AN EVALUATION OF NEW SCOTTISH CHEMISTRY SYLLABUSES

by

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L I S T   O F   C O N T E N T S

A B S T R A C T

During the early 1960's new syllabuses in Chemistry were intro:duced into Scottish schools. A research programme was begun to evaluate these new syllabuses by comparing the performance and atti:tudes of university students reared on the old and new systems. Differences were found in favour of the new syllabus students.

Initially, as a subsidiary part of this investigation, a study was made of the syllabus areas which the students reported to be diffi:cult. On analysis, these difficulties fell into two well defined groups -

(a) topics associated with formulae, equations and the mole, and,

(b) organic topics related to hydrolysis and condensation reactions.

To trace the source of these problems the investigation moved into schools at 'O' grade, 'H' grade and Sixth Year Studies levels. The same problem areas became evident at all of these levels and as far down as Third Form. Almost all of the calculations were based on the operation of simple proportion, a skill which was taught in primary school. The difficulties with organic were all related to spatial arrangements of molecular models and their corresponding representations as formulae.

Remedies were sought in terms of syllabus rearrangements and changes in method and these investigations are continuing. A close examination of the problems in the light of the developmental work of Piaget has shown that they are almost certainly linked with maturity barriers.

The operation of simple proportion introduced at primary school well /

well before the child has reached the necessary level of maturity (approx. 13) may well be at the root of the trouble with calculations. When this was then brought into contact with the multivariate thinking involved in writing chemical formulae, it was not surprising that problems occurred.

When the investigation was being carried out at Sixth Year Studies level the opportunity was taken to gather the views of both students and teachers as to how well the course was fulfilling the objectives around which it was designed. The findings, on the whole, were very favourable towards the syllabus.

The work embodied in this entire investigation is now actively being used by the Consultative Committee on the Curriculum in its planning of the "second generation" of new syllabuses.

INTRODUCTION

In the 1950's, consequent upon the launching of the Russian Sputniks, a concern, bordering upon panic, was felt in the United States about the condition of science education in that country. From this grew a number of programmes aimed at improving the quality of science education and among these were two in chemistry - Chemical Education Materials Study (Chem. Study) and Chemical Bond Approach (CBA). Syllabuses were produced with accompanying text-books, teachers' guides, films and laboratory programmes. The aims of these programmes were not very clearly defined in behavioral terms, but they did provoke, by their successes and failures, much more fundamental thinking about school chemistry.

Both Chem. Study and Chem. Bond were designed by teachers in tertiary education and presented to secondary teachers. This may to some extent explain the rapid disappearance of CBA and the later demise of Chem. Study. It is clear that insufficient care had been taken to design the course with the low quality of teachers and the lack of literacy of the students in mind.

However something of the new thinking in school chemistry was injected into Britain at the conference on chemical education held at Greystones in Ireland in March 1960 under the auspices of O.E.E.C. Among the speakers were two from the United States - J.A. Campbell (Chem. Study) and L.E. Strong.

British participants in the conference were conspicuous by their absence since only two delegates were present - J.R.M.M. Brown, H.M.I. of the Scottish Education Department and J.C. Stredder of Wellington School, Somerset.

Brown acted as joint editor of the proceedings of the conference which appeared in 1961 under the title of "New Thinking in School Chemistry".[1] The conference recommendations were clearly important, desirable and possible. To read these recommendations is to read, in outline, every modern chemistry syllabus which has appeared in Britain over the past ten years.

In parallel with the "Greystones thinking" a reappraisal of chemistry teaching in Scotland had been taking place under the guidance of A.J. Mee. The outcome was that Greystones material and the thinking of /

of other secondary teachers, including that of the author, was welded together by Mee to produce a pilot new syllabus in chemistry.

One of the Greystones recommendations reads "The Seminar suggests that O.E.E.C. recommends to Member countries who operate a national syllabus and examination, that designated schools be permitted to teach other approved courses on an experimental basis and that arrangements be made for the examination of such courses".[2]

From this was born the idea of an "Alternative Syllabus"[3] which was offered to schools in Scotland concurrently with the existing "Traditional Syllabus". The Alternative Syllabus incorporated the thinking of the most progressive secondary teachers and inspectors and was launched with less than the wholehearted support of all the universities. The Syllabus originated from the schools and was not imposed from above. No teachers were taken out of the teaching situation to form a committee charged with producing the Syllabus and so those who contributed to its compilation were constantly being subjected to the humbling and realistic demands of real pupils in real teaching and learning situations.

Although there was initially a strong reaction from schools to the introduction of the new material and its attendant new methods and spirit, the Alternative Syllabus was adopted very rapidly by schools (Table 1).

TABLE 1

S.C.E. 'O' Grade Candidates

	Traditional	Alternative	Total Presentation	% increase of presentation from one year to the next
1966	8444	3409	11853	
1967	4328	8146	12474	5.2%
1968	2039	11366	13405	7.5%
1969	690	13756	14446	7.8%
1970	200	15153	15353	6.3%
1971	66	17105	17171	10.6%

Within /

Within eight years of the introduction of the Alternative Syllabus, the examinations in the Traditional Syllabus were discontinued because of the lack of candidates. Meanwhile, in 1968, an additional Syllabus was introduced for sixth formers called Sixth Year Studies.[4]

However, before the Traditional Syllabus disappeared it was decided that some attempt should be made to compare these pupils with those brought up on the Alternative Syllabus. The comparison was to be made in a number of ways at various levels.

University first year students were to be compared in their performance and in their attitudes to their choice of chemistry as a study. A similar investigation was to be conducted at technical college level. Both studies were to be continued into second year to see if any of the differences in first year persisted into second year.

In parallel with this work, the new Syllabus was to be examined for areas of difficulty which might be attributed to lack of maturity of the students or the total unsuitability of the material and this in turn would form a basis for any future Syllabus revisions.

Similar studies were to be applied to the Sixth Year Studies Syllabus in chemistry.

From these investigations have grown a number of branches and now five research students (M.Sc.) are engaged in widening the research front. Where their work links with the main themes of this thesis will be indicated throughout.

CHAPTER 1

CHAPTER I

THE PERFORMANCE AND ATTITUDES OF "ALTERNATIVE" STUDENTS AT UNIVERSITY

In this chapter comparisons between Alternative and Traditional students will be made in two ways -

A. by analysis of their results in the written examinations set by the University of Glasgow each term,

B. by an analysis of a Questionnaire in which information was sought about the age of choice for a science course and the factors affecting that choice.

In addition to this, a preliminary exploration of areas of difficulty in the students' school courses was begun.

By the time this investigation began, students were entering university with passes in the new Certificate of Sixth Year Studies (S.Y.S.) and so the comparisons are complicated. Since there was no official Sixth Year Course for Traditional students, a further complication appears. Under the heading of "Traditional", in all the comparisons, is gathered together students with a variety of backgrounds. The common factor is that all of them followed the Traditional syllabus until the end of fifth year at school. After that the variations appear; for example -

(i) the bulk of the students came to university without doing any sixth year work

(ii) some stayed at school for a sixth year and repeated fifth year work in the hope of improving Higher Grade passes

(iii) some spent the sixth year doing advanced work for the University Bursary Examinations. There are also a few other minor variations.

Students /

Students gathered under the heading "Alternative" are not a homogeneous group either. Their common factor is that all of them followed the Alternative syllabus till the end of fifth year. The majority of them came straight to university without a sixth year; but a few of them stayed for a sixth year for the same reasons as their Traditional counterparts.

Although Sixth Year Studies students are, in some tables of results, treated separately, the fairest comparison is between those who sat Higher Chemistry on the Traditonal Syllabus with those who sat it on the Alternative Syllabus. This would involve the merging of the results for S.Y.S. students with those for Alternative students. The effect would be to enhance the differences between the Alternative and Traditional students.

A. Examination Results - University of Glasgow, Chemistry Department (Session 1969-70).

The comparisons in this section were done with 450 students reading Chemistry in the first year of their Pure Science Course. The class was divided into thirds (top, middle and bottom) because these were the units on which objective test statistics were already based to obtain discriminating powers.

TABLE 1.1

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TABLE 1.1

	Trad-itional	Alter-native	S.Y.S.	Alt. + S.Y.S.	G.C.E.
Proportion of Students in the year	25%	53%	16%	69%	6%
Nov. 1969 Top Third	13%	54%	26%	80%	7%
Middle Third	27%	47%	18%	65%	8%
Bottom Third	39%	48%	9%	57%	4%
Jan. 1970 Top Third	19%	47%	26%	73%	8%
Middle Third	17%	63%	15%	78%	5%
Bottom Third	42%	40%	13%	53%	5%
June 1970 Top Third	18%	47%	26%	73%	9%
Middle Third	22%	59%	16%	75%	3%
Bottom Third	29%	59%	8%	67%	4%
Exemptions from June 1970 exam included in Top Third	9%	59%	22%	81%	10%

Significance - (a) Taking TRAD. v ALT. + S.Y.S.

$\chi^2 = 37.3$ ∴ Significant at better than 1% level.

(b) Taking TRAD. v ALT. v S.Y.S.

$\chi^2 = 41.3$ ∴ Significant at better than 1% level.

From these results it is clear that students with an Alternative syllabus background were performing significantly better than their Traditional colleagues in the examination system used in the first year Pure Science Chemistry in Glasgow. The differences between the two groups persisted throughout the first year and, to a lesser extent, into /

into second year (Appendix p. A1.4).

DISCUSSION

The differences noted could arise in a number of ways. It is unlikely that any one of these factors is the sole cause of the differences or that any one is predominant.

1. The Glasgow first year course may be designed in content and approach to favour Alternative students.
2. The "better" schools may have taken up the Alternative syllabus more quickly than the others and so the differences are merely a reflection of school quality in terms of teaching and equip-:ment.
3. It could be that, arising from 2, the more able children from selective schools are showing their prowess and distorting the Alternative sample upwards.
4. The Alternative syllabus may encourage principle oriented think-:ing and may make the student more questioning.
5. The Sixth Year Studies Course may produce maturer students (maturer in age and in attitudes) who have learned to be independent and adopt good study habits.
6. The Sixth Year Studies Course may anticipate the content of the first year university course.

This list of factors is not exhaustive, but probably contains the most important ones.

These will be examined in turn and evidence for them assessed.

1. There was at this time no obvious attempt to bring the bulk of the Glasgow course into line with the thinking and approach adopted in schools. The principal aim of the course seemed to be the pur:veying of facts for later regurgitation in examinations. With a few exceptions, principle oriented teaching was obvious by its absence. At school the Alternative course placed less reliance on the memory and more on the ability to see patterns in facts and to reason with them. The form of the Glasgow course was more like the Traditional school course than the Alternative one. This is re:flected in the analysis of a university degree examination paper (p.A1.16) and substantiated by work done in another university.[44]

The syllabus content of the Glasgow course, within a few lectures, left the school courses, both Alternative and Traditional, far behind.

This first factor is, therefore, not considered to be a major contributor to the differences shown in Table 1.1.

2. The idea that the "better schools effect" was important seemed very plausible. To check this an investigation was done which showed that this factor was of no importance (Appendix p. A1.1).

3. It was found in investigating 2 that the selective schools did not figure prominently in producing the best students. When a com:parison was made of the Higher grades obtained by the Alternative and Traditional students no significant difference was found (Appendix p. A1.2). It is therefore very probable that the differ:ences between Alternative and Traditional students shown in Table 1.1 do not depend upon differences in school background or chemical ability.

4. /

4. The basic concept of the Alternative syllabus was to encourage the pupils to think about facts; to look for connections between them and to be critical of categorical statements. It has been the subjective observation of university teachers at tutorials that the Alternative and Sixth Year Studies students have shown these critical and synthetic faculties more than their Traditional students have. Despite the weight of factual material placed upon the students, these faculties have not been quenched even in second year provided that the tutors have abandoned a didactic approach.

This treatment of factual material may be an important factor in causing the differences between the two groups of students. Since university courses, unlike the more recent school courses, have not been based on clearly specified objectives, it was impossible to be sure what attributes a student required to satisfy the examiners. It may have been that the Alternative way of thinking was what the university had, consciously or unconsciously, been seeking in its students without taking clear educational steps to achieve it. University staff were almost unanimous in claiming that they wanted students "to think" but when asked to show what positive measures were being taken to foster this desirable quality, they were hard put to quote any.

5. The Sixth Year Studies course set out among its aims to provide situations which would encourage mature and independent thinking and working.[4] Members of the university staff, who have visited schools to observe S.Y.S. teaching including project work, have been impressed by the quality (not sophistication) and maturity of work exhibited by the sixth formers. There seemed to be a realisation that /

that students were capable of quite mature thought and judgement beyond the level usually asked of them in the normal first year course. This issued in a project/discussion approach being tried with sixty first year students in the University of Glasgow in Session 1970-71. The staff who participated were generally pleasantly surprised by the student performance in handling material well above the "learn-regurgitate" level and by their willingness to use library facilities.

These attitudes and abilities exhibited by S.Y.S. students is probably a major factor in their good performance shown in Table 1.1.

6. The S.Y.S. course was designed to have only a small content of new material compared with an 'A' level course. This was to allow time for discussion, and project work. In neither size nor scope was the course content anything like the Glasgow first year course. Some of the topics were common to both, at least in name, but not in treatment or depth. However, some of the more difficult first year course concepts were met in S.Y.S. at discussion level when students could clarify their thinking by direct interaction with a teacher. Examples of these were free energy, entropy and simple crystal field theory. A full discussion of this appears in Chapters 3 and 4.

CONCLUSION

It seems very likely that the differences shown in Table 1.1 can be best explained in terms of the new type of thinking engendered by the Alternative and S.Y.S. courses rather than by any school back-:ground effects.

A /

A detailed study of the effects of Sixth Year Studies Chemistry on students in all of the Scottish Universities is at present being carried out by D.E. Hoare of the University of Dundee.

Power of S.C.E. Higher Grades to predict first year university performance in Chemistry.

The opportunity was taken to examine the available statistics to compare the predictive power of Traditional and Alternative Higher grades.

The groups chosen for this exercise were -

(a) the class of 1966-7 which was wholly Traditional

(b) the Traditional portion of the 1969-70 class

(c) the Alternative portion of the 1969-70 class.

In each case the proportion of the Higher grades A, B and C was of the order of 25: 40: 35, that is, roughly in thirds. The relationship between A, B and C grade and the top third, the middle third and the bottom third of the university classes was calculated. The results are shown below and the detailed results appear in Appendix p. A1.3.

TABLE 1.2

S.C.E. Grade v. class position	χ^2	Contingency coefficient (c)*
Traditional 1966-7	52.8	0.39
Traditional 1969-70	84.0	0.47
Alternative 1969-70	107.9	0.51

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This is an indication of correlation between the two factors being compared. The value of c has a maximum at approximately 0.75. Therefore, values around 0.5 indicate quite high correlation.

CONCLUSION

There is a fairly good correlation between S.C.E. grades and university first year performance in chemistry. All the results have significance at better than the 1% level.

The Alternative prediction is rather better than that of the Traditional predictions. This is one more piece of evidence of the good "fit" of the Alternative course and the Glasgow first year course.

B. Attitudes of Traditional and Alternative Students.

On the first day of the Session 1969-70, all the first year students studying chemistry in the Universities of Glasgow and Strathclyde were asked to fill in a Questionnaire (Appendix p.A1.5). Replies were received from 1045 students (80% return).

The Questionnaire had three main purposes -

(a) to determine at what age the Students' inclination towards science occurred.

(b) to examine the factors which affected their choice of a science career

(c) to obtain the students' subjective appraisal of the school courses they had just completed.

At the same time a similar Questionnaire was given to 400 Arts students in the University of Glasgow to see how the Alternative syllabus had /

had affected their decision not to take up a scientific career.

(a) Age of Inclination

Question 8. - Science Questionnaire (p. A1.5).

"At what stage in your school career did you first detect an inclination towards science in general?" (Note that the question is about inclination and not final choice.)

RESPONSE

TABLE 1.3

	Whole sample without subject distinction				Whole sample	
	ALT.		TRAD.		ALT.	TRAD.
	Boys	Girls	Boys	Girls		
Primary	10.4%	6.9%	9.3%	4.9%	9.8%	8.7%
Early Secondary (11-13)	54.0%	61.2%	44.4%	68.2%	55.3%	47.6%
Mid Secondary (14-16)	29.5%	30.2%	34.7%	24.4%	29.6%	33.3%
Late Secondary (16+)	6.0%	1.6%	11.6%	2.4%	5.2%	10.6%
No. of Students	616	129	259	41	745	300

A detailed table of results showing the response for pure science, medical and engineering students appears in the Appendix p. A1.9.

DISCUSSION

In all cases the choices for Primary and Late Secondary were few.

About 60% of students had experienced the inclination towards science by the age of 13 with the tendency slightly higher in the

case /

case of the Alternative students. The girls tended to detect the inclination earlier than the boys.

By 'O' grade (age 16) about 90% of all students had indicated their interest in science.

In the light of this it seems that efforts made by tertiary centres to attract sixth formers into science by means of open days, lectures and propaganda literature is largely a waste of time since they are merely converting the converted. Where open days and literature could be helpful is in the area of detailed subject choice.

Publicity it would appear, should be aimed at a much lower level in schools if it is to have any effect upon the number of potential students.

These results also point to the critical importance of the early secondary school courses. Much effort has been expended on 'O' grade and more advanced courses while the juniors have sometimes been left to the mercies of integrated courses taught by non-specialists. There is perhaps a case here for the most skilled teachers to turn their attention to the juniors rather than devote the bulk of their time to seniors.

The Arts Questionnaire (Appendix p. A1.14) asked in Question 5 -
"At what stage did you opt out of science at school?"

RESPONSE

TABLE 1.4

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TABLE 1.4

	Alternative	Traditional	All Students
Early Secondary (11-13)	34.2%	65.7%	58.5%
'O' Grade (16)	19.5%	12.4%	14.0%
'H' Grade (17+) and later	46.3%	21.9%	27.5%

In this case there are quite distinct differences (significant at the 1% level) between Alternative and Traditional students. None of these students is pursuing the study of a science at university for career purposes and yet a considerable proportion of them con:tinued the study of a science up to the end of their school career. This is particularly noticeable in the case of Alternative students. The Scottish Higher system allows pupils to take five or six subjects to 'H' grade and it is interesting that so many Arts students were prepared to pursue a science subject as one of their 5 or 6 to an advanced level for its own sake. This is supported by the responses in Table 1.8, p.1.17 which show that the Arts students, while study:ing a science, had little or no intention of using it eventually for career purposes.

(b) Factors affecting inclination

Having established the age of inclination towards science it was decided to examine the factors which affected the choice of science. Students were offered a choice of five factors with room for additional factors to be supplied by the student. This last option was not taken up.

Science /

Science Questionnaire - Question 9.

"What do you think was the origin of this inclination?"

T A B L E 1.5

Factor	Responses without subject distinction				Overall responses	
	ALT.		TRAD.		ALT.	TRAD.
	Boys	Girls	Boys	Girls		
Books	14.8	4.8	19.1	10.0	13.0	17.8
Television	7.7	3.4	12.2	4.0	6.9	10.9
Good Teacher	28.9	41.8	34.0	46.0	31.2	35.8
Parental Occupation	7.7	9.6	5.6	6.0	8.0	5.6
Interesting school course	40.9	40.4	29.2	34.0	40.8	29.9
No. of students	675	146	288	50	821	338

Students were allowed to make more than one response. The results in the Table are expressed as a percentage of the total response.

A detailed Table of results showing the responses for pure science, medical and engineering students appears in Appendix p. A1.10.

DISCUSSION

There were a number of interesting differences shown up in this survey although none of them were highly significant (significant at 20% level). However, differences in the same directions were /

were shown in a follow-up survey conducted by the author in 1970-71 and processed by I.T. Paton.[6]

The two most important factors are "good teacher" and "interest-:ing school course".

The Alternative boys throughout favour "interesting school course" while the Traditional boys tend to opt for "good teacher".

Girls, on the other hand, favour "good teacher" but the Alterna-:tive girls chose "interesting school course" as a close second while Traditional girls relegate the course to a much lower level.

These results on their own do not constitute evidence for the superiority of Alternative courses over Traditional ones, but, taken together with the other evidence in the Questionnaire, they are an indication of such a trend.

The girls choice is very much as an experienced teacher would expect. Personality rather than abstract subject matter seems to be more important to them. The effects of books and television were fairly low and certainly lower than some public statements in the press would suggest. The effect of television was most marked in the case of engineering and medical students. This is not surprising when the composition of T.V. science programmes is examined. They tend to deal with applied science, e.g. "Tomorrow's World" and "Horizon", rather than with the pure sciences and so would tend to appeal to potential engineering and medical students.

There might be a case here for suggesting that general interest pure science programmes should be broadcast not only for the sake of potential students, but also for the intelligent layman.

To get the other side of the picture the Arts Questionnaire asked - "What factors made you decide against science?" (Question 7).

T A B L E 1.6

TABLE 1.6

Factor	Alternative	Traditional	All Students
Poor exam results	9.0	9.8	9.6
Moderate exam results but poorer than the other option	32.1	22.8	25.1
Revulsion against material-:istic science	7.7	8.2	8.1
Boring science courses	15.4	23.3	21.4
Poor teaching	11.5	11.0	11.2
Lack of experimental skill	3.8	6.5	5.9
Parental persuasion	1.3	1.2	1.2
Teacher persuasion	1.3	1.2	1.2
Difficulty with maths	17.9	15.9	16.4

Students were allowed to make more than one response and the frequencies above are expressed as percentages of the total response.

DISCUSSION

The Alternative and Traditional columns are remarkably similar. The main differences occur in two places -

(i) examination results, and

(ii) boring science courses.

These differences are significant.

(i) The first is a reflection of something which has been suspected for some time. When the new syllabus was launched emphasis was removed from rote learning and transferred to understanding. Teachers in their enthusiasm tended to set examination papers with little or no recall. /

recall. This in itself was not necessarily bad, but pupils found that the sciences were very different from their other subjects which still operated largely at recall level. Girls reacted particularly to this and, for a while, third year chemistry classes in schools contained few girls. Gradually the chemistry exams settled down to a compromise situation, numbers of boys and girls entering third year increased and the ratio of boys to girls settled at about 3 : 1.

The sciences have increased steadily (Table 1.7) over the years at a greater rate than comparable arts subjects. This might indicate that the increase is not merely a reflection of increased school population, but of a recovery of the sciences. (A similar pattern appears in the Introduction, Table 1.)

TABLE 1.7

PRESENTATION AT 'O' GRADE.[7]

Subject	1965	1970	% Increase
Chemistry	11,406	15,350	34.6
Physics	12,444	15,811	27.1
French	17,231	21,481	24.7

In both Chemistry and Physics about two-thirds of the pupils proceeded to sit Higher.

In French just over half of the 'O' grade candidates proceeded to Higher.

(ii) The complaint about "boring science courses" was considerably less for Alternative Students than for Traditional Students. This provides one more piece of evidence in favour of the Alternative courses.

One other piece of evidence was sought to give some indication of how many Arts students might have been swayed into science. The question was put in reverse to make it less blunt.

Arts Questionnaire, Question 8.

"In your case, was the choice between science and arts (a) a very difficult one to make (b) a fairly difficult one to make (c) an easy one to make?"

TABLE 1.8

EASE OF CHOICE BETWEEN SCIENCE AND ARTS

Difficulty	Alternative	Traditional	All Students
Very difficult	8.5%	6.0%	6.6%
Fairly difficult	15.3%	12.0%	12.8%
Easy	76.3%	82.0%	80.6%

There was nothing significant in the difference between the two groups.

Only about 20% of those doing Arts might have gone into the sciences, i.e. those who found the choice "very difficult" or "fairly difficult".

SUMMARY /

SUMMARY

TABLE 1.9

	ALTERNATIVE	TRADITIONAL
University Results	Favourable	Unfavourable
Age of Inclination to Science	Alternative earlier than Traditional	
Factors affecting Inclination	Good course then good teacher	Good teacher then good course
Arts students - age of opting out of science	Late secondary	Early secondary
Arts reaction to science course	Alternative less boring than Traditional	

CONCLUSION

The change to Alternative courses has altered both the performance and attitudes of the students in the right direction. This can be seen as phase one of a series of changes in this direction rather than as a once for all remedy. As can be seen from the remainder of this thesis, the work has a long way to go before the course is suitable for achieving the objectives set for it. In fact, some of the objectives may have to be rethought in the light of the studies on maturity and difficulty levels.

SEARCH FOR AREAS OF DIFFICULTY

In the previous section it was noted that the trend begun by the introduction of the Alternative syllabus was in the right direction. However, /

However, experience of teaching the syllabus left no one in any doubt that all was not well with the syllabus. This was also shown up when the national examinations were scrutinised from the setter's and examiner's point of view.[5] There were distinct areas in the syllabus which were not being accepted by the pupils. The reasons for this could be many; poor methods of teaching, topics in excess of the maturity levels of pupils, "clever" examinations, poorer quality of candidates corresponding with increased numbers sitting examinations and so on.

The opportunity was taken when the survey (Appendix p.A1.7) was being done to include a section on difficult areas to get the pupils' view of the situation.

The responses were taken from Alternative students in the first year of the Universities of Glasgow and Strathclyde. This was done twice, in sessions 1969-70 and 1970-71. The processing of the results of the latter was done by I.H. Paton while he was working under the direction of the author and they appear in his B.Sc. Thesis report.[6]

A list of school chemistry topics was provided and the students were asked to place each topic into one of four categories each of which was defined (Appendix p. A1.7).

The results are shown in the graphs below.

Graph 1.1	-	shows the topics "difficult to grasp" - University of Glasgow. (1969-70).
Graph 1.2 (overlay)	-	shows the same topics - University of Strathclyde. (1969-70).
Graph 1.3 (overlay)	-	shows the same topics - a composite of Glasgow and Strathclyde (1970-71).
Graph 1.3	-	is based on Paton's work.[6]

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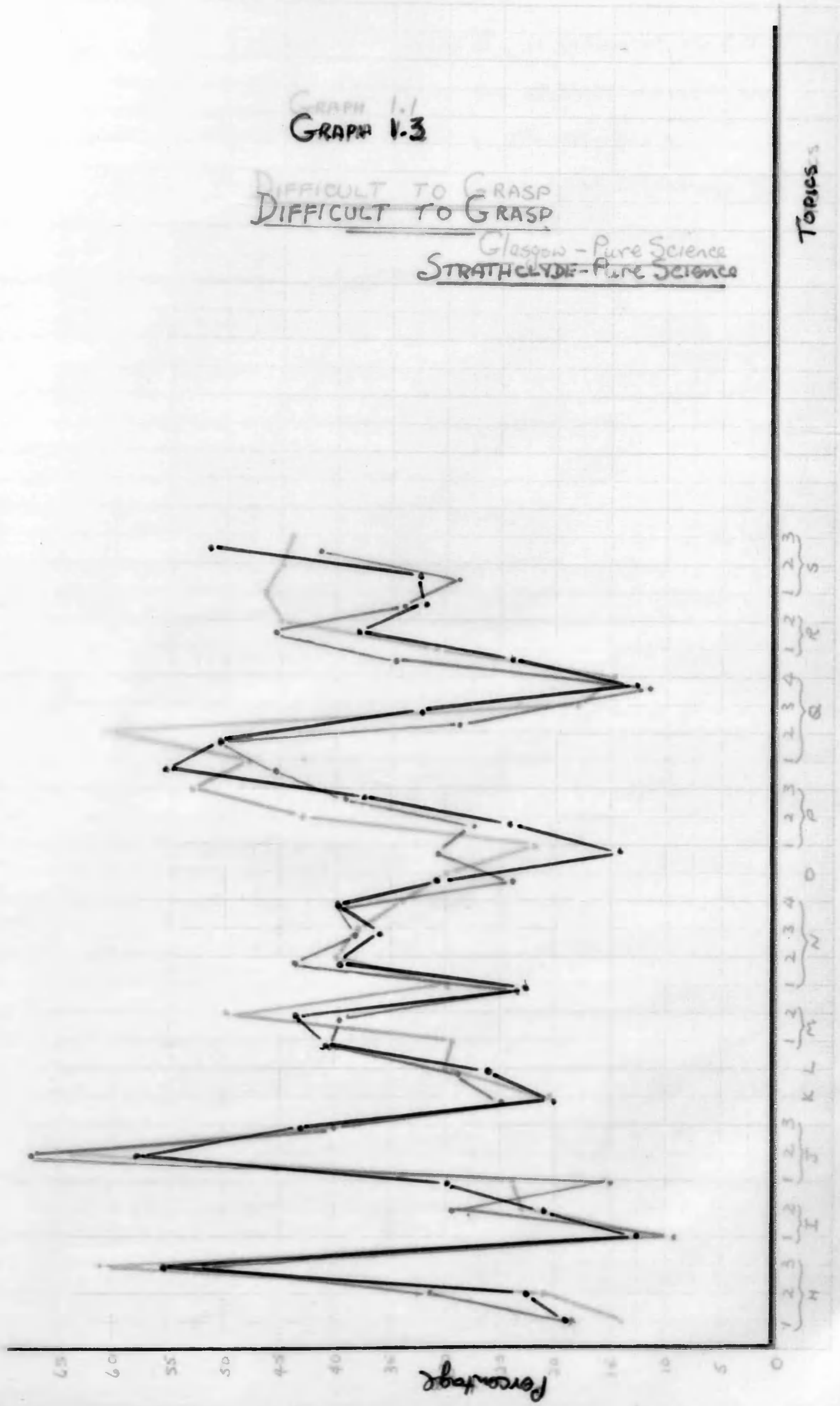
GRAPH 1.3

DIFFICULT TO GRASP

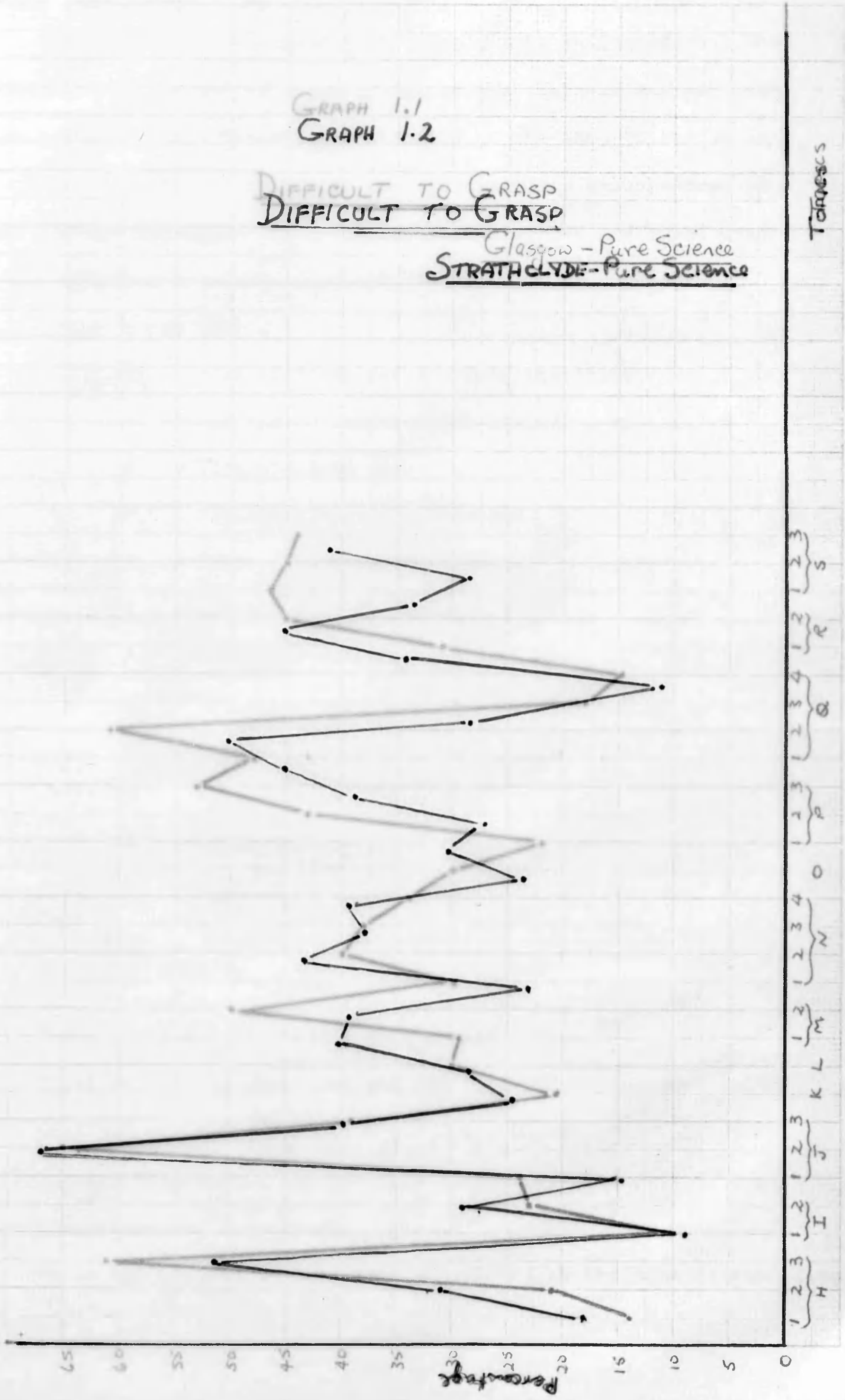
STRATHCLYDE - Pure Science

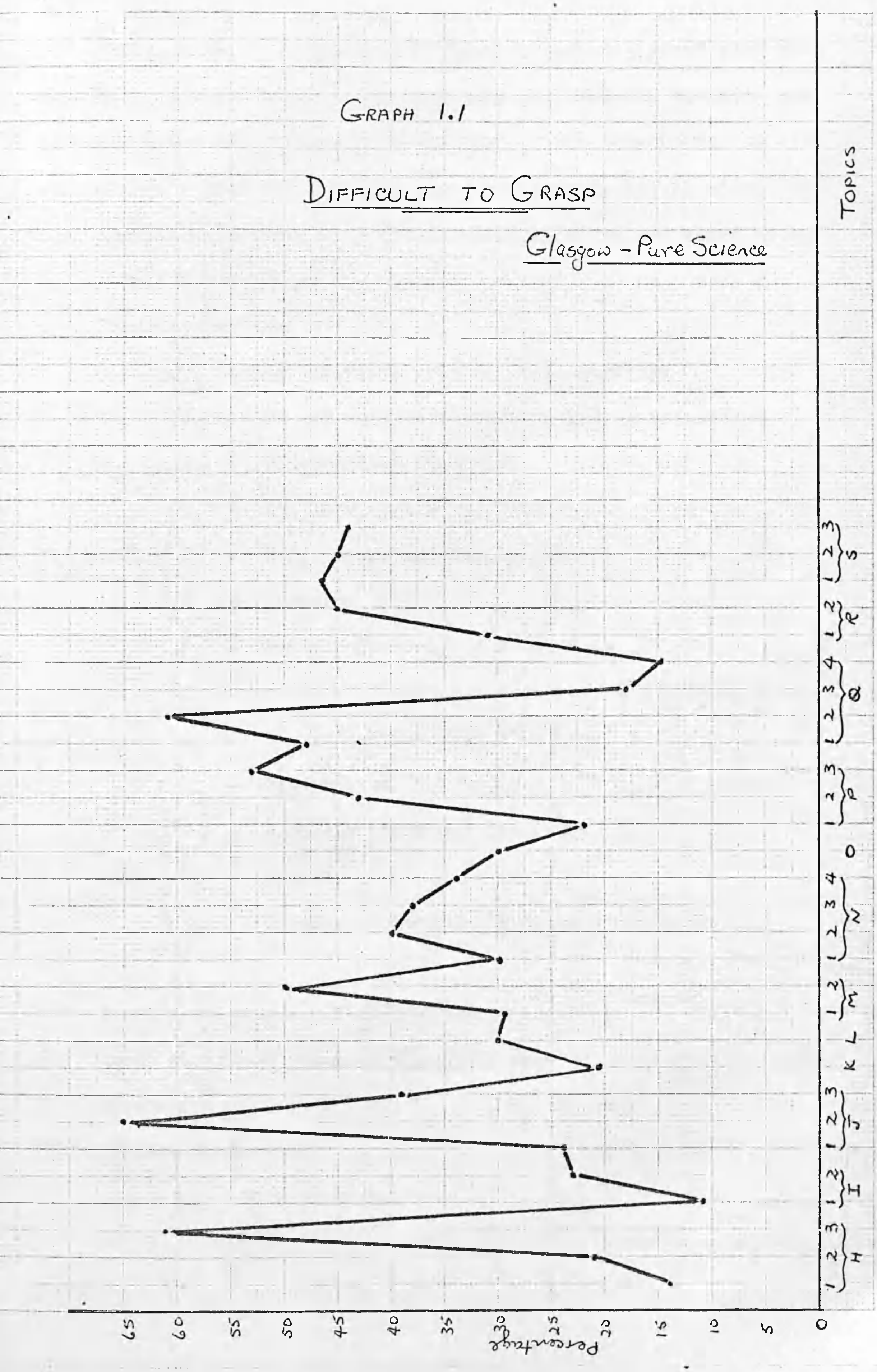


GRAPH 1.2

DIFFICULT TO GRASP

STRATHCLYDE - Pure Science




GRAPH 1.1
DIFFICULT TO GRASP
Glasgow - Pure Science
TOPICS
Percentage
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L
M
N
O
P
Q
R
S

DISCUSSION

The very close coincidence of these graphs indicated that the subjective assessment of these topics by the students was none the less significant. Clear peaks appeared at the same points on each graph showing that these topics were particularly troublesome. The code letters correspond with the Questionnaire and are based upon S.C.E. syllabus sections.

These topics were -

H_3 - Calculations arising from equations

J_2 - pH and volumetric work including molarities

M_2 - Ion-electron equations

'O' grade treatment:

- N_2 - Alcohols, Acids and Esters
- N_3 - Fats, Soaps and Detergents
- N_4 - Proteins

P_3 - Avogadro's Number and the Mole

Q_1 - Heats of Reaction, Hess's Law and Bond Energies

Q_2 - Redox Reactions and E^o values

R_2 - Equilibrium

'H' grade treatment:

- S_1 - Aromatic (Benzene) Chemistry
- S_2 - Amines
- S_3 - Carbonyl Compounds (Aldehydes and Ketones)

These problem areas fall into two main groups [8] -

(i) Those related to equations and the mole and having some arith-:metical content - H_3, J_2, M_2, P_3, Q_1, Q_2, R_2.

(ii) Organic topics with the possible link of esterification, con-:densation and hydrolysis.

It is interesting to note that substantially the same difficulties emerge /

emerge from a theoretical Piaget treatment of the 'O' level Nuffield Scheme.[10]

Under the author's direction links were sought between these topics by means of Punch-card optical coincidence (I.H. Paton).

The principle was that every student was given a number. Each topic was given a punch card and a hole was punched, at the appropriate position, for each student who found difficulty with the topic.

Cards were then superimposed in pairs on a lit stage and the number of coincident holes was counted. The percentage coincidence was then obtainable based on the card with the fewer holes.

It was now possible to determine if the students having difficulty with topic P_3 were the same as those having difficulty with M_2. (Appendix p. A1.11).

A detailed analysis is shown in the Appendix p. A1.12.

A few of the results are quoted below as samples.

TABLE 1.10

Topics	% Coincidence	
	Glasgow	Strathclyde
$H_3 + J_2$	64	68
$H_3 + P_3$	62	60
$J_2 + P_3$	71	70
$S_2 + S_3$	81	66
$P_3 + R_1$	44	30
$K + Q_4$	20	30

As /

As expected, there was a high coincidence between J_2 + P_3 both being based on the mole. S_2 + J_3 were both organic topics and correlated well.

However, there was low coincidence between K and Q_4 because any difficulties with sulphur chemistry (treated largely descriptively) and halogen chemistry (treated as a family) would not be the same.

P_3 and R_1 were not well related and this was not surprising for the concepts in P_3 (the mole) were not the same as those in R_1 (factors affecting rate and catalysis).

It was now possible to look for a series of clear relationships to link together the chain of thought common to the areas of diffi:culty (Table 1.11).

TABLE 1.11

Basic Topic	Good coincidence
H_2	H_3, M_2
H_3	J_2, P_3, Q_1, Q_2
J_2	P_3, Q_1, Q_2
P_3	none

A clear chain of development was now evident.

H_2 (formulae and equations) gave little trouble to the students, but, the moment they applied arithmetic to them, trouble began. This was seen in Volumetric work and the Mole, Heats of Reaction and E^o values. All of these required some arithmetical manipulation even as simple as addition and subtraction. From evidence based on examination /

examination performance, the arithmetical operation causing most trouble was simple proportion. Even in first year university, students in the laboratory had trouble in deciding "what should go on the top line".

Perhaps this area of difficulty goes further back into the Primary school where simple proportion may be introduced at too early a stage before the pupil's maturity is great enough to cope with it. Insecurity arising here could persist for a long time.

With the less able pupils the trouble with arithmetic was even more acute.[8] This is also seen in Chapter 2, p.6, where a normal 'O' grade sample is being considered, and also in a paper by Howe and Johnstone.[9]

The other difficult area - the organic - can be related similarly (Table 1.12).

TABLE 1.12

Basic Topic	Good coincidence	Fair coincidence
N_1	N_2, N_3, N_4	S_1, S_2, S_3
N_2	N_3, N_4, S_1, S_2, S_3	
N_3	N_4, S_1, S_2, S_3	
N_4	S_1, S_2, S_3	
S_1	S_2, S_3	
S_2	S_3	

All the organic topics were clearly related, but the common thread was more difficult to see. The reason may not have been an intellectual /

intellectual one at all.

In the Questionnaire students were offered a "never studied" column against each topic. The topics which were most frequently reported as "never studied" were N_4 (proteins) and S_1, S_2 and S_3 (the Higher organic topics). The students who had never studied these topics were not the same as those who reported these topics to be difficult. There is, however, a clue here.

The organic topics appear at the end of the 'O' grade printed syllabus and again at the end of the 'H' grade syllabus. Although the Syllabuses are not intended to be a teaching order, they are usually treated as such. As teaching time grows short before the national examinations the organic part of the work is skimped or omitted. More evidence for this appears in Chapter 2, p.2.6.

The time factor is probably not the only one and it is proposed during session 1972-3 to investigate other possibilities in depth. (See the suggestions in Chapter 5, p. 5.10.)

PARALLEL STUDY OF 'O' GRADE PUPILS IN ONC COURSES

Under the author's direction a study is being conducted in all the Scottish Technical Colleges by T.I. Morrison. He is investigating the effect of the Alternative course upon student performance and attitudes in the further education centres.

Some of his work is incorporated in an article in "Education in Chemistry".[8] His findings regarding areas of difficulty coincide exactly with those mentioned in this chapter.

In both of these surveys the students have been those who have successfully completed the 'O' grade or 'H' grade courses, but the Alternative /

Alternative syllabus is used for a much wider spectrum of pupils, some of whom may never attempt a national examination with any hope of passing. The reactions of pupils across the entire spectrum of ability are set out in Chapter 2.

APPENDIX TO CHAPTER 1

"BETTER SCHOOLS EFFECT"

A statistical comparison was made between the schools of origin of students in session 1966-7 and 1969-70. The former group con-:sisted almost entirely of Traditional Students and the latter con-:tained approximately 75% of Alternative Students.

The 1966-7 results were taken as a standard by which to identify the "better schools" and with this was compared the list of schools giving the Alternative Students in 1969-70.

The analysis was carried out as follows.

(a) An alphabetical list of schools was made in each case and the number of students provided by each school was recorded. A product moment correlation (r) was found between these two lists giving a value r = 0.6. This indicated that the same schools were providing the students in both samples in about the same proportion.

This is a not unexpected phenomenon in the Glasgow area. The University has traditionally drawn more than 90% of its students from the West of Scotland.[11]

(b) In both samples, the students were divided into top third, middle third and bottom third on the basis of their first year examinations. The schools in the top third of each sample were compared for their contribution of students. This was repeated for each of the other thirds.

The product moment correlations between the thirds is shown below.

Top third	1966-7	v.	Top third	1969-70	r	=	0.25
Middle third	"	v.	Middle "	"	r	=	0.12
Bottom third	"	v.	Bottom "	"	r	=	0.00

This /

This shows a poor relationship between the schools providing the best students in the early and late samples. Some schools which contributed heavily to the top third in 1966-7, contributed no students at all to the top third in 1969-70 and others which gave students to the bottom third only in 1966-7 figured prominently in the top third in 1969-70. In general the "named" selective schools did worse in 1969-70 than in 1966-7 and their places were taken by newer comprehensive schools.

The "better schools effect" was clearly not the factor causing the differences in Table 1.1.

The calculations of r for this experiment were done by Miss K. Urquhart.

COMPARISON OF HIGHER GRADES FOR TRADITIONAL AND ALTERNATIVE STUDENTS 1969-70

TABLE A1.1

S.C.E. Grade	Traditional	Alternative	S.Y.S.	Alt. and S.Y.S.
A	21%	20%	23%	21%
B	43%	45%	50%	46%
C	36%	35%	27%	33%

The differences are statistically not significant.

The difference in quality of higher pass between Traditional and Alternative Students cannot account for the differences in Table 1.1.

PREDICTIVE /

PREDICTIVE POWER OF S.C.E. CHEMISTRY GRADES.

1966-7 - All Traditional Candidates.

TABLE A1.2

Place in university class over the session	S.C.E. 'A' Grade	S.C.E. 'B' Grade	S.C.E. 'C' Grade
Top third	46% (60%)	42% (35%)	12% (13%)
Middle third	22% (30%)	46% (40%)	32% (35%)
Bottom third	9% (10%)	34% (25%)	57% (52%)
All over proportion in class	26%	41%	33%

Note - The figures in brackets are the percentage distributions of each grade over each third, e.g. an 'A' in S.E.C. gave a 60% chance of the candidate being in the top third of the University class.

1969-70 - Traditional Candidates.

TABLE A1.3

Place in university class over the session	S.C.E. 'A' Grade	S.C.E. 'B' Grade	S.C.E. 'C' Grade
Top third	46% (61%)	46% (31%)	8% (7%)
Middle third	18% (28%)	50% (40%)	32% (33%)
Bottom third	7% (11%)	36% (29%)	57% (60%)
All over proportion in class	23%	44%	34%

1969-70 /

1969-70 - Alternative Candidates.

TABLE A1.4

Place in university class over the session	S.C.E. 'A' Grade	S.C.E. 'B' Grade	S.C.E. 'C' Grade
Top third	45% (76%)	43% (35%)	12% (13%)
Middle third	12% (22%)	55% (48%)	34% (40%)
Bottom third	2% (2%)	33% (17%)	65% (47%)
All over proportion in class	21%	45%	33%

PERFORMANCE OF TRADITIONAL AND ALTERNATIVE STUDENTS IN SECOND YEAR - Session 1969-70.

TABLE A1.5

	Traditional	Alternative
Top third	59%	41%
Middle third	69%	31%
Bottom third	64%	36%
All over proportion in class	64%	36%

Note - Average scores over the session were used to determine the thirds.

In the top third the Alternative Students are rather better represented than their overall proportion in the class would indicate.

The significance of the differences are much poorer (about 20% level) than that for first year scores (better than the 1% level).

UNIVERSITY - SCIENCE QUESTIONNAIRE

We would value your co-operation in this piece of research by answering the questionnaire independently and seriously. The main objects of the exercise are as follows:-

1. To trace the factors which influence a young person at school to read science at university.

2. To determine at what age these factors come into play.

3. To obtain a critical survey of the material taught in school chemistry courses (up to 'H' (or 'A') grades) with a view to the improvement of the courses.

Since your name is not asked for, you can feel free to answer the questions frankly.

In most questions, answer should be made by ticking the appropriate box or boxes.

1. Male ☐ Female ☐

2. Where did you receive your secondary education?

   Scotland ☐
   England and Wales ☐
   Ireland ☐
   Europe (excluding U.K.) ☐
   Overseas ☐

3. What is your university entrance qualification?

   (a) Scottish Certificate of Education. ☐
   (b) G.C.E. ☐
   (c) Others .... ☐
   (please specify)

4. Your school chemistry course was: (Insert grade of pass in this box.)

   (a) Scottish Traditional ☐
   (b) Scottish Alternative ☐
   (c) G.C.E. Traditional ☐
   (d) G.C.E. New Syllabus (including Nuffield) ☐
   (e) Any other .... ☐
   (please specify)

5. Have you obtained the Certificate of Sixth Year Studies in Chemistry? (Scottish students only).

   (a) Yes (insert grade of pass in box)

   (b) No

6. You are intending to read chemistry this year for:-

   (a) An Honours degree in Chemistry

   (b) Medicine, Dentistry or Vet. Science

   (c) A subsidiary to a science degree in another subject

   (d) Engineering

7. At school you probably had to make a choice between chemistry and another subject. At that juncture, what made you choose chemistry?

   (a) A positive liking for chemistry

   (b) The lesser of evils

   (c) Career prospects of chemistry

   (d) Career necessities

   (e) Parental pressure

   (f) Teacher pressure

   (g) Good exam results

(Tick more than one box, if required)

8. At what stage in your school career did you first detect an inclination towards science in general? (Note that the question is about <u>inclination</u> and not final choice as in Q.7.)

   (a) Primary

   (b) Early Secondary (11-13)

   (c) Mid-Secondary (14-16)

   (d) Late Secondary (16+)

9. /

9. What do you think was the origin of this inclination?

(a) Science books and magazines

(b) Television

(c) A good science teacher

(d) Parental occupation

(e) An interesting school course

(f) Other causes - (please specify)

....

10. There is a list of school chemistry topics given below based on the Scottish Alternative Syllabus. Against each topic tick the appropriate box.

Definitions - 'Easy to Grasp' - means that the ideas were grasped first time or with little effort.

'Difficult to Grasp' - means that you mastered the topic only after con-:siderable effort.

'Never Grasped' - means that you still are hazy about the topic and would need to be taught it again.

'Never Studied' - means that this topic was not covered in your course.

List of Topics in School Chemistry

	Easy	Diffi-:cult	Never	Never Studied
H_1 - Electrovalent and Covalent Bonding				
H_2 - Formulae and Equations				
H_3 - Calculations arising from Equations				
I_1 - Activity Series				
I_2 - Corrosion and Extraction of Metals				

J_1 /

	Easy	Diffi-:cult	Never	Never Studied
J_1 - Acids, Bases, Neutralisation and Salt Formation				
J_2 - pH and Volumetric Work including Molarities (or Normalities)				
J_3 - Conductivity of Solutions during Neutralisation				
K - Sulphur Chemistry				
L - Hydrocarbons, Homologous Series and Isomerism				
M_1 - Ammonia, Nitric Acid and Fertilizers				
M_2 - Ion-electron Equations				
N_1 - Carbohydrates				
N_2 - Alcohols, Acids and Esters				
N_3 - Fats, Soaps and Detergents				
N_4 - Proteins				
O - Plastics and Polymerisation				
P_1 - Nuclear Chemistry, Radiochemistry and Half-life				
P_2 - Mass spectrometry				
P_3 - Avogadro's Number and the Mole				
Q_1 - Heats of Reaction, Hess's Law and Bond Energies				
Q_2 - Redox Reactions and E^o Values				
Q_3 - Periodic Properties of the Elements				
Q_4 - Halogens				
R_1 - Factors Affecting the Rate of a Reaction - Activation Energy, Catalysis				
R_2 - Equilibrium				
S_1 - Aromatic (Benzene) Chemistry				
S_2 - Amines				
S_3 - Carbonyl Compounds (Aldehydes and Ketones)				

TABLE A1.6

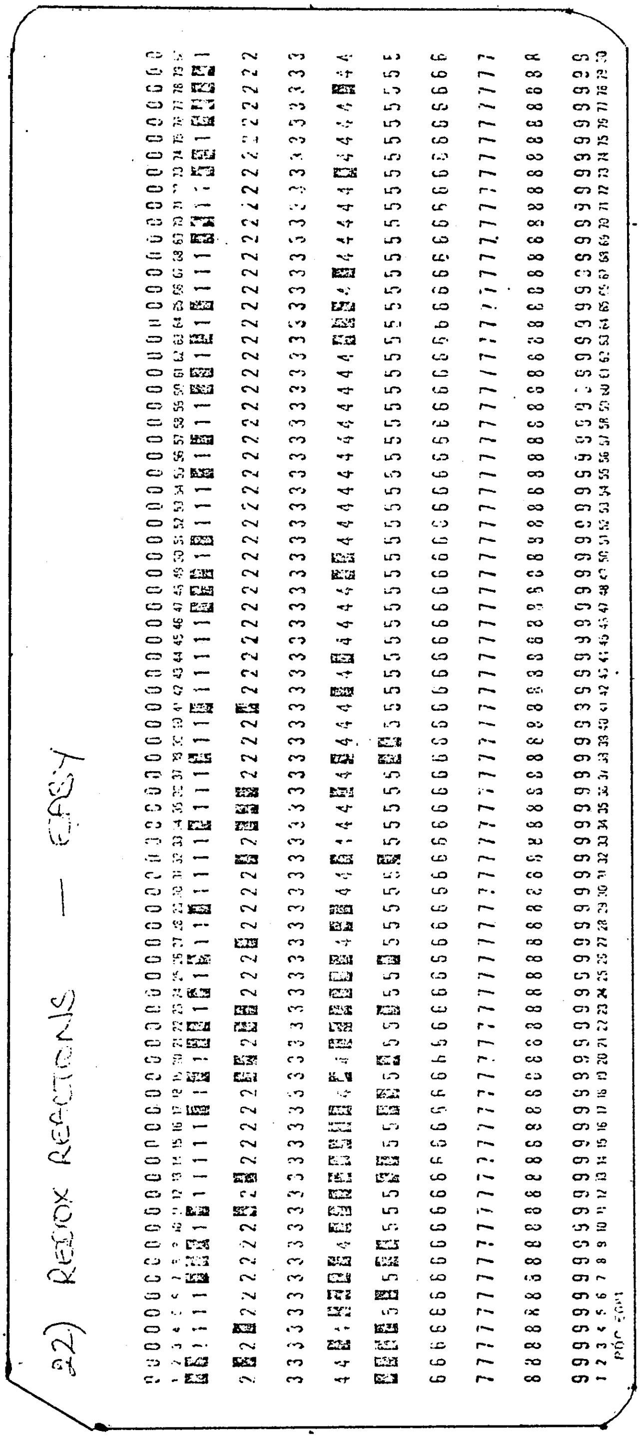
AGE OF INCLINATION IN FAVOUR OF SCIENCE

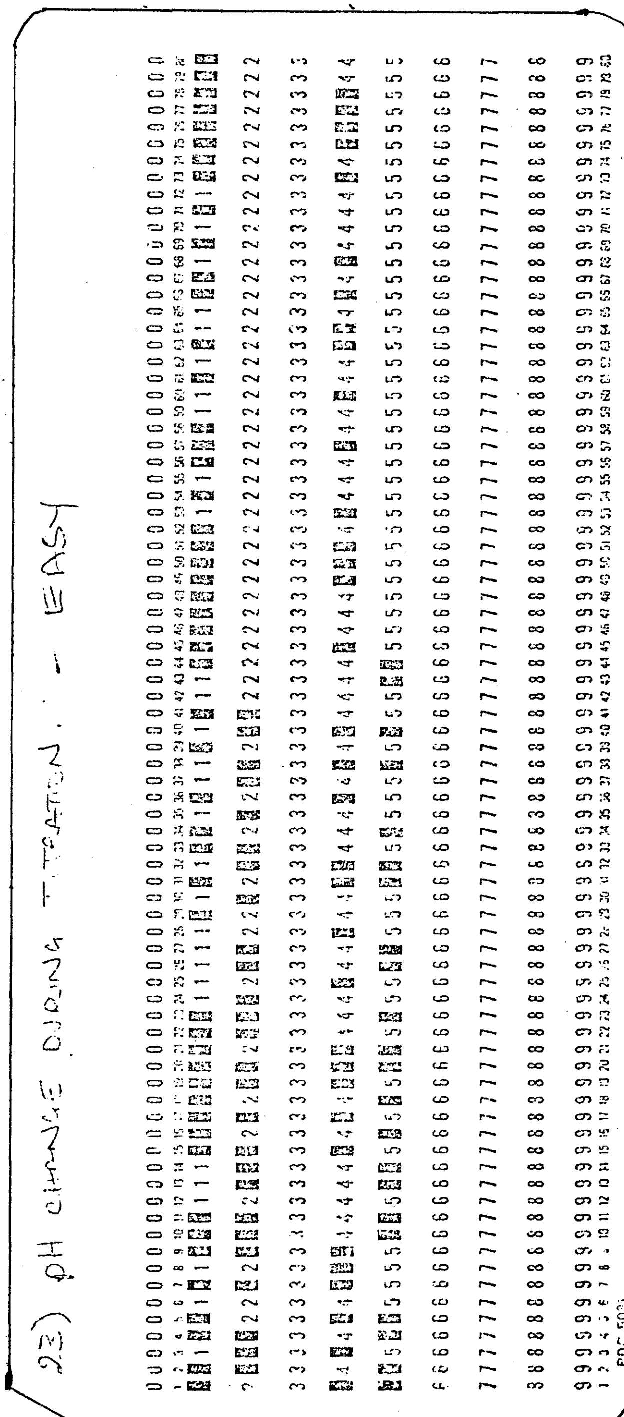
	Primary		Early Secondary (11-13)		Mid Secondary (14-16)		Late Secondary (16+)		Total No. Students	
	B	G	B	G	B	G	B	G	B	G
Glasgow Pure Science										
Alt.	9.5	3.8	57.6	67.3	29.2	27.0	3.6	1.9	137	52
Trad.	9.4	4.5	39.6	68.2	37.8	22.8	13.2	4.5	53	22
Strathclyde Pure Science										
Alt.	10.3	-	49.3	66.7	34.9	33.3	5.6	-	126	31
Trad.	10.9	-	36.4	-	38.2	-	14.5	-	55	-
Glasgow Engineers										
Alt.	10.9	-	54.4	-	30.4	-	4.3	-	92	-
Trad.	9.5	-	47.6	-	35.7	-	7.1	-	42	-
Strathclyde Engineers										
Alt.	12.9	-	59.6	-	22.7	-	4.9	-	163	-
Trad.	7.5	-	50.0	-	31.3	-	11.3	-	80	-
Glasgow Medics. etc.										
Alt.	7.1	13.0	45.9	52.2	33.7	32.6	13.3	2.2	98	46
Trad.	10.4	5.3	48.3	68.4	31.0	26.3	10.4	-	29	19
Without University or subject distinction										
Alt.	10.4	6.9	54.0	61.2	29.5	30.2	6.0	1.6	616	129
Trad.	9.3	4.9	44.4	68.2	34.7	24.4	11.6	2.4	259	41
B and G. Mixed										
Alt.	9.8		55.3		29.6		5.2		745	
Trad.	8.7		47.6		33.3		10.6		300	

TABLE A1.7

FACTORS AFFECTING INCLINATION TOWARDS THE SCIENCES

	Books		Television		Good Teacher		Parents' Occupation		Interesting school course		Totals of responses		Total of Students	
	B	G	B	G	B	G	B	G	B	G	B	G	B	G
Glasgow Pure Science														
Alt.	15.6	4.5	3.7	3.0	28.8	41.8	2.5	10.4	49.4	40.3	160	67	137	52
Trad.	22.8	7.1	12.1	7.1	28.8	39.3	6.1	10.7	30.3	35.7	66	28	53	22
Strathclyde Pure Science														
Alt.	16.3	2.7	7.0	2.7	35.6	43.3	7.0	5.4	44.9	45.9	143	37	126	31
Trad.	11.8	-	8.8	-	42.6	-	-	-	36.8	-	68	-	58	-
Glasgow Engineers														
Alt.	20.0	-	14.3	-	20.0	-	7.6	-	38.1	-	165	-	92	-
Trad.	24.4	-	13.3	-	33.3	-	6.7	-	22.2	-	145	-	42	-
Strathclyde Engineers														
Alt.	12.9	-	9.8	-	30.7	-	11.7	-	35.0	-	163	-	163	-
Trad.	21.2	-	15.0	-	33.7	-	3.7	-	26.2	-	80	-	80	-
Glasgow Medics, etc.														
Alt.	11.5	7.1	5.8	4.8	30.8	40.5	11.5	11.9	40.4	35.7	104	42	98	46
Trad.	13.8	13.6	10.3	-	27.6	54.5	20.6	-	27.6	31.8	29	22	30	19
Without University or Subject Distinction														
Alt.	14.8	4.8	7.7	3.4	28.9	41.8	7.7	9.6	40.9	40.4	675	146		
Trad.	19.1	10.0	12.2	4.0	34.0	46.0	5.6	6.0	29.2	34.0	288	50		
B and G Mixed														
Alt.	13.0		6.9		31.2		8.0		40.8		821			
Trad.	17.8		10.9		35.8		5.6		29.9		338			


22) REDOX REACTIONS — EASY


23) pH CHANGE DURING TITRATION - EASY

Cards 22 and 23 superimposed giving 68% coincidence.

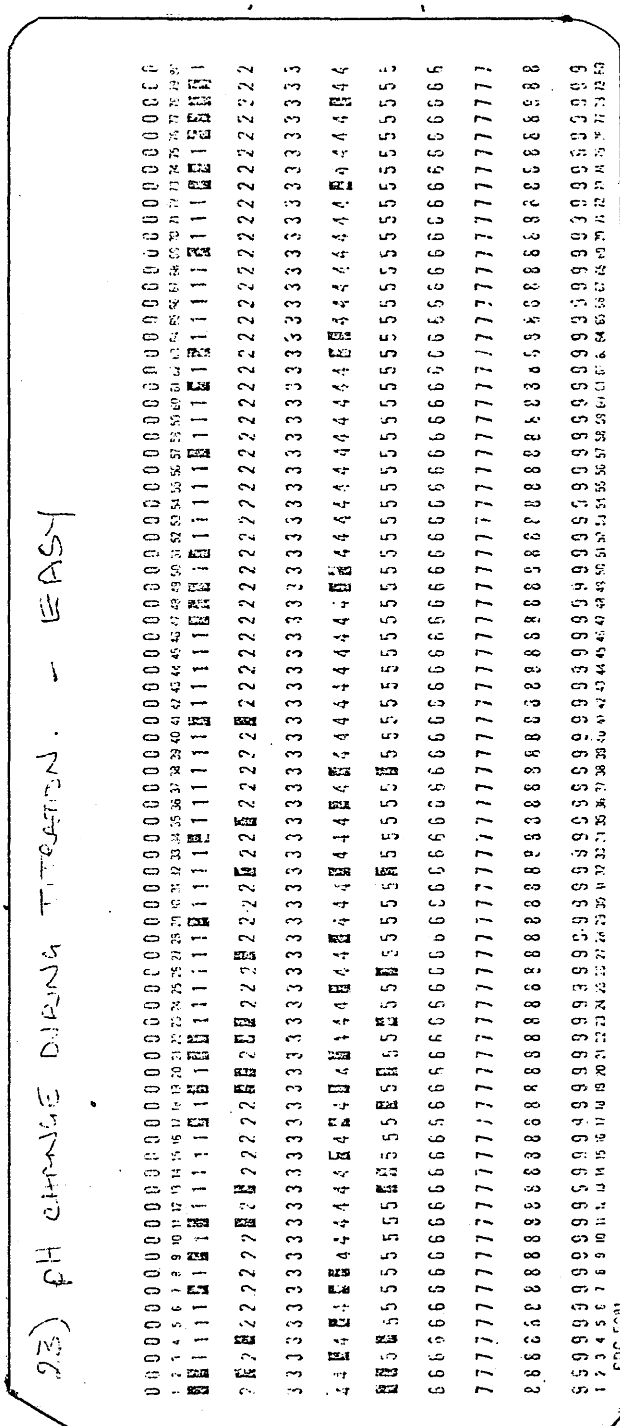


TABLE A1.8

COMPARISON OF TOPICS BY COINCIDENCE IN PAIRS

In this Table, coincidence is expressed as a percentage of the number of holes in the card carrying the fewer holes.

Topics	Glasgow	Strathclyde	Topics	Glasgow	Strathclyde
$H_3 + J_2$	64	68	$M_2 + Q_4$	47	41
$H_3 + P_3$	62	60	$I_1 + Q_2$	43	53
$H_3 + Q_1$	69	57	$S_1 + S_2$	79	63
$H_3 + Q_2$	63	52	$S_1 + S_3$	74	61
$J_2 + P_3$	71	70	$S_2 + S_3$	81	56
$J_2 + Q_1$	69	73	$N_1 + N_2$	60	65
$J_2 + Q_2$	66	71	$N_1 + N_3$	63	57
$P_3 + Q_2$	62	55	$N_1 + N_4$	45	53
$H_3 + R_1$	61	34	$N_2 + N_3$	69	67
$H_3 + R_2$	55	56	$N_2 + N_4$	65	67
$J_2 + R_1$	66	80	$N_3 + N_4$	55	70
$J_2 + R_2$	75	83	$N_1 + S_1$	55	32
$P_3 + R_1$	44	30	$N_1 + S_2$	48	43
$Q_1 + R_2$	53	57	$N_1 + S_3$	40	41
$Q_2 + R_1$	63	34	$N_2 + S_1$	60	68
$H_2 + H_3$	85	62	$N_2 + S_2$	56	61
$H_2 + M_2$	60	54	$N_2 + S_3$	55	73
$Q_3 + Q_4$	53	71	$N_3 + S_1$	64	56
$K + M_1$	64	70	$N_3 + S_2$	52	45
$K + Q_4$	20	30	$N_3 + S_3$	53	48
$M_1 + Q_4$	30	53	$N_4 + S_1$	65	61
$M_2 + K$	38	42	$N_4 + S_2$	65	44
$M_2 + M_1$	46	31	$N_4 + S_3$	43	53

TABLE A1.9

COMPARISON OF TOPICS BY COINCIDENCES IN THREES

Topics	% Coincidence	Topics	% Coincidence
$N_1 + N_2 + N_3$	56	$N_3 + S_1 + S_3$	38
$N_1 + N_3 + N_4$	42	$N_3 + S_2 + S_3$	39
$N_2 + N_3 + N_4$	45	$N_4 + S_1 + S_2$	40
$N_1 + N_2 + N_4$	43	$N_4 + S_1 + S_3$	37
$I_1 + Q_3 + Q_4$	13	$N_4 + S_2 + S_3$	38
$H_2 + M_1 + J_2$	36	$H_3 + J_2 + P_3$	42
$S_1 + S_2 + S_3$	59	$H_3 + J_2 + Q_2$	38
$N_1 + S_1 + S_2$	42	$H_3 + J_2 + R_1$	42
$N_1 + S_1 + S_3$	23	$H_3 + P_3 + R_1$	19
$N_1 + S_2 + S_3$	38	$H_3 + P_3 + Q_2$	37
$N_2 + S_1 + S_2$	46	$H_3 + Q_2 + R_1$	24
$N_2 + S_1 + S_3$	47	$J_2 + P_3 + Q_2$	42
$N_2 + S_2 + S_3$	45	$J_2 + P_3 + R_1$	27
$N_3 + S_1 + S_2$	41	$P_3 + Q_2 + R_1$	20

UNIVERSITY - ARTS QUESTIONNAIRE

We are trying to trace the factors which make school pupils decide for or against the study of the sciences at university level. We should, therefore, be grateful to have the views of those who have chosen not to pursue the sciences further. This is a serious survey the result of which may have considerable repercussions throughout education.

Please underline the appropriate response(s).

1. Your school background is (a) Scottish (b) English or Welsh (c) Irish (d) European (excluding U.K.) (e) Overseas.

2. Your entrance qualification is (a) S.C.E. (b) G.C.E. (c) Others.

3. Which of the sciences, if any, did you do at school? (a) General Science (b) Chemistry (c) Physics (d) Biology.

4. If you did any science at school, was it (a) Traditional Scottish (b) Alternative Scottish (c) Traditional G.C.E. (d) Nuffield G.C.E.

5. At what stage did you opt out of science at school? (a) Early secondary (11-13) (b) Mid-secondary (14-16) (c) Late secondary (16+).

6. What subject(s) did you choose instead of science?

   ....

7. What made you decide against science? (a) Poor school exam marks (b) Moderate exam marks but poorer than those in the other option (c) A revulsion against the materialistic aspects of science (d) Boring course (e) Poor teaching (f) Your lack of experimental skill (g) Parental persuasion (h) Teacher persuasion (i) Any other cause(s) - please specify ....

8. /

8. In your case, was the choice between science and arts (a) A very difficult one to make? (b) A fairly difficult one to make? (c) A very easy one to make?

Thank you for taking part in this survey.

ANALYSIS OF UNIVERSITY OF GLASGOW DEGREE EXAMINATION PAPER - JUNE 1970

Question	Recall	Comprehension	Application
2	8	4	-
3	3	8	-
4	4	-	7
5	8	3	-
6	7	4	-
7	-	5	12
8	10	7	-
9(a)	6	-	-
(b)	3	3	-
(c)	6	-	-
(d)	6	-	-
(e)	3	3	-
(f)	6	-	-
Totals	70	37	19
All over % distribution	56	29	15

Because of the choices offered in the paper student abilities could be tested to different extents. The extremes X and Y are shown below.

Choice X	74%	26%	0%
Choice Y	39%	33%	28%

C H A P T E R   2

CHAPTER 2

A MATURITY STUDY ON THIRD AND FOURTH FORMERS

During the author's teaching experience (since 1956) various topics in chemistry have proved to be difficult to teach and presumably difficult to learn. A careful consideration of these topics was made during the writing of the Chemistry Takes Shape [12] series in conjunction with T.I. Morrison, but any treatment which was given to these topics had to be subjective and intuitive. It was decided to seek evidence for these topic difficulties and possible remedies. This research was done in parallel with that reported in Chapter 1 and so some of the findings of Chapter 1 which would have been useful in this investigation were not incorporated in the first run of the experiment.

The experiment is now being repeated and branches from it are being researched under the author's direction by T.V. Howe and I.M. Duncan.

THEORY

From observation, the main areas of difficulty lay in the third form part of the syllabus while the highly topical and socially oriented material lay in the fourth form. It was argued that if the third and fourth form parts of the syllabus were interchanged, the overall difficulty of the course might decrease because pupils would meet the more difficult topics at a more mature level and be able to cope with them better.

EXPERIMENTAL DESIGN

(i) Ten schools involving more than 1000 third form pupils were invited /

invited to participate in the experiment.

(ii) The third form in each school was divided into matched sections based upon previous chemistry (or science) performance.

(iii) Both sections, called 'C' and 'I' respectively, set off along a common piece of work before dividing and taking separate routes (Table 2.1). The 'I' group followed the order in which the syllabus was written with the difficult material coming first, while the 'C' group followed a revised order in which the fourth year work was done in third year and vice versa.

(iv) Comparisons between the two groups were made in three ways.

(a) Ten common tests (Appendix p. A2.1-41) were applied to both groups at the appropriate points in their course; the first two tests were applied early in both courses when both were following a common piece of work. These first tests were designed to enable comparison to be made between the sections to check how well balanced they were.

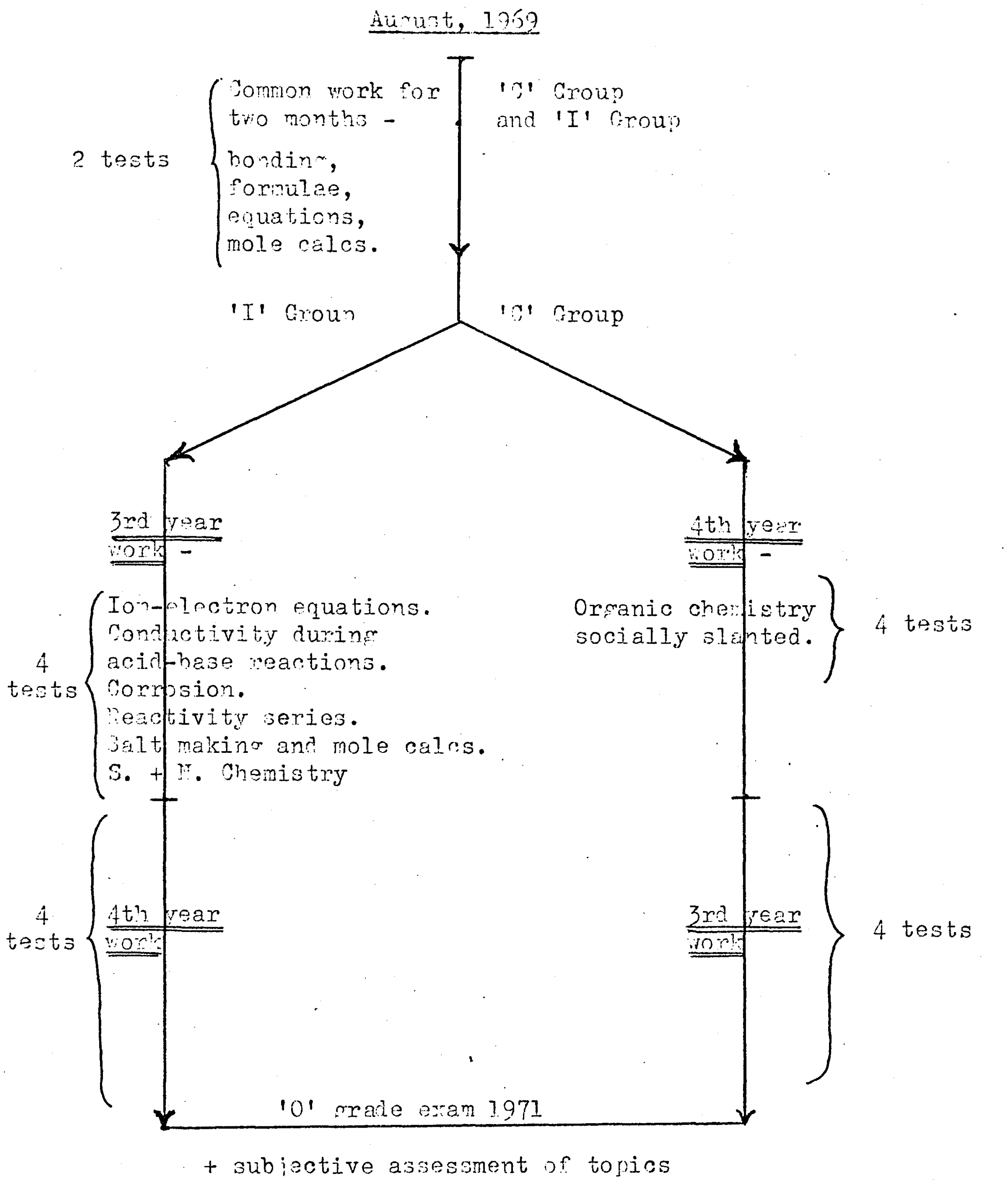
(b) Pupils were asked at the end of the course to arrange each course topic subjectively under the three headings - "Easy to grasp", "Difficult to grasp" and "Never grasped".

(c) The S.C.E. 'O' grade bands for the groups were obtained.

TABLE 2.1

/

TABLE 2.1



Results

Only four of the original set of schools completed the experiment and so the results are based on the work of 311 pupils instead of the expected 1000. (The whole experiment is being repeated with a further ten schools over session 1970-72.)

(a) COMPARISON BY TESTS

The ten tests and their marking briefs are in the Appendix to Chapter 2. All of the tests were objectively markable and were scored by the schools out of a possible score of 20 marks.

A Summary of the test results is shown in Table 2.2. The scores obtained in tests taken during fourth form are underlined. A full set of scores, school by school, appear in Appendix p. A2.42.

RESULTS OF TESTS

TABLE 2.2

Test Number	'I' Group mean	'C' Group mean
1 I + C	9.8	9.7
2 I + C	9.3	9.5
3 I	11.0	<u>12.6</u>
3 C	<u>10.8</u>	10.8
4 I	9.2	<u>9.4</u>
4 C	<u>12.0</u>	9.5
5 I	11.1	<u>11.5</u>
5 C	<u>13.8</u>	12.2
6 I	10.7	<u>11.1</u>
6 C	<u>12.9</u>	11.1
Average	11.1	10.7

DISCUSSION

Taken school by school the sections were only moderately well matched, but taken all together, as in Table 2.2, the matching was quite /

quite good.

The only clear pattern which emerged from the overall results was that the scores in tests done in fourth form tended to be better than those done in third form. However, the overall differences were statistically insignificant.

The 'C' group made a reasonable job of the organic material in third year and their attitudes to it showed interesting differences from those of the 'I' group (Graphs 1, 2 and 3, p. A2.43-45).

Similarly the 'I' group made as good a showing as the 'C' group on the non-organic topics so that meeting these topics a year later had made little difference to the 'C' group's test performances.

The work in Chapter 1 showed that the areas of difficulty had their origin further back than the point at which the 'C' and 'I' groups diverged, that is, in the common ground of formulae, equations, the mole and calculations arising from these. It would have been necessary to investigate the area which both groups had done in common for tests 1 'I' and 'C' and 2 'I' and 'C'.

This common ground is now being researched by T.V. Howe and I.M. Duncan and some of the results have been published. [9]

(b) <u>COMPARISON BY SUBJECTIVE TOPIC ASSESSMENT BY PUPILS</u>

The same pupils at the end of their 'O' grade course were invited to fill in a Questionnaire (Appendix p.A2.46) in which they were asked to rate their school topics under the headings -
(i) "Easy to Grasp", (ii) "Difficult to Grasp", (iii) "Never really Grasped". These terms were defined for the pupils. The results are set out in Graphs 1, 2 and 3 with 'C' and 'I' group reactions plotted separately (Appendix p. A2.43-45).

It /

It should be noted that the topic letters and numbers for this survey were similar to but not the same as those employed for the university surveys in Chapter 1.

(i) "Easy to Grasp" (Graph 1).

There is remarkable coincidence between the two graphs considering that they are based purely on subjective assessments of course topics. The only area where the 'C' graph is consistently on the easy side is for the organic topics. Elsewhere the fluctuations are random. Although the 'C' group, studying the organic part of the course a year before the 'I' group, did not do any better in the tests, they formed a better impression of the organic work than the 'I' group. The 'I' group would be rushed to complete the organic work whereas the 'C' group would take the work in a more leisurely fashion. A similar effect might have been expected in the areas in which the 'C' group were under pressure in fourth form, but none was evident.

(ii) "Difficult to Grasp" (Graph 2).

In this graph there is also good coincidence, with maxima at:-

H_2 - The difference between covalent and ionic bonding

H_3 - Using an ion detector to measure conductivity of solutions and understanding the results

H_5 - Writing chemical equations

H_7 - Calculations from equations

I_3 - Electron transfer in oxidation-reduction (redox) reactions

J_1 - Acidic and basic oxides

J_3 - Methods of preparing soluble salts

J_4 - Precipitation reactions for preparing insoluble salts

J_6 /

J_6 - Calculations to find the molarity of a solution

K_1 - Ion-electron half-equations

N_1 - Hydrolysis of carbohydrates

N_2 - Formation of esters

N_3 - Conversion of fats to soaps

O_1 - Condensation polymers

This set of results related very closely to those in the university surveys in Chapter 1, but this time the sample of pupils was a more representative one since they were taken from the whole 'O' grade spectrum and not just from the cream pupils who had achieved university entrance. Some of the links in the "difficulty chains" were now able to be pushed back even further. This group found difficulty with writing equations and Howe's work showed that their ability to write formulae was largely a matter of memory rather than reason. [9]

This 'O' grade group included the extra organic topic of N_1 (hydrolysis of carbohydrates) which completed the chain linking together all the topics involving hydrolysis and condensation reactions.

A new area of difficulty appeared in this group, namely salt formation. From teaching experience it has been noted that the motivation in this area was very low and it was further complicated by linking it to H_3 and H_2. Children have considerable difficulty with the mental gymnastics, in which chemists indulge, of jumping from the substance in the test-tube, to the symbols on the black-board, to the kind of bonding involved, to a possible reaction path and /

and then back again to reality as they see it. The less able the child, the more difficult is this exercise. It is doubtful if any service is being done to chemistry by dragging children through this salt formation area at all. (See Ingle and Shayer's article in Education in Chemistry [10] [28] where the same conclusion is arrived at by different means.)

(iii) "Never Grasped" (Graph 3)

The results have served to sharpen the points made in Graph 2 with J_6 (molarity calculations) and K (ion-electron equations) being the maxima.

The introduction of ionic formulae and ionic equations into the Alternative syllabus have raised more problems than they have solved. Teachers have encouraged pupils to write very dubious ionic formulae (e.g. $Al^{3+}(Cl^-)_3$) in a bewildering variety of ways. This has become evident to the author during his duties as Principal Setter and Examiner at 'O' grade and 'H' grade. For example, calcium chloride has appeared as $CaCl_2$, $Ca2Cl$, $Ca^{2+}Cl_2^-$, $Ca^{2+}2Cl^-$ and $Ca^{2+}(Cl^-)_2$.

This was further aggravated when balanced equations were written as:-

$$2Al^{3+}3SO_4^{2-} \quad + \quad 6Na^+OH^- \quad \rightarrow \quad 2Al^{3+}3OH^- \quad + \quad 2(2Na^+SO_4^{2-})$$

The ultimate in complication was the additional introduction of state symbols.

Steps which were meant to be helpful and illuminating have imposed such a burden on both pupils and teachers that a joint document of the Scottish Certificate of Education Examination Board and the Consultative Committee on the Curriculum has recently been published [13] recommending a /

a return to the simplest forms of formulae and equations showing ions and state symbols only when absolutely necessary to an argument.

As corroborative evidence of these difficult areas, every topic marked by a peak in Graphs 2 and 3 has been mentioned in the S.C.E. 'O' Grade Examiner's Report for 1971. [14]

These areas of difficulty are now under intense examination by the author and co-workers so that recommendations may be made to the Examination Board for later syllabus revisions. It may be that some topics will have to be removed from the syllabus or postponed for later treatment. [28] This will become even more imperative as the school leaving age is raised and more pupils of lower ability are brought into 'O' grade courses.

(c) COMPARISON OF S.C.E. 'O' GRADE RESULTS

To obtain an independent check on the overall performance of the two groups their S.C.E. 'O' Grade examination results were con:sulted. These were published in bands of five marks from 1 - 13. The lower the band number the higher the examination score.

TABLE 2.3

/

TABLE 2.3

	No. of Candidates in band	
BAND	'I' Group	'C' Group
1	4	2
2	2	3
3	9	4
4	10	11
5	18	21
6	19	30
7	16	20
8	19	7
9	25	18
10	11	6
11	11	14
12	3	13
13	1	7
Mean	7.1	7.5
S.D.	2.6	2.9

A detailed explanation of bands and a school by school analysis is given in the Appendix p. A2.48.

DISCUSSION

These results showed little or no difference between the groups. On the test results (p.2.4) the 'I' group was shown to be slightly better than the 'C' group and this is borne out in the 'O' grade results.

From /

From the three sets of results described in this chapter it was clear that there was no significant difference between the 'I' and 'C' groups. It might, therefore, be concluded that the course could be taught in either order without detriment to the pupils. However, the evidence in this chapter that groups of topics were causing considerable difficulty regardless of order, suggested that maturity barriers existed and persisted at least to 'O' grade, that is, well into the Piaget III level. There was the other factor that concepts, introduced before the child was ready for them, might have induced a feeling of insecurity even well into the stage of development where these concepts would normally be acceptable. The fact that both groups were given a full treatment on bonding, formula and equation writing, and mole calculations at the beginning of third year (age 15) when the majority of them were not intellectually ready for it would tend to colour their conceptual ideas far into their course. There may be teaching methods which can successfully over-:come these problems and these are being actively sought.

An investigation of this hypothesis was begun by the author and T.V. Howe in August 1971. Over 1000 pupils in ten schools have been divided into matched groups. All have followed the 'C' group order described in this chapter. Half of them have been taught bonding, formulae, equations and the mole before the rest of the course. The other half began with a simple treatment of bonding with emphasis on the covalent bond. Formulae, equations and the mole will be introduced only when necessary during the course. For the first two terms the only information required to write formulae will be that carbon forms 4 bonds, nitrogen 3, oxygen 2 and hydrogen 1. Skeletal formulae will be used throughout showing the bonds and so the formulae will /

will be akin to the molecular models which will be used. At a later stage (e.g. soap making) ions will be introduced and, much later still, calculations and the mole will come in. This is an attempt to relate concept to maturity.

Common tests will be applied to both groups.

The teaching order being used is:-

(i) Atomic theory and bonding

(ii) Formulae of simple binary compounds -

Particularly carbon forms 4 bonds, oxygen forms 2, nitrogen forms 3 and hydrogen forms 1.

(iii) Hydrocarbons - All formulae in structural form to allow pupils to count bonds.

(iv) Carbohydrates

(v) Proteins

(vi) Fats (but omit soap making)

(vii) Simple ionic binary compounds - revise ions.

(viii) Reactivity and corrosion

(ix) Ionic compounds involving oxy anions

(x) pH, conductivity, acids etc.

(xi) Salt making

(xii) Hard and soft water - soaps and detergents

(xiii) Sulphur chemistry

(xiv) Nitrogen chemistry

(xv) Calculations from formulae using examples from all previous work

(xvi) Macromolecules

Equations phased in as follows:-

(iii - vi) structural formulae → equations purely as a reaction summary - no balancing required

(viii) /

(viii) equations (not necessarily balanced) and introduce ion-electron equations and equations involving relevant species. Continued into (ix) - (xiii).

State symbols only where required

(xv) Full balanced equation for calculations.

APPENDIX TO CHAPTER 2

BATTERY OF TESTS USED IN MATURITY STUDY -

Written and compiled by A.H. Johnstone

Attempt all the questions.

1. There are three kinds of particles which make up an atom - the proton, the electron and the neutron.

   Which of these three appear in the nucleus?

   ....

2. An atom of arsenic has an atomic number of 33 and a mass number of 75.

   How many electrons does it have?.................................

   How many protons does it have?...................................

   How many neutrons does it have?..................................

3. If a neutral atom has 5 protons.

   How many electrons does it have?.................................

   How many neutrons does it have?..................................

4. Atoms of the same element having the same atomic number, but different mass numbers are called

   ....

5. Put a tick against the correct answer to the question.

   The atomic weight of sodium is 22.99. This means that:-

   A. All sodium atoms weigh 22.99 atomic mass units (amu).

   B. Most sodium atoms weigh 23 amu and a few weigh 22 amu.

   C. Most sodium atoms weigh 22 amu and a few weigh 23 amu.

   D. Most sodium atoms weigh 23 amu, but some of them have lost an electron.

6. What kind of bonding would you expect between the following pairs of elements?

   (a) Chlorine and chlorine ....

   (b) Lithium and bromine ....

   (c) Lithium and sodium ....

7. /

7. What kind of bonding would you expect to be present in the following substances, P, Q and R?

P Conducts electric current when in solid or liquid state

....

Q Conducts electric current in neither solid nor liquid state

....

R Conducts electric current when molten, but not when solid

....

8. Substance X boils at $100^{\circ}C$ and freezes at $0^{\circ}C$.

Substance Y boils at $35^{\circ}C$ and freezes at $-166^{\circ}C$.

Substance Z boils at $2230^{\circ}C$ and freezes at $1000^{\circ}C$.

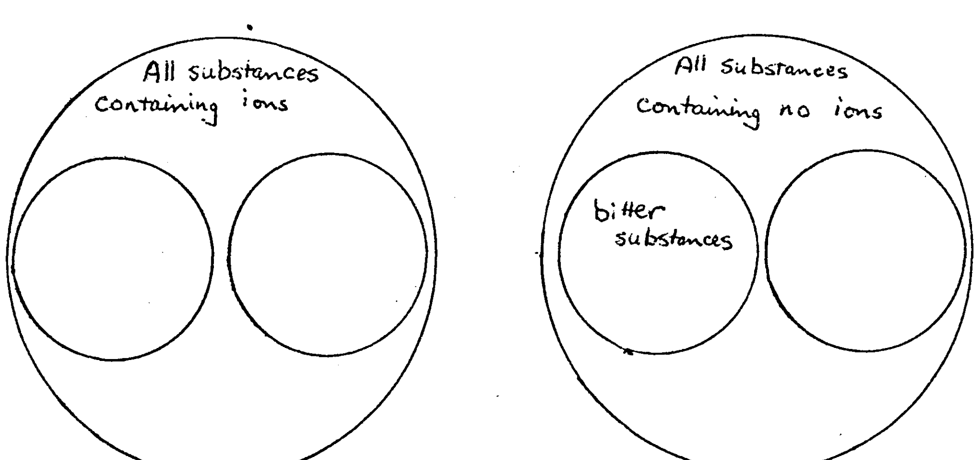
Think about the strength of the bonds which hold each molecule to its neighbour. Now write the letters for these substances in order - the one with the strongest bonds first.

....

9. Look carefully at these sets. Write the word 'SALTS' in a correct small circle.

Having done this, enter the following names in the correct circles:-

potassium chloride, hydrochloric acid, sugar solution in water.



MARKING BRIEF

1. 2 marks if completely correct.

   1 mark if all three given.

   1 mark if two given and one wrong.

2. 3 marks

3. 2 marks - number of neutrons is, of course, not known.

4. 1 mark

5. 1 mark - for B

6. 3 marks - accept the names for the bonds which you have taught, e.g. ionic or electrovalent.

7. 3 marks

8. 1 mark for completely right.

9. 4 marks.

   This simple Venn diagram is an experiment in this type of question. If pupils are not on new maths, explanation will be required before test.

Total - 20 marks

1. Write in the spaces provided, the chemical names of the following substances -

   (a) $PbCl_2$..

   (b) $Cu(NO_3)_2$..

   (c) Na_2SO_4..

   (d) NH_4Br..

   (e) NiO ....

2. Write in the spaces provided, the chemical formula for the following substances -

   (a) Ammonia (hydrogen nitride) ....

   (b) Nitric acid (hydrogen nitrate) ....

   (c) Iron (III) chloride ....

   (d) Ammonium phosphate ....

   (e) Aluminium sulphate ....

3. What mass of nitrogen is present in 196 g of the compound -

   NH_4Br ....

   Atomic weights - N = 14; H = 1; Br = 80.

4. Balance these equations -

   (a) $Cu + AgNO_3 \rightarrow Cu(NO_3)_2 + Ag$

   (b) $Na + Al_2O_3 \rightarrow Na_2O + Al.$

5. Here is a balanced equation. Use it to answer the questions below.

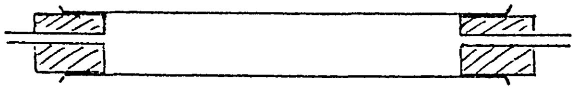
   $$2Pb(NO_3)_2(s) \rightarrow 2PbO(s) + 4NO_2(g) + O_2(g)$$

   (a) How many moles of nitrogen dioxide (NO_2) would you be able to get from 2 moles of lead nitrate? ....

   (b) How many moles of oxygen would you be able to get from 1 mole of lead nitrate? ....

6. /

6. You are asked to find out if iron metal can be obtained from iron oxide (FeO) by heating it with hydrogen. You are provided with the apparatus.



Draw in on this diagram -

(a) Where the oxide would be placed.

(b) How you would get rid of the extra hydrogen.

Suggest a test you might apply to show that iron had been obtained -

....

Suppose that iron is obtained, write an equation for the reaction ....

MARKING BRIEF

1. One mark for each correct answer to a total of 5.

2. One mark for each correct answer to a total of 5.

   Accept the answers in the form you have taught them, e.g. with or without charges, etc.

3. 1 mark for correct F. Wt. and 1 mark for correct result.

4. One mark for each correct equation.

5. Two marks.

6. Four marks.

   The test for Fe would be its attraction by a magnet. (Physics course shows Fe, Ni and Co are attracted by a magnet).

Total - 20 marks

1. The reactivity series can be divided into four portions:-

   (A) The very reactive metals like sodium.

   (B) The fairly reactive metals like iron.

   (C) The fairly unreactive metals like copper.

   (D) The very unreactive metals like gold.

   Here is a list of metals. Write the code letter A, B, C or D against each to show what part of the reactivity series you think it is in. (Note that a letter may be used more than once.)

   (i) Nickel (Ni)............

   (ii) Caesium (Cs)...........

   (iii) Platinum (Pt)..........

   (iv) Barium (Ba)............

2. Put a tick (✓) against the statements below which you think are correct. All the statements are about the metal lithium.

   ☐ (i) It is the least dense metal.

   ☐ (ii) Because of its lightness it is used for building aircraft.

   ☐ (iii) It is a soft metal able to be cut with a knife.

   ☐ (iv) It might catch fire if dropped into water.

   ☐ (v) It will not rust easily.

3. A few years ago an excavation was done at a Roman fort in Perthshire. In a sealed pit was found thousands of Roman nails in excellent condition despite having been buried for nearly 2000 years. Only the nails at the top and sides of the pit were rusty. Nobody knows the exact reason for the preservation of the nails. Here are four possible exclanations. Put a tick against the one which you think is most reasonable.

   ☐ (A) The nails were made of aluminium which hardly rusts at all.

   ☐ (B) The Romans had discovered a way of making non-rusting iron which has since been forgotten.

   ☐ (C) The pit contained only a limited amount of oxygen which was used up in rusting a few nails only.

   ☐ (D) The nails had been copper plated and the copper had rusted away thus protecting the iron nails.

4. /

4. When a piece of zinc is dropped into an excess of a solution of silver nitrate, the zinc disappears and silver appears in its place. During the reaction there is a rise in temperature. Which of the following statements is likely to be true:-

(A) For every gram of zinc that disappears, a gram of silver appears.

(B) For every gram of zinc that disappears, 2 grams of silver appear.

(C) For every gram of zinc that disappears, a definite mass of silver always appears.

(D) For every gram of zinc that disappears, it is impossible to say how much silver appears.

5. In the above experiment there was a temperature rise because:- (tick the most reasonable answer) -

(A) The zinc was disappearing as vapour.

(B) The water had to evaporate to allow the silver to crystallise.

(C) The heat energy taken in to turn zinc into zinc ions, was less than the heat energy given out to turn silver ions to silver.

(D) The heat energy given out when zinc turns into zinc ions is greater than the heat energy taken in to turn silver ions to silver.

6. There are four metals A, B, C and D and here are some facts about them. A can displace C from its salts, but is itself displaced by B. When D is attached to B, it prevents B from rusting. When A is attached to B, it makes B rust faster than usual. Which of the following is the correct reactivity order of the metals, the most reactive coming first? (Tick your answer).

(A) DBAC

(B) BDCA

(C) DBCA

(D) CABD

7. The reactions below fall into 4 categories:-

(A) Oxidation

(B) Reduction

(C) Decomposition

(D) Neutralisation (i.e. acids being 'cancelled out').

Write /

Write one of the letters A, B, C or D against each of the reactions below to show that you know what category it falls into. (Note - a letter may be used more than once.)

(i) $CaCO_3 \rightarrow CaO + CO_2$

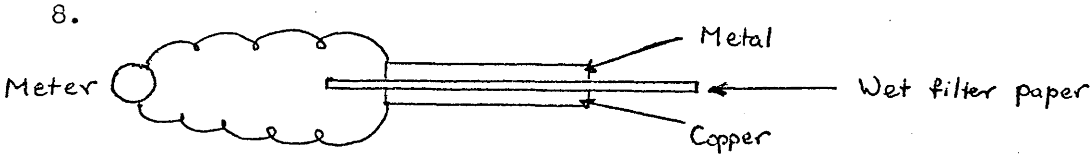
(ii) $Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e$

(iii) $S + 2e \rightarrow S^{2-}$

(iv) A reaction at a cathode during an electrolysis.

(v) $H_2SO_4 + ZnO \rightarrow ZnSO_4 + H_2O$

8.



In the experiment shown above there are several possible results when different metals are placed on top of the wet filter paper and copper.

(A) A large meter reading indicating flow of electrons from the metal to the copper.

(B) A large meter reading indicating flow of electrons from the copper to the metal.

(C) A small meter reading indicating flow of electrons from the metal to the copper.

(D) A small meter reading indicating flow of electrons from the copper to the metal.

(E) No meter reading indicating no flow of electrons in either direction.

Against the list of metals below, place the most suitable letter A, B, C, D or E. (Note - each letter may be used more than once.)

(i) Lead	(ii) Platinum	(iii) Sodium	(iv) Copper

MARKING BRIEF

1. (i) B

   (ii) A

   (iii) D

   (iv) A One mark each

2. Ticks against (i), (iii) and (iv) only - Three marks

   Since the parts of the question are interdependent this is not just a series of True-False answers.

   Therefore a wrong tick = One mark deducted.

   Therefore five ticks = One mark in total.

   Minimum mark = 0.

3. C - One mark.

4. C - One mark.

5. D - One mark.

6. (i) - One mark.

7. (i) C

   (ii) A

   (iii) B

   (iv) B

   (v) D One mark each

8. (i) C

   (ii) D

   (iii) A

   (iv) E One mark each

Total - 20 marks

1. From the list below pick out the best definition of a hydro-:carbon. It is a compound containing:-

(A) Carbon

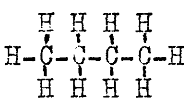
(B) Carbon and hydrogen

(C) Carbon and hydrogen only

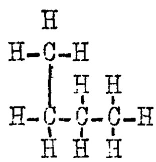
(D) Carbon and water only.

2. From the structures given below, pick out the one which is an isomer of (A):-

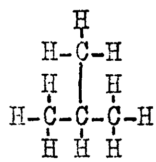
H



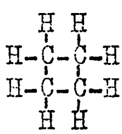
(A)



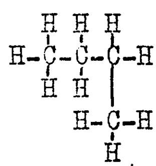
(B)



(C)



(D)



(E)

Answer ....

3. There are 3 cylinders each containing a different inflammable gas. A jet is attached to each cylinder and each gas is lit. Above each flame some chemical tests are carried out as shown in the Table below.

Gas in cylinder	Limewater test	Test for water	Tests for other gases
	Turns milky or chalky	None	None detected
	Nil	Positive	None detected
	Turns milky or chalky	Positive	None detected

From the list below select the correct answers which should appear in the blank column 1. Write the answers in the blank column.

Hydrogen, methane, water gas, carbon monoxide, carbon dioxide, on the evidence it is impossible to be sure.

4. /

4. You are given a bottle of a compound marked C_6H_{12}. Below there is a list of statements about it. Put a tick (✓) against each statement which could be true.

- [ ] (i) Its name is hexane.
- [ ] (ii) It is an unsaturated open chain compound.
- [ ] (iii) It is a saturated ring compound.
- [ ] (iv) It can make bromine water turn from colourless to brown.
- [ ] (v) It can burn.

5. Crude oil is a mixture of hydrocarbons. It is separated into its components on a large industrial scale by:-

- [ ] (A) Gas chromatography
- [ ] (B) Fractional distillation
- [ ] (C) Cracking
- [ ] (D) Polymerisation.

6. Which one of the following statements is true at room temperature?

- [ ] (A) Very low formula weight (molecular weight) hydrocarbons are solids.
- [ ] (B) Very high formula weight (molecular weight) hydrocarbons are gases.
- [ ] (C) Very low formula weight (molecular weight) hydrocarbons are liquids.
- [ ] (D) Very high formula weight (molecular weight) hydrocarbons are solids.

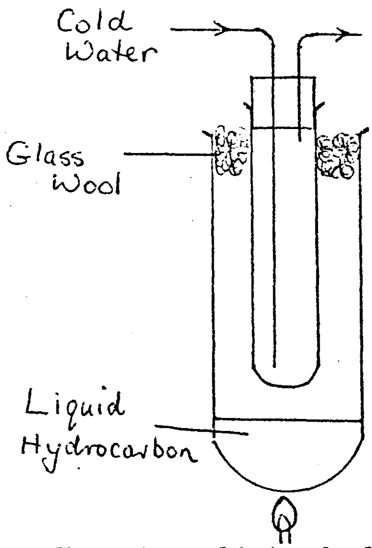
7. If some high molecular weight saturated hydrocarbon is cracked, what would you do to your product to show that cracking had taken place?

- [ ] (A) Smell it
- [ ] (B) Burn it
- [ ] (C) Shake it with bromine water
- [ ] (D) Shake it with limewater.

8./

8. What would you expect to see happening during the test you chose in Q.7. to convince you that the cracking had been successful?

....

9. 

The function of this apparatus is:-

(A) To allow the liquid to boil, but not to escape as vapour.

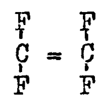
(B) To do a fractional distillation.

(C) To crack the hydrocarbons.

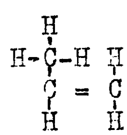
(D) To take away the water soluble part of the hydrocarbons.

10. Here is a list of plastics.

- Polythene (Polyethylene)
- Polypropylene (Polypropene)
- Polyvinylchloride (P.V.C.)
- Polytetrafluoroethylene (P.T.F.E.)
- Polystyrene.

Write (A) against the plastic formed by polymerising 

Write (B) against the plastic formed by polymerising -



MARKING BRIEF

1.	C	1 mark
2.	C	1 mark
3.	Carbon monoxide	1 mark
	Hydrogen	1 mark
	Impossible to be sure	1 mark
4.	(ii), (iii), (v)	3 marks
	Not just a TF question, because there is interrelation of ideas. (Deduct 1 mark if (iv) chosen; but minimum score is zero.)	
5.	B	1 mark
6.	D	1 mark
7.	C	1 mark
8.	Reasonable observation of C in Q.7	1 mark
9.	A	1 mark
10.	A - P.T.F.E.	1 mark
	B - Polypropylene	1 mark

Total - 15 marks

1. pH = 1   3   7   11   14

   (a)   (b)   (c)   (d)   (e)

In the boxes provided beside each of the following solutions write (a), (b), (c), (d) or (e) to indicate roughly its pH.

☐ (i) Pure water

☐ (ii) Orange juice

☐ (iii) Household ammonia.

2. A 17M solution of acetic acid has a low conductivity. It is:-

☐ (a) A concentrated solution of a weak acid.

☐ (b) A concentrated solution of a strong acid.

☐ (c) A strong solution of a dilute acid.

☐ (d) A dilute solution of a concentrated acid.

3. When 25 ml of M HCl is mixed with 25 ml M NaOH the temperature of the solution rises $6^{o}C$. If the acid and the alkali were both 2M what would the temperature rise be?

☐ (a) $6^{o}C$

☐ (b) $12^{o}C$

☐ (c) $18^{o}C$

☐ (d) $24^{o}C$

4. If in Q.3. 50 ml of 2M acid was mixed with 50 ml 2M alkali, the temperature rise would be -

☐ (a) $6^{o}C$

☐ (b) $12^{o}C$

☐ (c) $18^{o}C$

☐ (d) $24^{o}C$

5. If the conductivity of the following solutions is measured under identical conditions these results were obtained.

M HNO_3	100 units
M KOH	80 units
M KNO_3	70 units

Which /

Which of the following conclusions is correct on the basis of this evidence alone. (More than one correct answer is possible.)

(a) The hydrogen ion is more mobile than the potassium ion.

(b) The hydroxide ion is more mobile than the nitrate ion.

(c) The nitrate ion is more mobile than the potassium ion.

(d) The hydrogen ion is more mobile than the hydroxide ion.

6. Which of the following equations represents a neutralisation reaction -

(a) $Zn + CuSO_4 \rightarrow ZnSO_4 + Cu$

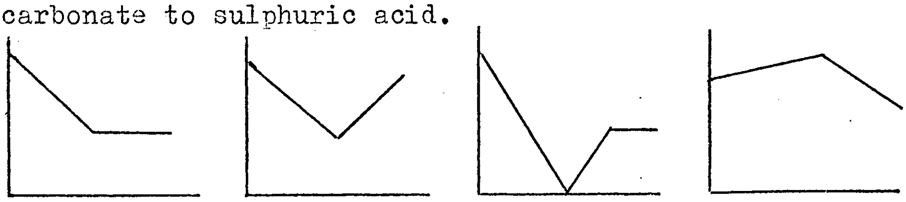
(b) $2KOH + Ni(NO_3)_2 \rightarrow 2KNO_3 + Ni(OH)_2$

(c) $KOH + HNO_3 \rightarrow KNO_3 + H_2O$

(d) $BaCl_2 + H_2SO_4 \rightarrow BaSO_4 + 2HCl$

7. One way of neutralising an acid is to add a carbonate. Which of the conductivity graphs below would be obtained by adding copper carbonate to sulphuric acid.

cond.



Amount of $CuCO_3$

(a) (b) (c) (d)

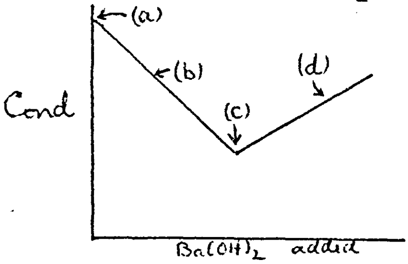
8. 50 ml of a 2M solution of hydrochloric acid (HCl) required 25 ml of a sodium hydroxide (NaOH) solution to neutralise it. What was the molarity of the NaOH? ....

9. If in Q.8. it had been 25 ml of $Ba(OH)_2$ instead of NaOH used up, what would the molarity of the $Ba(OH)_2$ have been? ....

10. How many ml of M $CuSO_4$ could be made from 16 g $CuSO_4$(s)?........

11. /

11. F ur points are marked on the conductivity graph when HCl is neutralised with $Ba(OH)_2$.



Against each of these letters below write in which ions are carrying the current.

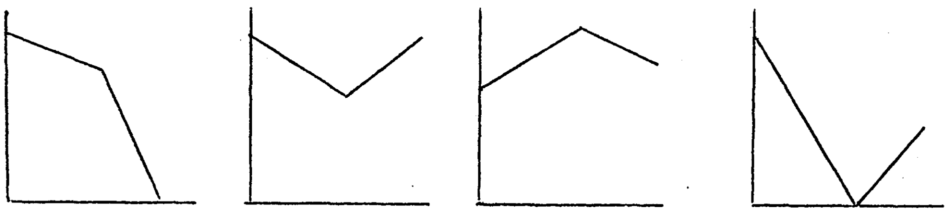
(a)

(b)

(c)

(d)

12. If sulphuric acid was used in Q.11. instead of hydrochloric acid the graph would have changed into:-



(a) ☐ (b) ☐ (c) ☐ (d) ☐

13. If in Q.11. an indicator had been in solution, at what lettered point would it have changed colour?..........................

MARKING BRIEF

1.	(i) - (c)	1 mark	
	(ii) - (b)	1 mark	
	(iii) - (e) (or accept (d))	1 mark	
2.	(a)	1 mark	
3.	(b)	1 mark	
4.	(b)	1 mark	
5.	(a)	1 mark	
	(b)	1 mark	
6.	(c)	1 mark	
7.	(a)	1 mark	
8.	4M	1 mark	
9.	2M	1 mark	
10.	100 ml	2 marks (give one mark for correct F.wt).	
11.	(a) H^+ + Cl^- (or in words)	1 mark	right or wrong
	(b) H^+ + Cl^- + Ba^{2+} (or in words)	1 mark	
	(c) Ba^{2+} + Cl^- (or in words)	1 mark	
	(d) Ba^{2+} + Cl^- + OH^- (or in words)	1 mark	
12.	(d)	1 mark	
13.	(c)	1 mark	

Total - 20 marks

1. The natural process by which CO_2 + H_2O are converted into carbohydrates in sunlight is called ....

2. In our bodies the reverse reaction takes place. It is called

....

3. Choose the most accurate description of a carbohydrate. Carbo-:hydrates are compounds of:-

☐ (a) Carbon and hydrogen only (any ratio)

☐ (b) Carbon dioxide and water (ratio 1 : 1)

☐ (c) Carbon, hydrogen and oxygen (H : O ratio = 1 : 1)

☐ (d) Carbon, hydrogen and oxygen (H : O ratio = 2 : 1).

4.

Compounds	Iodine Test	Fehling's or Benedict's Test
	Negative (no blue)	Positive
	Negative	Negative
	Positive (blue)	Negative
	Positive	Positive

In the "Compounds" column above enter each of the following substances in the correct box. Note that a box may contain the name of more than one substance.

Starch, glucose, maltose, sucrose (cane sugar).

5. Look at the list of properties below. Place the letter E against two of them which are properties of Ethanol and A against two of them which are properties of Acetic acid. (Note that A and E may be in the same box).

☐ (i) Soluble in water.

☐ (ii) Solid at room temperature (20°C).

☐ (iii) Low but not zero electrical conductivity.

☐ (iv) Neutral to litmus.

☐ (v) High electrical conductivity.

☐ (vi) Catches fire on contact with air.

6. /

6. Alcohol (ethanol) can be converted into acetic acid (ethanoic acid) by a process called:-

(a) Reduction

(b) Neutralisation

(c) Hydrolysis

(d) Oxidation

7. An alcohol and an acid can be combined together in the presence of sulphuric acid to give a new kind of compound called:-

(a) A carbohydrate

(b) An ester

(c) An aldehyde

(d) A salt

Questions 8, 9 and 10 refer to this list of processes -

(a) Condensation

(b) Neutralisation

(c) Hydrolysis

(d) Hydrogenation

By which of the types of reaction mentioned above can the following changes be brought about. (Enter the letter in the box provided.)

8. The combination of acetic acid and ethanol to form ethyl acetate.

9. The production of sodium sulphate from sodium hydroxide and sulphuric acid.

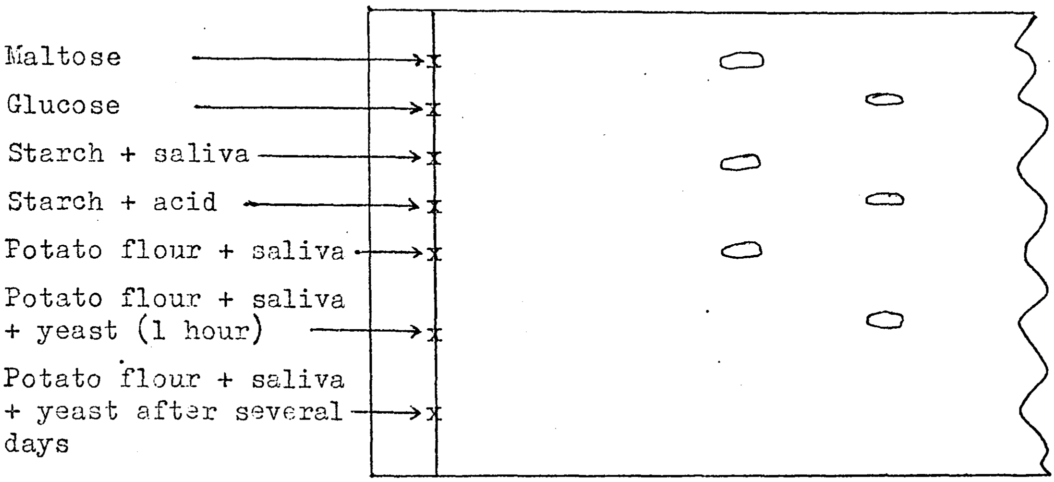
10. The combination of simple sugars to form starch.

11. What is the name given to natural catalysts in living things?

....

Questions /

Questions 12-14 refer to this diagram of a chromatogram.



12. A sample of starch is divided in two. One sample is boiled with dilute hydrochloric acid while the other is mixed with the catalyst in saliva at body temperature. After half-an-hour the reactions are complete and the solutions are chromatogrammed.

The catalyst in the saliva affects the starch differently from the acid in that it -

(a) cannot break the starch molecules as much as acid can.

(b) breaks the starch to a different, but equally simple sugar.

(c) takes longer than the acid to break the starch molecules and so the chromatogram was run too soon.

(d) was not allowed to react at a high enough temperature.

13. Potato flour, after treatment with saliva, was then left in contact with yeast for an hour. Which of the following is the most likely explanation for the results shown on the chromatogram.

(a) The yeast produces hydrochloric acid to continue the breaking-down process.

(b) The yeast produces new catalysts which continue the breaking-down process.

(c) The yeast catalysts operate faster than the saliva catalysts and so get further.

(d) The yeast causes the solution to boil and so breaks the maltose.

14. /

14. The experiment in Q.13. was repeated but the yeast was left with the solution for several days. A chromatogram of this solution shows no spots because the sugars had been converted into -

- [ ] (a) carbon dioxide and water.
- [ ] (b) their elements.
- [ ] (c) alcohol and carbon dioxide.
- [ ] (d) carbon and water.

MARKING BRIEF

1. Photosynthesis — 1 mark
2. Respiration — 1 mark
3. (d) — 1 mark
4. — 4 marks

Glucose maltose
sucrose
starch
---

5. — 4 marks

A	E

A	
E	

---	

6. (d) — 1 mark
7. (b) — 1 mark
8. (a) — 1 mark
9. (b) — 1 mark
10. (a) — 1 mark
11. Enzyme — 1 mark
12. (a) — 1 mark
13. (b) — 1 mark
14. (c) — 1 mark

Total = 20 marks

Put a tick in the box opposite the correct answer.

1. A piece of coal was found to have yellow-gold flakes in it. When the coal was burnt there was a smell of sulphur dioxide given off and a red ash was left. The most likely explana-:tion for the presence of sulphur dioxide is that:-

- [ ] (a) Coal is a compound of sulphur
- [ ] (b) Sulphur dioxide gas is trapped in the coal
- [ ] (c) The yellow-gold flakes are pieces of sulphur
- [ ] (d) The yellow-gold flakes are pieces of iron sulphide.

2. When a piece of filter paper wet with bromine water is held in sulphur dioxide gas, the brown bromine colour disappears. The reason for this is that:-

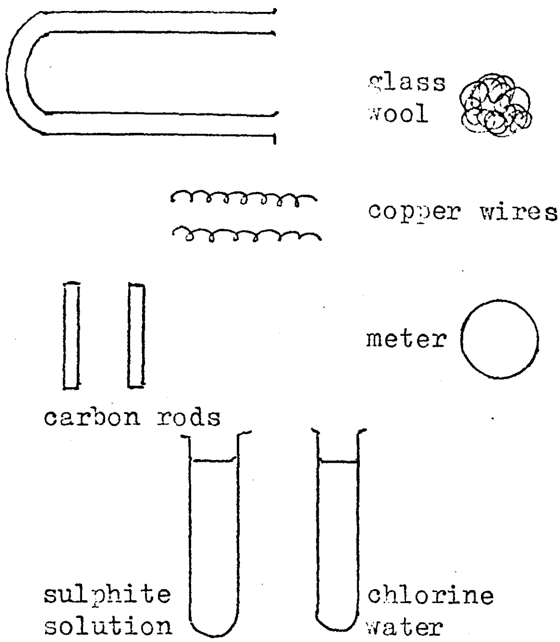
- [ ] (a) Oxygen from the SO_2 turns the bromine to colourless bromate ion (BrO_4^-).
- [ ] (b) The bromine and SO_2 react to give heat which makes the bromine escape as vapour.
- [ ] (c) The bromine gains electrons from the SO_2 to give colour-:less Br^- ions.
- [ ] (d) The bromine and SO_2 combine to give a new colourless compound Br_2SO_2.

3. Put a tick against <u>two</u> of the following properties which are <u>common to both</u> CO_2 and SO_2.

- [ ] (a) Denser than air
- [ ] (b) Extremely soluble in water
- [ ] (c) Burns in air
- [ ] (d) Allows magnesium to burn in it
- [ ] (e) Has no smell
- [ ] (f) Is a bleach.

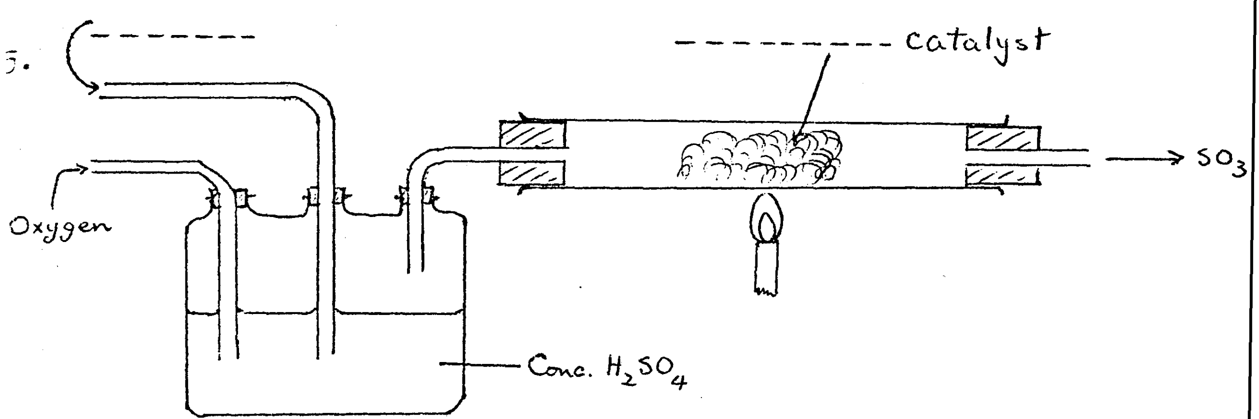
4. You are provided with the following pieces of apparatus and solutions. In the space provided sketch how you would set up the apparatus to show that there is an electron transfer between chlorine water and sulphite solution when they interact.

/



Above the meter draw an arrow to show in which direction you would expect the electrons to flow.

5.



Fill in the names on the labels.

6. An old bottle was found containing a chemical labelled GLAUBER'S SALT. The following tests were applied to the white solid to find its modern chemical name.

(a) It dissolved in water to give a solution with pH = 7.

(b) It gave a yellow flame test.

(c) When barium chloride solution was added to the solution in (a) a white precipitate formed which was insoluble in acid.

The modern name for Glauber's Salt is ....

7. /

7. (a) Oxidation only

(b) Reduction only

(c) Both oxidation and reduction

(d) Neither oxidation nor reduction.

Into which of the above categories do the following reactions fit?

(i) $Cu^{2+} + 2e \rightarrow Cu$

(ii) $CuSO_4 + H_2S \rightarrow CuS + H_2SO_4$

(iii) $SO_3^{2-}(aq) + I_2(s) + H_2O \rightarrow SO_4^{2-}(aq) + 2H^+(aq) + 2I^-(aq)$

(iv) $Zn(s) + 2H^+(aq) + SO_4^{2-}(aq) \rightarrow Zn^{2+}(aq) + SO_4^{2-}(aq) + H_2(g)$

(v) $2H^+(aq) + SO_3^{2-}(aq) \rightarrow SO_2(g) + H_2O(l)$

8. When concentrated sulphuric acid falls on to a piece of wood a black stain develops because:-

(a) The acid generates heat and chars the wood.

(b) The acid removes water from the 'wood molecules' leaving carbon.

(c) A black sulphate of wood forms.

(d) The acid draws a black tar out of the wood.

9. In a large power station 10 million tons of coal are burnt per year. If the coal contains 1% by mass of sulphur, what mass of sulphur dioxide will be released into the atmosphere annually?

$$S + O_2 \rightarrow SO_2$$

..............................tons

10. The main effect of this SO_2 in the atmosphere is -

(a) /

☐ (a) To bleach washing hanging out in the vicinity of the power station.

☐ (b) To disinfect the air and make it safer to breathe.

☐ (c) To preserve fruit in the surrounding orchards.

☐ (d) To produce sulphuric acid which causes damage to property and people.

- (a) To bleach washing hanging out in the vicinity of the power station.
- (b) To disinfect the air and make it safer to breathe.
- (c) To preserve fruit in the surrounding orchards.
- (d) To produce sulphuric acid which causes damage to property and people.

MARKING BRIEF

1.	(d)	1 mark
2.	(c)	1 mark
3.	(a) (d) 2 marks. Deduct a point if more than <u>two</u> answers.	
4.	2 marks for a completely workable sketch (1 mark for a partially workable sketch) 1 mark for arrow direction from sulphite to chlorine through the meter.	
5.	Sulphur dioxide	1 mark
	Platinum (or platinised asbestos)	1 mark
6.	Sodium (1 mark) Sulphate (1 mark)	
7.	(i) (b)	
	(ii) (d)	
	(iii) (c)	
	(iv) (c)	
	(v) (d)	5 marks
8.	(b)	1 mark
9.	Correct F. Wts. (or ratio)	1 mark
	Correct answer - 200,000 tons	1 mark
10.	(d)	1 mark

Total - 20 marks

Put a tick in the box opposite the correct answer in Questions 1 - 4.

1. Fats are classed as esters because they are made by linking an acid with:-

- [ ] (a) an alkane
- [ ] (b) an alcohol
- [ ] (c) an alkene
- [ ] (d) a sugar.

2. Which one of the following statements is <u>not always</u> true about the acid in a fat:-

- [ ] (a) it has a COOH group
- [ ] (b) it has a long chain of carbon atoms
- [ ] (c) it has a zig-zag chain of carbon atoms
- [ ] (d) it is stearic acid.

3. If you were provided with 1 g of each of the following sub:stances, which one would give out most heat when it burned completely?

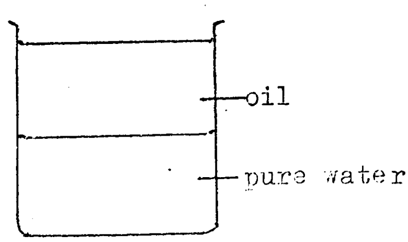
- [ ] (a) sugar
- [ ] (b) fat
- [ ] (c) egg white
- [ ] (d) starch.

4. To convert a fat into a soap you would heat it with:-

- [ ] (a) sodium chloride
- [ ] (b) sulphuric acid
- [ ] (c) sodium hydroxide
- [ ] (d) saturated brine

5. Use the symbol —O to represent a soap molecule in which the 'O' represents the COO^- group.

If this molecule were introduced into this beaker of liquid, draw (in the beaker) the most likely position it would take up.



6. Which one of the following solutions would you expect to be "hard"?

- [ ] (a) sodium chloride solution
- [ ] (b) sea water
- [ ] (c) distilled water with dissolved air
- [ ] (d) rain water with dissolved CO_2.

7. Show that you know the meaning of the term "hard water" by filling in the blanks in the sentences below.

Natural water is "hard" when it has .... ions dissolved in it.

Instead of forming a lather in hard water, soap forms a .....

....

8. Soapless detergents have the advantage over soap in that they:-

- [ ] (a) make clothes 'whiter than white'
- [ ] (b) can lather even in hard water
- [ ] (c) are 'kinder to the hands'
- [ ] (d) do not make clothes shrink.

9. The raw materials for making soapless detergents are:-

- [ ] (a) hydrocarbons and sulphuric acid
- [ ] (b) carbohydrates and nitric acid
- [ ] (c) fats and sodium hydroxide
- [ ] (d) proteins and hydrochloric acid.

10. Place the letter P in <u>two</u> of the boxes below against materials which are mainly protein:-

- [ ] (a) cornflakes
- [ ] (b) hair
- [ ] (c) eggs
- [ ] (d) sugar
- [ ] (e) butter

11. /

11. Which one of the following statements best describes all proteins:-

- [ ] (a) compounds of carbon
- [ ] (b) compounds of nitrogen
- [ ] (c) compounds of carbon and nitrogen
- [ ] (d) compounds of acids.

12. The 'building units' of proteins are called ....
....

13. These units are linked together by a process called:-

- [ ] (a) condensation
- [ ] (b) hydrolysis
- [ ] (c) distillation
- [ ] (d) hydrogenation.

14. A substance (X) was heated with soda lime and an alkaline gas was given off. On this evidence alone which one of the following conclusions is justified:-

- [ ] (a) the gas is ammonia
- [ ] (b) X is an ammonium salt
- [ ] (c) X is a nitrogen compound
- [ ] (d) X is a protein.

15. Name the type of catalyst which, in our bodies, 'digest' and 'reassemble' proteins ....

16. Fill in the table below in this way:-

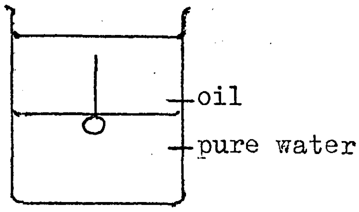
(a) Choose headings for the three columns.

(b) Write the following substances into the columns under the headings you have chosen.

Skin; blood; glucose; meat; lard; maltose; bread; wood; leather.

U.G./Chem.Ed./5 'C'

MARKING BRIEF

1.	(b)	1 mark
2.	(d)	1 mark
3.	(b)	1 mark
4.	(c)	1 mark
5.		1 mark
6.	(b)	1 mark
7.	Calcium or magnesium (or other reasonable suggestion)	1 mark
	Scum or curd (or other reasonable suggestion)	1 mark
8.	(b)	1 mark
9.	(a)	1 mark
10.	(b) and (c)	2 marks
11.	(c)	1 mark
12.	amino acids	1 mark
13.	(a)	1 mark
14.	(c)	1 mark
15.	Enzyme (or if a specific protein catalyst mentioned accept name)	1 mark
16.	A test of creative thinking to see what categories these compounds fall into.	3 marks for all 3 categories correct.

Deduct a maximum of one mark if the categories are correct, but the substances are not in correct columns.

Total - 20 marks

1. Rainwater is always acidic, but during a thunderstorm it is even more acidic. This increase is caused by -

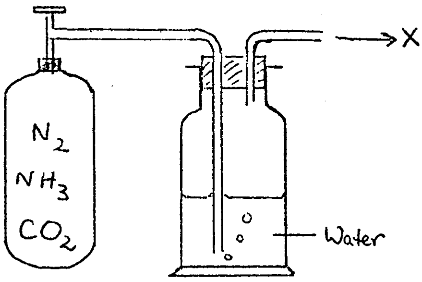
(a) More carbon dioxide than usual dissolving in the rain.

(b) Nitrogen and oxygen in the air combining and dissolving in the rain to give nitric acid.

(c) Sulphur dioxide becoming more soluble in rain during thunderstorms.

(d) Hydrogen in the rainwater ionising to give H^+ because of the lightning.

2.



A syphon contains a mixture of three dry gases - nitrogen, ammonia and carbon dioxide.

The mixture is bubbled into water. What is the gas mixture at X most likely to be?

(a) The original mixture unchanged.

(b) Mainly ammonia and nitrogen.

(c) Mainly nitrogen and carbon dioxide.

(d) Mainly ammonia and carbon dioxide.

After bubbling the mixture into the water for a very long time a crystalline solid appeared at the bottom of the bottle. What is it likely to be? ....

3. Ammonia gas burns only with great difficulty, but when the gas has electric sparks passed through it for some time its volume doubles and most of the gas now burns well. This can be explained as follows -

(a) Sparking makes the gas expand and hot gases burn better than cold.

(b) Sparking releases hydrogen from the ammonia and this burns well.

(c) Sparking adds energy to the gas and this energy is released in the form of flame.

(d) Sparking breaks the ammonia into nitrogen and hydrogen which recombine giving out heat.

4. /

4. Ammonia is a covalent gas. When it dissolves in water the solution conducts electricity. The best explanation of this is:-

(a) Ammonia takes a hydrogen ion (proton) from the water to give ammonium and hydroxyl ions.

(b) Ammonia, as it dissolves in water, releases nitrogen ions and hydrogen ions.

(c) Covalent compounds carry current and so a solution of such a compound should do so.

(d) Ammonia dissolves so well in water that it gives a concentrated solution which conducts well.

5. In industry nitric acid is made from ammonia by which one of the following processes?

(a) $NH_3 + 3H_2O \rightarrow HNO_3 + 4H_2$

(b) $\begin{cases} 4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O \\ 2N_2 + 12H_2O \rightarrow 4HNO_3 + 10H_2 \end{cases}$

(c) $NH_3 + 4CuO \rightarrow HNO_3 + 4Cu + H_2O$

(d) $\begin{cases} 4NH_3 + 7O_2 \rightarrow 4NO_2 + 6H_2O \\ 4NO_2 + 2H_2O \rightarrow 2HNO_3 + 2HNO_2 \end{cases}$

6. Which one of the following would be the safest and most convenient way to make potassium nitrate?

(a) Potassium metal + nitric acid.

(b) Potassium chloride + nitric acid.

(c) Potassium metal + copper nitrate solution.

(d) Potassium hydroxide solution + nitric acid.

7. Your knowledge of the reactivity series should help you to answer this question.

(a) Metal nitrite.

(b) Metal nitride.

(c) Metal oxide.

(d) Metal.

When /

When nitrates are heated a gas is given off and a solid is left. Which of the above solids would you expect to be left after heating:- (Enter the correct letter in the box.)

(1) Copper nitrate?

(2) Silver nitrate?

8. In which one of the following reactions is nitric acid (the nitrate ion) acting as an electron acceptor?

(a) $2HNO_3 + ZnO \rightarrow Zn(NO_3)_2 + H_2O$

(b) $8HNO_3 + 3Cu \rightarrow 3Cu(NO_3)_2 + 2NO + 4H_2O$

(c) $2HNO_3 + PbCO_3 \rightarrow Pb(NO_3)_2 + CO_2 + H_2O$

(d) $2HNO_3 + Mg \rightarrow Mg(NO_3)_2 + H_2$

9. All ammonium compounds smell of ammonia when they are:-

(a) Cold

(b) Strongly heated

(c) Heated with sulphuric acid

(d) Heated with sodium hydroxide.

10. A catalyst in a reaction:-

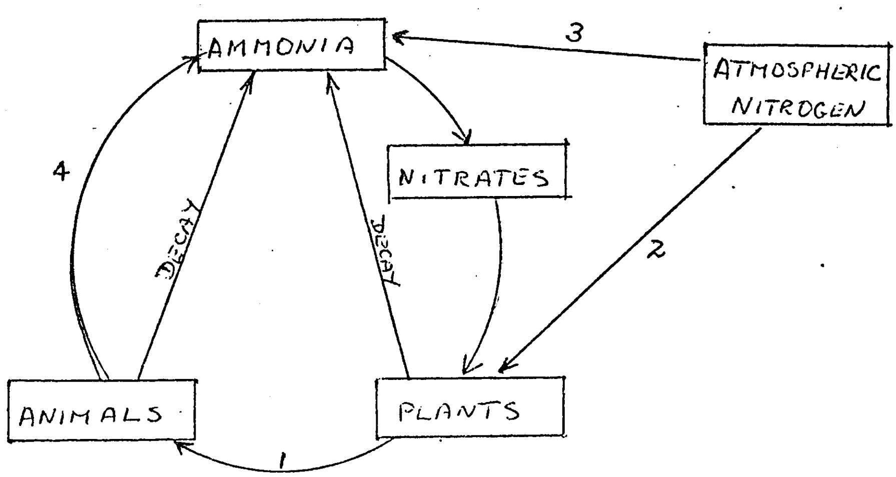
(a) Increases the yield of the product.

(b) Increases the rate at which the product forms.

(c) Takes no part in the reaction.

(d) Increases the purity of the product.

11. Here is one way of setting out the nitrogen cycle.



These /

These question numbers refer to the numbers in the diagram.

1 How are the nitrogen compounds in plants transmitted to animals? ....

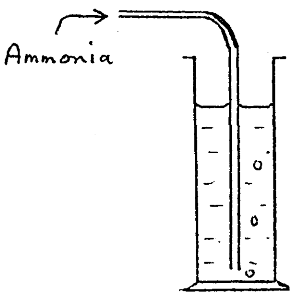
2 What plant family is able to use atmospheric nitrogen directly? ....

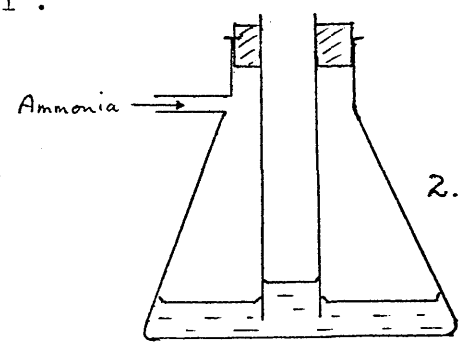
3 What industrial process is involved here? ....

4 Often the nitrogen cycle is not completed at this point. How does this break happen?................................
....

12. This question is designed to test your ability to think about a practical situation.

If a very soluble gas like ammonia is to be dissolved in water it could be done as shown in sketch 1 . However, there is a danger of the water being sucked back up the tube. Diagram 2 shows an apparatus for dissolving the gas which is supposed to be an improvement on 1 .





Place a tick against four of the statements below which you think make 2 a clear improvement over 1 .

	(a) A larger water surface is exposed to the gas.
	(b) The water cannot reach the inlet side-arm tube.
	(c) The gas can push the water up and out of the centre tube and so escape harmlessly.
	(d) The flask being full of air will slow down the adsorption of the gas by the water.
	(e) A sudden increase in gas pressure will force water up the centre tube until the bottom of the tube comes clear of the water in the flask. The water in the tube will then fall back into the flask.
	(f) As the water is pushed up the centre tube the increase in pressure will make the gas dissolve more rapidly.

MARKING BRIEF

1.	(b)	1 mark
2.	(c) Ammonium carbonate	2 marks
3.	(b)	1 mark
4.	(a)	1 mark
5.	(d)	1 mark
6.	(d)	1 mark
7.	(c) and (d)	2 marks
8.	(b)	1 mark
9.	(d)	1 mark
10.	(b)	1 mark
11.	(1) - eaten	
	(2) - pea or bean or leguminosae	
	(3) - Haber	
	(4) - sewage not returned to land	4 marks
12.	(a)	
	(b)	
	(e)	
	(f)	4 marks

Total - 20 marks

1. Fill in the blanks in this table.

Monomer	Polymer
	Starch
	Polythene
Tetrafluoroethylene	

2. Name the process by which small molecules link together to form large ones ....

3. When a colourless liquid monomer was left for some time, several changes took place in it. Which one of the following changes would lead you to believe that larger molecules had been formed. (Tick the most likely one.)

☐ (a) The substance became darker in colour.

☐ (b) The temperature of the liquid rose.

☐ (c) The liquid set into a solid.

☐ (d) The smell of the liquid altered.

4. Here is a list of descriptions which can be applied to polymers. Against each of the polymers in the table below write two of the descriptions which apply to that polymer. N.B. Descriptions can be used more than once.

Descriptions - naturally occurring; man made; linked by condensation; linked by addition; contains nitrogen; made from materials derived from oil.

Polypropylene	
Rayon	
Nylon	
Cellulose	

5. When polymers are burnt they usually give off a smell. Here are five common smells given off.

(a) Waxy

(b) Burning paper

(c) Burning wool

(d) Sharp acid smell

(e) Fruity

Against /

Against each of the polymers listed below write the letter for the smell you would be most likely to get when burning that polymer. (Note - letters may be used more than once.)

(i) Nylon

(ii) Polythene

(iii) Rayon

(iv) Polypropylene

6. Which one of the following statements about a plastic means that it is THERMOPLASTIC? (Tick the correct answer.)

(a) It was formed by an exothermic reaction.

(b) It can withstand heat without softening.

(c) It softens on heating and hardens on cooling.

(d) It gives out much heat when it burns.

7. For which one of the following uses would a <u>THERMOSETTING</u> plastic <u>be essential</u>? (Tick the correct answer.)

(a) Insulation of electric wires.

(b) Making pan handles.

(c) Making non-inflammable clothing.

(d) Making the bodies of pens.

8. Silicones have the general structure:-

$$
\begin{array}{ccccccccccc}
 & R & & & R & & & R & & & \\
 & | & & & | & & & | & & & \\
--- & Si & - & O & - & Si & - & O & - & Si & - & O & --- \\
 & | & & & | & & & | & & & \\
 & R & & & R & & & R & & &
\end{array}
$$

where R is an organic group.

When silicones burn in a plentiful supply of oxygen gaseous material is given off and a white solid is left. Which one of the following lists is most likely to be the products of burning a silicone. (Tick the correct answer).

(a) Carbon, silicon dioxide gas and steam.

(b) Silicon carbide and steam.

(c) Silicon hydride and carbon dioxide.

(d) Silicon dioxide, carbon dioxide and steam.

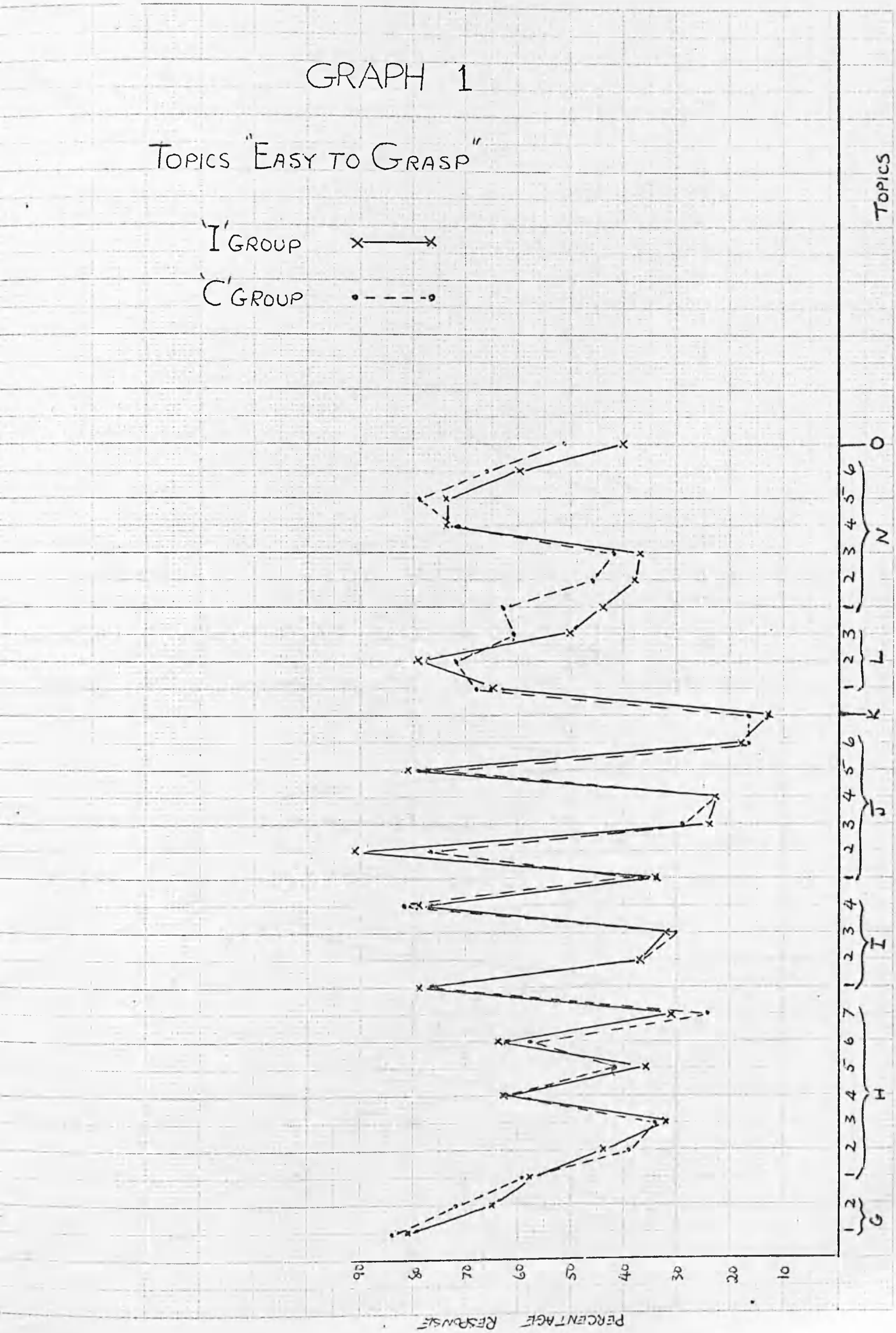
MARKING BRIEF

1.	Glucose, ethene (ethylene), P.T.F.E. (or in full)	3 marks
2.	Polymerisation (this is a more general term than Condensation or Addition).	1 mark
3.	(c)	1 mark
4.	Any two relevant descriptions	8 marks
5.	(c), (a), (b), (a)	4 marks
6.	(c)	1 mark
7.	(b)	1 mark
8.	(d)	1 mark
	Total =	20 marks

RESULTS OF TESTS IN MATURITY STUDY

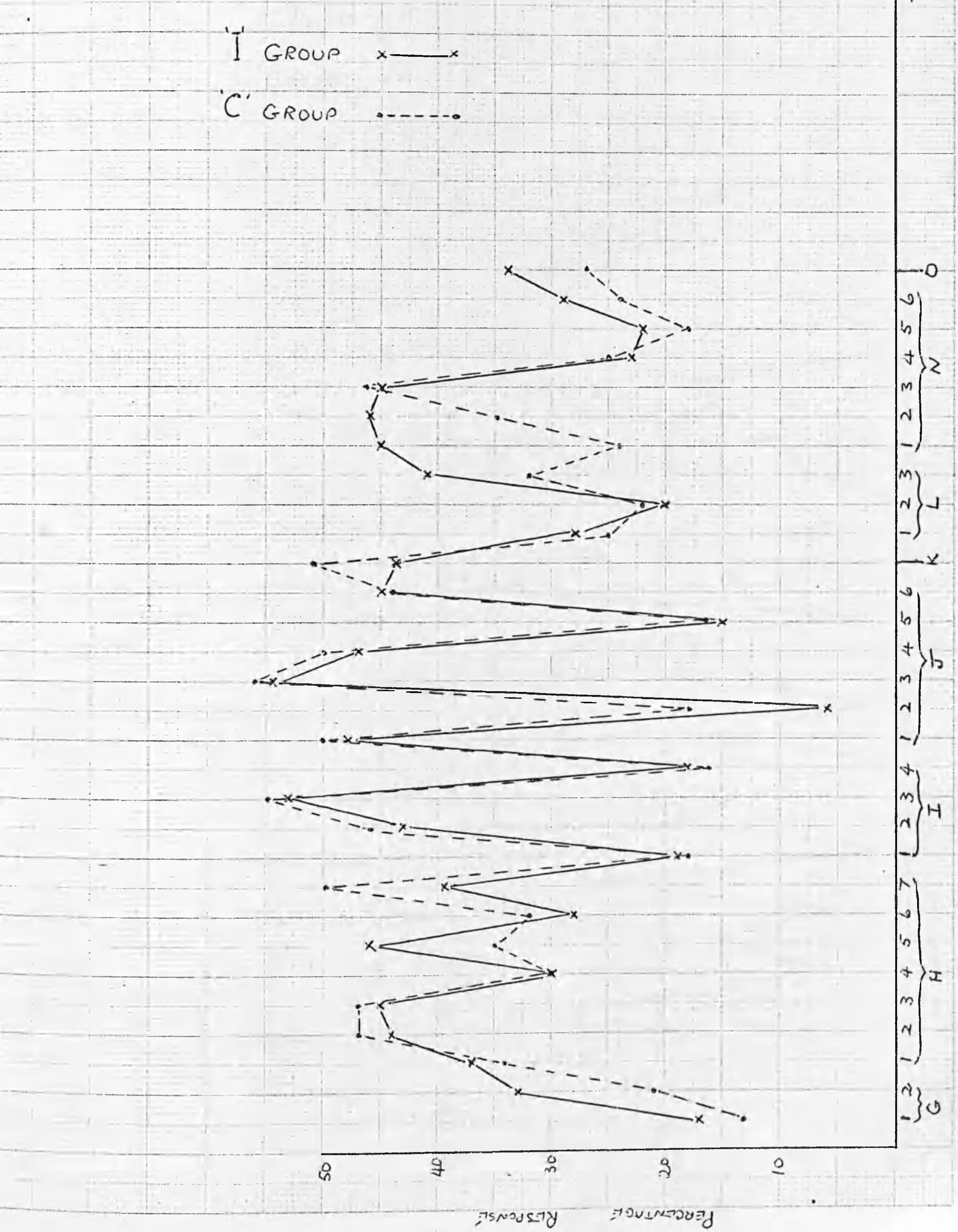
Test No.	School 1				School 2				School 3				School 4				All Over	
	I		C		I		C		I		C		I		C		I	C
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	Mean
1 I & C	10.2	3.7	10.7	4.0	9.5	1.5	8.0	3.2	8.8	1.0	9.2	3.7	12.4	4.1	13.2	3.7	9.8	9.7
2 I & C	12.3	2.1	13.0	2.4	9.3	3.9	8.0	3.7	7.4	5.0	7.8	3.7	8.8	3.5	12.0	3.5	9.3	9.5
3 I	12.5	5.9	13.9*	2.0	10.5	4.6	10.7	3.5	9.9	4.6	-	-	12.1	2.9	12.4	0.5	11.0	12.6
3 C	12.1	5.2	9.5	3.6	10.4	5.3	8.7	4.1	10.0	2.8	10.1	4.5	10.6	3.7	9.7	2.1	10.8	10.8
4 I	9.6	3.8	11.4	4.9	8.7	3.5	8.5	3.2	9.4	5.0	11.4	1.9	8.9	1.8	9.5	4.9	9.2	9.4
4 C	13.6	3.8	12.7	0.9	11.0	2.1	10.5	4.9	11.5	4.6	5.8	2.6	12.4	3.4	9.8	2.4	12.0	9.5
5 I	13.2	4.2	14.8	4.3	11.4	4.0	10.5	4.4	8.5	3.5	9.8	4.1	12.9	2.8	10.3	4.2	11.1	11.5
5 C	16.4	3.0	14.2	1.8	-	-	13.3	3.6	11.6	4.0	9.2	1.0	13.0	3.7	13.9	2.6	13.8	12.2
6 I	11.4	3.0	14.4	5.7	11.8	4.0	10.0	2.7	9.7	3.7	10.7	1.7	9.7	2.4	7.1	3.5	10.7	11.1
6 C	15.6	5.0	13.2	4.7	11.9	3.4	10.7	2.5	11.7	2.5	9.9	2.4	-	-	10.5	3.3	12.9	11.1
Average																	11.1	10.7

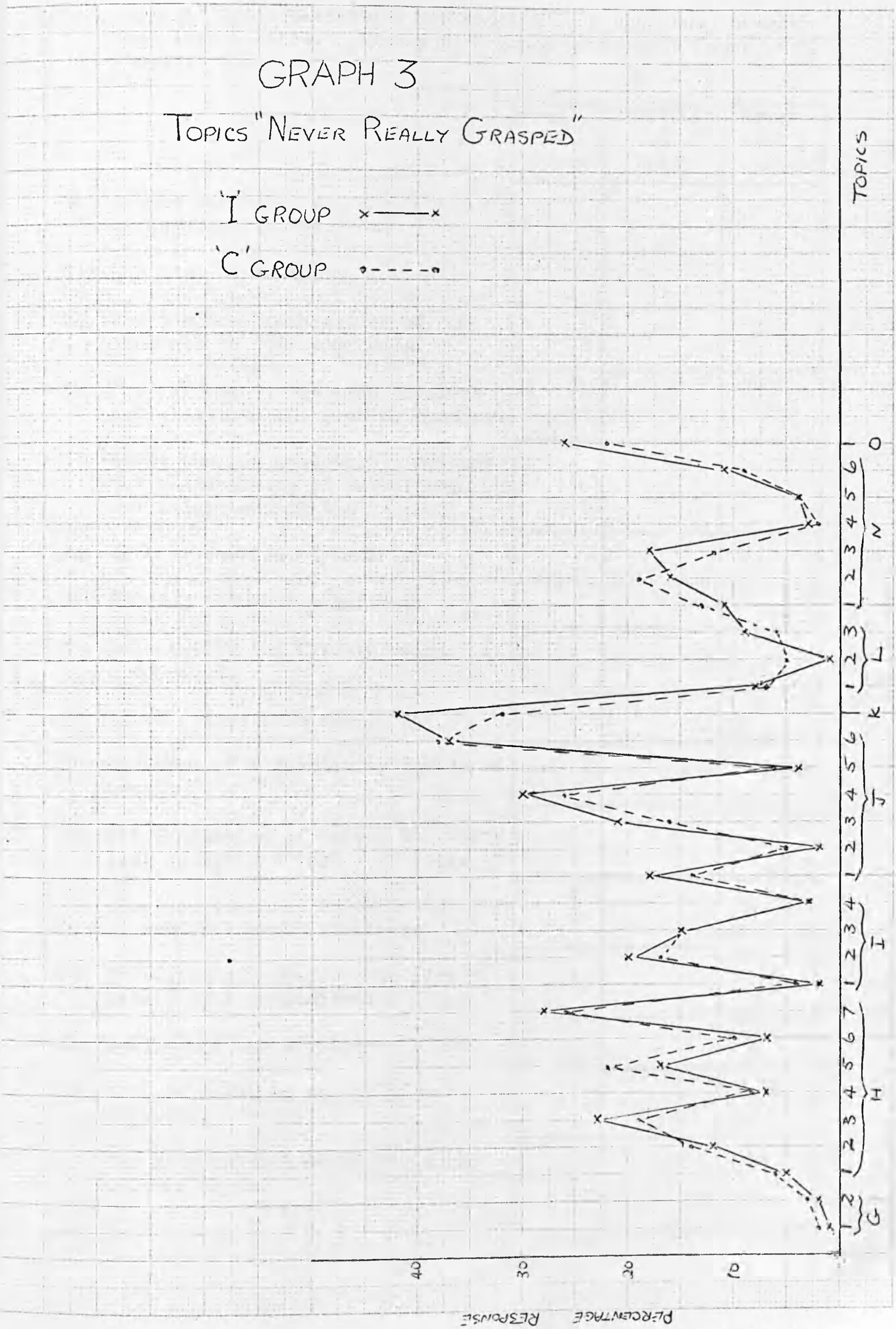
* Results underlined are those obtained by a fourth year group.


GRAPH 1
Topics "Easy to Grasp"
'I' Group
'C' Group
Topics
G
H
I
J
K
L
N
O
90
80
70
60
50
40
30
20
10
PERCENTAGE RESPONSE

GRAPH 2.

Topics "Difficult to Grasp"




GRAPH 3
TOPICS "NEVER REALLY GRASPED"
'I' GROUP
'C' GROUP
TOPICS
G 1 2
H 1 2 3 4 5 6 7
I 1 2 3 4
J 1 2 3 4 5 6
K
L 1 2 3
N 1 2 3 4 5 6
O
40
30
20
10
PERCENTAGE RESPONSE

Subjective Topic Assessment by Pupils in Maturity Study

Some of the topics which you studied in your school course are listed below. Tick your opinion of how you found each topic.

	Easy to Grasp	Difficult to Grasp	Never Really Grasped
G1. Atomic particles and their arrangement in the atom.			
G.2. The idea of isotopes.			
H1. The chemical combination of elements to form compounds.			
H2. The differences between covalent and electrovalent (ionic) bonding.			
H3. Using the ion detector to measure the conductivity of solutions, and understanding the results.			
H4. Writing chemical formulae.			
H5. Writing chemical equations.			
H6. Calculating the formula weight of a compound.			
H7. Calculations from equations.			
I1. The idea of a reactivity series of metals.			
I2. The ionisation of water. The meaning of $H_2O \rightarrow H^+(aq) + OH^-(aq)$.			
I3. Electron transfer in oxidation-reduction (Redox) reactions.			
I4. Corrosion of metals. The idea of sacrificial protection.			
J1. Acidic and basic oxides.			
J2. What is meant by the pH of a solution.			
J3. The various methods of preparing soluble salts.			

J4. /

	Easy to Grasp	Difficult to Grasp	Never Really Grasped
J4. Precipitation reactions for pre-:paring insoluble salts.			
J5. Using an indicator to tell when an acid has neutralised an alkali.			
J6. Calculations to find the molarity of a solution.			
K1. Ion-electron half-equations. The meaning of equations like $SO_3^{2-} + H_2O \rightarrow SO_4^{2-} + 2H^+ + 2e$ and $3e + NO_3^- + 4H^+ \rightarrow NO + 2H_2O$			
L1. The "cracking" of liquid hydro-carbons.			
L2. The distillation of crude oil to give a number of fractions.			
L3. The making of addition polymers, e.g. perspex, polystyrene, P.V.C.			
N1. The breaking down (hydrolysis) of carbohydrates using saliva or hydrochloric acid.			
N2. The formation of esters.			
N3. The conversion of fats to soaps.			
N4. How soaps and detergents clean.			
N5. Why a scum sometimes forms when soap is used for washing.			
N6. The importance of nitrogen con-:taining compounds.			
O1. Making condensation polymers, e.g. nylon, phenol-formaldehyde.			

COMPARISON OF S.C.E. 'O' GRADE RESULTS AFTER MATURITY EXPERIMENT

These results are published in bands of 5 marks as follows -

Band	1	2	3	4	5	6	7	8	9	10	11	12	13
Range	90+%	89-85	84-80	79-75	74-70	69-65	64-60	59-55	54-50	49-45	44-40	39-35	34-

	School 1		School 2		School 3		School 4		ALL OVER	
Band	I	C	I	C	I	C	I	C	I	C
1	3	2	-	-	1	-	-	-	4	2
2	2	1	-	-	-	2	-	-	2	3
3	4	3	1	-	2	1	2	-	9	4
4	4	7	1	-	5	1	-	3	10	11
5	7	13	4	2	6	4	1	2	18	21
6	7	11	5	5	5	10	2	4	19	30
7	4	7	4	5	4	6	4	2	16	20
8	4	1	2	2	10	-	3	4	19	7
9	5	1	8	8	7	9	5	-	25	18
10	1	-	4	2	5	3	1	1	11	6
11	1	-	5	4	5	9	-	1	11	14
12	-	-	1	4	2	8	-	1	3	13
13	-	1	-	1	-	5	1	-	1	7
Mean	5.7	5.3	8.0	8.4	7.4	8.7	7.5	6.9	7.1	7.5
S.D.	2.6	2.0	2.3	2.9	2.6	3.0	2.3	2.3	2.6	2.9

Note - The smaller the value for the mean the better the performance of the group.

Observation

The overall score for the 'I' group is marginally, but not significantly better than that for the 'C' group.

CHAPTER 3

CHAPTER 3

AN APPRAISAL OF SIXTH YEAR STUDIES CHEMISTRY

After the launching of the Alternative syllabus in the early 1960's an effort was made by the Scottish Education Department to introduce the equivalent of an 'A' level in all subjects. Specimen syllabuses were drawn up and, in chemistry, a highly academic document emerged.[15] This, along with those in other subjects, was heavily criticised by professional bodies and in the press and eventually the proposals were withdrawn. The criticism took three main lines.

(a) The principle of specialisation was strongly resisted. It was argued that the Higher grade would disappear and that pupils would be forced to study only three subjects post-'O' grade whereas 'H' grade allowed pupils to study 5-6 subjects up to university entrance.

(b) The proposed courses were much too narrowly academic and useful only to the few.

(c) Advanced (post 'H' grade) courses should be devoted to broadening the student's experience rather than to the acquisition of yet more factual material. The student should be trained to be a student rather than a schoolboy by encouragement of independent study, self-reliance, willingness to weigh up evidence and to argue about it. However, it should not be used for university entrance purposes.

From this third objection was born the idea of Sixth Year Studies (SYS). In 1965 a memorandum was sent from the S.C.E. Special Committee on Post-Higher Examination to the convenors of all subject panels of the Examinations Board [16] which contained the following advice.

The /

> The Special Committee is anxious to ensure that the examination provided by the Board should accord with the real purposes which a "proper sixth year" is intended to serve. It believes that the most important of these purposes is the development in the pupils of a greater degree of maturity of out-:look than they have generally acquired by the end of the fifth year. This purpose can best be achieved through a course of study which aims partly at broadening the pupil's general outlook and partly at deepening his knowledge and understanding of a limited range of subjects.
>
> The approach to such a course should "lead the pupil into habits of positive and rewarding private study, should promote individual thinking and judgement and should develop self-reliance and responsibility in place of his present almost absolute dependence on his teachers". (Report of the Advisory Council: "The Post-Fourth Year Examination Structure in Scotland" paragraph 23 ad fin.)

To avoid the "evil" of specialisation it was laid down that no student should present himself for more than three subjects and that these three S.Y.S. subjects should together occupy no more than one half to threefifths of the week. This then left about half the week for the pursuit of other interests.

Each subject course was designed with a relatively light core of new subject matter surrounded by areas where students and teachers could find room to pursue interests either in options or by means of projects. The time available for S.Y.S. study was about seven months with the examination coming immediately after Easter. These proposals were accepted by the Secretary of State for Scotland in 1966 (p. A3.1).

The Chemistry course was issued in draft form in 1967 when a group of pilot schools attempted it, and then in its final form in 1968. [4]

A list of objectives for the course appears in the Appendix p. A3.2. The design of the course was made against a background of broader /

broader objectives than these,[4] but this more definitive list of objectives is now being used to test the course with a view to future modifications. This work began in 1970 through a joint working party of the Examination Board and the Consultative Committee on the Curric-:ulum.

The design of the course to meet the original broad aims set out in the memorandum [16] was as follows.

(a) A brief core syllabus of advanced work occupying about 100 hours. The topics were chosen within these guidelines.

(i) They were to clarify or give more evidence for ideas taken on trust in the 'H' grade syllabus, e.g. Spectroscopy was chosen to give evidence for bonding and molecular shape. Thermodynamics was used to help to answer questions about direction of change.

(ii) They were to try to avoid as far as possible being a copy of first year university courses. ('A' level candidates, having anticipated first year university were often bored at Scottish universities and lost the habit of working.)

(iii) They were to provide room for discussion of ideas which were amenable to small group treatment, e.g. free energy, entropy, social aspects of organic chemistry.

The topics actually chosen are set out in some detail in the S.Y.S. booklet [4] and also appear in the Questionnaire in the Appendix, p.A3.10.

(b) To accompany the "lecture course" was a set practical course designed /

designed to operate in a number of ways.

(i) To raise the problem situations which led to the lectures/ discussions.

(ii) To illustrate theory.

(iii)To increase practical skills, both qualitative and quantita- :tive.

(c) About 60 hours was to be set aside for free ranging projects to fit in with the interests of pupils and teachers.

ASSESSMENT

This was designed to meet some of the aims of S.Y.S. It con- :sisted of five parts.

(a) An objective test to give quick coverage of both the 'H' grade and S.Y.S. syllabuses (implying that one course was part of the other). (50 marks)

(b) A structured question paper devoted mainly to the S.Y.S. course material. This was largely a test of sustained reasoning and argument. (100 marks)

(c) A dissertation of at least 2000 words based on the project work. This aimed to test skills of written presentation of private work. (20 marks)

(d) An oral interview based on the project in which the student could "defend" his work orally, face to face with a stranger. The student was required to justify assumptions and courses of action; to display the specialist knowledge he had gained and to interpret conclusions. (20 marks)

(e) /

(e) A check on course-work records for completeness, presentation and quality of work. (10 marks)

(c), (d) and (e) were examined by visiting teachers working on a fairly specific marking grid (Appendix A3.13).

EXPERIMENTAL

In June 1970 and again in June 1971 a survey was conducted on all S.Y.S. candidates in Scotland to see how far the course was achieving its aims (Appendix p. A3.8). In 1971 a survey was made of all S.Y.S. teachers to obtain their views (Chapter 4). The author, as Principal Examiner, had access to examination material which provided yet more evidence.

The material for this chapter has already been published in three reports to Scottish Education Department.[17 18 19]

RESULTS

The results of the 1970 and 1971 pupils' surveys were treated comparatively to look for any changes which had occurred as the teachers' experience of the course had increased.

1. RESPONSE

1970 - 766 pupils (Boy:Girl - 4:1) (99.3%) from 125 schools

1971 - 850 pupils (Boy:Girl - 3:1) (80.0%) from 160 schools

For statistical purposes, this was a satisfactory response.

2. /

2. HIGHER GRADE PASSES

In both years 72% of the students already held 5 or more 'H' grade passes before beginning S.Y.S. They, therefore, had university entrance qualifications but had chosen to remain at school for an extra year (p.3.23).

Some work was done to relate the quality and number of these 'H' grade passes to areas of difficulty (p.3.13) and to the tertiary centres for which they had been accepted (p.3.21).

3. FACTORS AFFECTING CHOICE TO STUDY S.Y.S. CHEMISTRY

Questionnaire - Question 3.

"Why did you decide to study S.Y.S. Chemistry?"

Pupils were given a list of factors and asked to choose one or more of these. The results are shown on a frequency graph (Graph 3.1). The main factor which was chosen was "Because the subject (i.e. 'H' grade chemistry) is interesting". All the other factors obtained a similar response for the two years with one significant exception. The 1970 students imagined that the S.Y.S. course would "improve their chances of university entrance" but by 1971 it had become accepted by most students that S.Y.S. had little or nothing to do with university entrance. However, in another part of the survey, p.3.6(a), 2% of the students had been offered university entrance on condition that they obtained a suitable standard in S.Y.S. This may be the earnest of a change in university policy contrary to the ideas of S.Y.S.

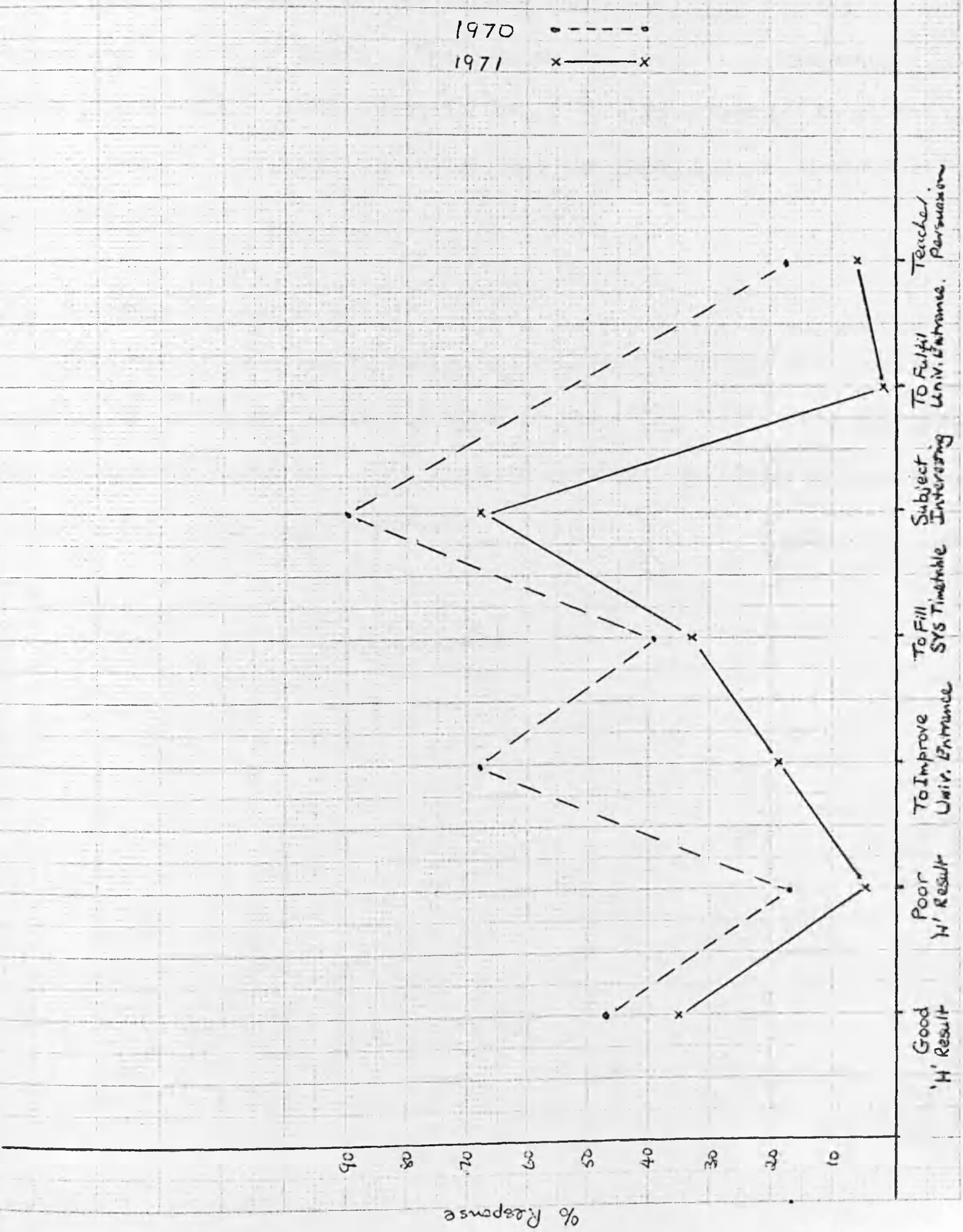
4. IMPRESSION OF THE COURSE

The Questionnaire approached the pupils' views on the course in three /

GRAPH 3.1

REASONS FOR STUDYING S.Y.S.

CHEMISTRY



three stages - (a) a general impression (b) detailed course topics (c) detailed course concepts.

(a) <u>General Impression</u>

Question 4 - "What has been your reaction to S.Y.S. Chemistry as a whole?"

A list of possibilities was offered and pupils were invited to choose one or more of these. The results are shown as a frequency graph (Graph 3.2). 1970 - dotted line, 1971 - full line. As might be expected in a purposely vague question the vague answer "reasonable" predominated.

(b) <u>Reaction to Course Topics</u>

This part of the Questionnaire was designed to detect any continuance of the areas of difficulty noted in the 'O' and 'H' Grade courses and to look for new areas. It was also seeking for relationships between "difficulty" and "boredom".

<u>TABLE 3.1</u>

GRAPH 3.2

REACTION TO S.Y.S. COURSE AS A WHOLE

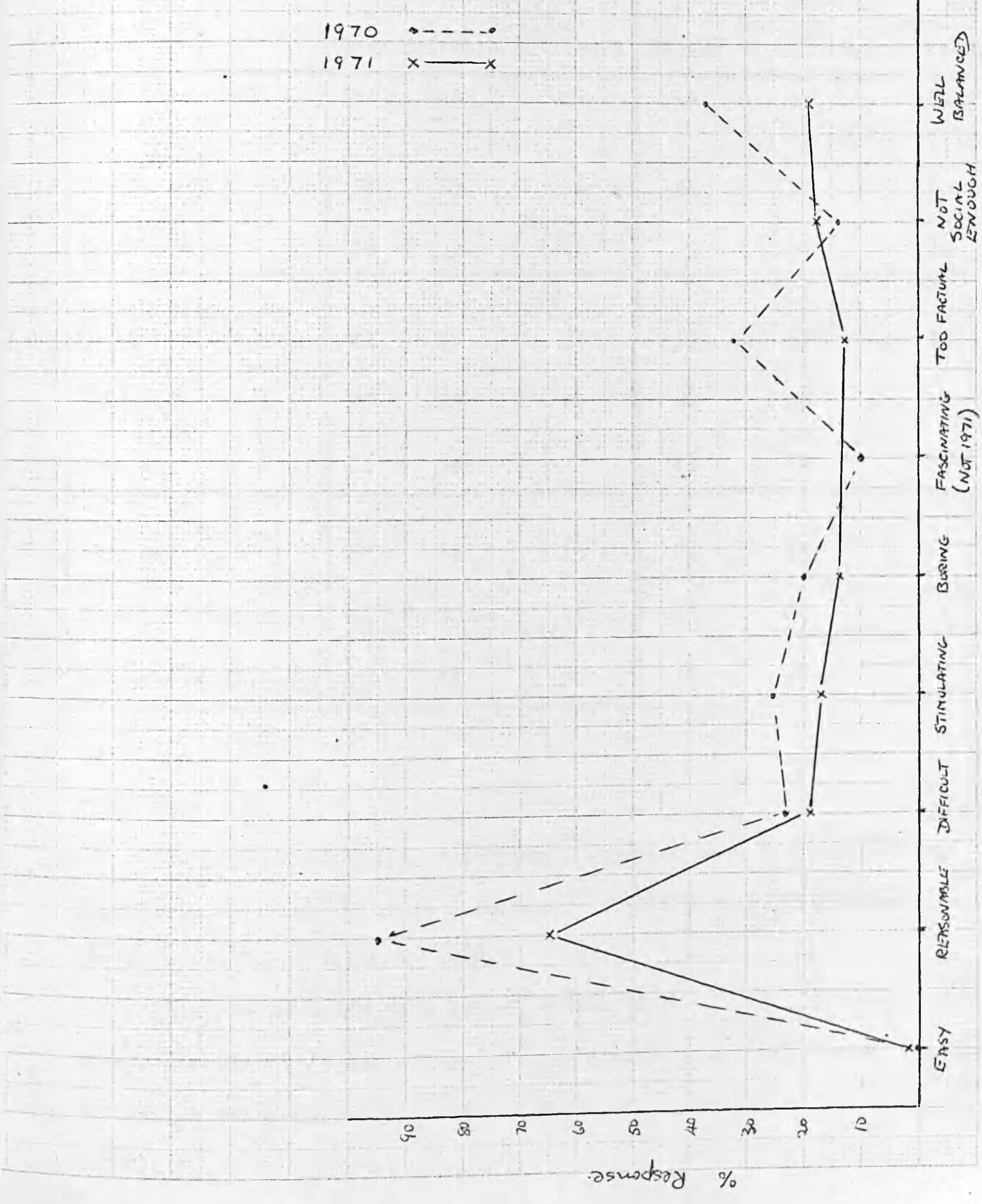


TABLE 3.1

Reaction to Course Topics (Table shows response/100 replies)

In each case there was a small number (less than 10%) of no response.

	Easy	Moderate	Difficult	Boring	Neither Boring Nor Stimulating	Stim-:ulating
Thermodynamics	27	55	15	19	59	15
Volumetric (incl. redox)	26	53	16	31	50	10
Spectroscopy	28	52	16	9	37	46
Atomic Structure (orbitals)	22	47	28	19	39	35
Molecular Shape	23	48	25	20	53	19
Organic	15	54	27	17	42	33
Rest of Group IV (Si, Ge, Sn, Pb)	15	62	15	24	53	12
Solution Chemistry	26	50	21	23	50	21
Transition Elements	16	55	20	15	45	31

DISCUSSION

The topics which were fairly well accepted were Thermodynamics, Volumetric work and Solution Chemistry. Table 3.2, p.3.14 showed that the Mole was being rated as easy.

This change could have arisen in two ways - (i) S.Y.S. students were generally the cream of the 'H' grade students. (ii) During the course the mole was reintroduced in terms of a quantity of electrons capable /

capable of bringing about a measured amount of chemical change. The students were now at the level of maturity which enabled them to absorb the mole concept readily whereas their 'H' grade colleagues were operating on a version of the mole concept introduced at age 15 when they were scarcely ready for it.

In the "difficult" column three topics were outstanding: Atomic Structure in terms of orbitals, Molecular Shape (Gillespie-Nyholm) and the Organic.

The Organic course consisted of a simple mechanistic treatment of alkyl halides and Grignard reagents but, despite the new treatment, the possible insecurity of the previous organic work at 'O' and 'H' grades seemed to persist. The vocabulary of the previous years was basic to the course and this may have been the link which carried over the feeling of difficulty. Another possible factor was that teachers, keen on organic, may have allowed their enthusiasm to make them overdo the treatment.

As far as the other two difficult topics are concerned, neither in itself is conceptually difficult, but taken together there are conflicts.

The pupils had been brought up with the idea of the spherical atom and were now introduced to an atomic picture which seemed far from spherical.[21] Orbitals sticking out in various directions pre-:sented the students at one and the same time with ideas of pro-:bability and of "concrete" spatial arrangement. It was very unlikely that any kind of "advance organiser" was offered to help him in his thought transition or accommodation. Might it have made a difference if he had been reminded that any object, no matter how obtuse, when rotated freely carves out for itself a spherical space?

While /

While the students were still grappling with these problems they were confronted with yet another. To the mature chemist it may be logical to progress from the atomic orbital situation (which is in a sense unreal) via some sort of hybridisation, to the molecular situation. Whether it is as logical or acceptable to a pupil is doubtful. They had to make a leap from the s, p, d orbital situation to what is, in effect, the hybridised situation of the Gillespie-Nyholm [20] treatment. Although the word hybridisation may not have been used, the pupil still had to reconcile the octahedral p orbitals of carbon and the tetrahedron of 'reality'.

It would seem that the juxtaposition of these two topics in the syllabus was unfortunate and it would have been better to hold over the idea of orbitals until just before the Transition Metal topic where the 'hybridisation' concept would have been unnecessary and where the orientation of d-orbitals would have been seen to have some point in a useful context. Of course, the syllabus is not a teaching order but teachers frequently treat it as such.

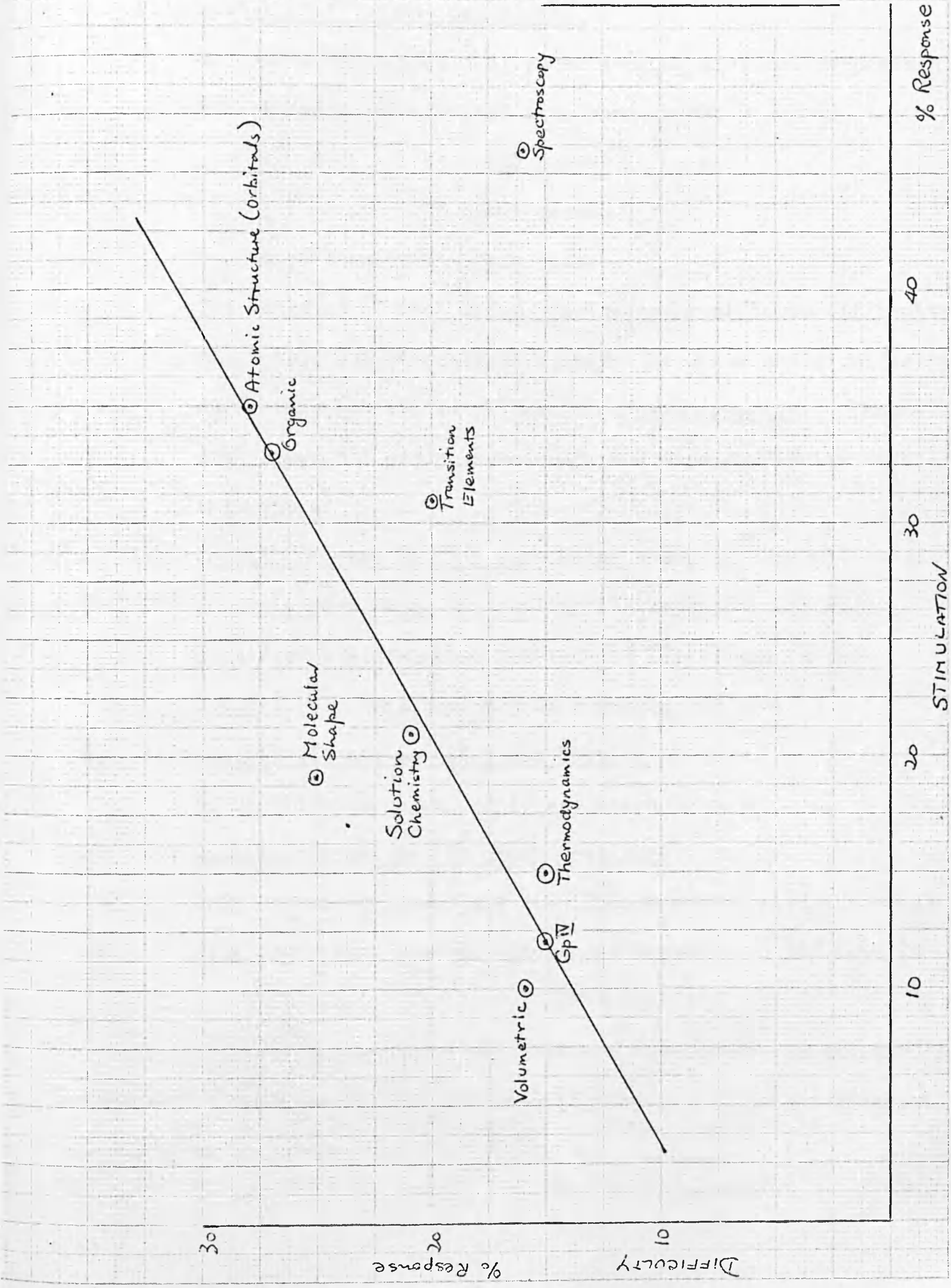
Two other topics appeared, perhaps unexpectedly, in the easy column: thermodynamics and spectroscopy. Both of these have traditionally been absent from Sixth Form courses on the grounds that they were too difficult. Mercifully, elementary thermodynamics has been released from its traditional straitjacket and has cast off the mystic of the Carnot cycle thanks to chemists such as J. A. Campbell [22] and C. Porter [23]. It has at last been seen to be meaningful to the chemist and to have philosophical interest of the kind enjoyed by Sixth Formers in other disciplines. Another possible factor affecting the student acceptance of thermodynamics is discussed on page 4.13.

The /

The treatment of spectroscopy at an empirical level as exem-:plified in "A Worksheet Introduction to Chemical Spectroscopy"[24] has been well received by students who found it not only easy, but very stimulating. The approach was aimed at giving the student evi-:dence for many of the things he had taken on trust earlier in his course, such as bonding and structure. Apart from this one case where ease and stimulation come together there is an interesting link between 'difficult' and 'stimulating' (Graph 3.3). Although the relationship is by no means perfectly linear there is a link between difficulty and stimulation, a characteristic of a good course which stretches and stimulates at the same time.

<u>GRAPH 3.3</u>

GRAPH 3.3 DIFFICULTY v. STIMULATION



RELATIONSHIP BETWEEN THE NUMBER AND QUALITY OF 'H' GRADE PASSES AND AREAS OF TOPIC DIFFICULTY

(i) Number of 'H' grade passes held.

To obtain three groups of roughly equal size for comparison the students were divided into those with:

1 - 4 'H' grade passes

5 'H' grade passes

more than 5 'H' grade passes

The reaction of each group to the areas of topic difficulty was noted, but the only area where there was any significant difference (at 10% level) was the Thermodynamics. Those with fewer 'H' grade passes reported more difficulty with this topic.

(ii) Quality of pass in 'H' grade Maths (i.e. A, B or C)

The only area where the quality of the Maths pass made significant differences (at the 10% level) was in the Volumetric. This was much as expected.

(iii) Quality of pass in 'H' grade Physics

No significant relationship was noted here.

(iv) Quality of pass in 'H' grade Chemistry

Only one topic showed any significant change with 'H' grade pass quality: Molecular Shape (at better than 10% level).

It could only be concluded that neither the number nor quality of previous 'H' grade passes had any important bearing upon the reported reactions to the course topics.

(c) /

(c) Reaction to Course Concepts

TABLE 3.2

(Table shows responses/100 replies - 1970 results are in brackets)

	Easy to Grasp	Difficult to Grasp	Never Grasped	Never Taught
Free Energy change (ΔG)	63 (61)	31 (35)	4 (4)	0
Entropy change (ΔS)	71 (69)	25 (28)	3 (3)	0
The Mole	80 (82)	16 (16)	1 (2)	2
Absorption Spectra	66 (68)	28 (28)	4 (4)	1
Orbitals related to Periodic Table	51 (53)	39 (42)	8 (5)	1
S_N1 and S_N2 Reactions	32 (38)	48 (47)	16 (15)	3
Grignard Reactions	39 (42)	43 (44)	15 (14)	3
pH and Buffers	58 (60)	33 (34)	5 (6)	2
Origin of Colour	50 (59)	32 (32)	5 (9)	11
Orbitals (degenerate and split)	41 (37)	41 (48)	9 (15)	6
Paramagnetism	52 (60)	27 (31)	8 (9)	11

Observations

Considering that these results are a subjective assessment of the concepts by the pupils, the agreement between 1970 and 1971 results is extremely good.

It also gives more weight to the supposition that these results reflect genuine pupil reaction to these concepts.

In this section the word 'concept' has been used loosely to mean sub-areas within the course topics which required new ways of thinking rather /

rather than just extra knowledge in a familiar pattern.

The concepts of Free Energy and Entropy were well received and this was substantiated by good scores in S.Y.S. examinations in both objective and long questions (Appendix p. A3.15-16). This effect was not just a superficial knowledge, but students were able to cope with parts of questions requiring higher abilities in thinking.

The concept of the Mole seemed to be well established, but S.Y.S. questions going beyond an understanding of the Mole into the operations of proportionality were still being badly done. In 1970 only one candidate out of the 250 candidates who attempted a fairly straightforward calculation got it correct (p. A3.17). The other 800 candidates did not even attempt it. Similar, if not quite such disastrous results have appeared in other S.Y.S. papers.

The most troublesome concepts were Organic followed closely by the ideas of Degenerate and Split Orbitals as part of a simple Crystal Field treatment. Investigations carried out by the author and J. McGuire indicated that many teachers did not clearly understand this material themselves and were trying to teach it without models. This prompted the design of the 'd' orbital model described in J. Chem. Educ. [21] by which the concepts of degeneracy and splitting could be readily taught.

McGuire, in a survey of practical work done in schools [25], noted that in the areas where the prescribed practical work was being skimped or omitted, the students fared badly in the same areas in the written examinations, and the same students reported the topic to be difficult in this survey.

RELATIONSHIP /

RELATIONSHIP BETWEEN THE NUMBER AND THE QUALITY OF 'H' GRADE PASSES AND THE AREAS OF CONCEPT DIFFICULTY

(a) Number of 'H' grade passes held.

The groups were decided (as described on p. 3.13) namely those with:

1 - 4 'H' grade passes

5 'H' grade passes

more than 5 'H' grade passes

The reaction of each group to the areas of concept diffi:culty was noted, but there were no significant differences.

(b) Quality of pass in 'H' grade Maths (i.e. A, B or C)

The quality of maths pass made no significant difference to the reaction of candidates to concept difficulties.

(c) Quality of pass in 'H' grade Physics (i.e. A, B or C)

The only notable difference here was that the better the physics pass, the more easy was the Mole concept reported to be.

(d) Quality of pass in 'H' grade Chemistry (i.e. A, B or C)

There was a significant (better than 10% level) direct connection between A, B and C passes in 'H' grade Chemistry and the ease with which the following concepts were grasped:-

The Mole, Orbitals related to the Periodic Table, S_N1 and S_N2 reactions and the reactions of Grignard Reagents.

Considering the traditional connection between Physics and Chemistry, there was little evidence in this survey to suggest that

a /

a good knowledge of Physics gave the students any advantage.

5. PROJECT WORK

The project was built in as a compulsory part of the course with the express purpose of helping pupils to develop in maturity and self-reliance as well as giving them an opportunity for a study in depth of a topic of their own interest.

In the teachers' survey (Chapter 4, p. 4.17) it was noted that the choice of project was substantially but not entirely that of the pupils.

TABLE 3.3

Method of Choice	% of Schools
Entirely by pupils	11
Mainly by pupils	58
Mainly by teacher	30

The projects were not meant to be minor original research topics, but they were to be original to the pupil. Some of them have been really original but these have been the exception. Lists of topics have been produced [26] and many of them have been published, in abstract, in various issues of "Satis" [27]. A card index of all projects is to be established at the National Curriculum Development Centre in Dundee so that teachers can have access to ideas and details of equipment and reagents required. Since S.Y.S. Chemistry began, about 3000 projects have been attempted.

To /

To obtain some information about the pupils' attitudes to projects, they were given a number of statements made by students in previous years and then asked to agree or disagree with them. The 1971 results are given in Table 3.4 with the 1970 results in brackets.

TABLE 3.4

Statements	Agree	Disagree
Waste of time	7 (5)%	93 (95)%
Valuable experience	92 (86)	8 (14)
An easy option to classwork	31 (35)	69 (65)
Made me more independent	82 (85)	18 (15)
Made me use books a lot	54 (45)	46 (55)
Gave me insight into real chemistry	51 (44)	49 (56)
An inefficient way of learning	24 (36)	76 (64)
Enabled me to see other chemists at work	24 (24)	76 (76)
Involved me in too advanced ideas	15 (12)	85 (88)
Got a real kick out of it	44 (39)	56 (61)
Made me frustrated	38 (34)	62 (66)
Left too much on my own without help	11 (9)	89 (91)
Too few marks devoted to it	64 -	36 -
Too little time devoted to it	57 (51)	43 (49)

There was good agreement between the two sets of subjective results which suggested that they were genuine.

The students were generally well disposed to projects despite the fact that most of them had encountered the frustrations common to all real scientific investigation. They were certainly aware of an increase in independence although they knew that help was available if /

if required. When projects were first mooted it was feared that pupils might be overwhelmed with advanced ideas but this fear seemed to be groundless.

There has been excellent co-operation from tertiary centres and from industry in projects. Pupils have been encouraged to visit firms and colleges to get information, to use spectrometers and to consult libraries. Frequently due to geographical difficulties these contacts have had to be restricted to correspondence or to telephone conversations, hence the low agreement with the statement "enabled me to see other chemists at work", but even this was a valuable learning experience.

From the author's observations of 100 S.Y.S. candidates in the High School of Stirling and elsewhere the project work has literally helped to convert schoolboys into students. Hesitant young people starting a project have ended up as confident young men able to argue a good case with adult chemists. This growth in maturity was diffi:cult to quantify, but it was none the less real.

In about 5% of the cases observed the project had an adverse effect. Some students were completely unmoved by the project and seemed to be bereft of any initiative or imagination. The more their neighbours progressed the more withdrawn they became. In each case these were students who further down the school had been dull, colour:less characters who had succeeded in passing 'H' grade chemistry at B grade. This might be taken to indicate a personality effect rather than an intellectual one.

6. CAREER PLANS

The opportunity was taken to enquire into the career plans of students. /

students.

This was done in four stages since it was recognised that many students at age 18 have only vague ideas of their future intentions. The clearly factual information, such as which university had accepted them, was separated from their "hopes and aspirations".

(a) Questionnaire, Question 8.

"What career do you have in mind?"

TABLE 3.5

Medicine, Dentistry, Vet.	18.9%
Education	5.3%
Research	3.3%
Industry	2.8%
Pure Sciences	17.4%
Engineering	12.7%
Pharmacy	2.8%
Biochemistry	3.9%
Don't knows	32.8%

As expected, there was a large proportion of "don't knows". About 60% of the students had chosen careers which would involve them in a further study of chemistry for at least one year. In the 1970 survey there were students intending to read arts, music, law and divinity (about 6%), It was encouraging to find that students were prepared to take the S.Y.S. chemistry course although it was not required for career /

career purposes. This was a continuation of a trend observed in Chapter 1, p. 1.12.

(b) "For what form of further education have you applied?"

TABLE 3.6

University	96.1%
College of Education	0.6%
College of Technology	0.8%
Industrial Training	0.1%
Others	2.3%

(c) "To which university have you applied?"

The opportunity was taken to relate the qualifications of students to the university of their choice. The results appear in Table 3.7.

TABLE 3.7

/

Table 3.7. UNIVERSITIES CHOSEN BY S.Y.S. STUDENTS

No. of 'H' passes	Glasgow	Edinburgh.	Stirling	Dundee	Heriot-Watt	S/clyde	St. Andrews	Aberdeen	Other Univ.	None	Total Students
1	-	-	1	-	-	-	-	-	1	-	2
2	2 1	2 1	-	-	3 6	5 4	-	2 2	1	2	17
3	5 2	4 2	1	4	8 17	18 15	1 2	9 8	2	3	55
4	37 17	31 15	2	6	15 32	29 24	7 13	21 18	4	4	156
5	100 47	96 45	3	9	16 34	49 41	31 56	50 43	9	3	366
6	61 29	71 33	-	3	5 11	16 13	12 22	30 26	5	5	208
7	9 4	8 4	-	1	-	2 2	4 7	4 3	-	-	28
8	-	1	-	-	-	-	-	-	-	-	1
Totals	214 (25•7)	213 (25•5)	7 (0•8)	23 (2•8)	47 (5•6)	119 (14•3)	55 (6•6)	116 (13•9)	22 (2•6)	17 (2•0)	833

In the row of totals the numbers in brackets were the percentage of all S.Y.S. students who had applied to each university. The left column under each university was the absolute number who had applied while the right column was the percentage of that university's "intake" having that number of 'H' grade passes.

The distribution of student qualifications was about the same in all four ancient universities (Glasgow, Edinburgh, St. Andrews and Aberdeen) with 70% of the students having at least 5 'H' grade passes.

The 'younger' universities had a slightly poorer intake.

Few students planned to 'emigrate' to other universities outside Scotland.

(d) "What form of acceptance have you had from your further education centre?"

T A B L E 3.8

Firm	78.5%
Provisional	18.0% (2% S.Y.S.)
None as yet	1.0%
Not applied	2.5%

This served to confirm the idea that most of the students were studying S.Y.S. chemistry for its own sake and not for any advantage it might give for university entrance.

SUMMARY /

SUMMARY

From the pupil's point of view the S.Y.S. chemistry course seems to be fairly satisfactory. It is providing them with challenging and stimulating material within a framework where there is freedom to explore, to question and to accept responsibility.

The course topics and concepts are not the only ones, nor are they necessarily the best ones to achieve the aims of the course. Further work will be needed in this area to decide if any of the topics need to be replaced.

The project work is an invaluable part of the course in providing a means of achieving the aims set out for all S.Y.S. work.

There are problems in the course, particularly those of assessment. These will be dealt with in the next chapter.

APPENDIX TO CHAPTER 3

SCOTTISH CERTIFICATE OF EDUCATION EXAMINATION BOARD

NEW SCOTTISH EXAMINATION

Certificate of Sixth Year Studies

The Secretary of State for Scotland, Mr. William Ross, M.P. has accepted the advice of the Scottish Certificate of Education Examina-:tion Board that an examination designed for sixth year pupils of Scottish secondary schools should be introduced. The examination is intended for pupils of a fairly wide range of ability and will cater for more practical and aesthetic as well as for more academic interests. Pupils who have pursued a sixth year of studies and taken the examina-:tion, which will begin in a limited range of subjects in 1968, will be awarded a "Certificate of Sixth Year Studies", indicating the stan-:dard reached in each subject.

The aim of this new examination is to give direction and purpose to sixth year work by encouraging pupils who have completed their main subjects at the Higher grade to engage in independent study in depth of a particular subject. The examination will not be marked on a Pass/Fail basis, but instead "Ranks" of attainment will be awarded, each covering a range of marks. The expectation is that candidates will not be presented for the examination in more than two or three subjects, and there should be no reason why a pupil should not enter in only one subject. As its title suggests the examination will be open only to pupils who are pursuing a course of sixth year studies in a secondary school.

For the first year the examination will be held in six subjects - Art, Commerce, English, French, Geography, Physics. Syllabuses and specimen papers in these subjects will be issued shortly. In succeeding years the range of subjects will be widened, according to the emerging needs of the schools.

The Secretary of State has asked the Board to make it clear that the new Certificate is intended, both by its character and by the con-:ditions of its award, to supplement, not to replace, the existing Certificates. In particular the additional examination involved is in no way an alternative to the Higher grade examination: nor has the new Certificate been introduced with the intention that it should come to be regarded either by the Universities or by the professions as a formal requirement for entrance.

August, 1966.

OBJECTIVES IN CHEMISTRY FOR 'O' AND 'H' GRADES AND C.S.Y.S.

A. Pupils should acquire -

1. (a) Knowledge of various symbols used by chemists. (O)

   (b) Comprehension of the use of symbols by chemists in formulae and equations. (O)

   (c) Ability to apply knowledge and comprehension of chemical symbols in the writing of formulae and equations. (O)

2. (a) Knowledge of quantitative relationships in chemistry. (O)

   (b) Facility in using a variety of standard methods in chemical arithmetic. (O)

   (c) Ability to carry out relevant calculations concerning a variety of concepts. (O)

3. (a) Knowledge of systematic nomenclature applied to some chemical species. (O)

   (b) Comprehension of the principles underlying systematic nomen-:clature as applied to chemical species. (O)

   (c) Ability to apply systematic chemical nomenclature to the naming of various species both known and unknown. (H)

4. (a) Knowledge of fundamental concepts contained in the syllabus. (O)

   (b) Comprehension of the fundamental concepts contained in the syllabus. (O)

   (c) Ability to apply fundamental concepts contained in the syllabus. (O)

5. (a) Knowledge of the chemistry of certain elements and their simple compounds. (O)

   (b) Comprehension of the principles underlying the chemistry of certain elements and their compounds. (O)

   (c) Ability to apply knowledge and comprehension of the chemistry of the elements and their compounds in a range of situations. (H)

6. (a) Knowledge of a variety of methods of effecting chemical change. (O)

   (b) Ability to apply methods of effecting chemical changes in new situations. (O)

7. /

7. (a) Knowledge of the chemistry of some industrial processes. (O)

   (b) Comprehension of the chemistry of some industrial pro-:cesses. (O)

   (c) Ability to apply the knowledge and understanding of the chemistry of various industrial processes in new situations. (H)

8. (a) Knowledge of the effects of chemicals on everyday life. (O)

   (b) Comprehension of the effects of chemicals on everyday life. (O)

   (c) Ability to apply the knowledge and comprehension of the effects of chemicals on everyday life to new situations.(O)

9. (a) Knowledge of the chemist's ability to produce new compounds.

   (b) Comprehension of the relationship between structure and properties of various chemical substances. (O)

10. (a) Knowledge that appropriate information can be obtained from a range of sources. (O)

   (b) Ability to find various types of information from a range of sources. (O)

11. (a) Knowledge of chemical classifications. (O)

   (b) Comprehension of chemical classification. (O)

   (c) Ability to classify chemical information in various ways. (O)

12. (a) Knowledge of methods of classifying chemical information. (H)

   (b) Comprehension of methods of classifying chemical informa-:tion. (H)

13. (a) Knowledge of limitations of precision involved in physical measurement. (O)

   (b) Comprehension of reasons for limitation of precision. (O)

   (c) Ability to apply a knowledge of the limitations on accuracy created in physical measurement where a range of precision levels apply. (H)

14. (a) Knowledge of laboratory equipment and techniques sufficient to enable the experimental procedures to be carried out adequately. (O)

   (b) Comprehension of laboratory techniques sufficient to enable experimental procedures to be carried out adequately. (O)

   (c) /

(c) Ability to select relevant techniques to enable experimental procedures to be carried out. (O)

15. (a) Knowledge of appropriate safety regulations to be observed in the laboratory. (O)

(b) Comprehension of the reasons underlying safety regulations in the laboratory. (O)

16. Ability to comprehend written and oral instructions. (O)

17. Ability to record and present information in various ways including graphical and diagrammatic representation as well as written statements. (O)

18. Ability to follow arguments about chemical ideas. (O)

19. Ability to criticise arguments about chemical ideas. (H)

20. Ability to consider experimental evidence in terms of two and three dimensional physical models. (O)

21. Ability to use experimental evidence to formulate hypotheses and conceptual models. (O)

22. Ability to design experiments to check predictions and hypotheses deduced from available information. (O)

23. Ability to deal with multi-variable situations. (O)

24. Ability to adopt a scientific approach in other fields of experience. (O)

B. Pupils should acquire in attitudes.

1. Awareness that chemistry can form the basis for many satisfy:ing careers. (O)

2. Awareness of the contribution of chemistry to the full devel:opment of the individual. (O)

3. Awareness of the contribution of chemistry to the economic and social welfare of the community. (O)

4. Awareness that a number of variables can influence an experi:mental situation. (O)

5. Awareness of the limitations inherent in analogies as 'Models'. (H)

6. Interest and enjoyment in chemistry. (O)

7. Acceptance of the chemist's ability to produce new compounds. (O)

8. /

8. Acceptance of the importance of observation in an experi-:mental procedure. (O)

9. Acceptance of the value of an experimental approach to problems. (O)

10. Acceptance of the desirability of working and discussing in groups in appropriate situations. (O)

11. Acceptance of responsibility for carrying out suitable safety procedures. (O)

12. Commitment to optimum precision of measurement. (O)

13. Commitment to optimum precision of statement. (O)

14. Commitment to cleanliness and neatness in experimentation. (O)

15. Commitment to the systematic recording of experimental results and other data. (O)

16. Commitment to objectivity in observation and assessment wherever possible. (O)

17. Commitment to arriving at conclusions from the information, knowledge and understanding available. (O)

18. Commitment to apply a scientific approach in other fields of experience. (O)

C. Pupils should acquire in practical skills.

1. Skill in using various pieces of equipment effectively and safely. (O)

2. Skill in drawing diagrams and visual representations of quantitative data. (O)

3. Skill in assembling relevant pieces of equipment into experi-:mental rigs.

4. Skill in using various measuring devices to the appropriate degree of precision. (O)

5. Skill in working at adequate speed and with reasonable neat-:ness and safety. (O)

6. Skill in handling materials with due attention to safety and economy. (O)

For /

For CSYS, in addition to the above, pupils should also acquire -

A - in knowledge and understanding.

1. Ability to develop a sustained approach to a particular problem.

2. Ability to verbalise conceptual problems concisely (to define a problem in words).

3. Ability to defend orally and in writing a given course of action and the conclusions arrived at.

4. Ability to work without detailed supervision.

5. Ability to suggest future work arising from a project.

B - in attitudes.

1. Acquisition of increasing self-confidence leading to a willingness to take decisions.

2. Realisation that many decisions are at best a compromise solution of conflicting interests.

3. Realisation that many decisions are necessarily taken on incomplete evidence.

4. Willingness to seek information and assistance from all appropriate sources.

<u>Project Work</u>

Many of the above objectives are achieved through project work. They have been rated on a 2-point scale as follows.

<u>Rating A</u> - essential to all practical projects but could also arise elsewhere in SYS work.

<u>Rating B</u> - desirable in all practical projects but not essential.

	Objective	Rating
A.	4(c)	B
	5(c)	A
	6(b)	B
	10(a)	A
	10(b)	A
	11(c)	B
	12(a)	B
	12(b)	B
	13(a)	B
	13(b)	B
	13(c)	B
	14(a)	A
	14(b)	A
	14(c)	A
	15(a)	A
	15(b)	A
	17	A
	18	A
	19	B
	20	B
	22	B
	23	A
	24	B

	Objective	Rating
B.	1	B
	4	A
	6	A
	8	A
	9	A
	11	A
	12	A
	13	A
	14	A
	16	A
	17	A
C.	1	A
	2	A
	3	A
	4	A
	5	A
	6	A
SYS A	1	A
	2	A
	3	A
	4	A
B	1	A
	3	B
	4	A

UNIVERSITY OF GLASGOW - CHEMISTRY DEPARTMENT

April, 1971

Sixth Year Studies in Chemistry - Questionnaire

You have just completed the S.Y.S. Chemistry Course and we are anxious to learn your views on it. We should be grateful if you would fill in this Questionnaire independently and frankly so that we can see where the strengths and weaknesses of the course lie. Your reply will form part of the basis of any future revision of the course.

Please tick the appropriate box(es) throughout or insert the required number.

1. Boy ☐

   Girl ☐

2. Higher passes.

   (a) How many Higher passes do you hold at present?

   (b) What grades did you obtain in the following Highers?

	A	B	C	Fail
Maths				
Chemistry				
Physics				
Biology				
Higher Science (Bot./Zoo)				
Any other Science Higher (specify)				

   (c) While you are in Sixth Form what other S.C.E. subject are you studying?

   S.Y.S. ....

   Higher Grade ....

   'O' Grade ....

3. /

3. Why did you decide to do S.Y.S. Chemistry? (Tick more than one box if required.)

Good 'H' Chemistry result ☐

Poor 'H' Chemistry result ☐

To improve your chances of getting into university ☐

To fill in a Sixth Year timetable ☐

Because the subject is interesting ☐

Because of teacher persuasion ☐

To fulfil obligations of a conditional acceptance of a university place. ☐

4. What has been your reaction to S.Y.S. Chemistry as a whole? (Tick more than one box if required)

Easy ☐

Reasonable ☐

Difficult ☐

Stimulating ☐

Boring ☐

Too factual ☐

Not concerned enough with social aspects of chemistry ☐

Well balanced ☐

5. Against each of the topics from the S.Y.S. Syllabus listed below, place a tick in one of the boxes a, b, c, and another in one of the boxes d, e, f.

/

	a	b	c	d	e	f
	Easy	Moder-:ate	Diffi-:cult	Bor-:ing	Neither boring nor Stim-:ulating	Stimul-:ing
Thermodynamics						
Volumetric work (including redox)						
Spectroscopy						
Atomic Structure (orbitals)						
Molecular Shape						
Organic						
Rest of Group IV						
Solution Chemistry (pH, acid strengths, etc.)						
Transition Elements						

6. Among the topics mentioned above, there are a number of concepts listed below. Tick your opinion of them.

	Easy to grasp	Difficult to grasp	Never Grasped	Never Taught
Free energy change (ΔG)				
Entropy change (ΔS)				
The Mole				
Absorption Spectra				
Orbitals related to Periodic Table				
S_N1 and S_N2 Reactions				
Grignard Reactions				
pH and Buffers				
Origin of Colour				
Orbitals (degenerate and split)				
Paramagnetism				

7. Your project will have taken about one quarter of your total chemistry time. What are your views on projects? (Tick more than one if required.) These are some comments offered by Sixth formers in previous years. Do you agree or disagree?

	Agree	Disagree
A waste of time		
Valuable experience		
An easy option to classwork		
Made me more independent		
Made me use books a lot		
Gave me an insight into real chemistry		
Too little time devoted to it		
An inefficient way of learning		
Enabled me to see other chemists at work		
Involved me in too advanced ideas		
Got a real kick out of it		
Made me frustrated		
Left too much on my own without help		
Too few marks devoted to it		

8. Further education and future career.

(a) What career do you have in mind? ....

(b) For what form of further education have you applied?

University ☐

College of Education ☐

College of Technology ☐

Industrial Training ☐

Any other (specify) ....

Qualification hoped for ....

(c) /

(c) Please give name of -

University ....

Faculty ....

Proposed First year
subjects (if known) ....

....

(d) What form of acceptance have you had from your further education centre?

Firm ☐

Provisional ☐

None as yet ☐

Thank you for your co-operation in answering this Questionnaire. Since no question has asked for your name or school, all the information you have given is absolubtly confidential.

SCOTTISH CERTIFICATE OF EDUCATION EXAMINATION BOARD

Certificate of Sixth Year Studies Examination in Chemistry, 1970

Notes for Guidance in Project Assessment

1. General

The assessment of projects will be based on

(1) Examination of the candidate's written report, oral examina-:tion of the candidate and inspection of the candidate's laboratory notebook - in each case by an External Assessor.

(2) The class teacher's assessment based on day to day discuss-:ions with the pupil, knowledge of the pupil and considera-:tion of the final report.

The External Assessor is required to consult with the class teacher regarding the allocation of marks and is asked to submit an agreed mark for each candidate to the Board on Form S.Y.3 - Supplement (Chemistry). Where agreement cannot be reached, the matter is to be referred to the Board for decision by the Principal Examiner.

The oral examination of the candidate which will normally take place in the presence of the class teacher, is an important part of the assessment and only in exceptional cases, such as illness, etc. will an estimate mark be accepted. In such cases, documentary evidence in support of the exceptional circumstances would require to be sub-:mitted.

2. Allocation of Marks

The 50 marks to be awarded are divided into three groups, each of which has been sub-divided into blocks carrying a maximum of 5 marks or in one case a maximum of 10 marks. Assessors will enter the award for each group in the appropriate column of the form. Marks awarded under each heading should be whole numbers. No finer divisions should be used.

(a) Project Report (20 marks)

5 Marks for general layout of the report with particular attention paid to diagrams, tabulation of data, etc.

5 marks for the presentation of the report which would include such points as adequate introduction, relevance of material to theme, background information, references, conclusion.

10 marks for the experimental aspects including points such as scientific content, assessment of problems, method of tackling, design of apparatus, technique, original thought, overcoming problems.

(b) /

( ) Oral Examination (20 marks)

5 marks for basic understanding.

5 marks for initiative, resourcefulness, originality, independence.

5 marks for clarity of expression.

5 marks for general estimate of the thesis including points such as an appreciation of errors, future possibility of the work.

(c) Course Work (10 marks)

5 marks for the record of the work based on points such as presentation, completeness of reports, range of work covered.

5 marks for the quality of the work based on experimental results obtained, initiative shown, development of one particular experimental line of enquiry, (which could be a subject of discussion with the candidate), etc.

3. Estimate Marks

In order to provide a working basis for the assessment, the teacher is asked to provide in column (d) of Form S.Y.3 - Supplement (Chemistry) a preliminary estimate given in terms of a five point scale A - E. One copy of the form is to be sent to the Board, and the other copy to the External Assessor along with the project reports, in each case by 1st May, 1970.

The range table for the teachers' preliminary estimate on the five point scale is:-

A	40	-	50
B	30	-	39
C	20	-	29
D	10	-	19
E	0	-	9

Scottish Certificate of Education
Examination Board,
140 Causewayside,
EDINBURGH.
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DECEMBER, 1969

ANALYSIS OF S.Y.S. PAPER I - 1970

Question Number	Mean Score	Range of Av. Scores per school	Topics	Complexity	Popularity
1	10.2	7.0 - 11.9	Thermo-dynamics	Knowledge + Comprehension	High
2	13.3	10.2 - 15.4	Spectra Social Organic	Knowledge + Application	V. High
3	8.9	6.4 - 13.0	Calculation of Composition + osmotic pressure	Application + Analysis	Low
4	10.3	5.5 - 14.8	Thermo-dynamics Organic (Mean 6.8/14)	Comprehension	High
5	12.5	6.0 - 14.1	Group IV elements	Knowledge + Comprehension	Moderate
6	9.6	2.5 - 13.5	Transition Elements	Knowledge + Comprehension + Application	Moderate
7	9.2	6.6 - 12.7	Conductivity + Concentra-:tion Cell	Comprehension	Moderate
8	10.3	4.0 - 12.0	Vth Form electrolysis	Application	Moderate
9	11.6	3.3 - 15.5	Solution Chemistry	Comprehension	Moderate

ANALYSIS OF OBJECTIVE TEST RESULTS (PAPER II)

Topic	1970 Range of F.V. (No. of items)	1969 Range of F.V. (No. of items)
Transition Elements	$\underbrace{0.55 - 0.59}_{0.57(2)}$	Nil
Solution Chemistry	$\underbrace{0.27 - 0.32}_{0.28(2)}$	$\underbrace{0.35 - 0.91}_{0.63(2)}$
Thermodynamics	$\underbrace{0.50 - 0.96}_{0.67(6)}$	$\underbrace{0.59 - 0.64}_{0.62(2)}$
Organic	$\underbrace{0.42 - 0.78}_{0.56(8)}$	$\underbrace{0.23 - 0.97}_{0.67(11)}$
E^{o}	$\underbrace{0.29 - 0.48}_{0.39(2)}$	$\underbrace{0.58 - 0.68}_{0.64(3)}$
Mole	$\underbrace{0.55 - 0.84}_{0.69(2)}$	$\underbrace{0.43 - 0.86}_{0.62(5)}$

Quote from Question 3 from S.C.E. Examination Board S.Y.S. Examination - 1970

In a given copper (II) salt, the copper ion is complexed with ammonia. From the experimental results given below, calculate how many ammonia molecules are associated with each copper ion.

A 1 g sample of the salt was dissolved in 50 ml M HCl and made up to 100 ml with water and mixed. The solution was treated as follows.

(i) 50 ml of it were titrated with M NaOH and 16.2 ml of the alkali were required for neutralisation.

(ii) Another 50 ml of the solution were titrated with a reagent called E.D.T.A. 1 mole of which is equivalent to 1 mole of copper (II) ion. The volume of M/10 E.D.T.A. required was 21.7 ml.

(7) marks

CHAPTER 4

CHAPTER 4

TEACHERS' VIEW OF SIXTH YEAR STUDIES

In parallel with the pupils' survey described in the previous chapter, a survey (Appendix p. A4.1) was made of teachers of Sixth Year Studies Chemistry in April, 1971. This was begun a year later than the pupils' survey to give the bulk of the teachers at least two years experience of teaching the syllabus.

Replies were received from 189 teachers (88% response) of whom 95% were men.

The aims of the survey were -

(a) To provide teachers with a national picture of the findings of their colleagues engaged in teaching S.Y.S. Chemistry.

(b) To allow teachers to see how they fitted into this picture and, if need be, to make adjustments in method and timing.

(c) To provide information about books in use (Appendix p. A4.11).

(d) To provide information of use to those who were planning syllabus modifications.

(e) To allow comparisons to be made between pupil reaction and teacher reaction.

1. HOW EXPERIENCED WERE THE TEACHERS?

(i) Years of teaching service (Appendix p. A4.13).

TABLE 4.1

Up to 10 years	48%
More than 10 but fewer than 20 years	30%
20 years or over	22%

(ii) /

(ii) Years teaching S.Y.S. Chemistry

TABLE 4.2

First year	27%
Two or more years	73%

DISCUSSION

It was interesting to note how much of this senior work was being taught by fairly young teachers with fewer than ten years experience. This was probably a good sign in that the up-to-date knowledge and enthusiasm of the young men was being employed. This was a change in the system of ten years ago in which a young teacher was seldom allowed to teach a senior form for the first two or three years of his career and the sixth form was the preserve of the head of department.

The fact that three-quarters of the teachers had taught the S.Y.S. course at least twice through indicated that a balanced rather than an emotional view of the course could be expected from the survey.

2. SCHOOL ORGANISATION

When the S.Y.S. course was being prepared for the Examination Board, the writers worked within some guidelines of time (Appendix p. A4.10). These were -

(i) The course would occupy about seven months

(ii) Schools would allocate about eight forty-minute periods per week

(iii) The time division between theory and set practical would be /

be 3 : 5.

(iv) The project would take about one-quarter of the total teaching time, i.e. just less than two months.

The survey set out to find how well the time allocation was operating. For this section only one teacher per school was asked to reply.

(a) The <u>best</u> sixth year pupils studied and sat:-

<u>T A B L E 4.3</u>

Sixth Form Course	% of Schools
University Bursary Competitions only	3
S.Y.S. only	71
Both of the above	26
G.C.E.	0

(b) The time allocation for S.Y.S. (in periods per week) was as follows:-

<u>T A B L E 4.4</u>

/

TABLE 4.4

Periods	% of Schools	
3	0.8	
4	2.3	
5	6.8	
6	15.2	
7	8.3	
8	43.2	
9	9.8	i.e. 66.8% of the 132 schools which replied
10	11.4	
11	0.8	
12	0.8	
15	0.8	

In about 30% of schools, their period allocation contained at least one block of three periods (2 hours) which allowed lengthier pieces of practical work to be tackled.

In only 15% of the schools some of the S.Y.S. time allocation was shared with fifth form pupils and in only one school was the whole of S.Y.S. time shared with fifth form.

Before the days of S.Y.S, it was common for sixth formers to spend all of their time with fifth formers either repeating the Higher course in an effort to improve the quality of the Higher pass or in doing sixth form work largely from text-books and with little teacher supervision. One of the aims of S.Y.S. was to provide a separate and advanced sixth year at school and from this survey it seemed that this was being achieved and that the pupils were in con-:tact with a teacher almost all the time.

(c) /

(c) Division of time between practical and theory.

TABLE 4.5

	Practical	Theory
On 6 periods per week the commonest division was	3	3
" 7 " " " " " " "	$3\frac{1}{2}$	$3\frac{1}{2}$
" 8 " " " " " " "	4	4
" 9 " " " " " " "	4	5
" 10 " " " " " " "	6	4

The more experienced the teachers were in presenting S.Y.S, the fewer theory periods were required and the bulk of them settled for 3 theory periods.

(d) Adequacy of time allocation

7 periods or fewer were generally reported as "too little"

8 periods were equally reported as "adequate" and "too little"

9 periods and over were generally reported as "adequate".

(e) Laboratory facilities

Only 14% of schools had a sixth form laboratory. However, when teachers were asked about the adequacy of their accommodation the result was as follows:

TABLE 4.6

	% of schools
Generous	5
Adequate	30
Barely adequate	40
Totally inadequate	25

DISCUSSION

The tendency shown in Table 4.3, p. 4.3, for the best pupils to study S.Y.S. only or in conjunction with a bursary course was a welcome change. When S.Y.S. was first introduced it was treated with some suspicion and headmasters tended to steer their best sixth formers into courses leading to university bursary competitions, not so much for the monetary reward (in some cases non-existent) as for the kudos.

The changeover has been expedited by the willingness of some, but not all universities to base their bursary examinations on the S.Y.S. course. So far the universities of Glasgow and St. Andrews have agreed to this. A second factor was that some English universities (notably those associated with J.M.B.) were prepared to accept S.Y.S. in place of 'A' levels for entrance.

The course planners had budgeted for 8 periods per week and so far 66.8% of the schools had managed to give this time allocation or more and as experience of teaching the course increased teachers were able to meet the planners balance of 3 periods of theory to 5 periods of practical.

It was not the policy of the Examinations Board to dictate to schools on time allocation or division and so these times were never stated publicly by the Board although there were unofficial leaks of information. Therefore it was gratifying to see the plans working out in practice.

The lack of a laboratory set aside specifically for S.Y.S. work seemed to have been less troublesome than expected. On purely economic grounds there was probably little justification for such laboratories which might stand empty for as much as two-thirds of the week /

week and the policy of the Scottish Education Department has been to discourage the building of such laboratories.[29] This has meant certain drawbacks for project work, but these have clearly not been insuperable.

3. TEACHING METHOD

It was decided to find out if teachers were using the S.Y.S. course to help pupils to make the transition between school teaching methods and university methods.

The fact that this was being done is shown in the results of (a) and (b) below.

(a) The theory part of the course was taught as follows:

TABLE 4.7

	% of schools
Lecture	51
Normal school lesson	29
Blend of both of these	10
Others (i.e. seminars, tutorials, etc.)	10

(b) Notes were given as follows:

TABLE 4.8

	% of schools
Notes taken by students during lesson	30
Printed handouts	16
Some of each of the above	54

(c) /

(c) Course practical (as distinct from Project work)

In the S.Y.S. syllabus [4] about fifty experiments were recommended, but these were not obligatory since it was not the Board's policy to dictate on teaching method. However, at the oral examination the student had to submit his laboratory notebook for inspection. The examiner was instructed to mark the book for "presentation, complete:ness of reports, range of work covered and its quality" (Appendix p. A3.14). By this indirect means the Board was encouraging schools to do as complete a practical course as possible.

The average number of experiments performed by each pupil during the session was:-

TABLE 4.9

No. of experiments	% of schools	
1 - 5	1.7	
6 - 10	10.2	
11 - 15	17.8	= 65.3%
16 - 20	22.9	
21 - 25	12.7	
26 - 30	17.8	
31 - 35	8.5	
36 - 40	6.8	
41 - 45	-	
46 - 50	1.7	

From the Board's point of view these results were disappointing since /

since two-thirds of schools were doing less than half of the recom-:mended practical work.

In conjunction with J. McGuire the author looked for any connec-:tion between the experiments which were done least and the parts of the S.Y.S. examination which were badly done. A close connection existed as shown in a preliminary paper. [25]

Some of the suggested experiments turned out to be unsatisfactory, but the bulk of them were quite adequate. A close examination of this practical work and its educational value is the subject of con-:tinuing research by J. McGuire and the author.

If the Board decides in future to place more emphasis on practical work, new thought will be required on the best method of persuading teachers to take the same view.

A question about the methods by which practical work was being organised yielded the following information.

T A B L E 4.10

Method	% of schools
Closely integrated with theory	72.2
Pupils work through in any order	23.8
Other methods (including demonstration and stations technique)	4.0

4. SYLLABUS CONTENT (Questions answered by all the teachers)

The purpose of this section was threefold -

(i) to ascertain the teachers' reaction to various parts of the syllabus to see if any of them were unteachable:

(ii) /

(ii) to compare the teachers' difficulty in presenting the material with the students' difficulty in grasping it, and,

(iii) to discover how much work teachers had to do to feel competent to teach the material.

For this last part a scale was used.

Very much work	4
Much work	3
Not much work	2
Very little work	1
No work	0

In Table 4.11, the teachers' reaction to syllabus topics appears.

TABLE 4.11

Topic	Easy to teach	Av. to teach	Diff. to teach	Work required
Thermodynamics	10	47	43	4.0
Volumetric work (including redox)	50	44	5	1.5
Spectroscopy	27	58	15	3.0
Atomic Structure (orbitals)	30	46	24	2.2
Molecular Shape	46	47	7	2.0
Organic	24	58	18	2.9
Rest of Group IV (Si, Ge, Sn, Pb)	20	60	20	2.5
Solution Chemistry	25	63	12	2.0
Transition Elements	22	52	26	3.0

Results /

Results are expressed as a percentage of the responses.

DISCUSSION

Two interesting observations emerge from this Table.

(i) The fairly close agreement between the "work required" column and the "difficult to teach" column

(ii) the strong disagreement between the "easy to teach" column and the "easy to grasp" column in Table 3.1, p. 3.8.

(i) When the "Difficult to teach" column and the "Time" column were ranked and compared the following results appeared.

TABLE 4.12

	Rank orders	
	Difficult to teach	Time
Thermodynamics	1	1
Volumetric work	9	9
Spectroscopy	6	2.5
Atomic Structure	3	6
Molecular Shape	8	7.5
Organic	5	4
Group IV (Si-Pb)	4	5
Solution Chemistry	7	7.5
Transition Elements	2	2.5

$\rho = \underline{0.80}$

The /

The largest discrepancy was in the case of Spectroscopy which also appeared in an anomalous position in Graph 3.3.

Thermodynamics was predictably at the top of the list in both cases. Teachers, in common with many other chemists, left university with little confidence in their ability to handle thermodynamics and with little idea of what it had to do with chemistry.

The crystal field part of the Transition Elements was, for the older teachers, quite new material. From analysis of S.Y.S. examina:tion papers it was clear that many teachers still did not understand this material, since every pupil from certain schools produced the same wrong material (Appendix p. A3.15).

Spectroscopy was a new topic in schools but, dealt with in the prescribed empirical fashion, it probably turned out to be less diffi:cult to teach than had been anticipated and tailor-made published material was available.[24]

The mechanistic Organic material cost the teachers a considerable amount of work, particularly in the case of the older men in whose university course this had not been covered.

The material which cost least effort by the teachers was the Volumetric. This was a return to a well-worn part of the Traditional Syllabus with which older teachers were familiar and on which the younger teachers had been reared. This, however, has been shown in the earlier part of this work to be potentially troublesome for students (Chapter 3, p. 3.8).

The correlation between the two columns was so good that it could be argued that a teacher's view of teaching difficulty could be at least as coloured by his own learning effort as by the reaction of his /

his students. An examination of the pupils' "difficult to grasp" results (Table 3.1, p. 3.8) would suggest that the teachers' learning effort is the main factor in his feelings of what was difficult to teach. It was difficult to believe that students reacted to the Volumetric work in such a way as to encourage the teacher in his belief that the work was getting across easily.

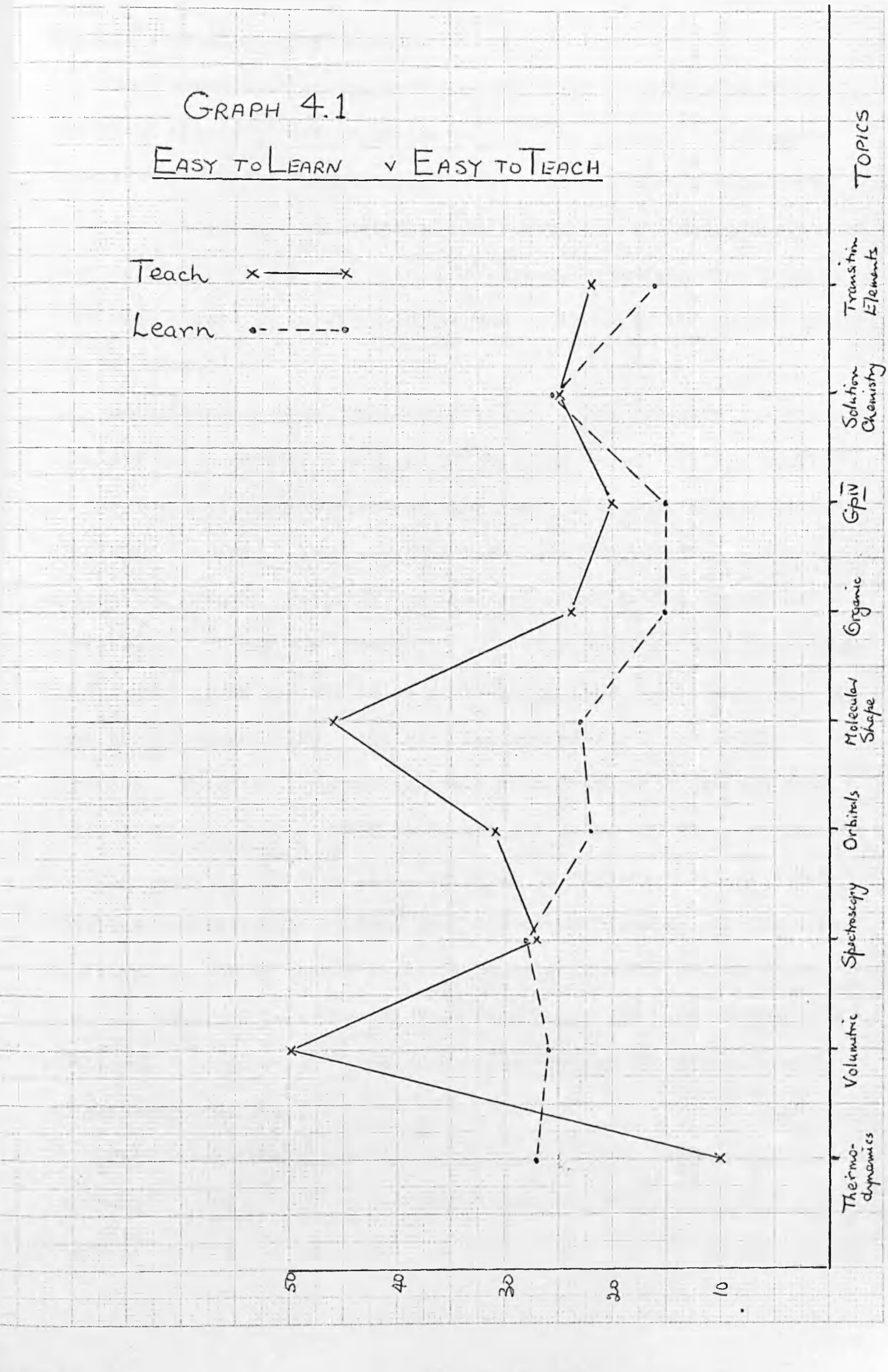
(ii) A comparison between the "Difficult to teach" column and the "Difficult to grasp" column was most remarkable. (Graph 4.1).

The discrepancies were quite large. Although accurate coinci-:dence would not have been expected, these differences shown in the graph are well outside anticipated results.

The pupils found the thermodynamics easier to grasp than the teachers expected and this was borne out in examination performance (Appendix p. A3.15). On the other hand the students had more diffi-:culty with the volumetric work than the teachers thought. The other large disparity was in the Molecular Shape area where the teachers thought that the material was easier than the pupils found it.

Coincidence was good in the areas of Spectroscopy and Solution Chemistry.

What explanation could be advanced to cover these disparities? One possibility was that if a teacher had had to work hard to master a topic, he had had to undergo the same learning process as his students would have to experience soon afterwards. He was aware of the learning problems at first hand and could communicate, perhaps unconsciously, with the pupil in a more sympathetic way. On the other hand it was so long since he had been a learner of some topics (e.g. /


GRAPH 4.1
EASY TO LEARN v EASY TO TEACH
Teach
Learn
TOPICS
Transitn Elements
Solution Chemistry
Gp IV
Organic
Molecular Shape
Orbitals
Spectroscopy
Volumetric
Thermo-dynamics
50
40
30
20
10

(e.g. in Volumetric) that he had ceased to see the topic from a learner's point of view.

Some areas such as Spectroscopy and Solution Chemistry needed a different kind of learning on the part of the teacher. This would have been more of a "brushing-up" process rather than a fundamental learning one because the material had been mastered and understood at some earlier period in the teacher's career. However, the benefit of this work showed up in the relative ease with which the pupils grasped the material.

This led to a very fundamental point. How reliable was the sub:jective assessment of a teacher of what was "good" for his pupils? On the basis of such assessments have been built most of our modern chemistry courses. Keen teachers have been removed from classroom situations (not in Scotland) and have sat round tables producing syllabuses. Their very keenness may have succeeded in blinding them to the real needs and abilities of their pupils. This deception may have been compounded when the material was sent out for trials in schools. Enthused teachers may well have confused their own enthus:iasm with what they assumed to be the enthusiasm of their pupils and in doing so they may have given approval to grossly unsuitable material. Problems really became evident when the normal teacher and the normal pupil in the normal school tried to grapple with the new material, e.g. the Nuffield treatment of Free energy and the Mole concept pre 'O' level. Shayer and Ingle have shown how far off the mark much of this work has been.[10 33]

This thesis has shown that a cross-section of teachers of varying degrees of experience and enthusiasm are not really sure what their pupils /

pupils can take and this uncertainty might very well be more marked in the enthusiastic and academically able teachers.

It would seem to be important that survey material of the kind embodied in this thesis should be carried out to bring some realism into the situation so that the second generation of syllabuses can be brought more into line with pupil abilities and aptitudes. Bloom[30] has to go hand in hand with Piaget [31] if syllabus planning is to be sound and realistic (Chapter 5).

GENERAL COMMENTS ON THE SYLLABUS

Only half of the teachers made any reply here. Of those who made comment only about 13% were wholly in favour of the syllabus in its present form. From the critics there was no unanimity. The organic material came in for the severest criticism, but no clear pattern emerged. Those who said it was "too mechanistic" were almost equally balanced by those who said it was "not mechanistic enough". There was an equal division between "intellectually lightweight" and "too big a gap between 'H' grade and S.Y.S." and a similar response between "more practical needed" and "amount of recommended practical too great".

Syllabus revisers could take little guidance from this and could be forgiven for leaving the syllabus intact.

5. PROJECT WORK (Questions in this section were answered by only one teacher per school.)

The questions in this section were designed to see if the original curriculum design was working out in practice. The rationale for the project part of the course was set out in Chapter 3. /

3. [illegible].17.

(a) The large majority of schools devoted between one-quarter and one-third of their time to projects. The time was allocated as follows:-

In a block	47%
Spread over most of the session	47%
Others	6%

(b) Choice of project

Method	Schools
Entirely by pupils	11%
Mainly by pupils	58%
Mainly by teacher	30%

(c) Liaison with industry for projects

Much	5%
Some	57%
None	37%

Were the industrial contacts cordial?

Yes	93%
Sometimes	6%
No	1%

(d) Liaison with tertiary centres (University, Technical Colleges)

Much	11%
Some	70%
None	19%

(e) Library facilities for project work

Good	17%
Moderate	47%
Poor	37%

DISCUSSION

DISCUSSION

Schools were free to operate the time allocation for projects as they chose and this was equally divided between two methods. The block method meant that students had, on average, eight periods per week for about two months. This allowed pupils to make fairly rapid progress. Psychologically this was sound in that enthusiasm was being maintained by obtaining results quickly. Pupils engaged in their first "research" found it hard to endure a "desert experience" with no results for several weeks. This feeling of frustration was common among students (interviewed by the author) who had done their project work spread out for about one hour per week over two terms. No sooner had they got under way when they had to pack up for another week.

It was interesting to note that the majority of schools had made some contact with industry and with tertiary centres in connection with project work and that the contacts had been cordial. Even schools in remote districts made contact with industry such as distilleries, fish meal factories, river purification boards and laundries.

(f) All teachers were asked for their views on projects as a teaching method. They were asked to agree or disagree with statements similar to those in the student survey (Chapter 3, p.3.18). Responses were expressed as percen-:tages.

T A B L E 4.13

/

TABLE 4.13

Statement	Agree	Disagree	No answer
1. A waste of time	0.5	98.0	1.5
2. Increases pupil independence	95.5	4.0	0.5
3. Makes pupils use books more than usual	89.0	9.0	2.0
4. An inefficient way of learning	21.0	75.0	3.0
5. Involves pupils in too advanced ideas	14.0	79.0	7.0
6. Enables the pupils to mature	87.0	8.0	5.0
7. Gives the pupil an opportunity to see other chemists at work	32.0	58.0	10.0
8. Makes the pupils frustrated	25.0	62.0	13.0
9. Gives the pupil a good pre-university training	81.0	12.0	7.0
10. Gets too few marks for the effort involved	50.0	45.0	5.0

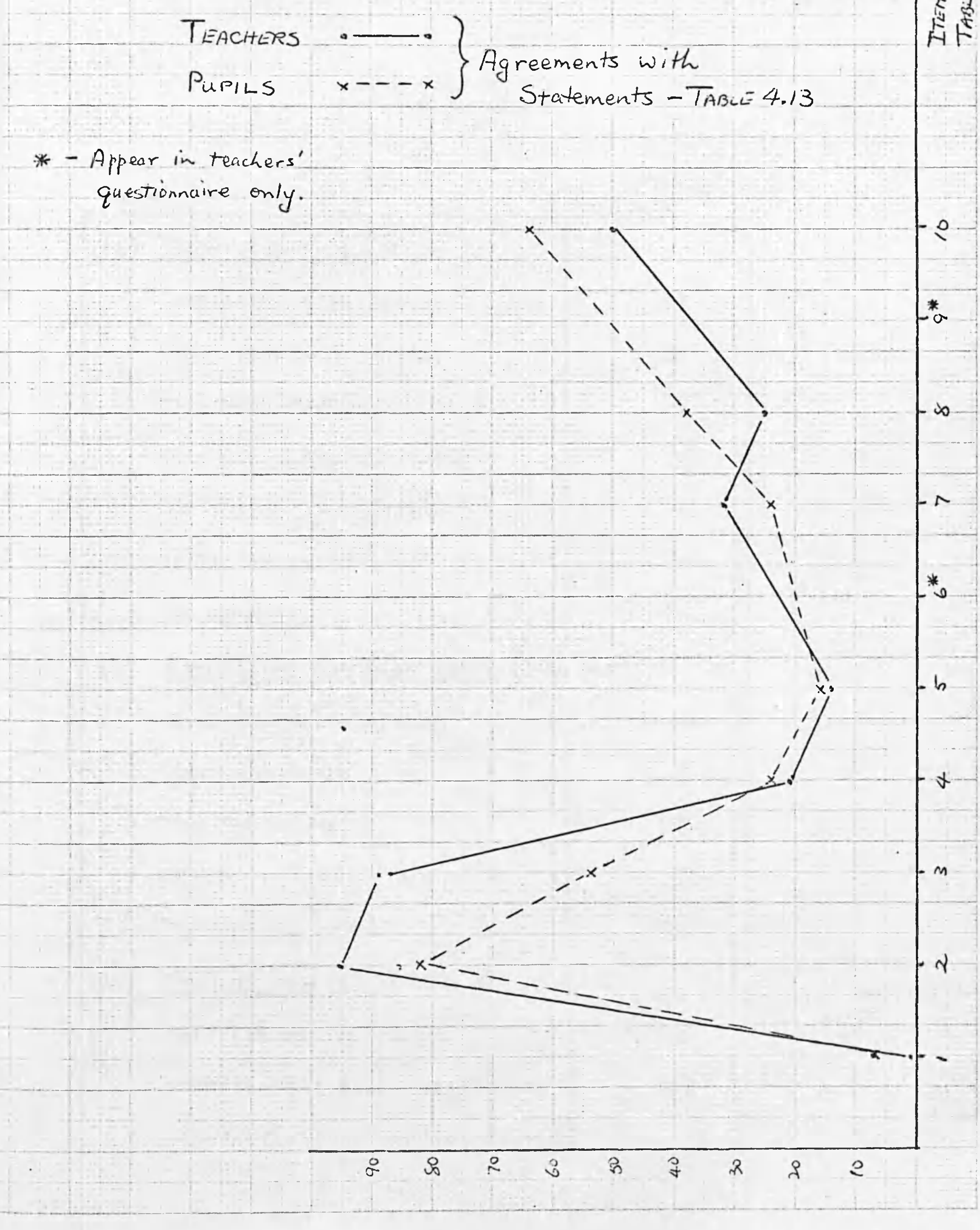
The responses from both pupils and teachers were very similar (Graph 4.2) but there was a large disagreement about the amount of reading done. Teachers seemed to think that there had been a greater increase in the use of books than students would admit. This may have tied in with the fact that library facilities were generally described as "moderate" to "poor" (84% of schools).

The general impression of projects, given by both teachers and pupils, was very favourable except that they felt that the proportion of the total assessment given to projects relative to formal examinations was too low.

The projects, it seemed, had succeeded in achieving the general aim set out in the original Examination Board's Memorandum [16] to give students /

GRAPH 4.2

PROJECTS - PUPILS' AND TEACHERS' VIEWS



students an opportunity to become more mature and independent. Teachers overwhelmingly agreed that the project had increased pupil independence and maturity and had provided a good pre-university training.

5. ASSESSMENT (All teachers were asked to give their views.)

The details of the assessment were given in Chapter 3, p.3.4.

TABLE 4.14

Teachers' views on:-

(a) Objective test (50 marks)	
Entirely satisfactory	40%
Objections to secrecy	10%
Too many marks allocated	5%
Too few marks allocated	3%
No choice - objection	2%
Other objections	2%
No comment	38%
(b) Structured question paper (100 marks)	
Entirely satisfactory	41%
Too many marks	7%
Too few marks	10%
Others	3%
No comment	39%
(c) Project report (20 marks)	
Entirely satisfactory	29%
Insufficient marks for effort	44%
Standardisation and objectivity suspect	13%
No comment	14%

(d) Oral interview (20 marks)	
Entirely satisfied	27%
Fewer marks	15%
More marks	9%
Dubious objectivity	8%
Weighted against nervous pupil	6%
Too much depends upon examiners	3%
Teacher assessment here only	2%
Others	2%
No comment	27%
(e) Class Practical Work (10marks)	
Entirely favourable	16%
Too many marks	7%
Too few marks	10%
Dubious objectivity	6%
Assessment of School and Teacher	10%
Unfair - discontinue	6%
Others	10%
No reply	35%

DISCUSSION

It was probably fair to take "no comment" to mean "no criticism". On this basis, the large majority of teachers offered no criticism of either the Objective Test or the Structured Question Paper. The criticisms which were expressed were usually self-cancelling.

The main objection to the Project Assessment was the light allo-:cation of marks for such a large effort. A feasibility calculation was /

was done to see the effect on the C.Y.S. order of merit, of increasing the allocation of marks for project and practical assessment from one-quarter of the whole to one-third of the whole. This was done for a random sample of 200 candidates in 1971. The Rank Order Correlation (ρ) was 0.98. For political reasons it would seem that the Examination Board should make the gesture of raising the allocation of marks for project work. One of the original reasons for the low allocation of marks was the uncertainty of the reliability of the project assessment. So far the assessment system has worked well in that only three appeals for arbitration have been made to the Principal Examiner in four years although about 2500 projects have been assessed in that time. This has not, however, removed the misgivings about reliability. By the present method the resident teacher assessed the project and then sent the report to an external examiner who visited the school to interview the candidates. The teacher and the examiner then had to arrive at a common mark.

Some work has been done to extend this procedure to examine consistency of marking. Forty teachers were given duplicated copies of three projects, a copy of the marking grid (Appendix p. A3.13) and asked to mark the projects independently. The results are in Table 4.15.

TABLE 4.15

TABLE 4.15

DISSERTATION SCORES (/20)			
	Project 1	Project 2	Project 3
	18	13	11
	16	11	13
	18	11	11
	16	14	10
	18	12	14
	14	15	10
	16	14	
	18	10	
	18	13	
	14	12	
	18	14	
	15	15	
	16	11	
	16	16	
	17	9	
	16	13	
	17	13	
	17	16	
	16		
	15		
Mean (Grade)	16.5 (A)	12.9 (B)	11.5 (C)
S.D.	1.3	1.9	1.5

The agreement was good for the A project, but not quite so good for the weaker ones. The marking was, however, as good (or as bad) as the spread obtained from teams of markers working on traditional examination questions.

Under the author's supervision, J. Handy has begun to extend this experiment as follows:-

(i) Teams of teachers marked the same projects independently.

(ii) The students who wrote the projects were available for interview and teachers were asked to modify their original mark in the light of the interview. These new marks were recorded.

(iii) The teachers were allowed to consult one other teacher to compare notes before giving a final score.

Examination was made of how these successive processes cause the original mark spread to narrow or widen. The results which were not encouraging, are embodied in a report by J. Handy and the author to the Scottish Education Department.[32] Work has now begun on devising and testing new project assessment schemes.

Class practical work assessment is the least popular, but, in view of the fact that teachers were not encouraging their students to do enough practical work, (p.4.4) some sanction may be thought to be necessary.

The comment that this "assesses the school and teacher" was true of all examinations, but since the teacher was present during this practical assessment he probably felt this more keenly.

The general picture of the Sixth Year Studies course from the teachers' /

teachers' point of view was favourable and served to confirm that the general aims of the course were being achieved. The course content was, in places, not entirely satisfactory but there was no guarantee that other topics would fare any better.

An interesting tailpiece to this became evident at a meeting of headmasters held in the University of Glasgow in December 1971 to dis-:cuss Sixth Year Studies in general.

More than half of the headmasters present stated that they were encouraging suitably qualified sixth formers to study S.Y.S. Chemistry, regardless of their career plans, because of its well balanced structure!

APPENDIX TO CHAPTER 4

UNIVERSITY OF GLASGOW - CHEMISTRY DEPARTMENT

Questionnaire for Teachers of Sixth Year Studies, Chemistry

You have just finished teaching the S.Y.S. Chemistry course and we are anxious to have your views on it. Since nowhere is your name required you can answer quite frankly. Your reply will contribute towards the future revision of the course.

Please tick the appropriate box(es) throughout or insert the required number.

1. Male ☐

   Female ☐

2. Number of years in the profession ☐

   Number of years teaching S.Y.S. ☐

   Of the S.Y.S. syllabus, you have taught - All ....

   Part............

3. School organisation - if more than one teacher in the school is answering this survey, only one should answer Question 3.

   (a) Your best sixth year pupils study and sit -

   Bursary Competition only ....

   S.Y.S. only ....

   Both of the above ....

   G.C.E. ....

   (b) Your time allocation for S.Y.S. is ☐ periods per week.

   These periods are allocated as follows .... (e.g. 2 x 3 periods and two singles)

   ....

   For how many periods are the pupils in contact with a teacher? ....

   For how many periods are S.Y.S. pupils sharing time with Vth year pupils? ....

   How is the time allocated between - practical..........

   - theory ....

In /

In your experience your time allocation is -

adequate ☐

too much ☐

too little ☐

(c) Do you have a sixth year laboratory? - Yes ☐

No ☐

You regard your laboratory accommodation for S.Y.S. as -

generous ☐

adequate ☐

barely adequate ☐

totally inadequate ☐

4. <u>Teaching Method</u> - to be answered by one person per school.

(a) Theory. You teach the theory part of the course by:-

Lecture ☐

Normal lesson ☐

Other method - (please specify) ☐

(b) Notes. Pupils obtain their notes mainly by:-

Notes taken during the lesson ☐

Printed handouts ☐

Some of each of the above ☐

(c) Books and other literature.

The publications mainly used by the pupils are:-

....

....

....

The number of books available in the laboratory for pupils to consult is approximately. -

....

(d) /

(d) Course - Practical. The average number of experiments done by each pupil during the session (excluding projects) is -

Practical work is organised as follows:-

Closely integrated with the theory	
Working through prescribed experiments in any order	
Any other method (please specify)	

....

....

In the Appendix is a list of the prescribed experiments for your comment.

5. <u>Syllabus Content</u>

The main syllabus topics are listed blow. Against each place a tick in the appropriate box to indicate how easy the topic is to teach:-

	Easy	Average	Difficult	
Thermodynamics				
Volumetric work (including redox)				
Spectroscopy				
Atomic Structure (orbitals)				
Molecular Shape				
Organic				
Rest of Group IV				
Solution Chemistry				
Transition Elements				

In the extreme righthand box enter one of the following numbers to indicate how much preparation work you had to do to become expert enough to teach the topic.

Very /

Very much - 4

Much - 3

Not much - 2

Very little - 1

None - 0

If you have any general views on the syllabus content, express them here.

6. Project Work - to be answered by one person per school.

(a) What fraction of your total time for the session is devoted to projects?

How is this time allocated? -

In a block ☐

Spread over most of the session ☐

Any other method (please specify) ☐

....

(b) How are projects chosen?

Entirely by pupils ☐

Mainly by pupils ☐

Mainly by teacher ☐

(c) How much liaison have you had with industry?

Much ☐

Some ☐

None ☐

Has /

Has the industrial liaison been cordial?

Yes

Sometimes

No

If there has been no industrial contact, please state why

....

....

(d) How much contact have you had with tertiary centres?

Much

Some

None

If there has been no tertiary contact, please state why

....

....

(e) How good are your library facilities for project work?

Good

Moderate

Poor

(f) <u>To be answered by all teachers.</u>

What are your views on projects as a method of training young people in chemistry? Indicate whether you agree or disagree with the following statements about projects.

/

	Agree	Disagree
A waste of time		
Increases pupil independence		
Makes the pupils use books more than usual		
An inefficient way of learning		
Involves the pupils in too advanced ideas		
Enables the pupil to mature		
Gives the pupil an opportunity to see other chemists at work		
Makes the pupils frustrated		
Gives the pupil a good pre-university training		
Gets too few marks for the effort involved		

If you have any other observations on projects, please give them here.

7. Assessment

The assessment is divided into five categories:-

(a) Objective test giving syllabus coverage and careful examination of educational abilities. (50 marks)

(b) Structured questions giving more room for extended thought. (100 marks)

(c) Project report - extended argument in cursive English. (20 marks)

(d) Oral interview giving the pupil opportunity to defend his views face to face with a stranger. (20 marks)

(e) A check of course work for completeness and method of working. (10 marks)

Please /

Please give your comments on each of these types of assessment considering desirability, objectivity of marking, weighting of marks, and any other relevant material.

Thank you for your co-operation in providing this information. A copy of the findings will be sent to your school in due course.

By means of a tick, indicate:

(a) which of the following experiments you have used this year, and,
(b) which of the experiments you have tried in previous years but have not repeated this year.

		(a)	(b)
1.	Heats of combustion of a series of alcohols		
2.	Hess's Law $NaOH/HCl$		
3.	Hess's Law Zn/Cu^{2+}		
4.	E.m.f. of a chemical cell Zn/Ag^{+}		
5.	Comparison between ΔG and ΔH Zn/Ag^{+} reaction		
6.	$CoCl_2$ hydrate/$SOCl_2$		
7.	Thermal decomposition of $NaHCO_3$		
8.	Equilibrium constant Fe^{3+}/NCS^{-} system (colorimetric)		
9.	Equilibrium constant. - Hydrolysis of an ester		
10.	Iodine coulometer		
11.	Estimation of Cl^{-} as $AgCl$		
12.	Methane and Chlorine under influence of light		
13.	Bromination of heptane in light		
14.	Alkene + Br_2 + Cl^{-}		
15.	Hydrolysis of t-butyl bromide		
16.	Relative ease of displacement of halogen in RCl, RBr and RI		
17.	Phenyl magnesium bromide and preparation of benzoic acid		
18.	Phenyl magnesium bromide and preparation of tri-phenyl methanol		
19.	Preparation of SnI_4		
20.	Preparation of $SnCl_2$		
21.	Preparation of $PbCl_2$		

22. /

22. Reactions of Sn^{2+} with MnO_4^- and Fe^{3+}

23. Successive dilution of M/10 acids and bases

24. Conductivities of acid solutions

25. pH of acid solutions

26. K_a from pH of known concentrations of acids

27. pH of salt solutions

28. pH changes during acid/base titrations

29. Changes in pH of buffer solutions with added base/acid

30. Changes in conductivity of buffer solutions with added base/acid

31. Reduction of vanadium compounds

32. Oxidation states of Mn

33. Preparation of $FeCl_2$, $FeCl_3$

34. Preparation of Tutton salts

35. Analysis of $Ni(NH_3)_6(BF_4)_2$

36. Conversion of $Ni(NH_3)_6(BF_4)_2$ to NiF_2

37. Preparation of $Ni(NH_3)_6(BF_4)_2$

38. Effect of ligands on colour of complexes

39. Use of Gouy balance with paramagnetic substances

40. Magnetic properties of ferrous ammonium sulphate and potassium ferrocyanide

TIME ALLOCATION SUGGESTED FOR EACH TOPIC

THEORY AND PRACTICAL

Sections	Time (hrs)
1 and 3	16
2	18
4	8
5	6
6	20
7	12
8	5
9	15
Total	100

The overall division was recommended as -

Theory 37% Practical 63%

Booklist

These are arranged in order of "popularity".

1.	College Chemistry - Mahan	Addison Wesley
2.	Chemistry - Sienko and Plane	McGraw-Hill
3.	Chemistry - A Unified Approach - Buttle and Daniels	Butterworth
4.	Basic Organic Chemistry (1) - Tedder and Nechvatal	Wiley
5.	Physical Chemistry - Heys	Harrap
6.	A Worksheet Introduction to Chemical Spectroscopy - Johnstone and Sharp	Heinemann
7.	Various Volumes in Longmans Concept Series including New Guide to Modern Valence Theory - Brown	
	Spectroscopy - Whitfield	
	Introduction to Chemical Energetics - Thompson	
8.	Chemistry Data Book - Stark and Wallace	J. Murray
9.	Comprehensive Chemistry - Hicks	Macmillan
10.	Chemistry: A Structural View - Stranks et al.	Cambridge
11.	Energy Changes in Chemistry - Allen	Blackie
12.	Chemistry Takes Shape (Book V) - Johnstone and Morrison	Heinemann
13.	Inorganic Chemistry - Wood and Holliday	Butterworth
14.	Physical Chemistry - Wood and Holliday	Butterworth
15.	Organic Chemistry - Wood and Holliday	Butterworth
16.	Experimental Chemistry - A Laboratory Manual - Rendle Vokins and Davis	Arnold
17.	Organic Chemistry - Stokes	Arnold

Other publications in minor use.

School /

School Science Review - A.S.E. J. Murray

Chemistry in Britain - C.S./R.I.C.

Education in Chemistry - C.S./R.I.C.

Unilever Booklets

Esso Publications

Nuffield Publications - Longman/Penguin

Journal of Chemical Education - American Chemical Society

In a recent national survey of teachers in Scotland [45] the proportion of chemistry teachers as a whole was:-

Up to 10 years experience	38%
More than 10 but fewer than 20 years	24%
20 years or over	37%

Thus the sample of chemists teaching S.Y.S. is distinctly younger than the national distribution of chemists.

C H A P T E R   5

CHAPTER 5

WHY THE DIFFICULTIES?

The disturbing thread which has appeared throughout this work is the fact that so many areas of the syllabus have proved difficult for the pupils.

On the face of it the syllabus has a logical development with a certain amount of cyclic treatment so that some topics such as 'reactivity' or 'acids and bases' appear several times with increasing degrees of sophistication. A large amount of practical work is prescribed to involve pupils in a 'discovery type' of learning experience but this is, clearly, not universally done. Despite this careful structuring something has gone wrong.

It was suggested in Chapter 4, p.4.16 that the key to the problem may be found in a study of the development of logical thinking in the adolescent. Much work has been done in this area by Piaget and Inhelder [31] and, although their samples were small, they showed that clear stages of development exist with implications for teachers in secondary schools and even in universities.

Stage I - extends from birth until the appearance of language ($\sim$18 months)

Stage II - continues till the beginning of adolescence ($\sim$13 years) end of second year in secondary school

Stage III - is substantially complete by age 15 - 16 ('O' grade)

The characteristic feature of Stage II is the appearance of the period of concrete operations. The child shows reasoning ability, but /

but in terms of concrete objects. There is an absence of the hypothetical, formal thinking so often required in early science and maths courses. The ability to hold other variables still while altering one, is not common at this stage. The generation of hypotheses and the elimination of unsatisfactory ones by mental operations alone is also uncommon. For these skills we must wait till Stage III. This is the time for abstract thinking of the algebraic type: the time for the pursuit of general laws and explanations. These abilities do not suddenly appear at age 12-13, but rather begin to show themselves then and reach development at about 15-16. However, Stage III is not independent of Stage II. The pupil may be able to reason in Stage III without handling concrete objects, but he often thinks in terms of objects and images and will continue to do so for the rest of his life. He is now able to accept the idea of conservation of volume because he can imagine the same liquid in a variety of containers. This brings in the concept of proportionality. If a given amount of liquid is transferred from one vessel to another, any gain in level must be "seen" to be related to a proportional decrease in cross-sectional area.

One other characteristic change between Stages II and III which is important in science, is the ability of the older pupil to see mentally, relations between comparisons whereas the younger child makes one comparison at a time. This is relevant when one is trying to construct a series in which information for it is obtained as a collection of small parts.

Experimental work in Britain [34] has substantially supported Piaget's ideas and Peel [35] has pointed out that the stages coincide with /

with mental age rather than with chronological age. Mealings [36] researching in comprehensive schools has suggested that a mental age of at least 13 is required for pupils to use the ideas of proportion:ality and relations between relations, and that a mental age of 15-16 is required before formal thinking can be expected. Beard [37] points out, however, that these developments must, to some extent, be controlled by society and by education.

In Piaget's work the impression is conveyed that the subjects of his investigations are meeting the problems for the first time without previous educational "interference". It is difficult to assess how far education can advance the onset of these developmental stages. It may be that the presentation of ideas, which would not normally occur spontaneously at a given stage, is a waste of time in that the child may 'learn', but not understand the material taught. In his attempt to assimilate the new idea he may have to 'bend' it to fit his stage of development or merely have to memorise it. This may then give rise to problems later when he exhibits the naivety of his ideas.

This is where problems may arise among senior school and univer:sity students.

Against this semi-theoretical background it is proposed to examine the areas of difficulty raised earlier in this thesis. It is assumed that the order in which the syllabus is written is the order in which it is generally taught.

There were two distinct areas of the work up to 'H' grade which had caused difficulty - A. Formulae, Equations and the Mole and B. The Organic. (Chapters 1 and 2).

A. /

A. FORMULAE, EQUATIONS AND THE MOLE

From Graph 2 in the Appendix to Chapter 2 the following peaks of difficulty appeared and these were supported by the results in Chapter 1 referring to University 1st year students.

(i) H_2 - The difference between covalent and electrovalent bonding.

(ii) H_3 - Using an "ion detector" to measure the conductivity of solutions and understanding the results.

(iii) $H_4 + H_5$ - Writing chemical formulae and equations.

(iv) $H_6 + H_7$ - Formula weights and calculations from equations.

(v) I_2 - The ionisation of water. The meaning of -

$$H_2O \rightarrow H^+(aq) + OH^-(aq)$$

(vi) I_3 - Electron transfer in redox reactions.

(vii) J_1 - Acidic and basic oxides.

(viii) J_3 - Various methods of preparing soluble salts.

(ix) J_4 - Precipitation reactions for preparing insoluble salts.

(x) J_6 - Calculations to find the molarity of a solution.

(xi) K - Ion electron half equations. The meaning of equations such as -

$$SO_3^{2-} + H_2O \rightarrow SO_4^{2-} + 2H^+ + 2e$$

$$3e + NO_3^- + 4H^+ \rightarrow NO + 2H_2O$$

This work was tackled by most pupils between the ages of 14 and 15, corresponding to Piaget's IIIA level. This was the stage at which formal thinking was appearing, but which leant heavily on the concrete thinking of the previous stage.

The /

The thinking demanded of pupils in topics (i) to (xi) above was on the limit of their ability particularly at the younger end. At the age of 14^+ most of the fundamental material was being taught (formulae, equations, balancing and calculations) upon which so much of the later material depended.

(i) In H_2 the pupil was confronted with the situation of deciding whether a compound would have covalent or ionic bonding. On what basis was this decision to be made - a knowledge of the Periodic Table; electronic configurations; atomic size; electronegativity? This juggling with an apparently multivariate situation was likely to be beyond him.

(ii) H_3 was another example of a similar problem. Pupils in S.C.E. (O) grade courses were required to understand the shape of this curve (Fig. 5.1) for the addition of a strong base to a strong acid while the solution con-:ductivity was being measured.

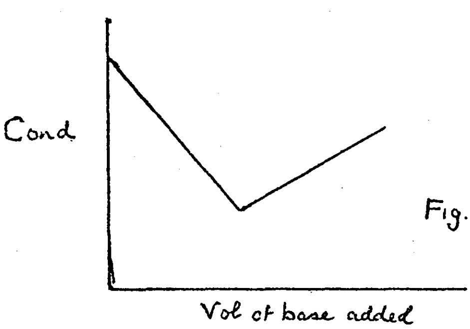


Fig. 5.1

They had to know simultaneously:-

1. The meaning of a "strong acid" and its significance in giving a high initial reading.
2. The fact that water was being formed and that its conductivity was low.
3. The fact that the number of free ions in solution was the same as far as the minimum of the curve.

4. /

4. The fact that the metal ions of the salt had a lower mobility than that of the hydrogen ions.
5. The significance of the minimum as the end-point.
6. The fact that the increase beyond the minimum was due to additional ions from the base.

This curve was simple when compared with this one (Fig. 5.2) for the addition of carbon dioxide gas to limewater!

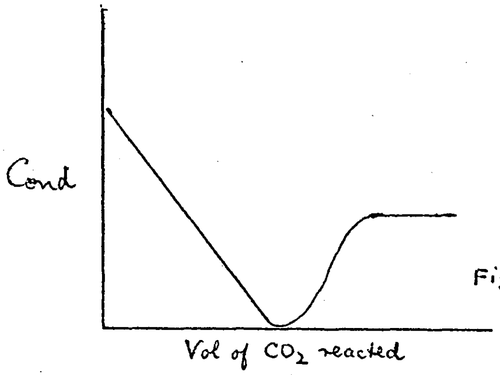


Fig 5.2

The amount of formal thinking required here was unlikely to be within the compass of most 14-15 year olds.

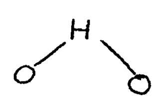
(iii) $H_3 + H_4$ have been studied in some detail by T.V. Howe and the author [9] during a Gagné study of the reasoning steps involved in writing a formula and an equation. Pupils were asked to write a named formula as follows:-

1. Name the elements in the compound.
2. Write the symbols for these.
3. Write the symbols and charges for the ions.
4. Now write the complete formula.

Pupils usually got some or all of steps 1, 2 and 3 wrong but, for common compounds, rather more than half of them got 4 correct. It was clear that if the result of 4 depended upon the reasoning steps 1, 2 and 3 almost none of the pupils would have got 4 correct. This /

This was repeated for less familiar but equally simple compounds and, in the vast majority of cases, steps 1 - 4 were wrong. This lead to the conclusion that formulae were correct if memorised and that reason-:ing did not enter into their construction. A similar conclusion was arrived at regarding balancing of equations. This was an indication that formal thinking was lying unused and that the way the pupil could give the appearance of coping, was to memorise what he could not under-:stand.

A possible consequence of this was shown at university level in some work done by Carnduff, Handy and the author [38]. A large sample of medical students was tested early in first year to enable lecturers to find the lowest common denominator of the students' chemical know-:ledge from school. Among the questions asked was "write the formula for water" (H_2O - 99.9% correct) and "draw its structure". 50% of the students answered thus



(iv) H_6 + H_7. Pupil difficulty with H_6 (calculations of formula weights) was less than with H_7 (calculations arising from equations). This was not very surprising since, given a formula, the calculation of formula weight involved the operations of multiplication and addition only. However, calculations from equations required a feel-:ing for proportionality - a skill probably not properly developed till age 16.

In Howe's work an experiment is in progress to see if the post-:ponement of teaching "calculations from equations" for a year (15^+) will make any significant difference to pupil performance.

(v) /

(v) I_2. The problem with this may have been related to an apparent self contradiction. In the conductivity work of H_3, water is taken to have virtually no free ions. But, in the consideration of elec-:trolysis, the free ions in water are alleged to take part in the preferential discharge processes at electrodes.

(vi) and (xi) I_3 + K. Redox equations and electron transfer are basically similar in thinking to H_2 and H_5.

(vii) J_1. Acidic and Basic Oxides are based upon a classification not much easier than that in H_2 since the bulk of oxides do not fit neatly into either category.

(viii) and (ix) J_3 + J_4. Involve the preparation of salts. In the first case particularly, mole relationships were required for the neutralisation reactions and proportionality was involved. In the preparation of insoluble salts a knowledge of ions, charges, solub-:ility of salts (both starting materials and products) were required and sometimes had to be repeated in multistage preparations.

(x) J_6. Calculations on molarities of solutions. In this part of the third form the mole concept was used for two purposes. The first was to emphasise differences such as the difference in size between moles of metals and hence the differences in atomic volume and in "reactivity". Or the differences in bulk between moles of salts each with a common ion thus emphasising the differences in size of the other ions. Now in J_6 moles of material were dissolved in water and made /

made up to equal volumes. Compounds reacted in equal volumes (or in simple whole number multiples) of equimolar solutions. This led to the dubious material which appeared in the Nuffield Scheme [39] and in some others based on the Job's plot. Equimolar solutions were mixed in progressive whole number ratios and the precipitates centrifuged. The first ratio which gave the maximum bulk of precipitate gave the formula of the compound. Since the formulae of the reactants had to be known before molar solutions could be prepared, the interacting ions and their charges were assumed and then used to prove the assumption. This kind of double thinking could only have been confusing to pupils - particularly to the intelligent ones.

A detailed study of various methods of teaching the mole concept by I. Duncan and the author is now in progress. Howe's work on order of presentation will give some insight into the part that age plays in grasping the chemical concepts considered above.

It was instructive to examine the parts of the syllabus which came low on the scale of difficulty to see if their conceptual content was different in nature from those discussed above.

(i) $G_1 + G_2 + H_1$ - Atomic particles and their arrangement in the atom and in isotopes and combination of atoms.

These were essentially pictorial and concrete, being treated either as a Bohr model or as a modified Gillespie-Nyholm model. [40]

(ii) I_1 - Reactivity series of metals.

This involved handling a limited range of familiar metals with constant reinforcement of their order of behaviour by several methods.

I_4 (Corrosion of metals) was related to I_1 and could be seen as

a /

a very practical every day chemical experience.

(iii) J_2 - pH of a Solution.

At this level pH was treated merely as a scale. It involved only the concrete operations of dipping pH paper into solutions and comparing the resulting colour with a scale. No understanding was demanded.

(iv) J_5 - Indicators for neutralisation.

This was a direct extension of the concrete operations in (iii).

It would therefore seem to be the case that the part of the syllabus customarily taught at 14^+ - 15^+ years was conceptually too difficult for the stage in the development of logical thinking which could be expected of the pupils. This would tend to be even more acutely obvious with less able pupils.

B. THE ORGANIC

Organic chemistry appeared in all three courses - 'O' Grade, 'H' Grade and S.Y.S. and each time difficulty was reported. In an earlier chapter (p.1.27) it was suggested that this might have been caused by the fact that the organic appeared at the end of the 'O' and 'H' syllabuses and so was in danger of being rushed or even omitted in the period immediately preceding the external examinations. There was some evidence for this in Graph 2 of Appendix to Chapter 2. Sections L, N and O were substantially organic. The 'C' group who had studied the organic in third form when they were not working against the clock had fewer difficulties than the 'I' group who were doing /

doing the work in fourth year immediately before the 'O' grade examination. Canvassing of informal opinion from university students indicated that the organic part of the course was the area most likely to be omitted or to be covered hurriedly by typed hand-outs and little or no experimental work. Similar information from teachers' meetings tended to corroborate this. [41]

CONCEPTUAL CONTENT OF THE ORGANIC

The 'O' Grade part of the course had a high topical interest value similar to that of corrosion in the earlier part of the course and few of its topics were reported to be as difficult as many of the topics discussed earlier in this chapter.

The thinking throughout was essentially concrete helped by three dimensional models and a large experimental content. The basic ideas were easy to visualise - chains being progressively lengthened (homologous series and polymerisation), shortened (cracking, hydrolysis and depolymerisation) and sorted into length (distillation and chromatography). The reported difficulties had the common element of condensation or hydrolysis - N_1 (hydrolysis of carbohydrates), N_2 (ester formation), N_3 (fats and soaps) and O (condensation polymers). This was further exemplified in the 'H' Grade course.

The problem may well have been related once more to formulae and equations. Particularly in this area chemists, for convenience, tended to write formulae backwards to allow 'lasso chemistry' to be performed.

$$R{-}C\begin{matrix}=O\\ -OH\end{matrix} \; + \; HO - R' \; \rightarrow \; R{-}C\begin{matrix}=O\\ -OR'\end{matrix} \; + \; H_2O$$

acid alcohol

whereas /

Whereas in the earlier part of the course a compound had one formula (no matter how ill understood), in the organic part, several formulae were apparently admissible for one compound. For example, ethanol could be shown as:-

$$\begin{array}{c}\ \ \ \ H\ \ \ \ H\\ \ \ \ \ |\ \ \ \ \ |\\ H-C-C-OH\\ \ \ \ \ |\ \ \ \ \ |\\ \ \ \ \ H\ \ \ \ H\end{array} \text{ or } CH_3CH_2OH \quad \text{or} \quad C_2H_5OH \text{ or } EtOH$$

or any of these written in reverse.

The teacher chose a form to make a particular point, but there may have been much subsequent bewilderment particularly when only one of these was clearly similar to any model of the molecule which may have been shown.

An experiment which may shed light on this is described in Chapter 2, p. 2.11.

DIFFICULTIES AT 'H' AND 'C.Y.S'

The problems at 'H' Grade follow on from those at 'O' Grade, for example, Heat's of Reaction, Hess's Law, Calculations of Bond Energies, E^o values and their use, Amines and Carbonyl Compounds.

Trouble was also reported in the concept of Equilibrium. This may have been an example of new ideas being assimilated into a previous framework giving rise to faulty concepts.

The pupils previous ideas of equilibrium have been static - as in Physics, e.g. a rod balanced on a fulcrum or a lamina suspended at its centre of gravity. In the case of the balanced rod, addition of material to one side caused the rod to dip towards that side and removal of material caused the opposite operation.

Chemical /

Chemical equilibrium was, on the other hand, dynamic. Material added to the right of a reaction sequence caused the reaction to go to the left and vice versa. The application of Le Chatelier's "Law" involved very formal thinking indeed. The problem could have been made more concrete by the employment of a dynamic model. [42] Equili-:brium situations were also multivariate, to which competing factors of pressure, temperature and concentration could be applied. Not all 'H' Grade pupils at 16^+ would have achieved the necessary mental dexterity to cope with these.

At S.Y.S. level the organic was still troublesome and the new area of crystal field theory and its consequences for colour and magnetic properties gave trouble. Here again very formal thinking was required to handle the essentially abstract ideas of probability (orbitals), splitting and the application of Hund's rules to the non-degenerate situation. However, pupils taught with a model [21] designed to allow them some concrete thought might have been better able to cope with this area of the syllabus.

CONSEQUENCES FOR UNIVERSITY

A quotation from Beard's "An Outline of Piaget's Developmental Psychology" p. 116-117 is relevant here.

"It may well be questioned whether discussion between pupils is used sufficiently, or sufficiently skilfully, in our secondary schools. Much class discussion consists in questions and answers between the teacher and individual pupils, and this may fail to provide the genuine exchange of viewpoints needed for the development of logical thinking, since the teacher inevitably tends to be accepted as an authority.

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Even at univ rsity level the quality of students' thinking in their own subjects may still only partly attain the level of formal operations, despite Piaget's finding that thinking at this level is normally more fully achieved at sixteen years; but this seems to have been an optimistic conclusion based on studies of rather few and perhaps unrepresentative samples of adolescents. Observations and experiments by Abercrombie (1960), with first-year university students in London showed that although they were well-grounded in the facts of biology, physics and chemistry they were often unable to use their information to solve slightly unfamiliar problems or to defend a view in argument, and they tended to observe what the text-book said should be there rather than what was actually on a slide or X-ray. To overcome these deficiences she experimented with free discussion among small groups of students of their own observations, definitions, evaluation of evidence or views on causation. In this way they became aware, to the dismay of some of them, that they made unconscious assumptions, took individual views of the same evidence or saw different features of an exhibit. Subsequently, students who had taken part in these discussions were compared with those who had attended the normal course of lectures and demonstrations: they discriminated better between facts and conclusions, drew fewer false inferences, considered more than one solution and were less adversely influenced in their approach to a problem by their experience of the preceding one. The discussion method, therefore, promoted a more scientific attitude by giving rise to more objective and flexible behaviour than did learning the facts of science by traditional methods. The implications for teachers of sixth-form sciences are obvious; but we may reasonably /

reasonably assume that these findings have applications in any subject, or at any age, where critical thinking is required."

It would also be unsafe to take the view that what had been taught at school was of no consequence. Material taught too soon at school may have left an insecurity that would take a long time to rectify. In Chapter 3, p.3.8 it was noticed that the complaints about the diffi:culty of the Mole subsided only at S.Y.S. level although the material had been taught several times in Forms 3, 4 and 5. Some 'H' grade and S.Y.S. material, if not grasped then, could have long lasting con:sequences for the university student and his teacher. Evidence for this is being sought by the author in collaboration with J. Straiton.[43]

It would therefore seem to be essential that the teaching of chemistry at all levels should be seen as a whole and that the effects of each level upon the others should be studied and the findings heeded. It would also seem to be necessary to temper the objectives of our courses and their content by a sober consideration of the psychological implications of our decisions.

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