orange	Orange- Yellow	2.1- 4.4
Methyl red	Red - Yellow	4.2 - 6.3
Bromthymol blue	Yellow - Blue	6.0 - 7.6
Phenolphthalein	Colourless - Red	8.3 - 10.0

pH meters are much more accurate but much more expensive!. They are electronic devices which measure the pH value and display it on a screen. A pH meter has attached to it a very sensitive glass tube (it is made with very thin glass and is easily broken). This is placed into the solution and the tiny electrical current from this glass electrode gives the meter reading.

pOH Scale

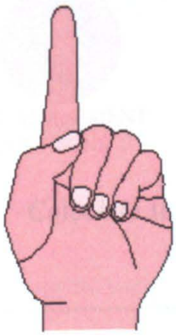
Scientists always use the pH scale. However, it is possible to think of a pOH scale. This scale could be used to measure the concentration of hydroxide ($[OH^-]$) ion in a substance.

$$\mathbf{pOH = -log\ [\ OH^-\ ]}$$

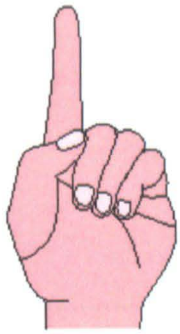
Here is a simple rule:

$$\mathbf{pH + pOH = 14}$$

The best way is to always work things out using pH and then use this rule to convert to pOH.



Would you like to gain some more confidence in solving problems involving pH and pOH?
The calculations are not difficult!



The calculations are not difficult! You may need to convert from concentrations to pH values OR to convert from pH values to concentrations.

Remember:

$$pH = -\log [H^+]$$

and

$$pH + pOH = 14$$

Let us try some calculations:

(1) **Calculating the pH from the Concentration**

Example:
A solution contains 0.0001 mole of H^+ per litre. What is the pH?

0.0001 moles per litre = 10^{-4} moles per litre

pH = -log [0.0001]
pH = -[-4]
pH = 4

This gives a pH of 4

Another example:
A solution contains 0.05 moles of H^+ per litre. What is the pH?

0.05 moles per litre = $10^{-1.3}$ moles per litre

You will need a calculator for this:

Press in 0.05
Then press log
You will get the answer -1.3

This gives a pH of 1.3

Q

SELF ASSESSMENT
QUESTIONS

Q2 Calculate the pH of 0.02 mol per litre hydrochloric acid solution?

....

....

....

Q3 A solution contains 0.0001 mole per litre of hydrogen ions. What is the pH?

....

....

....

Q4 What is the pH of a soluton contains 0.035 moles per litre of hydorchloric acid.

....

....

....

(2) **Calculating the concentration from the pH?**

Example
A solution of an acid is labelled: pH = 3. What is [H^+] in moles per litre.

Remember: **pH = -log [H^+]**

This means that: 3 = - log [H^+]

Thus: -3 = log [H^+]

> **Check:**
> 0.001 = 10^{-3}
> The logariththm of 10^{-3} is -3

This means that we have to find what value for [H^+] will give the value -3 when we take its logarithm.

If you look up logarithm tables, you can find the answer. The other way (and easier!) is to use a calculator. However, calculators do not always have exactly the same buttons - be careful.

Take your calculator, type in 3 and press ± to change it to -3.
Now press the key marked 10^x and you will have your answer.

You should obtain: 0.001

Thus, the solution contains 0.001 moles of hydrogen ions per litre of solution.

Remember, this sounds very little but it means that, in 1 litre of oslution, you have:
600,000,000,000,000,000,000 hydrogen ions !!

Another example
An acid solution is marked as 0.05 M. What is the concentration of hydrogen ions?

pH = -log [H^+]

Therefore: 0.05 = -log [H^+]

Thus, [H^+] = **0.89 moles per litre**

> **Watch!**
> If you obtained 1.12, you forgot to press the ± sign to make it negative!
> You can always check your answer by finding the logarithm of 0.89. It should be approximately 0.05.

SELF ASSESSMENT QUESTIONS

Q5 Some drinking water was found to have a pH of 6.
What is the [H+] concentration in moles per litre?

(3) **Find pH from pOH, or pOH from pH?**

This can be easily done by subtracting the value you have from 14, to get the other value?

Example
Suppose the pH of a solution is 3. What is the pOH

pOH = 14 - pH

Thus: pOH = 11

Q6 The pH of a solution is 4.6 . What is the pOH of the solution?

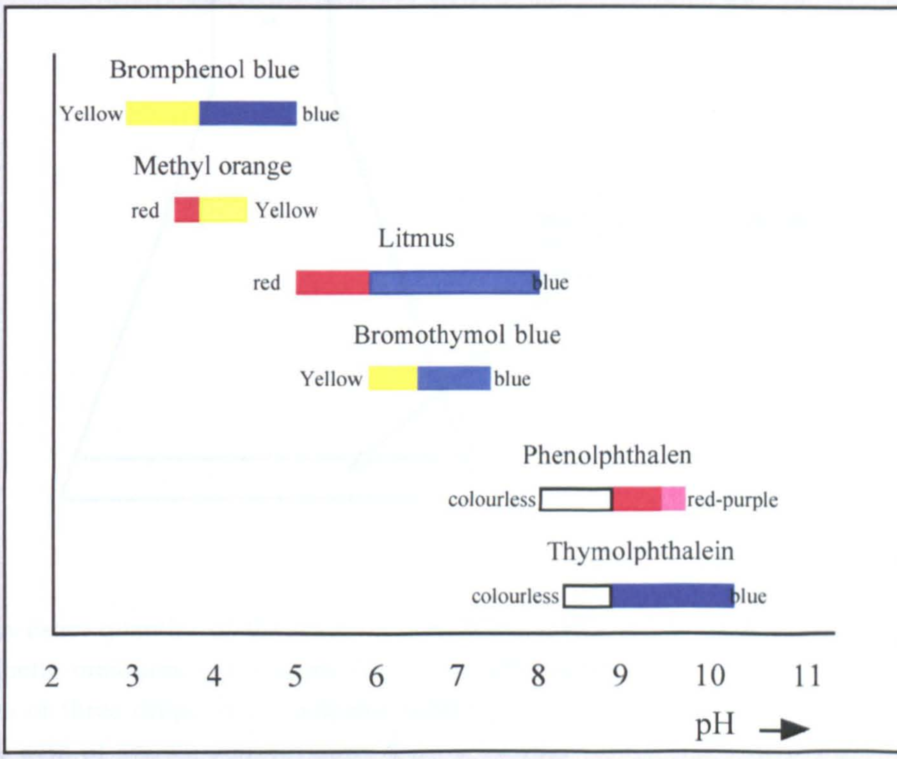
Q7 What is the pH of the solution whose pOH is 10.4 ?

Indicators and Titrations

Acid solutions can be added to alkaline solutions to give a neutral solution. However, we need to have a way to know when we have reached neutrality. This is achieved using substances called indicators.

Indicators are dyes which change colours as pH changes. The colour change takes place over a small range of pH values and the table below shows some of the common indicators.

Colours and pH range of indicators



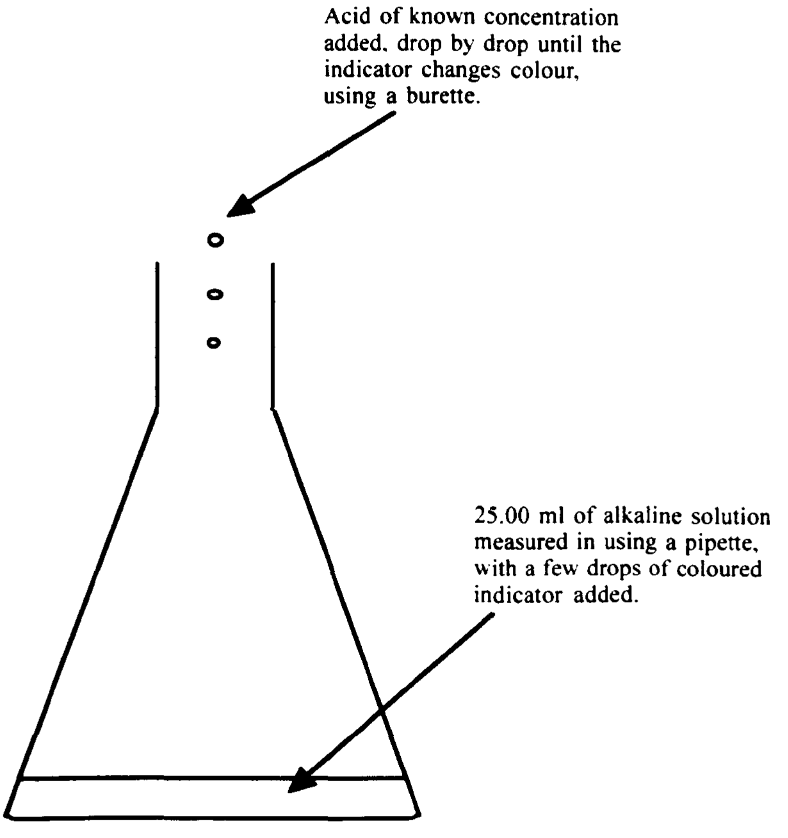
The process of mixing acids with alkalis, using indicators, is very important because it gives us a very useful technique for analysis.

Suppose we want to find out the concentration of acid in a river which is highly polluted. We could take a small known volume of the river water (say 25.00 ml exactly) and add alkali very slowly until we have exactly neutralised the acid in the river water. Suppose that we use 10.00 ml of alkali. If we know the concentration of the alkali we have used (suppose it is exactly 0.1moles per litre), we can calculate the precise concetnration of acid in the polluted river water.

This technique is known as **TITRATION** and it is very useful to find out the concentration of various substances in water. It is used in monitoring pollution, to measure substances in our bodies in medicine, and to check materials used in industry.

Titrations

Titration is an important laboratory technique used in chemical analysis. Here is how it is done.



(1) Place an exact quantity of the solution containing alkali in the flask using a pipette.
[The pipette measures one volume (eg 25.00 ml) exactly]

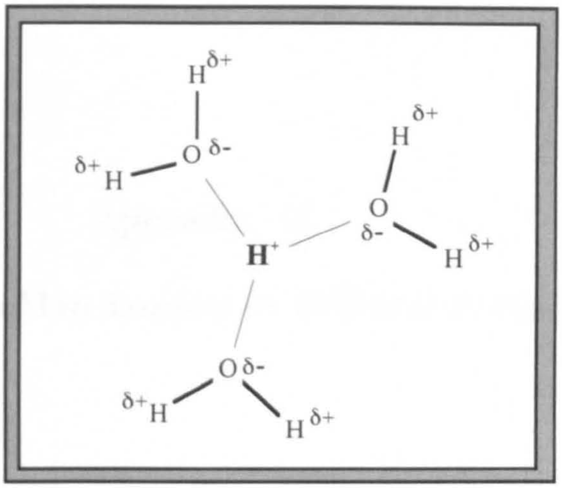
(2) Add two or three drops of an indicator solution.

(3) Add the acid of known concentration from a burette.
Go on adding the acid until the indicator just changes colour.
Note how much acid has been added.
[A burette is a long narrow tube with a scale marked on it - it measures *any* volume accurately]

(4) If we know the concentration of the acid and the volume used, we can calculate how much alkali is in the 25.00 ml of alhali at the start.

Answers

Q1: In practice, it often happens that three water molecules are grouped around one hydrogen ion in three dimensions. Try to draw this:



Q2 *Calculate the pH of 0.02 mole per litre hydrochloric acid solution?*

pH = -log [0.02]   pH = - [-1.047]   pH = 1.047

Q3 *A solution contains 0.0001 mole per litre of hydrogen ions. What is the pH?*

pH = -log [0.0001]   pH = - [-4]   pH = 4

Q4 *What is the pH of a solution containing 0.035 moles per litre of hydrochloric acid?*

pH = -log [0.035]   pH = - [-1.084]   pH = 1.084

Q5 *Some drinking water was found to have a pH of 6. What is the* [H+] *in moles per litre?*

pH = -log [H^+]   6 = -log [H^+]   log [H^+] = -6   [H^+] = 10^{-6} moles per litre

Q6 *The pH of a solution is 4.6 . What is the pOH of the solution?*

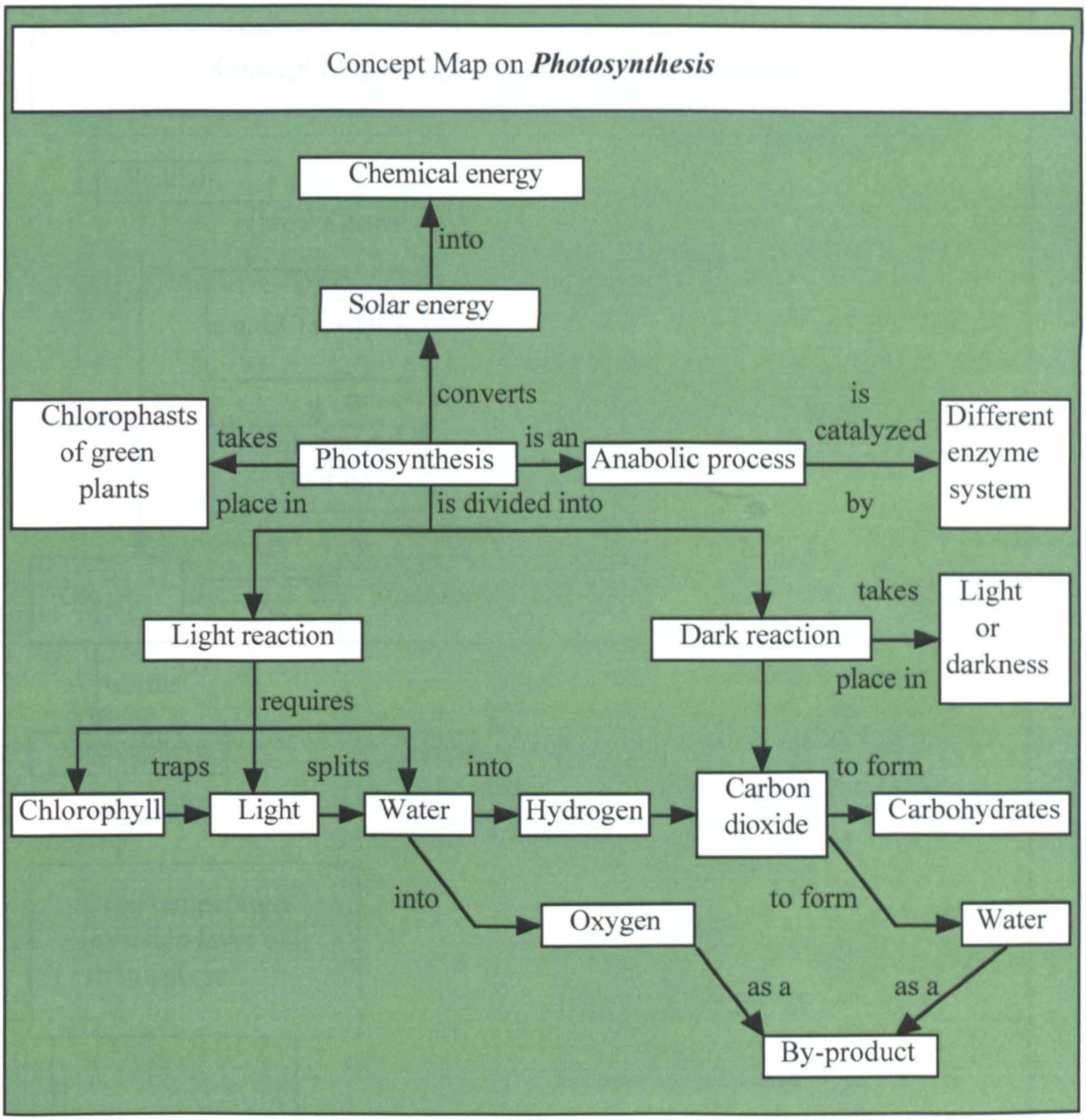
pH + pOH = 14   4.6 + pOH = 14   pOH = 14 - 4.6   pOH = 9.4

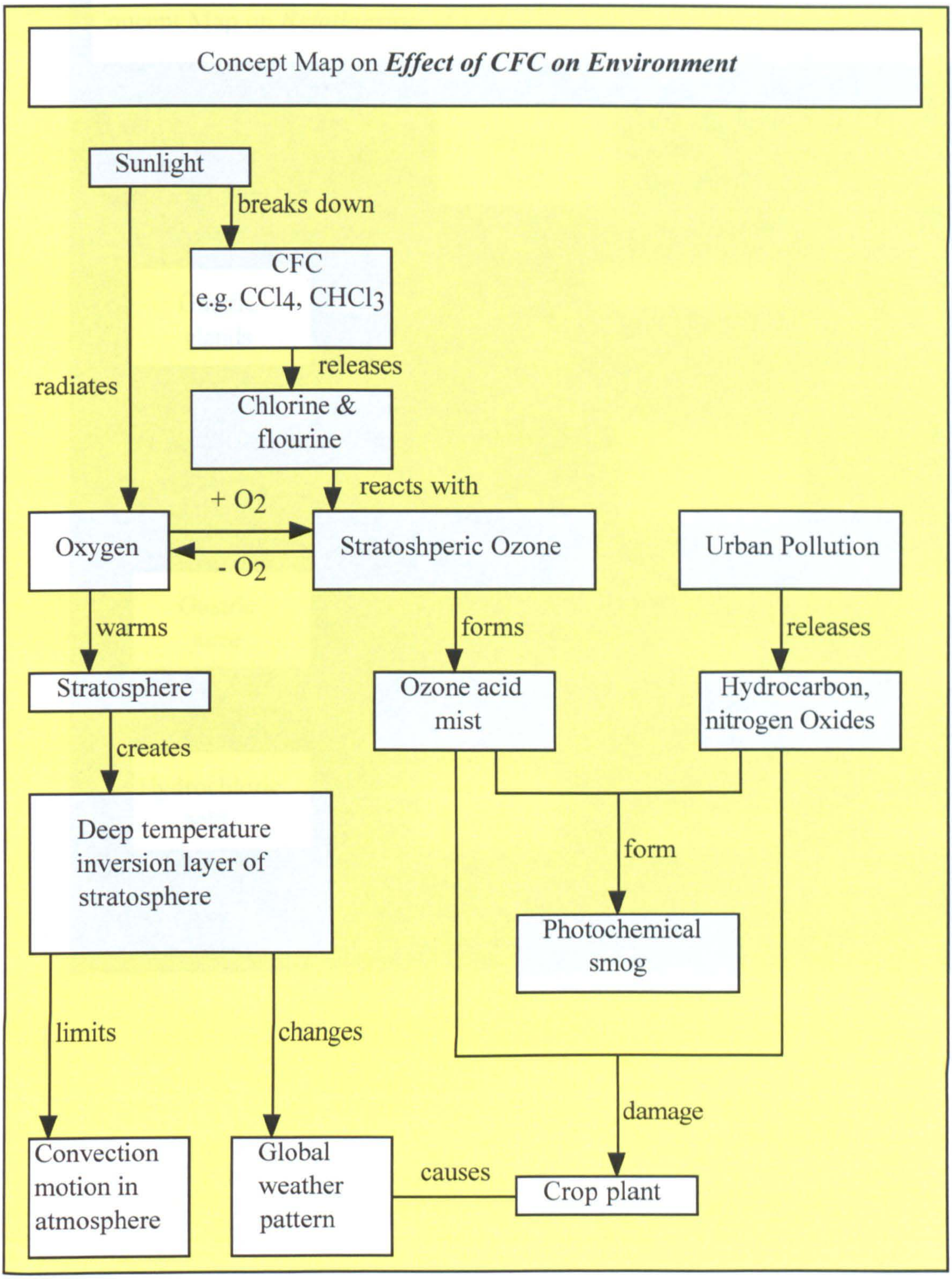
Q7 *What is the pH of the solution whose pOH is 10.4 ?*

pH + pOH = 14   pH + 10.4 = 14   pH = 14 - 10.4   pH = 3.6

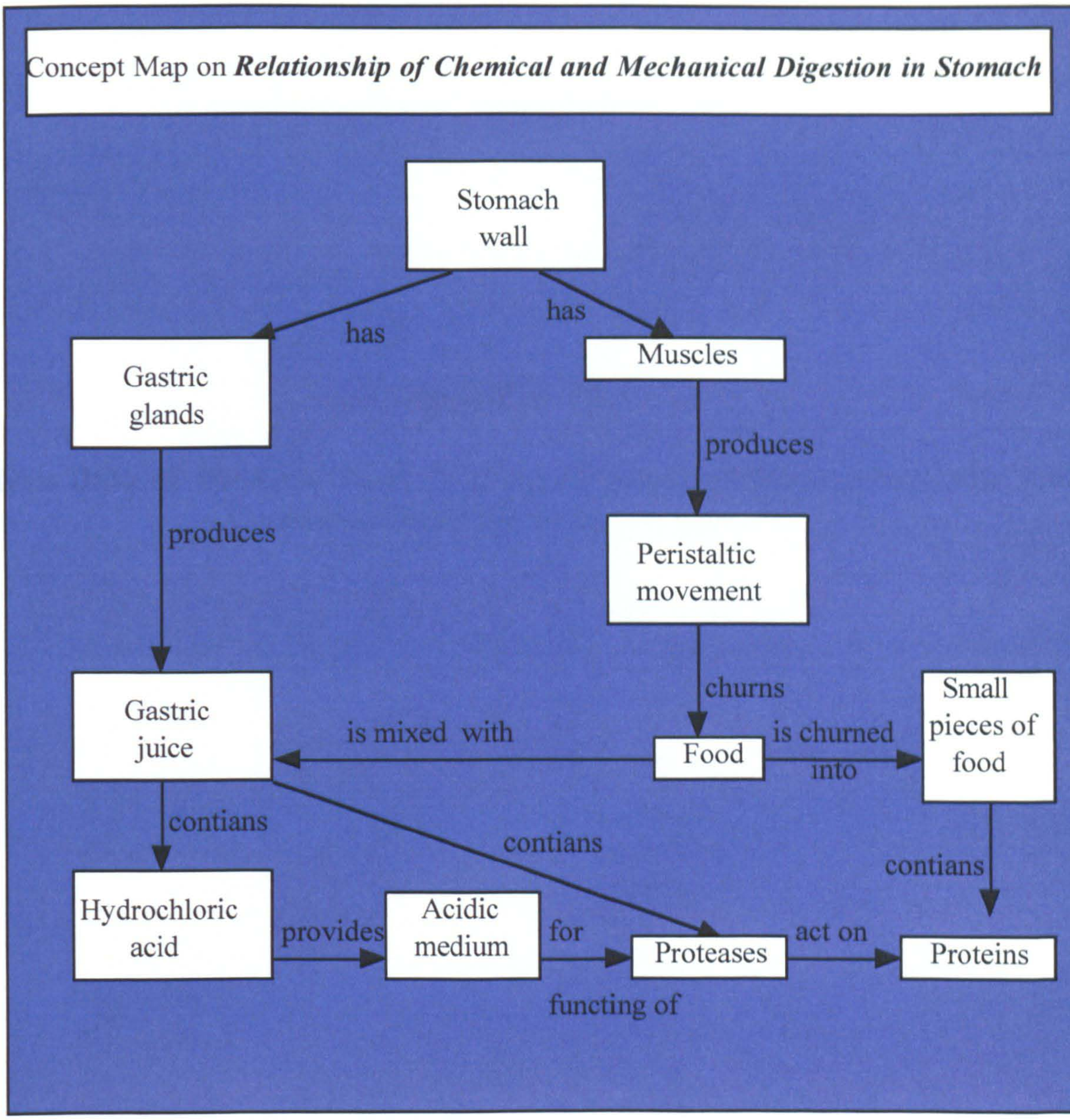
Appendix G

Concepts Map Samples on Different Areas


Concept Map on *Photosynthesis*
Chemical energy
into
Solar energy
converts
Chlorophasts of green plants
takes place in
Photosynthesis
is an
Anabolic process
is catalyzed by
Different enzyme system
is divided into
Light reaction
Dark reaction
takes place in
Light or darkness
requires
traps
splits
into
Chlorophyll
Light
Water
Hydrogen
Carbon dioxide
to form
Carbohydrates
into
Oxygen
to form
Water
as a
as a
By-product



Concept Map on *Effect of CFC on Environment*
Sunlight
breaks down
CFC
e.g. CCl_4, $CHCl_3$
releases
radiates
Chlorine & flourine
reacts with
+ O_2
Oxygen
- O_2
Stratoshperic Ozone
Urban Pollution
warms
forms
releases
Stratosphere
Ozone acid mist
Hydrocarbon, nitrogen Oxides
creates
Deep temperature inversion layer of stratosphere
form
Photochemical smog
limits
changes
damage
Convection motion in atmosphere
Global weather pattern
causes
Crop plant


Concept Map on *Relationship of Chemical and Mechanical Digestion in Stomach*
Stomach wall
has
has
Gastric glands
Muscles
produces
produces
Peristaltic movement
churns
Gastric juice
is mixed with
Food
is churned into
Small pieces of food
contians
contians
contians
Hydrochloric acid
provides
Acidic medium
for
Proteases
act on
Proteins
functing of

Appendix H

Analysis Data of the Grid Tests Students responses (Experiment groups and Control groups) for Year 10 and 11

Analysis Data for Year 10

Codes and Scores for Test Materials-*Control.Group*

Codes and Scores for Test Materials-*Control.Group*

Pup No	Sex	Periodic Table >>>> Q1 a	b	c	d	e	f	Q2 a	b	c	d	Q3 a	b	c	d	Q4 a	b	c	Q 5	MM Mk
1	F	20	30	51	30	10	20	10	11	10	11	21	21	20	20	1	1	1	2	11
2	F	10	31	41	30	11	10	11	10	11	0	30	20	31	10	1	1	1	1	12
3	F	10	20	61	20	10	21	11	10	10	10	20	20	31	20	1	1	1	1	13
4	F	11	30	0	0	0	10	11	10	20	11	30	30	21	20	1	1	1	1	12
5	F	20	31	0	0	0	21	0	10	21	11	30	30	21	20	1	1	1	1	11
6	F	10	30	0	0	0	10	20	10	11	10	30	31	21	20	1	1	1	2	14
7	F	20	30	0	0	0	11	11	11	11	0	31	31	21	21	1	1	1	1	12
8	F	20	30	41	21	0	21	11	10	21	10	31	30	21	20	1	1	1	1	13
9	F	10	21	11	21	11	11	21	10	20	10	30	30	21	20	1	1	1	1	10
10	F	20	20	11	11	11	11	11	11	11	10	30	30	30	20	1	1	1	1	11
11	F	20	10	0	31	0	11	20	10	21	10	11	21	21	20	1	1	1	1	11
12	F	21	30	0	0	0	10	20	10	20	11	21	11	21	10	1	1	1	1	12
13	F	21	30	0	0	0	21	21	10	21	11	21	21	30	20	1	1	1	2	13
14	F	21	20	0	0	0	10	11	10	20	11	21	21	11	21	0	1	0	1	12
15	F	20	21	0	11	0	11	21	0	20	11	31	31	21	21	1	1	1	1	11
16	F	10	21	0	11	0	11	21	10	21	10	31	31	21	21	1	1	1	1	13
17	F	10	20	11	21	0	11	20	10	11	10	31	31	20	10	1	1	1	2	12
18	F	20	30	0	11	0	21	21	0	11	11	11	31	21	21	1	1	1	1	12
19	F	20	30	0	11	0	11	11	0	21	10	11	21	11	21	1	1	0	1	10
20	F	20	30	0	11	0	10	0	0	20	11	11	11	21	20	1	1	1	2	12
21	F	20	30	0	11	0	20	21	10	11	11	11	11	21	21	0	0	0	1	12
22	F	20	30	0	11	0	21	21	10	21	10	11	11	21	21	1	0	1	1	13
23	F	20	30	0	11	0	11	20	10	20	11	11	31	20	11	1	1	1	1	13
24	F	21	11	0	21	0	11	11	11	21	10	0	31	20	20	1	1	1	1	14
25	F	11	21	0	0	0	21	21	10	20	0	0	31	21	20	1	1	1	2	12
26	F	20	31	0	0	0	10	11	10	20	10	0	31	21	21	1	1	1	1	13
27	F	20	30	0	0	0	10	11	0	21	10	0	31	21	21	1	1	1	2	12
28	F	20	30	0	0	0	10	20	0	11	10	0	30	21	20	1	1	1	1	11
29	F	20	30	11	21	0	21	21	10	11	10	0	30	21	21	1	1	0	1	11
30	F	20	30	11	21	0	21	0	10	21	11	11	21	21	20	1	1	1	2	12
31	F	20	30	0	21	0	11	11	10	20	11	11	11	21	20	1	1	1	1	10
32	F	20	30	31	30	20	20	21	10	11	11	30	30	11	11	1	1	1	2	12
33	F	20	30	41	30	11	20	21	10	21	11	30	30	21	10	1	1	1	2	11
34	F	20	30	51	31	11	20	20	10	21	10	30	30	21	11	1	1	1	1	12
35	F	20	30	60	30	11	20	21	11	21	10	30	30	11	20	1	1	1	1	11
36	F	20	30	11	21	0	11	11	11	11	11	31	30	21	21	1	1	0	1	12
37	F	20	20	0	11	0	11	11	0	20	10	21	21	21	21	1	1	1	1	12
38	F	20	30	0	11	0	11	21	10	21	11	11	11	21	21	1	1	1	1	11
39	F	20	30	0	11	0	10	21	11	20	11	11	11	20	10	1	1	1	2	13
40	F	20	30	0	21	0	10	0	11	20	10	11	11	21	21	1	1	1	1	10
41	F	20	30	0	11	0	10	20	10	21	11	11	11	20	21	1	1	1	1	12
42	F	20	30	0	21	0	10	21	10	11	10	11	11	21	20	1	1	0	2	11
43	F	20	31	0	11	0	10	11	10	11	0	11	30	21	21	1	1	1	1	12
44	F	20	31	0	0	0	20	11	10	21	10	30	30	21	21	1	1	1	1	11
45	F	20	30	0	0	0	20	11	10	20	10	30	31	20	11	1	1	1	1	11
46	F	20	30	0	0	0	20	11	10	11	10	30	31	30	20	1	1	1	2	12
47	F	20	20	0	0	0	10	11	10	21	10	30	30	21	20	1	0	0	1	12
48	F	20	30	0	0	0	20	20	10	20	11	31	30	21	21	1	1	1	1	11
49	F	20	30	0	0	0	20	21	10	21	11	31	30	11	21	1	1	1	1	10
50	F	20	30	0	0	0	20	20	10	20	11	30	21	20	20	1	1	1	2	13
51	F	20	30	0	0	0	20	21	10	20	11	30	11	21	21	1	0	1	1	12
52	F	20	30	0	11	0	11	20	10	21	10	11	21	21	20	1	1	1	2	12
53	F	20	30	0	0	0	10	11	10	11	10	21	21	21	20	1	1	1	1	11
54	F	20	30	0	0	0	20	11	0	11	11	21	31	21	21	1	0	1	1	12
55	F	20	30	0	0	0	10	11	11	21	10	21	31	20	11	1	1	1	1	13
56	F	20	31	0	0	0	20	20	10	20	11	31	31	30	10	1	1	1	1	12
57	F	20	31	0	11	0	20	20	10	11	11	31	31	11	20	1	1	1	1	12
58	F	20	30	0	11	0	21	0	10	21	10	31	21	11	21	0	0	1	1	12
59	F	20	30	11	21	11	21	21	11	21	10	11	11	21	21	0	1	1	1	12
60	F	20	30	21	31	21	21	20	10	20	10	11	11	21	21	1	1	1	1	11
61	F	21	30	21	21	21	21	21	10	20	10	11	11	21	11	1	1	1	2	13
62	F	21	30	31	21	20	20	20	10	21	10	30	31	30	21	1	1	1	1	10
63	F	20	30	41	11	11	21	20	10	20	10	30	31	30	21	1	1	1	0	12
64	F	21	30	41	21	21	21	21	10	20	10	30	31	21	20	0	1	1	2	11
65	F	10	30	41	31	21	20	21	11	20	10	30	31	21	21	1	0	0	1	13
66	F	10	30	31	31	0	11	21	10	21	10	30	31	30	21	1	1	1	1	12
67	F	20	30	21	31	0	11	11	10	11	10	30	30	21	21	1	0	1	2	11
68	F	20	30	0	11	0	11	21	10	0	11	11	30	21	21	1	0	1	1	11
69	F	20	30	11	21	0	11	21	10	0	10	11	21	21	21	1	1	1	1	9
70	F	20	10	11	21	0	11	21	10	0	0	11	21	21	21	1	1	1	1	12
71	F	20	30	11	21	0	10	11	10	0	10	21	21	21	21	1	1	1	1	11

Pup No	Scores Periodic Table Q1 a	b	c	d	e	f	Q2 a	b	c	d	Q3 a	b	c	d	Q4 a	b	c	Q 5	Total	Total %
1	1	1	0.7	1	0.5	1	0.5	0.6	0.5	0.6	0.4	0.4	0.7	1	1	1	1	2	18.5	74
2	0.5	0.8	0.5	1	0	0.5	0	1	0	0	1	0.7	0.8	0.5	1	1	1	1	15.2	61
3	0.5	0.7	0.9	0.7	0.5	0.7	0	1	0.5	0.6	1	1	0.4	1	1	1	1	1	17.7	71
4	0	1	0	0	0	0.5	0	1	1	1	1	1	0.4	1	1	1	1	1	15.9	64
5	1	0.8	0	0	0	0.7	0	1	0.7	0	1	0.8	0.4	1	1	1	1	1	14.9	60
6	0.5	1	0	0	0	0.5	1	1	0	1	0.8	0.8	0.4	1	1	1	1	2	17.6	70
7	1	1	0	0	0	0	0	0.6	0	1	0.8	1	0.4	0.7	1	1	1	1	14.4	58
8	1	1	0.5	0.4	0	0.7	0	1	0.7	1	1	1	0.4	1	1	1	1	1	18.0	72
9	0.5	0.4	0	0.4	0	0	0.7	1	1	1	1	1	1	1	1	1	1	1	16.3	65
10	1	0.7	0	0	0	0	0	0.6	0	0.6	0	0.4	0.4	1	1	1	1	1	12.3	49
11	1	0.3	0	0.8	0	0	1	1	0.7	0.6	0.4	0	0.4	1	1	1	1	1	14.8	59
12	0.7	1	0	0	0	0.5	1	1	1	0.6	0.4	0.4	1	0.5	1	1	1	1	16.1	64
13	0.7	1	0	0	0	0.7	0.7	1	0.7	0.6	0.4	0.4	0	1	1	1	1	2	16.4	66
14	0.7	0.7	0	0	0	0.5	0	1	1	1	0.8	0.8	0.4	0.7	0	1	0	1	13.4	54
15	1	0.4	0	0	0	0	0.7	0	1	1	0.8	0.8	0.4	0.7	1	1	1	1	14.3	57
16	0.5	0.4	0	0	0	0	0.7	1	0.7	0.6	0.8	0.8	0.7	0.7	1	1	1	1	15.0	60
17	0.5	0.7	0	0.4	0	0	1	1	0	1	0	0.8	0.4	0.5	1	1	1	2	15.2	61
18	1	1	0	0	0	0.7	0.7	0	0	0.6	0	0.4	0	0.7	1	1	1	1	13.0	52
19	1	1	0	0	0	0	0	0	0.7	0.6	0	0	0.4	0.7	1	1	0	1	10.7	43
20	1	1	0	0	0	0.5	0	0	1	1	0	0	0.4	1	1	1	1	2	14.9	60
21	1	1	0	0	0	1	0.7	1	0	0.6	0	0	0.4	0.7	0	0	0	1	11.3	45
22	1	1	0	0	0	0.7	0.7	1	0.7	1	0	0.8	0.7	0.7	1	0	1	1	15.4	62
23	1	1	0	0	0	0	1	1	1	0	0	0.8	0.7	0	1	1	1	1	14.8	59
24	0.7	0	0	0.4	0	0	0	0.6	0.7	1	0	0.8	0.4	1	1	1	1	1	14.2	57
25	0	0.4	0	0	0	0.7	0.7	1	1	1	0	0.8	0.4	1	1	1	1	2	15.9	64
26	1	0.8	0	0	0	0.5	0	1	1	1	0	0.8	0.4	0.7	1	1	1	1	15.4	62
27	1	1	0	0	0	0.5	0	0	0.7	1	0	1	0.4	0.7	1	1	1	2	15.2	61
28	1	1	0	0	0	0.5	1	0	0	0.6	0	1	0.4	1	1	1	1	1	14.2	57
29	1	1	0	0.4	0	0.7	0.7	1	0	0.6	0	0.4	0.4	0.7	1	1	0	1	13.5	54
30	1	1	0	0.4	0	0.7	0	1	0.7	0.6	0	0	0.4	1	1	1	1	2	15.7	63
31	1	1	0	0.4	0	0	0	1	1	0.6	1	1	0	1	1	1	1	1	15.3	61
32	1	1	0.3	1	1	1	0.7	1	0	1	1	1	0.4	0	1	1	1	2	19.4	77
33	1	1	0.5	1	0	1	0.7	1	0.7	1	1	1	0.4	0.5	1	1	1	2	19.4	78
34	1	1	0.7	0.8	0	1	1	1	0.7	0.6	1	1	0	0	1	1	1	1	17.7	71
35	1	1	1	1	0	1	0.7	0.6	0.7	1	0.8	1	0.4	1	1	1	1	1	18.8	75
36	1	1	0	0.4	0	0	0	0.6	0	0.6	0.4	0.4	0.4	0.7	1	1	0	1	12.5	50
37	1	0.7	0	0	0	0	0	0	1	0.6	0	0	0.4	0.7	1	1	1	1	12.3	49
38	1	1	0	0	0	0	0.7	1	0.7	1	0	0	0.7	0.7	1	1	1	1	14.3	57
39	1	1	0	0	0	0.5	0.7	0.6	1	0.6	0	0	0.4	0.5	1	1	1	2	15.6	62
40	1	1	0	0.4	0	0.5	0	0.6	1	1	0	0	0.7	0.7	1	1	1	1	14.2	57
41	1	1	0	0	0	0.5	1	1	0.7	0	0	0	0.4	0.7	1	1	1	1	14.2	57
42	1	1	0	0.4	0	0.5	0.7	1	0	1	0	1	0.4	1	1	1	0	2	15.6	63
43	1	0.8	0	0	0	0.5	0	1	0	1	1	1	0.4	0.7	1	1	1	1	15.3	61
44	1	0.8	0	0	0	1	0	1	0.7	1	1	0.8	0.7	0.7	1	1	1	1	16.2	65
45	1	1	0	0	0	1	0	1	1	1	1	0.8	1	0	1	1	1	1	16.4	66
46	1	1	0	0	0	1	0	1	0	0.6	1	1	0.4	1	1	1	1	2	17.0	68
47	1	0.7	0	0	0	0.5	0	1	0.7	0.6	0.8	1	0.4	1	1	0	0	1	13.6	54
48	1	1	0	0	0	1	1	1	1	0.6	0.8	1	0	0.7	1	1	1	1	16.7	67
49	1	1	0	0	0	1	0.7	1	0.7	0.6	1	0.4	0.7	0.7	1	1	1	1	16.0	64
50	1	1	0	0	0	1	1	1	1	1	1	0	0.4	1	1	1	1	2	18.7	75
51	1	1	0	0	0	1	0.7	1	1	1	0	0.4	0.4	0.7	1	0	1	1	15.1	61
52	1	1	0	0	0	0	1	1	0.7	0.6	0.4	0.4	0.4	1	1	1	1	2	16.5	66
53	1	1	0	0	0	0.5	0	1	0	1	0.4	0.8	0.4	1	1	1	1	1	14.7	59
54	1	1	0	0	0	1	0	0	0	0.6	0.4	0.8	0.7	0.7	1	0	1	1	13.1	52
55	1	1	0	0	0	0.5	0	0.6	0.7	0.6	0.8	0.8	1	0	1	1	1	1	15.2	61
56	1	0.8	0	0	0	1	1	1	1	1	0.8	0.8	0	0.5	1	1	1	1	16.8	67
57	1	0.8	0	0	0	1	1	1	0	1	0.8	0.4	0	1	1	1	1	1	15.9	64
58	1	1	0	0	0	0.7	0	1	0.7	1	0	0	0.4	0.7	0	0	1	1	12.4	50
59	1	1	0	0.4	0	0.7	0.7	0.6	0.7	1	0	0	0.4	0.7	0	1	1	1	14.1	56
60	1	1	0	0.8	0.7	0.7	1	1	1	1	0	0	0.4	0.7	1	1	1	1	16.8	67
61	0.7	1	0	0.4	0.7	0.7	0.7	1	1	1	1	0.8	1	0	1	1	1	2	19.2	77
62	0.7	1	0.3	0.4	1	1	1	1	0.7	1	1	0.8	1	0.7	1	1	1	1	18.8	75
63	1	1	0.5	0	0	0.7	1	1	1	1	1	0.8	0.4	0.7	1	1	1	0	17.0	68
64	0.7	1	0.5	0.4	0.7	0.7	0.7	1	1	1	1	0.8	0.4	1	0	1	1	2	18.4	74
65	0.5	1	0.5	0.8	0.7	1	0.7	0.6	1	1	1	0.8	1	0.7	1	0	0	1	17.4	70
66	0.5	1	0.3	0.8	0	0	0.7	1	0.7	0.6	1	1	0.4	0.7	1	1	1	1	16.6	66
67	1	1	0	0.8	0	0	0	1	0	1	0	1	0.4	0.7	1	0	1	2	14.5	58
68	1	1	0	0	0	0	0.7	1	0	0	0	0.4	0.4	0.7	1	0	1	1	11.8	47
69	1	1	0	0.4	0	0	0.7	1	0	1	0	0.4	0.4	0.7	1	1	1	1	13.5	54
70	1	0.3	0	0.4	0	0	0.7	1	0	1	0.4	0.4	0.4	0.7	1	1	1	1	14.3	57
71	1	1	0	0.4	0	0.5	0	1	0	1	0	0.4	0.4	0.7	1	1	1	1	14.0	56

72	F	20	30	11	21	0	10	11	10	0	10	11	21	21	20	1	1	1	1	11	1	1	0	0.4	0	0.5	0	1	0	1	0.4	0.4	0.4	1	1	1	1	1	14.8	59
73	F	20	30	21	31	11	21	11	11	11	10	21	21	21	11	1	1	0	1	11	1	1	0	0.8	0	0.7	0	0.6	0	0.6	0.4	0.4	0	0	1	1	0	1	12.1	48
74	F	20	31	21	31	11	21	11	11	11	10	21	21	11	20	1	1	1	1	11	1	0.8	0	0.8	0	0.7	0	0.6	0	0.6	0.8	1	0.4	1	1	1	1	1	15.2	61
75	F	20	30	31	30	21	21	11	11	11	11	31	30	21	11	1	1	1	1	11	1	1	0.3	1	0.7	0.7	0	0.6	0	0.6	0.4	1	0.4	0	1	1	1	1	15.3	61
76	F	20	30	21	30	21	20	20	10	20	11	21	30	21	10	1	1	1	2	10	1	1	0	1	0.7	1	1	1	1	0.6	0	0.4	0.4	0.5	1	1	1	2	17.9	72
77	F	20	30	0	11	0	11	21	10	20	11	11	21	21	10	1	1	1	1	11	1	1	0	0	0	0	0.7	1	1	1	0	0.4	0.4	0.5	1	1	1	1	14.6	59
78	F	20	30	0	11	0	11	21	10	21	11	11	21	21	20	1	1	1	2	12	1	1	0	0	0	0	0.7	1	0.7	1	0	0.4	0.4	1	1	1	1	2	16.1	65
79	F	20	30	0	21	0	11	11	10	20	10	11	21	21	10	1	1	1	1	11	1	1	0	0.4	0	0	0	1	1	0.6	0	0	0.4	0.5	1	1	1	1	13.6	54
80	F	20	30	0	11	0	11	11	10	20	10	0	11	21	20	1	1	1	2	11	1	1	0	0	0	0	0	1	1	1	0	0	0.7	1	1	1	1	2	15.3	61
81	F	20	30	0	11	0	10	11	10	21	11	0	11	20	20	1	1	1	1	11	1	1	0	0	0	0.5	0	1	0.7	0.6	0	0	0.7	1	1	1	1	1	14.1	56
82	F	20	30	0	21	0	10	0	10	11	10	0	11	20	20	1	1	0	1	11	1	1	0	0.4	0	0.5	0	1	0	0.6	0	1	0.4	1	1	1	0	1	13.6	54
83	F	20	30	0	11	0	10	0	10	11	11	0	30	21	10	1	1	1	1	9	1	1	0	0	0	0.5	0	1	0	1	0	1	0.4	0.5	1	1	1	1	13.4	54
84	F	20	30	0	11	0	10	0	10	21	11	0	30	21	10	1	1	1	1	11	1	1	0	0	0	0.5	0	1	0.7	1	0	0.8	0.7	0.5	1	1	1	1	14.8	59
85	F	20	30	0	0	0	10	0	10	20	10	0	31	20	20	1	1	1	1	12	1	1	0	0	0	0.5	0	1	1	1	1	0.8	0.4	1	1	1	1	1	16.7	67
86	F	20	30	21	30	21	20	20	10	11	10	30	31	21	20	1	1	1	1	11	1	1	0	1	0.7	1	1	1	0	1	1	1	0.4	1	1	1	1	1	18.7	75
87	F	20	30	21	31	21	20	20	10	21	10	30	30	21	10	1	1	1	1	12	1	1	0	0.8	0.7	1	1	1	0.7	1	1	1	0.4	0.5	1	1	1	1	19.0	76
88	F	20	21	11	21	11	21	21	11	11	10	30	30	21	10	1	1	1	2	12	1	0.4	0	0.4	0	0.7	0.7	0.6	0	1	1	1	0.4	0.5	1	1	1	2	16.6	67
89	F	20	30	11	21	0	11	21	10	11	10	30	30	21	21	1	1	1	1	12	1	1	0	0.4	0	0	0.7	1	0	1	1	0.4	0.4	0.7	1	1	1	1	15.5	62
90	F	20	30	11	21	0	11	21	11	11	10	30	21	21	21	1	1	1	1	11	1	1	0	0.4	0	0	0.7	0.6	0	0	1	0	1	0.7	1	1	1	1	14.0	56
91	F	20	30	11	11	0	11	11	11	11	10	30	11	30	21	1	1	1	1	12	1	1	0	0	0	0	0	0.6	0	0.6	1	0.4	1	0.7	1	1	1	1	14.3	57
92	F	20	30	31	21	0	11	11	0	11	0	30	21	30	20	1	1	1	1	13	1	1	0.3	0.4	0	0	0	0	0	1	0	0.4	0.4	1	1	1	1	1	13.8	55
93	F	20	21	11	21	0	11	20	10	20	11	11	21	21	11	1	1	1	0	12	1	0.4	0	0.4	0	0	1	1	1	0	0	0.8	0.4	0	1	1	1	0	13.0	52
94	F	20	20	0	11	0	11	21	10	21	10	11	31	21	20	1	1	1	1	10	1	0.7	0	0	0	0	0.7	1	0.7	1	0	0.8	0	1	1	1	1	1	14.1	56
95	F	20	30	0	21	0	11	21	10	20	0	11	31	11	20	1	1	1	1	11	1	1	0	0.4	0	0	0.7	1	1	1	0	0.8	0.4	1	1	1	1	1	15.9	64
96	F	20	30	0	21	0	11	21	10	20	10	11	31	21	21	1	1	1	1	10	1	1	0	0.4	0	0	0.7	1	1	1	0	0.8	0.4	0.7	1	1	1	1	15.2	61
97	F	20	30	0	21	0	11	21	10	21	10	11	31	21	21	1	1	1	1	11	1	1	0	0.4	0	0	0.7	1	0.7	1	0	0.4	0.7	0.7	1	1	1	1	15.1	61
98	F	20	30	0	11	0	21	21	10	11	10	11	21	20	10	1	1	0	1	11	1	1	0	0	0	0.7	0.7	1	0	0.6	0	0	0.7	0.5	1	1	0	1	12.8	51
99	F	20	30	0	11	0	21	20	10	11	10	0	11	20	21	1	1	0	2	11	1	1	0	0	0	0.7	1	1	0	0.6	0	0	0.8	0.7	1	1	0	2	14.4	57
100	F	20	30	0	31	0	21	20	10	21	11	0	11	31	20	1	0	1	1	11	1	1	0	0.8	0	0.7	1	1	0.7	0.6	0	0	1	1	1	0	1	1	15.4	61
101	M	20	30	0	11	0	21	20	10	20	11	0	11	30	21	1	1	1	1	13	1	1	0	0	0	0.7	1	1	1	0.6	0	0.8	1	0.7	1	1	1	1	17.0	68
102	M	20	30	0	0	0	11	21	10	11	11	0	31	30	11	1	0	1	1	11	1	1	0	0	0	0	0.7	1	0	1	0	0.8	1	0	1	0	1	1	13.1	52
103	M	20	31	0	0	0	10	11	11	21	11	0	31	30	10	1	1	1	2	12	1	0.8	0	0	0	0.5	0	0.6	0.7	1	1	0.8	0.4	0.5	1	1	1	2	16.2	65
104	M	20	31	41	30	20	20	21	10	20	10	30	31	21	20	1	1	1	1	9	1	0.8	0.5	1	1	1	0.7	1	1	0.6	0.4	0.8	0.4	1	1	1	1	1	18.1	72
105	M	20	10	11	21	11	21	21	11	21	10	21	31	21	20	1	0	1	1	9	1	0.3	0	0.4	0	0.7	0.7	0.6	0.7	1	0	0.8	0.4	1	1	0	1	1	13.5	54
106	M	20	21	11	21	0	21	11	11	11	11	11	31	21	10	0	1	1	1	11	1	0.4	0	0.4	0	0.7	0	0.6	0	0.6	0	1	0	0.5	0	1	1	1	11.8	47
107	M	20	11	0	11	0	21	11	0	11	10	11	30	11	10	1	1	1	1	10	1	0	0	0	0	0.7	0	0	0	0.6	0	1	0	0.5	1	1	1	1	11.1	44
108	M	20	31	0	11	0	11	11	10	11	11	0	30	11	10	1	0	1	1	11	1	0.8	0	0	0	0	0	1	0	1	0	0	0.4	0.5	1	0	1	1	11.3	45
109	M	20	30	0	0	0	11	11	10	11	11	0	0	21	20	1	1	1	1	10	1	1	0	0	0	0	0	1	0	0	0	0.8	1	1	1	1	1	1	13.1	52
110	M	20	21	0	0	0	10	0	10	0	10	0	31	30	10	1	1	0	1	11	1	0.4	0	0	0	0.5	0	1	0	1	0	1	0.7	0.5	1	1	0	1	12.7	51
111	M	20	30	11	0	0	10	0	10	0	0	0	30	20	10	1	1	1	2	12	1	1	0	0	0	0.5	0	1	0	1	1	1	0.4	0.5	1	1	1	2	16.4	66
112	M	20	30	21	31	11	21	20	10	20	10	30	30	21	20	1	1	0	1	12	1	1	0	0.8	0	0.7	1	1	1	1	1	1	0.4	1	1	1	0	1	17.8	71
113	M	20	30	11	21	11	21	21	10	20	10	30	30	21	20	1	1	1	1	13	1	1	0	0.4	0	0.7	0.7	1	1	1	1	0.4	0.4	1	1	1	1	1	17.9	71
114	M	20	30	31	30	21	20	20	10	20	10	30	21	21	10	1	1	1	2	11	1	1	0.3	1	0.7	1	1	1	1	1	1	0.4	0.4	0.5	1	1	1	2	19.9	80
115	M	20	30	41	21	11	21	21	11	20	10	30	21	21	11	1	1	1	1	12	1	1	0.5	0.4	0	0.7	0.7	0.6	1	1	1	0.4	0.4	0	1	1	1	1	16.6	67
116	M	20	31	31	30	20	20	20	10	20	10	30	21	21	20	1	1	1	0	13	1	0.8	0.3	1	1	1	1	1	1	1	1	0.8	0.4	1	1	1	1	0	19.5	78
117	M	20	20	21	31	11	20	20	10	20	10	30	31	21	21	1	1	1	2	12	1	0.7	0	0.8	0	1	1	1	1	1	1	0.4	0.4	0.7	1	1	1	2	18.9	76
118	M	20	10	11	21	0	21	21	11	20	10	30	21	21	20	1	1	1	1	12	1	0.3	0	0.4	0	0.7	0.7	0.6	1	1	1	1	0.4	1	1	1	1	1	17.1	68
119	M	20	30	21	31	11	21	20	10	20	10	30	30	21	20	1	0	1	2	12	1	1	0	0.8	0	0.7	1	1	1	1	1	1	0.4	1	1	0	1	2	18.8	75
120	M	20	30	31	30	20	20	20	10	21	10	30	30	21	21	1	1	1	1	12	1	1	0.3	1	1	1	1	1	0.7	1	0	0.4	0.4	0.7	1	1	1	1	18.4	74
121	M	20	30	21	31	21	20	20	10	21	10	11	21	21	10	1	1	1	1	12	1	1	0	0.8	0.7	1	1	1	0.7	0.6	0.4	0.4	0.4	0.5	1	1	1	1	17.4	70
122	M	20	30	11	21	0	11	21	11	11	10	21	21	21	10	1	1	1	1	10	1	1	0	0.4	0	0	0.7	0.6	0	0.6	0.4	0.4	0.4	0.5	1	1	1	1	13.3	53
123	M	20	30	11	21	0	11	11	11	20	11	21	21	21	11	1	1	0	1	11	1	1	0	0.4	0	0	0	0.6	1	0	0.4	0	0.4	0	1	1	0	1	11.5	46
124	M	20	30	11	31	0	11	11	11	21	11	21	11	21	20	1	1	1	1	10	1	1	0	0.8	0	0	0	0.6	0.7	0.6	0	0	0.4	1	1	1	1	1	13.4	53
125	M	20	30	11	21	0	11	20	10	20	0	11	11	21	20	1	1	0	0	11	1	1	0	0.4	0	0	1	1	1	1	0	0	0.4	1	1	1	0	0	13.5	54
126	M	20	30	0	21	0	11	21	11	20	11	11	11	21	20	1	1	1	2	11	1	1	0	0.4	0	0	0.7	0.6	1	0	0	0	0.7	1	1	1	1	2	15.0	60
127	M	20	30	0	11	0	11	11	11	21	10	11	11	20	21	1	1	1	1	11	1	1	0	0	0	0	0	0.6	0.7	1	0	0	0.3	0.7	1	1	1	1	12.9	52
128	M	20	30	0	11	0	11	11	10	11	0	11	11	10	20	1	1	1	1	11	1	1	0	0	0	0	0	1	0	1	0	0	0.4	1	1	1	1	1	13.1	52
129	M	20	30	0	11	0	11	0	11	11	10	11	11	21	20	1	1	1	2	13	1	1	0	0	0	0	0	0.6	0	1	1	0	0.7	1	1	1	1	2	15.6	62
130	M	20	30	0	21	0	11	20	11	21	10	30	11	20	20	1	1	1	1	13	1	1	0	0.4	0	0	1	0.6	0.7	1	1	0	0.4	1	1	1	1	1	16.4	66
131	M	20	21	0	0	0	11	11	10	20	10	30	11	21	10	1	1	1	1	11	1	0.4	0	0	0	0	0	1	1	0.6	1	1	0.4	0.5	1	1	1	1	14.6	58
132	M	20	20	0	0	0	10	11	10	11	10	30	30	21	11	1	1	1	2	12	1	0.7	0	0	0	0.5	0	1	0	0.6	1	1	0.4	0	1	1	1	2	15.2	61
133	M	20	30	0	0	0	20	21	11	21	11	30	30	21	20	1	1	1	1	14	1	1	0	0	0	1	0.7	0.6	0.7	0.6	0.8	0.8	0.7	1	1	1	1	1	17.4	70
134	M	20	30	0	0	0	20	11	11	20	11	31	31	20	21	1	1	1	1	11	1	1	0	0	0	1	0	0.6	1	0.6	0.8	0.8	0.7	0.7	1	1	1	1	15.7	63
135	M	20	30	0	0	0	20	20	10	21	11	31	31	20	21	1	1	1	1	10	1	1	0	0	0	1	1	1	0.7	1	1	1	0.8	0.7	1	1	1	1	17.4	70
136	M	20	30	11	21	0	20	20	10	20	11	30	30	31	20	1	1	1	2	11	1	1	0	0.4	0	1	1	1	1	1	1	1	0.7	1	1	1	1	2	19.7	79
137	M	20	30	11	31	0	11	21	11	20	10	30	30	20	21	1	0	1	1	9	1	1	0	0.8	0	0	0.7	0.6	1	0.6	0	1	0	0.7	1	0	1	1	13.3	53
138	M	20	30	11	21	0	10	11	11	21	10	11	30	11	20	1	1	1	1	12	1	1	0	0.4	0	0.5	0	0.6	0.7	1	0.4	0.4	0.7	1	1	1	1	1	15.6	63
139	M	20	30	11	21	0	21	21	11	11	11	21	21	20	20	0	1	1	1	13	1	1	0	0.4	0	0.7	0.7	0.6	0	0.6	0.4	0	0.7	1	0	1	1	1	14.3	57
140	M	20	30	0	21	0	11	21	10	11	10	21	11	20	11	1	1	1	1	11	1	1	0	0.4	0	0	0.7	1	0	0.6	0.4	0.4	0.4	0	1	1	1	1	13.5	54
141	M	20	30	0	11	0	11	20	10	21	11	21	21	21	11	1	1	1	1	12	1	1	0	0	0	0	1	1	0.7	1	0.8	0.4	0.4	0	1	1	1	1	15.2	61
142	M	20	30	0	0	0	11	21	11	20	11	31	21	21	11	1	1	1	1	11	1	1	0	0	0	0	0.7	0.6	1	0	0.8	0.8	0.7	0	1	1	1	1	14.1	56
143	M	20	31	11	21	0	11	11	11	11	10	31	31	20	10	1	1	1	1	11	1	0.8	0	0.4	0	0	0	0.6	0	1	0.8	0.8	0.7	0.5	1	1	1	1	14.1	56
144	M	20	30	11	31	11	21	0	0	21	0	31	31	20	21	1	1	1	1	10	1	1	0	0.8	0	0.7	0	0	0.7	1	0	0.8	0.4	0.7	1	1	1	1	14.2	57
145	M	20	30	21	30	21	20	21	10	20	10	11	31	21	21	1	1	1	1	12	1	1	0	1	0.7	1	0.7	1	1	1	0	0.8	0.4	0.7	1	1	1	1	18.2	73
146	M	20	30	31	30	11	20	21	10	20	10	11	31	21	21	1	1	1	1	12	1	1	0.3	1	0	1	0.7	1	1	0.6	0	0.4	1	0.7	1	1	1	1	17.6	71
147	M	20	31	11	21	0	11	20	0	11	10	11	21	30	11	1	1	1	2	13	1	0.8	0	0.4	0	0	1	0	0	0.6	0.4	0	0.4	0	1	1	1	2	13.9	56
148	M	20	30	11	21	0	11	11	10	20	11	21	11	21	21	1	1	0	1	12	1	1	0	0.4	0	0	0	1	1	1	0	0	0.4	0.7	1	1	0	1	13.5	54
149	M	20	30	11	21	0	10	21	11	21	11	11	11	21	21	1	1	0	1	11	1	1	0	0.4	0	0.5	0.7	0.6	0.7	0	0	0	0	0.7	1	1	0	1	12.2	49
150	M	20	30	0	11	0	21	11	11	20	10	11	11	11	20	1	1	0	1	9	1	1	0	0	0	0.7	0	0.6	1	1	0	0.8	0	1	1	1	0	1	13.0	52

151	M	20	30	0	11	0	11	11	10	20	0	11	31	11	21	1	1	0	0	8	1	1	0	0	0	0	0	1	1	1	0	0.8	0.7	0.7	1	1	0	0	11.8	47
152	M	20	20	0	11	0	10	20	10	21	10	0	31	20	21	1	1	0	2	11	1	0.7	0	0	0	0.5	1	1	0.7	1	0	0.8	0	0.7	1	1	0	2	14.9	60
153	M	20	21	0	11	0	11	20	11	11	10	0	31	11	11	1	1	0	1	11	1	0.4	0	0	0	0	1	0.6	0	1	0	0.8	0	0	1	1	0	1	11.4	46
154	M	20	30	0	11	0	10	21	11	11	10	0	31	11	10	1	1	1	1	11	1	1	0	0	0	0.5	0.7	0.6	0	0.6	0	0.8	0.4	0.5	1	1	1	1	13.7	55
155	M	20	30	0	11	0	10	21	10	21	10	0	31	21	21	1	1	1	2	12	1	1	0	0	0	0.5	0.7	1	0.7	0.6	0	1	0.7	0.7	1	1	1	2	16.8	67
156	M	20	30	0	0	0	20	20	10	20	11	0	30	20	21	0	1	1	1	11	1	1	0	0	0	1	1	1	1	0.6	0	1	0.4	0.7	0	1	1	1	15.3	61
157	M	20	30	11	21	0	20	21	11	11	11	0	30	21	10	0	1	1	1	11	1	1	0	0.4	0	1	0.7	0.6	0	0.6	0	0	0.4	0.5	0	1	1	1	12.8	51
158	M	20	30	11	21	0	11	11	11	21	11	11	0	21	10	1	1	1	1	12	1	1	0	0.4	0	0	0	0.6	0.7	1	0.4	0	0.7	0.5	1	1	1	1	14.2	57
159	M	20	30	11	21	0	10	11	11	11	11	21	0	20	10	0	1	1	2	13	1	1	0	0.4	0	0.5	0	0.6	0	1	0	0.8	0.4	0.5	0	1	1	2	14.5	58
160	M	20	30	11	31	0	10	21	10	0	10	11	31	21	10	1	1	1	1	12	1	1	0	0.8	0	0.5	0.7	1	0	0.6	0	0.8	0.8	0.5	1	1	1	1	15.5	62
161	M	20	30	0	21	0	11	20	10	0	10	11	31	31	20	1	1	1	2	12	1	1	0	0.4	0	0	1	1	0	1	0	0	0.8	1	1	1	1	2	16.2	65
162	M	20	30	0	11	0	11	21	11	0	11	11	0	31	20	0	1	1	1	12	1	1	0	0	0	0	0.7	0.6	0	0.6	0	0	0	1	0	1	1	1	11.9	47
163	M	20	30	0	11	0	11	21	11	0	10	11	0	0	20	1	1	1	2	12	1	1	0	0	0	0	0.7	0.6	0	0.6	0	0	0.7	1	1	1	1	2	14.5	58
164	M	20	30	0	0	0	11	20	0	0	11	11	0	20	10	0	1	1	1	12	1	1	0	0	0	0	1	0	0	1	1	1	0.4	0.5	0	1	1	1	13.9	56
165	M	20	31	31	30	20	20	20	10	20	11	30	30	21	20	1	1	1	2	13	1	0.8	0.3	1	1	1	1	1	1	1	0.4	0	0.4	1	1	1	1	2	20.2	81
166	M	20	31	31	31	21	20	21	10	20	10	21	11	21	20	1	1	1	1	10	1	0.8	0.3	0.8	0.7	1	0.7	1	1	1	0.4	0.4	0.4	1	1	1	1	1	17.7	71
167	M	20	20	21	31	21	20	21	10	20	10	21	21	21	11	1	1	1	1	12	1	0.7	0	0.8	0.7	1	0.7	1	1	1	1	0.4	0.4	0	1	1	1	1	17.6	70
168	M	20	30	21	21	11	20	20	10	20	10	30	21	21	11	1	1	1	1	10	1	1	0	0.4	0	1	1	1	1	1	1	0.4	1	0	1	1	1	1	17.1	69
169	M	20	30	11	21	11	20	20	10	20	10	30	21	30	20	1	1	1	2	12	1	1	0	0.4	0	1	1	1	1	1	1	1	0.4	1	1	1	1	2	19.8	79
170	M	20	30	11	21	21	21	21	11	20	10	30	30	21	10	1	1	1	1	12	1	1	0	0.4	0.7	0.7	0.7	0.6	1	1	1	1	0.4	0.5	1	1	1	1	17.9	72
171	M	20	30	11	31	11	21	21	10	21	10	30	30	21	10	1	1	1	1	12	1	1	0	0.8	0	0.7	0.7	1	0.7	1	1	1	0.4	0.5	1	1	1	1	17.7	71
172	M	20	30	41	30	20	20	21	10	20	10	30	30	21	20	1	1	1	1	12	1	1	0.5	1	1	1	0.7	1	1	1	1	1	1	1	1	1	1	1	21.2	85
173	M	20	30	41	30	20	20	20	10	20	10	30	30	30	20	1	1	0	2	11	1	1	0.5	1	1	1	1	1	1	0	0.4	0.4	0.4	1	1	1	0	2	18.4	73
174	M	20	30	41	31	21	20	20	10	20	10	21	21	21	20	1	1	0	1	11	1	1	0.5	0.8	0.7	1	1	1	1	0	0	0	0.4	1	1	1	0	1	16.0	64
175	M	20	30	11	21	0	11	0	11	20	0	11	11	21	20	1	1	1	1	10	1	1	0	0.4	0	0	0	0.6	1	0	0	0	0	1	1	1	1	1	12.3	49
176	M	20	30	0	21	0	11	0	11	21	0	11	11	11	10	1	1	1	0	12	1	1	0	0.4	0	0	0	0.6	0.7	0	0	0	0	0.5	1	1	1	0	11.2	45
177	M	20	30	0	11	0	11	20	10	20	0	11	11	11	10	1	1	1	2	11	1	1	0	0	0	0	1	1	1	0	0	0	0	0.5	1	1	1	2	14.2	57
178	M	20	30	0	11	0	11	20	10	20	0	11	11	0	21	1	1	1	1	9	1	1	0	0	0	0	1	1	1	0	0	1	0.4	0.7	1	1	1	1	14.1	56
179	M	20	30	0	11	0	11	21	11	21	0	11	30	21	20	1	1	1	1	11	1	1	0	0	0	0	0.7	0.6	0.7	0	0	1	0.4	1	1	1	1	1	14.0	56
180	M	20	30	0	11	0	11	21	11	11	0	11	30	21	21	1	1	1	1	11	1	1	0	0	0	0	0.7	0.6	0	0	0	0.8	0	0.7	1	1	1	1	12.4	49
181	M	20	30	0	21	0	11	21	10	11	0	11	31	0	21	1	1	1	1	12	1	1	0	0.4	0	0	0.7	1	0	0	0	0.8	0	0.7	1	1	1	1	13.5	54
182	M	20	30	0	0	0	10	20	10	21	0	11	31	0	20	1	1	1	2	13	1	1	0	0	0	0.5	1	1	0.7	0	1	1	0.7	1	1	1	1	2	18.2	73
183	M	20	30	0	0	0	10	21	10	20	0	30	30	20	21	1	1	1	1	12	1	1	0	0	0	0.5	0.7	1	1	0	1	1	0.8	0.7	1	1	1	1	16.6	66
184	M	20	30	0	0	0	10	11	10	11	0	30	30	31	20	1	1	1	1	12	1	1	0	0	0	0.5	0	1	0	0	1	1	0.7	1	1	1	1	1	15.2	61
185	M	20	30	0	0	0	10	11	10	21	0	30	30	20	20	1	1	1	1	11	1	1	0	0	0	0.5	0	1	0.7	0	1	0.4	0	1	1	1	1	1	14.2	57
186	M	20	30	11	0	0	20	11	10	0	0	30	21	0	11	1	1	1	2	10	1	1	0	0	0	1	0	1	0	0	0.8	0	0.4	0	1	1	1	2	13.5	54
187	M	20	30	11	21	0	20	11	10	21	0	31	11	21	21	1	1	1	1	12	1	1	0	0.4	0	1	0	1	0.7	0	0.8	0.4	0.4	0.7	1	1	1	1	15.3	61
188	M	20	30	0	21	0	20	11	10	20	0	31	21	21	21	0	1	1	2	10	1	1	0	0.4	0	1	0	1	1	1	1	0.4	1	0.7	0	1	1	2	16.8	67
189	M	20	30	0	21	0	11	0	11	0	0	30	21	30	10	1	1	0	1	11	1	1	0	0.4	0	0	0	0.6	0	1	1	0.8	0.4	0.5	1	1	0	1	13.3	53
190	M	20	30	41	30	21	20	20	10	20	10	30	31	21	21	1	1	1	1	10	1	1	0.5	1	0.7	1	1	1	1	0	0	0.8	0.4	0.7	1	1	1	1	17.3	69
191	M	20	30	41	31	11	20	11	10	21	10	11	31	21	21	1	1	1	1	12	1	1	0.5	0.8	0	1	0	1	0.7	0	0.4	0.8	0.4	0.7	1	1	1	1	16.1	65
192	M	20	30	11	31	0	21	0	11	0	0	21	31	21	21	0	1	1	1	13	1	1	0	0.8	0	0.7	0	0.6	0	0	0.4	0.8	0.4	0.7	0	1	1	1	13.6	54
193	M	20	30	21	31	0	21	0	11	21	0	21	31	21	11	0	0	1	2	12	1	1	0	0.8	0	0.7	0	0.6	0.7	0	0.4	0.4	0	0	0	0	1	2	12.5	50
194	M	10	20	11	21	0	21	20	10	21	0	21	21	0	21	0	1	0	1	12	0.5	0.7	0	0.4	0	0.7	1	1	0.7	0	0.8	0	0	0.7	0	1	0	1	12.3	49
195	M	20	10	0	21	0	11	21	10	20	0	31	11	0	21	0	1	1	1	12	1	0.3	0	0.4	0	0	0.7	1	1	0	0.8	0	0	0.7	0	1	1	1	12.8	51
196	M	20	11	0	11	0	11	21	10	20	0	31	11	0	20	0	1	0	1	12	1	0	0	0	0	0	0.7	1	1	0.6	0.8	0	0.4	1	0	1	0	1	12.4	50
197	M	21	20	0	11	0	11	21	10	21	0	31	11	21	21	1	1	0	1	12	0.7	0.7	0	0	0	0	0.7	1	0.7	1	0	0.8	0.4	0.7	1	1	0	1	13.5	54
198	M	20	10	0	21	0	10	0	11	0	11	11	31	21	21	1	1	1	1	11	1	0.3	0	0.4	0	0.5	0	0.6	0	1	0	0.8	0.4	0.7	1	1	1	1	13.3	53
199	M	20	30	41	31	21	20	20	10	20	10	11	31	21	20	1	1	1	1	10	1	1	0.5	0.8	0.7	1	1	1	1	0	0	0.8	1	1	1	1	1	1	18.0	72
200	M	20	30	41	30	20	20	20	10	20	10	11	31	30	20	1	0	1	2	10	1	1	0.5	1	1	1	1	1	1	0	0	0	0	1	1	0	1	2	16.8	67
Mean Marks (/1)																				11	1.0	0.9	0.1	0.3	0.1	0.5	0.5	0.8	0.6	0.7	0.4	0.6	0.5	0.7	0.9	0.9	0.9	1.2	15.2	61.0
Mean Marks (%)																				60	95	89	7	32	11	48	50	83	57	70	43	55	45	69	91	92	86	60	61.0	61
Standard Deviation																				5.8	15	22	18	34	27	40	42	28	43	37	44	38	26	31	29	28	35	47	8.6	8.6

des and Scores for Test Materials-*Experiment.Group*

Periodic Table >>>>

Sex	Q1						Q2				Q3				Q4			Q	MM
	a	b	c	d	e	f	a	b	c	d	a	b	c	d	a	b	c	5	Mk
F	10	20	61	20	20	20	20	11	10	11	21	20	30	10	0	1	1	2	13
F	20	10	50	21	21	20	10	10	21	10	30	30	31	20	1	0	1	2	14
F	20	30	40	30	10	20	20	10	21	10	30	31	31	20	1	1	1	1	13
F	20	30	31	30	20	20	20	10	10	0	30	20	30	21	0	1	1	1	12
F	21	30	41	31	10	21	20	0	10	10	21	30	20	21	1	1	1	1	12
F	20	31	40	21	20	10	10	10	20	10	30	30	30	20	0	1	1	2	13
F	10	31	40	20	20	20	20	11	20	11	21	21	30	21	1	1	1	2	13
F	20	20	50	20	11	20	20	10	20	10	30	21	10	20	1	1	1	2	12
F	20	10	50	10	10	20	20	10	20	10	0	30	30	20	1	1	1	2	16
F	21	30	40	20	20	10	20	11	20	10	30	21	30	11	1	1	1	2	14
F	20	30	40	30	20	10	20	10	10	11	20	30	30	11	1	1	1	1	12
F	21	30	61	21	20	20	20	11	20	10	20	21	30	11	0	1	1	2	15
F	20	30	60	20	21	20	20	11	20	10	30	21	31	11	1	1	0	2	13
F	20	30	60	21	20	11	20	10	10	11	30	30	30	21	0	1	1	2	11
F	20	30	40	20	10	20	20	10	20	10	30	30	30	21	0	1	1	1	13
F	20	30	40	10	10	10	21	10	20	11	21	30	31	21	1	1	1	2	11
F	20	30	50	11	10	20	10	0	21	10	30	31	30	11	1	1	1	1	12
F	20	11	50	30	20	11	10	10	21	10	30	30	30	21	0	1	1	0	14
F	20	21	50	30	20	20	20	10	20	0	21	30	30	21	1	1	1	0	13
F	20	30	60	21	20	20	10	11	11	10	30	30	21	20	1	1	1	2	12
F	20	21	60	20	20	10	20	11	20	11	30	31	30	21	1	0	1	1	12
F	20	30	41	21	21	20	21	10	21	10	20	30	30	21	1	1	1	1	13
F	10	10	41	20	21	20	21	10	10	10	30	30	30	11	1	0	0	2	14
F	20	30	31	30	10	10	21	10	10	11	30	30	31	11	1	1	1	1	12
F	20	30	50	30	10	20	10	10	20	10	20	30	30	20	0	1	1	0	12
F	20	30	61	31	10	20	20	10	20	10	30	31	20	21	1	1	1	2	13
F	20	30	31	31	10	10	20	11	10	11	20	30	30	21	1	1	1	1	12
F	20	31	40	20	20	20	20	10	20	10	30	30	21	20	1	1	1	1	13
F	20	30	40	21	20	20	20	10	21	10	20	21	30	21	1	1	1	1	13
F	20	30	30	20	20	20	20	10	21	11	30	11	30	20	1	1	1	2	12
F	20	30	30	30	20	20	20	10	21	11	21	10	30	20	1	0	1	1	13
F	21	30	60	30	20	20	20	10	20	11	30	10	30	11	0	1	1	1	10
F	20	30	40	21	20	20	20	11	20	11	30	30	31	11	1	1	1	1	13
F	20	31	40	21	21	20	20	11	20	11	21	30	30	11	1	1	1	1	12
F	20	20	40	20	20	20	20	10	10	11	30	31	30	11	1	1	1	1	12
F	20	30	40	20	10	10	20	10	20	10	30	30	30	21	1	1	0	1	12
F	20	30	50	10	10	20	20	11	10	10	30	30	30	21	1	1	1	1	13
F	20	30	50	10	20	20	20	10	20	10	20	30	30	21	1	1	1	1	12
F	20	30	31	10	20	11	20	10	20	10	30	30	30	11	1	1	1	1	12
F	20	30	41	31	20	20	20	10	20	10	30	30	31	21	1	1	1	2	16
F	20	30	41	20	20	20	20	0	20	10	20	30	30	21	1	1	1	0	17
F	10	30	50	21	20	20	20	10	20	10	30	31	30	20	1	1	1	1	11
F	20	31	50	20	10	20	10	10	20	10	30	30	11	21	1	1	1	1	12
F	20	31	40	20	20	10	20	10	10	10	21	30	30	21	1	1	1	1	12
F	20	30	40	21	20	20	20	11	21	0	30	30	30	11	1	1	1	1	11
F	20	30	30	20	21	20	20	10	21	10	30	21	30	11	1	1	1	1	11
F	20	30	30	21	11	10	20	10	20	10	30	21	30	20	1	1	1	1	11
F	20	20	40	20	10	20	20	10	20	10	21	30	30	21	1	1	1	1	11
F	20	10	40	20	10	20	20	10	20	11	20	30	21	21	1	1	1	1	12
F	20	30	50	30	10	20	20	10	20	10	30	30	30	20	1	1	1	1	13
F	20	30	50	30	20	20	20	11	11	10	30	30	30	21	1	1	1	2	12
F	20	30	50	30	20	20	20	10	20	10	30	30	30	20	1	1	1	1	17
F	20	30	50	30	20	11	20	10	20	10	30	30	30	20	1	1	1	2	10
F	20	30	50	30	20	20	20	11	20	10	30	10	30	11	0	1	1	1	10
F	20	30	50	30	20	20	20	11	20	11	30	30	30	11	1	1	1	2	10
F	20	11	50	30	20	20	20	10	20	10	20	30	30	11	1	1	1	2	11
F	20	30	50	30	20	20	20	10	20	10	30	30	31	11	1	1	1	2	11
F	20	30	50	30	10	20	20	11	20	10	20	30	30	21	1	1	1	2	13
F	20	30	50	30	10	10	20	11	10	11	21	30	30	21	1	1	1	2	11
F	20	30	50	31	10	20	20	11	20	11	30	21	30	21	1	1	1	2	12
F	21	30	50	21	21	20	20	10	20	11	30	30	30	11	1	1	1	1	18
F	21	30	50	20	21	20	20	10	20	10	21	10	30	21	1	1	1	1	11
F	20	30	40	11	20	20	20	0	20	10	21	30	20	21	1	1	1	1	12
F	20	21	41	11	20	10	20	0	20	10	30	10	30	20	1	1	1	2	13
F	20	20	41	20	20	20	20	0	20	10	30	30	30	21	1	1	1	1	12
F	20	30	51	30	20	20	20	10	10	10	30	10	30	21	1	1	0	1	12
F	20	30	31	31	20	20	20	10	10	10	30	30	20	21	1	1	1	1	13
F	20	30	30	21	21	20	20	11	10	10	30	30	30	21	1	1	1	1	13
F	20	30	30	20	11	20	20	10	20	11	30	21	30	21	1	1	1	2	14
F	20	30	60	20	10	20	20	11	21	11	20	30	30	21	1	1	1	1	11
F	20	30	60	21	10	10	20	11	21	10	30	30	30	21	1	1	1	1	12
F	20	30	60	10	20	10	20	11	21	10	20	31	30	11	1	1	1	2	12

Scores Periodic Table >>>>>>

Sex	Q1						Q2				Q3				Q4			Q	Total	%
	a	b	c	d	e	f	a	b	c	d	a	b	c	d	a	b	c	5		
F	0.5	0.7	0.9	0.7	1	1	1	0.6	0.5	0.6	0.4	0	1	0.5	0	1	1	2	17.7	71
F	1	0.3	0.9	0.4	0.7	1	0.5	1	0.7	1	1	1	0.8	1	1	0	1	2	19.9	80
F	1	1	0.7	1	0.5	1	1	1	0.7	1	1	0.8	0.8	1	1	1	1	1	20.7	83
F	1	1	0.3	1	1	1	1	1	0.5	0	1	0	1	1	0	1	1	1	17.8	71
F	0.7	1	0.5	0.8	0.5	0.7	1	0	0.5	1	0.4	1	0.7	1	1	1	1	1	17.7	71
F	1	0.8	0.7	0.4	1	0.5	0.5	1	1	1	1	1	1	1	0	1	1	2	20.2	81
F	0.5	0.8	0.7	0.7	1	1	1	0.6	1	0.6	0.4	0.4	1	1	1	1	1	2	20.0	80
F	1	0.7	0.9	0.7	0	1	1	1	1	1	1	0.4	0.3	1	1	1	1	2	20.0	80
F	1	0.3	0.9	0.3	0.5	1	1	1	1	1	0	1	1	0.5	1	1	1	2	20.9	84
F	0.7	1	0.7	0.7	1	0.5	1	0.6	1	1	1	0.4	1	1	1	1	1	2	21.2	85
F	1	1	0.7	1	1	0.5	1	1	0.5	0.6	0.7	1	1	0.7	1	1	1	1	19.6	79
F	0.7	1	0.9	0.4	1	1	1	0.6	1	1	0.7	0.4	1	0.7	0	1	1	2	20.3	81
F	1	1	1	0.7	0.7	1	1	0.6	1	1	1	0.4	0.8	0	1	1	0	2	19.4	78
F	1	1	1	0.4	1	0	1	1	0.5	0.6	1	1	1	0.7	0	1	1	2	18.8	75
F	1	1	0.7	0.7	0.5	1	1	1	1	1	1	1	1	0.7	0	1	1	1	19.9	79
F	1	1	0.7	0.3	0.5	0.5	0.7	1	1	0.6	0.4	1	0.8	0.7	1	1	1	2	18.8	75
F	1	1	0.9	0	0.5	1	0.5	0	0.7	1	1	0.8	1	0.7	1	1	1	1	18.0	72
F	1	0	0.9	1	1	0	0.5	1	0.7	1	1	1	1	1	0	1	1	0	17.7	71
F	1	0.4	0.9	1	1	1	1	1	1	0	0.4	1	1	0.7	1	1	1	0	18.7	75
F	1	1	1	0.4	1	1	0.5	0.6	0	1	1	1	0.4	0.7	1	1	1	2	19.6	78
F	1	0.4	1	0.7	1	0.5	1	0.6	1	0.6	1	0.8	1	0.7	1	0	1	1	18.2	73
F	1	1	0.5	0.4	0.7	1	0.7	1	0.7	1	0.7	1	1	0.7	1	1	1	1	19.6	78
F	0.5	0.3	0.5	0.7	0.7	1	0.7	1	0.5	1	1	1	1	0.7	1	0	0	2	18.2	73
F	1	1	0.3	1	0.5	0.5	0.7	1	0.5	0.6	1	1	0.8	0.7	1	1	1	1	18.5	74
F	1	1	0.9	1	0.5	1	0.5	1	1	1	0.7	1	1	0.7	0	1	1	0	18.2	73
F	1	1	0.9	0.8	0.5	1	1	1	1	1	1	0.8	0.7	0.7	1	1	1	2	21.6	86
F	1	1	0.3	0.8	0.5	0.5	1	0.6	0.5	0.6	0.7	1	1	0.7	1	1	1	1	18.1	72
F	1	0.8	0.7	0.7	1	1	1	1	1	1	1	1	0.4	0.7	1	1	1	1	20.5	82
F	1	1	0.7	0.4	1	1	1	1	0.7	1	0.7	0.4	1	0.7	1	1	1	1	19.8	79
F	1	1	0.5	0.7	1	1	1	1	0.7	0.6	1	0	1	0.5	1	1	1	2	19.9	80
F	1	1	0.5	1	1	1	1	1	0.7	0.6	0.4	0.3	1	1	1	0	1	1	18.8	75
F	0.7	1	1	1	1	1	1	1	1	0.6	1	0.3	1	0.7	0	1	1	1	18.6	74
F	1	1	0.7	0.4	1	1	1	0.6	1	0.6	1	1	0.8	0.7	1	1	1	1	20.1	80
F	1	0.8	0.7	0.4	0.7	1	1	0.6	1	0.6	0.4	1	1	0.7	1	1	1	1	18.8	75
F	1	0.7	0.7	0.7	1	1	1	1	0.5	0.6	1	0.8	1	0.7	1	1	1	1	19.6	78
F	1	1	0.7	0.7	0.5	0.5	1	1	1	1	1	1	1	1	1	1	0	1	19.4	77
F	1	1	0.9	0.3	0.5	1	1	0.6	0.5	1	1	1	1	0	1	1	1	1	19.2	77
F	1	1	0.9	0.3	1	1	1	1	1	1	0.7	1	1	0.7	1	1	1	1	20.6	82
F	1	1	0.3	0.3	1	0	1	1	1	1	1	1	1	0.7	1	1	1	1	19.3	77
F	1	1	0.5	0.8	1	1	1	1	1	1	1	1	0.8	0.7	1	1	1	2	23.0	92
F	1	1	0.5	0.7	1	1	1	0	1	1	0.7	1	1	0.7	1	1	1	0	20.2	81
F	0.5	1	0.9	0.4	1	1	1	1	1	1	1	0.8	1	1	1	1	1	1	20.2	81
F	1	0.8	0.9	0.7	0.5	1	0.5	1	1	1	1	1	0	0.7	1	1	1	1	19.0	76
F	1	0.8	0.7	0.7	1	0.5	1	1	0.5	1	0.4	1	1	1	1	1	1	1	19.5	78
F	1	1	0.7	0.4	1	1	1	0.6	0.7	0	1	1	1	0.7	1	1	1	1	18.7	75
F	1	1	0.5	0.7	0.7	1	1	1	0.7	1	1	0.4	1	0.7	1	1	1	1	19.2	77
F	1	1	0.5	0.4	0	0.5	1	1	1	1	1	0.4	1	0.7	1	1	1	1	18.1	73
F	1	0.7	0.7	0.7	0.5	1	1	1	1	1	0.4	1	1	0.7	1	1	1	1	19.3	77
F	1	0.3	0.7	0.7	0.5	1	1	1	1	0.6	0.7	1	0.4	1	1	1	1	1	18.9	75
F	1	1	0.9	1	0.5	1	1	1	1	1	1	1	1	0.7	1	1	1	1	21.4	86
F	1	1	0.9	1	1	1	1	0.6	0	1	1	1	1	0.7	1	1	1	2	21.2	85
F	1	1	0.9	1	1	1	1	1	1	1	1	1	1	0.7	1	1	1	1	23.2	93
F	1	1	0.9	1	1	0	1	1	1	1	1	1	1	0.7	1	1	1	2	20.9	84
F	1	1	0.9	1	1	1	1	0.6	1	1	1	0.3	1	0.5	0	1	1	1	18.7	75
F	1	1	0.9	1	1	1	1	0.6	1	0.6	1	1	1	0	1	1	1	2	20.4	82
F	1	0	0.9	1	1	1	1	1	1	1	0.7	1	1	0.7	1	1	1	2	20.9	84
F	1	1	0.9	1	1	1	1	1	1	1	1	1	0.8	0.7	1	1	1	2	22.0	88
F	1	1	0.9	1	0.5	1	1	0.6	1	1	0.7	1	1	0.7	1	1	1	2	21.7	87
F	1	1	0.9	1	0.5	0.5	1	0.6	0.5	0.6	0.4	1	1	0.7	1	1	1	2	19.3	77
F	1	1	0.9	0.8	0.5	1	1	0.6	1	0.6	1	0.4	1	1	1	1	1	2	20.8	83
F	0.7	1	0.9	0.4	0.7	1	1	1	1	0.6	1	1	1	0.7	1	1	1	1	21.9	88
F	0.7	1	0.9	0.7	0.7	1	1	1	1	1	0.4	0.3	1	1	1	1	1	1	19.3	77
F	1	1	0.7	0	1	1	1	0	1	1	0.4	1	0.7	0.7	1	1	1	1	18.4	74
F	1	0.4	0.5	0	1	0.5	1	0	1	1	1	0.3	1	0.7	1	1	1	2	18.7	75
F	1	0.7	0.5	0.7	1	1	1	0	1	1	1	1	1	0.7	1	1	1	1	19.5	78
F	1	1	0.7	1	1	1	1	1	0.5	1	1	0.3	1	0.7	1	1	0	1	19.2	77
F	1	1	0.3	0.8	1	1	1	1	0.5	1	1	1	0.7	1	1	1	1	1	20.6	82
F	1	1	0.5	0.4	0.7	1	1	0.6	0.5	1	1	1	1	0.7	1	1	1	1	19.7	79
F	1	1	0.5	0.7	0	1	1	1	1	0.6	1	0.4	1	1	1	1	1	2	20.8	83
F	1	1	1	0.7	0.5	1	1	0.6	0.7	0.6	0.7	1	1	1	1	1	1	1	19.4	78
F	1	1	1	0.4	0.5	0.5	1	0.6	0.7	1	1	1	1	0.7	1	1	1	1	19.3	77
F	1	1	1	0.3	1	0.5	1	0.6	0.7	1	0.7	0.8	1	1	1	1	1	2	20.5	82

73	F	20	30	60	10	20	20	20	11	20	10	30	30	30	11	1	1	1	1	12	1	1	1	0.3	1	1	1	0.6	1	1	1	1	1	0.7	1	1	1	1	20.6	82
74	F	20	30	50	10	20	20	20	11	20	10	30	30	21	11	1	1	1	1	13	1	1	0.9	0.3	1	1	1	0.6	1	1	1	1	0.4	0.7	1	1	1	1	20.2	81
75	F	20	30	50	11	20	20	20	10	20	10	30	30	30	11	1	1	1	1	14	1	1	0.9	0	1	1	1	1	1	1	1	1	1	0.7	1	1	1	1	21.2	85
76	F	20	30	61	11	10	20	20	10	20	10	20	30	10	11	1	1	1	1	12	1	1	0.9	0	0.5	1	1	1	1	1	0.7	1	0.3	0.7	1	1	1	1	19.1	76
77	F	20	30	60	10	10	20	20	10	20	10	30	31	30	11	1	1	1	2	12	1	1	1	0.3	0.5	1	1	1	1	1	1	0.8	1	1	1	1	1	2	21.6	86
78	F	20	30	40	20	20	11	20	10	20	0	30	30	30	11	1	1	1	2	17	1	1	0.7	0.7	1	0	1	1	1	0	1	1	1	0.7	1	1	1	2	21.7	87
79	F	20	30	40	20	10	20	20	10	20	10	30	30	30	11	0	1	1	1	14	1	1	0.7	0.7	0.5	1	1	1	1	1	1	1	1	1	0	1	1	1	20.5	82
80	F	20	31	40	20	10	20	20	10	20	10	30	31	20	11	1	1	1	1	10	1	0.8	0.7	0.7	0.5	1	1	1	1	1	1	0.8	0.7	1	1	1	1	1	19.4	77
81	F	20	31	40	20	10	20	20	11	10	10	10	30	30	11	1	1	1	2	12	1	0.8	0.7	0.7	0.5	1	1	0.6	0.5	1	0.3	1	1	0.7	1	1	1	2	19.7	79
82	F	20	20	50	10	10	10	20	10	10	10	30	30	30	0	1	1	1	1	12	1	0.7	0.9	0.3	0.5	0.5	1	1	0.5	1	1	1	1	1	1	1	1	1	19.4	78
83	F	20	10	50	21	10	10	10	10	10	11	30	31	30	0	1	1	1	1	12	1	0.3	0.9	0.4	0.5	0.5	0.5	1	0.5	0.6	1	0.8	1	0.7	1	1	1	1	17.7	71
84	F	20	10	41	21	10	20	20	11	20	11	30	30	21	0	1	1	1	1	13	1	0.3	0.5	0.4	0.5	1	1	0.6	1	0.6	1	1	0.4	0.7	1	1	1	1	18.3	73
85	F	20	30	31	21	21	20	20	11	20	11	30	30	30	0	1	1	1	1	12	1	1	0.3	0.4	0.7	1	1	0.6	1	0.6	1	1	1	0.7	1	1	1	1	19.2	77
86	F	20	30	30	21	21	20	20	11	20	10	30	30	30	11	1	1	1	1	12	1	1	0.5	0.4	0.7	1	1	0.6	1	1	1	1	1	0.7	1	1	1	1	19.8	79
	F	20	30	40	20	10	20	20	11	20	10	30	31	30	11	1	1	1	1	12	1	1	0.7	0.7	0.5	1	1	0.6	1	1	1	0.8	1	1	1	1	1	1	20.2	81
	F	20	30	41	11	10	11	20	11	20	0	11	30	21	11	1	1	1	1	10	1	1	0.5	0	0.5	0	1	0.6	1	0	0	1	0.4	0.7	1	1	1	1	15.0	60
	F	20	30	50	30	20	20	20	11	21	10	30	30	30	21	1	1	1	1	10	1	1	0.9	1	1	1	1	0.6	0.7	1	1	1	1	1	1	1	1	1	20.5	82
	F	20	30	50	30	20	20	20	11	21	10	30	30	30	21	1	1	1	1	10	1	1	0.9	1	1	1	1	0.6	0.7	1	1	1	1	1	1	1	1	1	20.5	82
	F	20	30	40	30	20	20	20	11	20	10	20	20	30	21	1	0	1	2	11	1	1	0.7	1	1	1	1	0.6	1	1	0.7	0	1	0.7	1	0	1	2	19.3	77
	F	20	30	30	30	20	20	20	11	20	10	30	30	20	20	1	1	1	2	11	1	1	0.5	1	1	1	1	0.6	1	1	1	1	0.7	1	1	1	1	2	21.4	86
	F	20	30	40	31	20	20	20	10	20	11	30	30	30	11	1	1	1	1	12	1	1	0.7	0.8	1	1	1	1	1	0.6	1	1	1	0.7	1	1	1	1	20.7	83
	F	20	30	40	20	20	20	20	10	20	10	30	21	30	11	1	1	1	1	13	1	1	0.7	0.7	1	1	1	1	1	1	1	0.4	1	0.7	1	1	1	1	20.8	83
	F	20	21	50	21	20	20	20	10	20	10	30	30	10	20	1	1	1	1	12	1	0.4	0.9	0.4	1	1	1	1	1	1	1	1	0.3	0.7	1	1	1	1	19.7	79
	F	20	30	41	20	20	20	20	10	20	10	30	30	30	21	1	1	1	1	13	1	1	0.5	0.7	1	1	1	1	1	1	1	1	1	0.7	1	1	1	1	21.2	85
	F	20	30	51	21	20	20	20	10	20	11	20	21	30	21	1	1	1	1	13	1	1	0.7	0.4	1	1	1	1	1	0.6	0.7	0.4	1	1	1	1	1	1	20.1	80
	F	20	30	40	20	21	20	20	10	20	10	30	30	30	11	1	1	1	0	14	1	1	0.7	0.7	0.7	1	1	1	1	1	1	1	1	0.7	1	1	1	0	20.4	82
	F	20	30	41	21	21	20	20	10	20	10	30	30	30	21	1	1	1	2	13	1	1	0.5	0.4	0.7	1	1	1	1	1	1	1	1	0.5	1	1	1	2	21.4	86
	F	20	30	50	20	21	20	20	10	10	0	30	30	30	20	1	1	1	1	13	1	1	0.9	0.7	0.7	1	1	1	0.5	0	1	1	1	1	1	1	1	1	20.1	80
	M	20	20	60	21	10	20	20	10	10	10	30	30	30	21	1	1	1	1	16	1	0.7	1	0.4	0.5	1	1	1	0.5	1	1	1	1	0	1	1	1	1	20.4	82
	M	20	30	60	30	10	10	20	10	10	10	30	30	30	11	1	1	1	1	12	1	1	1	1	0.5	0.5	1	1	0.5	1	1	1	1	0.7	1	1	1	1	20.2	81
	M	20	30	60	30	10	20	20	10	10	10	30	30	30	0	1	1	1	2	12	1	1	1	1	0.5	1	1	1	0.5	1	1	1	1	0.7	1	1	1	2	21.7	87
	M	20	30	60	30	20	20	20	10	10	11	21	31	21	20	1	1	1	2	13	1	1	1	1	1	1	1	1	0.5	0.6	0.4	0.8	0.4	0.7	1	1	1	2	20.7	83
	M	20	30	60	30	20	20	20	0	10	10	30	30	30	20	1	1	1	1	12	1	1	1	1	1	1	1	0	0.5	1	1	1	1	0.7	1	1	1	1	20.2	81
	M	20	30	60	30	20	10	20	10	10	10	30	30	30	11	1	1	1	1	9	1	1	1	1	1	0.5	1	1	0.5	1	1	1	1	0.7	1	1	1	1	19.7	79
	M	20	30	60	31	20	20	20	10	10	10	20	30	30	11	1	1	1	1	10	1	1	1	0.8	1	1	1	1	0.5	1	0.7	1	1	0.5	1	1	1	1	19.8	79
	M	20	31	60	21	20	20	20	10	20	11	30	30	31	11	1	1	1	1	10	1	0.8	1	0.4	1	1	1	1	1	0.6	1	1	0.8	0.7	1	1	1	1	19.5	78
	M	20	30	60	21	20	20	20	10	20	10	30	30	30	0	1	1	1	1	10	1	1	1	0.4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20.7	83
	M	20	30	60	20	20	20	20	11	20	10	20	30	30	0	1	1	1	1	14	1	1	1	0.7	1	1	1	0.6	1	1	0.7	1	1	1	1	1	1	1	21.6	86
	M	20	30	60	10	21	20	20	11	20	11	30	30	30	0	1	1	1	1	10	1	1	1	0.3	0.7	1	1	0.6	1	0.6	1	1	1	0	1	1	1	1	18.5	74
	M	20	30	31	10	21	20	20	11	20	10	21	30	30	11	1	1	1	1	10	1	1	0.3	0.3	0.7	1	1	0.6	1	1	0.4	1	1	0.7	1	1	1	1	18.3	73
	M	20	30	30	11	10	11	20	10	20	10	20	31	30	11	1	1	1	1	10	1	1	0.5	0	0.5	0	1	1	1	1	0.7	0.8	1	0.7	1	1	1	1	17.4	70
	M	11	11	51	10	10	20	20	10	20	10	30	30	30	11	1	1	1	1	10	0	0	0.7	0.3	0.5	1	1	1	1	1	1	1	1	0.7	1	1	1	1	17.5	70
	M	20	30	50	10	10	20	20	10	20	10	21	30	31	11	1	1	1	1	9	1	1	0.9	0.3	0.5	1	1	1	1	1	0.4	1	0.8	0.7	1	1	1	1	18.6	74
	M	20	30	41	10	10	11	20	11	20	10	30	30	30	11	1	1	1	1	11	1	1	0.5	0.3	0.5	0	1	0.6	1	1	1	1	1	0.7	1	1	1	1	18.3	73
	M	20	30	40	10	20	11	20	11	21	11	20	21	30	11	1	1	1	2	11	1	1	0.7	0.3	1	0	1	0.6	0.7	0.6	0.7	0.4	1	1	1	1	1	2	18.6	75
	M	20	30	40	10	20	20	20	10	21	10	30	21	30	20	1	1	1	1	11	1	1	0.7	0.3	1	1	1	1	0.7	1	1	0.4	1	0.7	1	1	1	1	19.4	78
	M	20	30	40	30	20	20	20	10	21	10	30	30	30	20	1	1	1	1	13	1	1	0.7	1	1	1	1	1	0.7	1	1	1	1	1	1	1	1	1	21.7	87
	M	20	30	40	30	20	20	20	0	21	10	30	30	30	11	1	1	1	1	11	1	1	0.7	1	1	1	1	0	0.7	1	1	1	1	1	1	1	1	1	20.0	80
	M	20	20	50	31	20	20	20	10	21	10	21	30	10	11	1	1	1	1	12	1	0.7	0.9	0.8	1	1	1	1	0.7	1	0.4	1	0.3	0	1	1	1	1	18.7	75
	M	20	30	51	21	20	20	20	10	20	0	30	10	30	11	1	1	1	1	14	1	1	0.7	0.4	1	1	1	1	1	0	1	0.3	1	0.7	1	1	1	1	19.8	79
	M	20	30	50	21	20	10	20	10	20	10	20	30	30	11	1	1	1	1	13	1	1	0.9	0.4	1	0.5	1	1	1	1	0.7	1	1	0.7	1	1	1	1	20.5	82
	M	20	30	60	20	20	21	20	11	10	10	30	30	30	11	1	1	1	1	11	1	1	1	0.7	1	0.7	1	0.6	0.5	1	1	1	1	0.7	1	1	1	1	19.8	79
	M	20	30	60	20	20	21	20	11	10	10	30	30	30	11	1	1	1	1	15	1	1	1	0.7	1	0.7	1	0.6	0.5	1	1	1	1	0.7	1	1	1	1	21.1	84
	M	20	11	60	20	20	10	20	10	10	10	30	30	31	11	1	1	1	1	12	1	0	1	0.7	1	0.5	1	1	0.5	1	1	1	0.8	0.7	1	1	1	1	19.1	76
	M	20	30	60	21	20	10	21	10	10	10	20	30	30	11	1	1	1	2	12	1	1	1	0.4	1	0.5	0.7	1	0.5	1	0.7	1	1	1	1	1	1	2	20.7	83
	M	20	30	60	21	20	20	10	10	20	10	20	30	30	11	1	1	1	1	13	1	1	1	0.4	1	1	0.5	1	1	1	0.7	1	1	0.7	1	1	1	1	20.6	82
	M	20	31	60	30	21	20	20	11	20	10	30	30	30	11	1	1	1	2	17	1	0.8	1	1	0.7	1	1	0.6	1	1	1	1	1	1	1	1	1	2	23.7	95
	M	20	30	60	30	21	20	20	11	20	10	20	30	30	0	1	1	1	2	10	1	1	1	1	0.7	1	1	0.6	1	1	0.7	1	1	1	1	1	1	2	21.3	85
	M	20	30	60	30	20	20	10	11	20	11	30	30	30	11	1	1	1	1	10	1	1	1	1	1	1	0.5	0.6	1	0.6	1	1	1	0	1	1	1	1	19.0	76
	M	20	31	60	30	20	20	20	11	20	10	30	30	30	11	1	1	1	1	10	1	0.8	1	1	1	1	1	0.6	1	1	1	1	1	0.7	1	1	1	1	20.4	81
	M	20	31	60	30	10	20	20	11	20	10	20	30	30	20	1	1	1	1	11	1	0.8	1	1	0.5	1	1	0.6	1	1	0.7	1	1	0.7	1	1	1	1	19.9	79
	M	20	30	60	30	10	20	20	10	20	10	20	30	30	21	1	0	1	1	12	1	1	1	1	0.5	1	1	1	1	1	0.7	1	1	0.7	1	0	1	1	19.8	79
	M	20	30	60	31	10	21	20	10	20	11	30	31	31	21	1	1	1	1	11	1	1	1	0.8	0.5	0.7	1	1	1	0.6	1	0.8	0.8	0.7	1	1	1	1	19.4	77
	M	20	30	60	21	10	21	20	10	20	10	30	30	30	20	1	1	1	1	13	1	1	1	0.4	0.5	0.7	1	1	1	1	1	1	1	0.7	1	1	1	1	20.6	82
	M	20	30	60	21	10	21	20	10	11	10	30	30	30	21	1	1	1	1	14	1	1	1	0.4	0.5	0.7	1	1	0	1	1	1	1	0.5	1	1	1	1	19.7	79
	M	20	20	60	20	10	20	20	10	20	10	30	31	30	20	1	1	1	2	12	1	0.7	1	0.7	0.5	1	1	1	1	1	1	0.8	1	0.7	1	1	1	2	21.3	85
	M	10	30	30	21	10	20	20	10	20	10	30	30	30	20	1	1	1	1	13	0.5	1	0.5	0.4	0.5	1	1	1	1	1	1	1	1	1	1	1	1	1	20.2	81
	M	20	30	40	20	20	20	20	10	20	10	30	30	30	11	1	0	1	1	15	1	1	0.7	0.7	1	1	1	1	1	1	1	1	1	1	1	0	1	1	21.4	85
	M	20	30	60	20	20	20	20	10	20	10	30	30	30	11	1	1	1	2	14	1	1	1	0.7	1	1	1	1	1	1	1	1	1	0	1	1	1	2	22.3	89
	M	20	30	60	20	20	20	20	10	20	10	30	30	21	11	1	1	1	1	12	1	1	1	0.7	1	1	1	1	1	1	1	1	0.4	0.7	1	1	1	1	20.7	83
	M	20	30	51	10	10	20	20	10	20	10	30	31	30	11	1	1	1	1	13	1	1	0.7	0.3	0.5	1	1	1	1	1	1	0.8	1	0.7	1	1	1	1	20.3	81
	M	20	30	51	10	11	20	20	10	20	10	30	30	30	21	1	1	1	1	10	1	1	0.7	0.3	0	1	1	1	1	1	1	1	1	0.7	1	1	1	1	19.0	76
	M	20	30	50	11	21	10	20	10	21	11	30	30	30	21	1	1	1	1	10	1	1	0.9	0	0.7	0.5	1	1	0.7	0.6	1	1	1	0.7	1	1	1	1	18.3	73
	M	20	30	40	11	20	10	20	10	21	10	30	31	31	21	1	1	1	1	12	1	1	0.7	0	1	0.5	1	1	0.7	1	1	0.8	0.8	0.7	1	1	1	1	19.0	76
	M	20	10	30	30	20	20	20	10	21	10	20	30	30	11	1	1	1	1	10	1	0.3	0.5	1	1	1	1	1	0.7	1	0.7	1	1	1	1	1	1	1	19.5	78
	M	20	30	40	30	11	20	20	10	21	10	30	30	30	21	1	1	1	1	10	1	1	0.7	1	0	1	1	1	0.7	1	1	1	1	0.7	1	1	1	1	19.4	77
	M	20	30	60	30	11	20	20	10	20	10	30	31	30	21	1	1	1	1	10	1	1	1	1	0	1	1	1	1	1	1	0.8	1	1	1	1	1	1	20.1	80
	M	20	30	60	30	21	20	20	10	20	10	20	30	30	20	1	1	1	1	9	1	1	1	1	0.7	1	1	1	1	1	0.7	1	1	1	1	1	1	1	20.3	81
	M	20	30	60	30	10	20	10	10	20	10	30	30	21	21	1	1	1	1	12	1	1	1	1	0.5	1	0.5	1	1	1	1	1	0.4	0	1	1	1	1	19.4	78
	M	20	30	20	31	10	20	20	0	20	10	20	30	30	21	1	1	1	1	13	1	1	0.3	0.8	0.5	1	1	0	1	1	0.7	1	1	0.7	1	1	1	1	19.2	77

153	M	20	30	30	10	10	20	20	11	20	0	30	30	30	11	1	1	1	1	13	1	1	0.5	0.3	0.5	1	1	0.6	1	0	1	1	1	0.7	1	1	1	1	18.9	76
154	M	20	30	30	10	20	10	20	10	20	10	30	21	30	11	1	1	1	1	13	1	1	0.5	0.3	1	0.5	1	1	1	1	1	0.4	1	0.7	1	1	1	1	19.7	79
155	M	20	30	30	10	20	20	20	10	20	10	20	21	30	0	1	1	1	1	12	1	1	0.5	0.3	1	1	1	1	1	1	0.7	0.4	1	0.7	1	1	1	1	19.6	78
156	M	20	30	30	21	20	20	20	10	10	10	30	30	31	0	1	1	1	2	12	1	1	0.5	0.4	1	1	1	1	0.5	1	1	1	0.8	0.7	1	1	1	2	20.8	83
157	M	20	10	31	21	20	10	20	10	10	10	20	30	31	0	1	1	1	1	12	1	0.3	0.3	0.4	1	0.5	1	1	0.5	1	0.7	1	0.8	1	1	1	1	1	18.5	74
158	M	20	30	31	20	20	20	20	10	10	10	30	30	30	0	1	1	1	1	18	1	1	0.3	0.7	1	1	1	1	0.5	1	1	1	1	0.7	1	1	1	1	22.1	89
159	M	20	30	31	10	20	20	10	10	10	10	30	30	30	0	1	1	1	1	13	1	1	0.3	0.3	1	1	0.5	1	0.5	1	1	1	1	1	1	1	1	1	20.0	80
160	M	20	30	30	10	21	21	20	11	10	10	30	30	30	0	1	1	1	2	11	1	1	0.5	0.3	0.7	0.7	1	0.6	0.5	1	1	1	1	1	1	1	1	2	19.9	80
161	M	20	30	31	10	21	20	20	11	20	11	30	30	30	0	1	1	1	2	11	1	1	0.3	0.3	0.7	1	1	0.6	1	0.6	1	1	1	0	1	1	1	2	19.2	77
162	M	20	30	30	11	20	20	20	11	20	11	20	30	20	0	1	1	1	2	11	1	1	0.5	0	1	1	1	0.6	1	0.6	0.7	1	0.7	0.7	1	1	1	2	19.4	78
163	M	20	30	60	30	20	20	20	11	20	10	30	21	30	0	1	1	1	2	12	1	1	1	1	1	1	1	0.6	1	1	1	0.4	1	0.7	1	1	1	2	21.7	87
164	M	20	30	60	30	10	10	20	10	20	10	30	30	30	0	1	1	1	1	10	1	1	1	1	0.5	0.5	1	1	1	1	1	1	1	0.7	1	1	1	1	20.0	80
165	M	20	31	40	30	20	10	20	10	20	10	20	30	21	20	1	1	1	1	11	1	0.8	0.7	1	1	0.5	1	1	1	1	0.7	1	0.4	0.7	1	1	1	1	19.4	77
166	M	20	31	40	30	20	10	20	10	20	10	30	30	30	20	1	1	1	1	11	1	0.8	0.7	1	1	0.5	1	1	1	1	1	1	1	0.7	1	1	1	1	20.3	81
167	M	20	30	50	31	20	20	20	10	20	10	30	21	30	11	1	1	1	1	10	1	1	0.9	0.8	1	1	1	1	1	1	1	0.4	1	1	1	1	1	1	20.4	82
168	M	20	30	60	31	20	20	20	10	20	10	20	30	30	11	1	1	1	1	10	1	1	1	0.8	1	1	1	1	1	1	0.7	1	1	0.7	1	1	1	1	20.4	82
169	M	20	30	60	21	20	20	20	10	21	10	30	30	21	20	1	1	1	1	10	1	1	1	0.4	1	1	1	1	0.7	1	1	1	0.4	1	1	1	1	1	19.8	79
170	M	20	30	61	21	20	20	20	10	20	11	30	30	30	11	1	1	1	1	10	1	1	0.9	0.4	1	1	1	1	1	0.6	1	1	1	1	1	1	1	1	20.2	81
	M	20	30	30	21	10	20	20	10	20	11	30	30	30	11	1	1	1	1	9	1	1	0.5	0.4	0.5	1	1	1	1	0.6	1	1	1	0	1	1	1	1	18.0	72
	M	20	30	31	21	10	20	20	10	20	11	21	21	21	20	1	1	0	1	12	1	1	0.3	0.4	0.5	1	1	1	1	0.6	0.4	0.4	0.4	0.7	1	1	0	1	16.7	67
	M	20	21	30	20	20	20	20	10	21	10	30	30	30	20	1	1	1	1	10	1	0.4	0.5	0.7	1	1	1	1	0.7	1	1	1	1	0.7	1	1	1	1	19.2	77
	M	20	21	30	20	20	20	20	10	21	10	30	30	30	11	1	1	1	2	10	1	0.4	0.5	0.7	1	1	1	1	0.7	1	1	1	1	0.7	1	1	1	2	20.2	81
	M	20	30	30	20	20	21	20	10	10	10	21	31	30	11	1	1	1	2	12	1	1	0.5	0.7	1	0.7	1	1	0.5	1	0.4	0.8	1	0.7	1	1	1	2	20.2	81
	M	20	30	40	10	20	11	20	10	20	10	21	30	31	11	1	1	1	2	12	1	1	0.7	0.3	1	0	1	1	1	1	0.4	1	0.8	0.7	1	1	1	2	19.9	79
	M	20	30	31	10	21	20	20	10	20	10	21	30	30	11	1	1	1	2	10	1	1	0.3	0.3	0.7	1	1	1	1	1	0.4	1	1	1	1	1	1	2	20.0	80
	M	20	21	40	10	21	20	20	10	20	10	30	30	30	11	1	1	1	2	11	1	0.4	0.7	0.3	0.7	1	1	1	1	1	1	1	1	0.7	1	1	1	2	20.4	82
	M	20	30	51	10	20	20	20	10	10	10	30	30	30	20	1	1	1	2	12	1	1	0.7	0.3	1	1	1	1	0.5	1	1	1	1	0.5	1	1	1	2	21.0	84
	M	20	30	41	30	20	10	20	10	10	10	30	31	30	21	1	1	1	2	10	1	1	0.5	1	1	0.5	1	1	0.5	1	1	0.8	1	1	1	1	1	2	20.6	82
	M	10	22	20	30	10	10	20	10	10	10	20	30	21	21	1	1	1	2	10	0.5	0	0.3	1	0.5	0.5	1	1	0.5	1	0.7	1	0.4	0	1	1	1	2	16.7	67
	M	20	30	30	30	10	21	20	10	10	10	30	30	30	20	1	1	1	2	12	1	1	0.5	1	0.5	0.7	1	1	0.5	1	1	1	1	0.7	1	1	1	2	20.8	83
	M	20	30	30	30	20	20	20	10	20	10	30	30	30	21	1	1	1	2	11	1	1	0.5	1	1	1	1	1	1	1	1	1	1	0.7	1	1	1	2	21.8	87
	M	20	30	30	30	20	21	20	10	20	10	30	31	30	20	1	1	1	1	11	1	1	0.5	1	1	0.7	1	1	1	1	1	0.8	1	0.7	1	1	1	1	20.3	81
	M	20	30	30	30	20	21	20	10	20	10	30	31	20	20	1	1	1	1	11	1	1	0.5	1	1	0.7	1	1	1	1	1	0.8	0.7	0.7	1	1	1	1	19.9	80
	M	20	10	40	30	20	10	20	10	20	11	11	30	30	11	1	1	1	2	11	1	0.3	0.7	1	1	0.5	1	1	1	0.6	0	1	1	0.7	1	1	1	2	19.5	78
	M	20	30	31	30	20	20	20	10	20	10	30	30	30	11	1	1	1	2	10	1	1	0.3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	21.6	87
	M	20	31	31	30	20	20	20	10	20	10	30	30	30	11	1	1	1	2	12	1	0.8	0.3	1	1	1	1	1	1	1	1	1	1	0.7	1	1	1	2	21.7	87
	M	20	30	31	31	20	20	20	0	20	11	20	30	30	11	1	0	1	2	11	1	1	0.3	0.8	1	1	1	0	1	0.6	0.7	1	1	1	1	0	1	2	19.0	76
	M	20	30	40	21	10	20	20	0	20	10	30	21	31	21	1	1	1	2	10	1	1	0.7	0.4	0.5	1	1	0	1	1	1	0.4	0.8	1	1	1	1	2	19.1	76
	M	20	30	41	20	10	20	20	10	10	10	20	21	30	21	1	1	1	2	10	1	1	0.5	0.7	0.5	1	1	1	0.5	1	0.7	0.4	1	0	1	1	1	2	18.6	74
	M	20	30	41	21	20	20	20	10	21	10	30	30	30	21	1	1	1	1	10	1	1	0.5	0.4	1	1	1	1	0.7	1	1	1	1	0.7	1	1	1	1	19.6	78
	M	10	30	31	20	20	20	20	10	21	11	20	10	31	11	1	1	1	2	11	0.5	1	0.3	0.7	1	1	1	1	0.7	0.6	0.7	0.3	0.8	1	1	1	1	2	19.2	77
	M	20	30	30	21	20	10	20	11	20	11	30	30	30	21	1	1	1	2	11	1	1	0.5	0.4	1	0.5	1	0.6	1	0.6	1	1	1	0.7	1	1	1	2	19.9	80
	M	20	30	31	20	20	20	20	11	20	10	30	30	30	21	1	1	1	2	12	1	1	0.3	0.7	1	1	1	0.6	1	1	1	1	1	0	1	1	1	2	20.6	82
	M	20	30	40	30	10	20	20	10	20	0	21	30	30	20	1	1	1	2	12	1	1	0.7	1	0.5	1	1	1	1	0	0.4	1	1	0	1	1	1	2	19.6	78
	M	21	30	40	30	20	10	20	10	20	10	30	21	30	21	0	1	1	2	11	0.7	1	0.7	1	1	0.5	1	1	1	1	1	0.4	1	0.7	0	1	1	2	19.6	78
	M	20	30	40	30	20	10	10	10	20	10	30	30	21	21	1	1	1	2	11	1	1	0.7	1	1	0.5	0.5	1	1	1	1	1	0.4	0.7	1	1	1	2	20.4	82
	M	20	30	50	30	21	21	11	10	20	10	30	30	30	20	1	1	1	1	10	1	1	0.9	1	0.7	0.7	0	1	1	1	1	1	1	0.7	1	1	1	1	19.2	77
	M	20	30	60	30	10	10	21	10	20	10	20	30	30	20	1	1	1	1	10	1	1	1	1	0.5	0.5	0.7	1	1	1	0.7	1	1	0.7	1	1	1	1	19.3	77
Marks (/1)																				12	1.0	0.9	0.7	0.6	0.8	0.8	1.0	0.8	0.8	0.9	0.9	0.9	0.9	0.7	0.9	1.0	1.0	1.3	19.8	79.4
Marks (%)																				63	97	89	73	64	78	84	95	84	83	87	85	86	90	70	94	96	98	66	79.4	79
ard Deviation																				9.3	13	24	23	29	26	28	15	27	23	25	24	26	20	25	24	20	16	52	4.8	4.8

Scores for Test Materials-*Control Group*

Pupil No.	Sex	Scores Chemical equation					Tot.	Tot.
		1	2	3	4(a)	4(b)	C.E.	%
1	F	8	8	2	0	3	21.00	66
2	F	7	6	4	3	0	20.00	63
3	F	6	8	4	3	3	24.00	75
4	F	7	6	4	3	0	20.00	63
5	F	8	8	2	0	0	18.00	56
6	F	8	10	2	3	0	23.00	72
7	F	7	9	2	3	3	24.00	75
8	F	10	8	2	3	0	23.00	72
9	F	11	10	2	3	0	26.00	81
10	F	8	8	2	3	0	21.00	66
11	F	6	8	4	3	0	21.00	66
12	F	6	7	4	3	0	20.00	63
13	F	7	5	4	3	0	19.00	59
14	F	8	6	4	0	3	21.00	66
15	F	9	7	4	3	0	23.00	72
16	F	8	6	4	0	0	18.00	56
17	F	12	6	4	3	0	25.00	78
18	F	12	10	2	3	0	27.00	84
19	F	10	8	2	3	0	23.00	72
20	F	11	7	4	3	0	25.00	78
21	F	9	6	4	3	0	22.00	69
22	F	8	5	4	0	0	17.00	53
23	F	8	4	4	0	3	19.00	59
24	F	7	5	2	0	3	17.00	53
25	F	6	5	2	3	3	19.00	59
26	F	6	6	2	3	3	20.00	63
27	F	8	6	2	3	3	22.00	69
28	F	7	6	2	3	3	21.00	66
29	F	7	6	4	3	0	20.00	63
30	F	8	8	4	0	0	20.00	63
31	F	7	7	4	3	0	21.00	66
32	F	6	6	4	0	0	16.00	50
33	F	8	8	4	3	0	23.00	72
34	F	8	10	4	3	0	25.00	78
35	F	7	7	4	3	0	21.00	66
36	F	8	6	4	0	3	21.00	66
37	F	8	6	4	0	3	21.00	66
38	F	6	6	2	3	3	20.00	63
39	F	7	6	2	3	3	21.00	66
40	F	7	5	2	0	3	17.00	53
41	F	8	4	4	0	0	16.00	50
42	F	6	6	4	0	3	19.00	59
43	F	6	6	4	0	3	19.00	59
44	F	7	8	4	3	3	25.00	78
45	F	9	7	4	3	3	26.00	81
46	F	12	8	4	3	3	30.00	94
47	F	11	8	4	3	3	29.00	91
48	F	12	9	4	3	3	31.00	97
49	F	12	10	2	3	3	30.00	94
50	F	11	10	2	3	3	29.00	91
51	F	12	10	2	3	0	27.00	84
52	F	10	8	4	3	3	28.00	88
53	F	10	9	4	0	3	26.00	81
54	F	9	9	4	0	0	22.00	69
55	F	8	8	4	3	0	23.00	72
56	F	7	8	4	0	0	19.00	59
57	F	8	5	4	3	0	20.00	63
58	F	7	6	2	0	0	15.00	47
59	F	9	6	2	0	0	17.00	53
60	F	10	6	2	3	3	24.00	75
61	F	8	7	4	3	3	25.00	78
62	F	9	8	4	3	3	27.00	84
63	F	10	8	4	3	3	28.00	88
64	F	11	9	2	0	3	25.00	78
65	F	10	8	2	0	0	20.00	63
66	F	8	8	2	3	0	21.00	66
67	F	6	6	2	0	0	14.00	44

68	F	5	7	2	0	0	14.00	44
69	F	7	10	2	0	0	19.00	59
70	F	6	9	4	0	0	19.00	59
71	F	7	8	4	3	0	22.00	69
72	F	8	8	4	3	0	23.00	72
73	F	8	7	4	3	0	22.00	69
74	F	9	7	4	3	0	23.00	72
75	F	9	6	4	3	0	22.00	69
76	F	11	5	4	3	0	23.00	72
77	F	12	8	4	3	0	27.00	84
78	F	10	8	2	3	0	23.00	72
79	F	10	8	2	3	3	26.00	81
80	F	9	10	4	0	3	26.00	81
81	F	9	9	4	3	3	28.00	88
82	F	10	6	4	3	3	26.00	81
83	F	8	7	4	3	3	25.00	78
84	F	7	8	4	0	3	22.00	69
85	F	8	8	4	0	0	20.00	63
86	F	8	7	4	0	3	22.00	69
87	F	9	6	4	3	0	22.00	69
88	F	10	8	4	3	0	25.00	78
89	F	10	10	2	3	0	25.00	78
90	F	10	9	2	0	0	21.00	66
91	F	8	7	4	0	3	22.00	69
92	F	7	6	4	0	3	20.00	63
93	F	6	7	4	3	3	23.00	72
94	F	5	8	4	3	3	23.00	72
95	F	6	8	2	3	0	19.00	59
96	F	6	9	2	3	0	20.00	63
97	F	9	10	4	3	0	26.00	81
98	F	10	8	4	3	0	25.00	78
99	F	8	8	4	0	3	23.00	72
100	F	10	6	4	3	3	26.00	81
101	M	11	6	4	3	3	27.00	84
102	M	11	5	4	3	3	26.00	81
103	M	12	7	4	3	0	26.00	81
104	M	8	8	2	3	0	21.00	66
105	M	8	8	2	3	0	21.00	66
106	M	7	9	2	0	0	18.00	56
107	M	8	8	2	0	0	18.00	56
108	M	9	8	4	0	3	24.00	75
109	M	6	8	2	0	3	19.00	59
110	M	6	8	4	3	3	24.00	75
111	M	8	6	4	3	0	21.00	66
112	M	9	7	4	3	0	23.00	72
113	M	10	7	2	0	0	19.00	59
114	M	11	7	2	3	0	23.00	72
115	M	10	7	4	3	0	24.00	75
116	M	10	8	4	3	0	25.00	78
117	M	12	6	4	3	3	28.00	88
118	M	8	8	4	0	3	23.00	72
119	M	9	10	4	0	3	26.00	81
120	M	10	8	2	3	3	26.00	81
121	M	7	7	4	3	3	24.00	75
122	M	8	8	4	3	3	26.00	81
123	M	12	8	4	3	3	30.00	94
124	M	11	6	4	3	3	27.00	84
125	M	10	6	4	3	3	26.00	81
126	M	10	6	4	3	3	26.00	81
127	M	9	7	4	3	0	23.00	72
128	M	10	8	4	3	3	28.00	88
129	M	10	8	4	0	0	22.00	69
130	M	11	8	4	3	0	26.00	81
131	M	11	9	2	0	0	22.00	69
132	M	7	10	2	0	3	22.00	69
133	M	6	8	4	3	3	24.00	75
134	M	7	10	4	3	3	27.00	84
135	M	5	9	4	3	0	21.00	66
136	M	7	8	2	3	0	20.00	63
137	M	7	7	2	3	0	19.00	59
138	M	8	6	2	3	3	22.00	69
139	M	9	5	4	3	3	24.00	75
140	M	8	4	4	3	3	22.00	69

141	M		10	6	4	3	0		23.00		72
142	M		12	6	4	0	0		22.00		69
143	M		11	7	4	0	0		22.00		69
144	M		11	8	4	0	0		23.00		72
145	M		10	8	4	3	0		25.00		78
146	M		10	9	4	0	3		26.00		81
147	M		9	10	2	3	3		27.00		84
148	M		8	8	4	0	0		20.00		63
149	M		8	8	2	0	3		21.00		66
150	M		7	8	4	0	3		22.00		69
151	M		8	7	4	3	3		25.00		78
152	M		7	8	4	3	3		25.00		78
153	M		7	8	4	3	3		25.00		78
154	M		6	10	4	0	3		23.00		72
155	M		5	8	4	3	0		20.00		63
156	M		8	9	4	3	0		24.00		75
157	M		8	8	4	3	0		23.00		72
158	M		9	7	4	0	0		20.00		63
159	M		10	7	4	0	3		24.00		75
160	M		9	6	4	3	0		22.00		69
161	M		12	5	2	3	0		22.00		69
162	M		11	6	2	3	0		22.00		69
163	M		11	6	4	3	0		24.00		75
164	M		10	6	4	3	0		23.00		72
165	M		8	7	2	0	0		17.00		53
166	M		10	8	4	3	0		25.00		78
167	M		10	9	4	0	3		26.00		81
168	M		10	10	4	0	3		27.00		84
169	M		10	9	4	0	3		26.00		81
170	M		8	6	4	3	0		21.00		66
171	M		11	6	4	3	3		27.00		84
172	M		10	6	4	3	3		26.00		81
173	M		6	6	4	3	3		22.00		69
174	M		7	6	4	3	3		23.00		72
175	M		8	7	2	3	0		20.00		63
176	M		6	6	4	3	3		22.00		69
177	M		8	8	2	3	3		24.00		75
178	M		7	9	4	0	0		20.00		63
179	M		6	10	4	3	3		26.00		81
180	M		5	9	4	3	3		24.00		75
181	M		8	7	4	3	0		22.00		69
182	M		8	8	4	3	0		23.00		72
183	M		10	6	2	3	0		21.00		66
184	M		9	8	2	0	0		19.00		59
185	M		8	8	4	3	3		26.00		81
186	M		6	7	2	3	3		21.00		66
187	M		6	6	2	0	3		17.00		53
188	M		5	5	4	0	3		17.00		53
189	M		7	6	4	3	3		23.00		72
190	M		6	6	4	3	3		22.00		69
191	M		6	8	4	3	3		24.00		75
192	M		7	8	4	3	0		22.00		69
193	M		7	6	4	3	0		20.00		63
194	M		6	6	4	0	3		19.00		59
195	M		8	6	4	0	3		21.00		66
196	M		7	6	2	0	3		18.00		56
197	M		7	6	4	3	3		23.00		72
198	M		9	9	4	3	0		25.00		78
199	M		8	8	4	3	0		23.00		72
200	M		10	10	4	3	3		30.00		94
Mean Marks (/1)			8.435	7.37	3.4	2.025	1.47		22.7		70.94
Mean Marks (%)			843.5	737	340	202.5	147		70.94		70.96
Standard Deviation			182.3	143.3	91.88	140.9	150.346		10.12		10.12

Scores for Test Materials-*Experiment Group*

Pupil No.	Sex	Scores Chemical equation 1	2	3	4(a)	4(b)	Tot. C.E.	Tot. %
1	F	9	8	4	3	3	27.00	84
2	F	8	8	4	3	3	26.00	81
3	F	8	10	4	3	3	28.00	88
4	F	7	10	4	0	3	24.00	75
5	F	10	8	2	3	3	26.00	81
6	F	7	9	2	3	0	21.00	66
7	F	8	10	2	3	0	23.00	72
8	F	9	10	4	0	0	23.00	72
9	F	12	9	4	3	0	28.00	88
10	F	12	9	4	3	3	31.00	97
11	F	11	9	2	3	3	28.00	88
12	F	8	10	2	3	3	26.00	81
13	F	7	10	4	3	3	27.00	84
14	F	9	8	4	3	3	27.00	84
15	F	8	8	2	3	3	24.00	75
16	F	11	8	2	3	3	27.00	84
17	F	10	8	2	3	3	26.00	81
18	F	10	9	4	0	0	23.00	72
19	F	8	10	4	0	0	22.00	69
20	F	9	9	4	3	3	28.00	88
21	F	11	8	4	3	3	29.00	91
22	F	10	8	2	3	0	23.00	72
23	F	10	10	2	3	0	25.00	78
24	F	8	8	4	3	3	26.00	81
25	F	7	8	2	3	3	23.00	72
26	F	7	7	2	0	3	19.00	59
27	F	7	8	4	3	3	25.00	78
28	F	8	8	4	3	0	23.00	72
29	F	9	8	4	0	3	24.00	75
30	F	9	8	2	3	3	25.00	78
31	F	7	10	2	3	3	25.00	78
32	F	6	8	4	3	3	24.00	75
33	F	7	8	4	3	3	25.00	78
34	F	7	7	2	0	0	16.00	50
35	F	9	9	4	3	0	25.00	78
36	F	10	9	4	3	0	26.00	81
37	F	11	10	4	3	3	31.00	97
38	F	11	9	4	0	3	27.00	84
39	F	10	8	4	3	0	25.00	78
40	F	9	8	2	3	3	25.00	78
41	F	7	8	2	3	3	23.00	72
42	F	7	9	4	3	0	23.00	72
43	F	7	10	4	3	0	24.00	75
44	F	8	10	2	0	0	20.00	63
45	F	11	8	4	3	3	29.00	91
46	F	10	8	4	3	3	28.00	88
47	F	10	7	4	3	3	27.00	84
48	F	7	6	4	0	3	20.00	63
49	F	8	8	4	3	3	26.00	81
50	F	8	9	4	3	3	27.00	84
51	F	10	8	4	3	3	28.00	88
52	F	9	10	2	0	3	24.00	75
53	F	8	10	4	3	0	25.00	78
54	F	8	8	4	3	3	26.00	81
55	F	8	9	2	3	3	25.00	78
56	F	7	10	2	3	0	22.00	69
57	F	8	10	2	0	3	23.00	72
58	F	8	8	4	3	3	26.00	81
59	F	11	10	4	3	0	28.00	88
60	F	11	10	2	3	3	29.00	91
61	F	9	8	2	0	3	22.00	69
62	F	9	9	4	0	3	25.00	78
63	F	10	10	4	3	0	27.00	84
64	F	10	7	4	3	3	27.00	84
65	F	7	6	4	3	3	23.00	72
66	F	8	7	4	3	3	25.00	78
67	F	8	10	2	3	3	26.00	81

68	F	8	9	4	3	3	27.00	84
69	F	9	8	2	3	3	25.00	78
70	F	10	8	2	3	0	23.00	72
71	F	8	10	2	3	3	26.00	81
72	F	12	10	2	0	0	24.00	75
73	F	11	10	4	0	0	25.00	78
74	F	12	8	4	3	3	30.00	94
75	F	10	9	4	3	3	29.00	91
76	F	9	8	4	3	0	24.00	75
77	F	8	10	4	3	3	28.00	88
78	F	8	9	4	3	3	27.00	84
79	F	7	8	4	3	3	25.00	78
80	F	6	9	2	3	3	23.00	72
81	F	10	7	2	3	0	22.00	69
82	F	12	7	2	0	3	24.00	75
83	F	11	7	4	0	3	25.00	78
84	F	12	9	4	3	0	28.00	88
85	F	12	10	4	3	3	32.00	100
86	F	12	10	4	3	3	32.00	100
87	F	11	8	2	3	3	27.00	84
88	F	9	9	2	3	0	23.00	72
89	F	8	9	4	3	3	27.00	84
90	F	8	7	4	0	3	22.00	69
91	F	7	8	2	3	3	23.00	72
92	F	8	10	4	3	3	28.00	88
93	F	8	8	4	3	3	26.00	81
94	F	8	8	4	0	3	23.00	72
95	F	9	8	4	3	3	27.00	84
96	F	10	8	4	3	3	28.00	88
97	F	12	7	2	3	0	24.00	75
98	F	10	7	2	0	3	22.00	69
99	F	10	7	4	3	3	27.00	84
100	F	9	8	4	3	3	27.00	84
101	M	8	10	4	3	0	25.00	78
102	M	8	8	4	3	0	23.00	72
103	M	7	8	4	3	3	25.00	78
104	M	12	8	4	0	3	27.00	84
105	M	12	7	4	0	0	23.00	72
106	M	11	8	4	3	0	26.00	81
107	M	12	10	4	0	3	29.00	91
108	M	11	10	2	3	3	29.00	91
109	M	8	7	4	3	3	25.00	78
110	M	8	6	4	0	3	21.00	66
111	M	7	10	4	3	3	27.00	84
112	M	8	10	4	3	3	28.00	88
113	M	9	10	4	3	0	26.00	81
114	M	9	8	4	0	3	24.00	75
115	M	7	8	2	0	0	17.00	53
116	M	7	8	4	3	3	25.00	78
117	M	11	9	4	3	3	30.00	94
118	M	10	9	4	3	0	26.00	81
119	M	11	9	2	3	3	28.00	88
120	M	11	8	4	0	3	26.00	81
121	M	8	7	4	0	0	19.00	59
122	M	8	9	4	3	0	24.00	75
123	M	11	8	4	3	3	29.00	91
124	M	10	8	4	3	3	28.00	88
125	M	9	8	4	0	3	24.00	75
126	M	9	9	4	3	3	28.00	88
127	M	8	10	4	3	3	28.00	88
128	M	12	7	4	0	3	26.00	81
129	M	12	7	4	3	3	29.00	91
130	M	11	6	4	3	3	27.00	84
131	M	8	8	4	3	3	26.00	81
132	M	9	8	4	0	0	21.00	66
133	M	9	8	2	0	3	22.00	69
134	M	10	9	4	0	3	26.00	81
135	M	12	10	4	3	3	32.00	100
136	M	11	10	4	3	0	28.00	88
137	M	11	7	4	3	3	28.00	88
138	M	12	7	4	3	3	29.00	91
139	M	9	8	2	3	3	25.00	78
140	M	9	10	4	3	3	29.00	91

141	M	8	8	4	0	3	23.00	72
142	M	8	8	4	3	3	26.00	81
143	M	7	7	4	3	3	24.00	75
144	M	8	10	4	3	0	25.00	78
145	M	9	9	4	3	3	28.00	88
146	M	10	10	4	3	3	30.00	94
147	M	11	8	4	3	3	29.00	91
148	M	12	10	2	3	3	30.00	94
149	M	11	7	4	3	0	25.00	78
150	M	12	6	4	0	3	25.00	78
151	M	10	10	4	0	0	24.00	75
152	M	9	8	4	0	0	21.00	66
153	M	9	8	4	3	0	24.00	75
154	M	8	8	2	3	3	24.00	75
155	M	9	10	4	3	3	29.00	91
156	M	10	10	4	3	3	30.00	94
157	M	12	7	4	0	3	26.00	81
158	M	8	8	4	3	3	26.00	81
159	M	9	8	4	3	3	27.00	84
160	M	10	9	4	3	3	29.00	91
161	M	10	10	4	3	3	30.00	94
162	M	11	6	4	3	3	27.00	84
163	M	10	7	4	3	0	24.00	75
164	M	8	10	4	3	0	25.00	78
165	M	8	10	4	3	3	28.00	88
166	M	9	7	4	0	3	23.00	72
167	M	9	7	4	3	0	23.00	72
168	M	11	8	4	0	0	23.00	72
169	M	12	8	2	3	3	28.00	88
170	M	10	7	4	3	3	27.00	84
171	M	10	9	4	0	3	26.00	81
172	M	10	10	4	3	3	30.00	94
173	M	11	10	2	3	3	29.00	91
174	M	8	8	4	3	3	26.00	81
175	M	9	9	4	3	3	28.00	88
176	M	9	9	4	0	3	25.00	78
177	M	12	8	4	3	3	30.00	94
178	M	11	7	4	3	0	25.00	78
179	M	9	7	4	0	0	20.00	63
180	M	9	7	4	3	0	23.00	72
181	M	10	8	2	0	3	23.00	72
182	M	9	9	4	0	3	25.00	78
183	M	0	10	4	3	0	17.00	53
184	M	8	7	4	3	3	25.00	78
185	M	8	7	4	3	0	22.00	69
186	M	10	6	4	3	0	23.00	72
187	M	12	5	4	3	0	24.00	75
188	M	11	10	2	0	0	23.00	72
189	M	8	10	4	0	3	25.00	78
190	M	9	9	4	3	3	28.00	88
191	M	9	8	4	3	3	27.00	84
192	M	10	9	4	3	3	29.00	91
193	M	12	8	4	3	3	30.00	94
194	M	12	8	4	3	3	30.00	94
195	M	11	8	4	3	3	29.00	91
196	M	10	9	4	3	3	29.00	91
197	M	8	9	4	0	0	21.00	66
198	M	8	8	4	3	3	26.00	81
199	M	7	9	4	3	3	26.00	81
200	M	10	9	4	3	3	29.00	91
Mean Marks (/1)		9.265	8.46	3.52	2.265	2.145	25.66	80.17
Mean Marks (%)		926.5	846	352	226.5	214.5	80.17	80.15
Standard Deviation		172	116	85.63	129.3	135.764	8.925	8.925

Analysis Data of Year 11

Codes and Scores for Test Materials-***Control.Group***

Pupil No.	Sex	Organic Chemistry											Scores											Totals	Total
		1(a)	1(b)	1(c)	1(d)	2(a)	2(b)	2(c)	2(d)	2(e)	3(a)	3(b)	1(a)	1(b)	1(c)	1(d)	2(a)	2(b)	2(c)	2(d)	2(e)	3(a)	3(b)	Org.Ch.	%
1	F	21	21	20	21	20	21	10	10	11	2	1	0.4	0.4	1	0.4	1	0.4	0	0.3	0	2	1	6.93	46
2	F	21	20	20	20	21	21	10	11	11	1	2	0.4	0.7	1	0.7	0.7	0.4	0.5	0	0	1	2	7.31	49
3	F	30	20	20	31	20	30	20	10	11	1	2	1	0.7	1	0.8	1	1	1	0.3	0	1	2	9.75	65
4	F	21	20	21	30	11	31	21	10	10	2	1	0.4	0.7	0.7	1	0	0.8	0.7	0.3	0.5	2	1	7.99	53
5	F	20	30	20	21	20	30	20	10	11	1	1	0.7	1	1	0.4	1	1	1	0.3	0	1	1	8.40	56
6	F	21	31	21	20	21	21	10	11	10	1	2	0.4	0.8	0.7	0.7	0.7	0.4	0.5	0	0.5	1	2	7.56	50
7	F	21	20	20	30	20	21	10	10	10	2	1	0.4	0.7	1	1	1	0.4	0.5	0.3	0.5	2	1	8.80	59
8	F	20	20	20	30	20	30	20	11	11	1	2	0.7	0.7	1	1	1	1	1	0	0	1	2	9.34	62
9	F	11	21	20	30	21	30	20	11	10	1	2	0	0.4	1	1	0.7	1	1	0	0.5	1	2	8.57	57
10	F	11	20	11	30	20	21	11	21	10	2	2	0	0.7	0	1	1	0.4	0	0.4	0.5	2	2	7.97	53
11	F	30	30	11	21	20	21	10	11	10	2	1	1	1	0	0.4	1	0.4	0.5	0	0.5	2	1	7.80	52
12	F	30	30	21	21	20	21	10	11	10	1	2	1	1	0.7	0.4	1	0.4	0.5	0	0.5	1	2	8.47	56
13	F	21	11	20	21	20	21	10	11	10	3	1	0.4	0	1	0.4	1	0.4	0.5	0	0.5	3	1	8.20	55
14	F	21	21	20	21	21	20	10	11	10	2	1	0.4	0.4	1	0.4	0.7	0.7	0.5	0	0.5	2	1	7.54	50
15	F	11	20	21	21	21	20	10	11	10	2	1	0	0.7	0.7	0.4	0.7	0.7	0.5	0	0.5	2	1	7.08	47
16	F	11	30	21	21	21	11	10	10	10	1	2	0	1	0.7	0.4	0.7	0	0.5	0.3	0.5	1	2	7.07	47
17	F	21	31	11	21	21	20	10	10	10	1	2	0.4	0.8	0	0.4	0.7	0.7	0.5	0.3	0.5	1	2	7.22	48
18	F	30	20	20	11	20	21	10	10	11	2	1	1	0.7	1	0	1	0.4	0.5	0.3	0	2	1	7.90	53
19	F	21	21	20	11	21	21	20	10	10	1	1	0.4	0.4	1	0	0.7	0.4	1	0.3	0.5	1	1	6.70	45
20	F	21	20	21	21	20	21	20	10	10	2	1	0.4	0.7	0.7	0.4	1	0.4	1	0.3	0.5	2	1	8.37	56
21	F	21	31	21	20	20	20	10	21	10	1	1	0.4	0.8	0.7	0.7	1	0.7	0.5	0.4	0.5	1	1	7.56	50
22	F	30	30	20	21	21	31	10	21	10	1	2	1	1	1	0.4	0.7	0.8	0.5	0.4	0.5	1	2	9.22	61
23	F	31	30	11	20	21	30	10	21	10	2	1	0.8	1	0	0.7	0.7	1	0.5	0.4	0.5	2	1	8.49	57
24	F	20	21	20	21	21	30	11	21	21	2	1	0.7	0.4	1	0.4	0.7	1	0	0.4	0.7	2	1	8.21	55
25	F	20	21	21	20	20	21	20	10	11	3	1	0.7	0.4	0.7	0.7	1	0.4	1	0.3	0	3	1	9.14	61
26	F	21	20	20	21	11	21	21	10	11	1	2	0.4	0.7	1	0.4	0	0.4	0.7	0.3	0	1	2	6.87	46
27	F	31	20	21	20	20	20	10	21	10	1	1	0.8	0.7	0.7	0.7	1	0.7	0.5	0.4	0.5	1	1	7.83	52
28	F	21	30	20	31	21	31	10	21	10	2	1	0.4	1	1	0.8	0.7	0.8	0.5	0.4	0.5	2	1	8.97	60
29	F	30	31	20	31	20	21	21	21	10	3	1	1	0.8	1	0.8	1	0.4	0.7	0.4	0.5	3	1	10.47	70
30	F	21	30	20	30	21	20	21	21	10	1	1	0.4	1	1	1	0.7	0.7	0.7	0.4	0.5	1	1	8.31	55
31	F	30	31	21	21	20	21	21	21	10	1	2	1	0.8	0.7	0.4	1	0.4	0.7	0.4	0.5	1	2	8.79	59
32	F	30	20	20	20	21	20	10	10	21	2	1	1	0.7	1	0.7	0.7	0.7	0.5	0.3	0.7	2	1	9.18	61
33	F	30	20	20	31	21	21	10	10	10	1	2	1	0.7	1	0.8	0.7	0.4	0.5	0.3	0.5	1	2	8.82	59
34	F	31	21	21	30	11	21	20	10	10	1	3	0.8	0.4	0.7	1	0	0.4	1	0.3	0.5	1	3	9.05	60
35	F	31	20	20	30	20	30	20	10	10	2	2	0.8	0.7	1	1	1	1	1	0.3	0.5	2	2	11.25	75
36	F	30	21	11	21	21	21	20	10	10	1	2	1	0.4	0	0.4	0.7	0.4	1	0.3	0.5	1	2	7.70	51
37	F	30	30	20	21	21	11	20	10	21	3	1	1	1	1	0.4	0.7	0	1	0.3	0.7	3	1	10.07	67
38	F	21	20	21	11	21	21	11	21	21	2	2	0.4	0.7	0.7	0	0.7	0.4	0	0.4	0.7	2	2	7.88	53
39	F	21	21	21	21	21	21	20	21	21	1	1	0.4	0.4	0.7	0.4	0.7	0.4	1	0.4	0.7	1	1	7.01	47
40	F	30	20	11	20	21	20	20	11	10	1	1	1	0.7	0	0.7	0.7	0.7	1	0	0.5	1	1	7.18	48
41	F	30	11	20	21	20	21	10	10	21	1	2	1	0	1	0.4	1	0.4	0.5	0.3	0.7	1	2	8.30	55
42	F	21	20	20	20	20	30	10	11	10	1	2	0.4	0.7	1	0.7	1	1	0.5	0	0.5	1	2	8.74	58
43	F	21	20	20	21	20	31	10	10	10	3	1	0.4	0.7	1	0.4	1	0.8	0.5	0.3	0.5	3	1	9.55	64
44	F	20	31	21	20	20	30	10	21	10	1	1	0.7	0.8	0.7	0.7	1	1	0.5	0.4	0.5	1	1	8.16	54
45	F	30	20	21	21	20	21	10	21	10	2	2	1	0.7	0.7	0.4	1	0.4	0.5	0.4	0.5	2	2	9.54	64
46	F	20	11	21	20	20	20	10	21	10	2	2	0.7	0	0.7	0.7	1	0.7	0.5	0.4	0.5	2	2	9.08	61
47	F	30	11	20	21	21	21	20	10	20	2	2	1	0	1	0.4	0.7	0.4	1	0.3	1	2	2	9.80	65
48	F	31	30	20	20	21	20	20	10	21	2	2	0.8	1	1	0.7	0.7	0.7	1	0.3	0.7	2	2	10.76	72
49	F	20	30	20	21	21	21	20	10	10	1	2	0.7	1	1	0.4	0.7	0.4	1	0.3	0.5	1	2	8.97	60
50	F	21	31	21	30	11	21	20	21	21	1	2	0.4	0.8	0.7	1	0	0.4	1	0.4	0.7	1	2	8.29	55
51	F	20	30	20	30	20	30	20	21	10	2	2	0.7	1	1	1	1	1	1	0.4	0.5	2	2	11.57	77
52	F	11	21	20	21	21	11	21	21	10	2	1	0	0.4	1	0.4	0.7	0	0.7	0.4	0.5	2	1	7.04	47
53	F	11	20	21	21	21	30	21	11	21	2	2	0	0.7	0.7	0.4	0.7	1	0.7	0	0.7	2	2	8.75	58
54	F	21	21	11	21	21	31	21	10	20	2	2	0.4	0.4	0	0.4	0.7	0.8	0.7	0.3	1	2	2	8.62	57
55	F	21	21	20	21	21	30	10	10	10	2	2	0.4	0.4	1	0.4	0.7	1	0.5	0.3	0.5	2	2	9.20	61
56	F	30	21	20	11	20	30	10	21	10	2	1	1	0.4	1	0	1	1	0.5	0.4	0.5	2	1	8.80	59
57	F	20	20	21	11	20	31	10	21	10	2	1	0.7	0.7	0.7	0	1	0.8	0.5	0.4	0.5	2	1	8.16	54
58	F	11	11	20	20	20	21	10	21	10	2	1	0	0	1	0.7	1	0.4	0.5	0.4	0.5	2	1	7.47	50
59	F	21	20	21	21	20	20	20	21	10	2	2	0.4	0.7	0.7	0.4	1	0.7	1	0.4	0.5	2	2	9.71	65
60	F	11	21	20	21	21	21	20	10	10	1	2	0	0.4	1	0.4	0.7	0.4	1	0.3	0.5	1	2	7.70	51
61	F	21	21	21	11	21	31	20	10	21	1	0	0.4	0.4	0.7	0	0.7	0.8	1	0.3	0.7	1	0	5.89	39
62	F	20	20	20	21	20	30	20	21	10	1	2	0.7	0.7	1	0.4	1	1	1	0.4	0.5	1	2	9.64	64
63	F	30	21	21	20	20	31	10	21	10	2	1	1	0.4	0.7	0.7	1	0.8	0.5	0.4	0.5	2	1	8.89	59
64	F	31	21	20	30	21	21	21	10	10	2	1	0.8	0.4	1	1	0.7	0.4	0.7	0.3	0.5	2	1	8.72	58
65	F	21	20	20	31	20	20	21	10	20	3	1	0.4	0.7	1	0.8	1	0.7	0.7	0.3	1	3	1	10.49	70

66	F	30	21	20	21	21	21	20	10	10	3	1	1	0.4	1	0.4	0.7	0.4	1	0.3	0.5	3	1	9.70	65
67	F	31	31	20	20	20	20	20	10	10	2	1	0.8	0.8	1	0.7	1	0.7	1	0.3	0.5	2	1	9.67	64
68	F	20	30	21	20	21	21	10	21	10	1	1	0.7	1	0.7	0.7	0.7	0.4	0.5	0.4	0.5	1	1	7.48	50
69	F	20	30	20	21	20	30	10	21	10	2	1	0.7	1	1	0.4	1	1	0.5	0.4	0.5	2	1	9.47	63
70	F	20	21	21	11	21	21	20	20	21	0	2	0.7	0.4	0.7	0	0.7	0.4	1	0.7	0.7	0	2	7.15	48
71	F	11	21	20	20	20	30	20	20	10	0	1	0	0.4	1	0.7	1	1	1	0.7	0.5	0	1	7.24	48
72	F	11	20	21	20	21	20	20	21	10	2	0	0	0.7	0.7	0.7	0.7	0.7	1	0.4	0.5	2	0	7.25	48
73	F	21	31	20	30	20	31	21	10	10	1	2	0.4	0.8	1	1	1	0.8	0.7	0.3	0.5	1	2	9.40	63
74	F	31	21	21	30	21	30	21	10	10	2	1	0.8	0.4	0.7	1	0.7	1	0.7	0.3	0.5	2	1	8.99	60
75	F	20	20	11	31	21	30	11	10	10	2	1	0.7	0.7	0	0.8	0.7	1	0	0.3	0.5	2	1	7.59	51
76	F	30	21	21	21	21	21	21	11	10	2	1	1	0.4	0.7	0.4	0.7	0.4	0.7	0	0.5	2	1	7.71	51
77	F	31	11	21	31	20	20	21	10	10	2	1	0.8	0	0.7	0.8	1	0.7	0.7	0.3	0.5	2	1	8.34	56
78	F	31	11	21	30	20	21	20	11	10	1	2	0.8	0	0.7	1	1	0.4	1	0	0.5	1	2	8.32	55
79	F	30	11	20	21	21	20	20	10	10	2	2	1	0	1	0.4	0.7	0.7	1	0.3	0.5	2	2	9.57	64
80	F	20	11	20	20	11	20	10	10	10	1	2	0.7	0	1	0.7	0	0.7	0.5	0.3	0.5	1	2	7.34	49
81	F	20	11	20	21	21	21	10	10	21	2	1	0.7	0	1	0.4	0.7	0.4	0.5	0.3	0.7	2	1	7.64	51
82	F	20	21	21	20	21	20	10	10	10	1	1	0.7	0.4	0.7	0.7	0.7	0.7	0.5	0.3	0.5	1	1	7.08	47
83	F	21	21	21	20	21	30	21	10	10	1	1	0.4	0.4	0.7	0.7	0.7	1	0.7	0.3	0.5	1	1	7.31	49
84	F	11	20	21	30	20	30	21	21	10	2	1	0	0.7	0.7	1	1	1	0.7	0.4	0.5	2	1	8.91	59
85	F	20	21	20	30	20	31	21	21	10	2	0	0.7	0.4	1	1	1	0.8	0.7	0.4	0.5	2	0	8.39	56
86	F	20	20	20	31	20	30	21	10	10	2	1	0.7	0.7	1	0.8	1	1	0.7	0.3	0.5	2	1	9.59	64
87	F	21	21	11	30	20	30	20	10	10	1	1	0.4	0.4	0	1	1	1	1	0.3	0.5	1	1	7.63	51
88	F	20	31	20	21	21	21	20	11	10	2	1	0.7	0.8	1	0.4	0.7	0.4	1	0	0.5	2	1	8.39	56
89	F	30	30	20	20	20	20	20	10	11	2	1	1	1	1	0.7	1	0.7	1	0.3	0	2	1	9.67	64
90	F	31	31	20	21	21	21	20	10	11	1	1	0.8	0.8	1	0.4	0.7	0.4	1	0.3	0	1	1	7.30	49
91	F	30	21	21	20	20	31	21	11	10	2	2	1	0.4	0.7	0.7	1	0.8	0.7	0	0.5	2	2	9.66	64
92	F	31	21	20	21	20	30	21	21	10	3	2	0.8	0.4	1	0.4	1	1	0.7	0.4	0.5	3	2	11.12	74
93	F	20	20	20	20	20	31	20	20	10	2	2	0.7	0.7	1	0.7	1	0.8	1	0.7	0.5	2	2	10.93	73
94	F	21	21	20	11	21	21	20	21	10	1	2	0.4	0.4	1	0	0.7	0.4	1	0.4	0.5	1	2	7.77	52
95	F	20	11	21	30	21	21	10	10	10	2	2	0.7	0	0.7	1	0.7	0.4	0.5	0.3	0.5	2	2	8.74	58
96	F	30	21	21	31	20	20	10	10	21	1	2	1	0.4	0.7	0.8	1	0.7	0.5	0.3	0.7	1	2	8.99	60
97	F	31	21	11	21	21	20	20	10	11	2	2	0.8	0.4	0	0.4	0.7	0.7	1	0.3	0	2	2	8.22	55
98	F	20	21	11	21	11	21	21	10	10	1	2	0.7	0.4	0	0.4	0	0.4	0.7	0.3	0.5	1	2	6.37	42
99	F	20	30	20	30	20	21	20	21	10	2	2	0.7	1	1	1	1	0.4	1	0.4	0.5	2	2	10.97	73
100	F	30	30	20	30	20	30	20	21	21	1	2	1	1	1	1	1	1	1	0.4	0.7	1	2	11.07	74
101	M	21	30	20	30	20	30	10	21	21	1	2	0.4	1	1	1	1	1	0.5	0.4	0.7	1	2	9.97	66
102	M	30	20	20	30	20	30	10	10	20	1	2	1	0.7	1	1	1	1	0.5	0.3	1	1	2	10.50	70
103	M	20	21	20	21	20	30	20	21	21	2	2	0.7	0.4	1	0.4	1	1	1	0.4	0.7	2	2	10.54	70
104	M	31	11	21	21	11	21	11	10	11	2	2	0.8	0	0.7	0.4	0	0.4	0	0.3	0	2	2	6.55	44
105	M	30	21	21	21	21	21	20	21	10	1	1	1	0.4	0.7	0.4	0.7	0.4	1	0.4	0.5	1	1	7.44	50
106	M	20	11	20	21	21	21	21	11	10	2	1	0.7	0	1	0.4	0.7	0.4	0.7	0	0.5	2	1	7.31	49
107	M	30	20	21	11	21	11	21	10	11	2	1	1	0.7	0.7	0	0.7	0	0.7	0.3	0	2	1	7.01	47
108	M	31	20	21	20	21	21	20	11	10	1	1	0.8	0.7	0.7	0.7	0.7	0.4	1	0	0.5	1	1	7.33	49
109	M	30	21	21	20	21	21	10	10	11	2	1	1	0.4	0.7	0.7	0.7	0.4	0.5	0.3	0	2	1	7.64	51
110	M	30	20	20	20	21	20	10	10	11	1	2	1	0.7	1	0.7	0.7	0.7	0.5	0.3	0	1	2	8.51	57
111	M	20	30	21	30	21	30	10	10	10	1	2	0.7	1	0.7	1	0.7	1	0.5	0.3	0.5	1	2	9.34	62
112	M	21	31	21	31	21	31	20	10	10	1	1	0.4	0.8	0.7	0.8	0.7	0.8	1	0.3	0.5	1	1	7.82	52
113	M	21	20	21	30	21	30	20	10	10	1	1	0.4	0.7	0.7	1	0.7	1	1	0.3	0.5	1	1	8.24	55
114	M	20	20	20	31	20	30	20	10	10	2	1	0.7	0.7	1	0.8	1	1	1	0.3	0.5	2	1	9.92	66
115	M	30	30	21	30	20	21	20	10	21	2	1	1	1	0.7	1	1	0.4	1	0.3	0.7	2	1	10.07	67
116	M	30	31	21	21	21	20	20	10	21	2	1	1	0.8	0.7	0.4	0.7	0.7	1	0.3	0.7	2	1	9.16	61
117	M	30	30	20	21	20	20	21	10	10	2	2	1	1	1	0.4	1	0.7	0.7	0.3	0.5	2	2	10.57	70
118	M	30	20	21	20	21	20	21	21	10	2	2	1	0.7	0.7	0.7	0.7	0.7	0.7	0.4	0.5	2	2	9.92	66
119	M	21	21	21	30	20	30	21	21	10	2	2	0.4	0.4	0.7	1	1	1	0.7	0.4	0.5	2	2	10.04	67
120	M	20	20	20	30	21	31	10	10	21	2	3	0.7	0.7	1	1	0.7	0.8	0.5	0.3	0.7	2	3	11.26	75
121	M	20	30	11	31	20	30	10	10	21	1	2	0.7	1	0	0.8	1	1	0.5	0.3	0.7	1	2	8.92	59
122	M	21	31	20	21	20	30	10	10	21	2	1	0.4	0.8	1	0.4	1	1	0.5	0.3	0.7	2	1	9.05	60
123	M	20	30	21	30	21	30	10	10	10	2	1	0.7	1	0.7	1	0.7	1	0.5	0.3	0.5	2	1	9.34	62
124	M	20	21	21	31	20	31	10	10	20	2	1	0.7	0.4	0.7	0.8	1	0.8	0.5	0.3	1	2	1	9.07	60
125	M	31	30	20	30	20	31	10	10	10	2	1	0.8	1	1	1	1	0.8	0.5	0.3	0.5	2	1	9.83	66
126	M	30	31	20	21	21	20	10	21	10	1	2	1	0.8	1	0.4	0.7	0.7	0.5	0.4	0.5	1	2	8.89	59
127	M	30	30	20	20	21	20	10	21	10	3	1	1	1	1	0.7	0.7	0.7	0.5	0.4	0.5	3	1	10.41	69
128	M	21	20	21	30	21	30	21	20	11	2	1	0.4	0.7	0.7	1	0.7	1	0.7	0.7	0	2	1	8.75	58
129	M	20	21	20	31	21	30	21	21	11	1	1	0.7	0.4	1	0.8	0.7	1	0.7	0.4	0	1	1	7.56	50
130	M	20	20	21	30	21	31	21	20	11	1	1	0.7	0.7	0.7	1	0.7	0.8	0.7	0.7	0	1	1	7.77	52
131	M	20	30	20	21	20	21	21	21	10	1	2	0.7	1	1	0.4	1	0.4	0.7	0.4	0.5	1	2	9.04	60
132	M	11	31	21	21	20	20	20	31	10	1	1	0	0.8	0.7	0.4	1	0.7	1	0.8	0.5	1	1	7.74	52
133	M	20	21	20	20	20	21	20	21	10	2	1	0.7	0.4	1	0.7	1	0.4	1	0.4	0.5	2	1	9.04	60
134	M	21	20	21	20	20	20	20	21	10	2	1	0.4	0.7	0.7	0.7	1	0.7	1	0.4	0.5	2	1	8.98	60
135	M	31	11	20	20	21	20	20	31	10	2	1	0.8	0	1	0.7	0.7	0.7	1	0.8	0.5	2	1	9.01	60
136	M	20	11	11	30	20	31	21	21	10	1	1	0.7	0	0	1	1	0.8	0.7	0.4	0.5	1	1	6.99	47

137	M	20	21	20	30	21	30	21	10	10	2	1	0.7	0.4	1	1	0.7	1	0.7	0.3	0.5	2	1	9.24	62
138	M	30	21	21	31	20	30	20	10	21	1	3	1	0.4	0.7	0.8	1	1	1	0.3	0.7	1	3	10.82	72
139	M	31	21	20	30	11	30	21	10	10	2	1	0.8	0.4	1	1	0	1	0.7	0.3	0.5	2	1	8.65	58
140	M	21	21	20	21	20	31	20	21	10	1	1	0.4	0.4	1	0.4	1	0.8	1	0.4	0.5	1	1	7.85	52
141	M	20	20	21	30	21	20	20	20	10	2	2	0.7	0.7	0.7	1	0.7	0.7	1	0.7	0.5	2	2	10.52	70
142	M	21	31	21	31	21	20	10	10	21	1	2	0.4	0.8	0.7	0.8	0.7	0.7	0.5	0.3	0.7	1	2	8.41	56
143	M	20	31	21	20	21	21	10	10	10	1	2	0.7	0.8	0.7	0.7	0.7	0.4	0.5	0.3	0.5	1	2	8.16	54
144	M	30	30	21	20	21	30	10	10	10	2	2	1	1	0.7	0.7	0.7	1	0.5	0.3	0.5	2	2	10.34	69
145	M	30	21	20	21	21	30	10	10	10	2	1	1	0.4	1	0.4	0.7	1	0.5	0.3	0.5	2	1	8.80	59
146	M	31	20	20	21	20	31	10	21	11	2	1	0.8	0.7	1	0.4	1	0.8	0.5	0.4	0	2	1	8.47	56
147	M	21	21	20	20	20	11	10	20	11	2	1	0.4	0.4	1	0.7	1	0	0.5	0.7	0	2	1	7.64	51
148	M	20	11	20	31	20	21	10	21	10	2	1	0.7	0	1	0.8	1	0.4	0.5	0.4	0.5	2	1	8.22	55
149	M	30	21	20	30	20	21	10	21	10	2	1	1	0.4	1	1	1	0.4	0.5	0.4	0.5	2	1	9.20	61
150	M	31	21	20	21	20	20	21	20	11	2	1	0.8	0.4	1	0.4	1	0.7	0.7	0.7	0	2	1	8.56	57
151	M	31	20	21	20	20	20	20	21	10	2	1	0.8	0.7	0.7	0.7	1	0.7	1	0.4	0.5	2	1	9.33	62
152	M	20	21	21	21	20	20	20	20	21	2	1	0.7	0.4	0.7	0.4	1	0.7	1	0.7	0.7	2	1	9.15	61
153	M	20	30	21	20	20	20	20	30	21	2	1	0.7	1	0.7	0.7	1	0.7	1	1	0.7	2	1	10.35	69
154	M	30	20	21	30	20	30	21	21	10	2	1	1	0.7	0.7	1	1	1	0.7	0.4	0.5	2	1	9.91	66
155	M	31	31	21	30	20	30	21	30	11	1	1	0.8	0.8	0.7	1	1	1	0.7	1	0	1	1	8.84	59
156	M	21	31	21	31	21	30	21	21	10	2	1	0.4	0.8	0.7	0.8	0.7	1	0.7	0.4	0.5	2	1	8.81	59
157	M	11	21	21	31	20	21	21	21	21	2	1	0	0.4	0.7	0.8	1	0.4	0.7	0.4	0.7	2	1	7.96	53
158	M	30	21	21	11	20	21	21	21	21	2	1	1	0.4	0.7	0	1	0.4	0.7	0.4	0.7	2	1	8.21	55
159	M	30	21	20	11	20	21	20	21	21	2	1	1	0.4	1	0	1	0.4	1	0.4	0.7	2	1	8.87	59
160	M	31	11	20	21	20	21	20	21	11	1	1	0.8	0	1	0.4	1	0.4	1	0.4	0	1	1	6.95	46
161	M	20	11	20	31	20	21	21	21	10	2	1	0.7	0	1	0.8	1	0.4	0.7	0.4	0.5	2	1	8.39	56
162	M	21	20	20	30	20	11	21	21	21	1	1	0.4	0.7	1	1	1	0	0.7	0.4	0.7	1	1	7.81	52
163	M	21	21	21	30	20	21	20	21	10	2	1	0.4	0.4	0.7	1	1	0.4	1	0.4	0.5	2	1	8.77	58
164	M	20	21	21	31	20	20	20	21	21	0	1	0.7	0.4	0.7	0.8	1	0.7	1	0.4	0.7	0	1	7.23	48
165	M	31	11	21	30	21	21	21	11	10	2	1	0.8	0	0.7	1	0.7	0.4	0.7	0	0.5	2	1	7.66	51
166	M	30	20	21	31	21	21	20	21	10	2	1	1	0.7	0.7	0.8	0.7	0.4	1	0.4	0.5	2	1	9.06	60
167	M	21	21	21	20	21	20	10	10	10	1	1	0.4	0.4	0.7	0.7	0.7	0.7	0.5	0.3	0.5	1	1	6.81	45
168	M	20	20	20	21	21	30	10	10	10	2	1	0.7	0.7	1	0.4	0.7	1	0.5	0.3	0.5	2	1	8.74	58
169	M	30	21	21	20	21	31	10	10	10	1	2	1	0.4	0.7	0.7	0.7	0.8	0.5	0.3	0.5	1	2	8.49	57
170	M	21	21	11	21	20	30	10	10	21	2	2	0.4	0.4	0	0.4	1	1	0.5	0.3	0.7	2	2	8.70	58
171	M	20	20	11	21	20	31	10	10	10	1	2	0.7	0.7	0	0.4	1	0.8	0.5	0.3	0.5	1	2	7.82	52
172	M	20	30	11	21	20	20	10	21	10	1	2	0.7	1	0	0.4	1	0.7	0.5	0.4	0.5	1	2	8.14	54
173	M	30	31	11	21	20	20	10	21	10	2	2	1	0.8	0	0.4	1	0.7	0.5	0.4	0.5	2	2	9.22	61
174	M	30	21	21	20	20	30	10	10	10	1	2	1	0.4	0.7	0.7	1	1	0.5	0.3	0.5	1	2	9.07	60
175	M	31	11	20	20	21	31	10	10	11	2	2	0.8	0	1	0.7	0.7	0.8	0.5	0.3	0	2	2	8.67	58
176	M	30	21	20	20	20	30	21	10	10	1	1	1	0.4	1	0.7	1	1	0.7	0.3	0.5	1	1	8.57	57
177	M	21	11	20	21	20	21	21	21	11	2	1	0.4	0	1	0.4	1	0.4	0.7	0.4	0	2	1	7.27	48
178	M	20	21	20	30	20	20	21	20	10	3	1	0.7	0.4	1	1	1	0.7	0.7	0.7	0.5	3	1	10.58	71
179	M	21	20	21	30	20	20	20	10	11	1	2	0.4	0.7	0.7	1	1	0.7	1	0.3	0	1	2	8.74	58
180	M	21	21	21	31	21	30	21	21	10	2	1	0.4	0.4	0.7	0.8	0.7	1	0.7	0.4	0.5	2	1	8.46	56
181	M	21	21	20	30	20	31	21	21	11	2	1	0.4	0.4	1	1	1	0.8	0.7	0.4	0	2	1	8.62	57
182	M	20	21	21	30	20	30	11	10	11	2	1	0.7	0.4	0.7	1	1	1	0	0.3	0	2	1	8.07	54
183	M	20	21	11	30	20	30	20	10	11	2	1	0.7	0.4	0	1	1	1	1	0.3	0	2	1	8.40	56
184	M	20	21	21	31	21	21	10	10	21	1	2	0.7	0.4	0.7	0.8	0.7	0.4	0.5	0.3	0.7	1	2	8.06	54
185	M	30	20	20	21	20	20	10	21	21	2	1	1	0.7	1	0.4	1	0.7	0.5	0.4	0.7	2	1	9.31	62
186	M	30	31	20	21	21	20	10	21	20	2	2	1	0.8	1	0.4	0.7	0.7	0.5	0.4	1	2	2	10.39	69
187	M	31	21	20	20	21	21	21	10	21	2	2	0.8	0.4	1	0.7	0.7	0.4	0.7	0.3	0.7	2	2	9.56	64
188	M	20	21	20	20	21	20	21	10	10	2	1	0.7	0.4	1	0.7	0.7	0.7	0.7	0.3	0.5	2	1	8.58	57
189	M	21	21	20	30	11	20	20	21	11	2	2	0.4	0.4	1	1	0	0.7	1	0.4	0	2	2	8.87	59
190	M	11	11	21	31	21	30	21	11	11	1	2	0	0	0.7	0.8	0.7	1	0.7	0	0	1	2	6.76	45
191	M	21	11	21	20	21	31	21	10	11	2	1	0.4	0	0.7	0.7	0.7	0.8	0.7	0.3	0	2	1	7.16	48
192	M	30	11	21	21	21	30	20	11	11	1	2	1	0	0.7	0.4	0.7	1	1	0	0	1	2	7.74	52
193	M	31	11	21	20	20	30	20	10	10	2	1	0.8	0	0.7	0.7	1	1	1	0.3	0.5	2	1	8.92	59
194	M	20	21	21	30	20	30	10	10	21	1	2	0.7	0.4	0.7	1	1	1	0.5	0.3	0.7	1	2	9.24	62
195	M	21	11	21	30	20	31	10	11	10	2	1	0.4	0	0.7	1	1	0.8	0.5	0	0.5	2	1	7.82	52
196	M	20	11	21	21	21	21	21	11	11	1	2	0.7	0	0.7	0.4	0.7	0.4	0.7	0	0	1	2	6.48	43
197	M	20	11	20	21	21	20	20	11	11	3	1	0.7	0	1	0.4	0.7	0.7	1	0	0	3	1	8.41	56
198	M	30	11	21	21	20	30	20	10	10	2	2	1	0	0.7	0.4	1	1	1	0.3	0.5	2	2	9.90	66
199	M	31	21	20	21	21	21	20	10	11	2	1	0.8	0.4	1	0.4	0.7	0.4	1	0.3	0	2	1	7.95	53
200	M	20	21	20	21	20	21	10	10	20	2	1	0.7	0.4	1	0.4	1	0.4	0.5	0.3	1	2	1	8.70	58
Mean Marks (/1)													**0.7**	**0.5**	**0.8**	**0.6**	**0.8**	**0.7**	**0.7**	**0.3**	**0.5**	**1.7**	**1.4**	**8.62**	**57**
Mean Marks (%)													**65**	**54**	**77**	**63**	**81**	**66**	**70**	**34**	**46**	**55**	**47**	**61.56**	**57**
Standard Deviation													**28**	**30**	**29**	**28**	**24**	**26**	**25**	**16**	**24**	**20**	**18**	**7.972064**	**7.44059**

Codes and Scores for Test Materials-*Experiment Group*

Pupil No.	Sex	Organic Chemistry											Scores											Totals	Total
		1(a)	1(b)	1(c)	1(d)	2(a)	2(b)	2(c)	2(d)	2(e)	3(a)	3(b)	1(a)	1(b)	1(c)	1(d)	2(a)	2(b)	2(c)	2(d)	2(e)	3(a)	3(b)	Org. Ch.	%
1	F	30	21	21	21	20	31	10	31	20	2	3	1	0.4	0.7	0.4	1	0.8	0.5	0.8	1	2	3	11.47	76
2	F	21	21	21	30	21	21	20	30	21	3	2	0.4	0.4	0.7	1	0.7	0.4	1	1	0.7	3	2	11.21	75
3	F	21	21	20	31	21	20	21	31	20	3	2	0.4	0.4	1	0.8	0.7	0.7	0.7	0.8	1	3	2	11.31	75
4	F	30	20	20	30	21	21	10	30	10	3	2	1	0.7	1	1	0.7	0.4	0.5	1	0.5	3	2	11.74	78
5	F	30	31	21	20	11	30	20	31	20	2	3	1	0.8	0.7	0.7	0	1	1	0.8	1	2	3	11.84	79
6	F	20	30	20	20	21	30	20	20	20	3	2	0.7	1	1	0.7	0.7	1	1	0.7	1	3	2	12.68	85
7	F	21	20	20	30	20	21	21	20	21	2	2	0.4	0.7	1	1	1	0.4	0.7	0.7	0.7	2	2	10.48	70
8	F	30	20	20	30	20	30	20	30	20	2	2	1	0.7	1	1	1	1	1	1	1	2	2	12.67	84
9	F	30	30	20	30	21	30	20	31	20	1	2	1	1	1	1	0.7	1	1	0.8	1	1	2	11.42	76
10	F	30	21	11	30	21	21	11	31	20	2	3	1	0.4	0	1	0.7	0.4	0	0.8	1	2	3	10.22	68
11	F	30	20	11	21	21	21	20	30	20	3	2	1	0.7	0	0.4	0.7	0.4	1	1	1	3	2	11.14	74
12	F	21	20	21	21	21	21	10	30	20	3	3	0.4	0.7	0.7	0.4	0.7	0.4	0.5	1	1	3	3	11.71	78
13	F	20	21	21	21	20	21	10	21	21	2	3	0.7	0.4	0.7	0.4	1	0.4	0.5	0.4	0.7	2	3	10.11	67
14	F	30	21	20	21	20	21	10	31	21	3	3	1	0.4	1	0.4	1	0.4	0.5	0.8	0.7	3	3	12.12	81
15	F	31	30	21	21	11	20	10	20	20	2	3	0.8	1	0.7	0.4	0	0.7	0.5	0.7	1	2	3	10.66	71
16	F	31	20	21	21	21	20	20	30	11	3	3	0.8	0.7	0.7	0.4	0.7	0.7	1	1	0	3	3	11.83	79
17	F	30	20	21	30	21	20	21	31	10	3	2	1	0.7	0.7	1	0.7	0.7	0.7	0.8	0.5	3	2	11.60	77
18	F	30	30	21	31	20	20	20	30	20	2	2	1	1	0.7	0.8	1	0.7	1	1	1	2	2	12.09	81
19	F	30	30	20	31	20	21	21	31	21	2	3	1	1	1	0.8	1	0.4	0.7	0.8	0.7	2	3	12.24	82
20	F	21	21	21	20	21	30	20	20	21	2	2	0.4	0.4	0.7	0.7	0.7	1	1	0.7	0.7	2	2	10.15	68
21	F	21	20	20	21	21	31	21	20	20	2	2	0.4	0.7	1	0.4	0.7	0.8	0.7	0.7	1	2	2	10.23	68
22	F	20	21	21	20	20	31	21	30	20	2	2	0.7	0.4	0.7	0.7	1	0.8	0.7	1	1	2	2	10.83	72
23	F	30	21	11	20	20	31	10	31	21	3	2	1	0.4	0	0.7	1	0.8	0.5	0.8	0.7	3	2	10.74	72
24	F	30	20	20	21	21	21	10	20	20	3	2	1	0.7	1	0.4	0.7	0.4	0.5	0.7	1	3	2	11.31	75
25	F	31	21	21	20	20	21	10	21	10	3	2	0.8	0.4	0.7	0.7	1	0.4	0.5	0.4	0.5	3	2	10.29	69
26	F	11	20	21	31	21	20	10	20	10	3	3	0	0.7	0.7	0.8	0.7	0.7	0.5	0.7	0.5	3	3	11.10	74
27	F	21	31	21	20	21	21	10	30	21	3	2	0.4	0.8	0.7	0.7	0.7	0.4	0.5	1	0.7	3	2	10.73	72
28	F	21	30	21	20	20	20	21	31	21	3	2	0.4	1	0.7	0.7	1	0.7	0.7	0.8	0.7	3	2	11.50	77
29	F	31	21	20	20	20	20	21	10	20	3	2	0.8	0.4	1	0.7	1	0.7	0.7	0.3	1	3	2	11.49	77
30	F	30	21	20	21	21	21	20	31	10	3	2	1	0.4	1	0.4	0.7	0.4	1	0.8	0.5	3	2	11.12	74
31	F	31	20	20	30	21	21	20	20	10	3	2	0.8	0.7	1	1	0.7	0.4	1	0.7	0.5	3	2	11.66	78
32	F	30	31	21	31	20	20	20	31	10	3	2	1	0.8	0.7	0.8	1	0.7	1	0.8	0.5	3	2	12.09	81
33	F	30	21	11	31	20	20	21	30	20	3	2	1	0.4	0	0.8	1	0.7	0.7	1	1	3	2	11.49	77
34	F	21	30	20	30	20	21	21	21	21	3	2	0.4	1	1	1	1	0.4	0.7	0.4	0.7	3	2	11.54	77
35	F	21	21	21	30	20	30	20	30	20	3	2	0.4	0.4	0.7	1	1	1	1	1	1	3	2	12.47	83
36	F	20	21	20	21	21	21	20	31	20	3	3	0.7	0.4	1	0.4	0.7	0.4	1	0.8	1	3	3	12.29	82
37	F	20	20	20	21	21	21	20	20	20	2	3	0.7	0.7	1	0.4	0.7	0.4	1	0.7	1	2	3	11.48	77
38	F	21	31	20	11	21	30	21	21	20	2	3	0.4	0.8	1	0	0.7	1	0.7	0.4	1	2	3	10.89	73
39	F	31	31	20	21	21	30	11	20	20	2	3	0.8	0.8	1	0.4	0.7	1	0	0.7	1	2	3	11.24	75
40	F	31	30	21	20	21	21	10	20	20	3	2	0.8	1	0.7	0.7	0.7	0.4	0.5	0.7	1	3	2	11.33	76
41	F	30	31	20	20	20	20	10	20	10	2	3	1	0.8	1	0.7	1	0.7	0.5	0.7	0.5	2	3	11.76	78
42	F	31	30	21	21	20	20	10	21	20	2	3	0.8	1	0.7	0.4	1	0.7	0.5	0.4	1	2	3	11.39	76
43	F	31	20	21	21	20	21	21	21	20	2	3	0.8	0.7	0.7	0.4	1	0.4	0.7	0.4	1	2	3	10.96	73
44	F	21	20	21	20	20	20	21	31	20	2	2	0.4	0.7	0.7	0.7	1	0.7	0.7	0.8	1	2	2	10.50	70
45	F	20	30	21	21	21	30	21	20	20	2	2	0.7	1	0.7	0.4	0.7	1	0.7	0.7	1	2	2	10.75	72
46	F	30	21	21	20	21	31	20	31	21	2	2	1	0.4	0.7	0.7	0.7	0.8	1	0.8	0.7	2	2	10.58	71
47	F	31	21	21	21	20	31	20	31	21	2	2	0.8	0.4	0.7	0.4	1	0.8	1	0.8	0.7	2	2	10.39	69
48	F	20	30	20	20	21	31	21	30	20	2	2	0.7	1	1	0.7	0.7	0.8	0.7	1	1	2	2	11.43	76
49	F	21	20	21	21	20	20	10	21	20	2	2	0.4	0.7	0.7	0.4	1	0.7	0.5	0.4	1	2	2	9.71	65
50	F	20	20	21	30	20	21	10	10	10	2	2	0.7	0.7	0.7	1	1	0.4	0.5	0.3	0.5	2	2	9.74	65
51	F	20	30	20	30	20	30	10	21	10	2	3	0.7	1	1	1	1	1	0.5	0.4	0.5	2	3	12.07	80
52	F	30	31	21	21	21	21	21	30	20	2	3	1	0.8	0.7	0.4	0.7	0.4	0.7	1	1	2	3	11.56	77
53	F	20	31	21	21	21	11	21	30	10	2	3	0.7	0.8	0.7	0.4	0.7	0	0.7	1	0.5	2	3	10.33	69
54	F	11	21	21	21	21	21	20	30	20	3	3	0	0.4	0.7	0.4	0.7	0.4	1	1	1	3	3	11.54	77
55	F	30	21	20	21	11	20	21	31	10	3	2	1	0.4	1	0.4	0	0.7	0.7	0.8	0.5	3	2	10.39	69
56	F	21	20	21	30	21	20	20	20	20	3	2	0.4	0.7	0.7	1	0.7	0.7	1	0.7	1	3	2	11.75	78
57	F	21	21	21	31	21	20	21	20	20	3	2	0.4	0.4	0.7	0.8	0.7	0.7	0.7	0.7	1	3	2	10.90	73
58	F	30	21	21	31	21	21	21	20	20	3	2	1	0.4	0.7	0.8	0.7	0.4	0.7	0.7	1	3	2	11.23	75
59	F	31	21	21	31	21	20	20	20	21	3	2	0.8	0.4	0.7	0.8	0.7	0.7	1	0.7	0.7	3	2	11.25	75
60	F	20	20	20	21	21	30	21	31	21	3	2	0.7	0.7	1	0.4	0.7	1	0.7	0.8	0.7	3	2	11.50	77
61	F	21	21	11	20	21	31	21	21	21	3	2	0.4	0.4	0	0.7	0.7	0.8	0.7	0.4	0.7	3	2	9.63	64
62	F	30	20	20	21	20	30	20	30	21	1	2	1	0.7	1	0.4	1	1	1	1	0.7	1	2	10.74	72
63	F	20	21	20	20	21	30	10	31	21	3	2	0.7	0.4	1	0.7	0.7	1	0.5	0.8	0.7	3	2	11.33	76
64	F	20	21	20	20	11	21	10	30	20	2	2	0.7	0.4	1	0.7	0	0.4	0.5	1	1	2	2	9.64	64
65	F	31	21	21	20	21	20	10	20	20	2	3	0.8	0.4	0.7	0.7	0.7	0.7	0.5	0.7	1	2	3	11.00	73
66	F	20	20	21	20	21	20	10	20	20	2	3	0.7	0.7	0.7	0.7	0.7	0.7	0.5	0.7	1	2	3	11.19	75
67	F	21	21	21	20	20	20	10	21	21	2	2	0.4	0.4	0.7	0.7	1	0.7	0.5	0.4	0.7	2	2	9.38	63

68	F	30	21	11	20	20	20	10	20	20	2	2	1	0.4	0	0.7	1	0.7	0.5	0.7	1	2	2	9.91	66
69	F	31	20	20	20	21	31	10	30	20	2	3	0.8	0.7	1	0.7	0.7	0.8	0.5	1	1	2	3	12.01	80
70	F	20	31	20	31	20	31	10	31	20	2	3	0.7	0.8	1	0.8	1	0.8	0.5	0.8	1	2	3	12.17	81
71	F	31	31	20	21	21	21	21	30	20	2	2	0.8	0.8	1	0.4	0.7	0.4	0.7	1	1	2	2	10.64	71
72	F	30	21	20	21	21	20	11	31	10	3	3	1	0.4	1	0.4	0.7	0.7	0	0.8	0.5	3	3	11.39	76
73	F	20	20	21	11	21	20	21	30	20	3	2	0.7	0.7	0.7	0	0.7	0.7	0.7	1	1	3	2	11.02	73
74	F	20	21	21	21	21	20	21	30	10	2	3	0.7	0.4	0.7	0.4	0.7	0.7	0.7	1	0.5	2	3	10.65	71
75	F	21	21	21	21	21	31	20	21	10	3	2	0.4	0.4	0.7	0.4	0.7	0.8	1	0.4	0.5	3	2	10.19	68
76	F	20	21	21	20	21	30	21	10	10	3	2	0.7	0.4	0.7	0.7	0.7	1	0.7	0.3	0.5	3	2	10.58	71
77	F	11	11	20	20	20	31	21	20	20	3	2	0	0	1	0.7	1	0.8	0.7	0.7	1	3	2	10.76	72
78	F	30	11	21	21	20	30	21	20	21	3	2	1	0	0.7	0.4	1	1	0.7	0.7	0.7	3	2	11.08	74
79	F	31	11	20	20	20	21	21	30	11	3	2	0.8	0	1	0.7	1	0.4	0.7	1	0	3	2	10.49	70
80	F	30	11	20	21	20	20	20	21	21	3	2	1	0	1	0.4	1	0.7	1	0.4	0.7	3	2	11.14	74
81	F	20	11	21	20	20	30	10	20	21	3	2	0.7	0	0.7	0.7	1	1	0.5	0.7	0.7	3	2	10.85	72
82	F	21	31	21	20	20	31	10	30	21	2	2	0.4	0.8	0.7	0.7	1	0.8	0.5	1	0.7	2	2	10.41	69
83	F	30	20	21	20	21	30	10	31	21	3	2	1	0.7	0.7	0.7	0.7	1	0.5	0.8	0.7	2	2	10.60	71
84	F	30	21	21	31	20	21	10	31	21	2	3	1	0.4	0.7	0.8	1	0.4	0.5	0.8	0.7	2	3	11.14	74
85	F	21	21	21	31	21	20	10	20	10	2	3	0.4	0.4	0.7	0.8	0.7	0.7	0.5	0.7	0.5	2	3	10.23	68
86	F	11	21	20	30	21	20	10	31	10	3	2	0	0.4	1	1	0.7	0.7	0.5	0.8	0.5	3	2	10.49	70
87	F	20	21	21	21	20	21	10	31	10	3	2	0.7	0.4	0.7	0.4	1	0.4	0.5	0.8	0.5	3	2	10.29	69
88	F	20	20	20	20	20	20	10	31	20	3	2	0.7	0.7	1	0.7	1	0.7	0.5	0.8	1	3	2	11.93	80
89	F	30	11	21	21	21	20	10	21	20	3	2	1	0	0.7	0.4	0.7	0.7	0.5	0.4	1	3	2	10.31	69
90	F	21	21	20	20	21	31	21	20	21	2	3	0.4	0.4	1	0.7	0.7	0.8	0.7	0.7	0.7	2	3	10.90	73
91	F	30	21	21	30	11	30	21	31	21	3	2	1	0.4	0.7	1	0	1	0.7	0.8	0.7	3	2	11.16	74
92	F	31	21	11	31	21	31	21	20	21	2	3	0.8	0.4	0	0.8	0.7	0.8	0.7	0.7	0.7	2	3	10.33	69
93	F	30	21	21	21	21	30	20	20	10	3	3	1	0.4	0.7	0.4	0.7	1	1	0.7	0.5	3	3	12.31	82
94	F	21	11	21	11	21	21	21	10	11	3	3	0.4	0	0.7	0	0.7	0.4	0.7	0.3	0	3	3	9.14	61
95	F	20	11	21	11	21	20	21	31	10	3	3	0.7	0	0.7	0	0.7	0.7	0.7	0.8	0.5	3	3	10.60	71
96	F	20	21	20	31	21	21	20	10	10	2	2	0.7	0.4	1	0.8	0.7	0.4	1	0.3	0.5	2	2	9.72	65
97	F	20	21	20	21	21	20	10	20	10	2	2	0.7	0.4	1	0.4	0.7	0.7	0.5	0.7	0.5	2	2	9.48	63
98	F	20	21	20	21	20	20	10	21	20	3	2	0.7	0.4	1	0.4	1	0.7	0.5	0.4	1	3	2	11.04	74
99	F	30	30	20	30	20	21	10	21	20	3	2	1	1	1	1	1	0.4	0.5	0.4	1	3	2	12.30	82
100	F	30	30	20	30	20	21	10	21	21	3	2	1	1	1	1	1	0.4	0.5	0.4	0.7	3	2	11.97	80
101	M	20	30	20	30	20	30	10	21	21	2	3	0.7	1	1	1	1	1	0.5	0.4	0.7	2	3	12.24	82
102	M	20	11	20	30	20	30	11	30	20	2	3	0.7	0	1	1	1	1	0	1	1	2	3	11.67	78
103	M	30	21	20	21	20	30	20	31	20	2	3	1	0.4	1	0.4	1	1	1	0.8	1	2	3	12.55	84
104	M	31	20	21	21	21	21	10	21	20	2	3	0.8	0.7	0.7	0.4	0.7	0.4	0.5	0.4	1	2	3	10.46	70
105	M	20	21	11	21	21	21	10	21	11	2	3	0.7	0.4	0	0.4	0.7	0.4	0.5	0.4	0	2	3	8.44	56
106	M	21	20	20	21	21	21	10	20	10	2	3	0.4	0.7	1	0.4	0.7	0.4	0.5	0.7	0.5	2	3	10.21	68
107	M	20	20	20	21	21	11	10	20	10	2	2	0.7	0.7	1	0.4	0.7	0	0.5	0.7	0.5	2	2	9.08	61
108	M	31	11	21	21	21	21	10	10	10	2	2	0.8	0	0.7	0.4	0.7	0.4	0.5	0.3	0.5	2	2	8.22	55
109	M	20	21	21	20	11	20	21	30	20	2	2	0.7	0.4	0.7	0.7	0	0.7	0.7	1	1	2	2	9.75	65
110	M	20	31	21	20	21	20	21	30	21	2	3	0.7	0.8	0.7	0.7	0.7	0.7	0.7	1	0.7	2	3	11.44	76
111	M	30	30	21	21	21	30	21	30	21	2	2	1	1	0.7	0.4	0.7	1	0.7	1	0.7	2	2	11.08	74
112	M	11	21	20	20	20	31	21	30	21	2	2	0	0.4	1	0.7	1	0.8	0.7	1	0.7	2	2	10.16	68
113	M	21	20	21	21	20	30	10	20	10	2	2	0.4	0.7	0.7	0.4	1	1	0.5	0.7	0.5	2	2	9.81	65
114	M	20	21	20	20	20	30	10	20	10	2	2	0.7	0.4	1	0.7	1	1	0.5	0.7	0.5	2	2	10.41	69
115	M	20	21	20	20	20	31	10	20	10	2	2	0.7	0.4	1	0.7	1	0.8	0.5	0.7	0.5	2	2	10.16	68
116	M	20	21	20	30	20	20	21	31	10	2	2	0.7	0.4	1	1	1	0.7	0.7	0.8	0.5	2	2	10.66	71
117	M	31	30	20	30	20	21	21	30	21	2	2	0.8	1	1	1	1	0.4	0.7	1	0.7	2	2	11.49	77
118	M	30	31	20	31	20	21	10	20	21	2	3	1	0.8	1	0.8	1	0.4	0.5	0.7	0.7	2	3	11.74	78
119	M	21	20	20	20	21	20	10	21	21	2	3	0.4	0.7	1	0.7	0.7	0.7	0.5	0.4	0.7	2	3	10.65	71
120	M	20	21	20	21	20	20	21	20	10	3	2	0.7	0.4	1	0.4	1	0.7	0.7	0.7	0.5	3	2	10.98	73
121	M	31	21	21	21	21	30	11	20	10	3	2	0.8	0.4	0.7	0.4	0.7	1	0	0.7	0.5	3	2	10.06	67
122	M	30	20	21	20	20	31	21	21	20	2	2	1	0.7	0.7	0.7	1	0.8	0.7	0.4	1	2	2	10.83	72
123	M	21	21	21	20	21	30	21	20	20	2	2	0.4	0.4	0.7	0.7	0.7	1	0.7	0.7	1	2	2	10.15	68
124	M	20	20	20	20	20	20	21	21	20	2	2	0.7	0.7	1	0.7	1	0.7	0.7	0.4	1	2	2	10.75	72
125	M	20	21	21	20	21	21	10	20	21	2	2	0.7	0.4	0.7	0.7	0.7	0.4	0.5	0.7	0.7	2	2	9.32	62
126	M	20	20	21	20	20	21	10	20	21	2	2	0.7	0.7	0.7	0.7	1	0.4	0.5	0.7	0.7	2	2	9.92	66
127	M	30	30	21	20	21	20	10	20	21	2	2	1	1	0.7	0.7	0.7	0.7	0.5	0.7	0.7	2	2	10.52	70
128	M	31	30	21	20	21	20	21	20	20	2	2	0.8	1	0.7	0.7	0.7	0.7	0.7	0.7	1	2	2	10.77	72
129	M	30	30	21	20	21	31	20	21	20	2	2	1	1	0.7	0.7	0.7	0.8	1	0.4	1	2	2	11.16	74
130	M	21	21	21	20	21	30	21	20	20	2	2	0.4	0.4	0.7	0.7	0.7	1	0.7	0.7	1	2	2	10.15	68
131	M	20	20	21	20	21	21	20	10	20	2	2	0.7	0.7	0.7	0.7	0.7	0.4	1	0.3	1	2	2	10.08	67
132	M	20	30	20	20	20	21	21	10	20	1	2	0.7	1	1	0.7	1	0.4	0.7	0.3	1	1	2	9.74	65
133	M	20	31	20	20	20	20	10	10	20	2	3	0.7	0.8	1	0.7	1	0.7	0.5	0.3	1	2	3	11.59	77
134	M	20	20	20	20	21	30	10	10	21	2	3	0.7	0.7	1	0.7	0.7	1	0.5	0.3	0.7	2	3	11.18	75
135	M	31	20	21	21	20	31	10	10	10	3	2	0.8	0.7	0.7	0.4	1	0.8	0.5	0.3	0.5	3	2	10.57	70
136	M	30	20	21	30	21	30	21	10	10	2	2	1	0.7	0.7	1	0.7	1	0.7	0.3	0.5	2	2	10.51	70
137	M	30	31	21	31	20	30	21	10	10	3	2	1	0.8	0.7	0.8	1	1	0.7	0.3	0.5	3	2	11.67	78
138	M	21	31	21	21	21	31	20	10	10	3	2	0.4	0.8	0.7	0.4	0.7	0.8	1	0.3	0.5	3	2	10.47	70
139	M	20	20	21	21	20	31	20	20	10	2	2	0.7	0.7	0.7	0.4	1	0.8	1	0.7	0.5	2	2	10.33	69
140	M	20	21	21	20	21	20	20	20	10	2	2	0.7	0.4	0.7	0.7	0.7	0.7	1	0.7	0.5	2	2	9.92	66

141	M	31	20	21	21	20	20	20	31	10	2	2	0.8	0.7	0.7	0.4	1	0.7	1	0.8	0.5	2	2	10.41	69
142	M	20	20	20	20	21	21	20	30	20	2	2	0.7	0.7	1	0.7	0.7	0.4	1	1	1	2	2	11.08	74
143	M	21	11	21	31	21	30	10	20	21	2	2	0.4	0	0.7	0.8	0.7	1	0.5	0.7	0.7	2	2	9.33	62
144	M	20	31	21	30	21	31	10	20	21	2	2	0.7	0.8	0.7	1	0.7	0.8	0.5	0.7	0.7	2	2	10.35	69
145	M	21	31	21	31	21	21	10	21	21	2	2	0.4	0.8	0.7	0.8	0.7	0.4	0.5	0.4	0.7	2	2	9.21	61
146	M	20	30	21	20	20	21	10	21	21	3	2	0.7	1	0.7	0.7	1	0.4	0.5	0.4	0.7	3	2	10.98	73
147	M	20	20	20	21	20	20	10	21	11	2	3	0.7	0.7	1	0.4	1	0.7	0.5	0.4	0	2	3	10.31	69
148	M	31	21	21	21	20	20	21	20	10	3	2	0.8	0.4	0.7	0.4	1	0.7	0.7	0.7	0.5	3	2	10.73	72
149	M	30	20	21	20	21	31	21	20	10	3	1	1	0.7	0.7	0.7	0.7	0.8	0.7	0.7	0.5	3	1	10.27	68
150	M	31	31	21	20	20	11	10	21	10	3	2	0.8	0.8	0.7	0.7	1	0	0.5	0.4	0.5	3	2	10.24	68
151	M	11	21	20	20	20	30	10	20	20	3	2	0	0.4	1	0.7	1	1	0.5	0.7	1	3	2	11.24	75
152	M	21	20	20	20	11	31	20	21	20	3	2	0.4	0.7	1	0.7	0	0.8	1	0.4	1	3	2	10.89	73
153	M	20	30	20	20	20	30	20	30	20	2	3	0.7	1	1	0.7	1	1	1	1	1	2	3	13.34	89
154	M	20	30	21	21	20	30	20	30	20	2	3	0.7	1	0.7	0.4	1	1	1	1	1	2	3	12.74	85
155	M	30	31	20	30	20	30	20	30	21	2	1	1	0.8	1	1	1	1	1	1	0.7	2	1	11.42	76
156	M	30	31	20	30	21	30	20	21	21	2	2	1	0.8	1	1	0.7	1	1	0.4	0.7	2	2	11.49	77
157	M	31	21	20	30	20	21	20	21	21	2	3	0.8	0.4	1	1	1	0.4	1	0.4	0.7	2	3	11.62	77
158	M	21	30	11	31	20	21	20	21	21	1	2	0.4	1	0	0.8	1	0.4	1	0.4	0.7	1	2	8.62	57
159	M	20	21	21	21	11	21	21	21	21	3	2	0.7	0.4	0.7	0.4	0	0.4	0.7	0.4	0.7	3	2	9.28	62
160	M	20	11	21	21	20	21	10	21	11	2	2	0.7	0	0.7	0.4	1	0.4	0.5	0.4	0	2	2	8.04	54
161	M	20	30	21	21	21	21	10	21	10	2	2	0.7	1	0.7	0.4	0.7	0.4	0.5	0.4	0.5	2	2	9.21	61
162	M	30	31	21	21	21	11	10	31	10	2	3	1	0.8	0.7	0.4	0.7	0	0.5	0.8	0.5	2	3	10.24	68
163	M	31	11	20	21	21	21	10	21	10	2	2	0.8	0	1	0.4	0.7	0.4	0.5	0.4	0.5	2	2	8.62	57
164	M	30	20	20	21	20	20	10	21	10	2	1	1	0.7	1	0.4	1	0.7	0.5	0.4	0.5	2	1	9.14	61
165	M	21	30	20	21	21	21	21	10	10	2	3	0.4	1	1	0.4	0.7	0.4	0.7	0.3	0.5	2	3	10.37	69
166	M	21	31	20	11	20	20	21	20	20	2	2	0.4	0.8	1	0	1	0.7	0.7	0.7	1	2	2	10.16	68
167	M	20	21	20	11	21	20	10	31	20	2	2	0.7	0.4	1	0	0.7	0.7	0.5	0.8	1	2	2	9.66	64
168	M	30	31	21	21	20	31	10	20	21	3	2	1	0.8	0.7	0.4	1	0.8	0.5	0.7	0.7	3	2	11.41	76
169	M	31	21	21	21	20	20	10	10	21	2	2	0.8	0.4	0.7	0.4	1	0.7	0.5	0.3	0.7	2	2	9.39	63
170	M	20	21	21	21	21	20	10	21	21	2	2	0.7	0.4	0.7	0.4	0.7	0.7	0.5	0.4	0.7	2	2	9.05	60
171	M	20	21	21	20	21	20	10	21	21	2	3	0.7	0.4	0.7	0.7	0.7	0.7	0.5	0.4	0.7	2	3	10.32	69
172	M	30	30	11	11	21	20	21	21	10	2	2	1	1	0	0	0.7	0.7	0.7	0.4	0.5	2	2	8.91	59
173	M	31	21	21	21	21	31	21	21	10	2	2	0.8	0.4	0.7	0.4	0.7	0.8	0.7	0.4	0.5	2	2	9.21	61
174	M	30	21	21	20	21	30	20	10	10	2	2	1	0.4	0.7	0.7	0.7	1	1	0.3	0.5	2	2	10.24	68
175	M	30	11	21	21	20	20	20	20	10	2	2	1	0	0.7	0.4	1	0.7	1	0.7	0.5	2	2	9.91	66
176	M	21	21	21	21	21	21	20	20	10	2	2	0.4	0.4	0.7	0.4	0.7	0.4	1	0.7	0.5	2	2	9.11	61
177	M	20	21	21	31	20	21	21	20	10	2	2	0.7	0.4	0.7	0.8	1	0.4	0.7	0.7	0.5	2	2	9.73	65
178	M	20	21	21	31	21	20	21	10	10	2	2	0.7	0.4	0.7	0.8	0.7	0.7	0.7	0.3	0.5	2	2	9.33	62
179	M	20	20	21	20	20	21	10	21	10	2	2	0.7	0.7	0.7	0.7	1	0.4	0.5	0.4	0.5	2	2	9.48	63
180	M	21	21	21	21	21	21	10	21	10	2	2	0.4	0.4	0.7	0.4	0.7	0.4	0.5	0.4	0.5	2	2	8.34	56
181	M	31	21	20	21	20	21	10	30	21	2	2	0.8	0.4	1	0.4	1	0.4	0.5	1	0.7	2	2	10.12	67
182	M	30	20	20	21	21	20	20	20	20	3	2	1	0.7	1	0.4	0.7	0.7	1	0.7	1	3	2	12.08	81
183	M	30	20	21	21	20	21	20	21	21	3	1	1	0.7	0.7	0.4	1	0.4	1	0.4	0.7	3	1	10.21	68
184	M	31	21	21	20	20	21	20	30	21	3	2	0.8	0.4	0.7	0.7	1	0.4	1	1	0.7	3	2	11.56	77
185	M	20	21	21	31	20	20	20	31	21	3	2	0.7	0.4	0.7	0.8	1	0.7	1	0.8	0.7	3	2	11.58	77
186	M	11	11	21	31	20	20	21	30	20	1	2	0	0	0.7	0.8	1	0.7	0.7	1	1	1	2	8.76	58
187	M	20	21	20	21	21	21	20	30	20	3	3	0.7	0.4	1	0.4	0.7	0.4	1	1	1	3	3	12.54	84
188	M	21	21	21	21	20	21	21	20	21	3	2	0.4	0.4	0.7	0.4	1	0.4	0.7	0.7	0.7	3	2	10.28	69
189	M	21	30	21	21	21	20	21	30	20	3	2	0.4	1	0.7	0.4	0.7	0.7	0.7	1	1	3	2	11.48	77
190	M	20	31	21	20	21	30	20	31	20	3	2	0.7	0.8	0.7	0.7	0.7	1	1	0.8	1	3	2	12.18	81
191	M	30	21	20	20	21	31	10	20	21	3	2	1	0.4	1	0.7	0.7	0.8	0.5	0.7	0.7	3	2	11.33	76
192	M	30	21	20	31	20	30	10	31	21	1	2	1	0.4	1	0.8	1	1	0.5	0.8	0.7	1	2	10.07	67
193	M	30	11	21	30	21	31	10	30	20	3	2	1	0	0.7	1	0.7	0.8	0.5	1	1	3	2	11.59	77
194	M	31	21	11	30	21	20	21	20	20	2	2	0.8	0.4	0	1	0.7	0.7	0.7	0.7	1	2	2	9.83	66
195	M	20	21	21	21	21	21	21	30	21	3	2	0.7	0.4	0.7	0.4	0.7	0.4	0.7	1	0.7	3	2	10.55	70
196	M	20	11	21	21	11	20	20	21	20	3	2	0.7	0	0.7	0.4	0	0.7	1	0.4	1	3	2	9.81	65
197	M	20	21	21	20	21	21	10	21	20	2	2	0.7	0.4	0.7	0.7	0.7	0.4	0.5	0.4	1	2	2	9.38	63
198	M	30	30	20	20	21	21	10	20	20	3	2	1	1	1	0.7	0.7	0.4	0.5	0.7	1	3	2	11.91	79
199	M	31	31	20	21	21	21	10	20	20	2	1	0.8	0.8	1	0.4	0.7	0.4	0.5	0.7	1	2	1	9.14	61
200	M	21	21	21	20	21	20	21	21	10	1	2	0.4	0.4	0.7	0.7	0.7	0.7	0.7	0.4	0.5	1	2	8.05	54
Mean Marks (/1)													**0.7**	**0.6**	**0.8**	**0.6**	**0.8**	**0.6**	**0.7**	**0.7**	**0.7**	**2.4**	**2.2**	**10.71**	**71**
Mean Marks (%)													**70**	**56**	**76**	**60**	**78**	**65**	**67**	**66**	**73**	**79**	**75**	**76.47**	**71**
Standard Deviation													**25**	**27**	**24**	**23**	**23**	**23**	**22**	**22**	**25**	**18**	**16**	**7.182951**	**6.70409**

Scores Acids and Alkilles-*Control Group*

Pup No	Sex	Scores Acids and Alkilles												Total
		Q1		Q2		Q3		Q4		Q5	Q6			Total
		a	b	a	b	a	b	a	b		a	b	Total	%
1	F	1	1	1	1	0	1	1	1	2	0	1	10.0	59
2	F	1	1	1	1	1	0	1	2	0	0	1	9.0	53
3	F	1	1	1	1	1	1	0	2	2	1	0	11.0	65
4	F	1	1	1	1	1	1	1	2	2	1	0	12.0	71
5	F	1	1	1	1	1	1	0	2	0	1	0	9.0	53
6	F	1	1	1	1	1	1	1	1	0	0	1	9.0	53
7	F	1	1	1	1	1	1	0	2	2	0	1	11.0	65
8	F	1	1	2	1	1	1	1	2	0	0	1	11.0	65
9	F	1	1	1	1	1	1	1	2	0	0	1	10.0	59
10	F	1	1	1	1	1	1	1	2	0	0	1	10.0	59
11	F	1	1	1	1	1	1	1	1	2	0	1	11.0	65
12	F	1	1	0	1	1	2	1	2	0	0	1	10.0	59
13	F	1	1	0	1	1	2	1	2	2	0	1	12.0	71
14	F	1	1	1	1	1	1	1	2	0	1	1	11.0	65
15	F	1	1	1	1	1	1	1	1	0	1	1	10.0	59
16	F	1	1	1	1	1	1	1	1	2	1	1	12.0	71
17	F	1	1	1	1	1	1	1	1	0	1	1	10.0	59
18	F	1	1	1	1	0	1	1	2	2	1	1	12.0	71
19	F	1	1	1	1	1	1	1	2	2	1	1	13.0	76
20	F	1	1	1	1	1	2	1	2	0	1	1	12.0	71
21	F	1	1	1	1	1	1	0	2	0	1	1	10.0	59
22	F	1	1	1	1	0	1	1	1	2	1	1	11.0	65
23	F	0	1	0	1	2	2	0	2	0	1	1	10.0	59
24	F	1	1	1	1	1	2	1	1	0	1	1	11.0	65
25	F	1	1	1	1	2	1	0	1	0	1	0	9.0	53
26	F	1	1	1	1	1	1	0	1	2	1	1	11.0	65
27	F	1	1	1	1	2	1	1	1	0	0	1	10.0	59
28	F	1	0	1	1	1	1	1	1	2	0	1	10.0	59
29	F	1	0	1	1	1	1	1	2	0	0	1	9.0	53
30	F	1	1	1	1	1	2	1	2	0	1	1	12.0	71
31	F	1	1	1	1	1	1	1	2	2	1	1	13.0	76
32	F	1	1	1	1	1	1	1	1	0	1	1	10.0	59
33	F	1	1	1	1	2	1	1	1	2	0	1	12.0	71
34	F	1	1	1	1	1	1	1	2	2	1	1	13.0	76
35	F	1	1	1	0	1	1	1	1	0	1	1	9.0	53
36	F	1	1	1	1	1	1	1	2	2	0	1	12.0	71
37	F	1	1	1	1	1	1	1	2	2	1	1	13.0	76
38	F	1	1	2	1	1	1	1	2	0	1	1	12.0	71
39	F	0	1	2	1	0	1	1	1	2	1	1	11.0	65
40	F	1	1	2	1	1	1	1	1	2	1	0	12.0	71
41	F	1	1	0	1	1	1	1	2	0	1	1	10.0	59
42	F	1	1	1	1	1	1	1	2	2	1	0	12.0	71
43	F	1	1	1	1	1	1	1	1	0	1	0	9.0	53
44	F	1	1	1	1	1	1	1	1	2	1	1	12.0	71
45	F	1	1	1	1	1	1	1	1	0	1	1	10.0	59
46	F	1	1	1	1	1	1	1	2	1	1	1	12.0	71
47	F	1	1	1	1	1	1	1	1	0	1	0	9.0	53
48	F	1	1	1	1	1	1	1	2	0	1	1	11.0	65
49	F	1	1	1	1	2	1	1	2	0	0	1	11.0	65
50	F	1	1	1	1	1	1	1	2	2	1	1	13.0	76
51	F	1	1	0	1	1	2	1	2	0	1	1	11.0	65
52	F	1	1	1	1	1	1	1	1	2	0	1	11.0	65
53	F	1	1	2	1	2	1	0	1	0	1	1	11.0	65
54	F	1	1	2	1	1	1	1	0	2	1	1	12.0	71
55	F	1	1	2	1	2	1	0	1	0	1	0	10.0	59
56	F	1	1	0	1	0	1	1	1	2	1	0	9.0	53
57	F	0	1	1	1	2	1	1	1	2	1	0	11.0	65
58	F	1	1	1	1	0	2	0	1	2	1	0	10.0	59
59	F	1	1	1	1	1	0	1	1	2	1	0	10.0	59
60	F	1	1	2	1	1	0	1	2	2	1	0	12.0	71
61	F	1	1	1	1	0	1	1	2	0	1	0	9.0	53
62	F	1	1	1	1	1	1	1	2	2	0	1	12.0	71
63	F	1	1	1	1	1	0	1	2	2	1	1	12.0	71
64	F	1	1	1	1	2	1	1	1	0	0	1	10.0	59
65	F	0	1	1	1	1	1	1	2	0	1	1	10.0	59
66	F	1	1	1	1	1	1	1	2	2	0	1	12.0	71
67	F	1	1	1	1	1	1	1	2	2	1	1	13.0	76
68	F	1	1	1	1	2	1	1	1	2	1	1	13.0	76
69	F	1	1	1	1	1	1	1	1	0	1	1	10.0	59
70	F	1	0	1	1	2	1	1	2	2	0	1	12.0	71
71	F	1	1	1	1	2	1	1	1	0	1	1	11.0	65
72	F	1	1	1	1	1	1	1	1	2	1	1	12.0	71

73	F	1	1	2	1	1	1	1	2	0	0	1	11.0	65
74	F	0	1	2	1	1	1	1	2	0	0	1	10.0	59
75	F	1	1	1	1	1	1	1	2	2	1	1	13.0	76
76	F	1	1	2	1	1	1	1	1	2	1	1	13.0	76
77	F	1	1	2	1	1	1	1	1	2	1	1	13.0	76
78	F	1	1	1	1	1	1	1	2	2	1	1	13.0	76
79	F	1	1	2	1	1	1	1	1	0	1	1	11.0	65
80	F	1	1	2	1	0	1	1	1	0	1	1	10.0	59
81	F	1	1	1	1	1	1	1	1	2	0	1	11.0	65
82	F	1	1	2	1	1	1	1	1	0	1	1	11.0	65
83	F	1	1	2	1	1	0	1	2	2	1	1	13.0	76
84	F	1	1	1	1	1	2	1	1	2	0	1	12.0	71
85	F	1	1	1	1	1	2	1	2	2	1	1	14.0	82
86	F	1	1	1	1	1	1	1	2	0	1	1	11.0	65
87	F	1	1	1	1	1	1	1	1	2	1	1	12.0	71
88	F	1	0	1	1	1	1	1	2	0	1	1	10.0	59
89	F	1	1	1	1	0	2	1	2	2	1	1	13.0	76
90	F	1	1	1	0	1	1	1	1	0	1	1	9.0	53
91	F	1	1	1	1	0	1	1	1	2	1	1	11.0	65
92	F	0	1	1	1	1	2	1	1	2	1	1	12.0	71
93	F	1	0	1	1	1	2	1	2	2	1	1	13.0	76
94	F	1	0	1	1	1	1	1	1	2	0	1	10.0	59
95	F	1	1	1	1	1	1	0	2	2	0	1	11.0	65
96	F	1	1	1	1	1	2	1	2	0	0	1	11.0	65
97	F	1	1	2	1	1	1	0	1	2	1	1	12.0	71
98	F	0	1	2	1	1	2	1	1	0	1	1	11.0	65
99	F	1	1	0	1	1	2	1	2	0	1	1	11.0	65
100	F	1	1	1	1	1	1	0	2	2	0	1	11.0	65
101	M	1	1	1	1	0	1	1	1	0	1	1	9.0	53
102	M	1	1	1	1	1	2	1	1	0	1	1	11.0	65
103	M	1	0	1	1	1	1	1	2	2	1	1	12.0	71
104	M	1	1	1	1	1	2	1	1	0	1	1	11.0	65
105	M	1	1	1	1	1	1	1	1	0	1	1	10.0	59
106	M	1	1	1	1	1	1	1	1	2	0	1	11.0	65
107	M	1	1	1	1	0	1	1	1	2	1	1	11.0	65
108	M	1	1	1	1	0	1	1	2	0	1	1	10.0	59
109	M	0	1	0	1	1	0	1	1	2	1	1	9.0	53
110	M	1	1	1	1	1	1	1	1	2	1	1	12.0	71
111	M	1	1	1	1	2	1	1	1	0	1	1	11.0	65
112	M	1	1	1	1	1	1	1	1	2	1	1	12.0	71
113	M	1	1	1	1	1	1	1	1	0	1	1	10.0	59
114	M	1	1	1	1	2	1	1	2	2	0	1	13.0	76
115	M	1	1	1	1	1	1	1	2	0	0	1	10.0	59
116	M	1	0	1	1	1	1	0	1	2	1	1	10.0	59
117	M	1	1	1	1	2	1	1	2	2	1	1	14.0	82
118	M	1	0	2	1	1	1	1	1	2	0	1	11.0	65
119	M	1	1	1	1	1	1	1	2	0	0	1	10.0	59
120	M	1	1	2	1	0	1	1	1	2	1	1	12.0	71
121	M	1	1	1	1	0	1	1	1	0	1	1	9.0	53
122	M	0	1	1	1	1	1	1	2	2	1	1	12.0	71
123	M	1	1	1	1	1	1	1	1	2	1	1	12.0	71
124	M	1	1	2	1	1	1	1	2	0	1	1	12.0	71
125	M	0	1	1	1	2	1	1	1	2	1	1	12.0	71
126	M	1	1	1	1	1	1	1	2	0	1	1	11.0	65
127	M	1	1	0	1	2	1	1	2	2	0	1	12.0	71
128	M	1	1	1	1	1	1	1	2	0	1	1	11.0	65
129	M	1	1	2	1	1	2	1	2	2	1	1	15.0	88
130	M	1	1	0	1	1	1	1	2	2	0	1	11.0	65
131	M	1	0	2	1	1	1	1	2	0	1	1	11.0	65
132	M	1	0	1	1	1	2	1	2	0	1	1	11.0	65
133	M	1	1	1	1	1	1	1	1	2	1	1	12.0	71
134	M	1	1	1	1	1	2	1	1	2	1	1	13.0	76
135	M	1	1	1	1	1	1	1	2	0	1	1	11.0	65
136	M	1	1	1	1	1	1	1	1	2	1	1	12.0	71
137	M	1	1	0	1	1	0	1	2	2	1	1	11.0	65
138	M	1	1	1	1	1	1	1	1	2	1	1	12.0	71
139	M	1	1	2	1	1	1	1	1	0	1	1	11.0	65
140	M	1	1	2	1	0	2	1	1	2	1	1	13.0	76
141	M	1	1	1	1	0	1	1	1	2	1	1	11.0	65
142	M	1	1	1	1	1	1	1	1	2	1	1	12.0	71
143	M	1	0	1	1	1	2	1	1	0	1	1	10.0	59
144	M	0	1	1	1	0	2	1	2	0	1	1	10.0	59
145	M	1	1	1	1	1	1	1	1	2	1	1	12.0	71
146	M	1	1	1	1	1	1	1	1	0	1	1	10.0	59
147	M	1	0	1	1	1	2	1	2	0	1	1	11.0	65
148	M	1	1	2	1	0	1	1	1	0	1	1	10.0	59
149	M	1	1	1	1	1	2	1	1	0	0	1	10.0	59
150	M	0	1	1	1	2	1	1	1	0	1	1	10.0	59
151	M	1	1	1	1	0	1	1	1	2	1	1	11.0	65
152	M	1	0	2	1	1	2	1	1	0	1	1	11.0	65

153	M	1	1	1	1	1	1	1	1	0	1	1	10.0	59
154	M	1	1	1	1	1	1	1	1	0	0	1	9.0	53
155	M	1	1	1	1	2	1	1	1	0	1	1	11.0	65
156	M	1	1	0	1	1	1	1	2	0	1	1	10.0	59
157	M	0	1	1	1	2	1	1	1	0	0	1	9.0	53
158	M	0	1	0	1	1	2	1	1	2	1	1	11.0	65
159	M	1	1	0	1	1	1	1	1	0	1	1	9.0	53
160	M	1	1	1	1	1	1	1	1	0	1	1	10.0	59
161	M	1	1	1	1	0	1	1	1	1	1	1	10.0	59
162	M	0	1	1	1	1	1	1	1	0	1	1	9.0	53
163	M	1	1	0	1	2	1	1	1	2	1	1	12.0	71
164	M	1	1	1	1	1	1	1	1	0	1	1	10.0	59
165	M	1	1	0	1	1	1	1	1	2	1	0	10.0	59
166	M	0	1	1	1	1	1	1	1	2	1	0	10.0	59
167	M	1	0	1	0	1	1	1	1	2	1	1	10.0	59
168	M	1	1	1	1	1	1	1	1	2	0	0	10.0	59
169	M	1	1	1	1	1	1	1	2	0	0	1	10.0	59
170	M	1	1	1	1	1	1	1	2	0	0	0	9.0	53
171	M	1	1	1	1	0	1	1	2	2	1	1	12.0	71
172	M	1	1	1	1	0	1	1	2	0	0	0	8.0	47
173	M	1	1	1	1	0	1	1	2	0	1	0	9.0	53
174	M	1	1	1	1	0	2	0	1	0	1	1	9.0	53
175	M	1	1	0	1	1	1	1	2	2	1	1	12.0	71
176	M	1	1	1	1	0	1	1	2	0	1	1	10.0	59
177	M	1	1	1	1	1	1	0	2	2	1	1	12.0	71
178	M	1	1	1	1	1	1	1	1	0	1	1	10.0	59
179	M	1	1	1	1	0	1	1	2	0	1	1	10.0	59
180	M	1	1	1	1	1	1	1	1	2	1	1	12.0	71
181	M	0	1	1	1	1	1	1	1	0	1	1	9.0	53
182	M	1	1	1	1	0	1	1	1	2	1	1	11.0	65
183	M	1	1	0	1	1	1	1	2	2	1	1	12.0	71
184	M	0	1	1	1	1	1	1	2	0	1	1	10.0	59
185	M	1	1	2	1	0	1	1	1	0	1	1	10.0	59
186	M	1	1	1	1	1	1	1	1	0	1	1	10.0	59
187	M	1	1	2	1	1	1	1	2	2	1	1	14.0	82
188	M	1	1	0	1	1	1	1	1	0	1	1	9.0	53
189	M	1	1	2	1	1	1	1	1	0	0	1	10.0	59
190	M	1	1	0	1	1	1	1	0	2	1	1	10.0	59
191	M	1	1	1	1	1	1	1	1	0	1	1	10.0	59
192	M	1	1	1	1	1	1	0	1	2	1	1	11.0	65
193	M	0	1	1	1	2	1	1	0	2	1	0	10.0	59
194	M	1	1	1	1	1	1	0	1	2	1	0	10.0	59
195	M	1	1	1	1	2	1	0	0	0	1	1	9.0	53
196	M	1	0	1	1	2	1	1	1	0	1	1	10.0	59
197	M	0	1	2	1	2	1	1	1	2	1	1	13.0	76
198	M	1	0	1	1	1	2	1	1	0	1	1	10.0	59
199	M	1	1	0	1	1	1	1	1	0	1	1	9.0	53
200	M	1	1	2	1	0	1	1	1	2	1	1	12.0	71
Mean Marks (/1)		0.9	0.915	1.055	0.985	0.975	1.115	0.905	1.4	1	0.78	0.885	10.9	64
Mean Marks (%)		90	91.5	105.5	98.5	97.5	111.5	90.5	140	100	78	88.5	1092	6421
Standard Deviation		30.075	27.96	51.31	12.19	52.51	41.55	29.4	53.05	99.75	41.53	31.98	7.52	7.5238

Scores Acids and Alkilles-*Experiment Group*

Pup No	Sex	Scores Acids and Alkilles												
		Q1		Q2		Q3		Q4		Q5	Q6			Total
		a	b	a	b	a	b	a	b		a	b	Total	%
1	F	1	1	2	1	2	2	1	1	0	1	1	13.0	76
2	F	1	1	1	1	1	0	1	1	2	0	1	10.0	59
3	F	1	1	0	1	2	1	1	2	2	1	0	12.0	71
4	F	1	1	2	1	2	1	0	1	2	1	1	13.0	76
5	F	1	1	2	1	2	1	1	1	0	1	1	12.0	71
6	F	1	1	2	1	2	1	1	1	2	1	1	14.0	82
7	F	1	1	2	1	2	1	1	2	0	1	1	13.0	76
8	F	1	1	2	1	1	1	1	1	2	1	1	13.0	76
9	F	1	1	2	1	1	1	1	1	2	1	1	13.0	76
10	F	1	1	2	1	1	2	1	2	2	1	1	15.0	88
11	F	1	1	2	1	1	2	0	1	2	1	1	13.0	76
12	F	1	1	1	1	1	2	1	2	0	1	1	12.0	71
13	F	1	1	1	1	2	2	1	1	2	1	1	14.0	82
14	F	1	1	1	1	1	2	1	1	0	1	1	11.0	65
15	F	1	1	1	1	2	2	1	2	2	1	1	15.0	88
16	F	1	1	1	1	2	2	0	2	2	1	1	14.0	82
17	F	1	1	1	1	2	0	1	1	2	1	1	12.0	71
18	F	1	1	1	1	2	2	1	3	2	1	1	16.0	94
19	F	1	1	1	1	0	2	1	2	2	1	1	13.0	76
20	F	1	1	1	1	1	2	1	3	2	1	0	14.0	82
21	F	1	1	1	1	1	2	1	1	2	1	1	13.0	76
22	F	1	0	1	1	1	2	1	3	2	1	0	13.0	76
23	F	1	0	0	1	1	2	1	2	2	1	1	12.0	71
24	F	1	0	1	1	1	2	1	1	2	1	1	12.0	71
25	F	1	0	1	1	1	2	1	2	2	1	1	13.0	76
26	F	1	1	1	1	1	2	0	2	2	1	1	13.0	76
27	F	1	1	1	1	1	1	1	2	2	1	1	13.0	76
28	F	1	1	1	1	1	1	1	1	2	1	1	12.0	71
29	F	0	1	1	1	1	1	1	2	2	1	1	12.0	71
30	F	0	1	1	1	2	1	1	1	0	1	1	10.0	59
31	F	1	1	1	1	2	1	0	2	2	1	1	13.0	76
32	F	1	1	1	1	2	1	1	2	0	1	1	12.0	71
33	F	1	1	1	0	2	1	1	2	2	1	1	13.0	76
34	F	1	1	1	1	2	1	1	1	2	1	1	13.0	76
35	F	1	1	1	1	2	0	1	3	2	0	1	13.0	76
36	F	1	1	1	1	2	2	1	1	2	0	1	13.0	76
37	F	1	0	1	1	2	2	1	1	0	1	1	11.0	65
38	F	1	1	1	1	2	2	1	3	0	0	1	13.0	76
39	F	1	1	2	1	2	2	1	1	0	1	1	13.0	76
40	F	1	1	2	1	2	2	0	1	2	1	1	14.0	82
41	F	1	1	1	1	1	2	1	2	2	1	0	13.0	76
42	F	1	1	1	1	1	2	1	2	2	0	1	13.0	76
43	F	1	0	2	1	2	2	0	1	2	1	1	13.0	76
44	F	1	0	2	1	2	2	1	2	2	1	1	15.0	88
45	F	1	1	1	1	2	2	1	1	2	1	1	14.0	82
46	F	1	1	2	1	2	2	1	1	2	1	1	15.0	88
47	F	1	1	2	1	2	2	1	1	0	1	1	13.0	76
48	F	1	1	2	1	2	2	1	1	2	1	1	15.0	88
49	F	1	1	2	1	2	2	1	1	0	1	1	13.0	76
50	F	1	1	2	1	1	2	1	2	2	1	1	15.0	88
51	F	1	1	2	1	1	2	0	2	0	1	1	12.0	71
52	F	1	1	2	1	1	1	1	1	2	1	1	13.0	76
53	F	1	1	1	1	1	1	1	2	2	1	1	13.0	76
54	F	1	1	1	1	1	1	1	1	2	1	1	12.0	71
55	F	0	1	1	1	1	1	1	3	2	1	1	13.0	76
56	F	0	1	1	1	1	1	0	1	2	1	1	10.0	59
57	F	1	1	1	1	1	1	1	1	2	1	1	12.0	71
58	F	1	1	1	1	1	1	1	2	2	1	1	13.0	76
59	F	1	1	1	1	1	1	1	2	2	1	1	13.0	76
60	F	1	1	1	1	1	1	1	3	2	1	0	13.0	76
61	F	1	1	1	1	1	1	1	1	2	1	1	12.0	71
62	F	1	1	1	1	1	2	1	1	2	1	1	13.0	76
63	F	1	1	1	1	1	2	1	2	2	1	1	14.0	82
64	F	1	1	1	1	1	2	1	1	2	1	1	13.0	76
65	F	1	1	1	1	1	2	1	2	2	1	0	13.0	76
66	F	1	1	1	1	1	2	1	2	2	1	1	14.0	82
67	F	1	1	1	1	1	2	1	2	2	1	1	14.0	82
68	F	1	1	1	0	1	2	1	1	2	0	1	11.0	65
69	F	1	1	1	1	1	2	1	2	0	1	1	12.0	71
70	F	1	1	1	1	1	2	0	2	2	1	1	13.0	76
71	F	1	1	2	1	1	2	1	1	0	1	1	12.0	71
72	F	1	1	2	1	1	2	1	1	2	1	1	14.0	82

73	F	1	0	2	1	0	2	0	1	2	1	1	11.0	65
74	F	1	1	2	1	2	2	0	2	0	1	1	13.0	76
75	F	1	1	2	1	2	2	1	2	2	1	1	16.0	94
76	F	1	1	2	1	2	1	0	1	2	1	1	13.0	76
77	F	1	1	2	1	1	1	1	2	2	1	1	14.0	82
78	F	1	1	2	1	1	1	1	2	2	1	1	14.0	82
79	F	1	1	1	1	2	1	1	2	2	1	1	14.0	82
80	F	1	1	2	1	1	1	1	1	2	1	0	12.0	71
81	F	1	1	2	1	1	1	1	1	2	1	1	13.0	76
82	F	1	1	2	1	1	1	1	1	2	1	0	12.0	71
83	F	1	0	2	1	0	1	1	2	2	1	1	12.0	71
84	F	1	0	1	1	1	1	1	1	2	1	1	11.0	65
85	F	1	0	2	1	1	1	0	2	2	1	0	11.0	65
86	F	1	0	1	1	1	1	1	2	2	1	1	12.0	71
87	F	1	1	2	1	1	2	1	2	0	1	1	13.0	76
88	F	1	1	1	1	1	2	1	2	2	1	1	14.0	82
89	F	1	1	2	1	1	2	1	1	2	1	1	14.0	82
90	F	1	1	2	1	2	2	0	2	2	1	1	15.0	88
91	F	1	1	1	1	1	2	1	1	2	1	1	13.0	76
92	F	1	1	1	1	1	2	1	2	2	1	1	14.0	82
93	F	1	1	1	1	1	2	1	1	0	1	1	11.0	65
94	F	1	1	1	1	2	2	1	1	0	1	1	12.0	71
95	F	1	1	1	0	1	2	1	1	2	1	1	12.0	71
96	F	1	1	1	1	1	2	1	1	2	1	1	13.0	76
97	F	1	1	1	1	1	2	0	2	2	1	1	13.0	76
98	F	1	1	1	1	2	0	1	2	2	1	1	13.0	76
99	F	1	1	1	1	2	0	1	1	2	1	1	12.0	71
100	F	1	1	1	1	2	1	1	1	2	1	0	12.0	71
101	M	1	1	1	1	1	1	1	2	2	1	1	13.0	76
102	M	1	1	1	1	2	1	1	1	2	1	0	12.0	71
103	M	1	1	1	1	1	1	1	1	2	1	1	12.0	71
104	M	1	1	1	1	2	1	1	2	2	1	1	14.0	82
105	M	1	1	1	1	2	1	1	1	0	1	1	11.0	65
106	M	1	1	1	1	1	1	0	2	2	1	1	12.0	71
107	M	1	1	1	1	1	1	1	1	2	0	1	11.0	65
108	M	1	1	1	1	1	1	1	0	2	1	1	11.0	65
109	M	1	1	1	1	2	1	1	1	2	1	1	13.0	76
110	M	1	1	1	1	2	2	1	1	0	1	1	12.0	71
111	M	1	1	1	1	2	2	1	2	2	1	1	15.0	88
112	M	1	1	1	1	2	2	1	3	0	1	1	14.0	82
113	M	1	1	2	0	2	2	1	2	0	1	1	13.0	76
114	M	1	1	2	1	2	2	1	1	2	1	1	15.0	88
115	M	0	1	2	1	1	2	0	1	2	1	1	12.0	71
116	M	1	0	1	1	2	1	0	2	2	1	1	12.0	71
117	M	1	1	2	1	1	1	1	1	2	1	1	13.0	76
118	M	1	0	2	1	2	1	1	2	2	1	1	14.0	82
119	M	1	1	2	1	1	1	1	1	2	1	1	13.0	76
120	M	1	1	2	1	1	1	1	2	0	1	1	12.0	71
121	M	1	1	2	1	2	1	0	2	2	1	1	14.0	82
122	M	1	1	2	1	2	1	1	2	2	1	0	14.0	82
123	M	1	1	2	1	2	1	1	1	2	1	1	14.0	82
124	M	1	1	2	1	2	1	1	2	2	1	0	14.0	82
125	M	1	1	2	1	1	1	1	1	2	1	1	13.0	76
126	M	1	1	2	1	1	1	1	1	0	1	1	11.0	65
127	M	1	1	2	1	1	1	1	1	2	0	1	12.0	71
128	M	1	1	2	1	1	1	1	1	2	1	1	13.0	76
129	M	1	1	2	1	1	0	1	1	2	1	1	12.0	71
130	M	1	1	1	1	1	0	1	1	2	1	1	11.0	65
131	M	1	1	2	1	1	0	1	1	2	1	1	12.0	71
132	M	1	1	1	1	1	0	1	1	2	1	1	11.0	65
133	M	1	1	2	0	1	0	1	1	2	0	1	10.0	59
134	M	1	1	2	1	1	1	1	2	2	1	0	13.0	76
135	M	1	1	2	1	1	1	1	1	0	1	1	11.0	65
136	M	1	0	2	1	1	1	1	1	2	1	1	12.0	71
137	M	1	0	2	1	0	1	1	2	2	1	1	12.0	71
138	M	1	1	2	1	0	1	1	1	2	1	1	12.0	71
139	M	1	1	0	1	2	1	0	2	2	1	1	12.0	71
140	M	1	1	2	1	2	1	1	1	2	1	1	14.0	82
141	M	1	1	2	1	1	1	1	1	2	1	1	13.0	76
142	M	1	1	2	1	1	1	0	1	2	1	1	12.0	71
143	M	1	1	1	1	2	1	1	1	2	1	1	13.0	76
144	M	1	1	1	1	1	1	1	1	2	1	1	12.0	71
145	M	1	1	1	1	2	1	1	1	2	1	1	13.0	76
146	M	1	1	1	1	1	1	1	1	0	1	1	10.0	59
147	M	1	0	1	1	2	1	1	1	2	1	1	12.0	71
148	M	1	1	1	1	1	1	1	2	2	1	1	13.0	76
149	M	1	1	1	1	2	1	1	1	2	1	1	13.0	76
150	M	1	1	1	1	2	1	1	1	2	1	0	12.0	71
151	M	1	1	1	1	2	1	1	2	2	1	1	14.0	82
152	M	1	1	1	1	2	1	1	1	2	1	1	13.0	76

153	M	1	0	1	1	2	1	1	2	2	0	1	12.0	71
154	M	1	1	1	1	1	1	1	1	2	1	1	12.0	71
155	M	1	1	1	1	1	0	1	2	2	1	1	12.0	71
156	M	1	1	1	1	1	0	0	2	2	1	1	11.0	65
157	M	1	1	1	1	1	1	0	1	2	1	1	11.0	65
158	M	1	1	0	1	1	1	1	1	2	1	1	11.0	65
159	M	1	1	1	0	2	1	1	2	2	1	1	13.0	76
160	M	1	1	1	1	1	1	1	2	2	1	1	13.0	76
161	M	1	1	1	1	1	1	1	2	2	1	1	13.0	76
162	M	1	1	1	1	2	1	1	1	2	1	0	12.0	71
163	M	1	1	1	1	2	2	1	1	2	1	1	14.0	82
164	M	0	1	1	1	2	2	1	1	2	1	1	13.0	76
165	M	1	1	1	1	2	2	1	1	2	1	0	13.0	76
166	M	1	1	1	1	2	2	1	2	2	1	1	15.0	88
167	M	1	0	2	1	1	2	1	2	2	1	0	13.0	76
168	M	1	1	2	1	2	2	1	2	0	1	1	14.0	82
169	M	1	1	2	1	2	2	1	1	2	0	1	14.0	82
170	M	1	1	2	1	1	2	1	1	2	1	1	14.0	82
171	M	1	1	2	1	1	2	1	2	0	1	1	13.0	76
172	M	1	1	2	1	1	2	1	1	2	1	1	14.0	82
173	M	1	1	2	1	2	1	1	1	2	1	1	14.0	82
174	M	1	1	2	1	1	1	1	1	2	1	1	13.0	76
175	M	1	1	2	0	1	1	1	1	2	1	1	12.0	71
176	M	1	0	2	1	1	1	1	1	2	1	1	12.0	71
177	M	1	1	2	1	1	1	1	1	2	1	1	13.0	76
178	M	1	0	2	1	0	1	1	1	2	1	1	11.0	65
179	M	1	1	1	1	1	1	1	2	2	1	1	13.0	76
180	M	1	1	2	1	1	1	0	1	2	1	1	12.0	71
181	M	1	0	2	1	1	1	1	2	0	1	1	11.0	65
182	M	1	0	2	1	1	1	1	1	2	1	1	12.0	71
183	M	1	1	2	1	1	1	1	1	2	1	1	13.0	76
184	M	1	1	1	1	1	1	1	2	2	1	1	13.0	76
185	M	1	1	1	1	1	0	1	1	2	1	1	11.0	65
186	M	1	1	2	1	1	1	1	1	2	1	1	13.0	76
187	M	1	1	2	1	1	1	1	1	2	1	1	13.0	76
188	M	1	1	2	1	2	1	1	1	0	0	1	11.0	65
189	M	1	1	2	1	1	1	1	1	2	1	1	13.0	76
190	M	1	1	2	1	2	1	1	2	2	1	1	15.0	88
191	M	1	1	2	1	2	1	1	1	2	1	1	14.0	82
192	M	1	1	2	1	1	1	1	1	2	1	1	13.0	76
193	M	1	1	2	1	1	1	1	1	2	1	1	13.0	76
194	M	1	1	1	1	1	1	1	2	2	1	1	13.0	76
195	M	1	1	2	1	1	1	1	1	2	1	1	13.0	76
196	M	1	1	2	1	1	1	1	1	2	1	1	13.0	76
197	M	1	1	1	1	1	1	1	1	2	1	1	12.0	71
198	M	1	1	2	1	1	1	1	1	2	1	1	13.0	76
199	M	1	1	2	1	2	1	1	1	2	1	1	14.0	82
200	M	1	1	2	1	2	1	1	2	0	1	1	13.0	76
Mean Marks (/1)		0.97	0.885	1.435	0.965	1.355	1.305	0.875	1.45	1.68	0.94	0.91	12.8	75
Mean Marks (%)		97	88.5	143.5	96.5	135.5	130.5	87.5	145	168	94	91	1277	7512
Standard Deviation		17.102	31.98	53.59	18.42	53.89	58.63	33.15	58.24	73.51	23.81	28.69	6.77	6.7678

Appendix I

The Raw Data of Attitudes Questionnaires / Year 10 and Year 11 (Experiment 2)

Attitudes Towards Chemistry/ Year 10

Number Of Students 400

Q3

I like chemistry lesson es	280	40	12	8	12	48	I hate chemistry lessones
Boring	80	4	4	8	20	284	Interesting
Easy	240	36	4	16	4	100	Difficult
Useless	40	32	8	8	20	292	Useful
Important	276	44	8	12	24	36	Unimportant
Enjoyable	264	48	4	4	12	68	Boring

Q4

I am enjoying the subject	252	32	16	12	28	60	I am NOT enjoying the subject
I feel I am NOT coping well	108	48	44	16	20	164	I feel I am coping well
I find it very easy	240	16	28	8	24	84	I find it very hard
I am growing intellectually	192	20	20	16	60	92	I am NOT growing intellecually
I am NOT obtaining a lot of new skills	72	28	20	32	36	212	I am obtaining a lot of new skills
I hate practical work	44	8	8	20	40	280	I am enjoying practical work
I am getting better in the subject	256	44	20	8	20	52	I am getting worse in the subject
I do not like my teacher	76	8	8	4	32	272	I like my teacher
I t is definitely ''my'' subject	120	32	8	52	8	180	It is definitely NOT ''my'' subject

Q5

240	Studying the theory	152	Studying chemistry applications in life
284	Doing practical work	288	Studying about chemical reactions in the human body
120	Explaining natural phenomena	60	Setting up apparatus
276	Drawing shapes (atoms, molecules, etc)	248	Studying how chemistry can improve my life
260	Writing formulae and chemical equations	140	Solving every day problems
272	Balancing chemical equations	268	Studying how chemistry can make our lives healthier

Q6

__Most__ important to me (Chemistry)	208	36	24	20	12	8	8	84	*__Least__* important to me
__Most__ important to me (Physics)	212	64	40	44	8	4	8	20	*__Least__* important to me
__Most__ important to me (Biology)	200	44	40	44	32	16	12	12	*__Least__* important to me
__Most__ important to me (Mathematics)	240	56	24	8	8	24	16	24	*__Least__* important to me

Q8

276	An interesting course
288	There are good possibilities of jobs
160	What my friends think
0	Television programmes
280	The wishes of my parents
180	Exciting experiments in class
240	An interesting textbook
200	A stimulating teacher
0	Anything else: ....

Attitudes Towards Chemistry/ Year 11

Number Of Students 400

Q3

I like chemistry lesson es	288	32	20	16	4	40	I hate chemistry lessones
Boring	72	8	8	12	28	272	Interesting
Easy	264	40	8	4	4	80	Difficult
Useless	60	20	8	12	20	280	Useful
Important	292	32	16	8	12	40	Unimportant
Enjoyable	276	52	8	16	8	40	Boring

Q4

I am enjoying the subject	264	24	8	8	20	76	I am NOT enjoying the subject
I feel I am NOT coping well	120	40	44	12	28	156	I feel I am coping well
I find it very easy	268	16	12	8	8	88	I find it very hard
I am growing intellectually	160	20	28	8	80	104	I am NOT growing intellecually
I am NOT obtaining a lot of new skills	20	36	40	36	48	220	I am obtaining a lot of new skills
I hate practical work	8	16	28	28	48	272	I am enjoying practical work
I am getting better in the subject	272	24	8	4	28	64	I am getting worse in the subject
I do not like my teacher	68	12	8	8	24	280	I like my teacher
I t is definitely "my" subject	140	36	56	80	80	8	It is definitely NOT "my" subject

Q5

248	Studying the theory	148	Studying chemistry applications in life
300	Doing practical work	264	Studying about chemical reactions in the human body
132	Explaining natural phenomena	44	Setting up apparatus
260	Drawing shapes (atoms, molecules, etc)	268	Studying how chemistry can improve my life
272	Writing formulae and chemical equations	156	Solving every day problems
280	Balancing chemical equations	276	Studying how chemistry can make our lives healthier

Q6

Most important to me (Chemistry)	228	44	8	16	8	4	12	80	*Least* important to me
Most important to me (Physics)	236	48	12	20	16	12	24	32	*Least* important to me
Most important to me (Biology)	212	52	56	40	8	8	8	16	*Least* important to me
Most important to me (Mathematics)	256	48	32	12	4	20	12	16	*Least* important to me

Q8

320 An interesting course
324 There are good possibilities of jobs
248 What my friends think
0 Television programmes
292 The wishes of my parents
252 Exciting experiments in class
264 An interesting textbook
316 A stimulating teacher
184 Anything else: ....