AN EVALUATION OF PRACTICAL WORK IN CHEMISTRY AT THE HIGHER GRADE OF THE S.C.E.

BY

COLIN A. WOOD

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CONTENTS

NOMENCLATURE

OECD	Organisation for Economic Co-operation and Development
SCE	Scottish Certificate of Education
SSSERC	Scottish Schools Science Equipment Research Centre
SYS	Sixth Year Studies
S3 etc.	means 3rd year of secondary education

Graphs appear at the end of the chapter to which they apply, and are numbered accordingly e.g. graph 5.2 is the second graph at the end of Chapter 5.

Numerical data is gathered as appendices, which all appear at the end of the thesis, and are numbered consecutively from 1 to 11.

SUMMARY

In the early 1960's, a new syllabus in Chemistry which embodied recent thinking in chemical education was introduced into Scottish schools. This was revised in 1969, and is used unchanged at the present time (1975). The syllabus consists of three parts, the first part covering the first two years of secondary education, the second two further years to 'O' grade, and the final part one year to 'H' grade. The present work was concerned with the practical content of 'H' grade.

The research programme was begun by evaluating this practical work by surveying schools to find out what practical work was being done, how it was being done and how useful teachers found it. This allowed identification of areas of the syllabus where practical work was unsatisfactory. An attempt was then made to produce experiments which could be used at these unsatisfactory points in the syllabus; eleven experiments were produced. Details of these experiments were circulated to schools, and these were evaluated by both teachers and pupils.

The evaluation was done using a set of course objectives for practical work drawn up by the author and ranked by a representative sample of experienced teachers. The evaluation was done by making two different sets of comparisons -

(a) The objectives achieved by each experiment as seen by the teachers were compared with those as seen by their pupils, to find out if the teachers were able to communicate their objectives to their pupils. In general they were, and this was thought to validate the set of objectives and the approach used.

(b) The objectives achieved by all eleven experiments taken together (as seen by the teachers) were compared with the teacher course objectives previously developed. There was reasonable agreement. However, the main point here is that this is the basis of a potentially useful tool for the evaluation and development of syllabus practical work. Practical work need not be chosen to "fit the content" alone, but can be selected to meet a specification for course practical work drawn up in terms of objectives.

Chapter 1 : Introduction

In the late 1950's and early 1960's, there was a growing dissatisfaction in a number of countries about the chemistry courses offered in schools, which had seen little change over many years. The syllabuses in use were old fashioned in their approach, and their content omitted much of relevance to the processes and materials in use; for example, there was little relevant organic chemistry. These criticisms applied to the chemistry syllabus for the new 'O' grade examinations, introduced in 1958, with the first examination set in 1962. The syllabus - to be covered in four years - was the old 'L' syllabus which had required five years. The length of the syllabus, and its old-fashioned content, came in for criticism by teachers and others.

A meeting, held under the auspices of O.E.C.D. at Graystones in Ireland, and attended by representatives of most European (and some other) countries, showed the participants that dissatisfaction with school Chemistry syllabuses was indeed world-wide. Discussion took place about the shape and content of new national syllabuses, and this was incorporated in the book published in July 1961, "New Thinking in School Chemistry". This included substantial contributions - both as an editor and contributor - by the Scottish representative, J.R.M.M. Brown, H.M.I.

Meantime, in England the A.S.E. produced what was in effect a new syllabus (1961), but this had little impact at the time, although some of the General Certificate of Education Examination Boards took this - and the later Nuffield proposals - into account when revising their syllabuses.

However, in Scotland, a number of schools were devising and trying out chemistry teaching material which was interesting and relevant to the pupil up to 'O' grade stage. "With regard to method, the aim was not to inculcate a body of factual knowledge, but to arrange for the study of ideas and concepts in an exploratory way, to teach pupils to exercise judgement and to establish theories which are of wide significance." (Hunter 1972) H.M.I.'s Brown and A.J. Mee wrote up the topics and/

edited them as an 'O' grade syllabus, which was published as Circular 512 of the Scottish Education Department in October 1962. This appeared as an "Alternative Chemistry Syllabus" because, while teachers were encouraged to adopt it, there was no compulsion until the traditional syllabus examinations ceased to be offered for lack of support after 1971.

A number of teachers were involved in developing the work which was to be incorporated in the syllabus, chief among whom were A.H.Johnstone (George Watson's Boys' College) who suggested and tried out almost all the third and fourth year topics; A.W.Jeffrey (Madras College, later H.M.I.); and W.J.Milne (Kirkcaldy High School, later S.C.E. Exam Board). Many more contributed by discussions and by assisting in writing memoranda on the teaching of the syllabus.

By early 1964, it was clear that the Alternative Syllabus was gaining widespread acceptance, but it was also clear that it was too heavy and difficult in places. This applied even to some of the more able pupils, but the problem was compounded by the popularity of the new examinations; many more pupils than the original 30% for whom it was designed were attempting the examination. This led to the setting up in 1964 by A.J.Mee, of a Working Party on Junior Secondary Science. The original remit was to produce a modern science syllabus for the less academic pupil (the 70% or so who would not expect to sit 'O' grade). However, a political decision half-way through the working party's life changed its remit; it was now to produce a common course suitable for mixed ability groupings in years I and II. The integrated science course (published by the S.E.D. as Curriculum Paper No.7 in 1969) was intended to establish scientific method, to be process-based rather than content based. This meant that some of the material previously taught in years I and II had now to be taught in years III and IV; correspondingly, some of the material previously in the 'O' grade syllabus was omitted or pushed into 'H' grade.

These changes, and others, were incorporated in the revision of Circular 512, and issued in March 1969 by the Scottish Certificate of Education Examination Board. The aims of the revised syllabus remained those which formed the basis of Circular 512.

"The approach therefore is conceptual rather than factual, and the relation of observed facts to fundamental principles is emphasised throughout. The two major concepts on which this approach to chemistry is based are structure and energy, and there should be constant reference to them in the presentation of the subject.

"The content of the syllabus is intended not only to conform to modern views of presenting the subject but also to relate to the needs of the pupils. The study of chemistry must serve a number of purposes. The majority of the pupils taking the subject are not intending to become professional chemists, and consequently the aims of the syllabus for them must be those which are common to all science teaching. These may be summarised as having to provide the pupil with :

1. Some knowledge of the empirical world around him.
2. Something of the vocabulary and grammar of science.
3. A training in objective observation.
4. Experience of problem solving in experimental situations.
5. Experience in thinking scientifically.
6. Exposure to the culture which is science.
7. Some appreciation of the part that science has to play in world economy.

"These aims will be developed, of course, within the context of chemistry. In order to achieve them it is necessary to teach the subject largely in an exploratory manner, where the pupil is not <u>told</u> all the facts, but as far as possible discovers them for himself. The arrangement of the syllabus is designed to that end.

"Topics chosen for study are arranged in three groups:

1. Sections A-F are intended to be covered in the first two years of secondary education. Here the pupils will gain an introduction to the subject. This stage is complete in itself, and even if the pupil does not study the subject further it will give him a sound background of chemical knowledge. As stated above, it is expected that all pupils, in whatever type of school, will be catered for in this part of the course.

2./

2. Sections G–O, are intended for years SIII and SIV. Here the principles learned in the earlier years are applied to a study of chemical combination and the chemistry of substances of world-wide economic importance. Sections A–O form the 'O' grade syllabus, which is a course complete in itself.
3. Sections P–S prepare the pupil for 'H' grade presentation. At this stage many of the pupils will be preparing to go on to Universities or other centres of higher education and the content is therefore somewhat more specialised, although it still provides a sufficiently general background of chemical knowledge for those not becoming professional chemists."

While the 'O' grade syllabus remained substantially unchanged in this revision (apart from considerable deletion), the 'H' grade syllabus was completely rewritten. Perhaps this reflected the fact that much of the 'O' grade material had been tried out in schools, but little of the original 'H' grade material had been refined in this way. The revised syllabus introduction explains:

"Many teachers have been reading too much into these sections and there was need for clarification and re-expression in the light of the experience gained both with the syllabus and with examining over the past six years. Furthermore, it was felt that parts of the syllabus needed re-writing to bring the work more into line with modern science and, since there had been some expression of opinion that the syllabus was too long for teaching in one year, the opportunity has been taken to omit some of the more traditional material and to re-balance the approach to the teaching of some of the descriptive material. On the other hand, however, it has been necessary to add a little work which is not now covered at 'O' grade. It is felt that the fifth year work proposed in the accompanying syllabus should be well within the compass of normal fifth year pupils and should be capable of being taught within the normal time allowance."

Thus at the start of this work in late 1972, the syllabus was about ten years old and had already seen one major revision. Was it now a good syllabus? Was it meeting its aims and objectives (whatever these are)? Perhaps the time had come for an objective evaluation of the syllabus, but for this to be done satisfactorily, prior evaluation of/

of its practical content seemed necessary. Thus the first part of the present work set out to find out what practical work was being done, how it was being done, and how useful teachers found it. This was done by means of a questionnaire to some 130 schools.

Whilst few would question the aims of the syllabus set out in the syllabus (see above), there would be less unanimity about objectives. In the second part of the work, a set of objectives for the syllabus as a whole was drawn up, and this was evaluated using a second questionnaire.

The final part of the work was to devise and circulate to schools experiments to replace some of those shown to be unsatisfactory by the first questionnaire. These were then evaluated using the objectives drawn up in part two (for the syllabus as a whole) by both teachers and pupils.

Chapter 2

An Examination of the Practical Work done in Schools for 'H' grade Chemistry

Introduction

In the original (1962) syllabus, 'H' grade included three sections over and above the 'O' grade material. These were: "Chemical Theory", "Further Development of the electronic theory of valency. Periodic Table" and "Carbon Compounds". There was no laid down practical work, but there was an expository essay on each section of the syllabus, and explanatory memoranda were issued over a period of years, eventually covering most sections of the syllabus.

In the revised syllabus (1969), 'H' grade was completely rewritten to show more clearly the depth of treatment required. Certain traditional style work was deleted (e.g. Gay Lussac's Law), and the organic section dealing with compounds derived from benzene was deleted. Two sections were modified and transferred from 'O' grade to 'H' grade (nuclear chemistry, halogens) and a section on alkali metals was added. The extension to 'H' grade was rewritten in four sections:- "Atoms, Molecules and the Mole", "Bonding and the Periodic Table", "Chemical Reactions" and "Carbon Compounds".

For each section of the syllabus, there was an explanatory note, and "suggested practical work" - with a prefix D or P meaning demonstration and pupil (or small group) experiment respectively. Like the original syllabus, no particular practical work was obligatory; neither was there a practical examination, so - in theory at least - there was no necessity for any practical work to be carried out.

While there has been no practical examination in Scottish schools for many years, measures are in force to bring pressure to bear on schools to carry out practical work. These include direct pressure on teachers by inspectors and others, and examination questions designed to test a candidate's practical ability. Note that Certificate of Sixth Year Studies Chemistry does not follow this pattern. Since its introduction in 1968, an external examiner has assessed each pupil's project and course practical, and additionally from 1974, candidates must have carried/

out at least two-thirds of a published list of experiments to be eligible for the award of a certificate. Since there is at present no external examiner of practical work for 'H' grade (and the larger number of candidates would seem to preclude this possibility) is it necessary (or indeed desirable) to set up some check on practical work at 'H' grade similar to that at S.Y.S.? Are the fears expressed that insufficient practical work is being done justified?

Objective

The objective of the first part of this work was thus to survey the 'H' grade practical work situation in Scottish schools, by finding out what practical work was being done, how it was being done, and how useful teachers found the practical work suggested in the syllabus. To this end a questionnaire - see appendix 1 - was sent to one hundred and thirty schools selected from a list of all schools presenting at 'H' grade S.C.E. Schools were selected at random, except that the proportion of each type of school (i.e. local authority, direct grant and independent) was the same in the sample as in the whole. Returns were made by seventy-eight schools (i.e. 60% of the sample).

The first and last pages of the questionnaire asked for general information about the school and its approach to the syllabus; the remainder listed the experiments suggested in the syllabus, and asked teachers if they carried out the particular experiment, and if so, by which method, and how useful it was found to be. Space was left for detailed comment on each group of experiments.

A statistical analysis of the results and a detailed examination of the teachers' comments on individual experiments or groups of experiments were carried out; discussion of individual experiments will be found in chapter 4, and the remainder of this chapter is intended to give an overall perspective of practical work.

RESULTS OF SURVEY

Average time devoted to chemistry per week = 220 minutes
(5.5 40-minute periods)
(see graph 2.1 for distribution)

Average/

Average number of pupils taking 'H' grade course = 47.3 per school
" " " " " " " " = 17.4 per section

Use of Textbooks

81% of schools issued "Chemistry Takes Shape" Book 5
by Johnstone and Morrison (Heinemann);
56% of schools issued extensive printed notes;
16% of schools issued "A Modern Approach to Chemistry"
by Stove and Philips (Heinemann);
6% of schools issued "Test Your Chemistry" edited by Morrison
(Heinemann);
5% of schools issued "Revision Examples at 'H' grade Chemistry"
by McKail and McLean (Heinemann);
5% of schools issued Foreground Chemistry Series - various titles
(Heinemann);
5% of schools issued "Physical Chemistry for Schools and Colleges"
by Heys (Harrap).

Notes :- (i) Many schools using "Chemistry Takes Shape" Book 5 also issued either or both of "Chemistry Takes Shape" Book 3/ "Chemistry Takes Shape" Book 4.

(ii) Books with less than 5% use are omitted.

(iii) Each entry above does not necessarily imply that schools issued that book alone.

Teaching Order

While there is nothing in the revised syllabus to suggest to teachers that they should adopt the syllabus order of topics as the order for teaching, it has been generally assumed that most teachers teach in the syllabus order. (In fact, - insofar as 'O' grade is concerned - research has been carried out to find if altering the order of introduction of certain key topics makes any difference in attainment (Johnstone 1972, Howe unpublished). Such research would perhaps not be so relevant at 'H' grade, where much of the work builds upon foundations laid earlier in the course, and where the maturation of pupils during the course is not as marked as in 'O' grade).

It is thus a little surprising that only 34% of schools in the sample did teach in the syllabus order (sections P Q R and S in that order). The next most popular order was S P Q R (17%), but in addition 23%/

23% sub-divided one or more sections and taught them at different times, and not necessarily in the syllabus order.

As far as the 4 main sections of the syllabus are concerned, all teachers taught Section S (Organic) in the order given, and all bar one taught Section R (Chemical Reactions) in the order given. Thus - while particular experiments may need attention (see Chap.5) - these two sections are satisfactory as to teaching order.

Section Q (Bonding and the Periodic Table) had its teaching order changed most (21% of the sample), while Section P (Atoms, Molecules and the Mole) fared a little better, 10% of the sample changing its order.

Teachers were asked about their teaching order at the end of a long and tedious questionnaire, and the figures could well be less than the true sample values. However, whether this be the case or not, further investigation into Sections Q and P of the syllabus is merited, in order to achieve an order as acceptable to teachers as Sections R and S.

<u>Recording of Practical Work</u>

The following was thought to cover the methods used in schools to record practical work :

A. Practical work not formally recorded, but theory written up by teacher
B. Practical work recorded in worksheets by pupil
C. Practical work recorded in pupils' notebooks, written up in detail by teacher.
D. Practical work recorded in pupils' notebooks, written up in detail by the pupil
E. Other methods (teachers were asked to describe)

Each school was asked to tick the methods they used - a double tick for a method frequently used and a single tick for methods used occasionally. The following results were obtained -

	Number of single ticks	Number of double ticks	Number using method	Total Number of ticks
Method A	17	6	23	29
Method B	13	12	25	37
Method C	17	30	47	77
Method D	27	24	51	75
Method E	4	4	8	12

The two most popular recording methods show that practical work is being recorded by pupils, with the detail being written up by the pupil and by the teacher in roughly equal proportion. This seems satisfactory.

Summary of Practical Work

The following gives the overall picture of 'H' grade practical work in schools. Totals are for all experiments, both for all schools and with means per school. The total number of experiments possible might be taken as about 60 (see note below).

		total	means per school	S.D.
Experiments Performed	regularly	3505	44.9 *	7.3
	was done but now abandoned	103	1.3	-
	never done	831	10.7	-
	done earlier in course only	239	3.1	-
Experimental Method Used	pupil	2579	33.1	10.0
	stations	134	1.7	-
	demonstration	737	9.5	-
	assisted demonstration	157	2.0	-
Usefulness of Experiments	very useful	2692	34.5	-
	fairly useful	735	9.4	-
	of little use	115	1.5	-

*graph 2.2 shows the distribution

Note - The total number of experiments possible is somewhat subjective because it is a matter of individual judgment whether certain listed practical work is treated as one extended experiment, or as a number of short individual experiments; e.g. in section Q6 (The/

(The Halogens) "Simple test-tube experiments to illustrate these points". However, considering the returns, a reasonable average for the number of experiments possible would be about 58 to 62.

The summary of practical work shows that most schools are carrying out plenty of practical, and that the bulk of it is being done by the pupils themselves. It will be seen in chapter 4 that demonstration experiments are used mainly when the nature of the experiment dictates this, e.g. reaction of sodium with alcohols, physical properties of benzene, reaction of aluminium and iodine with water. Few experiments done are deemed to be of little use; at least one teacher pointed out that such experiments should appear in column 3b or 3c (never done or abandoned).

A detailed consideration of individual experiments is given in Chapter 4; this includes an analysis of teachers' comments on the experiments.

CORRELATIONS

It was decided to try and find out if some of the factors on which information was collected had any relationship with any of the others e.g. it might be expected that a large chemistry set would carry out less experimental work, or perhaps do less pupil practical, than a smaller set.

The distribution of the numerical data is not normal; this means that correlation coefficients which assume a normal distribution (e.g. Pearson) cannot be used. The chi squared test, which makes no assumptions about the distributions of the numbers concerned, seemed appropriate and was used. Details of its application are given in Appendix 2, as are detailed results, but the results can be summarised as in the adjoining table, page 17.

From the table, it is seen that none of the 'external constraints' (viz time spent on chemistry, use of extensive printed notes, size of chemistry set) correlate significantly with the total number of experiments carried out. While this is perhaps unexpected, it was found that the more time that is spent on chemistry, the more likely are the experiments to be carried out by the pupils themselves rather than by demonstration. Similarly, the use of extensive printed notes may lead to more pupil rather than demonstration experiments, but a larger sample would/

	Method					
	No. of expts. performed regularly 3A	Pupil 4A	Demonstration 4C	Very useful 5A	Time spent on Chem.	Time allocation adequacy
No. of experiments performed regularly 3(A)	X	8.00 (+) 1%	0.005 not sig.	9.15 (+) 1%	0.90 not sig	0.19 not sig
Time spent on Chem.	0.90 not sig	4.61 (+) 5%	4.10 (-) 5%	0.09 not sig.	X	12.69 (+) 1%
Time allocation adequacy	0.19 not sig	2.39 (+) not sig.	3.95 (-) 5%	1.23 (-) not sig.	12.69 (+) 1%	X
Extensive printed notes	0.62 not sig	1.52 (+) not sig.	1.77 (-) not sig.	0.21 not sig.	3.99 (-) 5%	3.90 (-) 5%
Average size of Chem. set	0.85 (+) not sig	0.008 not sig.	0.04 not sig.	2.25 (+) not sig.	0.77 not sig.	0.03 not sig.

Note A '+' means that both factors increase together

A '-' means that one factor increases as the other decreases.

would be required to demonstrate the validity of this conclusion. The size of the chemistry set has no significant correlation with the pupil experiment/demonstration experiment ratio, or indeed on any of the other variables tested.

It will be seen that the actual time spent on chemistry, and a teacher's subjective view as to whether this time allocation is adequate, correlate very significantly; and further that these two have very similar correlations with the other variables tested. This shows that teachers are good at assessing the time requirements of the syllabus, and could suggest that there is a minimum time requirement to complete the syllabus, with or without practical work. (Further work would be required to estimate the value for this time). It can be seen that extensive printed notes are associated with an under-average time allocation: perhaps teachers compensate for an inadequate time allowance by issuing extensive printed notes.

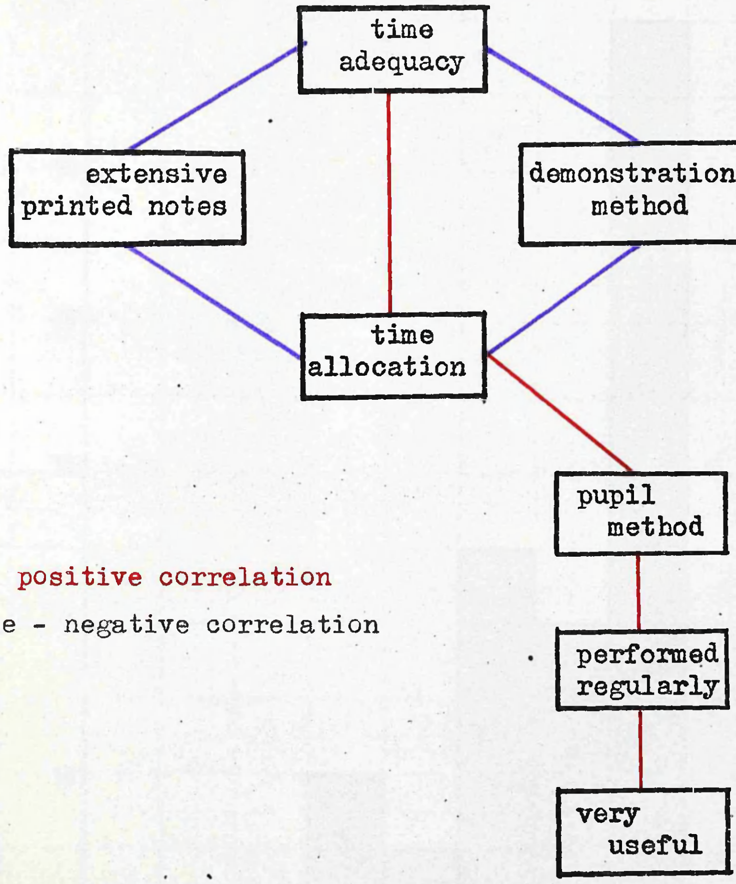
One might expect that all teachers would carry out the most useful experiments, and that the 'extra' experiments carried out by teachers doing more than the average would be the less useful ones. However, the reverse is the case - the more experiments that are carried out, the more useful teachers find them. This could be showing up the importance of the teacher's personality as seen in his view of practical work: the teacher who considers practical work useful and important tends to do lots of it (and indeed lots of it carried out by the pupils themselves rather than by demonstration).

Finally, consider the effect of set size in more detail. One might expect the teacher with a large set size to cut down the amount of practical work done, or at least the amount of pupil practical done, but the statistics show this not to be the case. Why? Consider the teaching situation. Assuming little problem with discipline (reasonable at 'H' grade with classes of motivated senior pupils), the problem is one of organisation, and (in the author's experience) it is little more difficult to organise a large class than a smaller one.

CONCLUSIONS/

CONCLUSIONS

1. More practical work is being done than is commonly alleged.
2. The following summarises the correlations found :

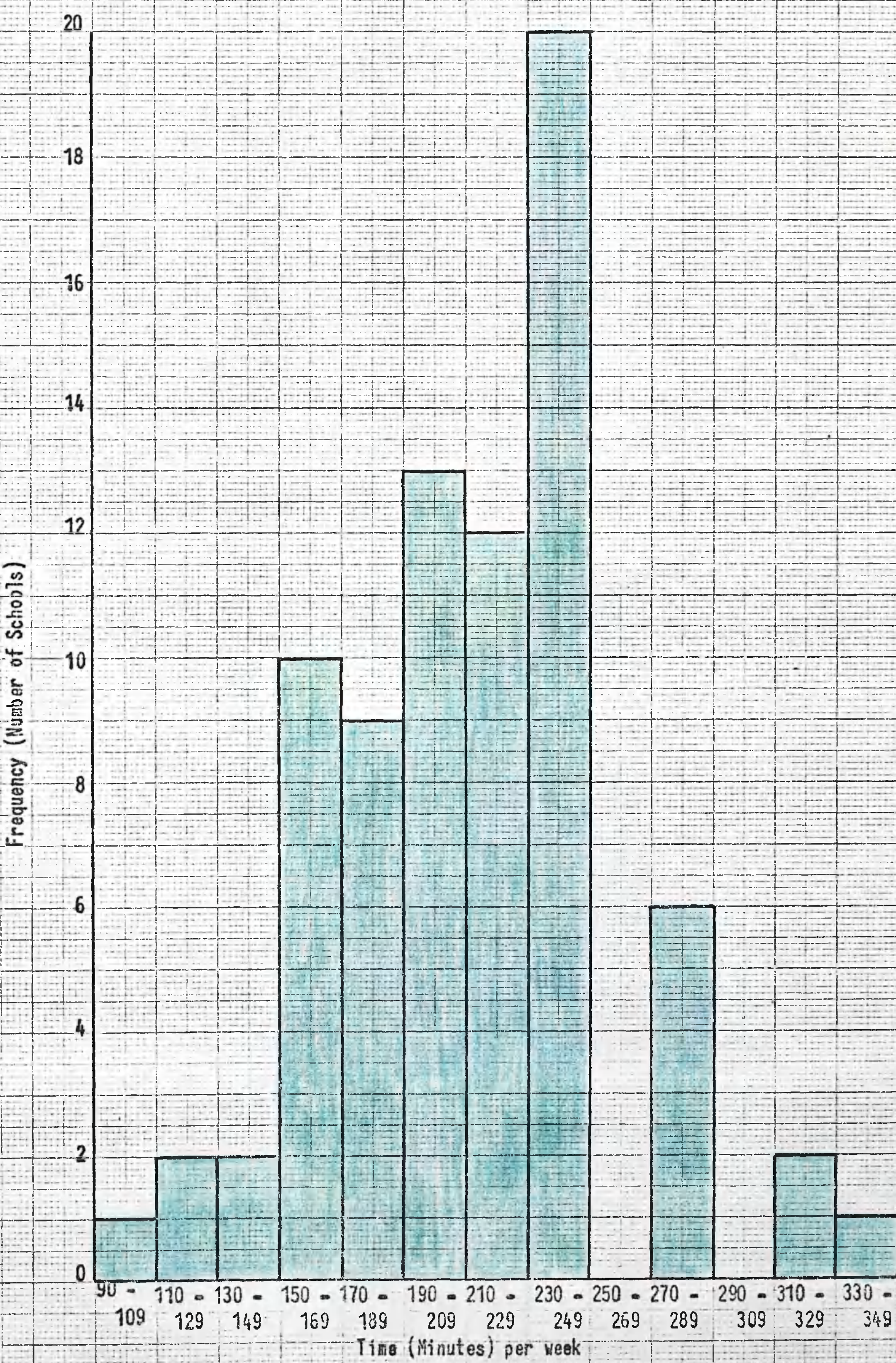


red - positive correlation

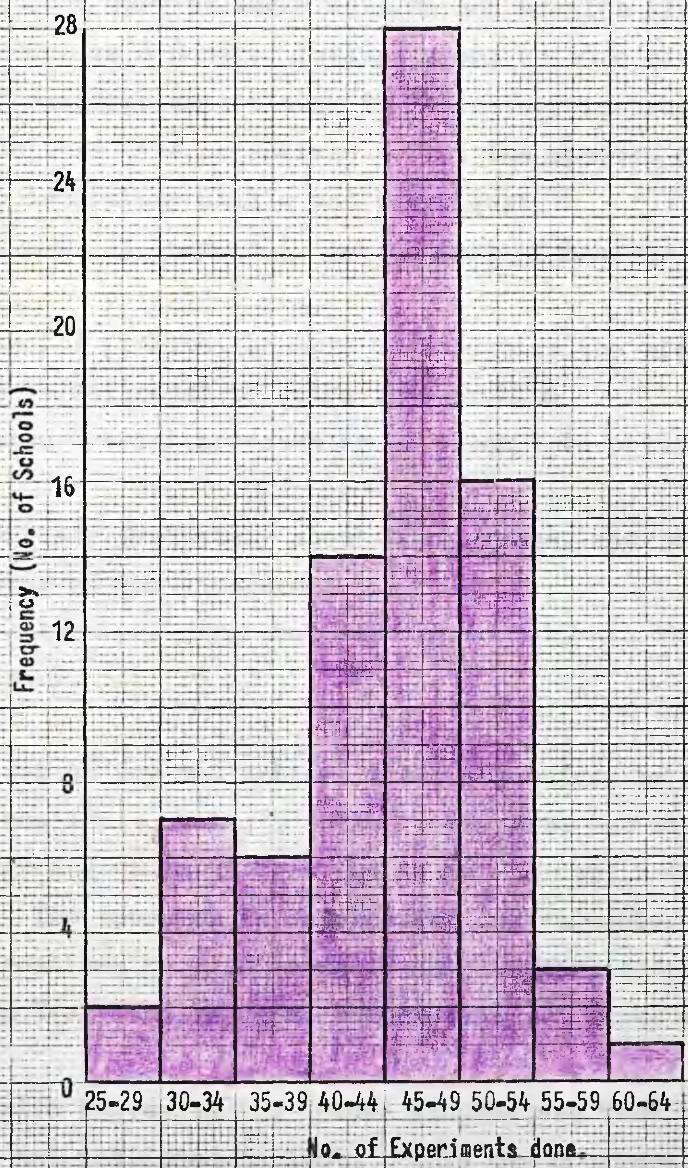
purple - negative correlation

It is seen that the external constraints under which a teacher operates (such as class size, or time allocation) have little effect on the amount of practical work done. At least as important is the teacher's attitude to practical work. Thus the following chapter attempts to find out about the teachers' attitude to practical work, as shown by the objectives they have in mind when carrying it out.

GRAPH 2.1 : Distribution of Time Allowance



GRAPH 2.2 : Distribution of No. of Experiments done



Chapter 3

Objectives of Practical Work

The literature shows that little research has been carried out to test the outcomes of laboratory instruction (Johnstone & McCallum 1972), and this has been associated with 'science education not having clearly defined goals of laboratory instruction' (Uricheck 1972). This is confirmed in more recent work by Venkatachelam and Rudolph (1974), who go on to say that there is a general feeling among science educators that some amount of research orientation in laboratory instruction is desirable. They defined five objectives - that the student should

1. Learn some basic laboratory skills and techniques
2. Be able to adapt a skill learned in one context to another laboratory situation
3. Given an experimental problem, be able to recognise the pieces of data that must be collected to solve that problem
4. Design his own experimental approach in an attempt to obtain relevant data
5. Be able to communicate adequately about the purpose, approach, results, and dependability of the experiment

in addition to the laboratory programme serving to motivate the student positively to chemistry.

They then set out to try and achieve these objectives by alternating 'learning cycles - challenge cycles'. The former gave the student experience and background which he then had to put to use in the second part of the cycle. The approach is interesting and valuable, but the extended practical sessions required seem to make it more relevant to Certificate of Sixth Year Studies work, rather than 'O' grade or 'H' grade.

The most extensive survey in the United Kingdom was that by J.F.Kerr carried out in 1961 and published in 1963. This was confined to grammar schools in England and Wales, where the practical work done in Chemistry (of which he was most critical) was old-fashioned, and consisted mainly of qualitative and quantitative analyses. His findings are perhaps of little relevance to the new syllabuses of today except for comparison. However, the rank order found by Kerr for the aims of practical work in English Sixth Form as seen by chemistry teachers is interesting -

1./

1. To encourage accurate observations and careful recording.
2. To elucidate the theoretical work so as to aid comprehension.
3. To be an integral part of the process of finding facts by investigation and arriving at principles.
4. To promote simple commonsense observation and careful recording.
5. To develop manipulative skills.
6. To verify facts and principles already taught.
7. To give training in problem solving.
8. To fit the requirements of practical examinations.
9. To make chemical phenomena more real through actual experience.
10. To arouse and maintain interest in chemistry.

It will be seen that all but two of these objectives could be classified as cognitive (number five is psychomoter and number ten affective).

R.W. West (1972) re-assessed these same objectives using a smaller sample of teachers (from both comprehensive and grammar schools). As might be expected, the rank orders obtained were different from those of the original study, and West discusses these changes in the light of changes in the approach to practical work in England and Wales.

In 1971, Buckley and Kempa published the results of an enquiry into (English) Sixth Form practical work. Teachers' views were obtained on a list of possible objectives for such practical work, by asking the teachers concerned to state whether they agreed that a given objective was a valid one. Most teachers thought that all four objectives offered were important, but there were small differences in teacher responses which led to the following rank order :

1= Development of observational powers
   Ability to interpret experimental data
3. Development of manipulative skills
4. Ability to plan experiments

The results of these enquiries were only fully applicable to England and Wales where Sixth Form practical work tended to be distorted by a terminal practical examination. This is in contrast to the situation in Scotland and with respect to Nuffield 'A' level: in both, practical work and theory can be integrated in the overall development of the course. Thus, while there is common ground between the present investigation and those described above, the different external constraints make direct comparison of dubious value. In any case, little of the above work was devoted/

devoted to an examination of the affect of practical work in the affective domain which was one of the objectives of the present work.

Nuffield Advanced Science (Chemistry) has 15% of its final assessment devoted to practical, and these marks are obtained by a continuous assessment procedure using a minimum of eight experiments. These experiments are used to assess the following: observation, interpretation, planning, manipulative skill, and attitude to practical work. However, the present work sets out to evaluate the practical work itself rather than the pupils' performance in it, and thus Nuffield was of little relevance to the present study (for details see Nuffield Advanced Science (Chemistry) 'Examinations and Assessment' (1972)).

In Scotland, the seven aims of the 1969 syllabus (set out in Chapter 1) were based on those of the 1962 syllabus. The integrated science syllabus (1969) listed objectives as well as aims, but only for years 1 and 2, and is not directly relevant.

More recently, a committee composed mainly of science teachers, under the guidance of H.M.I. A.W. Jeffrey, has drawn up an extensive list of objectives for 'O' and 'H' grade and Certificate of Sixth Year Studies Chemistry (Appendix 3). Some of these objectives are relevant to this investigation on 'H' grade practical work: for example A 14 and 22, B 14 and 15, and much of C (practical skills). However, the author felt that this list of objectives, while relevant and useful, is too long to be presented to pupils or teachers in the form of a survey, and it was thus not used in this form.

The most recent work carried out on practical work in Scotland is that by J. McGuire on Certificate of Sixth Year Studies practical work. He selected possible objectives, and asked both pupils and teachers to decide which of these objectives applied to each experiment carried out in Sixth Year Studies. The pupil rank order of objectives of course practical work in Certificate of Sixth Year Studies chemistry was as follows :-

Illustrating a property of a particular substance or group of substances;

Testing an explanation of chemical behaviour;

Increasing enjoyment of the study of chemistry;

Testing/

Testing a theory or law given in class;
Reinforcing theory learned in class;
Encouraging accurate measurement;
Increasing skill in handling apparatus.

The teachers agreed with this with some differences in rank order.

As with the English work, it was felt that the present study should be more concerned with objectives in the affective domain. A study of individual experiments in terms of both types of objectives could follow the present study.

The writer drew up a preliminary set of such objectives, and visited in all nine principal teachers of Chemistry to discuss them. It was found that most teachers agreed with the objectives, but had little to add to the list. This led to a different approach in subsequent visits; due notice of the reason for the visit was given, and the writer and the other principal teachers attempted to draw up a list of objectives from scratch. While prompting was necessary, this approach was more fruitful, and led to the list of objectives incorporated in the questionnaire shown in Appendix 4. It will be seen that nine objectives are expressed in terms of student behaviour, and two others in terms of organisational advantages of practical work from the teachers' point of view.

This questionnaire (Appendix 4) was circulated to the 130 schools which received the original questionnaire; 92 completed returns were received (71%). Teachers receiving the questionnaire were asked to classify the objectives listed as 'very important', 'fairly important' or 'not important', and were invited to add any objectives not listed in the questionnaire they thought important. Few did, but the following objectives were mentioned by more than one teacher -

(a) the ability to carry out written/oral instructions;
(b) development of self-confidence;
(c) various ideas about group dynamics,
    e.g. (i) the ability to co-operate and organise practical work within a group;
    (ii) that discussion within a group aids the understanding of the theory behind the experiment.

As/

As far as part C of the questionnaire (Appendix 4) is concerned, 57 teachers (62%) thought that 'H' grade practical work did form part of a logical progression from 'O' grade, through 'H' grade to Certificate of Sixth Year Studies, and thought that this was marked by the practical work (a) becoming more quantitative

(b) using more sophisticated apparatus

(c) requiring less supervision

(d) requiring more manipulation of the results concerned.

The results of the statistical survey are shown in graphical form in graph 3.1. It will be seen that the trends in 'not important' and 'fairly important' are similar, and are almost perfectly mirrored by 'very important'. It thus seems that teachers are effectively using two categories; if an objective is not rated 'very important', then some teachers rate it fairly important, others not important, but the latter two categories really are one and the same. This is shown in graph 3.2.

The most highly rated objectives are that the pupils should

A2 realise that chemical theory derives from observation

A4 be able to draw justifiable conclusions from personal observation

A8 be able to work safely and tidily in the laboratory.

The objectives with the lowest ratings are that pupils should

A5 develop a sense of curiosity

B1 (from teachers' viewpoint) practical work allows small group teaching

A6 have gained a sense of achievement as a result of making accurate and reproducible experimental observations

A1 become enthusiastic for the subject

A3 display initiativeness and resourcefulness in tackling practical problems.

Omitting B1, if one were looking for adjectives to describe the two sets of objectives, one might label the highly rated objectives 'cognitive' and the poorly rated objectives 'affective'. Is this a little disappointing, with all the publicity given to, and the importance made of, objectives in the affective domain?

In order to examine this further, the schools were subdivided into thirds with respect to the number of experiments carried out, and graphs corresponding/

corresponding to graph 3.2 were drawn for the top third and the bottom third: these appear as graphs 3.3 and 3.4 respectively. It will be seen that the two sets of teachers view some objectives very differently. The three with the most dramatic differences are three of the four 'affective objectives', which have low ratings in the bottom third, and much higher ratings in the top third, viz. that the pupil should

A5 develop a sense of curiosity

A1 become enthusiastic for the subject

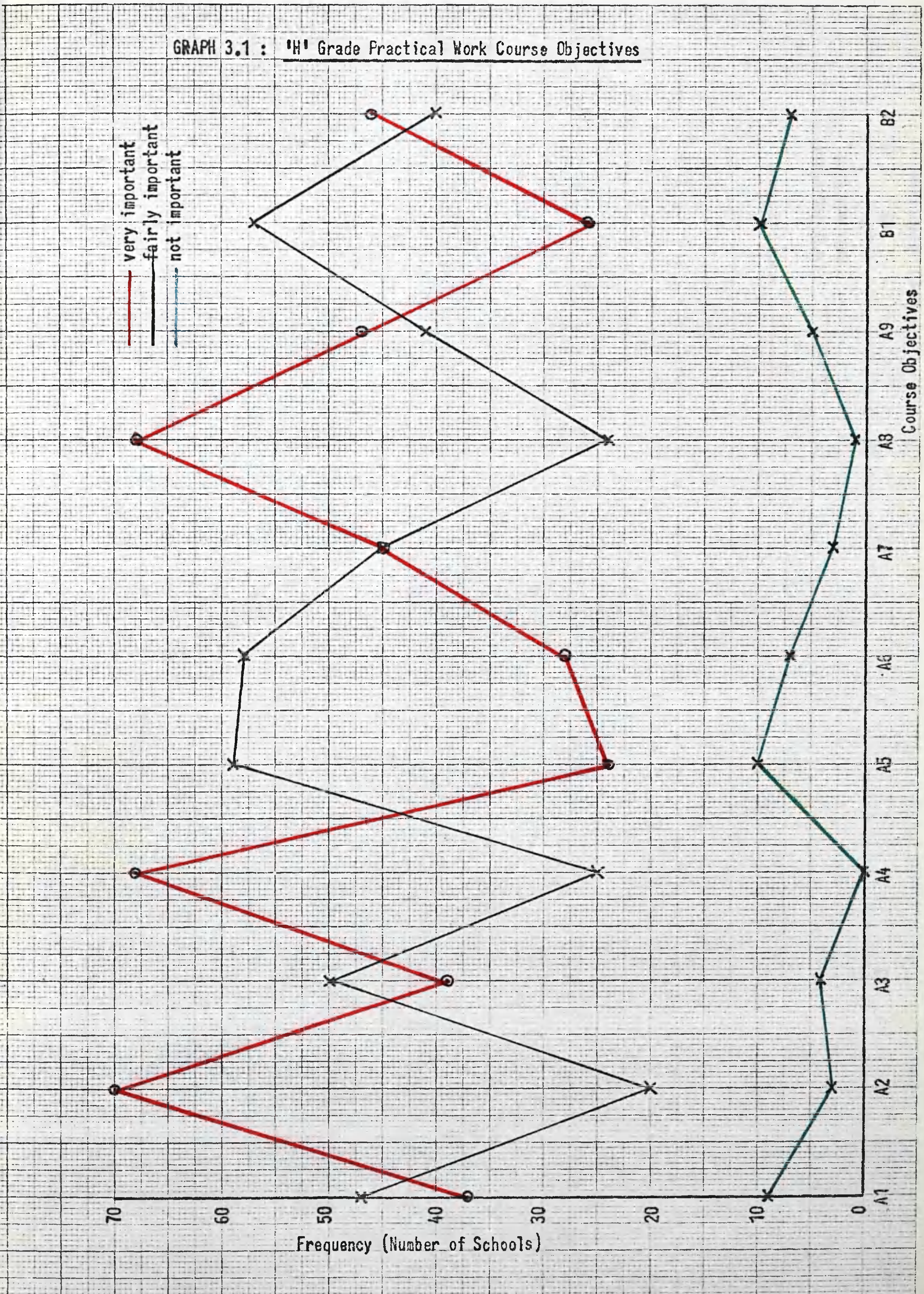
A3 display initiativeness and resourcefulness in tackling practical problems.

It seems - as suggested at the end of the previous chapter - that the personality of the teacher has a large effect on practical work. Perhaps it is a teacher who is interested in his pupils as individuals, and in their reaction to practical work, who does more practical work than most. To greatly oversimplify, it is the pupil-centred rather than the subject-centred teacher who sees most point in practical work and thus does more of it.

Thus a practical examination - which could well force more practical work to be done in the small proportion of schools which do insufficient - might not change the situation in the desired way, because it is unlikely in itself to change the teachers' objectives. If one believes in affective objectives for practical work, then these are more likely to be achieved by teacher education rather than by an edict that practical work be examined.

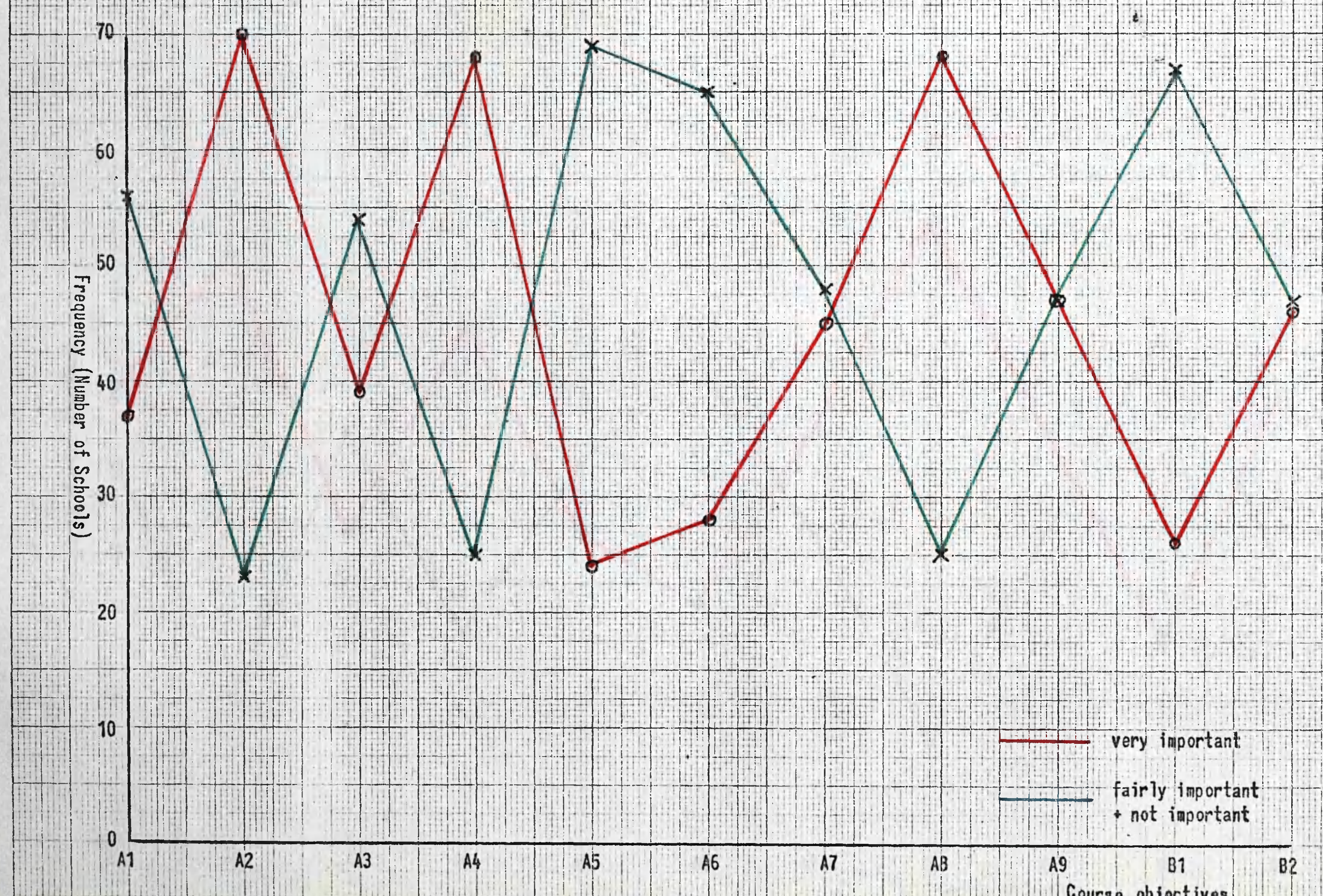
CONCLUSION

The results described in the chapter indicate that the approach to practical work depends upon the personality of the teacher, and that the introduction of any practical assessment would have to be done with the greatest of care, because such assessment is unlikely in itself to affect the teacher's objectives and the way practical work is done, only the quantity of it done, which seems less important to the author.

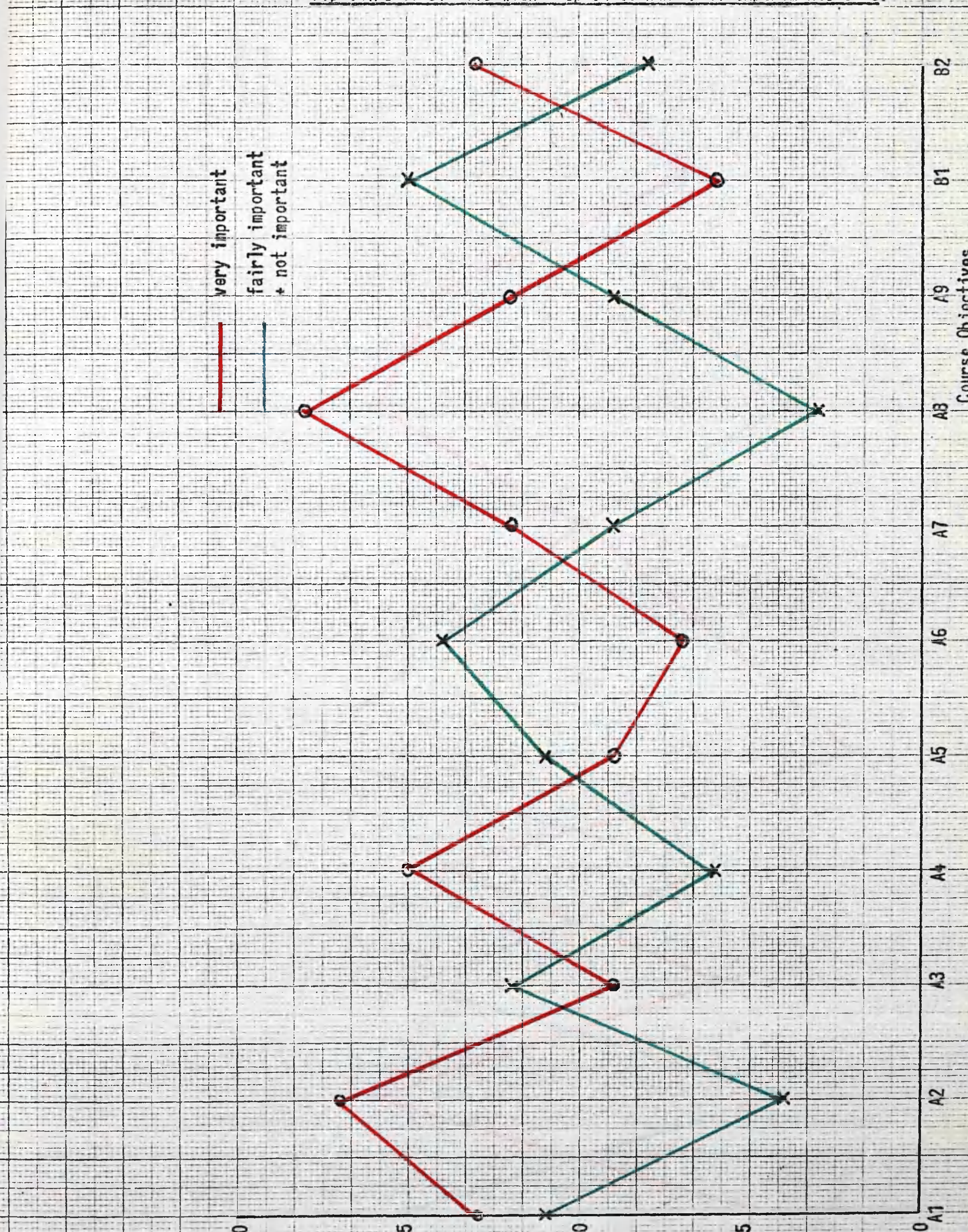


GRAPH 3.1 : 'H' Grade Practical Work Course Objectives

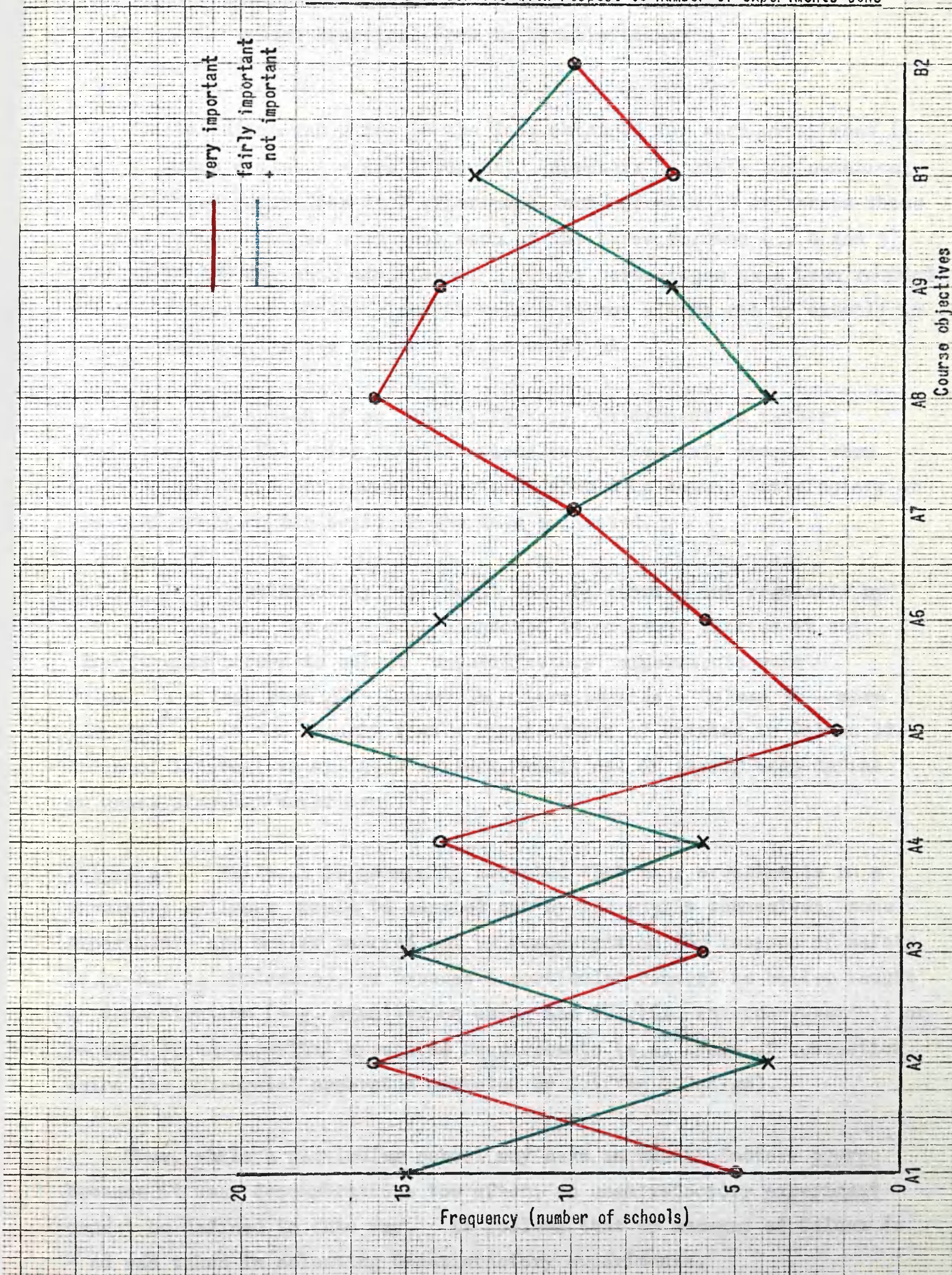
GRAPH 3.2 : 'H' Grade Practical Work Course Objectives



GRAPH 3.3 : 'H' Grade Practical Work Course Objectives - Top third of schools with respect to number of experiments done.



GRAPH 3.4 : 'H' Grade Practical Work Course Objectives - Bottom third of schools with respect to number of experiments done



*See footnote on next page.

Chapter 4

The Identification of Areas of the Syllabus where Practical Work is Unsatisfactory

Consideration was given to the data obtained for each experiment in the 'H' grade syllabus - see Appendix: Appendix 5A gives the numerical values (frequencies) for each experiment, and appendix 5B expresses these figures as percentages such that each of the three columns (3, 4 and 5) adds up to 100 for each experiment. (These percentages have been rounded off to the nearest integer, and therefore do not always add up exactly to 100). Graph 4.1 shows column 3 of appendix 5A.

While the notion of an unsatisfactory experiment is rather subjective, the following considerations were taken into account when deciding whether a particular experiment should be deemed satisfactory or unsatisfactory on the basis of the data collected.

<u>Column 3</u> A satisfactory experiment must be carried out regularly by most schools, and few must have abandoned it or never carried it out. (The figures chosen to select unsatisfactory experiments were - Column 3a - less than 40; Column 3b - more than 4; Column 3c - more than 19)*. It was thought that a large number of entries in Column 3d, while of interest to syllabus writers, would not of itself help define an unsatisfactory experiment.

<u>Column 4</u> While it is generally accepted that many experiments in a chemistry syllabus should be carried out by the pupils themselves, some experiments are better carried out by demonstration for reasons of safety (e.g. H_2/Cl_2 explosion), or because a particular concept is better taught by demonstration (e.g. equilibrium using the ICl/ICl_3 interconversion), or because of uneconomical apparatus requirements (e.g. heats of combustion using the commercial apparatus marketed by Griffen & George).

Thus, while a particular school may have an unsatisfactory <u>course</u> because it uses demonstrations too often, an unsatisfactory <u>experiment</u> cannot be defined in this way. It follows that no account of Column 4a - 4d was taken in selecting unsatisfactory experiments.

*See footnote on next page.

Column 5   Most schools should find a satisfactory experiment very useful or fairly useful, and few should find it of little use. (The figures chosen arbitrarily to select unsatisfactory experiments were:- Column 5a - less than 30; Column 5b - greater than 17; Column 5c - greater than 4*).

These criteria in columns 3 and 5, point to the following experiments being less than completely satisfactory :-

10	Principles of the mass spectrometer
20	Analogy experiments on nuclear rays
40	Finding gas densities→ 22.4 litres
60	Heats of combustion
70	Heats of solution
120	None in syllabus, but literature work on elements 1-20 encouraged
131-133	Compounds of elements 1-20 (oxides, chlorides and hydrides)
140	Making models of NaCl and CsCl structures
151-153	Alkali metals
250	Pyrophoric lead or iron
290	Hydrogen/Chlorine explosion
320	ICl/ICl_3 equilibrium
400	Addition reactions of alkynes
410	Oxidation of ethyne to ethanal
420	Physical properties of benzene

The following comments on these experiments are based upon the author's experience and upon the comments made on the experiments by teachers returning the original questionnaire.

Section P: Atoms, Molecules and the Mole

010 Principles of Mass Spectrometer

In the 1969 revision, this concept was taken into 'O' grade, and there seems little point in repetition at 'H' grade. In any case, it is possible that many teachers would not call the use of a model or film "practical work", and this could account for the poor showing of this experiment. However, it would appear worthwhile for pupils to examine fragmentation patterns obtained from molecules; while this is mentioned in the syllabus, it is not/

* Footnote While the choice of these particular numerical values is somewhat arbitrary, they were chosen (insofar as this is possible) to lie at a break in the sequence of number and so as to select a reasonable number of experiments as unsatisfactory. This was a subjective judgement made by the author in the light of his experience in teaching the practical work concerned.

not categorised as practical work, and no information was obtained from schools on it. It is, however, unlikely that many schools do this until Certificate of Sixth Year Studies stage.

020 Analogy Experiments on Nuclear Rays (and half-life)

The reason for the poor showing could well be that - as the syllabus says - much of this work will have been covered in Physics. Also, some schools carry out some of this work in section P3 in Form II, as was intended when the original syllabus was written.

040 Finding Gas Densities to find the Volume of one Mole of Gas

The main problem here seems to be getting a flask of sufficient size to contain enough gas for accurate determination of the mass of the gas. The other problem was allowing for the mass of air in the flask. These problems were sufficient for one teacher to declare in exasperation that the experiment was "a waste of time".

Details of a modified version of this experiment have been written up and circulated to schools: see Appendix 7.

<u>Section Q</u> : <u>Bonding and the Periodic Table</u>

It will be seen that many of the experiments deemed unsatisfactory appear in this section of the syllabus, which was criticised by teachers as being (variously) fragmented and difficult to teach, vague, trivial in places. As already discussed in chapter two, this section seems the least satisfactory from the point of view that many teachers find it necessary to split it up and teach different sub-sections throughout the session, perhaps because they think that their pupils can only take this material in small doses.

060 Heats of Combustion

070 Heats of Solution

Both these experiments were introduced into the 1969 review of the syllabus, as neither was specifically mentioned in the original (1962) syllabus; it appears that many classes carry out the former experiment (and Heats of Neutralisation), and then decide that it is not necessary to do the Heats of Solution experiment.

Both these experiments have been written up and circulated to schools: see Appendix 7.

120 Under suggested practical work the syllabus comments:- "Throughout this section pupils should be encouraged to gather data from available literature. This activity is regarded as valuable 'practical' work at this stage." Few teachers claimed to do this, so few in fact that it is possible that teachers when filling in the questionnaire did not read this guide line, and thus did not realise what is meant by 'practical' here. Even so, this section and the next section of the syllabus (section Q3 and Q4) seem less than satisfactory.

131-133 The syllabus is not very specific, and - from conversations with teachers - the real situation is not as bad as would appear from the questionnaire. Some schools make a host of compounds, and it is difficult to believe that so many have "never done" these experiments.

Compounds made included silane (36% of schools returning the questionnaire); phosphine (33%); aluminium chloride (29%); Column I and/or II oxides (22%); Column I and/or II chlorides (17%); aluminium oxide (15%).

It would appear that more specific guidance is required as to what data to gather (Q3), and what compounds to make (Q4) if the practical work in this section is to be successful.

A Sixth Former, during his Sixth Year Studies project work, has tried making many of the compounds possible in Q4 in an attempt to find out which are safe, interesting and suitable for class use; wherever possible he tried direct combination of the elements concerned, and the results of his investigation are included in Appendix 8.

140 Building models of CsCl and NaCl

It is at first sight surprising that so many teachers find this less than "very useful", but this may be because the schools concerned do this as a demonstration. The author's experience is that this is a most interesting and useful experiment if pupils are introduced gently to the concepts, and are then allowed to build up the models themselves.

Details of how this can be done simply and cheaply have been written up and circulated to schools; see Appendix 7.

151-153 Alkali Metals

There is no suggested practical work (other than building the NaCl and CsCl lattices). While it is possible that much of the practical work which could be done is done earlier in the course only, a detailed write-up, with specific experimental work mentioned, would appear to be worthwhile.

SECTION R : Chemical Reactions

250 Pyrophoric Iron or Lead

A number of teachers have mentioned the possible health hazard in dealing with the finely divided lead, but in any case this is a minor experiment, one of a number of possible alternatives, and there seems no need for concern about it. However, for safety reasons, the lead experiment might well be deleted from the syllabus. A brief note on how the pyrophoric elements are prepared would also be useful.

290 Hydrogen/Chlorine Explosion

This experiment produced the widest divergence of teachers' comments, varying from "can never get it to work", to "a highlight that I look forward to each year".

With proper safety precautions, there should be little doubt about safety; the main problem lies in securing a sufficiently powerful source of light. The author has tried photoflood bulbs, electronic flash (with its high U.V. content) and flash bulbs, but has had success only with the more powerful flash bulbs (PF5 or larger).

This experiment has been written up and circulated to schools: see Appendix 7.

320 ICl/ICl_3 Equilibrium

This is one of the most easily demonstrated chemical equilibrium situations, and it is surprising that many teachers have never tried it. Teachers' comments cast little light on the situation, although one teacher said it was a dangerous experiment, and had exploded the previous year.

This experiment has been written up and circulated to schools: see Appendix 7.

Section S : Carbon Compounds

400 Addition Reactions of Alkynes

410 Oxidation of Ethyne to Ethanal

Neither of these experiments appeared in the original syllabus, but this cannot explain their poor showing. Perhaps the former experiment adds little to a pupil's knowledge of unsaturation, but it does extend the concept and may be worth doing. However, the latter experiment is rather complex, seems to have little connection with the rest of the syllabus, and could well be omitted.

420 Physical Properties of Benzene

Many teachers omit this experiment because of the toxic properties of benzene but - even if benzene were harmless - the experiments suggested (burning, M.P., B.P.) are so simple that they would be more appropriate to Form I. This section is a relic from the original syllabus which included nitration of benzene, reduction of nitrobenzene to aniline, and the importance of aniline in making useful compounds (in practice, this often meant making dyestuffs).

It would appear that this section(S3) should be omitted altogether, or dealt with in an extended manner either in 'H' grade or in Sixth Year Studies. There seems little point in finding that benzene is 'saturated' when no explanation is intended.

A number of other experiments were devised, written up and circulated to schools. These were :-

Hess's Law (no number, because not in syllabus)

461-462 Properties of Phenol

481-482 Reactions of Amines

490 and 503 } Oxidation of alcohols to aldehydes

These are detailed in Appendix 7.

A number of clock reactions (No.280) were also examined by a Sixth Form pupil as his Certificate of Sixth Year Studies chemistry project. The syllabus suggests clock reactions as the 'simplest system' for the study of 'reaction mechanism and effect of concentration' (section R2), and goes on to say that they can also be used 'to examine the effect of temperature and catalysts'. It is not intended that actual rates should be measured, but that the time required for a reaction to proceed to a given point be measured, and there is no need for pupils to know the actual reactions involved.

If one thing emerges clearly from a study of this work (reported in Appendix 9), it is that the clock reactions studied are complex, and are not a good means for demonstrating that doubling the concentration of one of the reactants will double the number of effective collisions and thus double the reaction rate. There are many simple reactions available which show the effect of change of concentration, change of temperature, and of a catalyst (examples in Appendix 9B).

Why, then, have clock reactions remained in the syllabus? In the writer's opinion, the only reason is that pupils enjoy them. However, pupils enjoy the alternative experiments just as much, and it would appear that clock reactions - if retained at all - should merely be an interesting sideline, done for their own sake, and that the alternative experiments should be carried out when the collision theory is being taught.

CONCLUSION

Areas of practical work have been identified which are unsatisfactory, because they are never done, or have been abandoned, or are found not very useful, by many schools. An attempt was made to fill some of these gaps by producing eleven experiments, and circulating details of these experiments to all schools who (when told about the work) asked to participate. Teachers at these schools were asked to carry out each experiment at the normal time in the school year, and to report back on each experiment as it was done (see next chapter for details). This meant that quite some time would elapse before a statistically significant number of reports on each experiment could be received. As it turned out, a full year was to pass before the returns were analysed, and even then - with disruption in schools due to an industrial dispute - the number of returns was disappointing (again see next chapter for details).

Further Analysis of Data on Individual Experiments

During this waiting time, the results from the first questionnaire were analysed in greater depth, in an attempt to glean further information about each experiment in the 'H' grade syllabus. The results presented so far - in for example Appendix 5 - give no indication as to any interrelationships between (for example) the columns representing method and usefulness. Thus a particular experiment might show up in a different light if, say, the methods used were looked at only for those schools which found the experiment 'very useful' rather than for all schools which carried out the experiment.

In order to do this, each experiment from each school was examined with regard to columns 3, 4 and 5 in the first questionnaire (Appendix 5). Each experiment is given a 3 digit code a,b,c, the first digit 'a' referring to column 3, the second 'b' to column 4 and the third 'c' to column 5 as follows.

1st digit : 1 means experiment performed regularly
2 means experiment was done but now abandoned
3 means experiment never done
4 means experiment done earlier in course only

2nd digit (method) : 1 means pupil
2 means stations
3 means demonstration
4 means assisted demonstration

3rd digit (usefulness) : 1 means very useful
2 means fairly useful
3 means of little use

Thus (1, 1, 1) would specify an experiment as performed regularly, pupil method, very useful.

It was decided to examine the effect of one column on one other column independent of the entry in the third column. To this end, three lists were prepared :

(i) The responses for the frequency of use of each experiment was related to the method by which it was done. This was done by making up a list of all possible permutations of (a, b, c), except that the entry (which must be present) for usefulness (c) was ignored. This list appears as Appendix 6A, and part is shown graphically in graph 4.2.

(ii) Similarly, the frequency of use was related to the usefulness by listing all possible permutations of (a, b, c), but ignoring the entry for (b) (method). This list appears as Appendix 6B and in part as graph 4.3.

(iii) Similarly, method was related to usefulness by listing all possible permutations of (a,b,c), but ignoring the entry for (a) (frequency of use). This list appears as Appendix 6C and in part as graph 4.4.

Consider graph 4.2. Experiments not carried out regularly by many schools show up by a low total height in the histogram for that experiment. Let us assume that an experiment is unsatisfactory if it is carried out by less than two-thirds of the sample (78) i.e. by less than 52 schools. A line has been drawn across at this level, and the experiments thus deemed unsatisfactory (where the total column height is less than this level) are listed in the table following.

Once/

Once syllabus writers have the whole syllabus in a good teaching order (see end of chapter 2), they can then examine this chart so that each section has a good 'mix' of practical methods, with no doubt a preponderance of pupil experiments. Syllabus sections or subsections with little good practical (e.g. section P experiments 10-40, or Q 3-5 experiments 120 -153) should be looked at particularly critically, and if no good practical work is available, consideration should be given to deleting or shortening these sections.

Consider now graph 4.3. Here experiments done regularly are examined in terms of their usefulness. Total peak heights are the same as graph 4.2, so here the interest lies in the height of the (1,-,1) i.e. 'very useful' column. Only 20 experiments lie above the two-thirds line used in the previous graph: this would mean that the remaining 42 would be 'unsatisfactory' - too high a figure, so let us adopt a lower arbitrary limit: that half the schools (39) should do the experiment regularly and find it useful for the experiment to be deemed satisfactory. Once again, the unsatisfactory experiments are immediately evident, and again these are listed in the following table.

Finally, consider graph 4.4. This shows the method used for all experiments which are found to be very useful. The vast preponderance of pupil experiment is evident. The definition of a satisfactory experiment used here is that it should be carried out (independent of method) by at least half the schools (39), as this leads to about all the same number of experiments being designated unsatisfactory as in the two previous cases. Again, the following table lists these.

Tabulation of unsatisfactory practical work - as shown by analysis of graphs 4.2, 4.3 and 4.4

Experiment Number	Title of Experiment		Graph No. 4.2	4.3	4.4
10	Principle of Mass Spectrometer		x	x	x
20	Analogy experiments on nuclear rays		x	x	x
40	Molar Volume of Gases			x	x
60	Heats of Combustion			x	x
70	Heats of Solution		x	x	x
110	Measuring E.M.F. of Cells			x	
120	Elements 1 - 20		x	x	x
131			x	x	x
132	Compounds of elements 1 - 20		x	x	x
133			x	x	x
140	Models of NaCl and CsCl		x	x	x
151			x	x	x
152	Alkali metals		x	x	x
153			x	x	x
160		redox experiments	x	x	x
180	Halogens	stability of hydrides	x	x	x
190		reactions with metals	x	x	x
210	Factors	preliminary survey	x	x	x
250	affecting	pyrophoric Pb or Fe	x	x	x
260	speed of	light on AgX		x	x
270	reactions	$Al/I_2 + H_2O$	x	x	
290	$H_2 - Cl_2$ explosion		x	x	x
310	Salt hydrolysis		x	x	x
320	$ICl - ICl_3$ equilibrium		x	x	x
330	Acetic acid ionisation		x	x	x
360	Cracking of hydrocarbons		x	x	x
410	Oxidation of ethyne to ethanal		x	x	x
420	Physical properties of benzene		x	x	x
450	Build model of ethanol		x		
470	Hydrolysis of esters		x	x	
490	Preparation of carbonyl compounds		x		

Comparison of this list of unsatisfactory experiments with the list derived at the beginning of this chapter shows that they are much the same. If two entries in the above table are taken as designating an experiment as unsatisfactory, only one experiment in the original list does not appear in the new list - number 400 (addition reaction of alkynes). However, the different arbitrary limits set when drawing up both lists have led to the following experiments showing up as unsatisfactory only in the second list :

Section Q6	The Halogens - experiment	160	redox reactions
		180	stability of hydrides
		190	reactions with metals

It is surprising that these show up badly, as the section of the syllabus was originally in 'O' grade in an extended form. Perhaps this is due to practical work not being specified in detail - merely 'simple test-tube experiments to illustrate these points' - and a syllabus rewrite could easily rectify this.

Section R1 factors affecting speed of reaction.

Experiment 210: preliminary survey. Teachers may well decide not to 'steal their own thunder', and do no preliminary survey, but cover all the points needed in subsequent work. This is a matter of teaching technique, and means little as far as the syllabus is concerned.

Experiment 260: effect of light on silver halides. This just fails to meet the criteria, and is one of a number of experiments in a longish list in the syllabus. Even so, it is so simple for pupils to do (providing the sun is shining!) that it is a pity that more schools do not carry it out. Perhaps some schools do an alternative experiment using light to get a reaction going.

Experiment 270: $Al/I_2 + H_2O$. Again this just fails to meet the criteria. Perhaps the experiment, while not done earlier in the course (i.e. the certificate course) is done in years 1 or 2; or perhaps lack of fume cupboards in some schools depressed the figures for this spectacular experiment.

Section R6 No.310: salt hydrolysis

While a number of schools do this earlier in the course only, this is insufficient to explain the poor showing. Perhaps the syllabus is responsible, as no experimental work is laid down: in fact, it suggests re-interpretation of data obtained earlier in the course.

Section R7 No.330: acetic acid ionisation

This experiment just fails to meet the criteria, and - if the few schools who do the experiment earlier in the course only are included - it just about meets the criteria. The syllabus, too, is vague and does not specify this experiment in detail.

Section S2 No.360: cracking of hydrocarbons

The only reason for the experiment appearing here is that it is done by many schools earlier in the course only.

Section 4 No.470: ester formation and hydrolysis

This just fails the criteria, and if the schools who do this earlier in the course only are taken into account, the experiment is satisfactory. However, the questionnaire did not distinguish between the schools which made the esters, those which hydrolised them, and those which did both. Any further work should distinguish these.

With hindsight, it might have been worthwhile to have tried to formulate and circulate details of the three experiments in Q6 (The Halogens) and experiment 260 (effect of light on silver halides - or a substitute for it). However, the experimental write-ups that were circulated did cover all the really unsatisfactory experiments that the author considered necessary. The next chapter shows how the success (or otherwise) of these was evaluated.

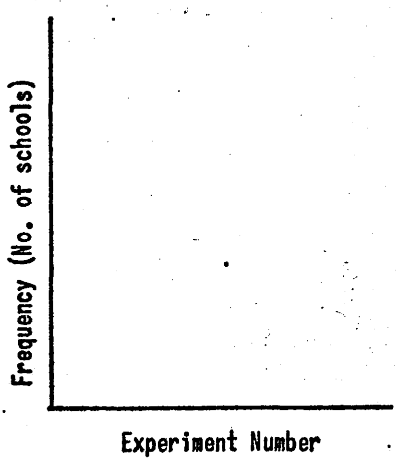
Conclusion

Criteria have been developed for identifying the areas of practical work that teachers find unsatisfactory: these areas are identified in the text.

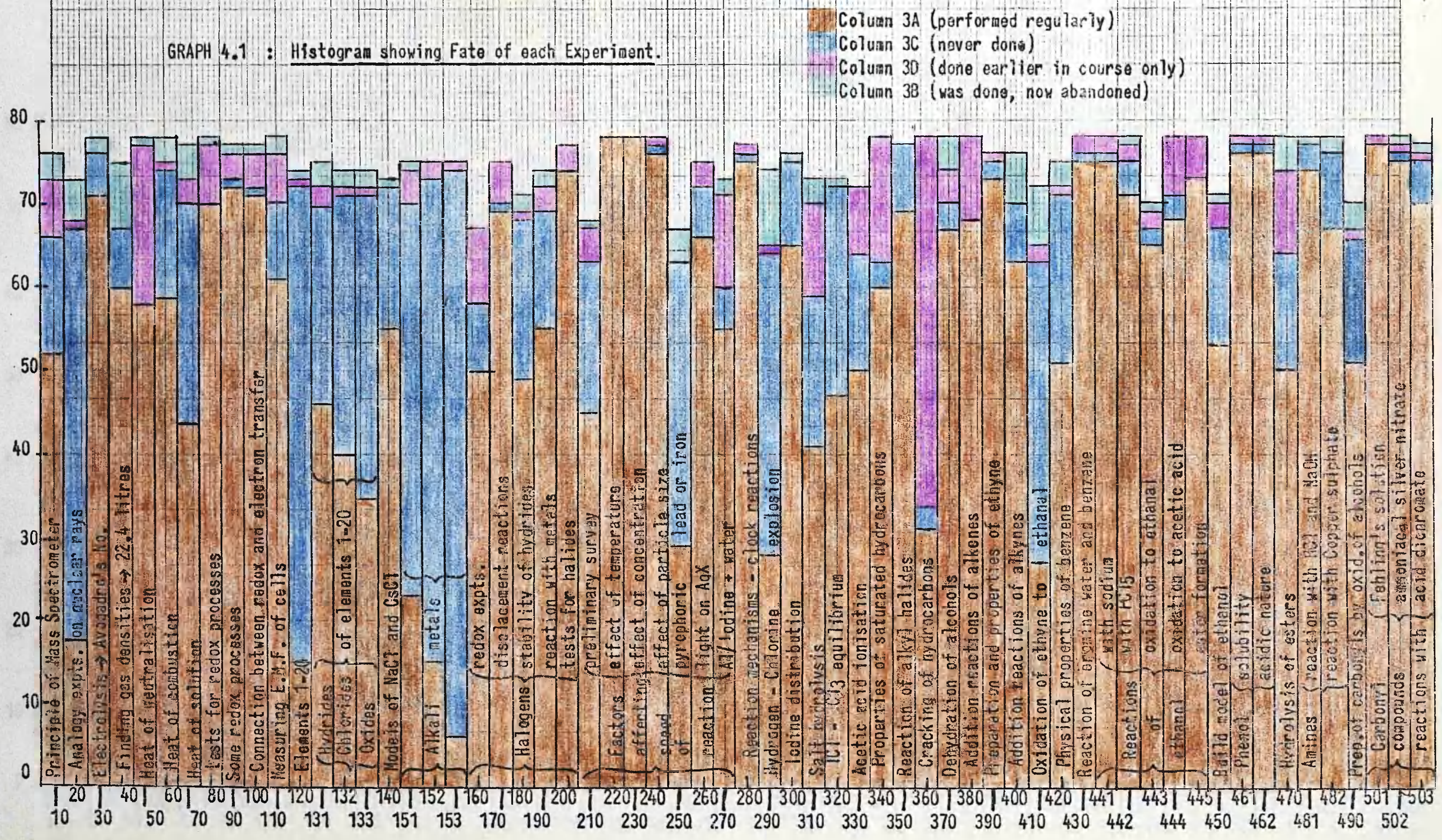
This survey shows only one side of the picture, and there are likely to be other areas of the syllabus which teachers find satisfactory, but pupils do not. Some of the standard organic work, such as reactions of alcohols with sodium and with phosphorus pentachloride, could fall into this category. Further work on this would be interesting and valuable.

Graphs 4.1 to 4.4

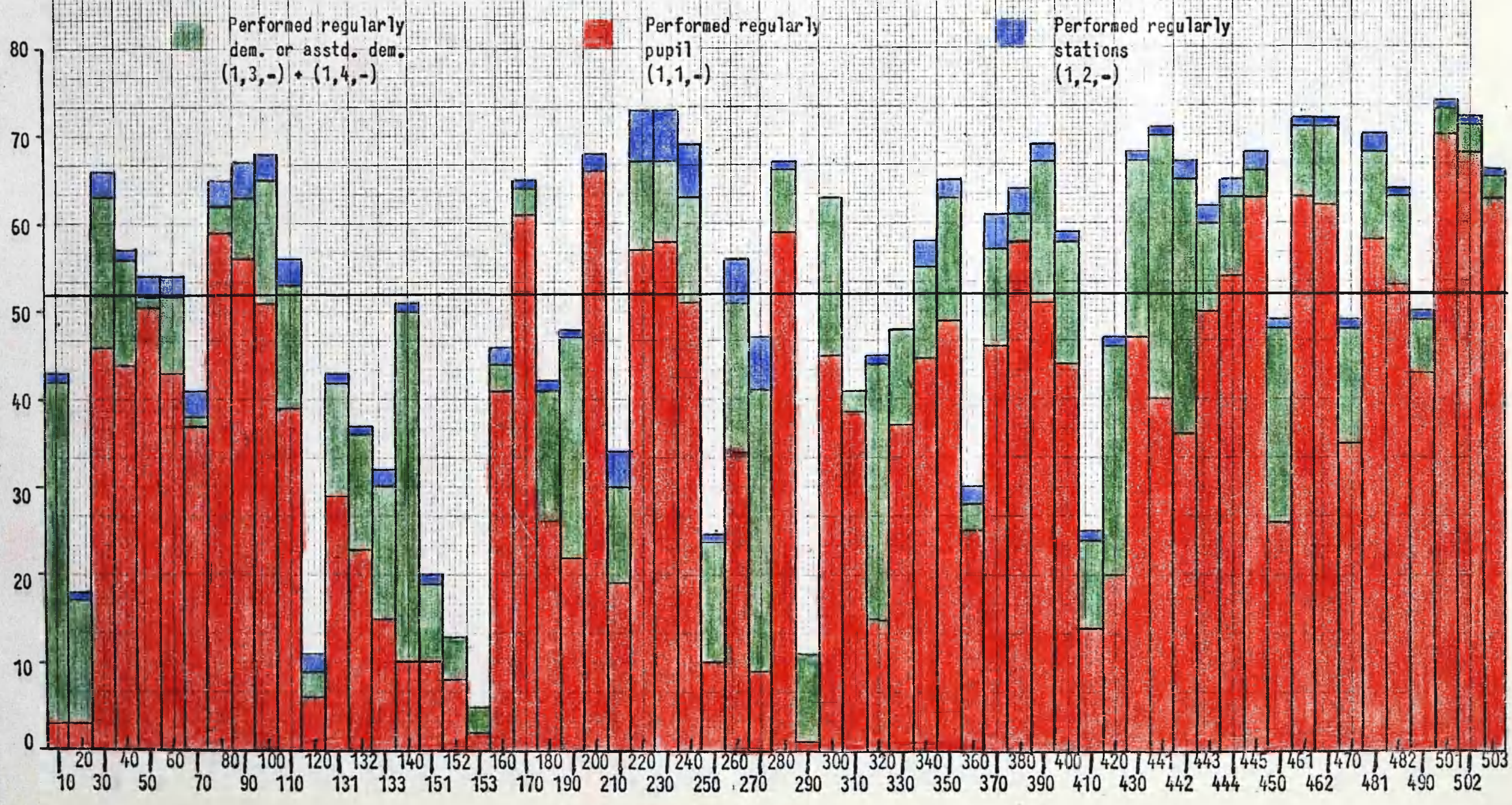
have axes as follows



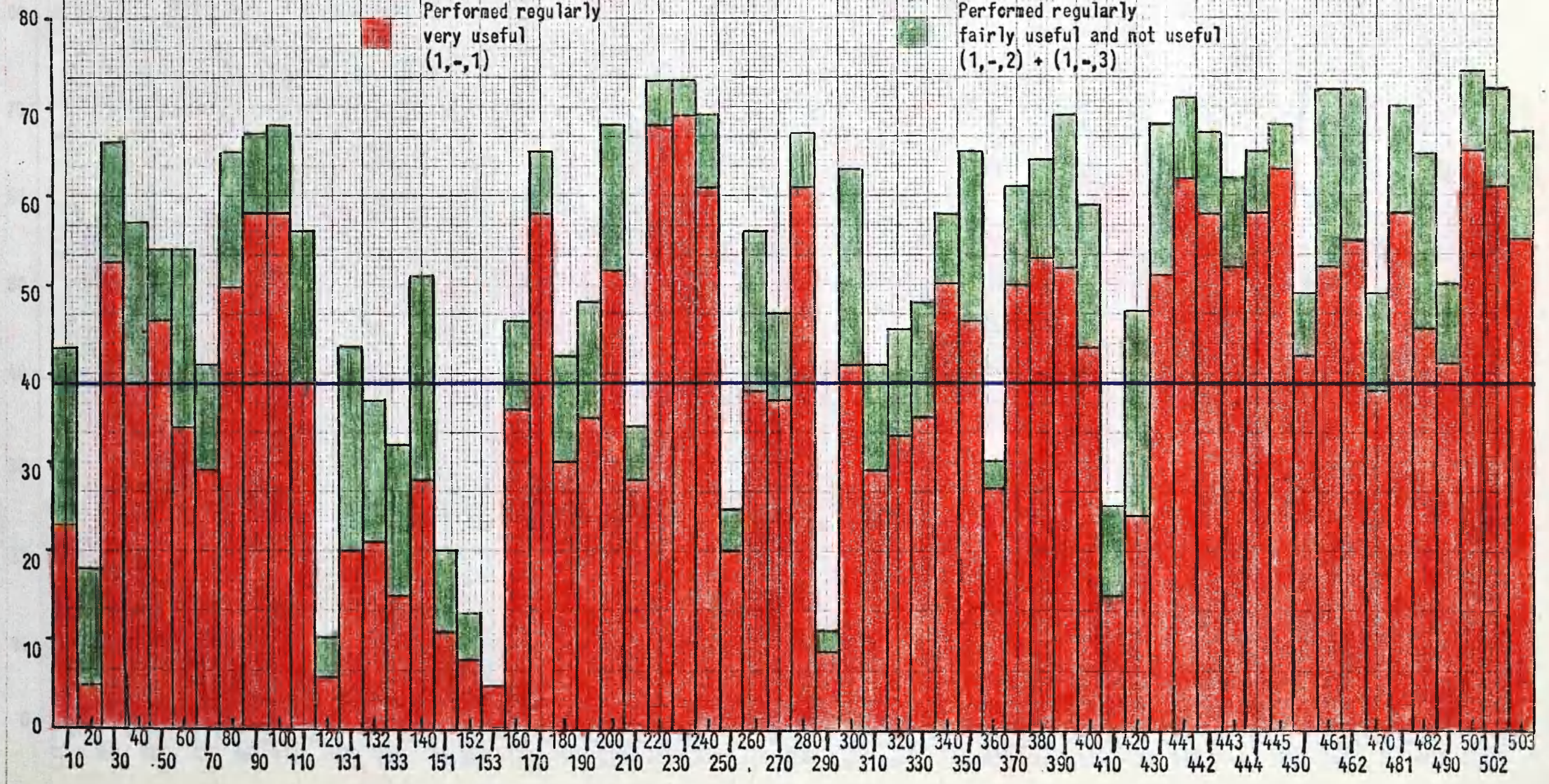
GRAPH 4.1 : Histogram showing Fate of each Experiment.

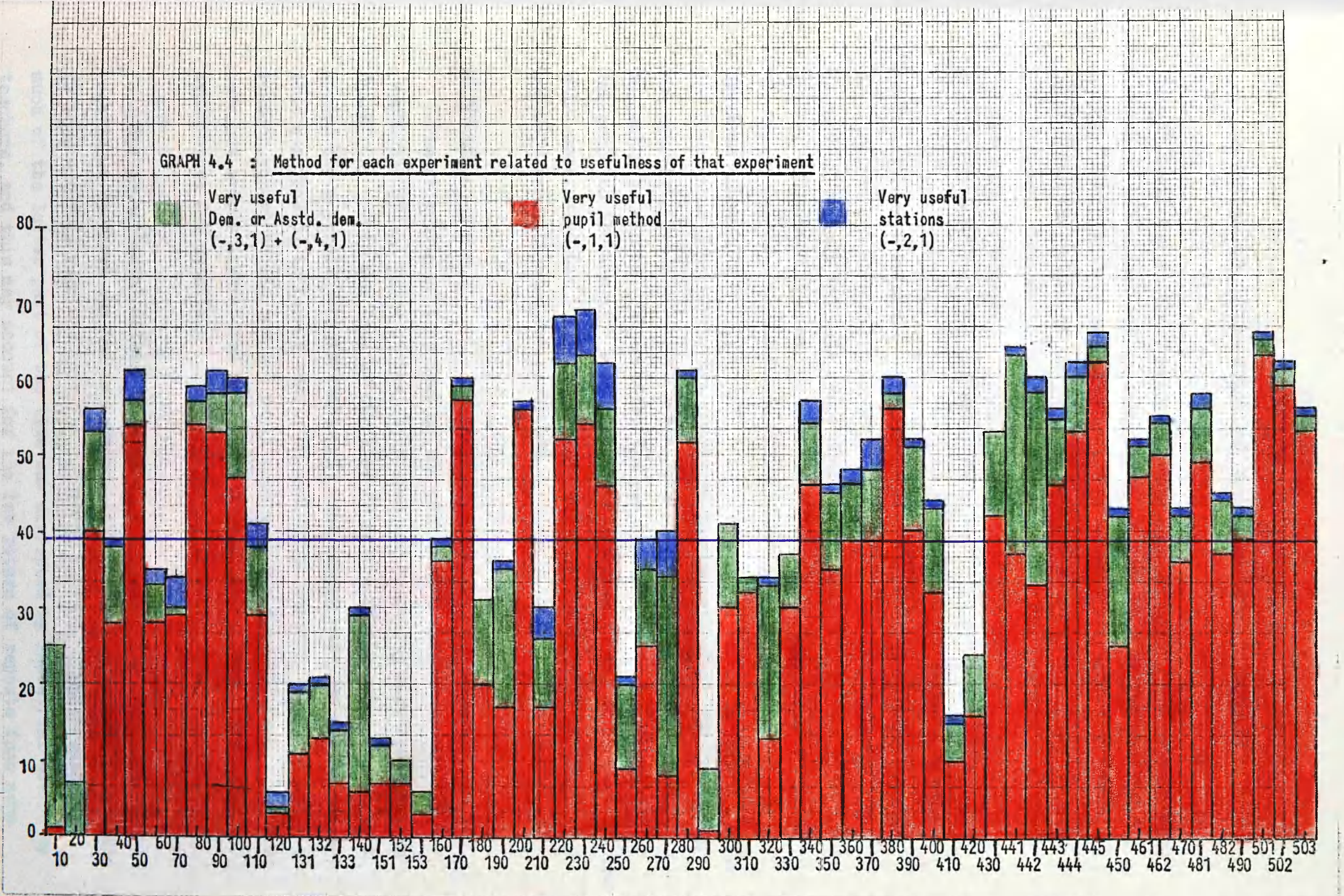


GRAPH 4.2 : Frequency of use of each Expt. related to the Method by which each is done



GRAPH 4.3 : Frequency of use related to usefulness for each experiment





GRAPH 4.4 : Method for each experiment related to usefulness of that experiment

Chapter 5

An Assessment of the Practical Work circulated to Schools

As described in the previous chapter, the following experiments were written up and circulated to schools, in an endeavour to improve the practical work done in schools,

1. Finding the volume of one mole of various gases
2. Heats of solution
3. Heats of combustion
4. Explosion of hydrogen and chlorine
5. Reactions of phenol
6. Reactions of amines
7. Alcohols and carbonyl compounds
8. Models of NaCl and CsCl structures
9. $ICl - ICl_3$ equilibrium
10. Hess's Law 1
11. Hess's Law 2

Appendix 7 shows what was sent to schools.

The first nine experiments are specified in the syllabus; the remaining two are specified for Certificate of Sixth Year Studies, but should logically be carried out in class 5 - see Appendix 7, page 96.
Reference to the appendix shows that some experiments had pupil instructions only, some notes for the teacher only, and some both. All except No.4 and No.9 were intended for pupil use.

Objective

The objective of this part of the work was to assess the above practical work in terms of the objectives for practical work developed in Chapter 2. This was done by circulating copies of the experimental work listed above to all schools wishing it, and asking both the pupils and the teachers to fill in report sheets on individual experiments. In all 113 teacher report sheets and 665 pupil report sheets were returned, but these were not evenly distributed over all the experiments (see individual experiments for details)

The experimental details were sent out in late 1973* and - as schools were asked to carry out the experiments at the normal time that they would do them - a full year was left for returns to be made. Unfortunately, much of the latter part of the time was disrupted by industrial action by teachers, and this may account for the low return of reports from some experiments.

*except No.9 - sent out in September 1974.

The Report Sheets

(a) Teacher (p.51): the objectives have identical wording to those used in the second questionnaire (Appendix 4, discussed in Chapter 2): those used to set up a list of objectives for the 'H' grade course practical work.

(b) Pupil (p.52): it was felt necessary to change the wording on the pupil report forms, so as to make sure that they would be fully understood by all pupils. Comparison of the two report sheets will show the changes made: numbers 1-7 inclusive have similar objectives reworded; numbers 9 and 11 (teacher) correspond to numbers 8 and 9(pupil) respectively; numbers 8 and 10 (teacher) had no corresponding pupil objective.

For the remainder of this chapter, the objective numbers referred to will be those of the teacher report sheet unless stated otherwise.

Results and Discussion

The results for each experiment are given in Appendix 10. The relatively small number of returns makes detailed statistical analysis of dubious value, and so this was not done; graphical methods were used instead.

A. Evaluation of the Eleven Experiments as a Whole

1. Comparison of the two sets of Teacher Objectives

Graph 5.11 shows the plot of three different frequencies. Consider for the moment only two of these - the two sets of teacher objectives, and the relationship between them. These two sets are

(a) the course objectives developed in chapter three
(b) the sums of the objectives for the eleven experiments circulated to schools and listed at the beginning of this chapter.

These two graphs are similar. There are differences, particularly in objectives 1, 5, 7 and 8 (where the sum of the experiments is less than what teachers think the course should be); however, these differences are not large, and the eleven experiments taken as a whole do meet the course objectives reasonably well.

A/

TEACHER REPORT SHEET ON 'H' GRADE PRACTICAL WORK.

Please tick the statements you think apply to <u>each</u> experiment completed by your pupils.

NAME :   SCHOOL :

Title of Experiment :

As a result of the experiment, pupils should –	very important	fairly important	not important
1. Become enthusiastic for the subject			
2. Realise that chemical theory derives from observation.			
3. Display initiative and resourcefulness in tackling practical problems			
4. Be able to draw justifiable conclusions from personal observations			
5. Develop a sense of curiosity			
6. Have gained a sense of achievement as a result of making accurate and reproducible experimental observations			
7. Have acquired skills and practical techniques			
8. Be able to work safely and tidily in the laboratory			
9. Realise that there are limitations in accuracy inherent in every experiment			

The experiments also –

10. Allowed small group teaching			
11. Allowed the pupil to digest new ideas and concepts by seeing them from a less theoretical engle			

PUPIL REPORT SHEET ON 'H' GRADE PRACTICAL WORK

Please fill in this sheet honestly, in order to provide a clear picture of the usefulness of this practical work. Tick the appropriate boxes.

NAME :   SCHOOL :

Title of experiment :

This experiment -	True	False	Don't Know
1. was interesting			
2. helped me realise that chemical theory derives from observation			
3. made me think out how to tackle the experiment			
4. allowed me to draw conclusions from my observations			
5. made me curious about what was going on			
6. gave me a sense of achievement			
7. taught me new skills in practical work			
8. made me realise that there are definite limitations in accuracy			
9. helped me to understand a theory previously taught in class			

A potentially useful tool for the evaluation of syllabus practical work has been developed here, and found to work successfully on a sample of eleven experiments. This has been done by setting up a standard against which to judge the syllabus practical work (i.e. teacher course objectives), and then evaluating each experiment to see if the sum of these meets this standard.

It would not be meaningful to make this comparison (between the two sets of teacher objectives) experiment by experiment, because different types of experiment will have different objectives (and a good course will have many types of experiment), and there is no merit in having any one experiment meeting the course objectives, so long as the sum of all the experiments does so.

2. Comparison of Teacher and Pupil Objectives

Again, consider graph 5.11, but now comparing the teachers' and pupils' views of the objectives of the eleven experiments taken as a whole (see footnote).

Footnote

When the original questionnaire (Appendix 4) was analysed (Chapter 2), it was found that teachers in practice divided the objectives of practical work into two categories, which one might call 'very important' and 'not important'. (The latter category is made up of 'fairly important' and 'not very important' added together). Furthermore, the two categories were mirror images of one another. Thus it seemed reasonable, in an effort to make the data for each experiment more manageable, to analyse the teacher returns using only the 'very important' category of objective. Pupil report forms were treated in a similar way: only the 'true' column was used, and this column was taken as equivalent to 'very important' in the teacher reports. Thus the graphical representations of the experiments made use of only these two columns - see graphs 5.1 to 5.10 for the individual experiments and 5.11 for the totals of these experiments. On each graph, the scales of the teacher and pupil frequencies are in approximately the same ratio as the number of teachers and pupils reporting that experiment, so the two are directly comparable.

If the objectives are a valid set of objectives, the teacher should be able to communicate his view of these objectives to his pupils via the experiment, and the two graphs should coincide for each experiment and thus for the sum of the eleven experiments. However, only in an ideal world (with perfect teachers, pupils and experiments) would they coincide: in the real world, the two graphs would at best have a similar shape. How then do they compare? First of all, consider the eleven experiments taken together.

Graph 5.11 shows that teachers and pupils agree closely on objectives 2, 4, 7 and 11 i.e. the experiments have adequately transmitted these objectives. Teachers rated objective 6 more highly than did the pupils, the converse holding for objectives 1, 3, 5 and 9, but only for objective 1 was the difference startling. While this large difference could in part be due to the different wordings adopted in the two report forms, the difference is so large that this is unlikely to be the only reason. Perhaps it is just that the fresh mind of the pupils finds more of interest than the teacher expects, or it might be that extra interest is generated in the pupil when he knows that he is doing a particular experiment as part of a research project (Hawthorne effect - see for example Nisbet and Entwhistle 1970).

B. <u>An Evaluation of the individual Experiments</u>

Let us now look at each experiment to see how successfully it transmitted the teachers' objectives to the pupils. To check the validity of the teachers' objectives, a common-sense appraisal of the nature of each experiment will be used.

<u>Experiment 1</u> Molar Volume of Gases

Teachers have a well-defined set of objectives (Nos. 2, 4, 9 and 10) and all of these are reasonable for the experiment. The difficulty of making sufficiently accurate observations is demonstrated by the high rating of No.9 by both teacher and pupil. Pupils rate objectives 1, 3, 5, 7, 9 and 11 more highly than do the teachers, perhaps showing that pupils get more out of this experiment than teachers think they do.

Experiment 2/

Experiment 2   Heats of Solution

There is little difference between the different objectives as rated by teachers: this could be because few teachers had used this experiment before, and were so concerned with the mechanics of the experiment that they gave little thought to its objectives. Pupils rated objectives 1 and 9 highly, more highly than teachers; 9 is surprising since it was not intended that these results should be compared with literature values (as at least one school did). However it is a reasonable result from any quantitative experiment such as this.

Experiment 3   Heats of Combustion

Teachers rated objectives 6, 9 and 11 most important: reasonable for this quantitative experiment which has the dubious reputation of being the most difficult experiment in the 'H' grade syllabus to get acceptable results from.

Pupils rated objectives 1 and 4 more highly than teachers, but objective 6 less so. The latter is disappointing as it could point to lack of success with the experiment - as one teacher said 'in practice, we found so many sources of error that the sense of achievement was replaced by frustration'.

The author has found it possible to get acceptable results with his classes (see Appendix 11): perhaps other teachers will manage the same in subsequent years, when they are more familiar with the experimental details and the many sources of error possible.

Experiment 4   Explosion of Hydrogen and Chlorine

Teachers rate objectives 2, 4, 5 and 11 most highly - again reasonable for this demonstration experiment. Pupils agreed, but added in objective 1.

Experiment 5   Reactions of Phenol

Teachers rated objectives 2, 4 and 8 most important: again much as expected. Pupils agreed, but added objectives 1, 5, 9 and 11, once again showing that pupils can get a lot out of a simple set of experiments. However, objective 9 is really only applicable to quantitative experiments, and it is difficult to rationalise its high pupil rating.

Experiment 6   Reactions of Amines

Teachers rated objectives 2, 4, 5 and 8 most important, i.e. much the same as the somewhat similar experiment 5. This is a more interesting set of experiments than experiment 5, and this shows up in the high rating of objective 5.

Pupils agreed, adding only No.1.

Experiment 7 Alcohols and Carbonyl Compounds

Teachers rated objectives 4 and 11 most highly; again much as expected. Considering the small sample sizes, pupils agreed reasonably well with their teachers although No.5 is a little disappointing. The author had hoped that the different behaviour of the isomeric alcohols would make the pupils curious about what was going on: perhaps the low pupil rating of objective 5 is because pupils had been taught the theory beforehand and knew what to expect. As in Experiment 5, it is difficult to justify the high pupil rating of objective 9.

Experiment 8 Models of NaCl and CsCl Structures

No reply sheets received: there is no indication as to why this should be. (The only communication from teachers on this experiment was one asking for a source for the polystyrene spheres!)

Experiment 9 ICl - ICl_3 equilibrium

This was recommended as a demonstration experiment, and all the teacher objectives relevant to such an experiment received some votes; the small sample would make comparison between them meaningless. Pupils generally agreed with their teachers but rated objectives 1, 4, 5 and 11 more highly than did their teachers. As with Experiment 1, pupils seem to get more out of experiments than teachers expect them to.

Experiment 10 Hess's Law 1

Teachers rated objectives 2, 4, 6 and 9 most highly: again, much as expected. Pupils generally agreed, except that they rated objectives 1 and 3 more highly, and objective 6 less highly. This latter observation is surprising, as these experiments can and do give spot-on results, and pupils should have a sense of achievement in getting such results. This is all the more surprising since one teacher took the trouble to comment (about this experiment and the next one) that 'they were both excellent experiments and gave better results than we have ever had for Hess's Law (better than those recommended for Certificate of Sixth Year Studies)', and one pupil added the word 'definitely' after objective 6.

Experiment 11 Hess's Law 2

This experiment is so similar to the previous one that one would expect the ratings of the different objectives to be much the same. This/

This is the case, except that the ratings for pupil objectives No.2 and teacher objective No.6 are now much lower, the latter being much the same as the corresponding pupil objective. It is difficult to account for this except to say that the small sample size must have played a part.

CONCLUSIONS

1. It has been shown that there is general agreement between
   (a) the objectives for each experiment as seen by pupils and their teachers
   (b) the objectives (as seen by both teachers and pupils) and the author's subjective view of the experiment concerned.

   This would seem to validate this approach to the evaluation and/or development of practical work, and shows it to be a potentially valuable tool for these purposes.

2. Taking the responses over all eleven experiments, it has been shown that (a) pupils rate objective 1 more highly than do their teachers. It has been suggested that this is due at least in part to the fresh enquiring mind of the pupil meeting the experiment for the first time finding more of interest than the teacher expects.

   (b) pupils rate objective 6 less and objective 9 more highly than do their teachers. This could indicate that pupils have difficulty in getting numerical results which are seen by them to be good i.e. pupils cannot assess errors sufficiently well to be able to recognise a good result.

3. It was seen in Chapter 3 that teachers teaching a lot of practical work tended to rate objectives 1, 3 and 5 more highly than the average teacher. It is interesting that pupils rate all three more highly than do their teachers. This points once again to the importance of the personality of the teacher: the teacher who does a lot of practical perhaps does so because he has retained a real interest in the practical, and he is then better at transmitting these (affective) objectives than the average teacher.

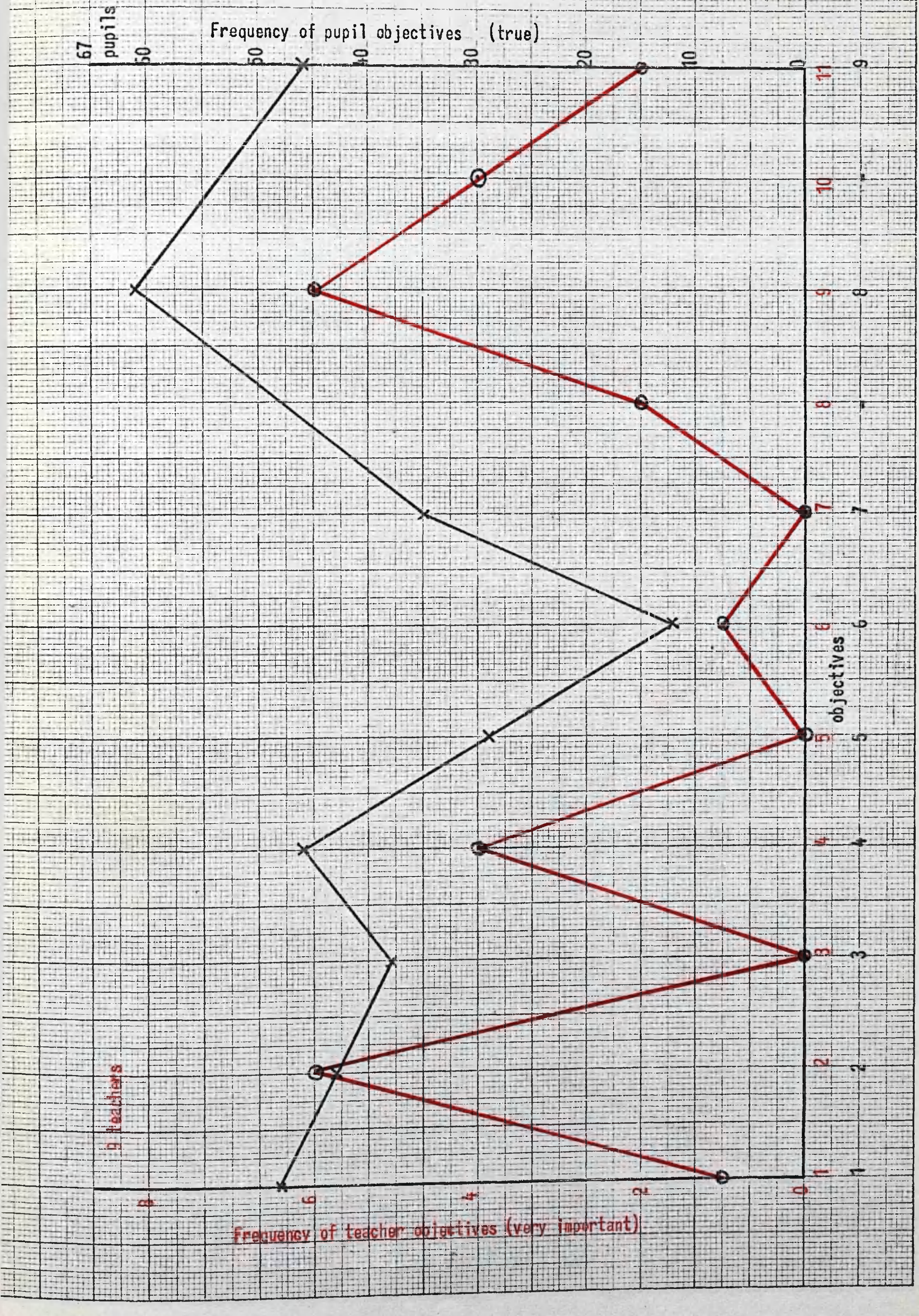
Graphs 5.1 to 5.11

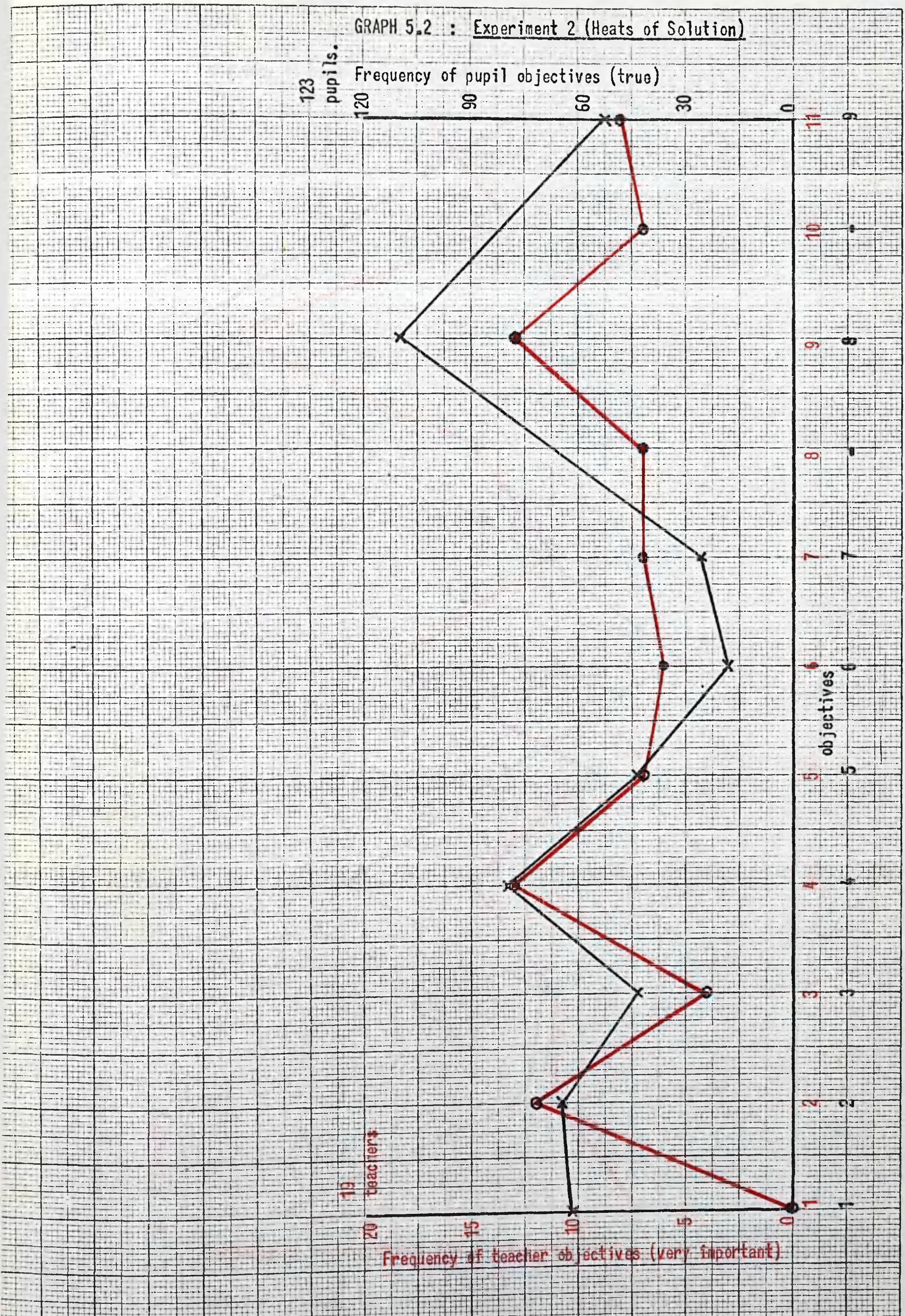
use the following colour coding

red lines refer to the left hand axis

black lines refer to the right hand axis

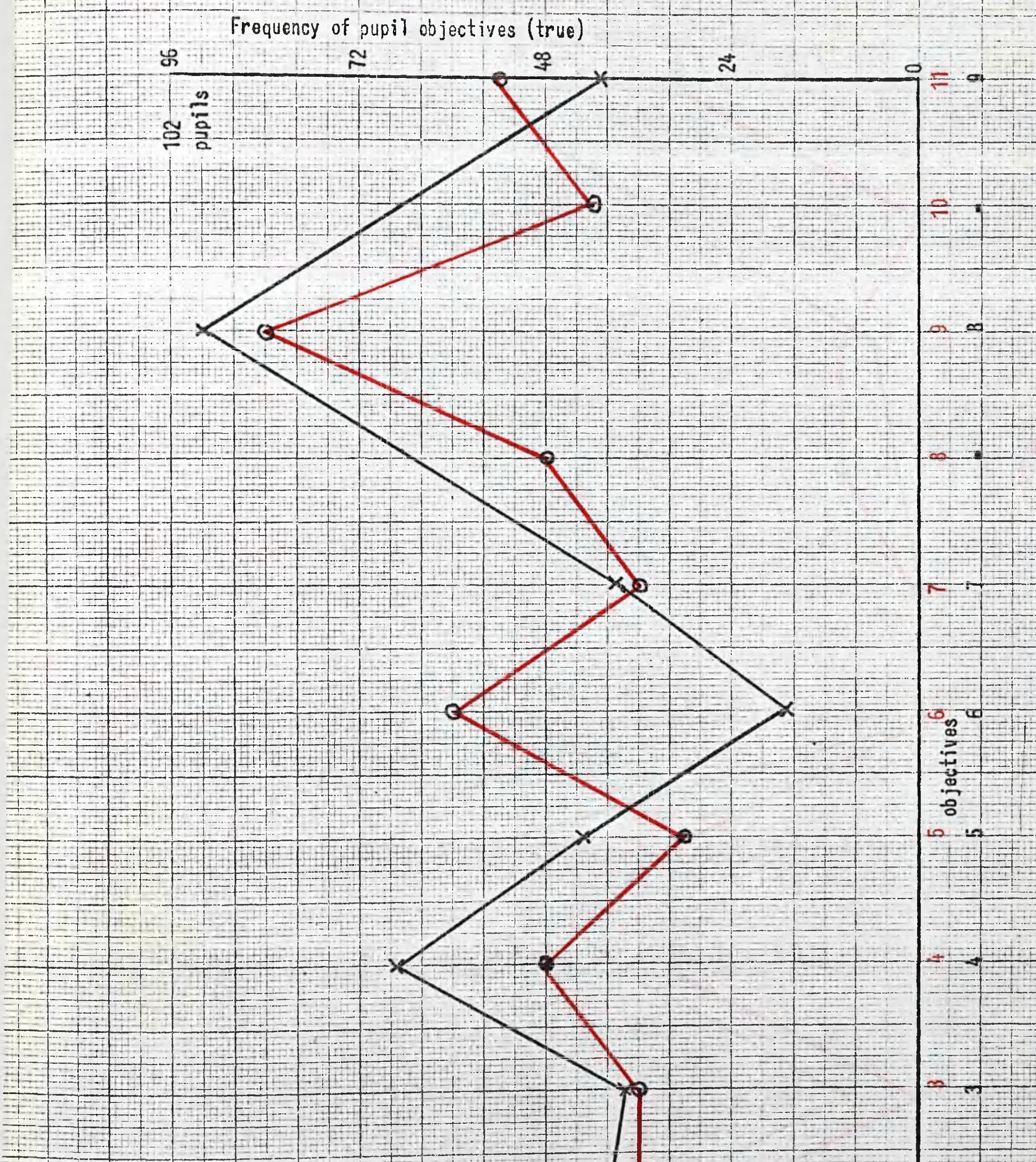
GRAPH 5.1 : Experiment 1 (Molar Volume of Gases)



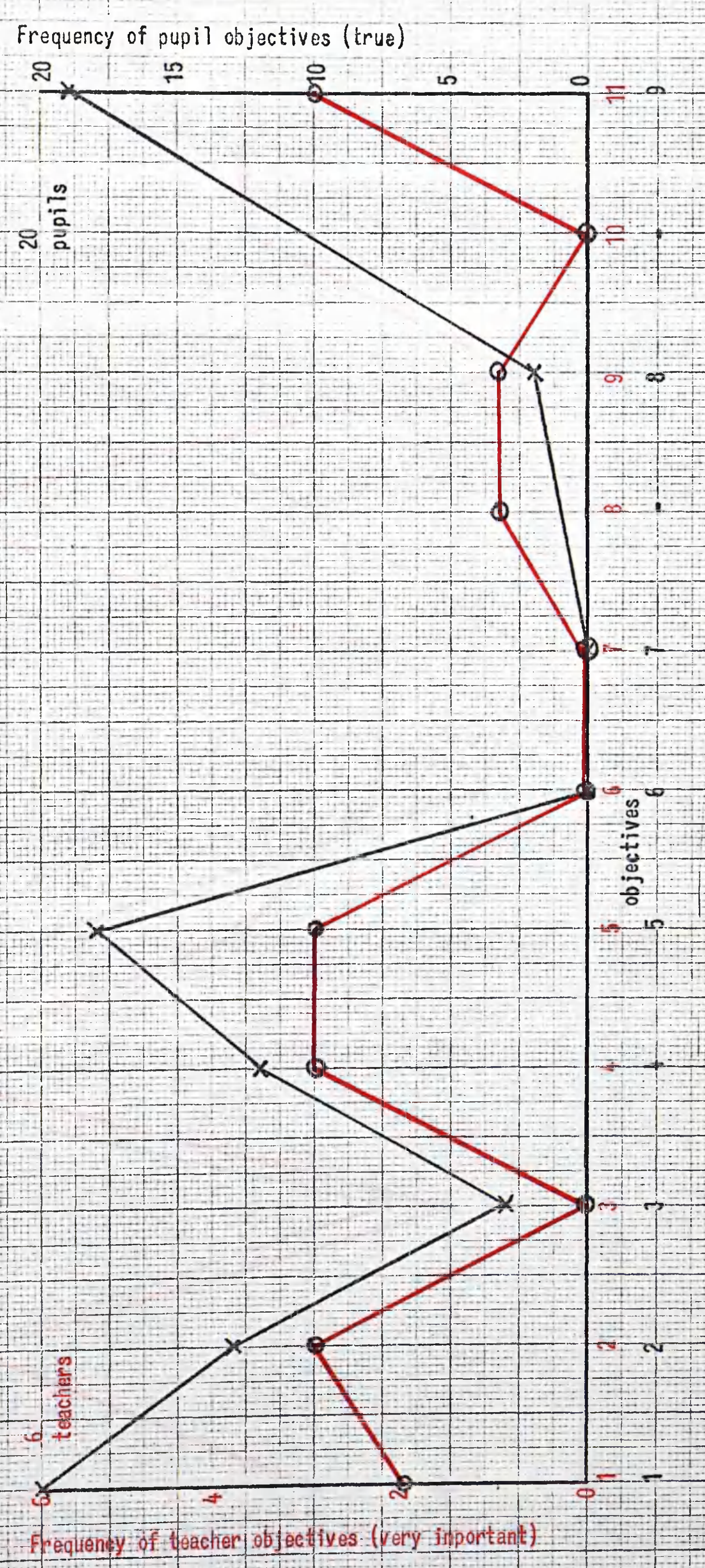


GRAPH 5.2 : Experiment 2 (Heats of Solution)

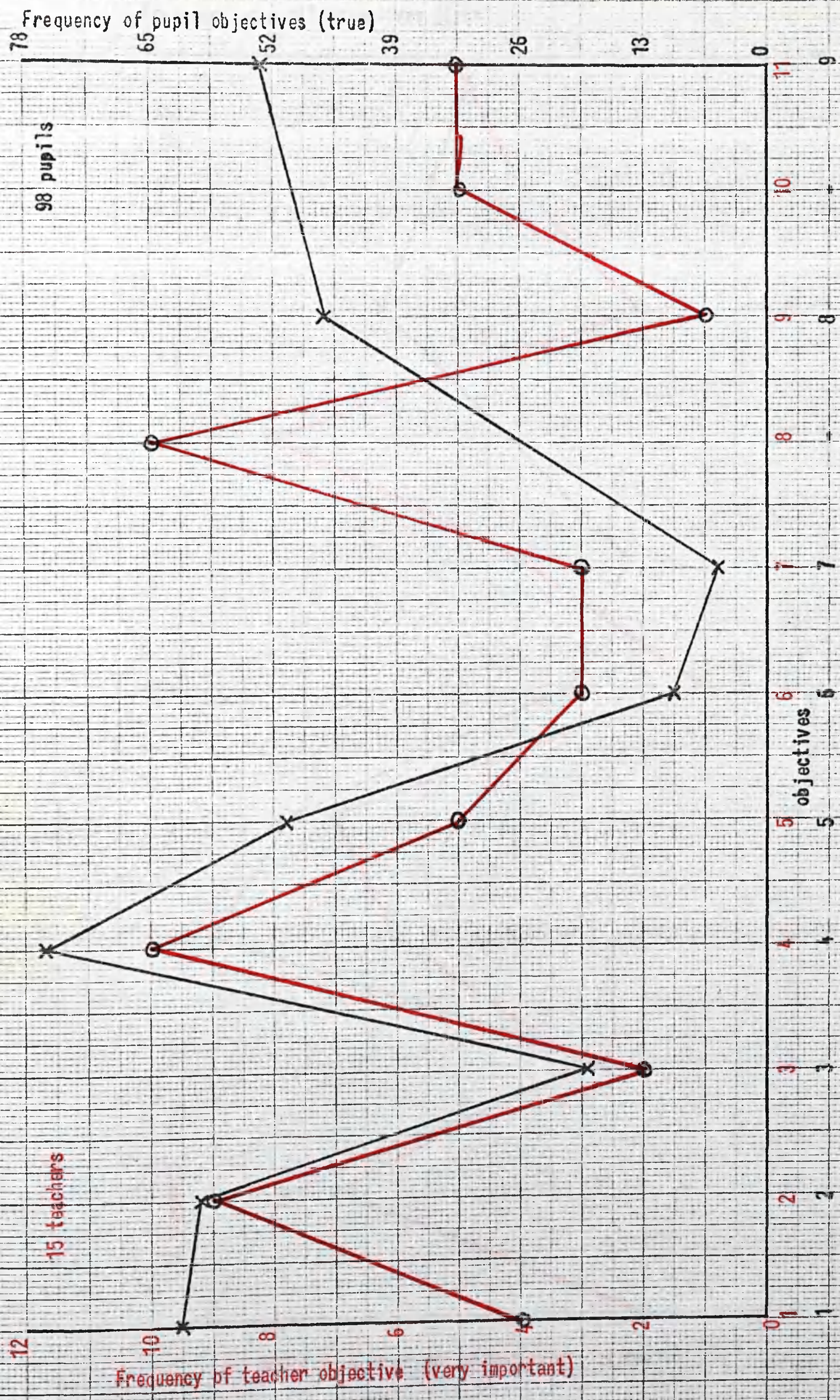
GRAPH 5.3 : Experiment 3 (Heats of Combustion)



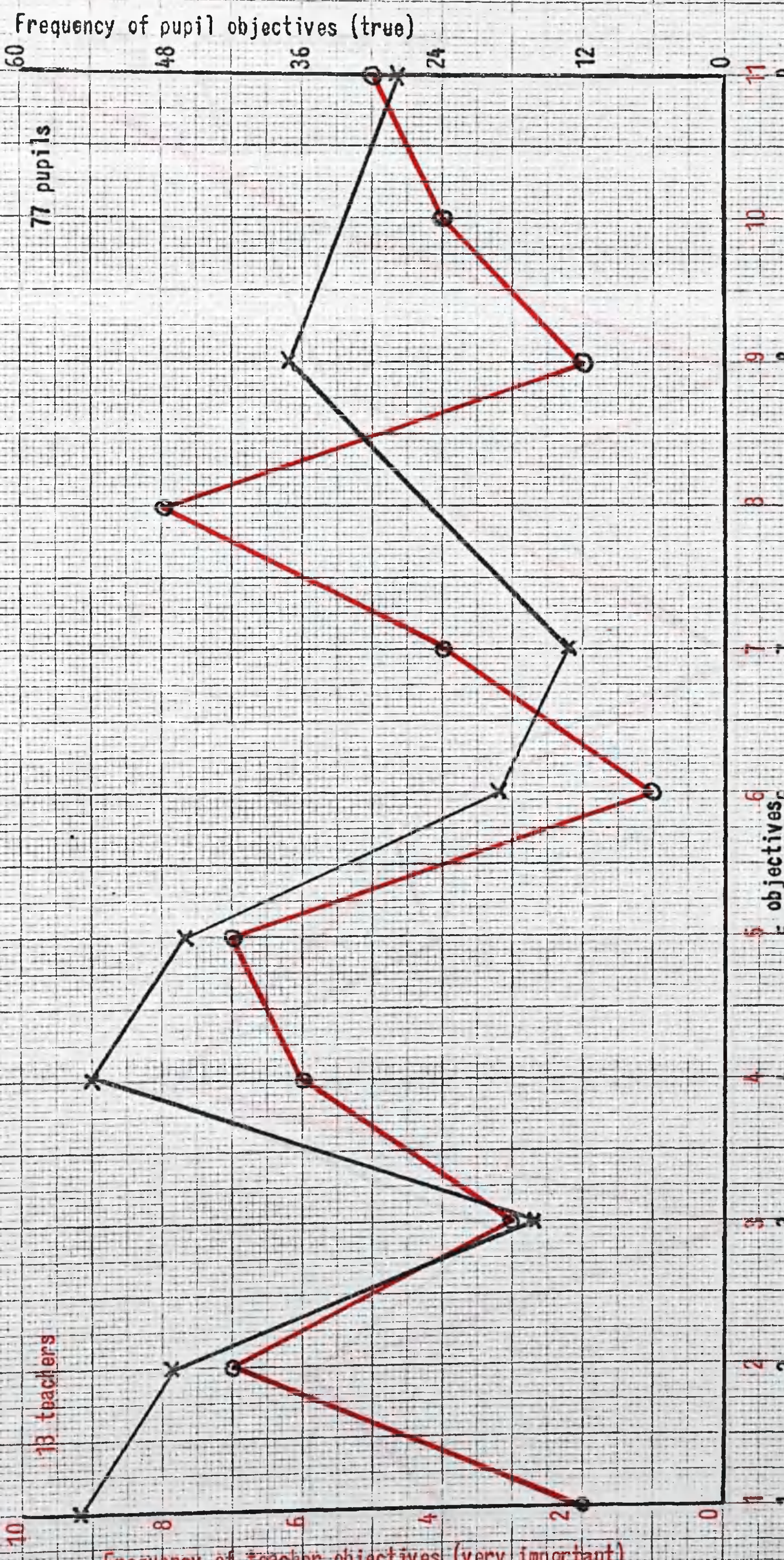
GRAPH 5.4 : Experiment 4 (Explosion of Hydrogen and Chlorine)



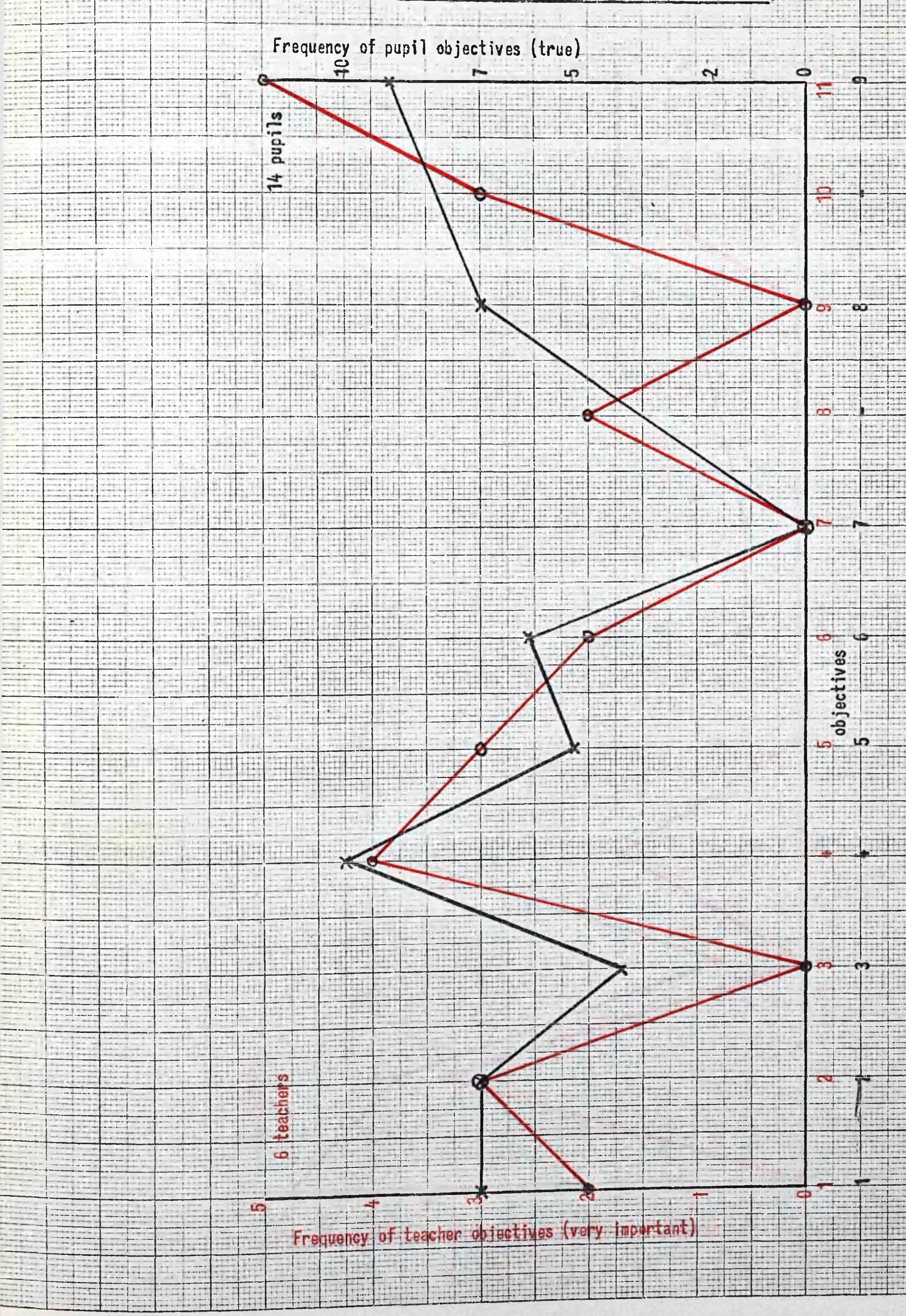
GRAPH 5.5 : Experiment 5 (Reactions of Phenol)



GRAPH 5.6 : Experiment 6 (Reactions of Amines)

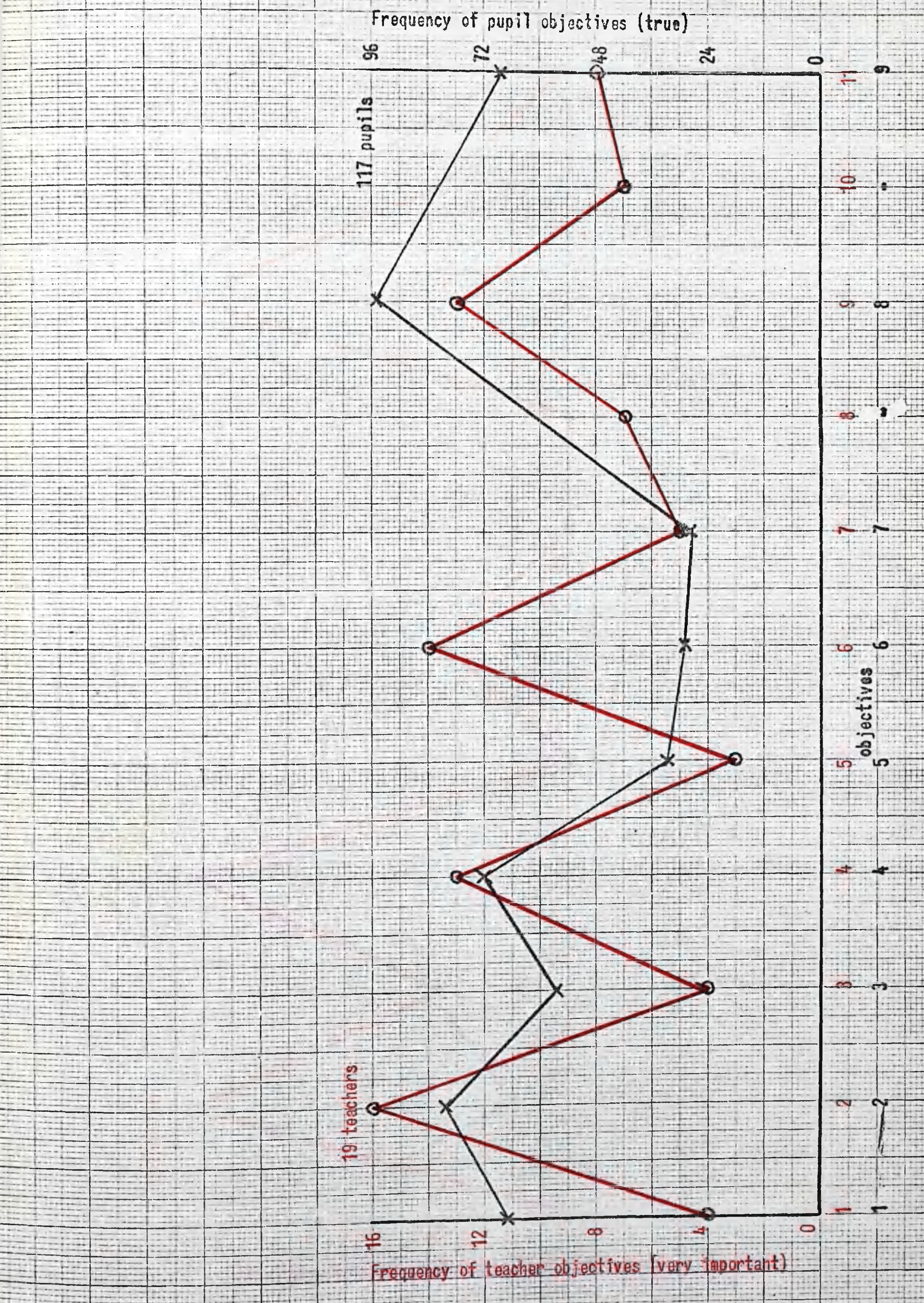


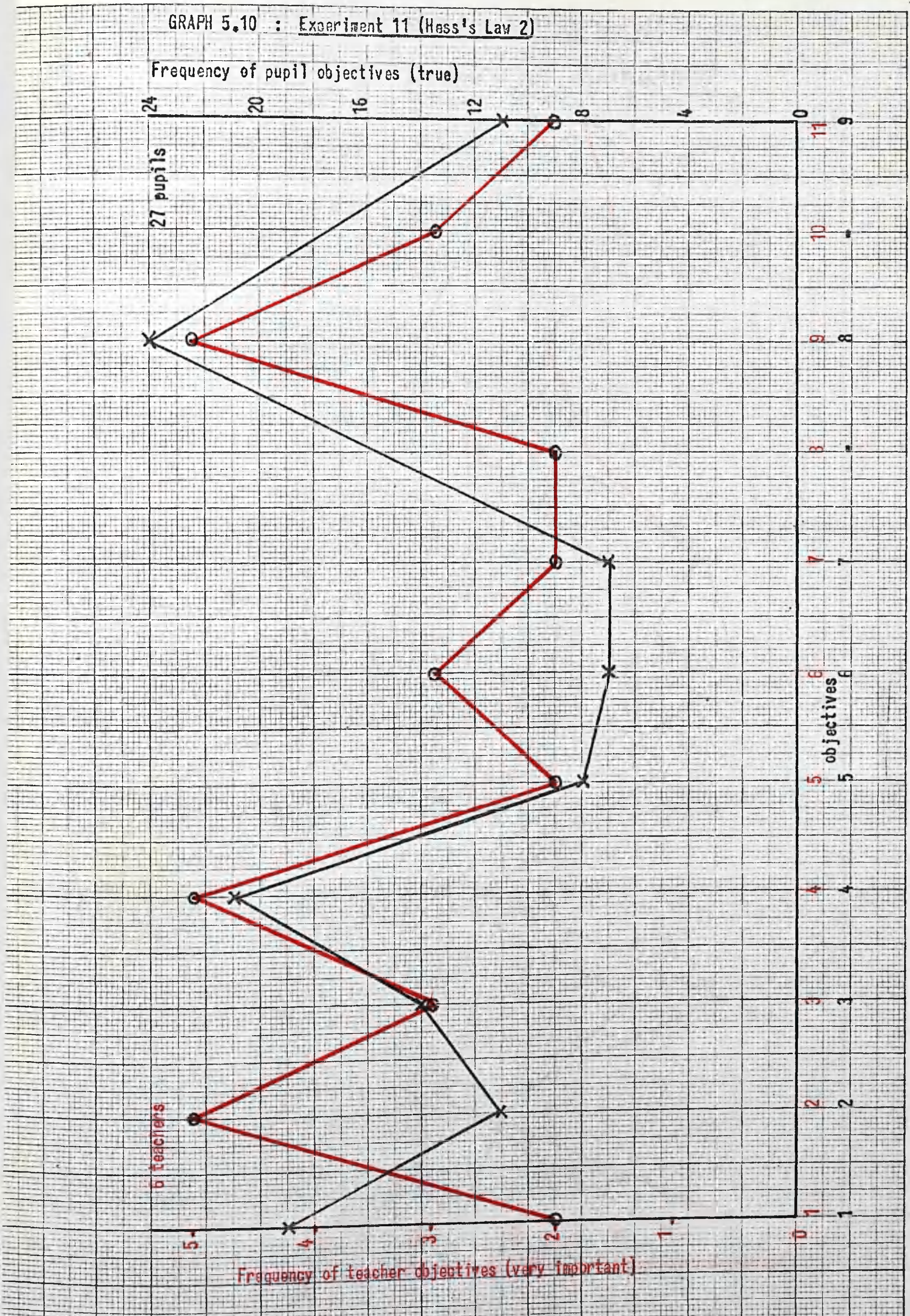
GRAPH 5.7 : Experiment 7 (Alcohols and Carbonyl Compounds)



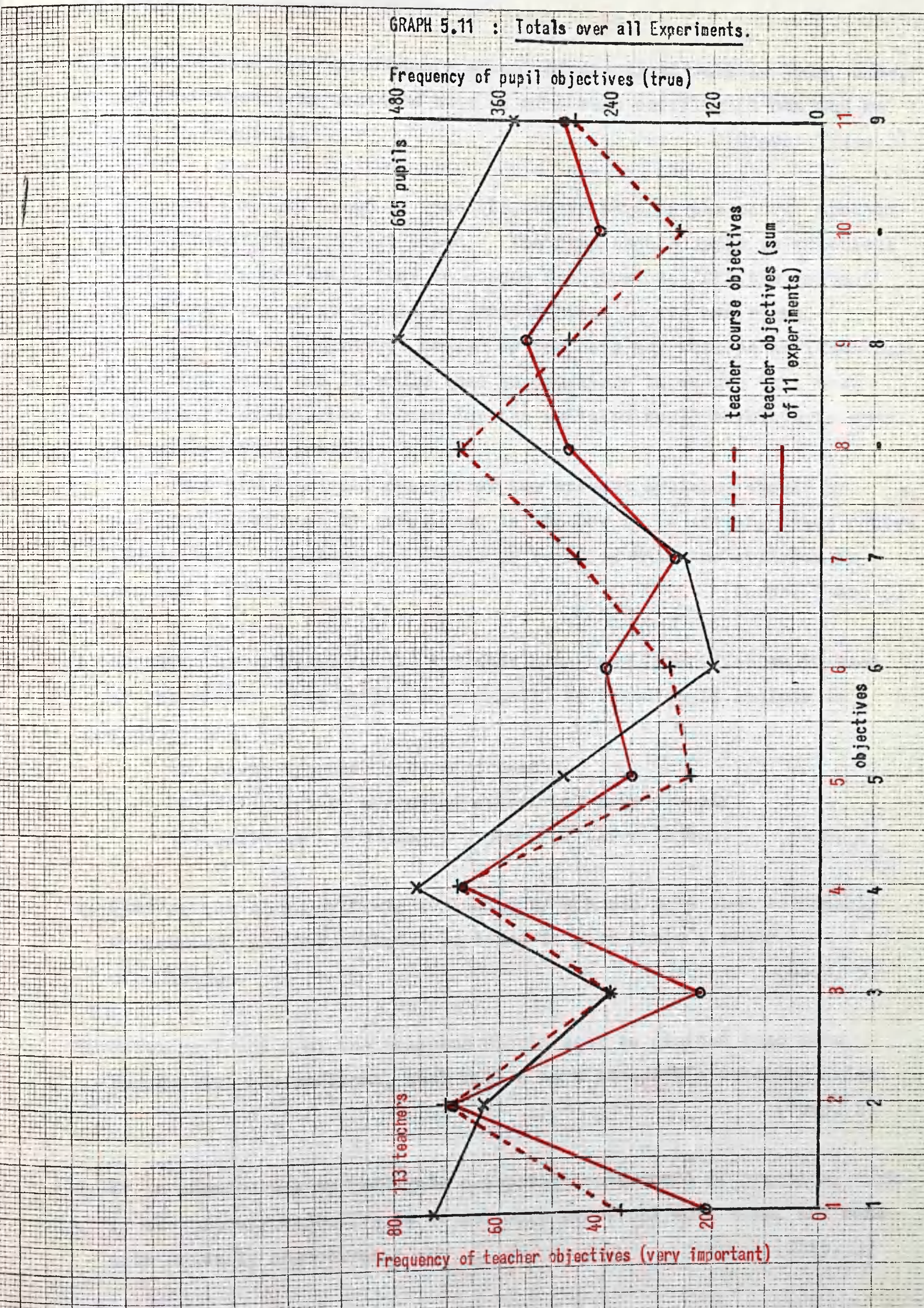
GRAPH 5.8 : Experiment 9 (ICl ⇌ ICl3 Equilibrium)

GRAPH 5.9 : Experiment 10 (Hess's Law I)





GRAPH 5.10 : Experiment 11 (Hess's Law 2)



GRAPH 5.11 : Totals over all Experiments.

CONCLUSIONS AND RECOMMENDATIONS

1. It would seem that an adequate amount of practical work is being done, but the objectives teachers have in mind when carrying it out may be open to question. (Chaps. 2 and 3)

2. There is a modern trend to make the theory part of the course process-based rather than content based. The same should apply to practical work: it is not sufficient to choose practical to 'fit the content' alone, but rather it should be process-based in its own right.

   The course objectives chosen by teachers may well be an ideal for practical work, and it would then be necessary to ensure that the balance of experiments chosen for the syllabus would enable a teacher to achieve this ideal.

   Thus the practical content of the present syllabus should be surveyed experiment by experiment to see how it is meeting these course objectives. Shortcomings should be remedied when the syllabus is revised. (Chaps. 3 and 5)

3. Specific experiments in the syllabus have been identified as in need of attention. The action which should be taken could include as appropriate
   (a) devising substitute experiments
   (b) defining the suggested experiment more closely
   (c) omitting (or adding to) parts of the syllabus. (Chap. 4)

4. Most of the 11 experiments evaluated by schools have been reasonably successful, and steps should be taken to give these a wider circulation. (Chap. 5)

5. Sections P and Q of the syllabus should each be divided into more homogeneous sub-sections, each with a more acceptable teaching order. (Chap. 2)

6. It is unnecessary to instigate a separate assessment of practical work if the primary objective is to get more practical work done, and done with suitable objectives. (Chap. 3)

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A copy of first questionnaire is in pocket at end of thesis

APPENDICES

APPENDIX 1 : Copy of first questionnaire is in pocket at end of thesis.

APPENDIX 2

(a) Chi squared test

This statistic uses categorical data e.g. in the present study, data such as that obtained from the question 'do you find the time allowance adequate?'. Where numerical data was involved (e.g. the time in minutes devoted to chemistry per week), this was categorised into 'above mean time' and 'below mean time'.

In every case a 2 x 2 contingency table was constructed; the following shows tables for both the observed frequencies, and the expected frequencies, i.e. the frequencies expected on the null hypothesis that there is no relationship between the two sets of data. Comparison of these two tables shows whether the correlation is positive or negative: the following example will show what is meant.

Consider the relationship between the two factors given as examples in paragraph one above. One would expect that there would be a relationship between them, such that those with above average time would think their time allocation is adequate. Is this the case?

		Observed frequencies is time above mean? No	Yes		Expected frequencies No	Yes
Is time allocation adequate?	Yes	18	30	Yes	26	22
	No	23	6	No	15	14

It can be seen that more than expected answered yes both times and no both times : this is a positive correlation, but is it significant?

Chi squared is essentially a measure of how much each of the four frequencies in the contingency table differs from the expected frequency. Standard texts show how it is calculated (e.g. Lewis 1967): the value here is 12.69. The larger this number, the more the observed frequencies differ from the expected frequencies, and the less likely is this difference to be due to chance. Tables show that - for the 2 x 2 contingency table - a value exceeding 6.64 will arise by chance in less than 1% of all random samples. Thus there is a relationship at the 1% level, such that teachers who have above average time think their time allocation adequate.

(b) Frequencies

All		No	Yes
	Yes		
	No		

	Observed		Expected		
	Above mean no. of experiments (3A)				
Time above mean	12	24	14	22	Chi squared = 0.90
	18	23	16	25	not sig.
	Above mean pupil method (4A)				
do.	11	25	16	20	Chi squared = 4.61 (+)
	22	18	17	23	sig. at 5%, not sig. at 1%
	Above mean demonstration (4C)				
do.	24	11	20	15	Chi squared = 3.80 (-)
	19	22	23	18	sig. at 5%, not sig. at 1%
	Above mean usefulness (5A)				
do.	14	21	13	22	Chi squared = 0.09
	15	26	16	25	not sig.
	Extensive notes.				
do	21	15	17	19	Chi squared = 3.99 (-)
	15	27	19	23	sig. at 5%, not sig. at 1%
	Above mean set size				
Above mean no. of experiments 3(A)	20	27	22	25	Chisquared = 0.85
	16	14	14	16	not sig.
	Above mean set size				
Above mean pupil method (4A)	20	23	20	23	Chi squared = 0.008
	15	18	15	18	not sig.
	Above mean set size				
Above mean usefulness (5A)	18	28	21	25	Chi squared = 2.25
	17	13	14	16	not sig.
	Above mean no. of experiments (3A)				
Above mean pupil method (4A)	11	32	17	26	Chi squared = 8.00 (+)
	19	14	13	20	sig. at 1%
	Above mean no. of experiments (3A)				
Above mean demonstration (4C)	13	20	13	20	Chi squared = 0.005
	17	27	17	27	not sig.
	Above mean no. of experiments (3A)				
Above mean usefulness (5A)	12	35	18	29	Chi squared = 9.15 (+)
	18	12	12	18	sig. at 1%

		Observed		Expected		
	Extensive notes					
Adequate time		26	22	22	26	Chi squared = 3.90 (-)
		9	20	13	16	sig. at 5%, not at 1%
	Above mean no. of experiments (3A)					
do.		20	28	19	29	Chi squared = 0.19
		11	19	12	18	not sig.
	Above mean pupil method (4A)					
do.		17	31	20	28	Chi squared = 2.39
		15	13	12	16	not sig.
	Above mean demonstration (4C)					
do.		31	17	27	21	Chi squared = 3.95 (-)
		12	17	16	13	sig. at 5%, not at 1%
Above mean no. of Expts. (3A)	Extensive notes					
		20	27	22	25	Chi squared = 0.62
		16	15	14	17	not sig.
	Extensive notes					
Above mean pupil method (4C)		13	21	16	18	Chi squared = 1.52
		23	21	20	24	not sig.
	Extensive notes					
Above mean usefulness (5A)		21	26	22	25	Chi squared = 0.21
		15	15	14	16	not sig.
	Extensive notes					
Above mean demonstration (4C)		13	21	16	18	Chi squared = 1.77
		23	20	20	23	not sig.
	Above mean set size					
do.		15	19	15	19	Chi squared = 0.04
		20	23	20	23	not sig.
	Above mean time					
Above mean set size		24	18	22	20	Chi squared = 0.77
		16	18	18	16	not sig.
	Time allocation adequacy					
do.		16	26	16	26	Chi squared = 0.03
		14	21	14	21	not sig.
	Above mean usefulness (5A)					
Time allocation adequacy		21	27	19	29	Chi squared = 1.23
		9	20	11	18	not sig.
	Above mean time					
do.		18	30	26	22	Chi squared = 12.69 (+)
		23	6	15	14	sig. at 1%

APPENDIX 3.

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 nomenclature 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.(a) Knowledge of the chemistry of some industrial processes. (O)
(b) Comprehension of the chemistry of some industrial processes. (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 information. (H)

13.(a) Knowledge of limitations of precision involved in physical measurement. (0)
(b) Comprehension of reasons for limitation of precision. (0)
(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. (0)
(b) Comprehension of laboratory techniques sufficient to enable experimental procedures to be carried out adequately. (0)
(d) Ability to select relevant techniques to enable experimental procedures to be carried out. (0)

15.(a) Knowledge of appropriate safety regulations to be observed in the laboratory. (0)
(b) Comprehension of the reasons underlying safety regulations in the laboratory. (0)

16. Ability to comprehend written and oral instructions. (0)

17. Ability to record and present information in various ways including graphical and diagrammatic representation as well as written statements. (0)

18. Ability to follow arguments about chemical ideas. (0)

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

20. Ability to consider experimental evidence in terms of two and three dimensional physical models. (0)

21. Ability to use experimental evidence to formulate hypotheses and conceptual models. (0)

22. Ability to design experiments to check predictions and hypotheses deduced from available information. (0)

23. Ability to deal with multi-variable situations. (0)

24. Ability to adopt a scientific approach in other fields of experience. (0)

B. Pupils should acquire in attitudes -

1. Awareness that chemistry can form the basis for many satisfying careers. (0)

2. Awareness of the contribution of chemistry to the full development of the individual. (0)

3. Awareness of the contribution of chemistry to the economic and social welfare of the community. (0)

4. Awareness that a number of variables can influence an experimental situation. (0)

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

6. Interest and enjoyment in chemistry. (0)

7. Acceptance of the chemist's ability to produce new compounds. (0)

8. Acceptance of the importance of observation in an experimental procedure. (0)

9. Acceptance of the value of an experimental approach to problems. (0)

10. Acceptance of the desirability of working and discussing in groups in appropriate situations. (0)

11. Acceptance of responsibility for carrying out suitable safety procedures. (0)

12. Commitment to optimum precision of measurement. (0)

13. Commitment to optimum precision of statement. (0)

14. Commitment to cleanliness and neatness in experimentation. (0)

15. Commitment to the systematic recording of experimental results and other data. (0)

16. Commitment to objectivity in observation and assessment wherever possible. (0)

17. Commitment to arriving at conclusions from the information, knowledge and understanding available. (0)

18. Commitment to apply a scientific approach in other fields of experience. (0)

C. Pupils should acquire in practical skills -

1. Skill in using various pieces of equipment effectively and safely. (0)

2. Skill in drawing diagrams and visual representations of quantitative data. (0)

3. Skill in assembling relevant pieces of equipment into experimental rigs.

4. Skill in using various measuring devices to the appropriate degree of precision. (0)

5. Skill in working at adequate speed and with reasonable neatness and safety. (0)

6. Skill in handling materials with due attention to safety and economy. (0)

For C.S.Y.S., in addition to the above, pupils should also acquire -

- in knowledge and understanding

  Ability to develop a sustained approach to a particular problem.
  Ability to verbalise conceptual problems concisely (to define a problem in words).
  Ability to defend orally and in writing a given course of action and the conclusion arrived at.
  Ability to work without detailed supervision.
  Ability to suggest future work arising from a project.

- in attitudes

  Acquisition of increasing self-confidence leading to a willingness to take decisions.
  Realisation that many decisions are at best a compromise solution of conflicting interests.
  Realisation that many decisions are necessarily taken on incomplete evidence.
  Willingness to seek information and assistance from all appropriate sources.

APPENDIX 4

SOME POSSIBLE OBJECTIVES FOR 'H' GRADE CHEMISTRY PRACTICAL WORK

A. These aims are expressed in terms of student behaviour which should become evident as a result of the course.

As a result of the practical work, pupils should -

	very important	fairly important	not important
1. Become enthusiastic for the subject			
2. Realise that chemical theory derives from observation			
3. Display initiative and resourcefulness in tackling practical problems			
4. Be able to draw justifiable conclusions from personal observation.			
5. Develop a sense of curiosity			
6. Have gained a sense of achievement as a result of making accurate and reproducible experimental observations			
7. Have acquired skills and practical techniques			
8. Be able to work safely and tidily in the laboratory			
9. Realise that there are limitations in accuracy inherent in every experiment			

Please list on the next page any others you think are important.

B. From the teacher's point of view, there may be organisational advantages of practical work such as :-

1. It allows for small group teaching			
2. It allows the pupil to digest new ideas and concepts by seeing them from a less theoretical angle			

There may be other advantages which you can see and we should be grateful if you would record these on the next page.

C. Do you see 'H' grade practical work being part of any logical progression in practical work from 'O' grade, through 'H' grade to S.Y.S.?

YES	
NO	

If yes, please try to specify, on the next page, how you see this progression developing.

Section A - Additional objectives

Section B - Additional advantages

Section C - Progression

Name of Principal Teacher : ....

Name and Address of School : ....

....

APPENDIX 5A : Observed Frequencies for Each Experiment

Description of Experiment	Syllabus Section	Expt.	3a	3b	3c	3d	4a	4b	4c	4d	5a	5b	5c
Principle of Mass Spectrometer	P.1	10	52	3	14	7	3	1	43	6	27	29	3
Analogy expts. on nuclear rays	P.3	20	18	5	49	1	3	1	13	4	7	14	3
Electrolysis to find Avogadro's No.	P.4	30	71	2	5	0	49	3	9	10	56	11	0
Finding gas densities → 22.4 litres	P.5	40	60	8	7	0	50	1	7	6	41	21	2
Heats of neutralisation	Q.1	50	58	1	0	19	69	4	1	1	62	9	1
Heats of combustion	Q.1	60	59	3	15	1	46	4	5	5	35	19	6
Heats of solution	Q.1	70	44	4	26	3	43	5	2	0	34	13	3
Tests for redox reactions	Q.2	80	70	1	0	7	67	4	0	4	60	13	0
Some redox processes	Q.2	90	72	1	1	3	62	5	2	5	62	10	0
Connection between redox and elec. transfer	Q.2	100	71	1	1	4	54	3	10	5	61	11	0
Measuring e.m.f. of cells	Q.2	110	61	2	9	6	43	4	11	7	41	19	2
None in syllabus - please indicate any done	Q.3	120	15	1	57	1	7	2	3	1	6	6	2
Hydrides, chlorides and oxides of elements 1-20: please indicate compounds made													
(a)	Q.4	131	46	3	23	3	33	1	11	4	20	22	5
(b)	Q.4	132	40	2	31	1	25	1	12	3	21	16	3
(c)	Q.4	133	34	2	37	1	16	2	10	5	16	14	5
Models of NaCl and CsCl structures	Q.5	140	55	1	17	0	11	2	37	4	31	20	5
Alkali metals - please indicate any practical work done.													
(a)	Q.5	151	23	1	47	4	13	2	10	0	15	9	1
(b)	Q.5	152	15	0	58	2	11	0	6	0	10	5	0
(c)	Q.5	153	6	0	68	1	4	0	2	1	6	0	0

	Description of Experiment	Syllabus Section	Expt.	3a	3b	3c	3d	4a	4b	4c	4d	5a	5b	5c
The Halogens	Redox experiments	Q.6	160	50	0	8	9	44	2	3	1	41	9	2
	Displacement reactions	Q.6	170	69	0	1	5	66	2	3	0	62	7	2
	Stability of hydrides	Q.6	180	49	2	19	1	28	2	14	3	33	12	4
	Reaction with metals	Q.6	190	55	2	14	3	23	3	26	3	37	13	1
	Tests for halides	Q.6	200	74	0	0	3	72	2	0	0	58	11	3
Factors affecting speed of reaction	Preliminary survey	R.1	210	45	1	18	4	23	4	13	1	32	6	0
	Effect of temperature	R.1	220	78	0	0	0	60	6	8	2	68	5	0
	Effect of concentration	R.1	230	78	0	0	0	61	6	7	2	69	4	0
	Effect of particle size	R.1	240	76	0	1	1	56	6	10	3	62	7	1
	Pyrophoric lead or iron	R.1	250	29	4	34	0	11	1	17	1	21	4	2
	Light on AgX	R.1	260	66	0	6	3	34	5	18	4	40	19	0
	$Al/I_2 + H_2O$	R.1	270	55	2	5	11	11	6	34	7	42	12	1
	Reaction mechanisms - clock reactions	R.2	280	75	0	1	1	60	1	8	1	61	5	2
	Hydrogen/chlorine explosion	R.5	290	28	9	36	1	1	0	20	2	11	2	5
Idea of Equilibrium	Iodine distribution	R.6	300	65	1	10	0	46	0	19	1	41	18	5
	Salt Hydrolyses	R.6	310	41	3	18	11	46	0	3	1	34	13	3
	ICl/ICl_3 equilibrium	R.7	320	47	1	25	0	15	1	28	4	34	12	2
	Acetic acid ionisation	R.7	330	50	0	14	8	41	0	12	1	37	14	1
	Props of saturated hydrocarbons	S.1	340	60	0	3	15	52	3	11	2	58	10	0
	Reaction of alkyl halides	S.1	350	69	0	8	0	50	2	13	2	47	19	1
	Cracking of hydrocarbons	S.2	360	31	0	3	44	44	4	10	1	49	8	2
	Dehydration of alcohols	S.2	370	67	4	3	4	47	4	13	2	55	13	1
	Addition reaction of alkenes/													

Description of Experiment (contd.)	Syllabus Section	Expt.	3a	3b	3c	3d	4a	4b	4c	4d	5a	5b	5c
Addition reactions of alkenes	S.2	380	68	0	0	10	67	3	2	1	62	10	1
Prep. and props of ethyne	S.2	390	73	0	2	1	51	2	16	2	53	20	0
Addition reactions of alkynes	S.2	400	63	6	7	0	46	1	14	4	46	18	2
Oxid. of ethyne to ethanal	S.2	410	27	7	36	2	17	1	12	1	18	9	5
Physical props. of benzene	S.3	420	51	3	20	1	21	1	28	2	24	22	5
Reaction of bromine water + benzene	S.3	430	75	0	1	2	51	1	23	0	53	16	2
Reactions of ethanol (a) with sodium	S.4	441	75	0	1	2	43	1	29	3	65	9	0
(b) with phosphorus pentachloride	S.4	442	71	1	4	2	37	2	30	3	61	8	1
(c) oxidation to ethanal	S.4	443	65	1	2	2	53	2	10	2	55	10	0
(d) oxidation to ethanoic acid	S.4	444	68	0	3	7	57	2	10	2	62	7	2
(e) ester formation	S.4	445	73	0	0	5	68	2	1	2	67	6	0
Build model of ethanol	S.4	450	53	1	14	3	26	1	24	4	43	8	1
Props. of phenol (a) solubility	S.4	461	76	1	1	0	64	1	8	2	52	18	2
(b) acidic nature	S.4	462	76	1	1	0	63	1	9	2	55	15	2
Hydrolyses of esters	S.4	470	50	4	14	10	41	1	11	3	43	12	2
Reaction of amines (a) with HCl and NaOH	S.5	481	74	1	3	0	62	2	7	3	58	12	1
(b) with copper sulphate solution	S.5	482	67	2	9	0	57	1	8	2	45	16	4
Prep. of carbonyl compounds by oxid. of alcohols	S.6	490	51	3	15	1	45	1	3	3	43	9	0
Reactions of carbonyl compounds with -													
(a) Fehling's solution	S.6	501	77	0	0	1	73	1	3	0	66	7	2
(b) ammoniacal silver nitrate	S.6	502	75	1	1	1	71	1	2	1	62	9	2
(c) acid dichromate	S.6	503	70	1	5	1	66	1	3	0	56	10	2

APPENDIX 5B : Percentages for Each Experiment

Description of Experiment	Syllabus Section	Expt.	3a	3b	3c	3d	4a	4b	4c	4d	5a	5b	5c
Principle of Mass Spectrometer	P.1	10	68	4	18	9	6	2	81	11	46	49	5
Analogy expts. on nuclear rays	P.3	20	25	7	67	1	14	5	62	19	29	58	13
Electrolysis to find Avogadro's No.	P.4	30	91	3	6	0	69	4	13	14	84	16	0
Finding gas densities → 22.4 litres	P.5	40	80	11	9	0	78	2	11	9	64	33	3
Heats of neutralisation	Q.1	50	74	1	0	24	92	5	1	1	86	13	1
Heats of combustion	Q.1	60	76	4	19	1	77	7	8	8	58	32	10
Heats of solution	Q.1	70	57	5	34	4	86	10	4	0	68	26	6
Tests for redox reactions	Q.2	80	90	1	0	9	89	5	0	5	82	18	0
Some redox processes	Q.2	90	94	1	1	4	84	7	3	7	86	14	0
Connection betweenredox and elec. transfer	Q.2	100	92	1	1	5	75	4	14	7	85	15	0
Measuring e.m.f. of cells	Q.2	110	78	3	11	8	66	6	17	11	66	31	3
None in syllabus - please indicate any done	Q.3	120	20	1	77	1	54	15	23	8	43	43	14
Hydrides, chlorides and oxides of elements 1-20 : please indicate compounds made													
(a)	Q.4	131	61	4	31	4	67	2	22	8	42	47	11
(b)	Q.4	132	54	3	42	1	61	2	29	7	52	40	8
(c)	Q.4	133	46	3	50	1	48	6	30	15	46	40	14
Models of NaCl and CsCl structures	Q.5	140	75	1	23	0	20	4	69	7	55	36	9
Alkali metals : please indicate any practical work done													
(a)	Q.5	151	31	1	63	5	52	8	40	0	60	36	4
(b)	Q.5	152	20	0	77	3	65	0	35	0	67	33	0
(c)	Q.5	153	8	0	91	1	57	0	29	14	100	0	0

	Description of Experiment	Syllabus Section	Expt.	3a	3b	3c	3d	4a	4b	4c	4d	5a	5b	5c
The Halogens	Redox experiments	Q.6	160	75	0	12	13	88	4	6	2	79	17	4
	Displacement reactions	Q.6	170	92	0	1	7	93	3	4	0	87	10	3
	Stability of hydrides	Q.6	180	69	3	27	1	60	4	30	6	67	24	8
	Reaction with metals	Q.6	190	74	3	19	4	42	5	47	5	73	25	2
	Tests for halides	Q.6	200	96	0	0	4	97	3	0	0	81	15	4
Factors affecting speed of reaction	Preliminary survey	R.1	210	66	1	26	6	56	10	32	2	84	16	0
	Effect of temperature	R.1	220	100	0	0	0	79	8	10	3	93	7	0
	Effect of concentration	R.1	230	100	0	0	0	80	8	9	3	95	5	0
	Effect of particle size	R.1	240	97	0	1	1	75	8	13	4	89	10	1
	Pyrophoric lead or iron	R.1	250	43	6	51	0	37	3	57	3	78	15	7
	Light on AgX	R.1	260	88	0	8	4	56	8	30	6	68	32	6
	$Al/I_2 + H_2O$	R.1	270	75	3	7	15	19	10	59	12	76	22	2
	Reaction mechanism : clock reactions	R.2	280	97	0	1	1	86	1	11	1	90	7	3
	Hydrogen/chlorine explosion	R.5	290	38	12	49	1	4	0	87	9	61	11	28
Idea of Equilibrium	Iodine distribution	R.6	300	86	1	13	0	70	0	29	1	64	28	8
	Salt hydrolyses	R.6	310	56	4	25	15	92	0	6	2	68	26	6
	ICl/ICl_3 equilibrium	R.7	320	64	1	34	0	31	2	58	8	71	25	4
	Acetic acid ionisation	R.7	330	69	0	19	11	76	0	22	2	71	27	2
	Props of saturated hydrocarbons	S.1	340	77	0	4	19	76	4	16	3	85	15	0
	Reaction of alkyl halides	S.1	350	90	0	10	0	75	3	19	3	70	28	1
	Cracking of hydrocarbons	S.2	360	40	0	4	56	75	7	17	2	83	14	3
	Dehydration of alcohols	S.2	370	86	5	4	5	71	6	20	3	80	19	1
	Addition reactions of alkenes/													

Description of Experiment (contd.)	Syllabus Section	Expt.	3a	3b	3c	3d	4a	4b	4c	4d	5a	5b	5c
Addition reactions of alkenes	S.2	380	87	0	0	13	92	4	3	1	85	14	1
Prep. and props of ethyne	S.2	390	96	0	3	1	72	3	22	3	73	27	0
Addition reactions of alkynes	S.2	400	83	8	9	0	71	2	21	6	70	27	3
Oxid. of ethyne to ethanal	S.2	410	37	10	50	3	55	3	39	3	56	28	16
Physical props of benzene	S.3	420	68	4	27	1	40	2	54	4	47	43	10
Reaction of bromine water + benzene	S.3	430	96	0	1	3	68	1	31	0	77	22	3
Reactions of ethanol (a) with sodium	S.4	441	96	0	1	3	57	1	38	4	88	12	0
(b) with phosphorus pentachloride	S.4	442	91	1	5	3	51	3	42	4	87	11	1
(c) oxidation toethanal	S.4	443	93	1	3	3	79	3	15	3	85	15	0
(d) oxidation to ethanoic acid	S.4	444	87	0	4	9	80	3	14	3	87	10	3
(e) ester formation	S.4	445	94	0	0	6	93	3	1	3	92	8	0
Build model of ethanol	S.4	450	75	1	20	4	47	2	44	7	83	15	2
Props of phenol (a) solubility	S.4	461	97	1	1	0	85	1	11	3	72	25	3
(b) acidic nature	S.4	462	97	1	1	0	84	1	12	3	76	21	3
Hydrolyses of esters	S.4	470	64	5	18	13	73	2	20	5	75	21	4
Reaction of amines (a) with HCl and NaOH	S.5	481	95	1	4	0	84	3	9	4	82	17	1
(b) with copper sulphate solution	S.5	482	86	3	11	0	84	1	12	3	69	25	6
Prep. of carbonyl compounds by oxid. of alcohols	S.6	490	73	4	21	1	86	2	6	6	83	17	0
Reactions of carbonyl compounds with													
(a) Fehling's solution	S.6	501	99	0	0	1	95	1	4	0	88	9	3
(b) ammoniacal silver nitrate	S.6	502	96	1	1	1	95	1	3	1	85	12	3
(c) acid dichromate	S.6	503	91	1	6	1	94	1	4	0	82	15	3

APPENDIX 6

FREQUENCIES

A. Expt.	1,1,-	1,2,-	1,3,-	1,4,-	2,1,-	2,2,-	2,3,-	2,4,-	3,1,-	3,2,-	3,3,-	3,4,-	4,1,-	4,2,-	4,3,-	4,4,-
10	3	1	34	5	0	0	2	0	0	0	0	0	0	0	6	1
20	3	1	10	4	0	0	1	0	0	0	0	0	0	0	1	0
30	46	3	7	10	0	0	1	0	0	0	0	0	0	0	0	0
40	44	1	6	6	3	0	1	0	0	0	0	0	0	0	0	0
50	50	3	1	0	0	1	0	0	0	0	0	0	15	0	0	1
60	43	3	3	5	1	0	2	0	0	0	0	0	1	0	0	0
70	37	3	1	0	1	2	1	0	1	0	0	0	3	0	0	0
80	59	3	0	3	1	0	0	0	0	0	0	0	5	0	0	1
90	56	4	2	5	1	0	0	0	0	0	0	0	3	0	0	0
100	51	3	10	4	1	0	0	0	0	0	0	0	2	0	0	0
110	39	3	8	6	0	0	1	0	0	0	0	0	2	1	1	0
120	6	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0
131	29	1	9	4	1	0	2	0	0	0	0	0	1	0	0	0
132	23	1	10	3	2	0	0	0	0	0	0	0	0	0	0	0
133	15	2	10	5	1	0	0	0	0	0	0	0	0	0	0	0
140	10	1	36	4	0	0	0	0	0	1	1	0	0	0	0	0
151	10	1	9	0	0	0	0	0	0	0	0	0	1	1	1	0
152	8	0	5	0	0	0	0	0	0	0	0	0	2	0	0	0
153	2	0	2	1	0	0	0	0	0	0	0	0	1	0	0	0
160	41	2	2	1	0	0	0	0	0	0	0	0	3	0	0	0
170	61	1	3	0	0	0	0	0	0	0	0	0	3	1	0	0
180	26	1	13	2	0	0	0	1	0	0	1	0	1	0	0	0
190	22	1	22	3	0	0	0	0	0	0	0	0	0	1	1	0
200	66	2	0	0	0	0	0	0	0	0	0	0	2	0	0	0
210	19	4	11	0	0	0	0	0	0	0	0	0	2	0	0	0
220	57	6	8	2	0	0	0	0	0	0	0	0	0	0	0	0
230	58	6	7	2	0	0	0	0	0	0	0	0	0	0	0	0
240	51	6	10	2	0	0	0	0	0	0	0	0	1	0	0	0
250	10	1	12	1	0	0	2	0	0	0	0	0	0	0	0	0
260	34	5	13	4	0	0	0	0	0	0	0	0	0	0	1	0
270	9	6	26	6	0	0	0	1	0	0	0	0	1	0	3	0
280	59	1	6	1	0	0	0	0	0	0	0	0	0	0	0	0
290	1	0	9	1	0	0	2	1	0	0	1	0	0	0	0	0
300	45	0	17	1	0	0	1	0	0	0	0	0	0	0	0	0

A.

Expt.	1,1,-	1,2,-	1,3,-	1,4,-	2,1,-	2,2,-	2,3,-	2,4,-	3,1,-	3,2,-	3,3,-	3,4,-	4,1,-	4,2,-	4,3,-	4,4,-
310	38	0	2	1	3	0	0	0	0	0	0	0	5	0	1	0
320	15	1	26	3	0	0	1	0	0	0	0	1	0	0	0	0
330	37	0	10	1	0	0	0	0	0	0	0	0	3	0	1	0
340	44	3	10	1	0	0	0	0	0	0	0	0	7	0	1	0
350	49	2	12	2	0	0	0	0	0	0	0	0	0	0	0	0
360	25	2	2	1	0	0	0	0	1	0	0	0	16	2	7	0
370	46	4	10	1	0	0	1	1	0	0	0	0	1	0	1	0
380	58	3	2	1	0	0	0	0	0	0	0	0	7	0	0	0
390	51	2	14	2	0	0	0	0	0	0	0	0	0	0	1	0
400	44	1	12	2	2	0	2	1	0	0	0	0	0	0	0	0
410	14	1	10	0	2	0	0	1	0	0	0	0	1	0	0	0
420	20	1	25	1	0	0	0	1	0	0	1	0	0	0	0	0
430	47	1	20	0	0	0	0	0	0	0	0	0	2	0	0	0
441	40	1	27	3	0	0	0	0	0	0	0	0	2	0	0	0
442	36	2	26	3	0	0	0	0	0	0	0	0	1	0	1	0
443	50	2	8	2	1	0	0	0	0	0	0	0	1	0	1	0
444	54	2	7	2	0	0	0	0	0	0	0	0	3	0	1	0
445	63	2	1	2	0	0	0	0	0	0	0	0	3	0	0	0
450	26	1	20	2	0	0	0	0	0	0	0	0	0	0	1	1
461	63	1	6	2	0	0	0	0	0	0	0	0	0	0	0	0
462	62	1	7	2	0	0	0	0	0	0	0	0	0	0	0	0
470	35	1	10	3	0	0	1	0	0	0	0	0	6	0	0	0
481	58	2	7	3	1	0	0	0	0	0	0	0	0	0	0	0
482	53	1	8	2	1	0	0	0	0	0	0	0	0	0	0	0
490	43	1	3	3	1	0	0	0	0	0	0	0	1	0	0	0
501	70	1	3	0	0	0	0	0	0	0	0	0	1	0	0	0
502	68	1	2	1	0	0	0	0	0	0	0	0	1	0	0	0
503	63	1	3	0	0	0	0	0	0	0	0	0	1	0	0	0

B. Expt.	1,-,1	1,-,2	1,-,3	2,-,1	2,-,2	2,-,3	3,-,1	3,-,2	3,-,3	4,-,1	4,-,2	4,-,3
10	23	20	0	0	0	2	0	0	0	2	5	0
20	5	12	1	1	0	0	0	0	0	1	0	0
30	56	10	0	0	1	0	0	0	0	0	0	0
40	39	18	0	0	2	2	0	0	0	0	0	0
50	46	8	0	1	0	0	0	0	0	14	1	1
60	34	15	5	0	2	1	0	0	0	1	0	0
70	29	11	1	1	2	1	1	0	0	3	0	0
80	53	12	0	1	0	0	0	0	0	5	1	0
90	58	9	0	1	0	0	0	0	0	2	1	0
100	58	10	0	1	0	0	0	0	0	1	1	0
110	39	15	2	1	0	0	0	0	0	1	3	0
120	6	5	0	0	0	0	0	0	0	0	0	0
131	20	18	5	0	3	0	0	0	0	0	1	0
132	21	13	3	0	2	0	0	0	0	0	0	0
133	15	13	4	0	1	0	0	0	0	0	0	0
140	28	20	3	0	0	0	2	0	0	0	0	0
151	11	8	1	0	0	0	0	0	0	2	1	0
152	8	5	0	0	0	0	0	0	0	2	0	0
153	5	0	0	0	0	0	0	0	0	1	0	0
160	36	8	2	0	0	0	0	0	0	3	0	0
170	58	6	1	0	0	0	0	0	0	2	1	1
180	30	9	3	0	1	0	0	1	0	1	0	0
190	35	12	1	0	0	0	0	0	0	1	1	0
200	55	10	3	0	0	0	0	0	0	2	0	0
210	28	6	0	0	0	0	0	0	0	2	0	0
220	68	5	0	0	0	0	0	0	0	0	0	0
230	69	4	0	0	0	0	0	0	0	0	0	0
240	61	7	1	0	0	0	0	0	0	1	0	0
250	20	4	0	1	0	1	0	0	0	0	0	0
260	38	18	0	0	0	0	0	0	0	1	0	0
270	37	10	0	0	0	1	0	0	0	3	1	0
280	61	5	1	0	0	0	0	0	0	0	0	0
290	9	1	1	0	0	3	0	1	0	0	0	0
300	41	18	4	0	0	1	0	0	0	0	0	0

B.

Expt.	1,-,1	1,-,2	1,-,3	2,-,1	2,-,2	2,-,3	3,-,1	3,-,2	3,-,3	4,-,1	4,-,2	4,-,3
310	29	11	1	1	0	2	0	0	0	4	2	0
320	33	11	1	1	0	0	0	0	1	0	0	0
330	35	12	1	0	0	0	0	0	0	2	2	0
340	50	8	0	0	0	0	0	0	0	7	1	0
350	46	18	1	0	0	0	0	0	0	0	0	0
360	27	2	1	0	0	0	0	0	1	21	4	0
370	50	11	0	0	2	0	0	0	0	2	0	0
380	53	10	1	0	0	0	0	0	0	7	0	0
390	52	17	0	0	0	0	0	0	0	0	1	0
400	43	16	0	1	2	2	0	0	0	0	0	0
410	15	7	3	0	2	1	0	0	0	1	0	0
420	24	19	4	0	1	0	0	1	0	0	0	0
430	51	15	2	0	0	0	0	0	0	2	0	0
441	62	9	0	0	0	0	0	0	0	2	0	0
442	58	8	1	0	0	0	0	0	0	2	0	0
443	52	10	0	1	0	0	0	0	0	2	0	0
444	58	6	1	0	0	0	0	0	0	4	0	0
445	63	5	0	0	0	0	0	0	0	3	0	0
450	42	7	0	0	0	0	0	0	0	1	1	0
461	52	18	2	0	0	0	0	0	0	0	0	0
462	55	15	2	0	0	0	0	0	0	0	0	0
470	38	9	2	0	1	0	0	0	0	5	1	0
481	58	12	0	0	0	1	0	0	0	0	0	0
482	45	16	3	0	0	1	0	0	0	0	0	0
490	41	9	0	1	0	0	0	0	0	1	0	0
501	65	7	2	0	0	0	0	0	0	1	0	0
502	61	9	2	0	0	0	0	0	0	1	0	0
503	55	10	2	0	0	0	0	0	0	1	0	0

C. Expt.	-,1,1	-,1,2	-,1,3	-,2,1	-,2,2	-,2,3	-,3,1	-,3,2	-,3,3	-,4,1	-,4,2	-,4,3
10	1	2	0	0	1	0	22	18	2	2	4	0
20	0	3	0	0	1	0	5	7	0	2	1	1
30	40	6	0	3	0	0	5	3	0	8	2	0
40	28	18	1	1	0	0	4	2	1	6	0	0
50	55	9	1	4	0	0	1	0	0	1	0	0
60	28	13	4	2	1	0	3	1	1	2	2	1
70	29	11	2	4	1	0	1	1	0	0	0	0
80	54	11	0	2	1	0	0	0	0	3	1	0
90	53	7	0	3	1	0	1	1	0	4	1	0
100	47	7	0	2	1	0	7	3	0	4	0	0
110	29	11	1	3	1	0	4	5	1	5	1	0
120	3	3	0	2	0	0	1	1	0	0	1	0
131	11	16	4	1	0	0	6	4	1	2	2	0
132	13	9	3	1	0	0	6	4	0	1	2	0
133	7	7	2	1	1	0	5	4	1	2	2	1
140	6	4	0	1	1	0	21	13	3	2	2	0
151	7	3	1	1	1	0	5	5	0	0	0	0
152	7	3	0	0	0	0	3	2	0	0	0	0
153	3	0	0	0	0	0	2	0	0	1	0	0
160	36	7	1	1	0	1	1	1	0	1	0	0
170	57	6	1	1	0	1	2	1	0	0	0	0
180	20	6	1	0	0	1	9	4	1	2	1	0
190	17	4	1	1	1	0	16	7	0	2	1	0
200	56	10	2	1	0	1	0	0	0	0	0	0
210	17	4	0	4	0	0	9	2	0	0	0	0
220	52	5	0	6	0	0	8	0	0	2	0	0
230	54	4	0	6	0	0	7	0	0	2	0	0
240	46	5	1	6	0	0	8	2	0	2	0	0
250	9	1	0	1	0	0	10	3	1	1	0	0
260	25	9	0	4	1	0	6	8	0	4	0	0
270	8	2	0	6	0	0	20	9	0	6	0	1
280	55	4	0	1	0	0	5	1	0	0	0	1
290	1	0	0	0	0	0	7	2	3	1	0	1
300	30	13	2	0	0	0	10	5	3	1	0	0

C.

Expt.	-,1,1	-,1,2	-,1,3	-,2,1	-,2,2	-,2,3	-,3,1	-,3,2	-,3,3	-,4,1	-,4,2	-,4,3
310	32	11	3	0	0	0	1	2	0	1	0	0
320	13	2	0	1	0	0	17	9	1	3	0	1
330	30	9	1	0	0	0	6	5	0	1	0	0
340	46	5	0	3	0	0	8	3	0	0	1	0
350	35	13	1	1	1	0	8	4	0	2	0	0
360	38	3	1	2	2	0	8	1	0	0	0	1
370	38	9	0	4	0	0	9	3	0	1	1	0
380	56	8	1	2	1	0	2	0	0	0	1	0
390	40	11	0	1	1	0	10	5	0	1	1	0
400	32	13	1	1	0	0	10	3	1	1	2	0
410	10	5	2	1	0	0	5	3	2	0	1	0
420	16	4	0	0	1	0	8	14	4	0	2	0
430	42	6	1	0	1	0	11	8	1	0	0	0
441	37	5	0	1	0	0	24	3	0	2	1	0
442	33	3	1	2	0	0	23	4	0	2	1	0
443	46	6	0	1	1	0	8	1	0	0	2	0
444	53	3	1	2	0	0	7	1	0	0	2	0
445	62	4	0	2	0	0	1	0	0	1	1	0
450	25	1	0	1	0	0	15	6	0	2	1	0
461	47	14	2	1	0	0	3	3	0	1	1	0
462	50	10	2	1	0	0	3	4	0	1	1	0
470	36	3	2	1	0	0	5	6	0	1	2	0
481	49	9	1	2	0	0	5	2	0	2	1	0
482	37	13	4	1	0	0	6	2	0	1	1	0
490	39	6	0	1	0	0	1	2	0	2	1	0
501	63	6	2	1	0	0	2	1	0	0	0	0
502	59	8	2	1	0	0	1	1	0	1	0	0
503	53	9	2	1	0	0	2	1	0	0	0	0

APPENDIX 7

Copy of experimental instruction circulated to schools.

Notes for Teacher

Expt. 1 : Finding the Volume of one Mole of Various Gases

Two main problems seem to have arisen in carrying out this experiment. The first is the lack of a balance of sufficient accuracy for the volumes of gas being used; the second arises from problems of buoyancy. The second problem has led to the rejection of any set-up using inflateable bags, and leaves syringes or round bottom flasks as the gas containers.

If a balance suitable for class use and weighing reproduceably to 3 decimal places is available, then method A is recommended; if only 2 decimal place accuracy is available, then method B is advised.

Method A

Expel all the gas from a 100 ml syringe, and seal off the end using a piece of rubber tubing or clip, or a rubber stopper with a small hole bored half way up. Pull out the plunger until there is 100 ml of "vacuum", and keep the plunger at this position using two pieces of wooden dowelling. Weigh the set-up. Fill the syringe in turn with various gases : subtracting the initial weight from these weights gives the mass of 100 ml of gas at room temperature and pressure.

Method B

Here the apparatus is 250 or 500 ml R.B. flasks each with a stopper. The stopper has a short length of glass tubing through it, and can be sealed off using a spring clip and piece of rubber tubing. Prior to the class experiment, the exact volumes of the flasks should be measured (by filling with water) and marked on them.

If an efficient vacuum pump is available, the mass of the evacuated flask can be found directly; if not, the mass of the air inside can be calculated in advance by the teacher, and the mass of the evacuated flask can be marked on it. Thereafter, procedure is as for Method A.

Recommended gases : O_2, N_2, CO_2, SO_2, butane

Note : the accuracy of this experiment does not justify conversion of gas volumes to S.T.P. before finding the molar volumes, and it is suggested that this step be omitted.

Notes for Teacher on Expts. 2, 3, 10 and 11

Heat Changes During Reaction

My survey showed that many schools are not wholly satisfied with this section of the syllabus, and the following notes and attached instruction sheets are for your guidance. Many teachers teach the 'H' grade organic near the beginning of the course, and splice this section on immediately thereafter.

Expt. 2 : Heats of Solution : this straightforward experiment has as its objective the familiarising of pupils with heat units and how to handle them. The experiment could be carried out before or after any work done on heats of neutralisation, but certainly should be done before heats of combustion. For simplicity, it is assumed that the specific heat capacity of the solution is the same as water, and no attempt is made to try and get across the idea of extrapolating the results to infinite dilution.

Expts. 10 and 11 : Hess's Law : while no experiments on Hess's Law are specified in the syllabus, an appreciation of the law is essential for an understanding of the calculation of average bond energies. The following two experiments have been found to give good results, and satisfaction to the pupils carrying them out. Prior knowledge by the pupils of the law is assumed, and the same assumption about specific heat capacity as in the previous experiment is made.

Expt. 3 : Heats of Combustion of a homologous series of alcohols : The experience of many teachers is that consistent results from this experiment are difficult to obtain, and yet it is a vital experiment, linking as it does structure and enthalpy changes. The writers have used the sophisticated apparatus developed by John McGuire (1973) with no more success than the simple alcohol burner heating a fixed mass of water in a beaker.

However, successful and reasonably consistent results have been obtained by a class of twenty-four using the attached method. Success seems to depend upon two things :- great attention to detail, and the pupils putting their results on the board and examining them critically in relation to other pupils' results. This allows any result that is seriously in error to be repeated and changed, and means that the class averages for the various alcohols do differ from adjacent alcohols by approximately the same amount - the objective of this experiment. This gives pupils experience in co-operative work as well as in care and manipulation of numerical results.

Note that unless the teacher standardises the burner-beaker distance for each group, the efficiency of the apparatus will differ from group to group, and so will the absolute values for each heat of combustion. This however, does NOT make the experiment any less convincing when class average differences (as above) are considered.

Apparatus : small baby food jar with hole in lid, and fibre glass wick dippers in the alcohol. Some cover is required to stop weight loss by evaporation except when the alcohol is burning - we used a 100 ml plastic beaker.

100 ml glass beaker containing 60 g water, clamped near the top (do not use a tripod or gauze - it mops up a variable amount of heat).

balance (2 decimal place accuracy - preferably a top loader)

-10 to 110^{o}C thermometer

primary alcohols - methanol to pentanol

Note : we would expect that all but the most able groups would require help in step 10, and in discerning a pattern in the results in step 11 (see pupil instruction sheet for Expt. 3).

Pupil Instruction Sheet

Expt. 2 : Heats of Solution

Introduction

You are setting out to determine the Heat of Solution of a number of salts. This is the heat change when one mole of salt is dissolved in water. The amount of water is somewhat arbitrary, but we shall choose one litre as our standard. Thus, we could dissolve one mole of salt in one litre of water, or one-tenth mole in one-tenth litre, or one-twentieth mole in one-twentieth litre etc. For convenience, we shall choose the last set of figures, but remember that you will have to scale up the heat change by the factor of twenty to get the heat change per mole.

Salts used (all anhydrous)

$NaCl$	FW = 58.44	$MgCl_2$	FW = 95.22	$CuSO_4$	FW = 159.61
$AlCl_3$	FW = 133.34	NH_4NO_3	FW = 80.04		

Instructions

1. Weigh out one-twentieth mole of one of the salts into a 100 ml dry beaker.
2. Measure out one-twentieth litre (50 ml) of water using a measuring cylinder, and place it in a 100 ml plastic beaker.
3. Record the temperature of the water.
4. Add the salt to the water slowly with stirring.
5. Stir until all the salt is dissolved.
6. Record the final temperature.
7. Calculate the heat change using $\Delta H = S M \Delta T$ when

   S = specific heat capacity of water = 4.2 kJ kg^{-1} K^{-1}

   M = mass of water = 50 g = 0.05 kg

   ΔT = temperature rise
8. Repeat the procedure for other salts, and tabulate your results.
9. Can you see any assumptions made which will lead to inaccuracies in the final result?

Pupil Instruction Sheet

Expt. 3 : Heats of Combustion

Introduction

You are setting out to determine the heat of combustion of each of a series of five alcohols. Remember that this is the heat evolved when one mole of alcohol is completely burned to CO_2 and H_2O. To find this, you will be burning a known weight of alcohol, and using the heat to warm up a known mass of water.

Unfortunately, not all of the heat produced can be used to heat the water. Here, this does not matter, but the vital point is that the same proportion of the heat must be caught by the water for each alcohol burned, i.e. you must standardise as many conditions as possible for this experiment.

A draught-free environment is essential - some pupils have found in a sink ideal!

Instructions

1. Clamp up a 100 ml beaker, and pour in 60 g (60 ml) of water. Select one of the alcohols which tend to burn with a smoky flame (pentanol or butanol), light it and find a distance between the burner and the beaker which leads to no smoke being deposited on the beaker. Measure this distance, and use this throughout the series of experiments.

2. Clamp up the beaker and water as in 1. Measure the temperature of the water.

3. Weigh the burner and cap.

4. Light the burner, and immediately push under the beaker of water. Stir the water gently.

5. When the temperature of the water has increased by 5^{0}, snuff out the burner, cap it and weigh it.

6. Find the mass of alcohol burned.

7. Calculate the heat taken up by the water using

$$\text{heat} = S \times M \times \Delta T \text{ kJ when}$$
$$S = 4.2 \text{ kJ Kg}^{-1}\text{K}^{-1}$$
$$M = 60 \text{ g} = 0.06 \text{ kg}$$
$$\Delta T = \text{temperature rise.}$$

8. Find by proportion the heat that would be taken in by the water if you had burned one mole of alcohol; we shall call this the heat of combustion of the alcohol concerned. Write your answer on the board.

9. Repeat step 2-8 for each alcohol, using fresh tap water each time. You may have to carry out a preliminary experiment in each case to get the flame height about the same as in your first experiment.

10. Look at your results on the board. Examine them critically, looking both at the trend of your own results, and by comparing them with those obtained by other class groups. Repeat any that look wrong - this is most important.

11. Once each group is satisfied with their results, you shall find the class average for each alcohol, to see if there is any pattern in the results. Consult your teacher!

Notes for Teacher

Expt. 4 : Explosion of Hydrogen and Chlorine

Teachers differed greatly on their views of this experiment - some finding it seldom if ever worked, others saying that it is a highlight of the year.

The following method seems to give a success rate of about two out of three attempts.

A 25 x 150 mm test tube was half filled with hydrogen, then with chlorine. The gases were generated in the usual way, and were collected by the downward displacement of water. A well greased bark stopper was placed in the test-tube - streamers of paper may be attached to it if wished. The test-tube was surrounded by a 4 cm diameter perspex guard tube, ½ metre long.

A PF5 flash bulb was clamped close to the guard tube, and aluminium foil was placed round the bulb and guard tube to surround them completely - the tail of the bulb is left pointing through to allow electric connections to be made.

Notes - 1. PF5 or PF5B bulbs are essential, and may have to be ordered specially by a local photographic dealer.

2. No explosions of the test-tube have been reported, but the guard tube seems a sensible precaution.

Pupil Instruction Sheet

Expt. 5 : Reaction of Phenol (C_6H_5OH)

Note : Phenol is corrosive, and both solid and solution can cause unpleasant blisters on skin contact. If you do get some on your skin, wash off immediately with water and then $NaHCO_3$ solution.

1. To ½" of water in a test-tube, add 2 or 3 crystals of phenol. Note characteristic smell. Divide solution into two :-

   (a) add 1 or 2 drops of pH indicator solution. Explain any change.

   (b) add 1 or 2 drops of $FeCl_3$ solution. Record any change.

2. To ½" of bench NaOH solution, add about one-fifth of the volume of phenol crystals. Do they dissolve readily? Why? Now add concentrated HCl dropwise in fume cupboard. What do you observe, and what does this tell you?

Expt. 6 : Reactions of Amines

Carry out the following tests, using concentrated ammonia, methylamine CH_3NH_2 and aniline $C_6H_5NH_2$. Use small quantities because of the irritant vapour, and take care not to get any on your hands (aniline is absorbed through the skin).

Describe the reactions as they are carried out.

1. Place ½" in each of three test-tubes. Test vapour with moist pH paper. If no change, test the liquid. Use same samples for next test.

2. (a) Hang one small drop of concentrated HCl, on a glass rod, above each liquid and record any change. Retain samples for test 3.

   (b) Add three drops of the amine to 1 ml of diluted HCl in a test-tube and record any changes.

In each case, a salt analogous to an ammonium salt is formed, e.g. methylammonium chloride. Write equations for each substance.

3. In a fume cupboard, warm your test-tube of amine gently, and test the vapour to see if it burns. Compare ammonia with methylamine (do not use aniline - too high BP). Retain samples for last test. Write equation for the combustion.

4. To ½" of copper sulphate solution in a test-tube add each amine dropwise with shaking, recording any changes that take place (equation not required).

Notes for Teacher

Expt. 7 : Alcohols and Carbonyl Compounds

The following experiment links together S4 (reactions of ethanol) (oxidation) and S6 (preparation of carbonyl compounds by oxidation of alcohols). If this is used, it would be logical to postpone S4 (phenol and relative acidities of alcohols, phenol, and acids) and S5 (amines) until after S6 (carbonyl group).

Each group of pupils is given a small sample of each of a primary, secondary and tertiary alcohol - preferably isomers, e.g. butan-1-ol, butan-2-ol and 2-methyl propan-2-ol. To each alcohol is added about 10X - 20X its volume of a dilute solution of $K_2Cr_2O_7$ dissolved in dilute H_2SO_4. The pupils are told that the dichromate turning green is a sign that something is being oxidised, and are asked to look out for any other sign of oxidation, e.g. temperature rise, change in smell.

All agree that the tertiary alcohol is not oxidised, and the other two are; the majority think that the primary alcohol uses up the dichromate fastest. This fits in with the fact that primary alcohols are undergoing two oxidation steps whereas the secondary is undergoing only one.

It is perhaps worthwhile setting fire to the tertiary alcohol at the end of the write-up of this experiment to show that they can be oxidised under appropriate conditions!

Notes for Teacher

Expt.8 : Models of NaCl and CsCl Structures

Before going into the detail of these structures, the concept of lattice energy should be introduced (Born-Haber cycle for NaCl ?). This leads in to the idea that each ion surrounds itself with as many of the opposite charge as there is room for, and therefore that the larger an ion is, the more ions of the opposite charge will surround it. A model can be used for this latter point. (Note 1).

Pupils could now be shown the Beevers models for NaCl and CsCl, and the structures explained briefly. (Note 2)

To understand the structures, pupils should build up the structures themselves. Each group of pupils should be provided with the following, which allows both structures to be built up. The following is based upon "Chemistry Takes Shape" Book 5, p.98.

10 x 10 x 1.5 cm wood or chipboard blocks drilled three-quarters way through with holes 2 cm apart - 25 holes in all in a square grid pattern

Arnold's wooden balls - three-quarter inch diameter - cat. no. KN020 - 50 red and 50 blue

Glass rods (or preferably metal) to fit through wooden balls, approximately 15 cm long - 25 required

Spacers of glass tubing, approximately 2 cm length - 100 required.

The structures can be built satisfactorily with less material than listed. Each structure can be built in two ways - close packed (with no spacers, and with some balls not on the metal rods), and spread out (like the Beever models) using spacers and with all the balls on rods. Pupils seem to enjoy building up both types.

Note 1. The following should be read alongside "Chemistry Takes Shape" Book 5 (Teachers' Guide) p.27.

The eight white spheres are 62.5 mm in diameter, and have a short length of metal inserted in each. The black spheres, drilled with eight holes as shown, are of diameter, 65 mm, 55 mm, 50mm, and 45 mm.

An additional white sphere can be mounted as shown on the wooden dowelling supporting the smallest black sphere. If this black sphere is drilled appropriately, six-fold co-ordination can be shown.

In use, it is found that the eight spheres easily fit round the large central sphere which represents the ion of the opposite charge. As the diameter of the central sphere decreases, the eight spheres (all of the same charge) come closer together, thus making the structure less stable. With the smallest central sphere, eight cannot pack round, and the co-ordination number changes to six.

Note 2. Descriptive literature on Beevers Models is available from :-

Beevers Miniature Models,
Simon Square Centre,
Pleasance,
EDINBURGH EH8 9HW.

Notes for Teacher

Expt. 9 : ICl - ICl_3 Equilibrium

This is an excellent experiment for demonstrating the dynamic nature of equilibrium; it should be carried out in a fume cupboard, or - if this is not available - the chlorine gas can be led out of a window through rubber tubing. The experiment is best done as a demonstration - not so much because of the fumes, but rather because the concept of a dynamic situation is best put across by explaining the observations as they are seen.

Put a little solid iodine in a U-tube, and connect one limb of it to a chlorine generator. As the chlorine passes through first a brown liquid forms (ICl), and then a yellow solid (ICl_3). The latter product corresponds to successful collisions between ICl and Cl_2 molecules.

How can we stop the forward reaction, and so allow the backward reaction to reform the ICl? By stopping collision between reactant molecules, e.g. by removing the chlorine. This is most readily done by disconnecting the rubber tubing from the chlorine generator, connecting it to a piece of glass tubing, and blowing gently. The effect is immediate as the yellow solid changes progressively to the brown liquid.

The whole process can be repeated as often as desired.

Two good teaching aids to this concept are -

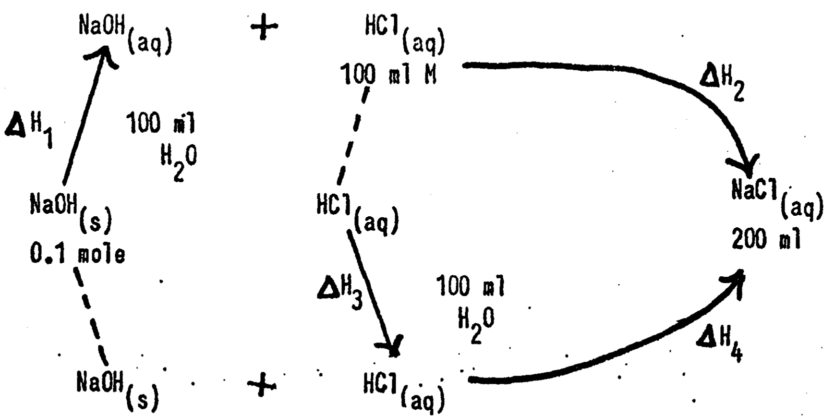
(a) Water trough analogue "Chemistry Takes Shape" book 5 p.140. This could, for example, represent the Haber Process, with trough A representing reactants(N_2 + $3H_2$) and B representing products (NH_3). Once equilibrium is attained, a third beaker to remove products from B can be used to represent the NH_3 being 'frozen out' of the equilibrium mixture.

(b) Scottish Schools' Science Equipment Research Centre overhead projector/ ball bearing analogue.

This is one for the technician to make; classes really do like it. For details, see S.S.S.E.R.C. Bulletin No.68 (Jan.1974).

Pupil Instruction Sheet

Expt.10 : Hess's Law I



Objective - To show that the heat changes by the two routes are the same i.e.

$$\Delta H_1 + \Delta H_2 = \Delta H_3 + \Delta H_4$$

Method - ΔH_1 Record the temperature of 100 ml water in a 250 ml plastic beaker. Add 0.1 mole $NaOH_{(s)}$, stir until dissolved, and record final temperature.

ΔH_2 The initial temperature is the average temperature of the two solutions - $NaOH_{(aq)}$ and $HCl_{(aq)}$. Record these, mix the two thoroughly, and record the final temperature.

ΔH_3 as for ΔH_2

ΔH_4 as for ΔH_1

Calculation - For each ΔH use

$\Delta H = S\ M\ \Delta T$ kjoules when

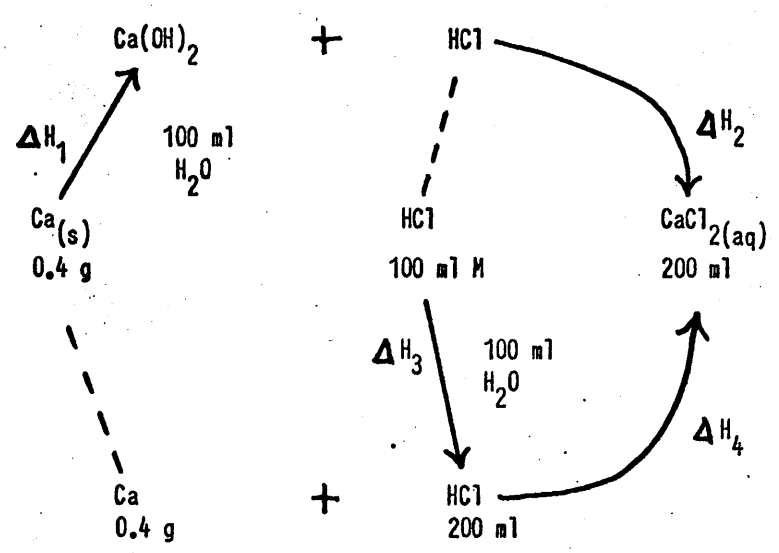
S = specific heat capacity for water
= 4.2 kJ $kg^{-1}K^{-1}$

M = mass (0.1 kg or 0.2 kg in each case)

ΔT = temperature rise

Pupil Instruction Sheet

Expt.11 : Hess's Law II



Objective - as for previous experiment

Method - as for previous experiment, but note that some calcium granules often float up to the surface, making the water boil there, and losing heat. It is, therefore, advisable to wrap the calcium in a little iron gauze before dropping it into the liquid. This will sink the metal.

Notes - 1. HCl is in excess to speed up reactions.

2. Lithium can be used in place of calcium.

APPENDIX 8 :

Hydrides, Chlorides and Oxides of Elements 1 - 20: summary of work carried out by G.R. Tait as C.S.Y.S. Chemistry Project under the guidance of C. Wood, with additional material by C. Wood.

A. HYDRIDES

Compound Made	Method	Comment
alkali metal hydrides	molten metal + hydrogen	Too dangerous.
CH_4	sodium acetate + soda lime	Very low yield. Uninteresting experiment.
C_2H_2	calcium carbide + water	Interesting experiment and product. Pupil experiment.
SiH_4	magnesium silicide + dilute HCl	Spectacular experiment and product. Pupil experiment.
NH_3	ammonium salt + soda lime	Useful revision. Pupil experiment.
PH_3	yellow P + sodium hydroxide	Interesting product. Demonstration experiment.
H_2O	$H_2 + O_2$ explosion in small plastic bag	Interesting experiment. Demonstration experiment.
H_2S	molten sulphur + hydrogen	Too dangerous. Low yield.
HF	sodium fluoride + H_2SO_4	Interesting (but dangerous) product. Pupil experiment to etch glass.
HCl	$H_2 + Cl_2$ + light *	Spectacular experiment. Demonstration experiment.

* Perhaps best done with section R5, when light energy is used as a source of activation energy.

B. CHLORIDES

Compound	Method	Comment
Metallic Chlorides	metal + dry chlorine	$AlCl_3$: interesting experiment and product.
CCl_4	CH_4 + excess chlorine	If H_2/Cl_2 reaction done, not worth adding this in.
$SiCl_4$	silicon + dry chlorine	Reasonable experiment.
NCl_3	$NH_3 + Cl_2$	Too dangerous
PCl_3	Red P + Cl_2	Good demonstration experiment.
ClO_2	potassium chlorate + conc. H_2SO_2	Too dangerous for pupils. Interesting experiment.
ICl/ICl_3	$I_2 + Cl_2$*	Interesting experiment.

* but best done with R7 (factors affecting the position of equilibrium)

C. OXIDES

Compound	Method	Comment
Metal oxide, CO_2, P_2O_5, SO_2	element* + O_2 (Arculas) *red phosphorus	Interesting revision experiment. Pupil experiment.
NO_2	spark air	Useful revision experiment. Demonstration experiment.
SO_3	Contact process	Useful revision experiment.
ClO_2	potassium chlorate + conc. H_2SO_4	Dangerous, but see chlorides above.

References used by G.R. Tait :

Rendle Vokins and Davis : Experimental Chemistry - a Lab Manual, E.J. Arnold, 2nd Edition 1973.

A. King : Inorganic Preparations - A systematic course of experiments Allen & Unwin 1936.

G.D. Muir : Hazards in the Chemical Laboratory, R.I.C. 1971.

APPENDIX 9A

Clock Reactions : a summary of work carried out by Douglas B.M. King as CSYS project under the guidance of C. Wood.

D. King assessed clock reaction on the basis that "the best clock reaction would be one that followed easily understandable predictions", i.e. that one should be able to predict what effect changing the concentration of one reactant would have, and then show that this is the case in practice.

He ordered the clock as follows, best first -

1. $KI/H_2O_2/Na_2S_2O_3$ clock

$$2H^+ + H_2O_2 + 2I^- \longrightarrow 2H_2O + I_2$$

$$I_2 + 2S_2O_3^{2-} \longrightarrow 2I^- + S_4O_6^{2-}$$

When thiosulphate is used up, I_2 + starch $\longrightarrow$ blue complex.

It was found that the rate increased with increasing concentration of peroxide, iodide, hydrogen ion, and with decreasing concentration of thiosulphate. All these were satisfactorily explained using the above mechanism.

2. Methanal clock.

$$H.CHO + HSO_3^- \longrightarrow CH_2.OH.HSO_3$$

$$H.CHO + SO_3^{2-} \longrightarrow CH_2.OH.HSO_3 + OH^-$$

$$OH^- + HSO_3^- \longrightarrow SO_3^{2-} + H_2O$$

When HSO_3^- used up, OH^- + phenolphthalein $\longrightarrow$ pink colour.

It was found that the rate increased with increasing concentration of methanal, sulphite, with decreasing concentration of bisulphite, and was independent of the volume of water. Problems arose in attempting to rationalise these results.

3. Iodine clock

$$IO_3^- + 3\,SO_3^{2-} \longrightarrow I^- + 3SO_4^{2-}$$

$$5I^- + IO_3^- + 6H^+ \longrightarrow 3I_2 + 3H_2O$$

$$I_2 + SO_3^{2-} + H_2O \longrightarrow 2I^- + SO_4^{2-} + 2H^+$$

When SO_3^{2-} used up, I_2 + starch $\longrightarrow$ blue complex.

It was found that the rate increased with increasing concentration of iodate, hydrogen ion, and was independent of sulphite concentration. There was a much greater scatter in results than in the previous two cases, and there was no readily understood explanation of the effect of change in sulphite concentrate.

4. Time was insufficient for investigation of the persulphate-iodine clock.

$$S_2O_8^{2-} + 2I^- \longrightarrow 2\,SO_4^{2-} + I_2$$

$$I_2 + 2\,S_2O_3^{2-} \longrightarrow S_4O_6^{2-} + 2I^-$$

When the $S_2O_3^{2-}$ is used up, I_2 + starch $\longrightarrow$ blue complex.

APPENDIX 9B

Reactions which can be used instead of Clock Reaction in studying reaction rate.

The writer uses the following experiment with Class 5 - as do the other teachers in his department - with success.

1. Effect of Concentration.

A 100 ml glass beaker containing about 20 ml thiosulphate solution (of indeterminate concentration) is placed on top of a piece of paper with a pencil cross upon it. One drop of dilute acid is added and the time taken for the colloided sulphur to obscure the cross is noted. The experiment is repeated varying only the number of drops of acid, and a graph of time v number of drops acid drawn.

2. Effect of Temperature.

The oxalic acid/permanganate reaction is carried out at different temperatures, using the former in excess, and taking completion of reaction being when the permanganate colour disappears. A graph of temperature against time is drawn.

3. Catalyses

Earlier work when catalysts were used can be discussed e.g. cracking of hydrocarbons, Contact, Haber, Ostwald Processes, oxidation of ethanol $\rightarrow$ ethanoic acid. However, the fact that a catalyst takes part in a reaction is well shown by the decomposition of hydrogen peroxide, catalysed by Cr^{2+} ions. The colour changes from pink Cr(II) to green Cr(III) as the reaction proceeds, and reverts to its pink colour when all the peroxide is decomposed.

APPENDIX 10 SUMMARY OF RETURNS OF EXPERIMENTS CIRCULATED TO SCHOOLS

Experiment 1. Molar volume of gases.

9 teachers				67 pupils			
Objective	VI	FI	NI	Objective	T	F	DK
1	1	3	4	1	48	15	4
2	6	2	1	2	43	14	10
3	-	8	-	3	38	19	7
4	4	2	1	4	46	16	3
5	-	4	4	5	29	33	5
6	1	7	1	6	12	51	2
7	-	7	1	7	35	27	5
8	2	2	4	-			
9	6	2	-	8	61	7	1
10	4	-	4	-			
11	2	7	-	9	46	20	1

Experiment 2. Heats of solution

19 teachers				123 pupils.			
Objective	VI	FI	NI	Objective	T	F	DK
1	-	12	8	1	62	45	14
2	12	3	3	2	64	35	21
3	4	14	1	3	44	65	11
4	13	5	1	4	80	33	10
5	7	9	3	5	44	65	9
6	6	13	-	6	18	95	9
7	7	9	3	7	26	93	5
8	7	11	1	-			
9	13	5	1	8	109	12	2
10	7	10	2	-			
11	8	7	2	9	53	57	12

Experiment 3. Heats of combustion

17 teachers				102 pupils.			
Objective	VI	FI	NI	Objective	T	F	DK
1	4	6	6	1	74	21	2
2	6	6	5	2	38	45	17
3	6	9	2	3	36	53	10
4	8	8	2	4	66	26	8
5	5	5	5	5	42	54	4
6	10	3	3	6	15	81	4
7	6	9	2	7	38	53	7
8	8	7	2	-			
9	14	3	1	8	89	7	2
10	7	5	5	-			
11	9	6	2	9	38	50	10

(Key on last page of this appendix)

Experiment 4. Hydrogen-chlorine explosion

6 teachers

Objective	VI	FI	NI
1	2	3	1
2	3	1	2
3	-	1	3
4	3	2	-
5	3	2	1
6	-	-	4
7	-	1	4
8	1	1	3
9	1	-	5
10	-	-	4
11	3	2	1

20 pupils

Objective	T	F	DK
1	20	-	-
2	13	4	4
3	3	14	3
4	12	5	4
5	19	-	1
6	-	16	4
7	-	17	3
-			
8	2	11	7
-			
9	19	1	-

Experiment 5. Reaction of Phenol

15 teachers

Objective	VI	FI	NI
1	4	7	3
2	9	7	-
3	2	6	7
4	10	5	-
5	5	6	2
6	3	4	8
7	3	8	4
8	10	4	1
9	1	5	8
10	5	6	3
11	5	8	1

98 pupils

Objective	T	F	DK
1	62	30	7
2	59	27	12
3	19	72	6
4	75	15	8
5	51	49	8
6	10	73	10
7	5	83	10
-			
8	47	30	20
-			
9	52	36	9

Experiment 6. Reaction of amines

13 teachers

Objective	VI	FI	NI
1	2	8	2
2	7	6	-
3	3	6	4
4	6	6	1
5	7	5	1
6	1	8	3
7	4	7	2
8	8	5	-
9	2	4	6
10	4	6	2
11	5	4	1

77 pupils

Objective	T	F	DK
1	55	16	6
2	47	24	8
3	16	51	8
4	54	17	5
5	47	21	9
6	19	51	7
7	13	57	6
-			
8	37	32	7
-			
9	28	42	6

(Key on last page of this appendix)

Experiment 7. Carbonyl Compounds

6 teachers

Objective	VI	FI	NI
1	2	2	2
2	3	3	-
3	-	4	2
4	4	2	-
5	3	1	2
6	2	1	3
7	-	2	4
8	2	2	2
9	-	2	4
10	3	2	1
11	5	1	-

14 pupils

Objective	T	F	DK
1	7	6	1
2	7	4	3
3	4	9	1
4	10	4	-
5	5	6	2
6	6	8	-
7	-	10	4
-			
8	7	5	2
-			
9	9	2	3

Experiment 8. ICl/ICl_3 equilibrium

3 teachers

Objective	VI	FI	NI
1	-	3	-
2	2	1	-
3	-	1	2
4	1	2	-
5	-	1	1
6	-	1	2
7	-	-	3
8	-	1	2
9	-	-	3
10	1	1	1
11	1	1	1

20 pupils

Objective	T	F	DK
1	19	1	-
2	15	-	5
3	3	13	4
4	15	4	1
5	13	6	1
6	2	17	1
7	2	18	-
-			
8	4	12	4
-			
9	17	3	-

Experiment 10. Hess's Law I

19 teachers

Objective	VI	FI	NI
1	4	9	5
2	16	3	1
3	4	11	3
4	13	5	-
5	3	7	6
6	14	5	-
7	5	8	4
8	7	10	1
9	13	6	-
10	7	9	2
11	8	8	1

117 pupils

Objective	T	F	DK
1	67	45	3
2	81	30	5
3	56	52	6
4	72	33	10
5	32	74	9
6	29	81	5
7	28	85	3
-			
8	95	15	5
-			
9	68	37	11

(Key on next page)

Experiment 11. Hess's Law 2

6 teachers

Objective	VI	FI	NI
1	2	2	2
2	5	1	-
3	3	3	-
4	5	1	-
5	2	2	2
6	3	3	-
7	2	4	-
8	2	4	-
9	5	1	-
10	3	2	1
11	2	4	-

27 pupils

Objective	T	F	DK
1	19	9	-
2	11	17	-
3	14	14	-
4	21	8	-
5	8	19	1
6	7	20	1
7	7	20	1
-			
8	24	4	1
-			
9	11	13	3

Totals

113 teachers

Objective	VI	FI	NI
1	21	55	33
2	69	32	12
3	22	63	24
4	67	38	5
5	35	42	27
6	40	45	24
7	27	55	24
8	47	45	16
9	55	30	28
10	41	41	26
11	48	48	9

665 pupils

Objective	T	F	DK
1	433	188	37
2	378	200	85
3	233	362	56
4	398	161	49
5	290	326	49
6	118	493	43
7	154	453	44
-			
8	475	135	51
-			
9	341	261	55

Key :-

VI - very important
FI - fairly important
NI - not important
T - true
F - false
DK - don't know

APPENDIX 11

Results obtained by the author's class for the Heat of Combustion of Alcohols Experiment.

CLASS A

Group	Methanol	Ethanol	Propanol	Butanol	Pentanol
1	-268	-483	-663	-877	-1232
2	-224	-401	-621	-811	-1122
3	-224	-483	-700	-971	-1232
4	-	-483	-580	-953	-
5	-240	-411	-651	-910	-1124
6	-280	-360	-698	-870	-
7	-210	-340	-730	-995	-1191
8	-330	-640	-930	-1243	-1400
Average	-242	-445	-682	-936	-1217

Differences: 203, 237, 254, 281

CLASS B

Group	Methanol	Ethanol	Propanol	Butanol	Pentanol
1	-300	-440	-650	-930	-1400
2	-280	-450	-690	-930	-1400
3	-250	-580	-760	-1000	-1400
4	-340	-405	-750	-930	-1300
5	-270	-580	-630	-850	-
6	-320	-370	-760	-	-1300
Average	-276	-471	-707	-947	-1360

Differences: 195, 236, 240, 413

Notes : Units are kJ mol^{-1}.

Groups consisted of 2 or 3 pupils working together.

GU/Chem Ed/C.W./1972/1

University of Glasgow - Research in Chemical Education

AN EVALUATION OF PRACTICAL WORK IN SCHOOL 'H'-GRADE CHEMISTRY COURSES

1. Name of school (optional) . . . .
2. Name of P.T. of Chemistry (optional) . . . .
3. Total no. of periods per week devoted to Chemistry . . . . .
4. No. of these periods in a lab. . . . .
5. Length of school period . . . .
6. Do you find the time allowance adequate? . . . .

   If not, what time do you require? . . . . periods total; . . .
   . . . . of them in lab.
7. No. of pupils taking 'H'-grade course in 1972-73 . . . . . .
8. Average size of 'H'-grade Chemistry section . . . .

Recording of Practical Work

Please tick any of the following methods used in your school to record practical work. Use a double tick for a method frequently used - a single tick for a method used occasionally.

a. Practical work not formally recorded, but theory written up by teacher ☐

b. Practical work recorded in worksheets by pupil ☐

c. Practical work recorded in pupils' notebooks, written up in detail by teacher ☐

d. Practical work recorded in pupils' notebooks, written up in detail by the pupil ☐

e. Other method - please describe ☐

Notes on Questionnaire (see next page for detailed column headings)

Column 1 - gives the code of the relevant section in S.C.E.E.B. syllabus. Please refer to these as you go through the questionnaire, as the experiment titles have of necessity been abbreviated.

Column 2 - code number for statistical work

Column 3 - please tick the relevant space according to whether the particular experiment is done regularly, used to be done but is now abandoned, has never been done in your school, or is done earlier in the course, and is not repeated as part of the 'H' course.

Column 4 - please tick the relevant space according to the method by which the experiment is usually done. (Assisted dem. - involves pupil participation in an experiment performed at the teacher's bench. Stations - involves a series of experiments which the pupils work through, each group carrying out different experiments and then moving on.

Column 5 - please tick the space which most closely describes your attitude to the experiment - according to its use as an aid to the understanding of the topic concerned.

Column 6 - for any special points with regard to the expt. concerned.

Comments - after each syllabus section, a place has been left for a note of the experiments carried out which are NOT mentioned in the syllabus. This is most important if the survey is to present an accurate picture of 'H' grade practical work: the briefest detail will suffice.

TWO copies of the questionnaire are enclosed - ONE to be returned, the other for your own use.

Col. 1	Col. 2 Expt. No.	Description of Experiment	Col. 3 Performed				Col 4 Method				Col. 5 Usefulness			Col. 6 Notes
'H' Grade Section			regularly	was done but now abandoned	never done	done earlier in course only	pupil	stations	demonstration	assisted dem.	very useful	fairly useful	of little use	

Col. 1	Col. 2	Description of Experiment	Col. 3	Col. 4	Col. 5	Col. 6
P 1	01	Principle of Mass Spec.				Method?
P 3	02	Analogy expts. on nuclear rays				"
P 4	03	Electrolysis to find Avagadro's No.				Electrolyte?
P 5	04	Finding gas densities → 22·4 litres				Gases?

Comments on section P experimental (continue overleaf if necessary)

Col. 1	Col. 2	Description of Experiment	Col. 3	Col. 4	Col. 5	Col. 6
Q 1	05	Heats of neutralisation				Do you do any experiments to verify Hess's Law
Q 1	06	Heats of combustion				
Q 1	07	Heats of solution				

Comments

Col. 1	Col. 2	Description of Experiment	Col. 3	Col. 4	Col. 5	Col. 6
Q 2	08	Tests for redox reactions				
Q 2	09	Some redox processes				
Q 2	10	Connection between redox and elec. transfer				
Q 2	11	Measuring e.m.f. of cells				

Comments

Col. 1	Col. 2	Description of Experiment	Col. 3	Col. 4	Col. 5	Col. 6
Q 3	12	None in syllabus - please indicate any done				
Q 4	13	Please indicate compounds made a) b) c)				

Comments

Col. 1	Col. 2	Description of Experiment	Col. 3	Col. 4	Col. 5	Col. 6
Q 5	14	Models of NaCl and CsCl structures				
Q 5	15	Please indicate any practical work done a) b) c)				

Comments

Col. 1	Col. 2	Description of Experiment	Col. 3	Col. 4	Col. 5	Col. 6
Q 6	16	Redox experiments				
Q 6	17	Displacement reactions				
Q 6	18	Stability of hydrides				
Q 6	19	Reaction with metals				
Q 6	20	Tests for halides				

Comments

Col. 1	Col. 2	Description of Experiment	Col. 3	Col. 4	Col. 5	Col. 6
R 1	21	Preliminary survey				Say which experiment?
R 1	22	Effect of temperature				
R 1	23	Effect of concentration				
R 1	24	Effect of particle size				
R 1	25	Pyrophoric lead or iron				Which metal?
R 1	26	Light on AgX				
R 1	27	$Al/I_2 + H_2O$				

Comments

R 2	28	Clock Reactions				Which

Comments

R 3		Effect of temperature - comments
R 4		Effect of catalysts - comments
R 5		Hydrogen/chlorine explosion

Comments

Col. 1	Col. 2	Description of Experiment	Col. 3	Col. 4	Col. 5	Col. 6
R 6	30	Iodine distribution				
R 6	31	Salt hydrolyses				

Comments

R7	32	ICl/ICl_3 equilibrium				
R7	33	Acetic acid ionisation				

Comments

R 8		Equilibrium in practice - comments				
S 1	34	Props of saturated hydrocarbons				
S 1	35	Reaction of alkyl halides				
S 2	36	Cracking of hydrocarbons				
S 2	37	Dehydration of alcohols				
S 2	38	Addition reactions of alkenes				
S 2	39	Prep. and props of ethyne				
S 2	40	Addition reactions of alkynes				
S 2	41	Oxid. of ethyne to ethanol				

Comments

S 3	42	Physical props of benzene				
S 3	43	Reaction of bromine water + benzene				

Comments

Col. 1	Col. 2	Description of Experiment	Col. 3	Col. 4	Col. 5	Col. 6
S 4	44	Reactions of ethanol				
		a) with sodium				
		b) with phosphorus pentachloride				
		c) oxidation to ethanol				
		d) oxidation to ethanoic acid				
		e) ester formation				
S 4	45	Build model of ethanol				
S 4	46	Props of phenol a) solubility				
		b) acidic nature				
S 4	47	Hydrolyses of esters				

Comments

S 5	48	Reaction of amines				
		a) with HCl and NaOH				
		b) with copper sulphate soln.				

Comments

S 6	49	Prep of carbonyl compounds by oxid. of alcohols				
S 6	50	Reactions of carbonyl compounds with				
		a) Fehling's solution				
		b) ammoniacal silver nitrate				
		c) acid dichromate				

Comments

Thank you most sincerely for completing the questionnaire. if you can manage, please answer the following two questions.-

A. Write down your teaching order (preferably in terms of the syllabus sections)

. . . .

B. Please name any textbook or data issued to your pupils for their retention during the session (if extensive printed notes are issued instead, please say so).

. . . .

. . . .