Chemistry

Examinations and assessment

Nuffield Advanced Science

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Nuffield Advanced Science
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Contents

Foreword

It is almost a decade since the Trustees of the Nuffield Foundation decided to sponsor curriculum development programmes in science. Over the past few years a succession of materials and aids appropriate to teaching and learning over a wide variety of age and ability ranges has been published. We hope that they may have made a small contribution to the renewal of the science curriculum which is currently so evident in the schools. The strength of the development has unquestionably lain in the most valued part that has been played in the work by practising teachers and the guidance and help that have been received from the consultative committees to each Project.

The stage has now been reached for the publication of materials suitable for advanced courses in the sciences. In many ways the task has been a more difficult one to accomplish. The sixth form has received more than its fair share of study in recent years and there is now an increasing acceptance that an attempt should be made to preserve breadth in studies in the 16–19 year age range. This is no easy task in a system which by virtue of its pattern of tertiary education requires standards for the sixth form which in many other countries might well be found in first year university courses.

Advanced courses are therefore at once both a difficult and an interesting venture. They have been designed to be of value to teacher and student, be they in sixth forms or other forms of education in a similar age range. Furthermore, it is expected that teachers in universities, polytechnics, and colleges of education may find some of the ideas of value in their own work.

If these advanced courses meet with the success and appreciation I believe they deserve, it will be in no small measure due to a very large number of people in the team so ably led by Ernest Coulson, in the consultative committee, and in the schools in which trials have been held. The programme could not have been brought to a successful conclusion without their help and that of the examination boards, local authorities, the universities, and the professional associations of science teachers. Finally, the Project materials could not have reached successful publication without the expert assistance that has been received from William Anderson and his editorial staff in the Nuffield Science Publications Unit and from the editorial and production teams of Penguin Education.

K. W. Keohane
Co-ordinator of the Nuffield Foundation Science Teaching Project

Author's preface

Throughout the period of planning and trials of the Nuffield Advanced Chemistry course, educational aims and objectives provided the framework upon which the materials and activities of the course were built. But an essential part of curriculum development is curriculum assessment and an essential part of the latter is assessing student attainment. From the start the Project was concerned not only with what the students ought to do during the course but with what they had been able to achieve: development and assessment were closely linked.

The purpose of this book is to give an account of the present form of assessment and the reasons which lie behind its adoption. It is hoped that it will lead to an understanding of the structure and techniques of the external examination and give guidance to teachers in their own internal assessment.

This book was written in the light of experience gained in the school trials of the course and it would be wrong to suppose that the form of assessment described here will not be subject to change. Several new techniques, previously untried at this level, have been introduced and some of them may well be the subject of research and refinement in the years to come. However, there are signs of a general trend towards the form of assessment described here and to variants of it, and it is not expected that any part of it will become redundant in the near future.

The second part of this book contains examples of various types of questions which have been used for assessment purposes. Teachers may find some of them useful in internal tests, but it is hoped that they will also use them to guide their own writing of questions and tests. Many of the questions were written during trials and most of them by the teachers themselves. Some questions (marked *) have been used in the Nuffield A-level examination and are reproduced, with some modification to S.I. units, by kind permission of the University of London School Examinations Department. Few of the questions are beyond criticism – the question which will please everyone has yet to be written – but teachers will find the exercise of criticizing the published questions and then trying to write better ones rewarding; it will help them to look at the course from the point of view of what their students are able to achieve; and this, after all, is what teaching is about.

Important. Before starting the Advanced Chemistry course teachers must apply to the University of London School Examinations Department (66–72 Gower

Street, London WC1) for a supply of record cards (two per student should suffice) to use in the internal assessment of practical work (see Chapter 3) and for the notes on how this assessment should be conducted.

Part one

Introduction

Chapter 1

The purpose of assessment

The word 'assessment' as well as 'examination', has been used deliberately in the title. Examinations imply formal written tests and, although they still make up a large part, they do not constitute the whole of the assessment procedures. It is sometimes difficult to distinguish between them, and we refer to the 'Nuffield A-level examination' even though it contains an element of assessment which is not a written examination.

Why is assessment necessary? Few people, particularly those on the receiving end, enjoy the process. To put it as simply as possible, its purpose is to measure, in the most reliable way, how far the educational objectives of the course are being attained. There are many reasons for this exercise. First of all, if there are objectives in mind, it is not possible to make progress in teaching unless there is some way of measuring the extent to which the objectives are attained. So the prime purpose of assessment is to provide information about present attainment to guide teaching and learning in the future; in other words, assessment can be an instrument for educational progress.

In addition to the educational need for internal assessment, there is an inevitable, some think unfortunate, demand for grading of students about to leave school, and educational attainment is at present the basis for it. This demand is met by public examinations.

The Chemistry Project had to keep in mind both the internal and external functions of assessment. Primarily our desire was to test how far the objectives of the course are attained. But this assessment must be capable of adaptation to the conditions of public examinations.

There are two aspects to be considered when designing an assessment procedure; one is its reliability and the other its validity. By reliability we mean the accuracy and consistency of a particular form of assessment. It is the degree to which the results of the same test applied to the same candidates can be reproduced. If, for example, the candidates' scripts were re-marked after an interval and gave rise to completely different results, the assessment would be unreliable.

By validity we mean the extent to which the assessment measures what it is intended to measure. Of course, it is impossible to make a valid measurement with an assessment instrument which is itself unreliable, but it is quite possible to make a highly reliable measurement the outcome of which is completely invalid. It would be possible, for example, to measure accurately the extent to which pupils could remember the atomic weights of all the elements; but as a measure of the attainment of the objectives of the Nuffield course, or – for that matter – any chemistry course, the assessment would have little, if any, validity.

By what criteria should the validity of a form of assessment of the Nuffield course be judged?

A Content

First, the assessment should cover all the essential material content of the course. If students are expected to have covered all the nineteen topics (page 17) of the course, then the assessment should require them to demonstrate their attainment in all of them, keeping in mind that there is choice of material within the topics. But, to some extent, the topics of the course are simply a convenient way in which the total material can be broken up into teaching units; the detailed material which they contain could be subject to variation. It follows that a course with similar objectives could be written using different topics. A more fundamental way of considering the coverage of the course is to think of the content in terms of general themes rather than specific topics. By themes we mean the essential framework of chemistry which gives it coherence and makes it worthy of study at this level as a discipline in its own right. Therefore, in judging the validity of a form of assessment of the Nuffield course, it is necessary to consider the extent to which each of the following chemical themes are represented in it.

1 Materials exhibit *specific* behaviour and composition.
2 Materials exhibit *patterns* in behaviour and composition.
3 Behaviour and composition can be explained in terms of *structure* and *bonding*.
4 *Kinetics* – how fast changes take place.
5 *Equilibria* – how far changes go towards completion.
6 *Energetics* – structure and changes in materials are related to energy and changes in energy.
7 Chemistry is something which is *applied* and which influences society.

B Skills and abilities

On its own, adequate coverage of the content of the course is not sufficient to ensure that assessment is valid. The chemical content of the course is important and much time was spent before and during the school trials in determining the most appropriate material for inclusion, but the course is much more than a detailed syllabus, lesson notes, and information for students. The content of the course provides the context in which the students work, but more important are the skills and abilities which they develop as a result of working with the material.

The same ground could have been covered in a course demanding nothing more of students than the ability to remember, but the Nuffield course seeks to develop other abilities. If assessment is to be valid it must assess these abilities, which means they must be specified in categories which can be recognized by teachers and examiners.

There was a similar need in the O-level project and it was met by using a simplified and modified version of the educational objectives specified in Bloom's *Taxonomy of Educational Objectives*. The same system of classification has been applied to the advanced level project:

1 *Knowledge* – the ability to recall information. As well as specific facts, this may include recall of terminology, techniques, theories, and so on.

2 *Comprehension* – the ability to interpret familiar information. This is a routine level of understanding. The solution of problems and calculations in a manner with which the students are familiar would fall into this category.

3 *Application* – the ability of students to use their knowledge and understanding in situations which, to some extent, are unfamiliar or to deal with familiar situations by unfamiliar methods.

4 *Analysis/evaluation* – the ability to analyse a complex communication or situation into its various parts, to see the relationships between the parts, and – possibly – to make judgements about the relative merits of the parts in specific situations.

5 *Synthesis* – the ability to compose a complex communication. That is, to bring together several areas of knowledge and understanding and transform them into a statement complete in itself.

These categories will only become meaningful when associated with particular questions in an assessment, and reference will be made to them again in the chapter dealing with the writing of questions and in the sample questions. Meanwhile two points should be noted with regard to the list of abilities.

First, they are arranged in a hierarchy. That is the intellectual demands which are made on students increase in complexity from 1 to 5: the ability to analyse and evaluate an unfamiliar passage from chemical literature requires more complex thinking than does the solution of a routine problem based on the gas laws.

Second, each ability in the hierarchy usually requires an element of those lower than it. For example the ability to comment on an unfamiliar method of extracting a metal (ability 3) will require both knowledge and comprehension (abilities 1 and 2) of the general methods which are used to extract metals.

It follows that if the objectives of the course include the development of all these abilities the students must be given the chance to display them in examinations and any other forms of assessment if the assessment is to be valid.

C Activities or methods of teaching and learning

It has been frequently said in the past that the methods which a teacher uses are his concern alone and not those of an examiner. While it is generally accepted that examiners should not prescribe what those methods should be, neither should they construct their tests in such a way as to inhibit desirable approaches to teaching. This is particularly important in the Nuffield Chemistry Projects in which certain distinctive approaches to teaching and learning are used. Of the many different activities encouraged by the Nuffield approach two can be singled out for special mention: first, the use of practical techniques to solve chemical problems; and second, the free discussion of chemical topics unhindered by the need always to produce the 'right' answer. It may be stretching the usual meaning of the term validity, but examiners should not regard assessment as appropriate if it inhibits these or any other of the teaching and learning activities regarded as desirable in the Nuffield course.

In other words, the assessment situation should not be radically different from the teaching/learning situations. Students who have been engaged in certain activities during the course should find themselves engaged in similar activities during their assessment. If this is not so, given the pressure for examination success which exists, the examination will tend to give rise to other, and possibly less desirable teaching methods.

These four aspects of the course, Topics, Themes, Abilities, and Activities, coupled with the need for a reliable and nationally acceptable form of assessment, formed the basis on which the assessment of Nuffield Advanced Chemistry has been designed. It must be regarded as flexible but in the following section there is an account of the form in which it has started.

There are other methods by which the validity of an assessment can be judged. The chief of these is the extent to which student performance in the assessment correlates with other forms of assessment such as his teacher's estimate of his attainment or his subsequent attainment in employment and higher education. While the former can be determined fairly easily and in fact is used in the assessment, the latter must be the subject of long term research and will not be discussed here.

Chapter 2

The written examination

The written examination consists of three papers: Paper 1 is an objective test; Paper 2 consists of structured questions; Paper 3 is in two sections, section A being concerned with the Special Studies, and section B consisting of free response questions. The weighting between the papers is at present: Paper 1, 30 per cent; Paper 2, 30 per cent; and Paper 3, 25 per cent; the remaining 15 per cent is allocated to the assessment of practical work.

It can be seen that the written examination has a complex form. Including the subdivisions of Paper 3, there are four distinct types of question, each requiring a different method of marking. Complexity for its own sake is no more desirable in examinations than it is in any other aspect of education and the case for such diversity needs to be justified using the criteria established in Chapter 1.

Paper 1

At present, this paper consists of fifty fixed response items. All items are to be attempted and there is a time allowance of $1\frac{1}{4}$ hours. A fixed response item is defined as a test situation to which there is only one correct answer. Candidates are presented with a number of suggested responses and asked to choose the best one. More details of the structure of these questions are given in Chapter 4 and again in Section A. Five different types of fixed response item are used in the Nuffield examination: simple multiple choice, classification sets, situation sets, multiple completion, and relationship analysis. The balance between the five types is not necessarily fixed and some may be dropped in the future, but multiple completion items have been found very useful at advanced level and the proportion of this type of item is greater than at O-level.

Since the introduction of objective testing in the O-level chemistry examination, there has been a rapid growth in this form of assessment, so rapid that it is probably worth while to set out once more the main reasons for its adoption, although these reasons will, by now, be familiar to many readers.

The advantages of objective tests

In Chapter 1 it was established that one of the criteria for judging an examination was that the students should be engaged in the same activities as they had been during the course, and the examination should reflect the teaching but not determine it. It is important to establish, therefore, that fixed response items do reflect some aspects of good teaching and learning activities.

A situation must arise many times during chemistry classes in which a teacher cannot get from the majority of his class a response to an open-ended question. Perhaps during a practical demonstration the teacher asks such questions as 'What is the next step in the procedure?', 'What is the function of this piece of the apparatus?', or 'What safety precaution should I take at this stage?' All who have taught chemistry know that the response to this sort of questioning is by no means unanimous. Often only a few respond at all and of these a still smaller number of responses are worthy of serious consideration.

What does one do in such a situation? The teacher could pick out the correct answer himself, commend the answerer, and get on with the lesson. But it is probably more fruitful not to select the correct response oneself, but to throw the problem back at the class: 'You know the situation, you have heard the problem, you have heard four or five possible solutions to the problem, weigh up the evidence and then *choose* which one of the suggested solutions you consider to be the best.' In this way it is possible to get some response from most of the class and, in doing so, the teacher is using the multiple choice technique in a teaching situation. Choosing from amongst a number of possible answers does not always demand as high a level of ability as that required to answer spontaneously and unprompted, but at least it is better than no response at all. Many situations and problems in the teaching of chemistry are too complex for pupils to see solutions without some prompting and in these situations the opportunity to weigh evidence and choose between a small number of prescribed solutions is good educational practice. There seems every reason, therefore, for extending these opportunities from the teaching and learning situation to examinations.

Another advantage of the fixed response item is that the candidate, if he can answer correctly, is left in no doubt about the form and content of his answer. He does not need to make decisions about exactly what material the examiner expects in the answer or how long the answer should be. There are occasions, of course, when part of the exercise is for a candidate to judge what the content and length of his answer should be and on these occasions the fixed response technique is inappropriate; but on many others this is not so and then the fixed response question is appropriate.

The time which a candidate spends on a fixed response test is nearly all spent in thinking; there is little or no time spent in writing. This makes for very concentrated effort. Many more questions can be answered in a given time than is possible with the more traditional types of question so a wide range of subject matter and educational objectives can be tested in a short time. The effort of such concentrated thought and the need to switch rapidly from one area of subject matter to another is, of course, mentally tiring. It is for this reason that

Paper 1 is comparatively short, but in terms of the amount of subject matter and educational objectives which are tested in a given time, there is no doubt that this form of testing is very productive. In Chapter 1 the point was made that an examination should cover all the essential subject matter and educational objectives of the course if it is to be regarded as a valid assessment; Paper 1 makes the major contribution to this aim.

Those who have experience of writing will know that fixed response items can be directed, with more exactness than traditional questions, towards specific parts of the subject matter and towards specific abilities in the candidates. The function of each item can be classified with more precision than has been possible in the past with conventional questions. Of course there will never be complete agreement on precisely what a particular item tests, but experience shows that it is possible to get a greater measure of agreement on what fixed response items test than with other forms of questions. Thus the objective test as a whole can be constructed so that it at least approximately conforms to predetermined specifications of subject matter and objectives. It would be wrong to overemphasize the precision with which statements about the specification of objective tests can be made, but at least the attempt is worth while and the use of objective tests makes precision more likely.

There is only one correct answer to each of the questions in Paper 1 and candidates signify their answers by making a pencil mark in the appropriate space on an answer sheet. There are no penalty marks and a candidate either chooses the correct response and gains one mark or he chooses the wrong or no response and gets no marks. The marking of the answer sheets is completely objective: there is no room for difference of opinion; in fact, the sheets are marked by machine. This is not the main reason for introducing this form of test but it does lead to a saving in the resources which normally have to be used in marking scripts.

A characteristic of the form of testing used in Paper 1 is the switch of resources to the setting of questions. If an examination is to reflect what is good in teaching, the expertise of teachers must be used where it can be more creative, that is in the constructing of questions rather than the marking of answers; and it is important that the experience of many teachers is used rather than that of one or two. A brief description of how Paper 1 is constructed may give point to this argument.

Construction of Paper 1

The fixed response questions are written by a panel consisting almost entirely of teachers with first hand experience of teaching the Nuffield Advanced Chemistry course and a majority of them have attended at least one course of training on the technique of writing these questions. Each year approximately twenty members of the panel are asked to write about twenty items each. These items are then reviewed and amended by a smaller group.

The art of writing this type of question is not easily acquired and a considerable number of the original items are inevitably rejected as unsuitable and, of those that remain, few escape without some amendment. From the amended items a selection is made by a test construction committee and two objective tests are constructed each approximately equivalent to each other and to the predetermined test specification. These two tests are then pre-tested by administering them to a sample of students. The results are analysed and from the results of the pre-testing it is possible to determine some essential features of the way in which each item functions:

1 How easy it is; that is the percentage of students who got the right answer.

2 How well it discriminates between the good and bad candidates. (This and other matters relating to item analysis are discussed in more detail in Appendix 3.)

3 How well each of the incorrect responses acts as a distractor from the correct response.

In the light of the evidence from (1), (2), and (3) the defects of each question can be determined with rather more exactness than is possible from the subjective judgement of the reviewers. Some questions may be found to be too easy or too difficult; others may reveal ambiguities which have unintentionally distracted students from the correct response.

Armed with the data from pre-testing, the test construction committee select items for inclusion in the operational test. If possible, items are selected unaltered from the two pre-tests; sometimes small amendments are necessary to improve the function of an item, but rarely are substantial changes made to an item at this stage unless it is to be pre-tested again.

It can be seen that fixed response items receive both subjective and objective scrutiny which is a good deal more exacting than that to which traditional questions have been subjected and they only go into an operational test after considerable refinement. This is not to say that they are perfect; far from it. The author has yet to see an examination question which could not be faulted, and no amount of pre-testing will make a poor item into a good one. Refinement is a routine and necessary process, but it is the first idea for an item which is critical. We look for good chemistry, good teaching, and a flair for asking pertinent questions, in our item writers; the final test reflects their ability. Some detailed guidance on item writing will be given in Chapter 4.

Fixed response and free response

Objective testing clearly has much to recommend it, but its very advantages bring disadvantages. For one, the answer which the student is to give if he is to get a mark, is always exactly predetermined by the examiner – there can be no deviation from it – and the answer is always prompted. There is no place in which a candidate can justify the selection or rejection of a particular response. Furthermore, the need to answer a large number of questions in a short time requires a candidate to move from one topic to another very quickly; there is little time in which he can study a particular situation in some depth and record his spontaneous reactions to it.

Perhaps even more serious is that objective tests give no opportunity for discussion, no opportunity for a candidate to write at length on chemical matters which interest him: his response in an objective test is *fixed* if he is to gain credit. But an essential part of chemical education as set out in the Nuffield course is that students should have the freedom to discuss and write at some length on topics of special interest, and to respond to situations and problems with enthusiasm and imagination without the need to produce solutions to these situations and problems which are always exactly right and in agreement with what teachers and examiners consider to be the only correct solution. As this freedom is a part of the learning process it should also be part of the examining process and Paper 1 gives no opportunity for it to be exercised.

To meet this need, some part of the examination must have the following characteristics:

1 It must not be subject to a rigid, predetermined mark scheme.

2 It must include material from within the course and from outside the course which is not necessarily studied by everyone.

3 It must allow a large freedom of choice of question and form of answer to the candidates.

Paper 3 was designed with these characteristics in mind. To take the analogy of a polar molecule, Paper 1 constitutes one pole of the examination, highly objective, fixed response, and no choice of questions: Paper 3 constitutes the other pole, marked by impression, free response, and a wide choice of questions. To some extent the flexibility of Paper 3 is a deliberate attempt to temper the rigidity of Paper 1 and perhaps it is appropriate to describe its structure at this point before giving an account of Paper 2.

Paper 3

At present, Paper 3 is in two sections, section A in which the Special Studies are assessed and section B which includes materials from the remainder of the course and possibly materials to cater for wider interests outside the course.

Section A

The present form of assessment is to set one question, usually in several parts, on each of the Special Studies. Each question contains a compulsory element which deals with the basic principles of the Special Study and then a choice between two more elements, one concerned with practical work in the laboratory and the other with the industrial or domestic applications of the Special Study. Each answer is subject to a fairly detailed mark scheme but the latter is flexible enough to allow for possible differences in the materials which the candidates have studied.

The form of assessment of Special Studies is under review. There are two possible defects in the present form. One is the danger of questions becoming stereotyped over the years and the other is that it does not fully meet the need for diversity in the Special Studies.

Section B

In this section candidates are required to select three questions from a total of eight or nine and they are invited to answer the questions with the minimum of inhibition. The atmosphere which the examiners hope to create can be best expressed by quoting the rubric at the beginning of the paper.

'This paper provides you with the opportunity to display your understanding and interests with greater freedom than was possible in Papers 1 and 2. Some questions deal with topics which are part of your basic chemistry course, but others lie outside it. Try to answer in the form most appropriate to the question: sometimes you will consider it necessary to write at some length in the form of an essay, but at others you may think a more concise form with subheadings is preferable. Remember that other forms of communication such as graphs, diagrams, tables, and equations, can sometimes be more meaningful than words alone. Above all, try to express yourself with clarity.'

The questions aim to provide for a wide range of topics and interests and at least one question raises some of the social implications of the study of chemistry. Candidates are allowed to use their *Book of data* when sitting Paper 3; some questions are deliberately designed so that use of the *Book of data* is essential, but candidates are free to use it to help them with any of the questions, provided that they quote the source of data which they use. Although many of the questions may require the use of precise data, the form and content of the answer is not prescribed by the examiner with the rigidity that it is in Papers 1 and 2; the questions therefore, are usually framed in fairly general terms. Examples of actual questions are given in Section C.

No part of the examination is intended by the examiners to be a race. But, while a certain quickness of thought may be an advantage in Papers 1 and 2, the opportunity for a more leisurely and discursive approach is essential to Paper 3 and two and a half hours are allowed in which to answer the four questions, which should give sufficient time for the candidates to organize their material and to pay some attention to the appropriate structure of their answers. There are no automatic penalties for poor quality of English, but, if an answer is so poorly constructed and written as to impede communication from the candidate to the examiner, it is inevitable that the candidate will get a lower mark than the content of the answer might otherwise have merited.

Freedom of response by the candidates cannot be matched by precision of marking by the examiners; in fact, attempts to increase the latter could well inhibit the former. At the same time, however, it is essential in any examination at this level to make this part of the assessment as reliable as possible and it has been the concern of the examiners to ensure reasonable compatibility between freedom of response on the one hand and reliability on the other.

No detailed mark scheme is assigned to each question. Instead, general criteria for judgement are laid down and the examiners are asked to read each script quickly, looking for evidence of merit rather than faults to penalize and, without putting any corrections or marks on the scripts, to grade each answer on a six point scale:

5 Excellent - difficult to fault at this level
4 Above average
3 Average
2 Below average
1 Little merit
0 No merit

Only in this way can credit be given for the very wide variety of material which is to be found in answers to these questions. 'Average' is defined as what the examiners regard as average for A-level candidates in general, not the average of the particular batch of scripts which he is marking.

The assessment takes the form of grading by impression rather than marking according to a detailed scheme, and like any impression it can vary between individuals. The possibility of decreased reliability is recognized and some safeguards are adopted:

1 It is important to use examiners who are experienced in the general standards which can be expected of A-level candidates and who can maintain a consistent standard throughout their marking. The examiners are subject to agreement trials before and during the actual marking.

2 It has been shown that reliability of impression marking increases if more than one marker is used. In this examination each answer is graded by two examiners, neither of whom know the grade awarded by the other, and the two grades are then added to give a total mark with a maximum of 10.

3 Answers in which examiners have differed by more than two grades are marked a third time.

The double grading by two different examiners does give rise to some difficulties, particularly in the rapid circulation of scripts, but there are advantages in this type of marking. It is much quicker to mark a script by impression than from a detailed mark scheme. This increases the output of the markers and in turn aids the rapid circulation of scripts from one to another. Of course the first few scripts require rather closer scrutiny until the marker has established a consistency of grading and these first scripts should always be regraded. Thereafter it only requires a review of a sample of scripts by the Chief Examiner to establish that consistency is being maintained.

Paper 2

It was felt that to polarize the examination completely into fixed response questions and free response questions would not entirely meet the criteria set out in Chapter 1. For many students the ability to synthesize the sort of communication which is demanded in Paper 3 is very difficult to attain. The difficulty may arise from a lack of understanding of the subject, but, more often, it arises from an inability to describe a complex situation in a form which is appropriate to an examination paper. The difficulty is often a linguistic one and all teachers of science will have met the student who, while being an able chemist, is unable to decide what to write and how to write it when faced with the open-ended and general type of question which will be encountered in Paper 3.

It became clear to the examiners that there was a need for another type of question which would be a half-way house between the fixed and free response, with some of the characteristics of both, but with a distinct function of its own. These questions are called structured questions for reasons which will become apparent in the following review of their outstanding features.

Structured questions

The basis of a set of structured questions is a situation which as a whole is usually complex. The situation which constitutes the stem of a set of questions may be one of various types: it could be a laboratory experiment or an industrial process, data in tabular or other forms, a passage from the chemical literature, in fact anything which is worthy of study by a student of chemistry at this level. If, in the set of questions, the students are required to exercise the higher abilities of application and analysis, the information which forms the stem of the question must, to some extent, be unfamiliar to them.

The presentation of unfamiliar information to which the student is expected to respond is not confined to structured questions; it is an increasingly common feature of many different modes of examining. Such information could be followed by a set of fixed response questions as in Paper 1 or by the requirement to write an essay as in Paper 3. The purpose of a structured question lies in the need to respond to the information without being prompted as he would be in Paper 1 and without the need to design a long complex communication as in Paper 3.

It may be argued that candidates *ought* to be able to construct a long and complex response in an examination. If this is so, then the free response questions in Paper 3 supply the opportunity. But one of the faults of the traditional essay type of examination was that *all* the questions demanded this particular ability and that many candidates failed because of this universal demand. This was a pity because in many instances the examiner had already in mind the structure of the answer which he expected and, in fact, had a highly structured mark scheme to apply to the answers. If the main purpose of a question is not to test the ability to construct a complex communication and if the examiner has already determined the structure of the answer which he prefers, there is no reason why this structure should be kept secret from the candidates. So what the examiner does in a structured question is to break down a complex situation into smaller parts, each part requiring a short and less complex answer. In this way the examiner leaves the candidates in much less doubt about what he expects them to do and the order and form in which to do it.

At the same time the candidates are allowed to respond to each part of the set of questions as they think fit. Of course the examiner has in mind what will constitute the best response but does not prompt the candidate or make the correct answer completely rigid by setting the questions in fixed response form.

In many ways a set of structured questions resembles a chemistry lesson. A typical teaching situation, for example, would be the study of data on the extraction of an element from a natural source. Gone are the days, one hopes, when the students are simply asked to learn the extraction with a view to repeating it in essay form at a later date. More likely in modern chemistry teaching is that the teacher leads his students to an understanding of the process by discussion and by a series of open-ended questions. The art of this style of teaching lies in the ability of a teacher to break down the complex situation into a set of simpler questions with which he probes and guides the response of his students.

The first questions in class will usually be the easier ones, getting progressively more difficult until the whole situation has been explored. As it is in teaching so it is in examining; the art of writing a structured question is very much akin to that of teaching - and this is proper.

In a set of structured questions each part should be complete in itself, as far as possible, and the correct answer to one part should not rest too much on the correct answer to a former part. At the same time each of the parts should refer to the same situation and contribute to the overall purpose of the set. In order to give further guidance to the candidates it is the practice in this examination to leave spaces after each question giving an appropriate number of lines in which the answers are to be written. The candidates are also given guidance about the relative importance of the questions by a statement of the mark allocation to each part.

The writing of structured questions is every bit as demanding as that of fixed response questions. It is not always easy to provide suitable information on which to base the questions and, even after the information has been found, the art of structuring the responses into a set of questions requires experience of both examining and teaching. There is a need for a constant flow of new ideas and for variety in the construction of the questions. To this end a panel of teachers, similar to that which writes fixed response questions, has been established to write questions for Paper 2. Only in this way can what is best in teaching be reflected in the examination and the danger of the examination becoming stamped with the personality of one or two Chief Examiners be avoided.

At present Paper 2 consists of eight or nine structured questions with a varying number of parts to each question. The candidates are required to attempt all the questions and they are allowed two hours in which to do so. The answers are marked from a mark scheme of the conventional type, but experience has shown that the pre-structuring of the questions does make this form of marking much easier and more objective than when applied to questions of the unstructured type.

The examination specification

It will appear from what has been said in this chapter and in Chapter 1 that the structure of the written part of the Nuffield Chemistry examination is a good deal more complex than that of traditional examinations. There are many factors between which and within which a balance has to be kept: topics, themes, educational objectives, teaching/learning activities, and types of question. Each of these is divided into a number of categories and the final decision on the weighting which should appropriately apply to each of the various categories rests with a consultative committee for Nuffield Advanced Chemistry set up by the London University Entrance and School Examinations Council which administers the examination on behalf of all the GCE Examining Boards. At present there is very little empirical evidence on which these decisions can be based and for the time being decisions such as the relative weighting to be placed on each of the seven major Themes must rest largely on the consensus of opinion of those with whom the decision rests.

In the early years of examining a new course it would be unwise to try to prescribe exactly what the specification of the examination should be. Nevertheless, it is important that some move is made towards a quantitative specification of what the examination is testing. Without such specifications it is difficult to make meaningful statements about the validity of the examination.

If an examination specification is to have any meaning it must apply to all candidates and it follows that some parts of the examination should be common to all candidates. This is the function of Papers 1 and 2, consisting of compulsory questions, and the examination specification is the combined specifications of these two papers. Since each paper at present carries 30 per cent of the total marks, 60 per cent of the examination gives candidates no choice of question and at first sight this may appear to be unduly restrictive. In this connection, however, two points should be made. The first is that every effort is made to ensure that Papers 1 and 2 require only that knowledge which is basic to the course and anything which candidates cannot be expected to remember is included in the stems of the questions. In brief, Papers 1 and 2 are concerned with essential chemistry and student abilities. The second point is that in the remainder of the assessment, both written and practical, students and teachers have been given a degree of freedom, hitherto unknown in science examinations at this level. It is hoped that in this way a reasonable balance between restriction and freedom has been achieved.

The specifications take the form of two grids, each with two axes. A common axis to them both is that of the categories of student ability (see Chapter 1). The other two axes are designated by Topics and Themes.

Topic	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Total
Ability																				
1																				
2																				
3																				
4																				
5																				
Total																				

Theme	1	2	3	4	5	6	7	Total
Ability								
1								
2								
3								
4								
5								
Total								

The various categories in these specifications are mentioned elsewhere in the publications, but for ease of reference a key to them is given below.

Abilities

1 Knowledge
2 Comprehension
3 Application
4 Analysis/evaluation
5 Synthesis

Topics

1 Amount of substance
2 Periodicity
3 The masses of molecules and atoms: the Avogadro constant
4 Atomic structure
5 The halogens and oxidation numbers
6 The s-block elements and the acid–base concept
7 Energy changes and bonding
8 Structure and bonding
9 Carbon chemistry, part 1
10 Intermolecular forces
11 Solvation
12 Equilibria: gaseous and ionic
13 Carbon chemistry, part 2
14 Reaction rates
15 Equilibria: redox and acid–base systems
16 Some d-block elements
17 Equilibrium and free energy
18 Carbon compounds with large molecules
19 Some p-block elements

Themes

1 Materials exhibit *specific* behaviour and composition.
2 Materials exhibit *patterns* in behaviour and composition.
3 Behaviour and composition can be explained in terms of *structure* and *bonding*.
4 *Kinetics* – how fast changes take place.
5 *Equilibria* – how far changes go towards completion.
6 *Energetics* – structure and changes in materials are related to energy and changes in energy.
7 Chemistry is something which is *applied* and influences society.

It may be worth while to make the general point that the form and content of the examination is an attempt to reflect what goes on during the whole of two years' study of chemistry and that the best way to prepare for it is to concentrate on the objectives, methods, and material of the course throughout those two years. It may well be that success in the examination does not depend quite so much on cramming for the few weeks immediately preceding it, although some revision will undoubtedly be necessary. Those who seek examination success solely through late revision one can only advise to think twice before starting the course.

In addition to these two types of specification (page 16) the examiners must take note of the main categories of activities in which the students can be expected to engage in their study of chemistry:

A Studying the behaviour of specific substances by non-practical methods.
B Using practical techniques to investigate the behaviour of materials.
C Looking for and using patterns in the behaviour of substances.
D Using mathematical techniques to solve problems.
E Using concepts (without the aid of mathematics) to solve problems.

It has been said earlier that the examination activities should reflect learning activities. So that, when classifying an examination question an examiner must ask himself 'What type of learning activity would be the best preparation for tackling this question?' This way of classifying examination questions is relatively untried and one must approach it tentatively. For a start, the Nuffield examiners have decided to attach a quantitative weighting (in Papers 1 and 2) to Activities B (approximately 20 per cent) and D (approximately 18 per cent) only. The weighting attached to Activity B has special significance in the assessment of practical work and will be discussed in more detail in the next chapter.

There are two other categories of learning activity which are superimposed on the five listed above. These are:

1 Activities which are aimed to produce a definite outcome – that is an outcome which can be said to be right or wrong.

2 Activities which are aimed to encourage discussion and speculation to which there is no outcome which, *at this level*, can be said to be right or wrong.

To decide on the relative weighting between these two overriding activities is not easy and the nearest to a quantitative specification in the written examination is shown in the relative weighting between Paper 3 and the other two papers. However, the examiners also encourage the reward of an open-ended, speculative approach to some elements in the assessment of practical work (see Chapter 3).

Chapter 3

Assessment of practical work

The pattern of the written examination is not unlike that of the Nuffield O-level Chemistry examination and the techniques of assessment used at O-level have been applicable, with some modification, to A-level. As experience grows, the techniques become more refined and there is evidence of their more general acceptance in other GCE examinations. There is never cause for complacency in examining, but at least a reasonably effective pattern for the written mode of assessment seems to have been established; in the assessment of practical work it is a different matter.

A separate chapter has been devoted to practical work because of the novel and relatively untried technique which has been applied to its assessment. It is not intended to imply that, because it is assessed separately and specified separately, practical work is in any sense separate from chemistry. This is certainly not so in the Nuffield course in which practical work is an integral part of the whole study of chemistry; it is there as the characteristic method by which chemists solve problems and make progress and it is in no way divorced from the material of the course.

As practical work is an essential activity in the course, any assessment which ignored this activity could not be regarded as completely valid. This is not to say that an assessment is worthless if it does not contain an element devoted to practical work. One can imagine instances in which the attempt at assessment of practical work could have an adverse effect on the teaching and learning of chemistry; in such a circumstance the rejection of any assessment may be quite proper until a more appropriate technique can be found. But the Nuffield course is strongly orientated towards practical investigations and in designing assessment procedures it was decided that every effort should be made to devise a form of assessment which would include that of practical work.

Having made this decision, there were really only two available lines of action: one was to institute a practical examination either of the traditional or of a new type; and the second was to try to assess attainment in all or part of the practical work which went on during the course itself, using teachers themselves as the assessors. Criticism of existing practical examinations is well-trodden ground and this is not the place to go over the same ground again. It is proper, however, to specify the merits of assessment of practical work by teachers during the course and later to point out the difficulties to which such a procedure can give rise.

The advantages of assessment of course practical work by teachers

An assessment which is carried out by someone actually observing the students at work in the laboratory over a long period of time can take note of many attributes which would not be apparent in the written evidence which arises from a practical examination. This makes possible an assessment of attainment of much more varied objectives in practical work. This is not to say that written evidence of achievement in practical work is not useful, but all teachers know that one learns a good deal more about the quality of students' practical work by actually watching them than by reading an account of their results.

A fundamental principle of examining is that an assessment should cover all the essential aspects of a course. The course in practical work covers a wide range of subject matter, many different objectives, and a variety of techniques. It is simply not possible to assess all these factors on a single occasion. By assessing on many occasions throughout a course one is much more likely to include most of the essential aspects of practical work and so produce a more valid assessment of it.

The present scheme of assessment of practical work in Nuffield Chemistry is based on course work. The experiments are done as part of normal work, whether they are assessed or not. Any experiment may be assessed if the teacher wishes to do so and it follows that a great variety of experiments and techniques can be included. This is not so in large-scale practical examinations, which are restricted to those experiments which can be successfully administered to many candidates on the same occasion and in a limited time; such experiments are few, although perhaps not so few as practical examinations have used in the past. But the experiments in a practical examination tend to become stereotyped with undesirable and restrictive effects on practical work in schools. A teacher, dealing with much smaller numbers, can choose which experiments best suit his own scheme of assessment and the experiments do not have to be chosen from those in the Nuffield publications; in this way freedom and flexibility can be maintained for teachers and students alike.

In general, the more frequently assessments are made the more reliable the sum of them will be. There are dangers in over-assessment, but at least assessment at intervals during the course is less likely to give rise to the chance failure or chance success which can be a feature of single occasion practical examinations. There are times when a teacher knows that a student gets a poor result for an experiment through no fault of his own and allowance can be made for this circumstance; the scheme is flexible enough for the whole experiment to be ignored or possibly repeated for assessment purposes.

Some difficulties of internal assessment of practical work

The scheme which is outlined later in this chapter is the outcome of trials which took place while the materials of the course were being evaluated in schools. The scheme underwent several modifications in the light of comments from the teachers who undertook the trials. It is fair to say that the internal assessment of practical work was preferred to an externally administered practical examination; at the same time, it is only proper to draw attention to some of the difficulties which can arise.

While it is relatively easy to award a mark when assessing a written account of a piece of practical work, it is much more difficult to award a mark for those qualities which can only be assessed by the direct observation of students while at work. In a large class it may not be possible to give all members equal attention during a session of practical work and, during the trials, teachers felt that some faults and some virtues would escape their attention. This is probably so on a particular occasion, but it is here that the continuous nature of the assessment is helpful, because over two years it is most unlikely that one student will always be able to hide his deficiencies or another to have his merits overlooked.

It may be that a student changes schools during his sixth form career. If the move does not involve a change from a different course, the student's new teacher takes note of the entries already made on the student's record card, continues with the assessment and sends the card, with any comments he thinks fit to make, to the examiner at the appointed time. If, however, the student changes to a Nuffield course from a different course, the new teacher will have to start a record card for him and try to assess the prescribed minimum of experiments before the end of the course. Students who have not followed an assessed course of practical work, and therefore cannot offer a signed record card, cannot be awarded a mark for practical work. It is not possible to lay down rules for every eventuality and the statements made in this paragraph apply only to the conditions at the time of writing; but the examiners will consider sympathetically any statements about the unusual circumstances which are bound to arise with regard to individual pupils and if teachers are in any doubt about procedure they should communicate with the Examining Board *as early as possible.*

Questions on procedure have arisen when teachers change during a course and when more than one teacher teaches a single set of students. In the first event the procedure is the same as if the student changes schools. In the second the assessment can either be undertaken by one teacher or it can be done jointly; in general, it is probably better if it is done jointly – the opinion of two teachers is likely to be more reliable than that of one – and any discussion which arises could well lead to a better insight into the objectives of practical work.

The problem of assessing group practical work was considered during the trials. The ratio of individual to group work varies considerably from school to school and, although it should be possible to find sufficient pieces of individual work to meet the prescribed minimum of assessed experiments, it could happen that several important pieces of practical work are undertaken in pairs or in larger groups. Clearly, it is more difficult to determine individual contributions to such work, but it is not proposed that assessment should be confined to work done by individuals.

It would be idle to pretend that the internal assessment of practical work does not make demands on the teacher; if it did not, it would hardly be worth doing. No doubt teachers already make some assessment of their students' laboratory work and there is certainly nothing new in awarding marks to the written outcome of the work as shown in laboratory notebooks. But the Nuffield scheme does call for a more varied assessment and the compiling of the record cards is, in itself, no light task. The very novelty of this form of assessment makes it more arduous, but it is hoped that with familiarity, and as routines develop, it will become less so. It is fair to say that some form of disciplined assessment of practical work *ought* to be undertaken by teachers, whether it is to be a part of the A-level examination or not. Only by having some objectives in mind, and some means of finding out attainment of them, can teachers give the sort of guidance which their students require. In other words, assessment is an essential part of teaching.

There is a difference, however, between assessment for purely internal, educational purposes and assessment which is to be used for selection purposes. The pressure for A-level success is such that teachers are bound to experience some change in attitude when the students are aware that what they do throughout the course can affect their final result. During the school trials it was found that most students applied themselves rather more diligently to their practical work, especially when they knew that a particular experiment was to be assessed. A major change in the relationship between teachers and students, resulting from internal assessment, would be undesirable, but it is hoped that such a change will not come about – certainly not once the novelty of this form of assessment has gone. Essential as assessment is to the educational process, it should never obtrude on the primary role of the teacher; teaching and learning must always come first and assessment should encroach as little as possible, both on time and resources.

Another possible difficulty is that different teachers will look for and assess different qualities in the practical work of their students. After some years of teaching, everyone develops idiosyncracies about some aspects of practical work in schools; sometimes these are important and commonly agreed, sometimes they are not. In a national scheme of internal assessment, while allowing as much flexibility as possible, it is important that teachers' individual likes and dislikes do not cause too great a difference in the qualities which are being assessed. More will be said later about a common basis for the assessment.

Even if there is reasonable agreement about the objectives of practical work, there remains the difficulty of comparability of standards between one teaching set and the next. Any scheme of this sort assumes that teachers can allocate marks so that their students are placed in a more reliable order of merit, according to their ability in practical work, than is possible by any other method of assessment; and that the students are appropriately distributed within the range of marks which has been used. This seems to be a reasonable assumption, if at the end of two years of continuous supervision of students' practical work, teachers *cannot* say that one student's work is better or worse than that of another, then it is difficult to conceive of any other viable scheme of assessment which can result in such a statement.

But no matter how accurately a teacher distinguishes between the attainment of one student and another *within* his teaching set, he is not in a position to distinguish between the general standard of his set as a whole and that of another set which he does not teach. It may be that there is no significant difference between the standard of practical work in different teaching sets. The general opinion between teachers, as far as one's subjective judgement can discern, is that there may be a difference in standard from one set or one school to another, but if there is, the spread in practical ability is not likely to be as great as that shown in the conventional written tests of ability. But this is only opinion; there is very little empirical evidence one way or the other.

It would be very convenient if there were no significant difference in the standard of practical work of different sets of students. Then the marks awarded by each teacher could be scaled to a mean mark common to all the sets. But for the present it is probably wiser to assume that there is a significant difference and to try to take account of it. To do so requires some independent means of comparing the proficiency in practical work, not between one student and another, but between one teaching set and another. Such a scheme has been devised and is described later.

The outcome of school trials

It is probably true to say that the method of assessing practical work gave rise to more discussion and was the subject of more effort than any other of the assessment techniques – this despite the fact that it accounts for only 15 per cent of the total A-level examination. The first trial scheme for assessment was considerably modified as a result of the teachers' evaluation of it and a brief account of the trial scheme may be helpful in understanding how the present scheme developed.

During the trials, eight experiments were specified by the Project Team for assessment over the two year period. Detailed guidance on the conduct of each experiment, the objectives to be assessed, and the method of awarding marks was also given. Details of each student's performance in each experiment were entered on a record card and these cards were analysed at the Project Headquarters. From the results of this analysis and from the comments of the teachers in the trial schools some common factors emerged:

1 Teachers felt that the prescription of specified experiments for assessment constrained them too much and that choice of experiments should be left to them. In this way teachers would be free to exercise their own preference as to which experiments were most suitable for assessment.

2 Similarly, teachers found that the prescription of specified objectives and methods of allocating marks to each experiment, far from helping them, which was the intention, actually made assessment more difficult. Detailed guidance from outside put the teachers into a rigid framework when undertaking these experiments and this did not accord with the flexibility which is essential in teaching. In short, the eight prescribed experiments tended to become eight practical examinations in which teachers felt themselves obliged to fulfil to the letter the detailed instructions which had been given to them. Clearly, this situation did not conform to the general principle that assessment should be based on normal course work and it will be seen from the account which follows that the present scheme is much more flexible.

3 It also became clear during the trials that some further thought would have to be given to the objectives of practical work in a chemistry course at this level. There was rarely unanimous agreement on why a particular experiment was being undertaken in terms of the abilities which would be developed in the students who were actually doing the experiment. While admitting that opinion on what objectives a particular experiment could be aimed at could differ, it was thought that a consensus of opinion on the objectives of practical work as a whole would have to be sought if a suitable form of assessment of attainment of these objectives was to be devised.

It is a matter for regret that the specific statements about cognitive objectives in chemical education have not been matched by equally specific statements about the objectives of practical work. The point has been made that theoretical and practical work are so well integrated in a course of this type that it is difficult to separate objectives in practical work. This is so, but, if an attempt is to be made to assess attainment in practical work separately, and traditionally this has been the case, there is a need to have some clearly identifiable objectives which relate specifically to practical work.

There is very little work available which identifies objectives in practical work and, as this is a completely new course, it was thought advisable to seek the views of the teachers engaged in the school trials. They were asked to state, in an order of priority, the objectives of the practical work which they were undertaking in terms of the skills, abilities, and attitudes which should develop in the students as a result of the work. The statement of objectives which is given below, together with their relative weighting is the outcome of this enquiry. It is not claimed that this statement is in any sense absolute and further work to identify appropriate objectives is required, but at least it does express the general views of what teachers hope their students will achieve as a result of engaging in practical work at this level and, as such, it forms a suitable basis for the assessment.

4 It became clear, both from feedback from teachers and from direct observation of assessed practical classes, that the method of awarding marks for practical work fell into two categories. The first concerned concrete evidence of proficiency: accuracy of results, statements of observation and inference, percentage yield, purity of product and so on. These could all be made subject to a fairly precise mark scheme. The second concerned objectives which could only be assessed on less precise evidence: general manual dexterity, orderliness, persistence, originality etc. It was the latter which were the more difficult to assess in a quantitative manner and yet the majority of teachers thought that they should be assessed, if only by general impression. There was general agreement, however, that on a particular occasion it was not possible to look for and assess more than one of the less concrete attributes of the students.

5 An analysis of the record cards revealed two trends in the marks common to all the teachers. The first was that the whole range of marks which it was possible to award was never used and the second was that the average mark was always greater than the half mark. For example, if the maximum mark for a piece of practical work was 15, the marks of a set of students might range between 7 and 14. Of course, some teachers tended to mark higher or lower than others and the award of the same mark by two different teachers did not necessarily indicate exactly the same standard, but there appear to be two general conclusions which can be drawn from these trends in the marks:

a The range of ability in practical work is not as great as in written work.

b Most students attain a satisfactory standard of practical ability during the two year course. In other words, rarely can a student be said to have *failed* in practical work.

The present form of assessment of practical work

One of the general conclusions from the school trials was that teachers should not be restricted by too many detailed instructions if they were to undertake the assessment of practical work. But in any national examination in which comparability of results is necessary, it is not possible to allow complete freedom to individuals; there are certain aspects of the assessment which should be held in common if the outcome is to have any general validity:

1 Similar objectives of practical work.
2 Similar coverage of subject matter, and of types of practical work.
3 Similar criteria for the awarding and recording of marks.

It was felt that to ensure an appropriate coverage of the main aspects of practical work the assessment of a minimum of eight assessed experiments would be necessary. Marks can also be awarded by the teacher's general impression over a period of time, but, in addition, the examiners do require evidence that some objectives were assessed on specific occasions – hence the prescribed minimum of assessed experiments. Some teachers, in fact, find that they need to use many more occasions than eight.

A The objectives of practical work

Five main categories of objectives emerged from the survey carried out during the trials. These are set out below and the frequency with which they were mentioned and the priority they were given was translated into the weighting shown against each.

1 The ability to *observe* 25 per cent
2 The ability to *interpret* observations 15 per cent
3 The ability to *plan* experiments 10 per cent
4 Skill in *manipulation* 30 per cent
5 Appropriate *attitudes* to practical work 20 per cent

These categories are very general and only become really meaningful when related to actual practical work; only then can teachers recognize students proficiency, or lack of it, in any of them. The important thing in this form of assessment is that teachers come to learn the occasions on which the attainment of these objectives can best be recognized and the means by which appropriate marks or grades can be awarded. In time, some teachers will find that certain experiments highlight most clearly the qualities they are looking for in their students; other teachers will find that other experiments serve their purpose better. What should be common ground, however, are the five main categories of objectives stated above and a short amplification of each of them may be useful for those who are about to embark on the Nuffield course for the first time.

1 Observation

It is never possible to know exactly what it is that a student observes: we can only know what he *tells* us he observes and lack of ability to communicate may inhibit him in this. But lack of ability to communicate is not a problem confined to the assessment of practical work; it inhibits in most areas except that of objective testing. In internal assessment teachers can at least make allowance for this. They can, for example, allow verbal evidence as well as written evidence. Some students can be persuaded to say what they have observed even if they cannot write it. It is hoped that the opportunities for oral assessment are not overlooked and that written evidence and the marking of notebooks does not form the only mode of awarding marks. It must be admitted, however, that to award a mark for verbal response is not as easy as it is for written response and one has often to rely on general impression rather than detailed marking. This too, has its place in the scheme and more will be said about grading by impression later.

2 Interpretation

If, as they should be, many of the experiments are investigational and not simply illustrative, students should have the opportunity to draw conclusions from their work. It does not follow that the experiments which are best suited for assessing this ability are those to which there are clear cut answers. On the contrary, answers to the latter can often be found in textbooks. It is perhaps more important to test students' reactions to observations to which there is no clear cut, right or wrong conclusion. The ability to speculate and to use judgement without necessarily being obliged always to produce the 'right' answer is one to be valued. It is hoped that, in looking for the ability to interpret, teachers will take note of imagination and originality in the students, provided, of course, that it is disciplined and in accord with such evidence as is available from the particular student's experiment. It is not suggested for a moment that faulty reasoning should gain merit; what is required is a flexible system whereby an original turn of mind is not inhibited as it may well be if the idea of correct interpretation is applied too rigidly.

3 Planning

Similarly, there is not much point in assessing a student's ability to plan an experiment, details of which are precisely stated in the *Students' book*. There are suggested experiments, for which full details are not given and, in any event, it is hoped that teachers will cultivate new experiments or modifications of experiments, which better suit their purpose. Evidence of planning may be written or verbal, but obviously it is of little use if the student has already seen one of his fellows conducting the same experiment.

It can be argued that the ability to interpret observations and the ability to plan experiments can be determined by a written paper. There is something in this. Certainly it is possible, but not easy, to devise written questions on these two objectives, for which the best background is actual practical work. To this extent experience and comprehension of practical work can be assessed by a written paper and in the Nuffield examinations a significant proportion of the questions are of this type. But it can equally well be argued that the context in which students have to respond to practical questions is important and the response to an actual situation, when the student is on his feet at the bench with an actual job to do or real observations to interpret, may well be different from his response to the same situation presented to him in a written examination. A real situation gives a chance to adjust and replan if things start to go wrong and everyone recognizes this as a day-to-day occurrence in a chemist's work. It is not easy to give this sort of flexibility to a written question and a written answer.

4 Manipulative skill

Some teachers are surprised to find that manipulative skill rates only 30 per cent of the total weighting in situations which are in essence practical. Manipulative skill alone, however, does not necessarily make for good practical chemistry. The abilities to see the unlikely, to think on one's feet, and to persevere when things are not going well are equally, if not more, important and no amount of manipulative skill will compensate for their lack. However, manipulative skill is an asset not to be underrated even at school level, and this particular ability has been rated higher than any other.

How does one recognize it and – even more difficult – assess it? Sometimes there is material evidence of manipulative skill – good yields, pure products, consistent titration results or meter readings; speed of completion may *sometimes* be an indication of manipulative skill, so may the ability to adapt to a new technique without seeking the teacher's aid. There will be particular experiments in which this ability can be assessed with some precision – a preparation or an analysis for example – but, in addition, teachers may also want to give credit to the student whom they know, by direct observation, day-in, day-out, to be good with his fingers. There is no reason why teachers should not do either or both; it is up to them to use the scheme of assessment as they think best.

5 Attitudes to practical work

There was a general feeling amongst the teachers in the trial schools that the objectives of practical work were more extensive than the mixture of intellectual and manipulative skills just described. When asked what they considered to be the important outcomes of practical work they emphasized such qualities as compliance with the normal routine of chemistry laboratories (particularly with respect to safety precautions), persistence, resourcefulness, and general enthusiasm for practical work. These qualities are different in kind from those which are normally assessed in practical tests, although they may very well be reflected in the outcome of the other parts of the assessment: persistence, for example, may be rewarded by more accurate observations. In this sense, the qualities included in objective 5 may be indirectly rewarded; but there was a strong feeling that these qualities should also be directly rewarded, so that someone who consistently displayed them should be given credit over and above his marks for the other objectives on the grounds that these qualities are not only worthy attainments at school level, they are also important in those who want to continue their practical work in science and technology after school.

It is most unlikely that marks or grades can be awarded under this head for particular experiments. For one thing, a quality such as persistence may well be simulated on a particular occasion. Teachers will probably make more reliable judgements in this area by awarding a grade at intervals, say at the end of each term, or each year, or just once at the end of the course. These judgements, of course, will be the result of numerous observations of students' performance throughout the course, but a mental note of the various occasions is probably more appropriate than an attempt to use a formal and detailed written record.

B The subject matter and techniques

This account of the general framework in which the assessment should be conducted has begun with the most important part: the skills, abilities, and attitudes of the students themselves. But these cannot be assessed in isolation; they must be capable of demonstration in the context of a study of chemistry. Unfortunately, in the past the chemical subject matter and techniques required in traditional practical tests have been fairly limited. To make this form of assessment reasonably valid it was thought necessary to prescribe, in general terms, the main areas of subject matter and types of practical work so that there would be common ground between the various individual assessments. If this had not been done there would be the danger that some teaching sets would leave out some major aspect of the work in the course of their assessment. This would be a pity because one of the merits of this form of assessment is the possibility of covering a wide field of topics and techniques and hence increasing its content validity.

At present, the experiments on the students' record cards are expected to contain at least one on each of the following.

Subject matter

a Changes in materials. (This, for the moment, is a deliberately wide area and may, in the future, be subdivided. An obvious division would be to make a requirement for both inorganic and organic chemistry.)

b Kinetics.

c Equilibria.

d Energetics.

Types of experiment

a Quantitative.

b Qualitative.

c Preparative.

This should avoid specialization in the assessment and it is hoped that teachers will not find it restrictive. Further enquiry into the operation of the assessment may lead to modifications and readers are advised to ask the Examining Board whether changes have been made, before they start on the course.

C Awarding marks

During the school trials the methods and criteria for awarding marks were laid down for each experiment. This proved too restrictive, but, nevertheless, some guidance is necessary and although the actual A-level marks will not be the same as the raw marks of the teachers, some common pattern is desirable, particularly in the event of a change of schools by teacher or student.

Some objectives, such as accuracy, observation, inference, and planning, can be marked from written evidence and teachers may use whatever mark scheme best suits their purpose on each occasion. This should not cause much difficulty, but there are the other objectives, already mentioned, for which evidence is not so material and for these a detailed mark scheme is not appropriate. Instead it is suggested that teachers adopt a form of grading based on impression. One which was found to be useful during the trials (and is used by the examiners of Paper 3) is:

Excellent	5
Above average	4
Average	3
Below average	2
Little merit	1
No merit	0

The question immediately arose 'Average of what?' Should teachers take note of the general level of performance in practical work of their own set, or of their whole school, or of sixth form work in general? The decision, after much debate, was that the criteria should be the performance of sixth form work in general. An argument against this is that teachers just starting in the profession and those with limited experience would not know what standard to expect. But teachers are not usually so isolated. They have their own sixth form work and professional training as a background and, when taking over a new set of students, they may well know less of the standard of that particular set than they do of the general standard of all A-level students.

In the end, it is the teacher's order and distribution of his students which matters rather than an absolute scale of marks. The main aim is to be consistent in the internal allocation of marks and the grades listed above are intended as a help towards consistency. Some teachers prefer a scale with more grades on it and, less frequently, one with fewer grades on it. This is allowable and makes no difference to the final summary on the record cards where the performance of all students is shown as a percentage. Unless a teacher has an exceptionally bad or good set, one expects that the marks will tend to cluster round the average and much less frequently to be found at 5 or 1 if the scale shown above is used. But again this is left to the individual teacher's judgement.

A feature of this form of assessment which caused rather more concern was that teachers often felt at the end of a practical lesson that there was not a great deal to choose between their students. This is to be expected. It was stated earlier that marks awarded for practical work in this manner tended to fall within a limited range of the total marks available. It does not matter greatly if, on a particular occasion, most students in a set get the same mark when one aspect of their work is being graded by impression. Even if only one or two stand out as above or below average on one occasion, the cumulative effect of assessments over the two years should be to increase the spread of marks. It is important to assess fairly frequently because, in general, the more frequently assessment takes place the more reliable is the overall assessment likely to be; this is one reason why a minimum of assessments is laid down. At the same time one must repeat that assessment should not override teaching: it should be unobtrusive and should not restrict the principal role of a teacher, which is to teach.

The question is often asked 'Should the students be told when they are being assessed?' It is not easy to lay down rules about this; it depends to some extent on the relationship between particular teachers and their students. Students should certainly be told that their work will be assessed and that the outcome will be used as a part of the final A-level grade. It is also the author's view that students should know what the objectives of the practical work are so that they know by what criteria they will be assessed. And, if part of the assessment is to be by general impression, the students should know that in one sense all their work will contribute. There will be occasions, however, when a particular experiment is obviously the target for assessment and, on infrequent occasions, it may even be necessary to run a piece of practical work as an actual practical test. In these circumstances there is no point in trying to hide from students the fact that assessment is taking place.

This completes the outline of the general framework of the assessment. Within this framework it is hoped that teachers will feel free to adopt as flexible a system of assessment as they wish. The guide lines are very general ones and should not be restrictive. Some common basis for the assessment is essential if it is to achieve national cognizance; but if a teacher does feel that he would like to make a *substantial* departure from this basis it would be wise to seek the views of the Examining Board before starting the course.

The moderation of teachers' marks

The need for the moderation of the marks as they appear on the record cards has already been discussed (page 23). It would be idle to pretend that instruments of assessment exist which can, with accuracy, determine the relative merits of the practical work of one set of students when compared with that of another. It was therefore decided to approach this problem from a slightly different angle and devise some means whereby sets which paid less attention to practical work would have their practical marks scaled to a lower mean mark than that of the average sets; and those who gave unusual prominence to practical work would have their marks scaled to a mean which was higher than that of the average sets. What was then required was some means whereby the teaching sets could be divided into three groups and a different mean mark for practical work allocated to each group. Thus taking a maximum mark of 100 for practical work:

Group A might have a mean mark of 75 and would comprise those sets which appear to have given above average attention to practical work.

Group B might have a mean mark of 65 and would comprise those sets which represented the average in practical work.

Group C might have a mean mark of 55 and would comprise those sets which appear to have paid less attention to practical work compared with the others.

There remained the problem of finding the means whereby the sets could be divided into these categories. Two main criteria need to be satisfied: the moderating process must reflect the extent and understanding of practical work, and it must be quick, not making excessive claims on resources. The latter is particularly important as the number of candidates grows. It was felt that performance in the whole or part of the written examination might be used as a moderating instrument. Paper 3 had to be excluded because it contains a substantial element of choice; furthermore it does demand the ability to write at some length and an inability to do this may well hide a considerable knowledge and understanding of practical work.

Papers 1 and 2 together do not have either of these disadvantages but the majority of the questions do not relate directly to practical work and success in them would not necessarily reflect a comparable attention to practical work. However, a substantial number of questions in Papers 1 and 2 do relate directly to practical work, the examination specification allowing 20 per cent of these questions. Of all the possible sources of information about the relative emphasis placed on practical work by the teaching sets, performance in these questions (hereafter called practical questions) would appear to be the most valid for drawing quantitative distinctions. This information is still not likely to be precise, but it seems reasonable to suppose that those teaching sets which neglected practical work during the course would do relatively badly in this group of questions and those which gave it prominence would do relatively better.

At present, these practical questions in written Papers 1 and 2 do form the basis of the moderating procedure. Teaching sets (not individual students) are arranged in order of performance in the practical questions, the marks being abstracted from the answer sheets of Paper 1 and from the appropriate sections of Paper 2. The top 20 per cent of teaching sets are placed in group A, the bottom 20 per cent in group C, and the remainder in group B. The teachers' marks for each set are then scaled to the appropriate mean mark.

The mean marks quoted above are only approximations and should not be taken as those actually used, but it is true to say that the mean marks of all the groups are high, certainly higher than the half mark. This is to accord with the findings from the school trials. The mean mark for all candidates, therefore, is higher for the practical assessment than it is for the written papers.

In conclusion to this rather long section on practical work, it might be worth while to emphasize a few salient points. It is difficult to conceive of any form of valid assessment of practical work which does not make use of internal assessment of course work by teachers. To be valid the assessment must be based on a common framework of objectives, subject matter, and types of work. To be reliable, teachers must apply their criteria for assessment consistently and fairly frequently. In no event should the assessment obtrude on teaching: both teachers and students may find that they are rather too conscious of it at first, but in time it is hoped that it will become an unobtrusive part of the normal routine. Finally, the fears of a few people that the system may be abused; bogus reports made, and practical work neglected, seem to take a rather pessimistic view both of the teaching profession and the students. Neither group is likely to tolerate a course in which practical work is neglected. If the worst happens and it is neglected, the penalty will be paid in the high proportion of questions which are directed to it in all three of the written papers.

Chapter 4

Constructing tests for internal use

It is common practice to assess the progress of sixth form students at intervals during the course by the use of tests. The frequency and style of these tests varies greatly from teacher to teacher and there is no reason why teachers should abandon completely the testing procedures to which they are accustomed simply because they are changing to the Nuffield course. But the A-level examination itself differs considerably in its form and type of questions from the traditional examinations and it will be advisable to introduce, as a part of internal assessment, tests which use the type of questions which will face the students when they come to the A-level examination itself.

The first, and more obvious reason, is that students should not meet the new types of question for the first time in the A-level examination. This is especially pertinent to the fixed response questions which make up Paper 1. Some students will already have met those questions at O-level and there is no doubt that many more teachers and students are familiar with them than was the case a few years ago. Nevertheless, it is desirable that all students should have some practice in answering the types of question which they will meet in Paper 1. The form of some of the questions is quite complex and could certainly result in students not doing themselves justice if they had no previous experience of them. A frequent diet of objective tests, however, is not desirable; some practice may raise the level of student performance but frequent practice produces little, if any, improvement and the time spent in testing would have been better spent in teaching.

The actual A-level objective tests will not be published, therefore they will not be available for practice. Some questions are to be found in this book and it may be that others will be published; but it is suggested that teachers should write their own questions, either themselves or – better still – in groups. The production of this type of question for the A-level examination is very much a group activity and those for internal use could equally well be produced in this way. The establishment of Science Teachers' Centres has brought together large numbers of teachers and a profitable activity of the Centres could well be the production of individual fixed response questions and, possibly, complete tests for common use. In this way variety can be maintained and the work shared. Those who have tried will know that writing fixed response questions is not easy without some training and much practice. For those who want to construct their own tests the following notes may be useful.

Construction of fixed response tests

Some technical terms

1 Item

Not all so-called questions are actual questions; some are problems, others completions of statements and so on. The term item is increasingly used to denote any unit in a test. Many teachers in the United Kingdom, including the author, find it difficult to relinquish the term 'question', so as far as this book is concerned, question can be regarded as synonymous with item.

2 Stem

The stem of the question is that part in which the task which the student has to undertake is set out, together with any data which is necessary for him to answer correctly. The stem can be in a variety of forms: see the examples given later.

3 Responses

This refers to the five possible ways in which candidates may answer. In all questions of this type there is only one correct response and it carries one mark. The other four responses are sometimes called *distractors*.

4 Scoring

This refers to the method of marking. If the correct response is chosen, one mark is awarded. If a distractor is chosen or if no response is chosen, no mark is awarded. In this test no penalty is applied if an incorrect response is chosen.

5 The key

This is a list of the correct responses to a test in which the correct response to each question is denoted by its letter.

6 Non-functioning response

If subsequent analysis shows that no candidates, or very few candidates, chose a particular response, that response is said to be non-functioning. In other words, it was so obviously incorrect that it has not acted as a distractor and, in effect, there was a total of four responses rather than five. There may be more than one non-functioning response in a question and the element of choice is then still further reduced.

7 Pre-test and item analysis

It is customary to try out fixed response questions on a sample of students before using the questions in the actual A-level examination. This is called pre-testing and the subsequent analysis of the outcome shows how each item performed in the test.

8 Discrimination

One of the functions of an examination is to spread the performance of the candidates so that the good candidates can be distinguished from the weak ones. Each item in a test should help in the process so that for each item a greater percentage of good candidates should pick the correct response than do the weaker candidates. This process of discrimination can be stated quantitatively for each item and a more detailed account of it is given in Appendix 3.

9 Facility

Another important piece of information which arises from pre-testing is the relative facility of each item and it is expressed as the percentage of all the candidates who picked the correct response to a particular item. Examples are given in the sample items and in Appendix 3.

Types of fixed response item

There are many types of fixed response item and of these the Nuffield A-level examination uses five in Paper 1. Whether all five types will continue to be used is a matter for discussion and research. Meanwhile, teachers might wish to know something of the structure and function of each.

1 Multiple choice items

These are the most familiar and they are used in objective tests throughout the world. Essentially they consist of a stem, followed by five responses. Each item stands alone - that is it does not depend on information common to a group of items. For this reason they are sometimes called simple multiple choice, but this term is confusing because it carries implications that the items are easy, whereas the real implication is that the items are independent of each other.

2 Situation sets of items

One of the faults of a test composed entirely of simple multiple choice items is that the students have to switch their thoughts from one topic to another very rapidly. A certain amount of this switching is inevitable but it is hardly characteristic of normal procedure in the classroom or laboratory. There it is more usual to concentrate on one main situation, maybe an experiment or an account of an industrial process, or some data or a passage from the literature and so on; and to probe the situation by a series of questions and discussions. A situation set of items is intended to be comparable, giving some information to the candidates and then proceeding to probe their understanding of it by a series of questions. Each question is in multiple choice form, but each is related to the situation presented to the candidate at the beginning of the set of questions. As far as possible, the examiners make sure that the answer to one question in the set does not depend on a correct answer to another in the set.

3 Classification sets of items

Although chemistry is ultimately concerned with the behaviour and structure of individual substances, much of the study of chemistry consists of a search for *patterns* in behaviour and structure, and chemical education in the past few years has certainly increased the emphasis on this search for patterns and generalizations in order to assist in meaningful groupings of like substances and like behaviour. This process of classification is both a tool of science and a tool of education in science and should be reflected in assessment procedures.

The basis of a classification set of items is a list of five general categories. Each of these categories may consist of anything which contains many specific entities; for example they may be a list of types of reaction, or types of substance, or types of structure, or groups of the Periodic Table. Each question in the set then consists of a specific example and the student is required to classify the specific example into the appropriate general category.

4 Multiple completion items

A criticism of simple multiple choice items is that if a student immediately recognizes the correct response, he need not consider the others. This is not always so, in fact in a well written item, testing the higher intellectual abilities, it should rarely be so. Nevertheless, it is often desirable to frame a question to which there is more than one correct response and, in general, the higher the level of study the more likely are such questions to arise.

For example one might wish to test the student's ability to recognize correct variants of the ideal gas equation; it might be desirable to test the ability to recognize more than one variant. To meet this requirement the multiple choice item can be modified as follows:

Q Which of the following are correct statements of the ideal gas equation?

1 $pV = \rho MRT$

2 $pV = nRT$

3 $pV = \dfrac{M}{w} RT$

4 $pM = \rho RT$

(w = weight of gas in grammes; M = molecular mass of the gas; n = number of moles of gas; ρ = density of the gas in g dm^{-3})

It is possible to make this into a type of multiple choice by specifying the following responses:

A *2* only
B *1* and *3*
C *2* and *4*
D *1, 3,* and *4*
E All four are correct

In practice, when many such questions may be used, it is probably better to use a fixed pattern of possible responses as follows:

A Responses *1*, *2*, and *3* are correct
B Responses *1* and *3* are correct
C Responses *2* and *4* are correct
D Response *4* only is correct
E Some other response or combination of responses is/are correct

There are disadvantages in such a fixed pattern, but they are probably outweighed by the fact that students can get used to this pattern and do not waste time unravelling a different pattern each time.

5 Relationship analysis items

So often in chemistry the teacher is asked the question 'Why?' Students continuously seek concepts which can be applied to and explain more concrete observations and facts, and a good deal of chemistry teaching is concerned with a guided search for concepts which satisfy this need to seek explanations of the facts.

Relationship analysis questions are intended to reflect this process. Each consists of an assertion and a supposed explanation and students are required to make the following decisions:
Is the assertion, as it stands, true?
Is the supposed reason, as it stands, true?
If the answer to both is 'yes', is the reason one which can be correctly applied to the assertion in this particular case?

Of all the five types of fixed response questions the relationship analysis type is probably the most difficult to write. Explanations which sound convincing when given on the spur of the moment in class rarely look so convincing in print and in the cold light of an examination. But, so long as teaching is concerned with the truth or falsity of asserted facts and the validity or invalidity of concepts applied to those facts, questions of this or a similar type should be used.

Writing fixed response items

No one can learn how to write fixed response items by reading or listening to someone else doing it. If ever there was a skill to be learned by practice and experience, this is it. There are, however, a few points of guidance which teachers may find useful before embarking on test construction:

1 The stem

The first step is to find a suitable idea for the stem of the question. For questions requiring no more than recall or routine comprehension, the construction of a stem is not difficult, but for questions demanding the ability to apply understanding to unfamiliar situations or to analyse unfamiliar data the stems are not easily come by; it is certainly very difficult simply to sit at a desk and construct good quality items without some external source of inspiration.

Without doubt, a main source of inspiration comes from teaching itself. It may come from a question from a student or a problem arising during a practical class or from general class discussion. Of course, there is no time in the middle of a lesson to drop what one is doing and write a complete question, but at least the idea for the stem of the question should be noted for further development. It is important to jot down the idea; if you do not you will find that it is ephemeral and in a few hours of a busy teaching day it will have gone.

There are other sources, reading the chemical literature for example. Provided that it is at an appropriate level, a good deal of what is written in the literature is suitable material on which students can work. To achieve a degree of unfamiliarity in the data included in the stem of a question one must look outside the normal work of the course and outside the standard texts, and there are now many suitable journals which can provide such data. The level of writing may well be aimed at a reading population of higher level than the sixth form, but such extracts can still provide suitable information for inclusion in the stem of questions. It does not necessarily follow that because the information itself is unfamiliar, and to some extent more complex, that the subsequent questions need be difficult. After all, every new topic is unfamiliar when it is introduced at school; it is part of the art of teaching to so structure the approach to the new information that the level of difficulty is within the abilities of the students. Exactly the same approach applies to question writing.

A good data book can be very useful in providing the basis of questions. In general there are plenty of data available in the field of energetics and equilibria; data on reaction kinetics are less easy to come by and recourse may have to be made to original papers.

In addition to the sources already mentioned there is always the teacher's own inventiveness. It is often necessary to disregard external sources and produce something from within. There is one precaution which ought to be taken: if the basis for a question involves practical work and the behaviour of specific substances, the teacher should make sure that the techniques and reactions which he describes do, in fact, take place as he says they will. So often things do not go as one expects and if there is any doubt at all, it is suggested that the item writer actually performs the experiment himself to see exactly what does happen before writing the information into the stem of a question. This applies to all questions: in modern examinations there is often much more chemical information in the stem of a question than there is in the answer to the question and it is important that all data is checked.

2 The responses

The best method of writing the responses is to imagine the replies one would get if the question were put to a class of students in an open-ended manner. If they are serious and considered responses to the question they will all contain an element of reason which has been thwarted by a misconception; it is these replies which make the best distractors. As for the correct response, of course it must be the best response available at the particular level of study. It does not follow that the correct response is necessarily taken to be absolutely correct at all levels of study; indeed the greater chemical knowledge of some readers may well lead them to point out obvious defects in a supposedly correct response. What is a satisfying answer to a sixth form student may not satisfy a graduate chemist; but it is at the level of the student at which the correctness or otherwise of a response is to be judged.

The responses should be grammatically consistent with the stem of the question. If, for example, the stem of the question is an incomplete statement, then each response should complete it grammatically. And the responses should be chemically consistent with the stem. For example, if the stem of the question clearly requires a response in terms of equilibrium constants, it would be inconsistent if one response were given in terms of rate constants. In other words, the stem and responses should be homogeneous, they should not contain elements which are at variance with the general purpose or specific content of the item. This homogeneity should also extend to the length of the responses; one response which is considerably longer or shorter than all the others will be conspicuous and draw attention to itself for reasons which have nothing to do with the purpose of the item.

3 The facility of an item

In assessment the facility of an item is defined as the degree of success with which students pick the correct response. Failure to pick the correct response indicates the difficulty of an item and it may be caused by several factors. One may be a deficiency in learning, another may be a deficiency in teaching, but neither of these can be changed by changes in the construction of the examination.

Two other factors, however, are under the control of the item writer. The first is the intrinsic difficulty of the material and the problem. Some parts of chemistry are normally found to be more difficult than others and some questions are less readily answered than others; such questions obviously will be more difficult. But even simple material and apparently easy questions can be made more difficult by constructing responses which are very close together in their meaning. In this way the student's decision and choice of the correct response is rendered more difficult. Conversely, the more dissimilar the responses, the more likely students are to pick the correct one.

4 The educational objective of an item

The various abilities which are required of candidates are discussed on pages 2 to 4. In the Nuffield examinations the percentage of items which require the candidate to do no more than recall information is small; most of the items require the exercise of the higher educational abilities: comprehension, application, and analysis. It is not always possible to predetermine the category of objective of an item before it is written; for that matter, it is not easy to do so after it is written. However, it is advisable to begin with the intention of constructing most items for the higher abilities and relatively few for simple recall. And it is as well to remember that candidates cannot readily demonstrate their ability to use their knowledge at the higher levels if there is no material in the stem of the question on which they may work.

Under this heading it is also appropriate to remind teachers to include in their internal tests items which are directed towards specific types of work, particularly practical work. The point has already been made that 20 per cent of questions in Papers 1 and 2 are designed to test the student's familiarity with practical work and every attempt is made to ensure that these items are relatively easy for those students who have paid due attention to practical work and relatively difficult for those who have not. Practice in answering such items is desirable and a reasonable proportion should be included in internal tests.

5 Item reviewing

Fixed response items rarely improve with keeping. Re-read them after a few days of first writing and faults will be only too evident. This is the time to revise and edit them. If the revision can be done by someone else or better still as a group exercise, so much the better: other eyes can often see faults which have escaped the writer. Group reviewing and test construction is easier in schools in which a large staff of chemistry teachers can share the work. For someone working alone the task of writing fixed response tests can be formidable.

It is not possible to mention in detail all the points for which an item reviewer should look, but a list of the main ones may be helpful:

a Format should be standard so that students are not confused by unexpected changes in it. Items are normally numbered. The five responses are lettered in capitals A to E and, unless they are very short, each should be on a separate line for ease of reading. The general instructions for each type of item should be in the standard form.

b Check that there is only one correct response to the item.

c Check for grammatical consistency. The item should be concise and precise. Negatives should be in capitals and double negatives avoided.

d Check for chemical accuracy and for homogeneity of the stem and responses.

e Check that the item is testing something of consequence in chemical education. It should normally be directed to one important aspect of chemistry and this aim should not be confused by others which are not immediately relevant.

6 Test construction

The assembling of all the individual items into a single test is the final task. The main points to consider are:

a Balance of item facility.

b Balance of chemical topics.

c Balance of educational objectives.

d Keys to items should be randomly arranged.

e Items of the same type should be grouped together.

f The arrangement of items within each group is not of great consequence but it is probably better if each group begins with the easier items.

g For internal use there are no firm rules about the total number of items in a test. For tests which are used frequently as a teaching aid to diagnose those areas in which students are finding difficulty the number of items could be as few as ten, although twenty would probably be more appropriate. At some time during the course students should be given practice in one or two tests of about the same length and duration as that used at A-level.

h It is advisable to use answer sheets and to retain the items for future tests.

i An elementary form of item analysis can be carried out on the results of tests. Even if the number of students is quite small, and the results not statistically very significant, analysis will reveal faults such as ambiguities and non-functioning responses and will also indicate the level of difficulty of each item. A simple form of item analysis is given in Appendix 3.

Writing structured questions

Much emphasis has been given in recent years to the writing of fixed response questions and several training courses have been arranged expressly for this purpose. This is welcomed, but it is a pity that this emphasis has obscured, to some extent, the need for training in the writing of structured questions. The skills required to do the latter may be different but they are certainly no less and the writing of one structured question can take a very long time.

The stem of a structured question is rather like that of a situation set of fixed response items (page 37): information is given and the general purpose of the set of questions is stated. The questions which follow are also similar in that they are structured in the same way as one would structure a series of questions related to the same information during a lesson. The difference lies in that the answers to the questions are not prompted by using the fixed response form. At the same time, it is not the intention of the examiner to allow a completely free response as in Paper 3B of the examination; he has a precise answer in mind when he asks the question and if the marking of the answers is to be as objective as possible he must see to it that he frames his question in such a way as to demand uniformity of response.

There are two main skills required in devising these questions. The first is to arrive at a sequence of questions which is appropriate to the information in the stem and which follows the normal sequence which would arise in a teaching situation. The second is to be able to foresee the answers which the students will give to each part. Both these skills are closely allied to those of teaching.

As each part of the question is written (the number of parts normally lies between four and eight) it is helpful if the desired answer is written at the same time. In this way the teacher devises a mark scheme and, at the same time, can indicate to the students how many marks will be awarded to each part and approximately how much space will be required in which to set out the answer. Of course, it is not possible to predetermine exactly all the answers which will arise and teachers will have to be prepared to modify the scheme after reading some scripts. But large changes should not be necessary if the question has been correctly structured and each part precisely stated.

Many teachers may find that the labour of writing structured questions is such that it is only worth while for end of term or annual tests. A variant, which may be more popular and capable of more frequent use, is to give the structured questions orally. There is nothing new in this; most teachers have been in the habit of breaking down a complex topic into very small parts and asking each question orally while the students respond by means of short written answers. There is no essential difference between this and a written structured question and for day-to-day use the oral form could be a good deal more effective.

In addition to the mark scheme and mark weighting, each part of a structured question should be classified in much the same way as a fixed response question, taking note of the educational objective, the chemical theme, the course topic, and – where appropriate – the learning activity. (With reference to the latter it should be noted that approximately 20 per cent of the marks on structured questions in the A-level examination are allocated to questions dealing with practical work.) In this way a test specification can be constructed in much the same way as for an objective test except that allowance must be made for the different mark allocation to the sub-questions and more overlap between categories is to be expected, particularly in the longer answers.

Writing free response questions

This is probably somewhat less difficult than writing fixed response and structured questions; but the task should not be underestimated nor should it be supposed that these questions are necessarily the same as those of the traditional essay type. Some general points of guidance may be useful:

1 The questions should allow a genuine free response at least in part. Of course, it is more than likely that the teacher will be able to forecast a good deal of the material which will be contained in an answer; but, if he can forecast it all, he should consider changing the question.

2 It should be remembered that this is the only part of the examination in which students are given the opportunity to select appropriate information and to arrange it in an appropriate form; in other words to exercise their ability to synthesize (see page 3). Some account of this ability should be taken when laying down the criteria by which the answers are to be graded.

3 As in all questions, the ability to remember information must weigh largely in the ability to construct a suitable answer. A free response question, however, should not lean too heavily on this element of recall and there is every reason for allowing students to use suitable sources for reference. In the examination itself the *Book of data* is allowed; during the course other books could also be allowed as aids to answering these questions.

4 Many free response questions may be quite brief, but not so brief that the student is uncertain of the examiner's intentions. There is no harm at all in telling

the students the criteria by which their answers will be judged.

5 Free response questions are not necessarily brief. They can, in fact contain a good deal of information on which the students can be asked to comment in their own words and in a form of their choosing. Use can be made of various data, including passages from the literature. This use of unfamiliar information on which to base a question can be common to all three types of question used in the Nuffield examination; the difference lies in the degree to which the student's response is predetermined by the teacher.

6 It is not possible to classify free response questions and arrive at a specification in the same way as the other two types of question, except that there should be a common element of synthesis in them all. In any event, such an attempt at classification would be nullified by the choice which the students are allowed amongst those questions.

7 If it is at all possible, a form of marking similar to that used in the examination should be adopted, that is double marking by impression using a six point scale, 5-4-3-2-1-0. It may be that the double marking will have to be done by the same teacher, but if it is possible to obtain the cooperation of colleagues in this matter it would be very fruitful not only in improving the grading but in initiating discussion about the course and chemistry teaching in general.

8 Although students should be given some practice in answering free response questions under examination conditions, there is no need always to do so. A more leisurely approach to the questions is often desirable so that students can spend more time in designing their answers and in searching for suitable information. This leads one to the conclusion that free response questions are probably the most suitable of the three types for use as homework.

Coda

One of the most interesting remarks made to the author during the trials of the Nuffield materials was 'It wasn't until I began to construct questions that I realized what this course was all about.' It has long been acknowledged that teaching a subject is one of the best ways of attaining an insight into the subject. To this should be added that assessing attainment in a subject brings further insight into one's teaching. This is not surprising. Disciplined assessment, using a variety of question types and with clear operational objectives, demands a look at the subject from the point of view of what the students are capable of doing as a result of a study of it. What the students can or cannot do is pre-eminent in assessment and one is forced into looking at the course from *their* point of view. Nothing could be more valuable to the teaching of chemistry. For this reason alone, teachers will find it profitable to write their own questions and construct their own tests. If this can be done in cooperation with their colleagues or with other schools, so much the better. This individual and group work, constructing and analysing questions, could be most fruitful from a professional point of view. There follows many examples of questions which have been used in the Nuffield trial and operational examinations. Other sample questions will no doubt be published. Use them as they stand if they are suitable, modify them if necessary, use them as examples, but, having done so, adopt the attitude 'I can do better than that' and write your own.

Part two

Sample questions

Section A

Objective questions

Most of the questions in this section were used in the internal examinations of the trial schools between 1967 and 1969 and many of them were written by the teachers themselves. There are many criteria by which they could be arranged: facility, topic, objective, type, theme, ready made tests, etc. and clearly it is not possible to take account of them all. The items are divided into groups according to their type. There are some overlaps; for example, some situation sets of items are in multiple choice form, others in multiple completion form, but this is of no great consequence. The main thing is for teachers to select those items most suitable for their immediate purpose. As an aid to those selecting items for tests, the characteristics of each item – as far as they are known – are given in the table at the end of the section. For many of them the facility is available from item analysis, but it should be remembered that this data was obtained during school trials of the materials and it will not necessarily apply to a situation in which the final form of the materials has been adopted. It should also be noted that the classification of an item to a particular educational objective is a fairly subjective process; there is room for difference of opinion, but at least the classification should indicate to teachers those items which require only the ability to recall and those which require higher abilities. The discrimination index of all the items which follow was found to be positive in the trial examinations; that is performance in each item correlated positively with performance in the test as a whole. These discrimination indices are not quoted since they are not meaningful unless related to a complete test.

The fact that items appear amongst this sample does not imply that they are all suitable for examination use. Some, for example, have facility indices of 90 per cent or higher and others may have lower discriminating power than would normally be found in an operational objective test. The reason for the inclusion of such items is that an important function of internal tests is to diagnose weaknesses in students' attainment and so aid better teaching and better learning. When tests are used for diagnostic purposes they need not, in fact should not, have the same characteristics as those used for grading purposes.

It will also be found that some items are based on material which, although used in the trials, is not in the published materials. It was thought that those items might still have value for test purposes, but what once required no more than the ability to recall, will require higher abilities from students who have not previously come across the subject matter of the item.

A1 Multiple choice questions

1 The following five people all did original work on the structure of matter; which of them worked at a different period of time from the other four?

A Avogadro
B Geiger
C Rutherford
D Moseley
E Bohr

2 Isotopes of titanium include the following. Two of them are radioactive. Which isotope is most likely to decay by electron (β^-) emission?

A $^{46}_{22}Ti$
B $^{47}_{22}Ti$
C $^{48}_{22}Ti$
D $^{49}_{22}Ti$
E $^{50}_{22}Ti$

3 Which of the following quantities of ionic compounds contains the greatest number of ions?

A 50 g NaCl (formula mass 58)
B 50 g K_2O (formula mass 94)
C 50 g Na_2O (formula mass 62)
D 50 g $CaCl_2$ (formula mass 111)
E 50 g $BaCl_2$ (formula mass 208)

4 The copper(II) ion has two positive charges (Cu^{2+}). How many electrons would be required to deposit 6.35 g of copper at the cathode during the electrolysis of an aqueous solution of copper(II) sulphate (atomic mass of copper = 63.5, L = the Avogadro constant)?

A $L/20$
B $L/10$
C $L/5$
D $L/2$
E $2L$

5 What weight of barium hydroxide, $Ba(OH)_2$, (formula mass 171) should be dissolved to make 1 dm^3 of solution, 0.01M with respect to hydroxide ions?
A 0.855 g
B 1.71 g
C 3.42 g
D 85.5 g
E 171 g

6 A substance X was a white solid. On heating it lost weight giving off oxygen and leaving a white residue Y. When an aqueous solution of Y was treated with chlorine an orange coloured solution was obtained. X gave a green coloured flame when heated on a platinum wire. Which of the following substances could it be?
A Potassium bromide
B Potassium bromate
C Barium bromate
D Potassium chlorate
E Barium chlorate

7 Which of the following fluorides is most likely to be capable of further reaction with fluorine?
A CaF_2
B SF_6
C IF_5
D NaF
E CF_4

8 Which of the following elements is extracted *commercially* by the electrolysis of an aqueous solution of one of its compounds?
A Sodium
B Aluminium
C Graphite
D Bromine
E Chlorine

9 Which of the following would be the appropriate method of indicating the position of hydrogen atoms within molecules of a substance?
A X-ray diffraction
B Electron diffraction
C Effect on polarized light
D Emission spectrum
E Mass spectrometry

10 Each of the following pairs of components will combine. Which of the combinations is best explained by the theory of dative covalency?

A $Na + \frac{1}{2}Cl_2$
B $H_2 + Cl_2$
C $Mg + \frac{1}{2}O_2$
D $H_{at} + H_{at}$
E $H^+ + H_2O$

11 Consider the reaction in which 1 mole of ethane is completely burned:

$$C_2H_6(g) + 3\tfrac{1}{2}O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l)$$

Which of the following expressions will equal the heat of combustion of ethane?

A $\Delta H^{\ominus}_{f,298}[CO_2(g)] + \Delta H^{\ominus}_{f,298}[H_2O(l)] - \Delta H^{\ominus}_{f,298}[C_2H_6(g)]$
B $2\Delta H^{\ominus}_{f,298}[CO_2(g)] + 3\Delta H^{\ominus}_{f,298}[H_2O(l)] - \Delta H^{\ominus}_{f,298}[C_2H_6(g)]$
C $\Delta H^{\ominus}_{f,298}[C_2H_6(g)] - \Delta H^{\ominus}_{f,298}[CO_2(g)] - \Delta H^{\ominus}_{f,298}[H_2O(l)]$
D $\Delta H^{\ominus}_{f,298}[C_2H_6(g)] - 2\Delta H^{\ominus}_{f,298}[CO_2(g)] - 3\Delta H^{\ominus}_{f,298}[H_2O(l)]$
E $2\Delta H^{\ominus}_{\text{combustion},298}[C(s)] + 3\Delta H^{\ominus}_{\text{combustion},298}[H_2(g)]$

12 Which of the following would make the most concentrated solution of Cr^{3+} ions, when dissolved in the same volume of water?

A 250 grammes of $Cr_2(SO_4)_3$ (formula mass 392)
B 500 grammes of $K_2Cr_2O_7$ (formula mass 294)
C 150 grammes of $CrCl_3$ (formula mass 158)
D 400 grammes of K_2CrO_4 (formula mass 194)
E 250 grammes of $CrCl_3, 6H_2O$ (formula mass 267)

13 In the presence of a catalyst, ammonia reacts with oxygen. The observed volume increase is about 11 per cent when neither gas is in excess. Assuming that the products, as well as the reactants, are all gaseous, which of the following equations could be the correct one?

A $4NH_3 + 7O_2 \rightarrow 4NO_2 + 6H_2O$
B $4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O$
C $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$
D $2NH_3 + O_2 \rightarrow 3H_2 + 2NO$
E $2NH_3 + 3O_2 \rightarrow 3H_2O + N_2O_3$

14 In which of the following reactions has the named substance acted as a *base*?

A $H_3O^+(aq) + OH^-(aq) \rightarrow 2H_2O(l)$ *hydronium ion*

B $HCl(g) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$ *hydrogen chloride*

C $H_2O(l) + NH_3(g) \rightarrow NH_4^+(aq) + OH^-(aq)$ *water*

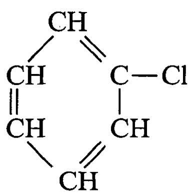
D $CH_3—CO—CH_3(aq) + HCl(aq) \rightarrow$
$CH_3—C(OH)—CH_3^+(aq) + Cl^-(aq)$ *acetone*

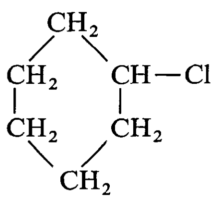
E $C_6H_5—O^-Na^+(s) + CH_3—CO—Cl(l) \rightarrow$
$C_6H_5—O—CO—CH_3(s) + Na^+Cl^-$ *the acetyl group*

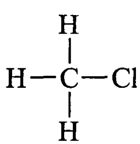
15 An alkaline solution was run from a burette into 20 cm^3 of acid, the pH of the mixture being taken after each cm^3 addition. The results are shown in the graph (figure 1, page 56). With which of the following pairs of solutions could the titration have taken place?

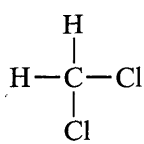
A 0.1M sodium hydroxide with 0.1M acetic acid
B 0.1M sodium hydroxide with 0.15M acetic acid
C 0.1M ammonia solution with 0.1M hydrochloric acid
D 0.1M ammonia solution with 0.15M hydrochloric acid
E 0.15M ammonia solution with 0.1M acetic acid

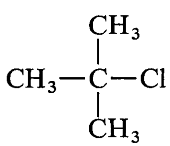
16 In which of the following compounds is the delocalization of a pair of electrons from the chlorine likely to occur?

A


B


C


D


E


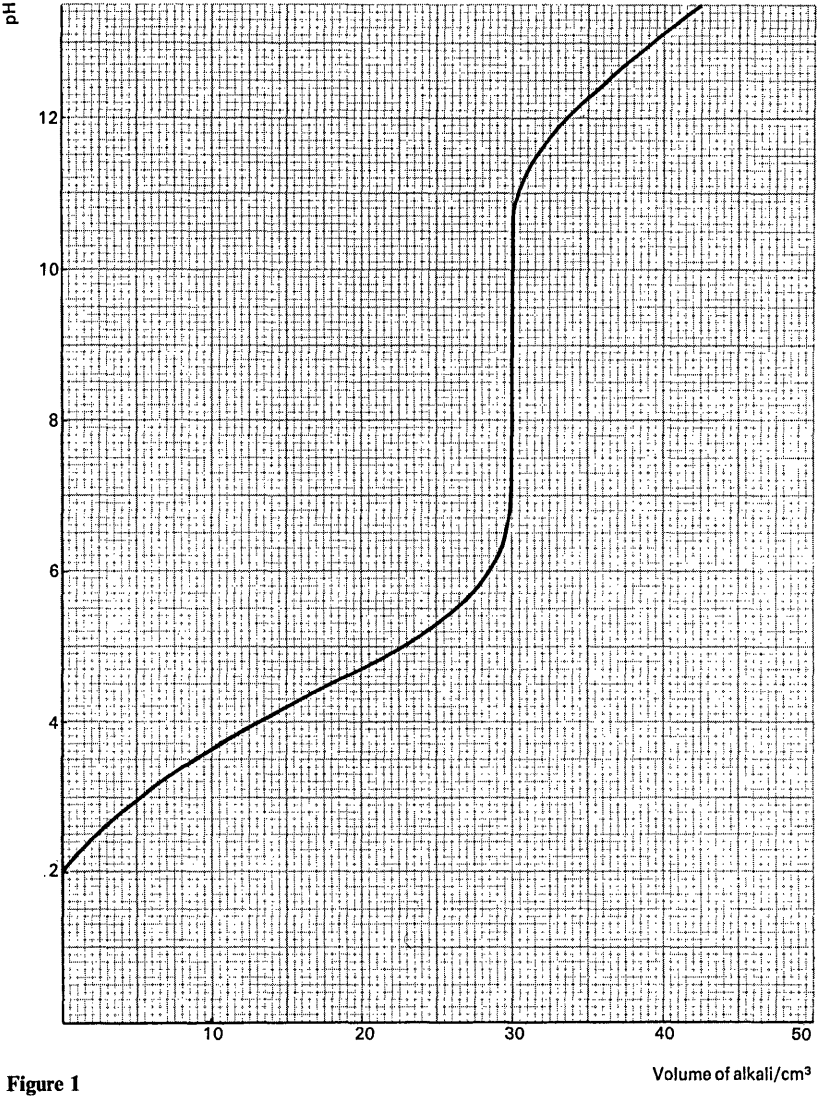


Figure 1

17 An iron electrode was put into 25 cm^3 of Fe^{2+}(aq) solution and the potential difference between it and a standard hydrogen electrode was measured at intervals while a solution of $KMnO_4$(aq) was run in from a burette (temperature, 298 K). The results are shown in the graph.

$$E = E^{\ominus} + \frac{0.06}{z} \lg \frac{[\text{oxidized form}]}{[\text{reduced form}]}$$

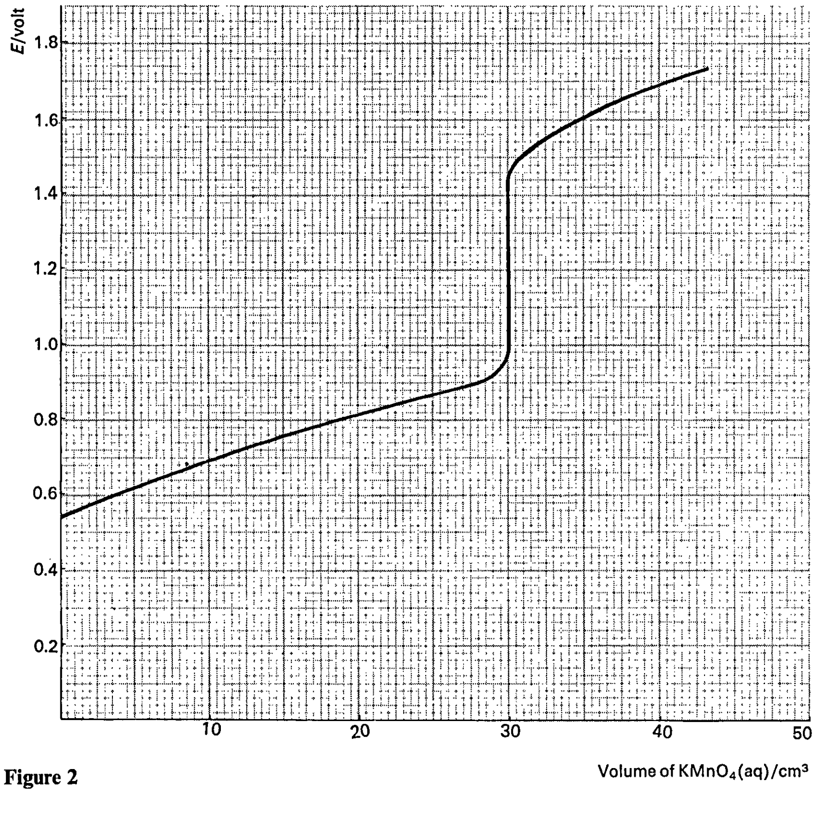


Figure 2

Which of the following is $E^{\ominus}$ for the cell (volt):

$Pt[H_2(g)]|2H^+(aq)\vdots Fe^{3+}(aq), Fe^{2+}(aq)|Pt$?

A 0.54

B 0.76

C 0.94

D 1.20

E 1.46

18 The e.m.f. of each of the following cells was measured under identical, but non-standard, conditions:

$Cu(s)|Cu^{2+}(aq)\vdots[2IO_3^-(aq) + 12H^+(aq)], [I_2(aq) + 6H_2O(l)]|Pt;$ $E = +0.85$ volt

$Cu(s)|Cu^{2+}(aq)\vdots Zn^{2+}(aq)|Zn(s);$ $E = -1.10$ volt

$Cu(s)|Cu^{2+}(aq)\vdots 2H^+(aq)|[H_2(g)]Pt;$ $E = -0.34$ volt

Under the same conditions, what would be the e.m.f. of the cell

$Zn(s)|Zn^{2+}(aq)\vdots[2IO_3^-(aq) + 12H^+(aq)], [I_2(aq) + 6H_2O(l)]|Pt?$

A -0.59 volt
B -0.25 volt
C $+0.25$ volt
D $+1.95$ volt
E $+2.29$ volt

19 The hydrolysis of ethyl acetate in the presence of acidified water is found to be first order with respect both to hydrogen ion and to ethyl acetate, and second order overall. The stoichiometric equation is

$$CH_3CO_2C_2H_5 + H_2O \rightarrow C_2H_5OH + CH_3CO_2H$$

Which of the following correctly expresses the rate of reaction?

A $k\,[\text{ester}]^{\frac{1}{2}}\,[H^+(aq)]^{\frac{1}{2}}$
B $k\,[\text{ester}]\,[H^+(aq)]$
C $k\,[\text{ester}]^2\,[H^+(aq)]^2$
D $k\,[\text{ester}]\,[H^+(aq)]\,[H_2O]$
E $k\,[\text{ester}]\,[H_2O]$

20 The rate of a reaction can be expressed by

$$k = Ae^{-E/RT}$$

In this equation which of the following does E represent?

A The fraction of molecules with an energy greater than the activation energy of the reaction
B The total energy of the reacting molecules at a temperature T
C The energy above which all the colliding molecules will react
D The energy below which colliding molecules will not react
E The average energy of all the reacting molecules

21 Hydrogen peroxide decomposes in the presence of a finely divided d-block element:

$$H_2O_2(aq) \rightarrow H_2O(l) + \tfrac{1}{2}O_2(g)$$

Which of the following graphs would show correctly that the reaction was of the first order with respect to hydrogen peroxide?

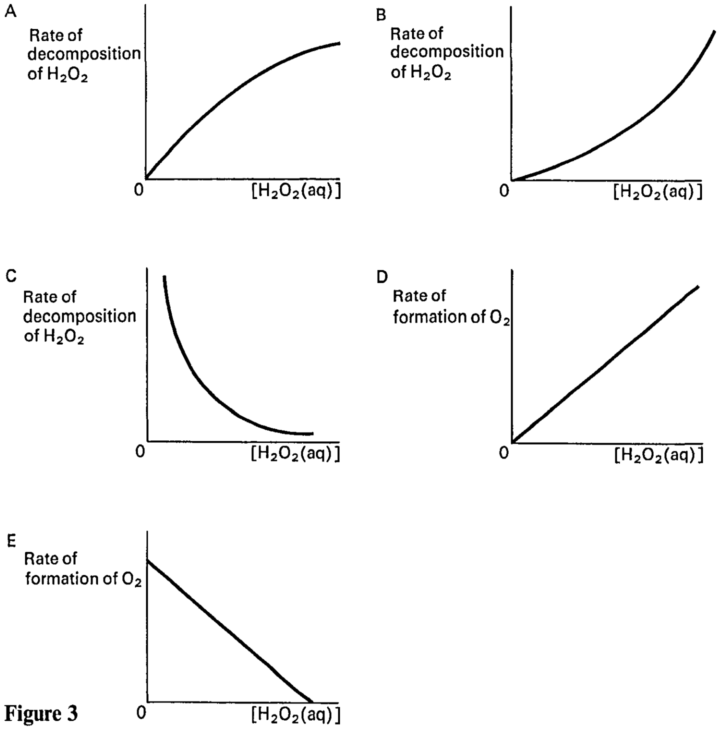


Figure 3

22 The standard enthalpy of formation at 298 K, $\Delta H^{\ominus}_{f,298}$ for methane, $CH_4(g)$, is -74.9 kJ mol^{-1}. In order to calculate from this the average energy given out in the formation of a C—H link it is necessary to know also

A the dissociation energy of the hydrogen molecule, H_2

B the dissociation energy of H_2 and the heat of sublimation of carbon

C the first four ionization energies of carbon

D the first four ionization energies of carbon and the electron affinity of hydrogen

E the latent heat of vaporization of methane

23 You are required to make up a solution of nitric acid which is two-thirds molar. If you are given molar nitric acid and distilled water would you

A mix 3 volumes of nitric acid with 2 volumes of water
B mix 2 volumes of nitric acid with 5 volumes of water
C mix 2 volumes of nitric acid with enough water to make it up to 5 volumes
D mix 3 volumes of nitric acid with 1 volume of water
E mix 2 volumes of nitric acid with enough water to make it up to 3 volumes?

24 Barium ions, Ba^{2+}, form a highly insoluble precipitate of barium sulphate, $BaSO_4$, when they come into contact with sulphate ions, SO_4^{2-}. A solution of aluminium sulphate $Al_2(SO_4)_3$ is labelled '0.2M with respect to Al^{3+}': what is the minimum volume of barium chloride solution, 0.1M with respect to $BaCl_2$, which will precipitate all the sulphate ions in 20 cm^3 of the aluminium sulphate solution?

A 10 cm^3
B 20 cm^3
C 30 cm^3
D 45 cm^3
E 60 cm^3

25 A certain element combines with chlorine in the proportion of 1 mole of atoms of the element to 1 mole of chlorine atoms, and the chloride gives an acidic solution in water. The element is a solid which melts at 114 °C and does not burn in oxygen. To which periodic group is the element most likely to belong?

A Either group I or group VII
B Group I
C Group VII
D Group II
E Group VI

26 Solutions of chromium(II) salts have powerful reducing properties and can be used for absorbing gaseous oxygen. The half-reactions are:

$$Cr^{2+}(aq) \rightarrow Cr^{3+}(aq) + e^-$$

$$\tfrac{1}{2}O_2(g) + 2H^+(aq) + 2e^- \rightarrow H_2O(l)$$

What approximate volume of oxygen, at room temperature, could be absorbed by 100 cm^3 of a molar solution of Cr^{2+} ions? (Molar volume of a gas under normal laboratory conditions = approximately 24 dm^3.)

A 200 cm^3
B 400 cm^3
C 600 cm^3
D 1.2 dm^3
E 2.4 dm^3

27 The manganate ion MnO_4^{2-} and the manganese(III) ion Mn^{3+} react separately in aqueous solution as follows:

$$3MnO_4^{2-}(aq) + 2H_2O(l) \rightarrow 2MnO_4^-(aq) + MnO_2(s) + 4OH^-(aq)$$

$$2Mn^{3+}(aq) + 6H_2O(l) \rightarrow Mn^{2+}(aq) + MnO_2(s) + 4H_3O^+(aq)$$

These reactions resemble each other in that in both cases

A water is acting as an oxidizing agent
B water is acting as an acid
C the oxidation number of the manganese is increased
D the oxidation number of the manganese is both increased and decreased
E the oxidation number of the manganese is decreased

28 In an experiment to measure the enthalpy change (which is positive) for the dissolving of sodium nitrite in water, the quantities were chosen so that the initial temperature of the water was 4 °C above room temperature and the final temperature of the solution was 4 °C below room temperature. This final temperature was reached in 4 minutes. In calculating the enthalpy change, which of the following is a correct statement about temperature correction?

A Add to the temperature change $4 \times \frac{1}{2} \times$ rate of cooling (°C min^{-1}) at the higher temperature
B Subtract the quantity given in A
C Add to the temperature change $4 \times \frac{1}{4}$ rate of cooling
D Subtract the quantity given in C
E No temperature correction is required

29 Which of the following molecules is linear?

A $CH \equiv CH$
B H_2O
C NH_3
D CH_3OH
E $CH_2{=}CH_2$

30 Which one of the following structures would NOT be expected to transmit light when placed between crossed polaroids?

A Long molecular chains
B Planar molecules
C Spherical cations and rod-like anions
D Spherical cations and spherical anions
E Spherical cations and planar anions

31 Which of the following liquids is NOT deflected by a non-uniform electrostatic field?

A Water
B Chloroform
C Nitrobenzene
D Hydrochloric acid
E Hexane

32 Which of the following compounds of elements in group IV would you expect to be most ionic in character?

A $PbCl_2$
B $PbCl_4$
C $SiCl_4$
D $GeCl_4$
E CCl_4

33 Information about the structure of substances from infra-red spectroscopy is possible because

A particular bond vibrations in molecules radiate energy of specific frequencies

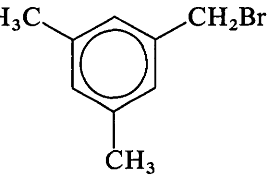
B each atom in a molecule absorbs at a given frequency according to its position in the molecule

C the frequency of the radiation from a particular molecule depends upon the angle between the various bonds

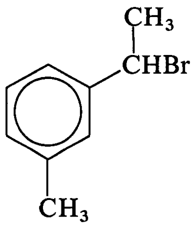
D the emission spectra consist of lines or bands corresponding to the energy of bending or other deformation of the bonds

E the absorption of energy by the particular bond depends upon the type of bond and its possible vibrations

34 Substances 1 to 4 are brominated hydrocarbons of the same molecular formula, $C_9H_{11}Br$.



1



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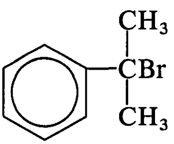

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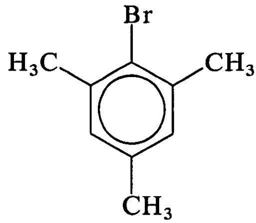


4

If a few drops of each of these substances are dissolved in ethanol and then shaken with an aqueous solution of silver nitrate, in what order (shortest first) would you expect to find the times taken for the production of a precipitate of silver bromide in each case?

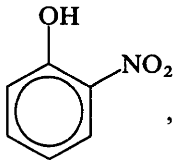
A 1, 2, 3, 4
B 3, 2, 1, 4
C 4, 3, 2, 1
D 4, 1, 2, 3
E 1, 4, 3, 2

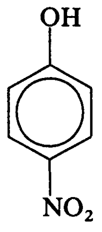
35

1 $H_2O \ldots\ldots H_2O$
2 $HF \ldots\ldots HF$
3 $CH_3COCH_3 \ldots\ldots CH_3COCH_3$
4 $C_4H_{10} \ldots\ldots C_4H_{10}$

If the above pairs of molecules are arranged in the order of the strength of the interaction between them, putting the pair with the strongest interaction first, the order will be

A 1, 2, 3, 4
B 2, 1, 3, 4
C 4, 3, 2, 1
D 3, 4, 2, 1
E 3, 2, 4, 1

36 *o*-Nitrophenol, , has a considerably lower boiling point

than *p*-nitrophenol, . The best explanation of this is

A hydrogen bonding within molecules in the *ortho* isomer, but between molecules in *para*

B more symmetrical structure of *para*, giving more stability and higher boiling point

C benzene ring less stable in *ortho*

D *para* is more polarized than *ortho*

E more interleaving of molecules in *para*, using more energy to separate the molecules

37 A certain compound had the following properties:

liquid at 25 °C

soluble in water

reacted readily with bromine in cold aqueous solution

reacted with hydrogen iodide to form a product the molecular weight of which was 128 more than that of the original compound (atomic weight of iodine = 127)

reacted exothermically with aqueous sodium hydroxide to form a solution from which a solid could be obtained by evaporation

Which of the following is the compound most likely to be?

A $CH_3C{\equiv}CCO_2CH_3$

B $CH_3CH{=}CHCO_2CH_3$

C $CH_3CH{=}CHCH_2OH$

D $CH_3CH{=}CHCO_2H$

E $CH_3C{\equiv}CCOCl$

38 In figure 4 the labels Y and X on the two axes are not specified.

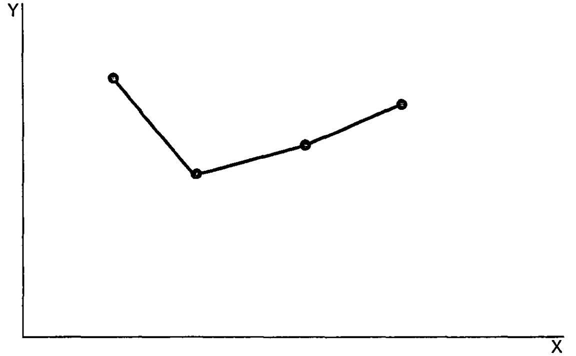


Figure 4

Which of the following pairs of labels would be most appropriate to this figure?

A Y = first ionization energies
X = the first four elements in ascending atomic number in any group of the Periodic Table

B Y = first ionization energies
X = Li, Na, K, Rb

C Y = melting points
X = H_2O, H_2S, H_2Se, H_2Te

D Y = melting points
X = He, Ne, Ar, Kr

E Y = the acid dissociation constants (K_a)
X = molar solutions of HF, HCl, HBr, and HI

39 Manganese ions in aqueous solution can be estimated by titration with a solution of EDTA (ethylenediaminetetra-acetic acid, disodium salt) using Eriochrome Black as an indicator. Which of the following is the order of stability of manganese complexes putting the most stable first?

A Water, EDTA, Eriochrome Black
B EDTA, water, Eriochrome Black
C EDTA, Eriochrome Black, water
D Eriochrome Black, EDTA, water
E Eriochrome Black, water, EDTA

40 The reactions represented by the following equations are quantitative.

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

$$2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$$

Suppose that 25 cm^3 of 0.10M iodine (I_2) were added to 25 cm^3 of 0.05M sulphite (SO_3^{2-}) solution, and the resulting solution titrated against 0.10M thiosulphate ($S_2O_3^{2-}$) solution. The volume (cm^3) of thiosulphate solution required would be:

A 0
B 12.5
C 25
D 50
E 100

41 In the cell

$Ni(s)|Ni^{2+}(aq)\vdots Cu^{2+}(aq)|Cu(s)$; $E^\ominus = +0.77$ volt,

which of the following changes would *increase* the e.m.f. of the cell?

A Pass some ammonia into the Cu^{2+} solution
B Increase the size of the metal electrodes
C Decrease the concentration of $Cu^{2+}(aq)$
D Put a conductor of lower resistance between the metal electrodes
E Decrease the concentration of $Ni^{2+}(aq)$

42 Which of the following is the most convincing evidence that a certain chloride is that of an element in group III of the Periodic Table?

A It has a high melting point. It dissolves in water giving a neutral solution containing chloride ions, the enthalpy of solution being small and positive

B It vaporizes easily. It combines with chlorine to form a chloride in which the element is in a higher oxidation state. It dissolves in water forming chloride ions, the enthalpy of solution being large and negative

C It vaporizes readily. It is chemically rather inert and does not dissolve in water

D It is gaseous at room temperature. It dissolves in water forming an acidic solution containing chloride ions

E It vaporizes readily. It dissolves in water forming chloride ions, the enthalpy of solution being large and negative. It does not combine with chlorine

43 The first ionization energy of sodium is 500 kJ mol^{-1}. This denotes:

A The energy given out when 1 mole of sodium atoms dissolves in water to form sodium ions

B The energy required to remove 1 electron to infinity from 1 atom of sodium

C The energy required to raise the electrons in 1 mole of gaseous sodium atoms to a higher energy level

D The energy required to change 1 mole of gaseous sodium atoms into gaseous ions (Na^+)

E The energy required to vaporize 1 mole of sodium atoms

44 When a solution containing dichromate ions, $Cr_2O_7^{2-}$(aq), is run from a burette into an acidified solution of iron(II) ions, the following reaction takes place quantitatively:

$Cr_2O_7^{2-}(aq) + 6Fe^{2+}(aq) + 14H^+(aq) \rightarrow 2Cr^{3+}(aq) + 6Fe^{3+}(aq) + 7H_2O$

Which of the following statements about what happens is INCORRECT?

A The oxidation number of chromium changes from +6 to +3

B Fe^{2+}(aq) is oxidized by the H^+(aq) to Fe^{3+}(aq)

C A suitable indicator of the end-point would be one which underwent a sharp colour change with the first small excess of dichromate ions

D $Cr_2O_7^{2-}$(aq) ions are reduced to Cr^{3+}(aq) ions

E H^+(aq) ions are used up in the process

***45** Figure 5 represents *part* of a mass spectrum. Which of the following samples could NOT possibly have produced this spectrum?

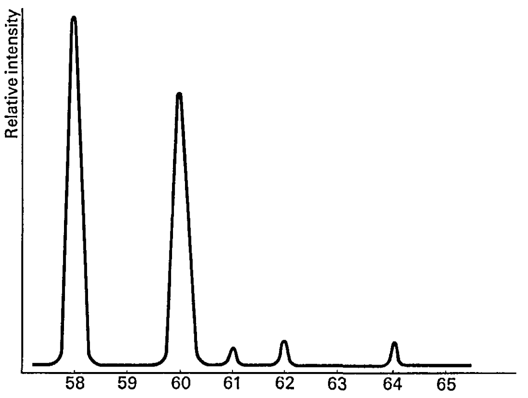


Figure 5

A Pure butane (C_4H_{10})

B Pure hexane (C_6H_4)

C Pure, naturally occurring tin

D An alloy of nickel and tin

E A molecule of phenylacetaldehyde ($C_6H_5CH_2CHO$)

(Atomic masses: H = 1.0; C = 12.0; O = 16.0; Ni = 58.7; Sn = 118.7.)
(Atomic numbers: H = 1; C = 6; O = 8; Ni = 28; Sn = 50.)

***46** Given
1 Standard enthalpy of combustion of graphite
2 Standard enthalpy of combustion of hydrogen
which one of the following is necessary to calculate the standard enthalpy of formation of ethane, C_2H_6?
A Molecular mass of ethane
B Enthalpy of vaporization of ethane
C Enthalpy of atomization of graphite
D Bond dissociation energy of hydrogen
E Standard enthalpy of combustion of ethane

47 Hydrogen and nitrogen do not occupy precisely identical volumes per mole at s.t.p. because they have different
A forces between molecules
B numbers of atoms per mole
C numbers of molecules per mole
D forces within molecules
E average molecular velocities

Multiple choice – item classification

Item	Theme	Ability	Key	Facility/%
1	7	1	A	90
2	3	3	E	62
3	1	2	C	17
4	1	2	C	36
5	1	2	A	43
6	1	4	C	69
7	2	3	C	53
8	1	1	E	36
9	3	1	B	65
10	3	2	E	58
11	6	2	B	56
12	2	2	A	18
13	2	2	C	67
14	2	3	D	68
15	5	2	B	34
16	3	2	A	61
17	5	4	B	19
18	5	3	D	65
19	4	2	B	69

Item	Theme	Ability	Key	Facility/%
20	4	2	D	30
21	4	2	D	47
22	6	2	B	41
23	1	2	E	65
24	1	2	E	47
25	2	4	C	30
26	1	2	C	22
27	2	3	D	55
28	6	2	E	65
29	3	1	A	91
30	3	1	D	31
31	3	2	E	74
32	3	2	A	44
33	3	2	E	52
34	4	3	B	33
35	3	2	B	–
36	3	3	A	26
37	1	3	D	–
38	2	4	C	–
39	5	2	C	–
40	1	2	C	–
41	5	3	E	–
42	2	4	E	–
43	3	2	D	–
44	1	2	B	–
45	3	3	A	–
46	6	2	E	–
47	1	2	A	–

A2 Classification sets of questions

Directions Each group of questions consists of five lettered headings followed by a list of numbered statements. For each numbered statement select the one heading which is most appropriate. Each heading may be used once, more than once, or not at all.

Q 1 to 4

In this group of questions classify each of the changes represented by the equations into one of the lettered types.

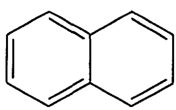
A Oxidation/reduction
B Acid/base
C Ionic precipitation
D Decomposition
E Disproportionation

1 $H_2O(l) + HBr(g) \rightarrow H_3O^+(aq) + Br^-(aq)$
2 $NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(g) + H_2O(l)$
3 $2Tl^+(aq) + CrO_4^{2-}(aq) \rightarrow Tl_2CrO_4(s)$
4 $2VO_3^-(aq) + 3Zn(s) + 12H^+(aq) \rightarrow 2V^{2+}(aq) + 3Zn^{2+}(aq) + 6H_2O(l)$

Q 5 to 10

Classify the numbered substances into one of the following lettered categories.

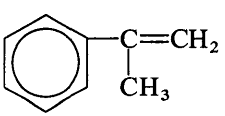
A Alkane
B Alkene
C Arene
D Both alkane and arene
E Both alkene and arene

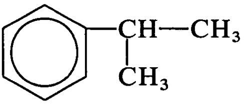
5 

6 C_3H_8

7 $CH_3-CH(CH_3)-CH(CH_3)-CH_3$

8 $CH_3-CH=CH-CH_3$

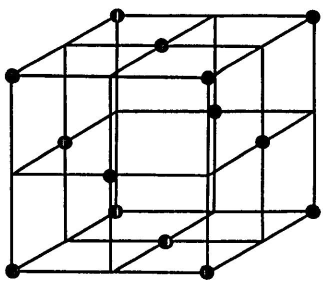
9 

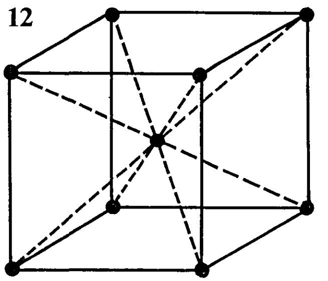
10 

Q 11 to 13

Assign each of the following sketches to one of the lettered types of crystal structure.

A Diamond
B Face-centred cubic
C Fluorite
D Body-centred cubic
E Hexagonal

11 

12 

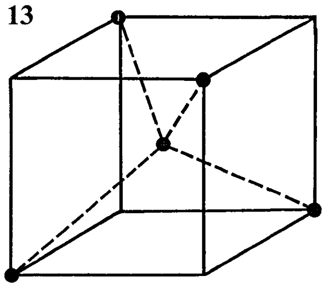
13 

Figure 6

Q 14 to 17

Classify each of the elements described in the numbered questions into one of the lettered groups.

A Group I
B Group II
C Group IV
D Group VII
E Some other group

14 This element is a conductor; it forms compounds XH_4 and XO_2 with hydrogen and oxygen respectively. Its chloride is a non-electrolyte.

15 The first three ionization potentials of this element are 118 eV, 1091 eV, 1652 eV.

16 This element has at least two allotropes: one a giant structure; the other consisting of molecules of the type Y_4. It forms compounds Y_2O_3 and Y_2O_5 with oxygen.

17 This element is a conductor, and strong reducing agent. It forms compounds YH and Y_2O with hydrogen and oxygen respectively. Its boiling point is 757 °C.

Q 18 to 21

Which of the lettered measurements could be determined by the numbered methods?

A The relative size of the nucleus of an atom
B The charge on the nucleus of an atom
C The relative weights of the nuclei of atoms
D The ease of removal of the outer electrons from an atom
E The rate of spontaneous emission of electrons from the nuclei of certain atoms

18 Observation of the sudden sharp rise in current, as the voltage is increased during electron bombardment of low pressure vapours.

19 Following the path of a positive ion of an element which has been accelerated by an electric field and deflected by a magnetic field.

20 Recording the variation of the angle through which particles are deflected by a thin metal sheet.

21 Electron bombardment of metals, viewing the subsequent X-ray frequencies.

Q 22 to 26

These questions refer to the graphs A to E (see figure 7) which represent trends found in the values of different quantities. The vertical scales are arbitrary and are not the same for related questions. For each question select the graph which most closely represents the trend for the quantity specified. Each graph may be used once, more than once, or not at all.

22 The logarithms of the first four ionization energies of the element sodium.

23 The first ionization energies of the elements magnesium, calcium, strontium, and barium.

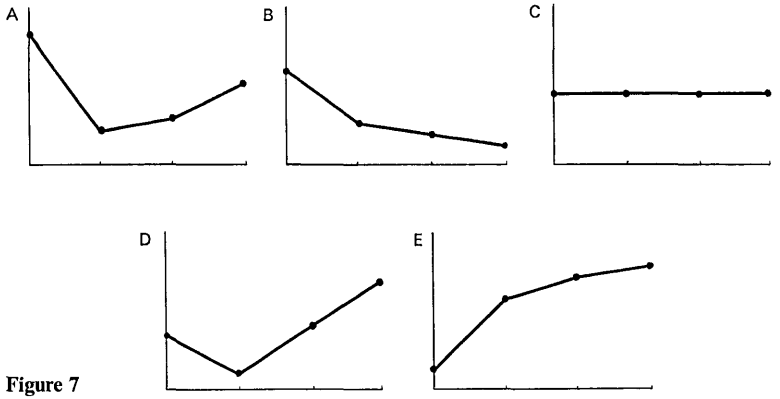


Figure 7

24 The atomic radii for the elements magnesium, calcium, strontium, and barium.

25 The boiling points of hydrogen fluoride, hydrogen chloride, hydrogen bromide, and hydrogen iodide.

26 The volumes at 100 °C and 760 mmHg (1 atm) occupied by 1 g of hydrogen fluoride, hydrogen chloride, hydrogen bromide, and hydrogen iodide.

Q 27 to 31

These questions concern different types of forces between atoms and molecules. The headings A to E show five such types. For each of the questions which follow, select the heading which shows the force responsible for the effect stated.

A Hydrogen bonding
B Van der Waals' forces
C Ion-dipole attraction
D Dipole-dipole attraction
E Covalent linkage

27 The surface tension of liquid tetrachloromethane (CCl_4).

28 The formation of a compound between boron trifluoride (BF_3) and ammonia (NH_3).

29 The provision of energy to break down the crystalline lattice of sodium chloride when it dissolves in water.

30 The rigidity of candle wax (e.g. $C_{25}H_{52}$).

31 The value for 120 found for the molecular mass of acetic acid (CH_3CO_2H: formula mass 60) in benzene solution.

Q 32 to 35

The five physical methods A to E can be used for obtaining information about the structure of substances.

A Electron diffraction
B Ultraviolet spectroscopy
C Infra-red spectroscopy
D X-ray diffraction
E Visible and ultraviolet emission spectroscopy

Which one could be used to obtain the following information?

32 COH bond angle in alcohols.
33 Ionization energy of sodium.
34 Presence of the $-\overset{O}{\overset{/\!/}{C}}H$ group in hexanal, $CH_3(CH_2)_4CHO$.
35 Inter-nuclear distances in salts.

Q 36 to 40

Classify the numbered compounds listed below into one of the five lettered categories.

A A primary alcohol, RCH_2OH
B A hydrocarbon
C An acyl halide, RCOX
D A halogenoalkane
E None of these

36 2-methyl propan-1-ol.
37 $CH_2{=}CHCl$.
38 butan-2-ol.
39 $C_6H_{13}Cl$.
40 buta-1,3-diene.

Q 41 to 43

Classify the named substance in each of the questions into one of the following lettered categories:

A The substance undergoes oxidation
B The substance undergoes reduction
C The substance acts as an acid
D The substance acts as a base
E The substance does none of these

41 The hexacyanoferrate(III) ion in the following cell.

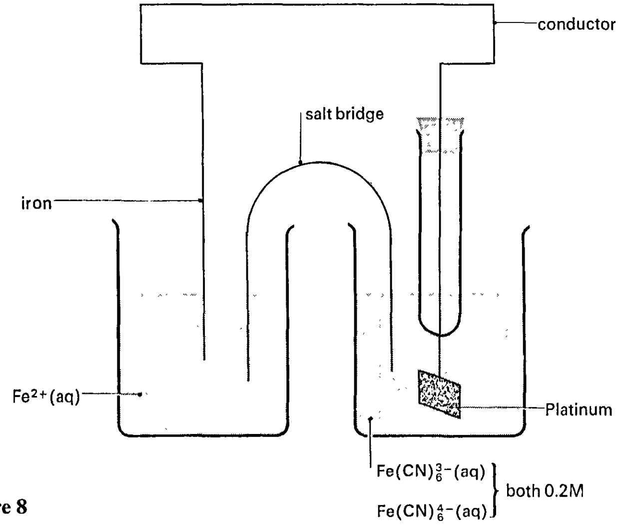


Figure 8

$E^\ominus$ for the electrode $Fe(CN)_6^{3-}(aq), Fe(CN)_6^{4-}(aq)|Pt = +0.36$ volt

$E^\ominus$ for the electrode $Fe^{2+}(aq)|Fe(s) = -0.48$ volt

42 The platinum in the cell in figure 8.

43 Phosphine (PH_3) in its action with hydrogen iodide.

Q 44 to 48

The data describe five metallic elements. The numbered questions each state a use to which metals are put. For each question choose the most appropriate metal.

Metal A

Density 4.5 g cm^{-3}.
Readily forms high strength alloys which retain strength characteristics to high temperatures.
Extremely resistant to corrosion in many aqueous media including sea water and aqueous oxidizing agents.
The commercially pure variety has low residual activity after irradiation.

Metal B

Density 11.4 g cm^{-3}.
Extremely resistant to water (more so than metal D).
Very strong absorbing power for thermal neutrons.
Low coefficient of thermal expansion.
Higher thermal conductivity than metal A.

Metal C.
Density 1.85 g cm^{-3}.
Exceptionally elastic.
Very low neutron absorbing characteristics.
Excellent thermal conductivity.
Highest specific heat capacity of any structural metal.
Resistant to carbon dioxide up to 600 °C.
Toxic.

Metal D.
Density 6.4 g cm^{-3}.
Very resistant to water, but not as resistant as metal B.
Forms alloy resistant to carbon dioxide up to 500 °C.
Very high heat of reaction with oxygen.

Metal E
Density 16.6 g cm^{-3}.
Very high melting point (3000 °C).
Remarkably high resistance to corrosion by nearly all acids.
High ductility and easily worked.
Forms an anodic film of great chemical and electrical stability.
Price: approximately £150 kg^{-1}.

44 Surgical implants which may stay in the body for a lifetime.
45 Thin foil for producing a bright light in photographic flash bulbs.
46 Compressor blades in jet aero-engines.
47 Canning material for fuel elements in gas cooled nuclear reactors.
48 Remotely controlled, long life, chemical plant involving the use of 20 per cent oleum.

Q 49 to 51
Figure 9 is a diagrammatic outline of the main blocks of elements in the Periodic Table.

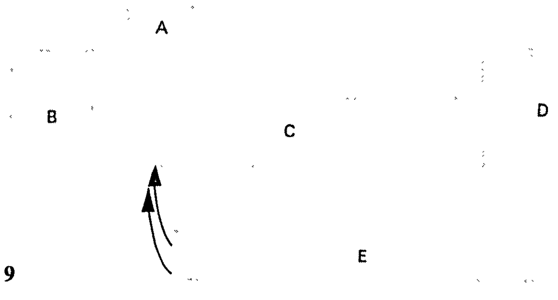


Figure 9

49 In which are the s-block elements?

A B C D E

50 In which are the p-block elements?

A B C D E

51 In which are the d-block elements?

A B C D E

Q 52 to 56

The following techniques have contributed to our understanding of the nature of matter:

A The bombardment of metal foil with alpha particles

B The measurement of the wavelength of X-rays emitted from elements exposed to an electron beam

C The acceleration of charged atoms by an electric field and their subsequent deflection by a variable magnetic field

D The spectroscopic examination of the light emitted by vaporized elements subjected to electric discharge

E The photographing of the diffraction patterns which arise when X-rays are passed through crystals

For each of the following discoveries choose from the above list the technique which gave rise to it.

52 The concept of atomic number.

53 The masses of the isotopes of an element.

54 The arrangement of particles within a solid.

55 The relative size of the nucleus to the size of the whole atom.

56 The energy levels of electrons within an atom.

Q 57 and 58

Some categories of substances are listed below.

A An s-block element
B A d-block element
C A non-metallic p-block element
D A compound containing s- and p-block elements
E A compound containing d- and p-block elements

Select the appropriate category for the substance described in each of the following questions.

***57** This substance is a radioactive solid melting at 1000 °C. It is soluble in water forming a neutral solution which readily conducts electricity evolving hydrogen at the cathode.

***58** This substance is a solid at room temperature, but it vaporizes readily. It is a bad conductor of electricity. It reacts vigorously with zinc to form a single product which is a water soluble electrolyte.

Classification sets – item classification

Item	Theme	Ability	Key	Facility/%
1	2	2	B	43
2	2	2	B	33
3	2	3	C	76
4	2	3	A	70
5	2	2	C	84
6	2	2	A	94
7	2	2	A	89
8	2	2	B	91
9	2	2	E	90
10	2	2	D	87
11	2/3	2	B	90
12	2/3	2	D	89
13	2/3	2	A	64
14	2	2	C	84
15	2	2	A	75
16	2	2	E	69
17	2	2	A	69
18	2/3	1	D	84
19	2/3	1	C	61
20	2/3	1	A	70
21	2/3	1	B	22

Item	Theme	Ability	Key	Facility/%
22	2	2	E	85
23	2	2	B	55
24	2	2	E	60
25	2	2	A	16
26	2	2	B	35
27	2/3	3	B	62
28	2/3	2	E	46
29	2/3	2	C	63
30	2/3	3	B	36
31	2/3	2	A	54
32	2/3	2	A	40
33	2/3	2	E	51
34	2/3	3	C	46
35	2/3	2	D	71
36	2	2	A	67
37	2	2	E	71
38	2	2	E	52
39	2	2	D	92
40	2	2	B	73
41	2/4	4	B	–
42	1	2	E	–
43	2	3	D	–
44	7	4	A	–
45	7	4	D	–
46	7	4	A	–
47	7	4	C	–
48	7	4	E	–
49	2	1	B	–
50	2	1	D	–
51	2	1	C	–
52	2/3	1	B	–
53	2/3	1	C	–
54	2/3	1	E	–
55	2/3	1	A	–
56	2/3	1	D	–
57	2	4	D	–
58	2	4	C	–

A3 Situation sets of questions

Q 1 to 3

For this group of questions refer to the following information about the oxides of five different elements. One of the elements is in group I, another in group II, and another in group VI of the Periodic Table.

Oxide	Melting point /°C	Composition g-atoms of oxygen ÷ g-atoms of other element	Solubility in water and pH of solution	Electrical conductance at 500 °C
A	236	$\frac{1}{2}$	soluble, pH more than 7	conducts
B	17	$\frac{3}{1}$	soluble, pH less than 7	non-conductor
C	−207	$\frac{1}{1}$	insoluble	non-conductor
D	−91	$\frac{1}{2}$	soluble, pH 7	non-conductor
E	2570	$\frac{1}{1}$	soluble, pH more than 7	non-conductor

1 Which is likely to be the oxide of a group I element?
2 Which is likely to be the oxide of a group II element?
3 Which is likely to be the oxide of a group VI element?

Q 4 to 6

This group of questions deals with the fluorides of a certain element X (X is not its real symbol). The formulae of the fluorides are XF_2, XF_4, X_2F_{10}, and XF_6. On hydrolysis, each of these compounds gives rise to fluoride ions, and these ions in aqueous solution react quantitatively with lead(II) ions:

$$Pb^{2+}(aq) + 2F^-(aq) \rightarrow PbF_2(s)$$

4 In which of the following groups of the Periodic Table would you expect the element X to be?

A II
B IV
C V
D VI
E VII

5 Suppose that 0.01 g-formula of the fluoride X_2F_{10} was hydrolysed. With which of the following volumes of 0.1M $Pb(NO_3)_2(aq)$ would the resulting fluoride ions react?

A 10 cm^3
B 50 cm^3
C 100 cm^3
D 500 cm^3
E 1000 cm^3

6 When the compound XF_4 is hydrolysed, which of the following statements about the oxidation state of fluorine is correct?

A It changes from +4 to −1
B It changes from −4 to −1
C It changes from +4 to +1
D It does not change
E It is not possible to decide

Q 7 to 11

This group of questions deals with the titration of a solution of a chloride with a standard solution of silver nitrate. The silver nitrate solution was to be put into a burette, and 10 cm^3 portions of the chloride solution were to be used rather than larger portions. Before the start of the experiment the apparatus had been washed with distilled water, but not dried.

7 Which of the following procedures should you carry out before filling the burette?

A Dry the burette by passing warm air through it
B Dry the burette by rinsing it with alcohol, then passing cold air through it
C Rinse the burette with more distilled water
D Rinse the burette with one or two cm^3 of chloride solution
E Rinse the burette with one or two cm^3 of silver nitrate solution

8 Suppose a 10 cm^3 pipette was not available, which of the following procedures should you use to obtain a similar 10 cm^3 portion of chloride solution?

A Weigh 10 g of the solution
B Weigh 10 × the density of the solution (g/cm^3)
C Dispense 10 cm^3 from a measuring cylinder
D Dispense 20 cm^3 from a 20 cm^3 pipette and divide it into two equal parts
E Dispense 10 cm^3 from another burette

9 Suppose, after the first titration, you wanted to re-use the same titration flask, which of the following procedures should you use to rinse the flask?

A Rinse with tap water followed by distilled water
B Rinse with tap water only
C Rinse with a little of the chloride solution
D Rinse with a little of the silver nitrate solution
E Rinse with a little of the chloride solution followed by distilled water

10 If the results showed that 10 cm^3 of 0.05M solution of chloride required 10 cm^3 of 0.1M solution of silver nitrate, which of the following would be the formula of the chloride? (X stands for the symbol of the element other than chlorine.)

A X_2Cl
B XCl
C X_2Cl_2
D XCl_2
E XCl_4

11 Suppose that, in a different chloride solution, you obtained the following successive titration results: 10.5, 10.4, 10.4, 10.9 cm^3, and that there was not time to do a further titration. Which of the following should you use in your calculations?

A 10.4 cm^3
B 10.43 cm^3 [(10.5 + 10.4 + 10.4) ÷ 3]
C 10.5 cm^3
D 10.55 cm^3 [(10.5 + 10.4 + 10.4 + 10.9) ÷ 4]
E 10.9 cm^3

Q 12 and 13

When the gas ethene is exploded with oxygen, the reaction can be represented by: $C_2H_4(g) + 3O_2(g) \rightarrow 2CO_2(g) + 2H_2O(g)$. (All measurements of volume made at 110 °C and 1 atm.)

12 Which of the following is a correct conclusion about the change in oxidation state of carbon in this reaction?

A No change (constant at +4 in both compounds)
B No change (constant at +2 in both compounds)
C −4 changing to +4
D −2 changing to +4
E −4 changing to +2

13 Which of the following is the most reasonable conclusion about the total amount of products compared with the total amount of reactants?

A The weight and volume of the products are greater
B The weight and volume of the products are the same
C The weight of products is the same, but the volume of products is greater
D The weight of products is the same, but the volume of products is less
E The weight and volume of products are less

Q 14 to 17

The following table summarizes the solubilities of some salts in water at room temperature. S means the salt is soluble, S.S. means that it is sparingly soluble, and I.S. means that it can be considered to be insoluble. Use this information to answer the questions below.

	Sulphate	Chloride	Nitrate	Carbonate
Sodium	S	S	S	S
Calcium	S.S.	S	S	I.S.
Barium	I.S.	S	S	I.S.
Silver	S	I.S.	S	I.S.
Lead	I.S.	S.S.	S	I.S.
Zinc	S	S	S	I.S.

14 A white powder is known to be either barium carbonate or calcium carbonate. Which of the following tests would be used to enable you to make a definite identification?

A Dissolve some of the powder in water and add molar sodium sulphate solution
B Dissolve some of the powder in dilute nitric acid and add molar sodium sulphate solution
C Shake about 5 g of powder with about 20 cm^3 of dilute sulphuric acid
D Dissolve some of the powder in dilute nitric acid and add some saturated calcium sulphate solution
E Dissolve some of the powder in dilute nitric acid and add silver nitrate solution

15 Which of the following methods should you use to prepare a reasonably pure sample of lead sulphate?

A To a solution of lead carbonate in dilute sulphuric acid add sodium sulphate solution. Filter, wash, and dry the precipitate
B To an aqueous solution of lead nitrate add sodium sulphate solution. Filter, wash, and dry the precipitate

C Shake some lead chloride with excess dilute sulphuric acid. Filter, wash, and dry the precipitate

D Pass sulphur dioxide gas over heated lead chloride until no further reaction takes place

E To a solution of lead carbonate in water add barium sulphate solution. Filter, wash, and dry the precipitate

16 Which of the following tests could be used to detect the presence of sulphate ions in a solution that could contain any of the anions listed in the table?

A Add excess of zinc nitrate solution, filter, and add barium nitrate solution to the filtrate

B Add barium chloride solution

C Add lead chloride solution to one portion of the solution and silver nitrate solution to another

D Add excess of sodium carbonate solution, filter, and test the residue with barium nitrate solution

E Evaporate a sample of the solution to dryness, redissolve the residue in dilute nitric acid, and add lead nitrate solution

17 A substance Y when dissolved in water gives a precipitate with sodium carbonate solution and with sodium chloride solution but gives no precipitate with sodium sulphate solution. Which of the following is a possible identity of Y?

A Lead nitrate
B Lead sulphate
C Silver nitrate
D Barium chloride
E Barium nitrate

Q 18 to 20

A solution 0.100M with respect to Fe^{2+} ions was titrated with 0.02M potassium permanganate ($KMnO_4$) in aqueous solution acidified with sulphuric acid. Equal volumes of the two solutions were required at the end-point. The permanganate reacts according to the equation

$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O$$

18 Which of the following is a correct statement about the use of an indicator in this titration?

A Use methyl orange and watch for a change from red to orange at the end-point

B Use potassium chromate and watch for a change from yellow to red at the end-point

C The colour change of iron ions acts as an indicator
D The colour change $MnO_4^-(aq) \rightarrow Mn^{2+}(aq)$ acts as an indicator
E The end-point in this titration does NOT depend on a colour change

19 A student found that he had difficulty in reading the level of the permanganate solution, before and after the titration, in the burette because the level was uneven rather than straight.

Which of the following is the likeliest explanation?
A There was variation in the diameter of the burette
B The meniscus curved upwards
C The permanganate solution was more concentrated than that usually used
D The burette walls were greasy
E There were flaws in the glass of the burette

20 Which of the following is a correct statement about the change in oxidation state of the manganese in this reaction?
A $+4 \rightarrow +2$
B $+8 \rightarrow +2$
C $+8 \rightarrow +0$
D $+7 \rightarrow +2$
E $-1 \rightarrow +2$

Q 21 to 24
When butan-1-ol is heated with excess potassium bromide and concentrated sulphuric acid, 1-bromobutane is formed. In one experiment starting from 3.7 g of butan-1-ol a 40 per cent yield was obtained. (Atomic masses: C, 12; O, 16; H, 1; Br, 80.)

$$CH_3CH_2CH_2CH_2OH \longrightarrow CH_3CH_2CH_2CH_2Br$$

21 When butan-1-ol is changed into 1-bromobutane which of the following bonds must be broken?
A C—C
B C—H
C C—O
D O—H
E O—O

22 In the formation of 1-bromobutane in this reaction which of the following bonds must be formed?

A C—Br
B H—Br
C Br—Br
D O—Br
E C—H

23 Which of the following is LEAST likely to be a by-product of the reaction?

A but-1-ene, $CH_3CH_2CH{=}CH_2$
B hydrogen bromide, HBr
C but-2-ene, $CH_3CH{=}CHCH_3$
D potassium sulphate (or potassium hydrogen sulphate), K_2SO_4 (or $KHSO_4$)
E bromine

24 Which of the following would be the yield of 1-bromobutane?

A 0.4 g
B 1.48 g
C 2.7 g
D 6.8 g
E 13.7 g

Q 25 to 29

For this set of questions use the data given in figure 10 in which the atoms and ions of five elements in the same short period of the Periodic Table are represented by circles drawn to a scale of 1 cm to 0.1 nm. (The ions are those of the elements in their most stable oxidation states.)

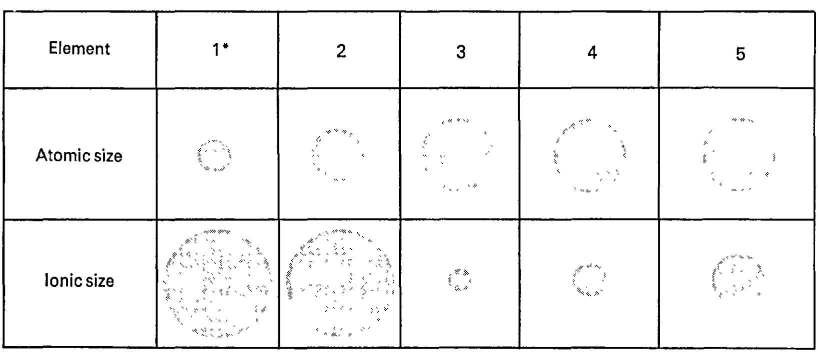


Figure 10
*These are not the group numbers.

25 Which of the following pairs of elements could be non-metals?

A 1 and 2
B 2 and 3
C 3 and 4
D 4 and 5
E 1 and 5

26 Which of the following pairs of elements could be metals?

A 1 and 2
B 2 and 3
C 1 and 3
D 3 and 4
E 1 and 5

27 In which of the elements is the charge on the ion likely to be 1+ ?

A 1
B 2
C 3
D 4
E 5

28 In which of the elements is the charge on the ion likely to be 3+ ?

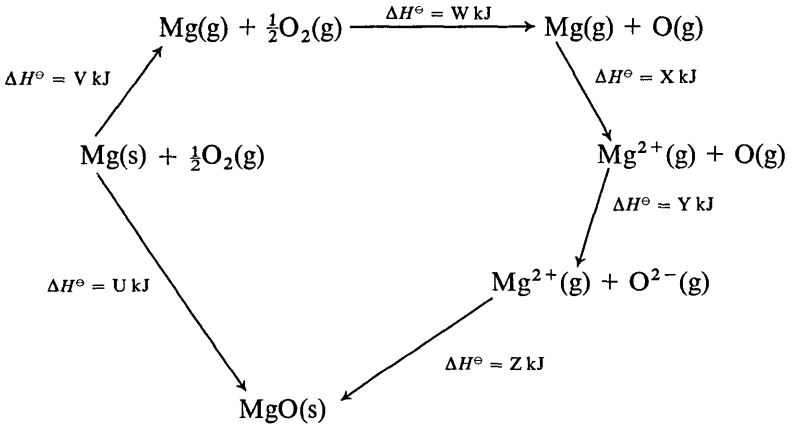
A 1
B 2
C 3
D 4
E 5

29 Which of the elements would you expect to have the smallest first ionization energy?

A 1
B 2
C 3
D 4
E 5

Q 30 to 33

These questions refer to the following information:



30 Which of the following is $\Delta H_f^\ominus$ of magnesium oxide?

A U
B Z
C X + Y
D V + W
E Z − U

31 Which of the following is $\Delta H_{at}^\ominus$ of magnesium?

A V
B X
C W
D U − V
E Z − U

32 Which of the following is the lattice energy of magnesium oxide?

A U
B Z
C X + Y
D V + W
E Z − U

33 Which of the following is a correct statement about X?
A The energy required to vaporize 1 mole of magnesium atoms
B The lattice energy of 1 mole of magnesium atoms
C The first ionization energy of magnesium
D The second ionization energy of magnesium
E The sum of the first two ionization energies of magnesium

Q 34 to 36

Figure 11 shows a unit cell (enclosed by dotted lines) of fluorite, $Ca^{2+}(F^-)_2$.

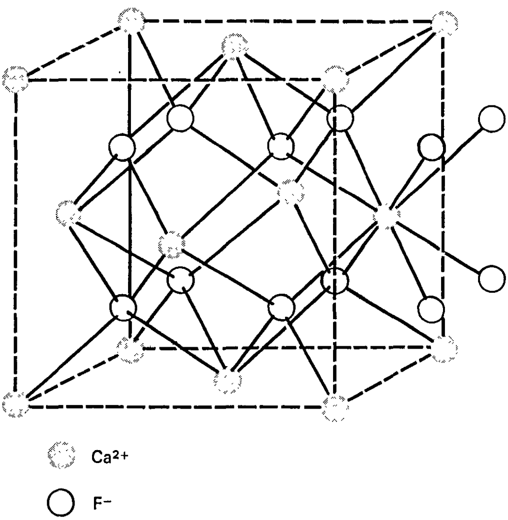


Figure 11

34 The fluoride ions form
A a hexagonal close-packed lattice
B a simple cubic lattice
C a body-centred cubic lattice
D a face-centred cubic lattice
E none of A to D

35 The number of fluoride ions per unit cell is
A 2
B 6
C 8
D 12
E 27

36 The coordination numbers of the ions in this lattice are

	Calcium	Fluoride
A	8	8
B	4	27
C	8	4
D	1	2
E	2	1

Q 37 to 40

Diagrams P, Q, R, S, T, U, and V (figure 12) show components of laboratory equipment, some of which may be linked together in various combinations. Select that combination of components which could best be used to carry out the processes described below. Each component may be used once, more than once, or not at all.

37 The preparation of a sample of ethyne, C_2H_2, (b.p. $-84\,°C$) by reaction between solid calcium carbide, CaC_2, and water.

A V connected to U
B V connected to R
C Q connected to T
D S, and afterwards Q connected to R
E V connected to T

38 The preparation of a sample of ethene, C_2H_4, (b.p. $-105\,°C$) by the dehydration of ethanol, C_2H_5OH.

A P connected to U
B S, and afterwards Q connected to U
C V connected to T
D P connected to R
E S, and afterwards Q connected to R

39 The preparation of a sample of propanoic acid, $CH_3CH_2CO_2H$, (b.p. 141 °C) by the action of a mixture of sodium dichromate and concentrated sulphuric acid on propan-1-ol, $CH_3CH_2CH_2OH$.

A V connected to T
B S, and afterwards Q connected to U
C V connected to T, and afterwards Q connected to T
D S, and afterwards Q connected to T
E Q connected to T

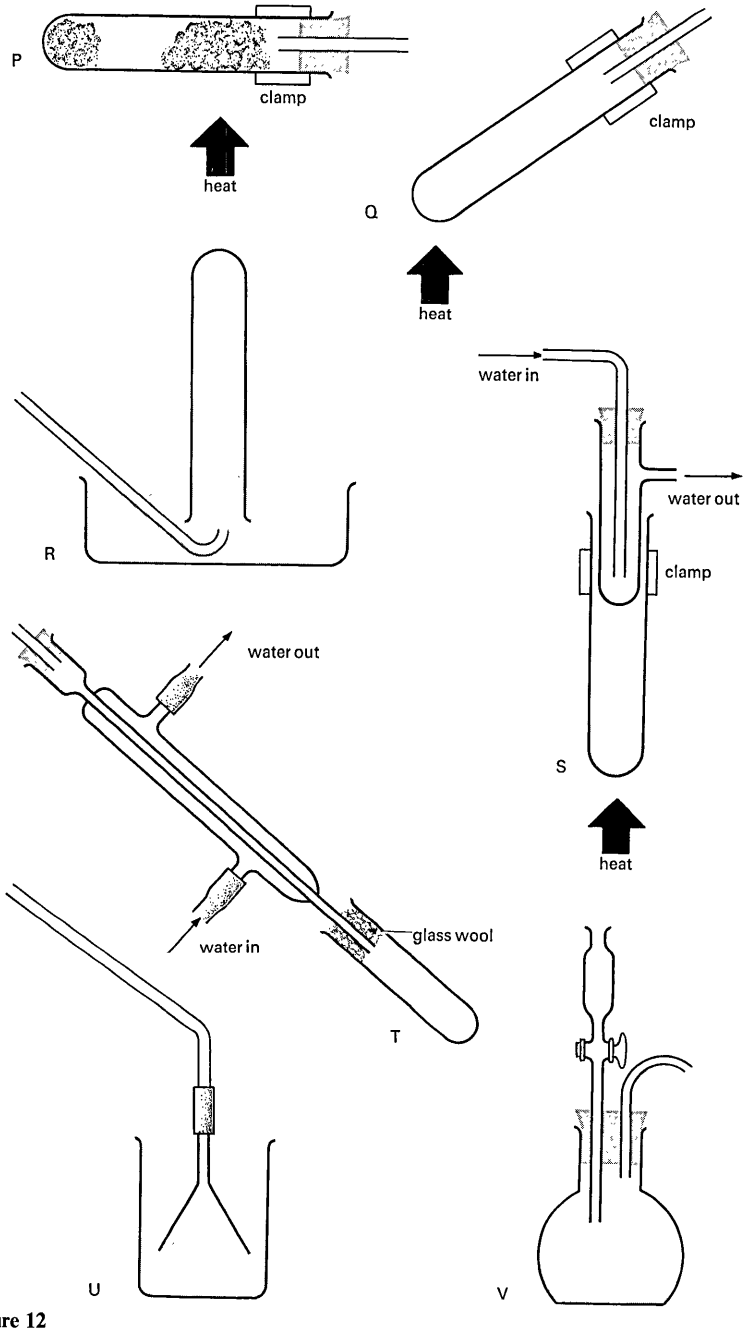
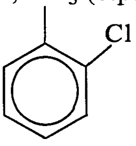

P
clamp
heat
clamp
Q
heat
R
water in
water out
clamp
S
heat
water out
water in
glass wool
T
U
V

Figure 12

40 The separation of a mixture of tetrachloromethane, CCl_4 (b.p. 76 °C) and orthochlorotoluene, CH_3 (b.p. 162 °C).



A Q connected to R
B S, and afterwards Q connected to T
C Q connected to T
D P connected to T
E S, and afterwards Q connected to U

Q 41 to 44

This group of questions concerns the preparation of an aqueous solution of hydrogen iodide from the gas which is formed by the action of phosphoric acid on potassium iodide. The five sets of apparatus shown in figure 13 were suggested by students.

41 Which sets of apparatus required the boring of a cork?
A 1, 2, and 4
B 1 and 4
C 2 only
D 3 and 5
E All of them

42 In which is there a danger of water being sucked back into the reactants?
A 1 only
B 2 only
C 1 and 2
D 3 and 5
E 1 and 3

43 Which is likely to be the quickest to assemble (including the boring of corks if necessary)?
A 1
B 2
C 3
D 4
E 5

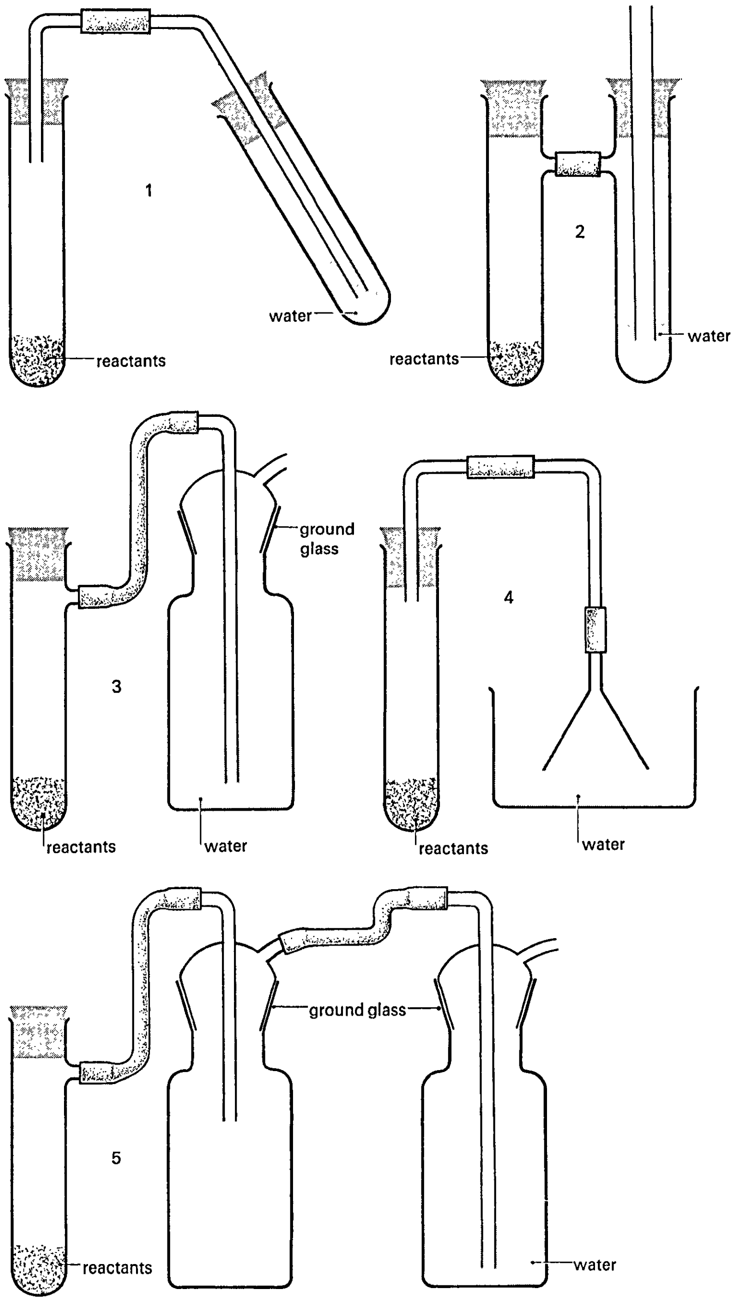

1
water
reactants
2
water
reactants
3
ground glass
reactants
water
4
reactants
water
5
ground glass
reactants
water

Figure 13

44 Which set of apparatus is likely to be the cheapest?

A 1
B 2
C 3
D 4
E 5

Q 45 and 46

Use the data in the table on the ions of five elements to answer the questions which follow.

Ion	Ionic charge	Ionic radius/nm
A	3+	0.050
B	+	0.060
C	2+	0.065
D	+	0.133
E	2+	0.135

45 Which ion will have the biggest heat of hydration?
46 Which ion will have the least heat of hydration?

Q 47 to 48

These refer to data in the table on five liquids:

Liquid	Dipole moment	Dielectric constant
A	0	1.9
B	0.9	22
C	1.1	4.8
D	1.9	80
E	3	114

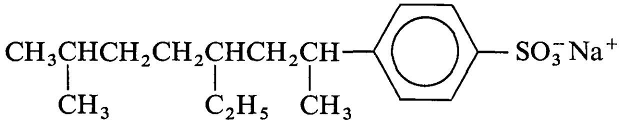
In which of the liquids will the following solids most readily dissolve?

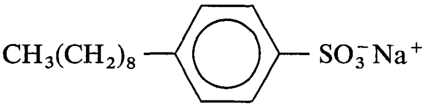
47 Candle wax.
48 Potassium iodide.

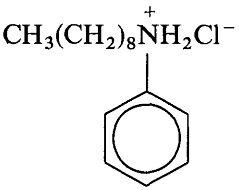
Q 49 to 51

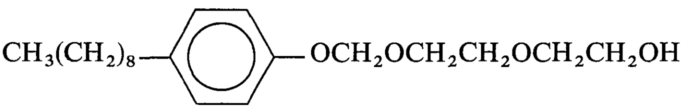
This group of questions concerns the following detergents:

A $CH_3(CH_2)_6CH{=}CH(CH_2)_6CO_2^- Na^+$

B 

C 

D 

E 

49 Which is most likely to be a liquid?

50 Which is likely to cause the most persistent foam in sewage disposal?

51 Which is likely to be least effective in hard water?

Q 52 to 56

These questions refer to the Born–Haber cycle for calcium oxide shown in figure 14 (not exactly to scale), in which five of the energy changes are denoted by the letters, A, B, C, D, and E.

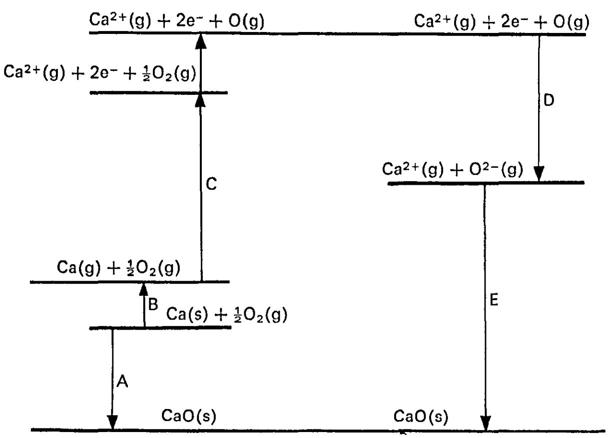


Figure 14

Which letter denotes each of the following?

52 The lattice energy of calcium oxide.

53 $\Delta H_f^\ominus$ CaO(s).

54 Enthalpy of atomization of calcium.

55 The electron affinity of oxygen.

56 The sum of the first two ionization energies of calcium.

Situation sets – item classification

Item	Theme	Ability	Key	Facility/%
1	2	4	A	72
2	2	4	E	62
3	2	4	B	39
4	2	4	D	33
5	1	3	D	19
6	2	2	D	33
7	1	2	E	90
8	1	2	E	84
9	1	2	A	79
10	1	2	D	56
11	1	4	A	26
12	1	2	D	60
13	2	2	B	54
14	1	3	D	20
15	1	3	B	64
16	1	4	A	25
17	1	3	C	69
18	1	2	D	64
19	1	1	D	62
20	1	2	D	89
21	3	2	C	92
22	3	2	A	93
23	1	4	C	67
24	1	2	C	68
25	2	2	A	76
26	2	2	D	74
27	2	2	E	53
28	2	2	C	57
29	2	2	E	48
30	6	2	A	85
31	6	2	A	72
32	6	2	B	72

Item	Theme	Ability	Key	Facility/%
33	6	2	E	69
34	3	2	B	46
35	3	2	C	79
36	3	2	C	72
37	1	4	B	82
38	1	4	D	71
39	1	4	D	33
40	1	4	C	73
41	1	2	A	–
42	1	4	E	–
43	1	4	C	–
44	1	4	A	–
45	6	2	A	–
46	6	2	D	–
47	3	2	A	–
48	3	2	E	–
49	2	3	E	–
50	2	3	B	–
51	2	3	A	–
52	6	2	E	–
53	6	2	A	–
54	6	2	B	–
55	6	2	D	–
56	6	2	C	–

A4 **Multiple completion questions**

Directions For each question ONE or MORE of the four responses are correct. Decide which of the responses is/are correct, then answer

A if only *1*, *2*, and *3* are correct
B if only *1* and *3* are correct
C if only *2* and *4* are correct
D if only *4* is correct
E if some other response or combination of responses, of those given, is correct

Directions summarized

A	B	C	D	E
1, 2, 3 only	*1, 3* only	*2, 4* only	*4* only	some other response or combination of responses

1 Atoms of adjacent elements in a period of the Periodic Table differ from each other by

1 one unit of atomic weight
2 one neutron
3 one alpha particle
4 one proton

2 Which of the following properties of a pure substance depend(s) on the *quantity* of the substance present?

1 Melting point
2 Volume
3 Density
4 Heat required to fuse the substance

3 The tendency of $Cr_2O_7^{2-}$(aq) to reduce to Cr^{3+}(aq) is greater than the tendency of Fe^{3+}(aq) to reduce to Fe^{2+}(aq). It follows that

1 $Cr_2O_7^{2-}$(aq) should oxidize Fe^{2+}(aq)
2 Fe^{3+}(aq) should oxidize $Cr_2O_7^{2-}$(aq)
3 Fe^{2+}(aq) should reduce $Cr_2O_7^{2-}$(aq)
4 $Cr_2O_7^{2-}$(aq) should reduce Fe^{3+}(aq)

4 Which of the following is/are an example of Gay Lussac's Law?

1 When the temperature of 20 cm^3 of hydrogen sulphide gas is raised from 300 K to 600 K its volume increases to 40 cm^3 (all measurements of volume made at 1 atm)

2 There are equal numbers of molecules in 20 cm^3 of hydrogen sulphide, 20 cm^3 of steam, and 20 cm^3 of sulphur dioxide (all measurements of volume made at 400 K and 1 atm)

3 When the pressure on 20 cm^3 of hydrogen sulphide is decreased from 1 atm to $\frac{1}{2}$ atm, its volume increases to 40 cm^3 (all measurements of volume made at 400 K)

4 When 20 cm^3 of hydrogen sulphide gas is burned, it reacts with 30 cm^3 of oxygen to form 20 cm^3 of steam and 20 cm^3 of sulphur dioxide (all measurements of volume made at 400 K and 1 atm)

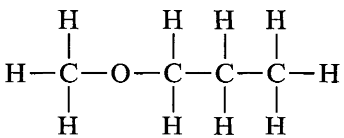
5 Atoms of the same element

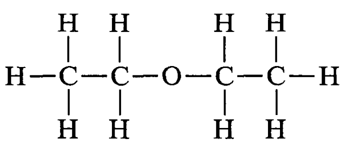
1 are identical in mass
2 have the same number of neutrons per nucleus
3 are identical in all respects
4 have the same number of protons per nucleus

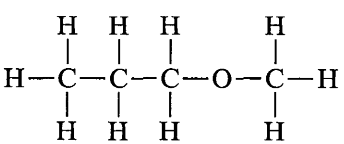
6 Elements of fixed oxidation state include

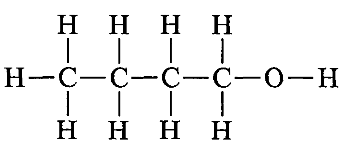
1 sodium
2 chlorine
3 fluorine
4 barium

7 Which of the following structures represent the same substance?

1 

2 

3 

4 

8 The elements in group I of the Periodic Table are alike in that
1 they have a fixed oxidation state in their compounds
2 they do not form anions
3 the same quantity of electricity will liberate 1 mole of each of them in electrolysis
4 they have the same atomic number

9 When a mass spectrometer is used to determine the abundance ratio of the isotopes of an element, which of the following are involved?
1 Production of positive ions
2 Deflection by a magnetic field
3 Use of a gaseous sample
4 Production of a line spectrum

10 If the following reactions were carried out and the resulting enthalpy change measured, which would give the standard enthalpy of formation of the named compound?
1 Sulphur dioxide
$S(s) + O_2(g) \rightarrow SO_2(l)$

2 Carbon dioxide
$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(l)$

3 Water
$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

4 Phosphorus trichloride
$P(s) + 1\frac{1}{2}Cl_2(g) \rightarrow PCl_3(l)$

11 Which of the following conversions would require the use of an oxidizing agent?
1 $Cl_2(aq) \rightarrow 2Cl^-(aq)$
2 $Cr_2O_7^{2-}(aq) \rightarrow 2CrO_4^{2-}(aq)$
3 $IO_3^-(aq) \rightarrow I^-(aq)$
4 $Fe^{2+}(aq) \rightarrow Fe^{3+}(aq)$

12 In this diagram of a carbon atom (figure 15) which of the following are properly represented?
1 The position of the electrons
2 The movement of the electrons
3 The relative size of the nucleus and the whole atom
4 The number of electrons surrounding the nucleus

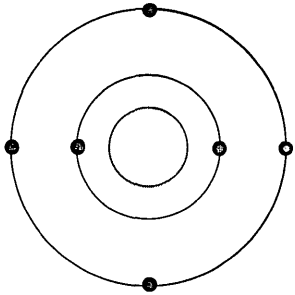


Figure 15

13 In the diagram of the structure of a molecule of ammonia, which of the following are represented?

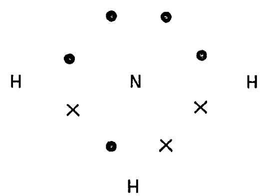


Figure 16

1 The number of nitrogen electrons which take part in bonding in the compound
2 A lone pair of electrons
3 The shape of the molecule
4 The total number of electrons in the molecule

14 In which of the following will $K_p = K_c$?
1 $I_2(g) \rightleftharpoons 2I(g)$
2 $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$
3 $H_2O(g) + C(s) \rightleftharpoons H_2(g) + CO(g)$
4 $N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$

Directions summarized

A	B	C	D	E
1, 2, 3 only	*1, 3* only	*2, 4* only	*4* only	some other response or combination of responses

15 Figure 17 represents the partial pressures of the gases in the equilibrium at 1000 °C:

$$H_2(g) + CO_2(g) \rightleftharpoons H_2O(g) + CO(g); \Delta H = +38.9 \text{ kJ}$$

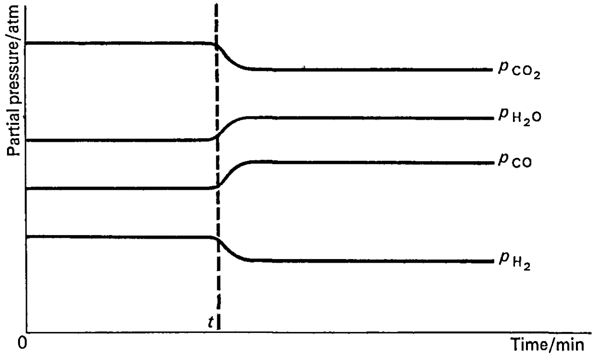


Figure 17

At a certain time *t* one or more changes were made, resulting in the changes in partial pressures shown in the diagram. Which of the following changes, made individually, would produce this result?

1 Introduction of a catalyst (temperature and total pressure constant)
2 Increase in total pressure (temperature constant)
3 Adding argon but keeping the same total pressure (temperature constant)
4 Increasing the temperature (total pressure constant)

16

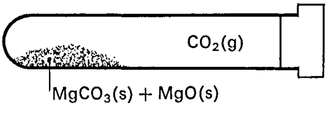


Figure 18

Magnesium carbonate is heated to a constant temperature in a steel container until equilibrium is reached. It can then be said that:

1 The intensive properties of the contents of the tube are constant
2 The magnesium carbonate stops decomposing
3 If magnesium oxide and carbon dioxide were kept under the same conditions as this experiment some magnesium carbonate would be formed
4 The equilibrium $MgCO_3(s) \rightleftharpoons MgO(s) + CO_2(g)$ is only possible at one temperature

17 When iron(III) hydroxide is left in contact with the water the equilibrium

$$Fe(OH)_3(s) \rightleftharpoons Fe^{3+}(aq) + 3OH^-(aq)$$

is set up, and lg K_{sp} at 14 °C = − 38.
It follows that

1 $[Fe^{3+}(aq)]_{eqm}[OH^-(aq)]^3_{eqm} = 10^{-38}\ mol^4\ dm^{-12}$
2 $[Fe^{3+}(aq)]_{eqm}[OH^-(aq)]_{eqm} = 10^{-38}\ mol^2\ dm^{-6}$
3 $[Fe(OH)_3(s)]_{eqm}$ is constant
4 $[Fe^{3+}(aq)]_{eqm} = [OH^-(aq)]^3_{eqm}$

18 If 10 cm³ of a solution of $NiCl_2$, 0.1M with respect to nickel ions, are mixed with 10 cm³ of 0.1M $NH_3(aq)$ at 25 °C, the following equilibrium is established.

$$Ni^{2+}(aq) + 6NH_3(aq) \rightleftharpoons Ni(NH_3)_6^{2+}(aq); K_c = 10^8$$

In so doing

1 $[Ni^{2+}(aq)]$ decreases to less than 0.05M
2 $[Cl^-(aq)]$ decreases to 0.1M
3 $[NH_3(aq)]$ becomes less than $[Ni^{2+}(aq)]$
4 $[NH_3(aq)]$ decreases to 0.05M

19 Using the data:

$[PbO_2(s) + 2H_2O(l)], [Pb(OH)_2(s) + 2OH^-(aq)]|Pt; E^\ominus = +0.25$ volt
$[ClO^-(aq) + H_2O(l)], [Cl^-(aq) + 2OH^-(aq)]|Pt; E^\ominus = +0.89$ volt

predict which of the following reactions can occur.

1 $Cl^-(aq) + 2OH^-(aq) + Pb(OH)_2(s) \rightarrow PbO_2(s) + ClO^-(aq) + H_2O(l)$
2 $PbO_2(s) + ClO^-(aq) + H_2O(l) \rightarrow Pb(OH)_2(s) + Cl^-(aq) + 2OH^-(aq)$
3 $PbO_2(s) + H_2O(l) + Cl^-(aq) \rightarrow ClO^-(aq) + Pb(OH)_2(s)$
4 $ClO^-(aq) + Pb(OH)_2(s) \rightarrow PbO_2(s) + H_2O(l) + Cl^-(aq)$

20 In a reaction of the type

$$A(g) + 2B(g) \rightarrow C(g)$$

1 The rate of increase of [C] = rate of decrease of [A]
2 The rate of increase of [C] = the rate of decrease of [B]
3 The rate of reaction can be expressed by $\frac{d[C]}{dt}$
4 The rate of reaction is proportional to [C]

Directions summarized

A	B	C	D	E
1, 2, 3 only	*1; 3* only	*2, 4* only	*4* only	some other response or combination of responses

21 Factors which can favour the increase in the rate of a reaction include:
1 Increase in the energy of reacting molecules
2 A favourable orientation of reacting molecules
3 The direct formation of the products without intermediate steps
4 The formation of a transition complex of low enthalpy of formation

22 The substance $(C_6H_{11}O_5)_2O$ is slowly converted to $C_6H_{11}O_5OH$ by the action of water to which acid has been added.

$$(C_6H_{11}O_5)_2O + H_2O \xrightarrow{\text{slow}} 2C_6H_{11}O_5OH$$

The rate of reaction (determined experimentally)

$$= k[(C_6H_{11}O_5)_2O(aq)][H^+(aq)]$$

Which of the following suggested reactions will be UNLIKELY to be part of the mechanism of the reaction?
1 $H^+ + H_2O(l) \xrightarrow{\text{slow}} H_3O^+(aq)$
2 $(C_6H_{11}O_5)_2O + H_3O^+(aq) \xrightarrow{\text{slow}} C_6H_{11}O_5OH + C_6H_{11}O_5OH_2^+$
3 $(C_6H_{11}O_5)_2O + H_2O \xrightarrow{\text{slow}} 2C_6H_{11}O_5OH$
4 $C_6H_{11}O_5OH_2^+ + H_2O \xrightarrow{\text{fast}} C_6H_{11}O_5OH + H_3O^+(aq)$

23 At a given temperature and pressure which of the following agree with Avogadro's hypotheses?
1 A mole of neon, Ne, occupies the same volume as a mole of oxygen, O_2
2 A mole of krypton, Kr, occupies one-third of the volume of a mole of ozone, O_3
3 A mole of hydrogen, H_2, occupies the same volume as a mole of carbon monoxide, CO
4 A mole of oxygen, O_2, occupies two-thirds of the volume of a mole of ozone, O_3

24 The ideal gas law is expressed by the equation $PV = nRT$. From this equation we may deduce that
1 the pressure of a given mass of an ideal gas is inversely proportional to its volume, if the temperature remains constant
2 the pressures exerted by different gases, separately occupying the same container at the same temperature, are *inversely* proportional to the numbers of moles of the gases admitted to the container
3 one mole of an ideal gas will occupy the same volume as one mole of another ideal gas at the same temperature and pressure
4 the volume of a given mass of an ideal gas will be doubled if it is heated from 50 °C to 100 °C, its pressure being kept constant

25 A student performed a flame test on a powder of unknown composition by the following procedure.
He dipped the wire into concentrated hydrochloric acid, then into the powder, and then held the tip of the wire at the edge of a roaring Bunsen flame. He observed the colour through a direct vision spectroscope.
Which of the following would be an improvement in the technique?

1 To have used a luminous Bunsen flame
2 To have held the wire in the centre of the flame
3 To have used concentrated sulphuric acid instead of hydrochloric acid
4 To have cleaned the wire before he used it

26 An inexperienced student has been attempting to determine the percentage of chlorine in sodium chloride by titrating portions of sodium chloride solution with a standard solution of silver nitrate, using phenosafranine as indicator. His titration values vary over a range of about 0.3 cm^3 and his answer for the percentage of chlorine is slightly lower than that found by his more experienced friends. It seems likely that his practical technique is at fault and he may have been

1 reading the level of the top, instead of the bottom, of the meniscus in his burette
2 rinsing his titration flask with sodium chloride solution, instead of with water, between titrations
3 overshooting the end-point because of unfamiliarity with the colour change
4 allowing insufficient time for his pipette to drain when delivering the portions of sodium chloride solution

27 The isomers of the alkane octane

1 all contain the same number of carbon atoms and hydrogen atoms
2 all have the same molecular weight
3 all have different boiling points
4 all have equal carbon chain lengths

Directions summarized

A	B	C	D	E
1, 2, 3 only	*1, 3* only	*2, 4* only	*4* only	some other response or combination of responses

28 A compound X has a molecular formula CH_4O
Which of the following statements is/are correct?

1 X can be easily dehydrated
2 X forms hydrogen chloride on treatment with phosphorus pentachloride
3 X forms an ester with ethyl chloride
4 X has isomers

29

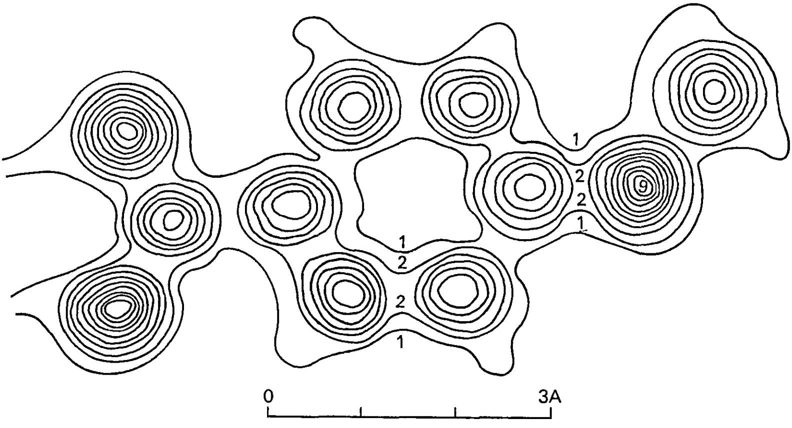


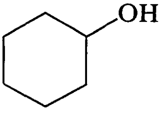
Figure 19
By courtesy of Dr J. P. G. Richards, Department of Physics, University College, Cardiff

Figure 19 is an electron density map of a sample of methoxybenzoic acid. *From this diagram* it can be deduced that

1 it is the *para*-form of the isomer
2 oxygen atoms have a higher electron density than carbon atoms
3 all the carbon atoms are coplanar
4 the formula of the methoxy group is —O—CH_3

Questions 30 to 32 are about the chemical constitution and behaviour of *cyclo*-hexanol, $C_6H_{11}OH$.

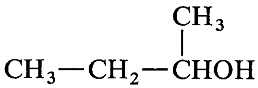
30 The formula of *cyclo*hexanol is sometimes written

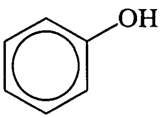


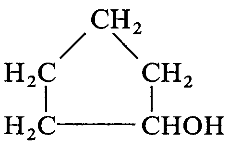
This formula indicates

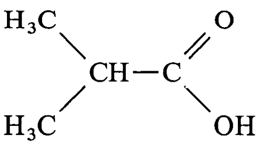
1 that *cyclo*hexanol is unsaturated
2 the number of carbon atoms present in a molecule of *cyclo*hexanol
3 the relative positions in space of the atoms in a molecule
4 that carbon and oxygen are linked together in the molecule

31 The —OH group in *cyclo*hexanol is likely to behave very similarly to the —OH group in

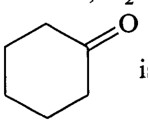
1 

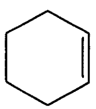
2 

3 

4 

32 When *cyclo*hexanol is treated with sodium dichromate, $Na_2Cr_2O_7$, and excess of concentrated sulphuric acid, H_2SO_4, it is likely that

1 some *cyclo*hexanone,  is formed

2 some *cyclo*hexene,  is formed

3 *cyclo*hexanol is oxidized

4 the colour of the solution changes from green to yellow

Directions summarized

A	B	C	D	E
1, 2, 3 only	*1, 3* only	*2, 4* only	*4* only	some other response or combination of responses

33 Which of the following are correct statements about equilibria?

1 The equilibrium state can be approached from either direction

2 Stable equilibria can only be attained in a closed system (a system which cannot exchange matter with its surroundings)

3 At equilibrium the intensive properties of the components of the system do not change

4 In stable equilibria reactions in the forward and reverse directions have stopped

34 Two liquids X and Y mix with each other to form a system which shows a positive deviation from Raoult's Law. Which of the following confirms this?

1

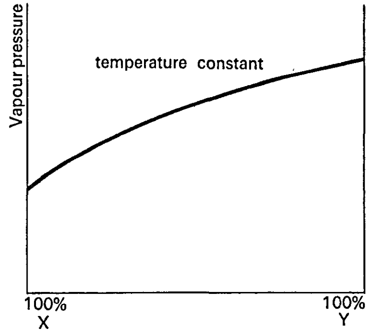


Figure 20

2 The boiling points of mixtures X and Y all lie between those of the two pure substances

3 When X and Y at equal temperatures and equimolar proportions are mixed, the resulting mixture shows a drop in temperature

4 A single stage distillation of an equimolar mixture of X and Y does not produce either of the pure substances

35 In which of the following does the oxidation number of nitrogen equal the number of nitrogen electrons used in bonding?

1 Calcium nitrate

2 Hydrazine ($H_2N—NH_2$)

3 Ammonia

4 Nitrogen

Directions summarized				
A	**B**	**C**	**D**	**E**
1, 2, 3 only	*1, 3* only	*2, 4* only	*4* only	some other response or combination of responses

36 When carbon and oxygen are mixed under standard conditions there is no perceptible reaction. Which of the following are valid statements about the situation?

1 Under standard conditions an equilibrium

$$C(s) + O_2(g) \rightleftharpoons CO_2(g)$$

is established in which K_p is so small that the amount of carbon dioxide is imperceptible

2 Under standard conditions any reaction between carbon and oxygen is so slow as to be imperceptible

3 An increase in temperature will favour an increase in K_p

4 Under standard conditions there is insufficient energy to raise a perceptible amount of the reactants up to their activation energy

37 A certain substance X has the following properties: formed a crystalline precipitate with 2,4-dinitrophenylhydrazine; on reduction formed an alcohol with a molecular weight two units more than the molecular weight of X; had no reaction on Fehling's solution. Which of the following could X be?

1 $CH_3COCH_2CH_2Br$
2 $CH_3COCH{=}CHCH_3$
3 $CH_3COCH_2NH_2$
4 $CH_3CH{=}CHCH_2OH$

38 For which of the numbered operations would the apparatus in figure 21 be suitable?

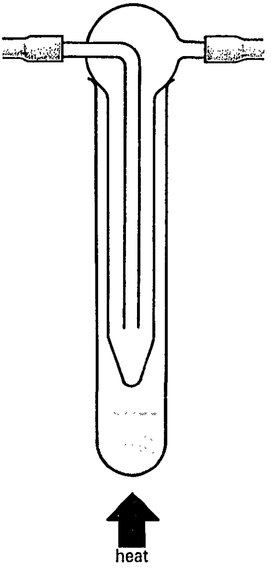


Figure 21

1 The investigation of the action of phosphorus pentachloride on boiling diethyl ether

2 The preparation of ethene by the dehydration of boiling ethanol

3 The preparation of monochloracetic acid ($ClCH_2CO_2H$) by the action of chlorine on boiling acetic acid

4 The oxidation of propanol to propanoic (propionic) acid by boiling with aqueous sulphuric acid and a dichromate

39 For which of the numbered operations would the apparatus in figure 22 be suitable? (The apparatus would be used in a fume cupboard.)

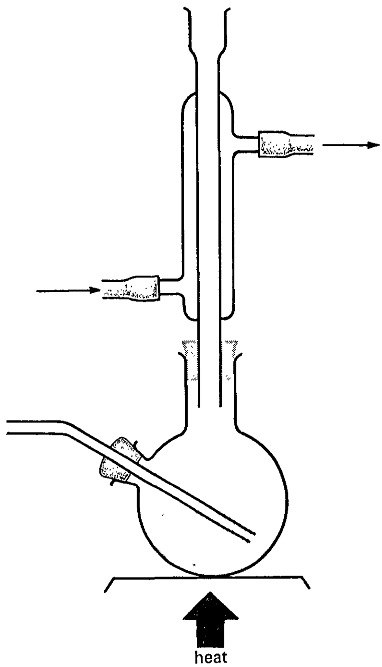
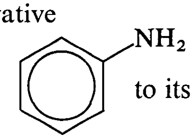


Figure 22

1 The hydrolysis of acetamide, CH_3CONH_2, accompanied by the collection of the resulting ammonia

2 The conversion of an inflammable aldehyde, susceptible to atmospheric oxidation, to its 2,4-dinitrophenylhydrazine derivative

3 The conversion of the toxic liquid amine  to its sulphate

4 The conversion of acetic acid to monochloracetic acid
$CH_3CO_2H + Cl_2 \rightarrow ClCH_2CO_2H + HCl$

40 Which of the following is evidence pointing to a reaction being of the first order with respect to one of the reactants (X)?

1 The time taken for the concentration of X to decrease by a half is constant

2 A graph of the concentration of X against the rate of the reaction is a straight line

3 In a balanced equation of the reaction only one molecule of X is shown

4 The rate of the reaction is independent of any of the other reactants shown in the equation

41 When solid iodine dissolves in cyclohexane

1 some $I_2 \ldots I_2$ interactions are broken

2 some I—I bonds are broken

3 some $I_2 \ldots$ cyclohexane interaction takes place

4 NO cyclohexane . . . cyclohexane interaction takes place

42 Which of the following are generalizations of the behaviour of ideal gases (p = pressure, V = volume, n = number of moles, M = molecular weight, w = weight in grammes, ρ = density in g dm^{-3}, R = gas constant, T = temperature/K)?

1 $pV = \rho MRT$

2 $pV = nRT$

3 $pV = \dfrac{MRT}{w}$

4 $pM = \rho RT$

43 Which of the following statements about a solution containing 96.47 g of ammonium iron(III) sulphate crystals in 1 dm^3 is/are correct?

$(NH_4)_2SO_4Fe_2(SO_4)_3 24H_2O$ (formula mass 964.7)

1 It is 0.2M with respect to Fe^{3+}

2 It is 0.2M with respect to NH_4^+

3 It is 0.1M with respect to $(NH_4)_2SO_4Fe_2(SO_4)_3 24H_2O$

4 It is 0.2M with respect to SO_4^{2-}

Directions summarized

A	B	C	D	E
1, 2, 3 only	*1, 3* only	*2, 4* only	*4* only	some other response or combination of responses

44 For which of the following changes will ΔH be negative?
1 $Na(g) \rightarrow Na^+(g) + e^-$
2 $Na(g) \rightarrow Na(s)$
3 $Mg(g) \rightarrow Mg^{2+}(g) + 2e^-$
4 $Cl(g) + e^- \rightarrow Cl^-(g)$

Questions 45 and 46 concern the determination of the molecular weight of a volatile liquid using the apparatus in figure 23.

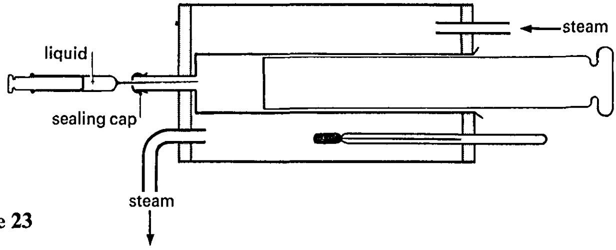


Figure 23

***45** Which of the following is an essential part of the procedure?
1 The hypodermic needle must be held vertically and the plunger pressed to expel air bubbles, before insertion into the sealing cap
2 Before the liquid is injected into the glass syringe, all the air must be expelled from the glass syringe
3 Superfluous liquid on the outside of the hypodermic needle should be dried off
4 The liquid must be non-flammable

***46** Which of the following measurements must be taken?
1 The weight of the hypodermic syringe plus liquid before injection
2 The weight of the hypodermic syringe plus liquid after injection
3 The atmospheric pressure
4 The density of the liquid

47 A certain solid element has an internuclear distance of 0.266 nm between neighbouring atoms. Its ionic radius is 0.216 nm.
Which of the following statements about the element is correct?
1 The element is metallic
2 The formation of an ion from this element results in a decrease in size
3 The atomic radius is 0.133 nm
4 The element forms negative ions

***48** Which of the following methods could be used to investigate the kinetics of the reaction:

$$CH_3CO_2C_2H_5(l) + OH^-(aq) \rightarrow CH_3CO_2^-(aq) + C_2H_5OH(aq)$$

1 Follow the increase in volume using a gas syringe
2 Weigh the mixture at regular intervals
3 Follow the change in optical activity of the mixture
4 Remove samples at given time intervals and titrate with acid of known molarity

***49** The system below was allowed to reach equilibrium at 25 °C.

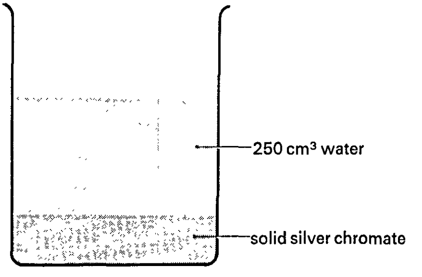


Figure 24

The solubility product of silver chromate (Ag_2CrO_4) is 3×10^{-12} mol³ dm⁻⁹. Suppose 0.02 mole of silver nitrate were added; which of the following changes will have taken place in the system once equilibrium has been re-established at 25 °C?

1 Some solid silver nitrate will remain
2 The conductance of the solution will have increased
3 The boiling point of the solution will have decreased
4 The concentration of chromate ion will have decreased

Directions summarized				
A	**B**	**C**	**D**	**E**
1, 2, 3 only	*1, 3* only	*2, 4* only	*4* only	some other response or combination of responses

Multiple completion items—classification

Item	Theme	Ability	Key	Facility/%
1	3	2	D	60
2	1	2	C	83
3	1	2	B	53
4	2	2	D	29
5	3	2	D	75
6	1	1	E	49
7	1	2	B	90
8	2	2	A	42
9	3	1	A	53
10	6	2	D	25
11	2	2	D	56
12	3	2	D	64
13	3	2	E	66
14	5	2	D	42
15	5	4	D	30
16	5	4	B	57
17	5	2	B	52
18	5	3	A	12
19	5	3	D	33
20	4	2	B	30
21	4	2	E	24
22	4	4	B	17
23	2	2	B	71
24	2	2	B	41
25	1	2	D	55
26	1	2	D	17
27	2	2	A	82
28	1	2	E	44
29	3	3	A	36
30	3	3	C	47
31	2	3	B	43
32	1	3	A	12
33	5	2	A	–
34	3	2	B	–
35	2/3	2	B	–
36	5	4	C	–
37	1	4	B	–
38	1	3	D	–

Item	Theme	Ability	Key	Facility/%
39	1	3	D	–
40	4	2	E	–
41	3	2	B	–
42	2	2	C	–
43	2	2	A	–
44	6	1	C	–
45	1	2	B	–
46	1	2	A	–
47	3	4	E	–
48	5	4	D	–
49	4	4	C	–

A5 **Relationship analysis questions**

Each question in this group consists of an *assertion* in the lefthand column and a *reason* in the righthand column.

Select

A if both assertion and reason are true statements and the reason is a *correct explanation* of the assertion

B if both assertion and reason are true statements and the reason is *NOT a correct explanation* of the assertion

C if the assertion is true, but the reason is a false statement

D if the assertion is false, but the reason is a true statement

E if both assertion and reason are false statements

Directions summarized

	assertion	**reason**	
A	true	true	reason is a *correct explanation*
B	true	true	reason is *not a correct explanation*
C	true	false	
D	false	true	
E	false	false	

	Assertion	*Reason*
1	The first ionization energy of helium is less than twice the first ionization energy of hydrogen	The mutual repulsion between the two helium electrons partly offsets the attractive effect of the double positive charge on the helium nucleus
2	The thermal stability of the hydrogen halides decreases with increasing atomic number of the halogens	The bond energy between hydrogen and halogen decreases with increasing atomic number of the halogen
3	Sodium chloride can form a cubic lattice when it crystallizes	The ions in sodium chloride are spherically symmetrical
4	In its compounds the oxidation state of potassium is NOT greater than one	The first ionization energy of potassium is small and the second and subsequent ionization energies are much larger

	Assertion	*Reason*
5	Radium spontaneously undergoes radioactive decay	It has the lowest first ionization energy of any group II element
6	The ionization energies of a given element increase as successive electrons are removed	As electrons are removed the charge on the nucleus increases
7	If the nucleus of an atom absorbs a neutron a new chemical element is formed	The absorption of the neutron increases the mass number of the element by one
8	The standard enthalpy of formation of a compound has the same numerical value as the enthalpy of atomization of the compound, but is opposite in sign	The formation of a compound from its elements in their standard states is the reverse of the breakdown of the compound into separate atoms
9	Some molecules do not react even if they collide with an energy greater than the activation energy for the reaction	Some orientations of colliding molecules do not favour a reaction between them
10	An aqueous solution of known molarity with respect to both $C_2H_5CO_2H$ and $C_2H_5CO_2^-Na^+$ can be used as a buffer solution	If H^+(aq) ions are added the following change takes place: $C_2H_5CO_2^-(aq) + H^+(aq) \rightarrow C_2H_5CO_2H(aq)$ and if OH^-(aq) ions are added: $C_2H_5CO_2H(aq) + OH^-(aq) \rightarrow C_2H_5CO_2^-(aq) + H_2O(l)$
11	The volume of a gram-molecule of most gases is almost the same at s.t.p.	The volume occupied by gaseous molecules is independent of the size of the molecules
12	The forces holding the particles together in an atomic nucleus must be great	α-particles can be deflected from their paths through very large angles by collision with atomic nuclei

	Assertion	*Reason*
13	Graphite is a good conductor of electricity whereas diamond is not	Unlike diamond, graphite is anisotropic
14	Unlike the tetrachloromethane molecule, the trichloromethane molecule is polar	The electrons between the carbon and hydrogen atoms in trichloromethane are delocalized
15	Alkanes and cycloalkanes with the same number of carbon atoms have the same molecular weights	Alkanes and cycloalkanes differ only in arrangement of atoms, not in molecular formula
16	Tin(IV) chloride, $SnCl_4$, will have a lower boiling point than tin(II) chloride	Tin(IV) chloride is less ionic than is tin(II) chloride
17	An aqueous solution of phenol has a lower pH than an aqueous solution of ethanol of the same molarity	One pair of electrons in the oxygen atom in phenol enters the delocalized electron system of the benzene ring and causes the O—H bond to be weakened. This delocalization is not possible when the OH group is attached to an alkyl group, therefore the O—H bond is stronger, and the hydrogen atom is less readily released as a proton
18	If 50 cm^3 0.1M ammonia solution is added to 25 cm^3 0.1M sulphuric acid, the resulting solution is acidic	Sulphuric acid is dibasic, that is, it provides twice as many $H^+(aq)$ ions per molecule of acid as a monobasic acid does
19	Magnesium hydroxide is less likely to be precipitated from an aqueous solution of Mg^{2+} ions by reaction with methylamine, CH_3NH_2, if methylammonium chloride, CH_3NH_3Cl, is present	The presence of $CH_3\overset{+}{N}H_3$ from methylammonium chloride affects the equilibrium $CH_3NH_2(aq) + H_2O \rightleftharpoons CH_3NH_3^+(aq) + OH^-(aq)$ decreasing the concentration of $OH^-(aq)$ ions and thus decreasing the likelihood of exceeding the solubility product of magnesium hydroxide

	Assertion	*Reason*
20	The atomic weight of an element is often NOT a whole number	In most of the elements there are more neutrons than protons in the nucleus
21	The conductance of tetrachloromethane is high and increases with temperature	In liquid ionic substances the ions are free to carry electricity and their mobility increases with temperature
22	The first ionization energy of rubidium is less than that of sodium	The charge on the rubidium nucleus is greater than that on the sodium nucleus
23	Equal numbers of moles of ideal gases exert the same pressure at constant volume and temperature	The average speed of molecules of ideal gases is the same at constant temperature
24	When 1 mole of hydrochloric or nitric acid reacts with 1 mole of sodium hydroxide (all in dilute aqueous solution) the same amount of heat is evolved	Both acids can be regarded as completely ionized and undergo the same reaction, $H_3O^+(aq) + OH^-(aq) \rightarrow 2H_2O(l)$, for which ΔH is negative
*25	An experiment in which bromine ($50\ cm^3$) is being transferred from one beaker to another should be done in a fume chamber	If bromine is spilled on the fingers a painful burn is caused

Directions summarized

	assertion	reason	
A	true	true	reason is a *correct explanation*
B	true	true	reason is *not a correct explanation*
C	true	false	
D	false	true	
E	false	false	

Relationship analysis - item classification

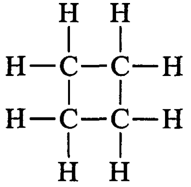
Item	Theme	Ability	Key	Facility/%
1	3	4	A	73
2	6	4	A	46
3	3	2	A	23
4	2	4	A	42
5	3	4	B	60
6	3	2	C	75
7	3	2	D	75
8	6	2	E	60
9	4	4	A	74
10	5	4	A	48
11	2	4	A	43
12	3	4	B	65
13	3	4	B	50
14	3	2	C	52
15	2	2	E	63
16	1	4	A	26
17	3	4	A	–
18	1	4	B	–
19	5	4	A	–
20	3	4	B	–
21	3	2	D	–
22	3	4	B	–
23	2	2	C	–
24	6	4	A	–
25	1	4	B	–

Section B

Structured questions

Some of these questions were used in the internal examinations of the trial schools, others are taken from the Nuffield A-level examinations by kind permission of the London University School Examinations Department. The questions are normally set out with appropriate spaces in which the answers are to be written; to save space these have been omitted here. Some of the questions are based on trial material which may not be found in the published materials. Suggested marks are given for each question down the righthand sides of the pages.

1 For this question use the following data concerning cyclobutane:



$\bar{E}$ (bond energy term) C—C = 345 kJ mol^{-1}
$\bar{E}$ (bond energy term) C—H = 413 kJ mol^{-1}

a What is meant by $\bar{E}$ (bond energy term)? 2
b From the bond energy terms predict $\Delta H^{\ominus}_{f,\mathrm{at}}$ for cyclobutane. 2
c The actual $\Delta H^{\ominus}_{f,\mathrm{at}}$ for cyclobutane is −4578 kJ mol^{-1}. Explain the difference between this figure and that obtained in answer to (b). 2

2 On reduction of a solution of ammonium vanadate (NH_4VO_3) a solution containing vanadium ions (V^{n+}) can be obtained (*n* is a small whole number). This reduced vanadium can be oxidized back to its original form by adding an appropriate volume of acidified potassium permanganate solution. In this reaction the permanganate ion undergoes the following change:

$$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O$$

25 cm^3 of 0.02M solution of ammonium vanadate was reduced and the resulting solution required 15 cm^3 of 0.02M permanganate to oxidize it back to its original state.

Calculate *n*. You should explain and show all the steps in your calculation. You may, if you wish, express your answer in the following steps.

a What is the oxidation state of vanadium in the vanadate ion (VO_3^-)? *1*
b How many millimoles of vanadium are there in 25 cm^3 of 0.02M vanadium solution? (A millimole is $\frac{1}{1000}$ of a mole.) *1*

c How many millimoles of $MnO_4^-(aq)$ are there in 15 cm^3 of 0.02M permanganate solution? *1*

d What fraction of a mole of permanganate ion reacts with 1 mole of V^{n+} ion in this reaction? *1*

e Deduce a value for *n*. *3*

3 The apparatus shown in figure 25 was used to boil methanol (CH_3OH) with propionic acid ($CH_3CH_2CO_2H$) and a few drops of concentrated sulphuric acid for ten minutes.

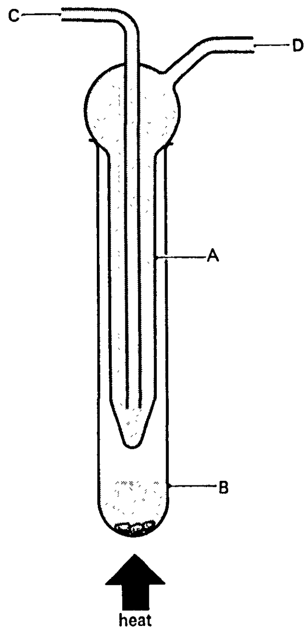


Figure 25

a Name the piece of apparatus A. *1*

b Where does the tube C lead to or from? *1*

c Where does tube D lead to or from? *1*

d Describe *briefly* the function of the apparatus A. *3*

e Some anti-bumping granules were used in B.

i What is meant by bumping? *1*

ii Name one material of which the granules could be made. *1*

f Name and draw the structural formula of the main product of the reaction between methanol and propionic acid. *2*

g Suppose A was removed what would finally remain in B if heating was continued? *1*

4 A student was given a solution of a chloride A and asked to determine whether it was the chloride of a group I (excluding lithium) or a group II (excluding beryllium) element.

He took 0.5 cm^3 of the chloride solution and added 4 drops of another solution B one drop at a time, shaking the solution between additions. He observed a white precipitate C and concluded that A was the chloride of a group II element. As a confirmatory test he isolated the precipitate C, dissolved it in a small quantity of hydrochloric acid, and did a flame test which gave a pale green colour.

a Which would be the most appropriate piece of apparatus to contain the 0.5 cm^3 of the chloride solution? *1*
b Name an appropriate solution for B. *1*
c What would be the most appropriate method of adding B? *1*
d Name the anion in the white precipitate C. *1*
e What would be the quickest method of isolating the precipitate C? 2
f Name the group II element. *1*

5 The apparatus in figure 26 has been used to determine the molecular weights of gases.

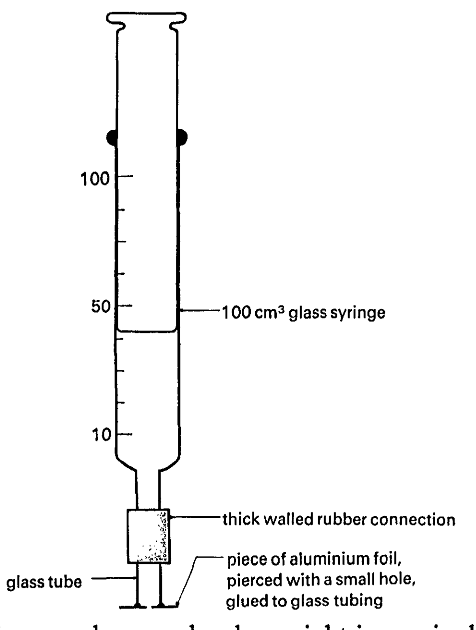


Figure 26

The syringe is filled with the gas whose molecular weight is required, the glass tube is fitted into position, and the syringe clamped vertically. The piston of the syringe is then allowed to fall under its own weight and the time for 100 cm^3 of gas to be expelled from the syringe is measured with a stopclock.

Theory

According to the law of effusion:
time taken to expel 100 cm^3 of gas $\propto \sqrt{\text{molecular weight of gas}}$

a The expression given above under *theory* as a guide to working out results is a proportionality. You cannot therefore determine the molecular weight of a gas using it alone. List the experiments you would perform and any assumptions you would have to make to determine the molecular weight of a gas whose chemical nature you did not know. *4*

b When the glass tube is fitted on to the syringe, it contains air so the first gas that is pushed out through the hole in the aluminium foil is air. Do you think this would cause an error in the results? If you do, explain how you would overcome the difficulty; if you do not, explain why not. *4*

c Would you get more accurate results with the apparatus by using a small or a large hole? Give the reason for your choice. 2

d Arrange the following gases in increasing order of time taken for 100 cm^3 of gas to be expelled:

hydrogen sulphide, carbon dioxide, oxygen, nitrogen, air, hydrogen.
(Atomic weights: H = 1, S = 32, C = 12, O = 16, N = 14) 2

6 The enthalpies of neutralization of some acids and alkalis are:

	$\Delta H^\ominus$/kJ mol^{-1} acid
hydrochloric acid and sodium hydroxide solutions	−57.3
phosphoric acid and sodium hydroxide solutions	−172.0
oxalic acid and sodium hydroxide solutions	−111.3

a From the above results, how many moles of hydrogen ions per mole of acid are replaceable by sodium ions in

i phosphoric acid
ii oxalic acid?

Briefly explain your answer. *4*

b The result for oxalic acid is lower than expected. Explain why. 2

c Partial neutralizations of phosphoric acid solution by sodium hydroxide solutions can be carried out and given enthalpies of neutralization of −57.3 and −114.6 kJ. Write equations for the reactions between phosphoric acid and sodium hydroxide when $\Delta H^\ominus$ is

i −172.0 kJ
ii −114.6 kJ
iii −57.3 kJ

(Phosphate ion has formula PO_4^{n-}.) *3*

7 A solution of titanium(III) sulphate is a good reducing agent, and can be used to estimate the composition of reducible compounds. During the reduction, the titanium(III) sulphate is oxidized to titanium(IV) sulphate, according to the equation:

$$Ti^{3+}(aq) - e^- \rightarrow Ti^{4+}(aq)$$

An experiment was carried out to find the percentage of iron(III) present in a hydrated form of iron(III) chloride. The iron(III) was reduced to iron(II) by the titanium(III) sulphate solution. 27 g of hydrated iron(III) chloride was weighed out and dissolved to make 1 dm^3 of solution. 20 cm^3 of this solution were reduced by exactly 10 cm^3 of titanium(III) sulphate solution, 0.2M with respect to Ti^{3+} ions. (Fe = 56.)

a Write down the overall ionic equation for the oxidation-reduction reaction. 2

b From the equation, how many moles of titanium(III) ions reduce 1 mole of iron(III) ions? *1*

c From the experimental results and the equation, what volume of the hydrated iron(III) chloride solution contains 1 mole of iron(III) ions? *3*

d What weight of iron(III) is present per cubic decimetre of hydrated iron(III) chloride solution? 2

e What percentage of iron(III) is present in the hydrated salt? *1*

8 A student was given the following instructions and information for an experiment to determine the equilibrium constant for the reaction:

ethyl acetate + water ⇌ acetic acid + ethanol

$$CH_3CO_2C_2H_5(l) + H_2O(l) \rightleftharpoons CH_3CO_2H(l) + C_2H_5OH(l)$$

Instructions

Measure 20.0 cm^3 of ethyl acetate, 12.0 cm^3 of water, and 3.0 cm^3 of concentrated hydrochloric acid into a flask. Measure 32.0 cm^3 of water and 3.0 cm^3 of concentrated hydrochloric acid into another flask. Stopper both flasks and leave them for two days. Remove 10.0 cm^3 portions from each flask and titrate them separately with 1.00M sodium hydroxide solution.

Data

Formula weight of ethyl acetate = 88
Density of ethyl acetate = 0.900 g cm^{-3}
Formula weight of water = 18
Density of water = 1.00 g cm^{-3}
Formula weight of acetic acid = 60
Density of acetic acid = 1.05 g cm^{-3}

Results

Titration readings: 43.9 cm^3 and 9.2 cm^3 of 1.00M sodium hydroxide solution

a Suggest a reason for the inclusion of hydrochloric acid. *1*

b By what means should you measure out the quantities of starting materials? *3*

c Two pieces of the data are *not* required in the calculation; which are they? *2*

d The student said that he was unable to calculate accurately the number of moles of water present after two days because of insufficient data. What further data are required? *2*

e Calculate the number of moles of each of the following in the first flask at the end of two days:

i Acetic acid *2*

ii Water (estimated) *2*

iii Ethyl acetate *2*

iv Ethanol *1*

f Calculate the equilibrium constant for the reaction. *2*

g The student claimed that the calculated equilibrium constant was not very meaningful because the instructions for the conduct of the experiment were inadequate in two important respects. Suggest two further instructions which *you* would think should have been given. *3*

9 Figure 27 shows the electron density pattern (obtained from X-ray diffraction studies) of hexamethylbenzene, $(CH_3)_6C_6$.

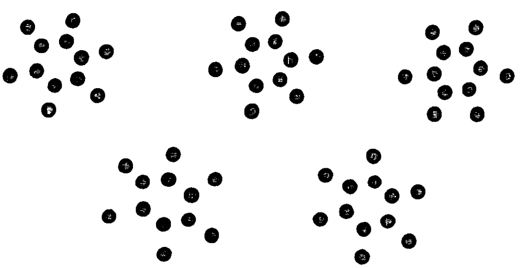


Figure 27

a State two pieces of information regarding the structure of hexamethylbenzene that may be obtained from the X-ray pattern. *2*

b Which atoms are represented by the black dots? *1*

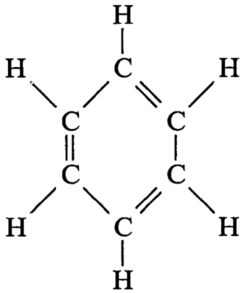
c Which atoms are missing from the pattern? *1*

d Why are they missing? *1*

e Name (only) ONE method utilized to determine the position of the missing atoms. *1*

f Are ALL the atoms in the same plane? If not, why not? **2**

g Comment briefly on the inadequacy of the Kekulé structure of this molecule with regard to the bond lengths suggested by the structure and those found experimentally. The Kekulé structure of benzene is: **2**



10 The gas keten, CH_2CO (boiling point $-41\,°C$), is prepared by the thermal cracking of acetone vapour (CH_3COCH_3) at 700 °C. It is extremely reactive and combines rapidly with substances of the type HX, where X may be OH, NH_2, OC_2H_5, or certain other groups. The reaction is of the form:

$$CH_2CO + HX \rightarrow CH_3\underset{\displaystyle X}{\underset{|}{C}}O$$

a Write a possible equation for the preparation of keten and suggest:

i A method of separating the products from any unchanged acetone

ii A way of collecting and confirming the identity of the other product of the cracking **5**

b Draw a 'dot-and-cross' diagram to show the arrangement of the bonding electrons (and any unshared electrons) in keten. On a separate diagram indicate the shape you would expect for the molecule, showing the angles between bonds and stating clearly whether or not you expect all five atoms to lie in the same plane. Do you think that the molecule will be polar? Explain your reasoning. **5**

c Write formulae and give names for the products likely to be formed by the combination of keten with:

i ethanol

ii dilute hydrochloric acid **2**

11 The following results were obtained in experiments to determine the structure of an unknown compound.

i Composition – carbon 92.4 per cent, hydrogen 7.6 per cent

ii 5.1 g occupied a volume of 1.14 dm^3, when corrected to s.t.p.

iii C—C bond length measurements gave two results: 0.146 nm and 0.133 nm (C—C single, 0.154 nm; C=C double, 0.134 nm; C—C in benzene, 0.139 nm)

iv The compound was unsaturated and could be made by polymerizing acetylene (ethyne)

a Find the empirical formula, molecular weight, and molecular formula. *5*

b Draw possible structural formulae. *3*

c Discuss how well these formulae fit the observations in (*iii*) and (*iv*). *4*

d Suggest a name for this compound. *3*

12 The curves in the graph (figure 28) show, for mixtures of acetone, CH_3COCH_3, and carbon disulphide, CS_2, of different compositions (at a fixed temperature):

i the total vapour pressure of the mixture

ii the partial pressure of acetone

iii the partial pressure of carbon disulphide vapour

In each case the 'ideal' values are indicated by the dotted lines.

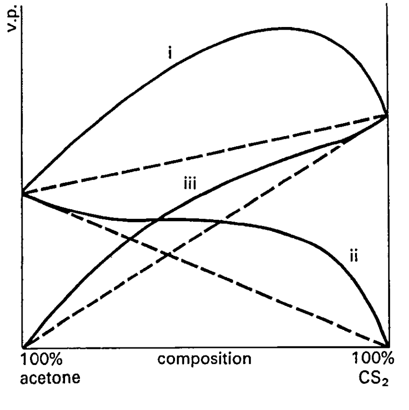


Figure 28

a Draw structures (showing bonds, not electrons) to describe the shapes of the two molecules and say whether or not each is polar. *4*

b Explain briefly why the partial pressure of acetone vapour over a mixture is greater than the 'ideal' value. 2

c Sketch a graph showing how boiling points of mixtures of acetone and carbon disulphide are likely to vary with the compositions of the mixtures. 2

d Fractional distillation sorts out from any mixed solution the component, or mixture, which has the lowest boiling point. Explain briefly why this process is not suitable for separating acetone and carbon disulphide. *1*

e In which sense, if at all, do you think the temperature may change when acetone and carbon disulphide are mixed? Give reasons for your answer. 2

13 Figure 29 shows the electron density map of a metallic halide. (The contours are in electrons $Å^{-3}$; $1\ Å = 10^{-1}$ nm.)

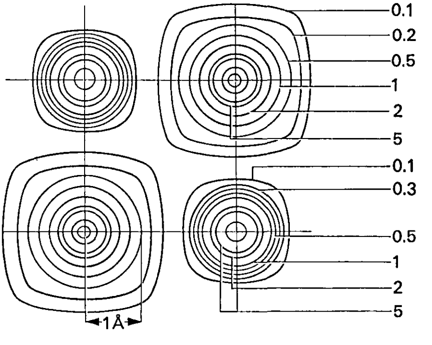


Figure 29
After Witte, H. and Wolfel, E. (1958) Reviews of modern physics, **30**, 51–5

a By what technique are electron density maps determined? *1*

b In your own diagram label the metal and non-metal ions. 2

c What is the least electron density at which (*i*) the metal ion, and (*ii*) the non-metal ion, can be regarded as spherical? 2

d What is the distance between the centres of the metal and non-metal ions? *1*

e Why is it not possible to determine the ionic radii from this diagram alone? 2

f Values given for the radius of a particular ion vary slightly depending on the compound of which the ion is a component. Give one reason for the variation. 2

14 The apparatus shown in figure 30 was set up by a student to prepare the volatile, solid chloride of a metal.

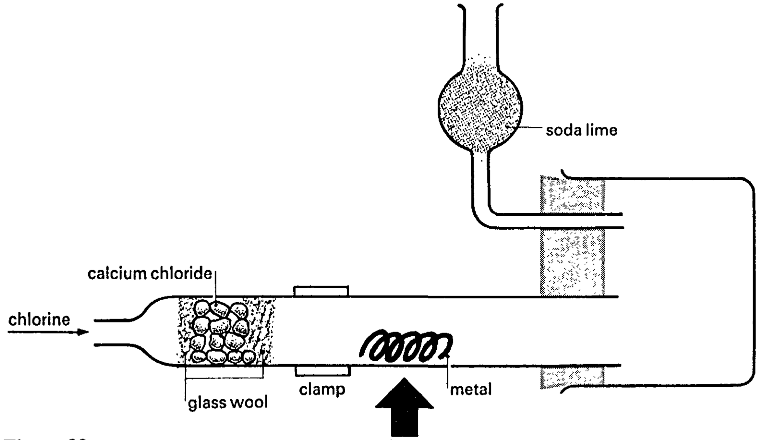


Figure 30

a What is the purpose of the soda lime tube? *1*
b What is the purpose of the calcium chloride? *1*
c What is the purpose of the glass wool? *1*
d There is a fault in the apparatus. What is it? *2*
e Suggest two safety measures which apply to this experiment. *2*
f Is the chloride likely to be ionic or molecular? *1*
What evidence is there to support your answer? *1*

g The apparatus would not be very suitable for a *quantitative* experiment to determine directly the maximum weight of the chloride which could be obtained from a given weight of metal. Why is it not suitable? *3*

15

a From your *Book of data*, record $\Delta H_f^\ominus$ of
$NaCl(s)$ $MgCl_2(s)$ $AlCl_3(s)$
$SiCl_4(l)$ $PCl_5(s)$ *1*

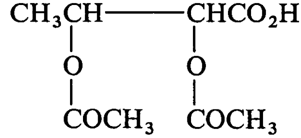
b Convert the figures you have recorded to kJ per mole of chlorine atoms. *2*

c Which of the chlorides would you expect to be most thermally stable with respect to formation from its elements? *1*
Briefly give a reason for your choice. *2*

d What general trend do your figures indicate in $\Delta H_f^\ominus$ per mole of chlorine atoms along a period of the Periodic Table? *2*

e Assuming that there is a regular trend in $\Delta H_f^\ominus$ of the chlorides of calcium, strontium, barium, and radium, estimate $\Delta H_f^\ominus$ of $RaCl_2(s)$. (Use your *Book of data*. $\Delta H_f^\ominus$ $BaCl_2(s) = -862\ \text{kJ mol}^{-1}$.) *2*

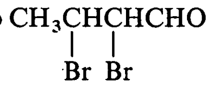
16 State concisely how a compound of the formula $CH_3CH{=}CHCHO$ could be converted into a compound of formula



by the steps suggested below.

For each step state the appropriate reagents and the type of reaction.

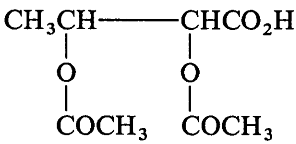
a Convert the first compound into **2**



b From (a) into $CH_3CHBrCHBrCO_2H$ **2**

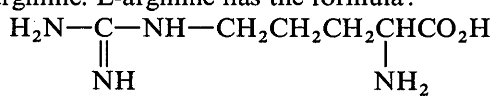
c From (b) into $CH_3CH(OH)CH(OH)CO_2H$ **2**

d From (c) into **2**



e State briefly how the end product would react with sodium hydroxide. **2**

17 Figure 31 (page 132) represents a section through a three-dimensional electron density map calculated from X-ray diffraction patterns of the dihydrate of L-arginine. L-arginine has the formula:



a Name the atoms numbered 1 to 13 in the electron density map. **5**

b The atoms labelled 1 are the same, but the electron density of one is higher than the other. Briefly suggest an explanation of this. **2**

c The atoms labelled 1 are further away from the remaining atoms than the latter are from each other. Briefly suggest an explanation of this. **3**

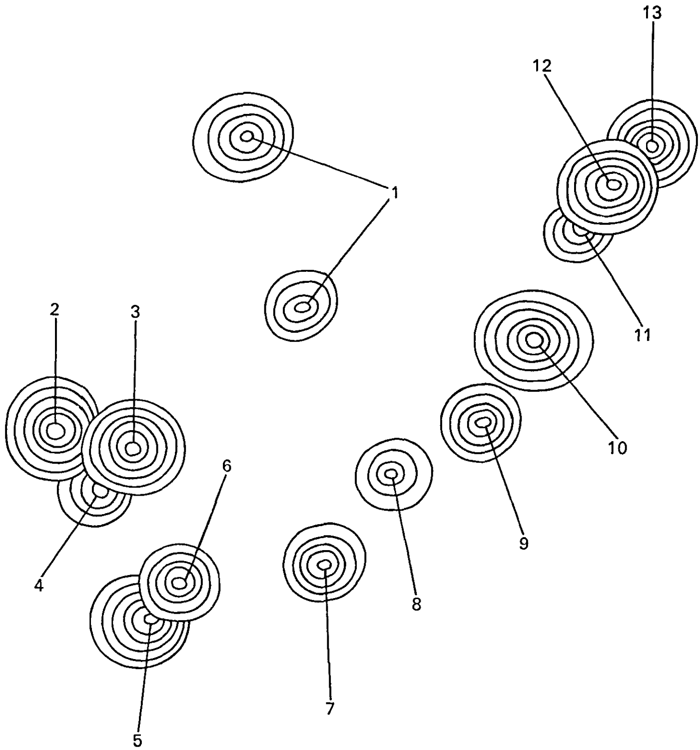


Figure 31

18 A certain reaction can be represented in general terms by the equation:
$A(g) + B(s) \rightleftharpoons C(g) + D(g)$

The graph (figure 32) shows the change of $\lg K_p$ with $(T/K)^{-1}$ for the equilibrium.

a Will the forward reaction be exothermic or endothermic? *1*
What evidence is there for your answer? *1*

b What will be the effect on the yield of C and D of
i increasing temperature *1*
ii increasing pressure? *1*

c Calculate the mean value of $\Delta H^{\ominus}$ for the forward reaction. ($R = 8.37\ \mathrm{J\ mol^{-1}\ K^{-1}}$.) *4*

d Calculate the value of $\Delta G^{\ominus}$ for the forward reaction at 500 K *3*

e At 500 °C will the position of the equilibrium be largely to the left or to the right? What evidence is there for your answer? 2

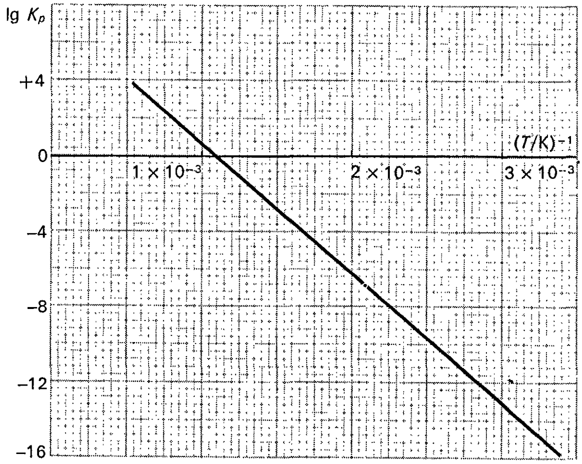


Figure 32

19 Figure 33 represents a circuit which can be used to determine the limiting (maximum) work which can be obtained from a cell of the type:

metal A | ions(aq) of metal A ⁞ ions(aq) of metal B | metal B

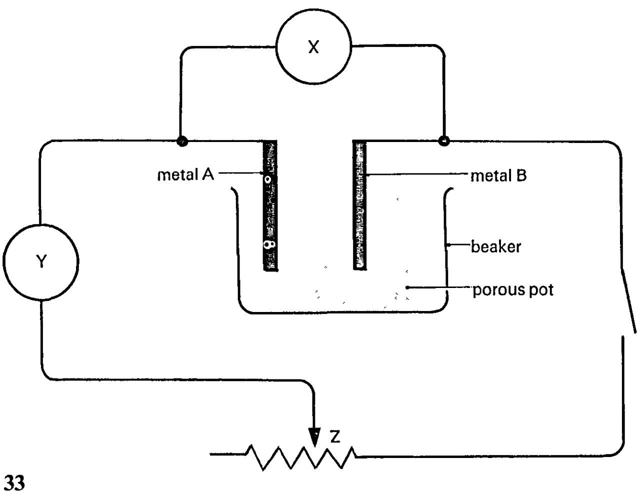


Figure 33

a Name the instruments which should be used at X, Y, and Z. ***3***

b What should be the contents of (*i*) the beaker, and (*ii*) the porous pot? ***2***

c What is the purpose of the porous pot? ***1***

d Outline, in note form, the procedure for the conduct of the experiment. *4*

e Show how you would interpret the results in order to obtain a value for the limiting work. *5*

20 The data given below refer to the change in the rate constant, k, for the decomposition of dinitrogen pentoxide, N_2O_5, with temperature T/K. In the graph (figure 34), $1/T$ is plotted against lg k.

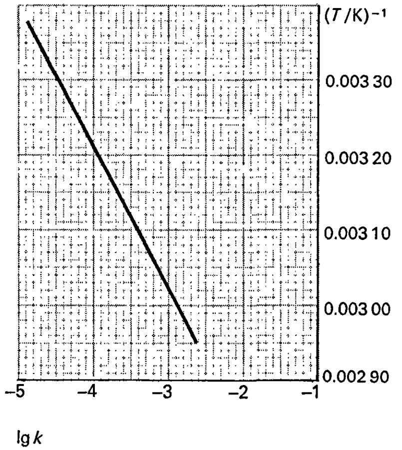


Figure 34

$$\lg k = \frac{-E}{2.3R} \times \frac{1}{T} + \lg A$$

$$R = 8.37\ \mathrm{J\ mol^{-1}\ K^{-1}}$$

a What is E called? *1*

b Use the graph to calculate E for this reaction. Show how you arrive at your answer. *5*

c State concisely the significance of E in relation to the rate of decomposition of nitrogen pentoxide. **2**

21 Solutions of cerium(IV) salts can be used as standard oxidizing agents in volumetric analysis; for example, aqueous solutions of arsenites, AsO_3^{3-}, are quantitatively oxidized to arsenate, AsO_4^{3-}. The solution of cerium(IV) salt is reduced to cerium(III). Under favourable conditions no indicator is required.

a What can be deduced from the fact that no indicator is necessary? *1*

b If an indicator has to be used, state three characteristics for which you would look in the chosen indicator. *3*

c What is the oxidation state of arsenic in (*i*) arsenite ions, and (*ii*) arsenate ions? 2

d A solution was made of 15.8 g of cerium(IV) ammonium sulphate in 250 cm^3. 20.0 cm^3 of this solution exactly reacted with 25.0 cm^3 of a solution of sodium arsenite.
(Cerium(IV) ammonium sulphate, $(NH_4)_4\ [Ce(SO_4)_4]2H_2O$, formula weight 632. Sodium arsenite, Na_3AsO_3, formula weight 192.)

i Construct an equation to show the reaction between cerium(IV) ions and arsenite ions in aqueous solution (in order to balance the equation you will need to show water as one of the reactants and hydrogen ion as one of the products). 2

ii Calculate the concentration of the sodium arsenite in g dm^{-3}. 5

***22** The first ionization energies of several elements of consecutively increasing atomic number are:

A	B	C	D	E	F	G	
1012	999	1254	1517	418	589	631	kJ mol^{-1}

a Which of the elements is likely to be
i a noble gas
ii an alkali metal? 2

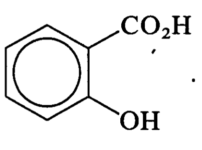
b Which two of the elements, A to G, would be most likely to combine to form an ionic compound? 2

c State two other physical properties of elements which also show a periodic trend. 2

d What differences in physical properties would you expect between the chlorides of the elements A and E? 4

e Outline how you would investigate a chemical property of the chlorides of the elements, which would show a periodic trend.
What trend would you expect in these properties? 6

***23** Acetylsalicylic acid (aspirin) can be made by the action of acetyl chloride on salicylic acid



. The reaction proceeds more efficiently in the presence of pyridine (a weak base), but the pyridine does not alter the product.
Suitable quantities for a small scale preparation are:

1.5 g of salicylic acid (a solid)
20 drops of pyridine
30 drops of acetyl chloride

The reaction is rather violent at first and has to be slowed down, but after all the reactants have been mixed, they require gentle heat (below 100 °C) to complete the reaction. Crystals of aspirin are deposited when water is added to the mixture.

a Make a comprehensive list of all the apparatus you would require. Where necessary indicate the size of the apparatus. **5**

b Outline in brief note form a procedure for this preparation, showing the use to which you would put each piece of apparatus. ***6***

c Name the method by which the aspirin crystals could be purified. ***1***

d Name the method by which the purity of the aspirin crystals could be tested. ***1***

e Write an equation for the reaction between salicylic acid and acetyl chloride. **2**

*__24__ Figure 35 shows the partial vapour pressures of water and dioxane ($C_4H_8O_2$) above various mixtures of the two liquids at constant temperature.

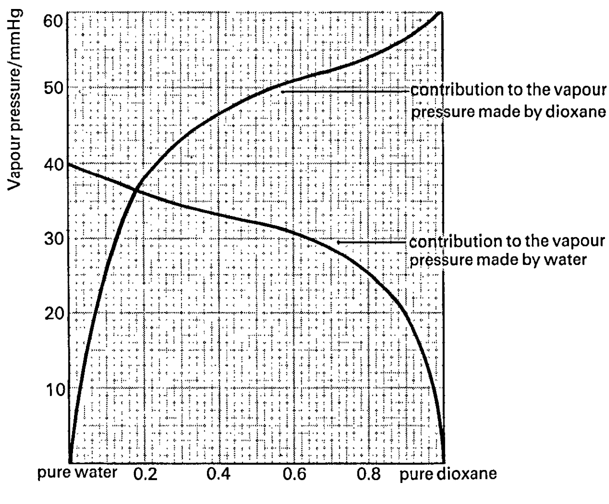


Figure 35

a What would be the vapour pressure in a mixture containing a mole fraction of 0.6 dioxane of

i the water

ii the dioxane

iii the whole mixture? ***3***

b If the mixture obeyed Raoult's Law, how would the vapour pressures of water and dioxane change as the composition of the mixture changes? You may show the relationship between vapour pressures and composition by means of a diagram if you wish. *3*

c In what way does the mixture deviate from Raoult's Law? Suggest concisely reasons for this. *6*

***25** Listed below are four liquids and four solids. For each solid choose two of the liquids which are most likely to dissolve it. Briefly state your reasons for each choice.

Liquids
water (dipole moment 1.8D)
methanol, CH_3OH (dipole moment 1.7D)
xylene, $C_6H_4(CH_3)_2$ (dipole moment 0)
octane, $CH_3(CH_2)_6CH_3$ (dipole moment 0)

Solids
a Rubidium chloride, RbCl *3*
b Naphthalene, $C_{10}H_6$ *3*
c Sulphur, S_8 *3*
d Fructose, $CH_2OH(CHOH)_3COCH_2OH$ *3*

***26** The questions which follow are concerned with an experiment to investigate the e.m.f. of a cell consisting of two metal electrodes, A and B, in 0.01M solutions of their salts. The circuit and other information are given in figure 36.

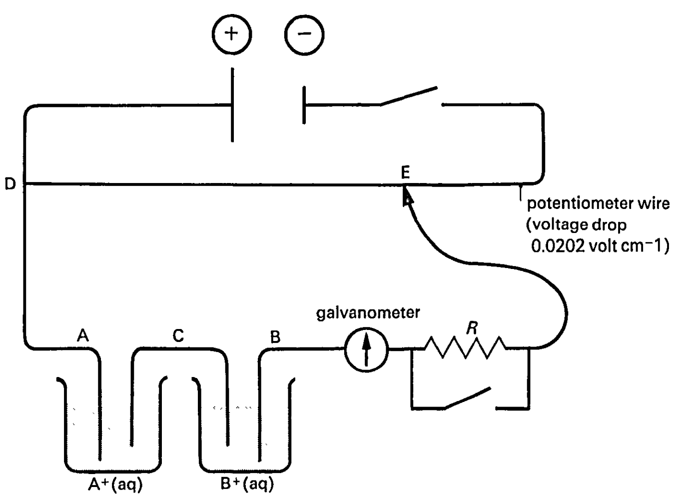


Figure 36

a What is C called and of what could it be made? 2

b How would you clean the metal electrodes before using them in this cell? 2

c If the metal A was in the form of thin and rather fragile foil, how would you make a good electrical connection with it? 2

d What is the purpose of the resistance *R*? 2

e In the first experiment a balance point was found at E (DE = 75.0 cm). What is the e.m.f. of the cell

$$A(s)|A^{+}(aq)\vdots B^{2+}(aq)|B(s)?$$

What is the polarity of the righthand electrode? 3

f Suppose that A and B were connected directly to each other through a conductor. Give the equations for the reactions which would occur at the two electrodes. 4

***27** The simplified energy diagram given in figure 37 relates to the reaction:
$H_2(g) + I_2(g) \rightarrow 2HI(g)$

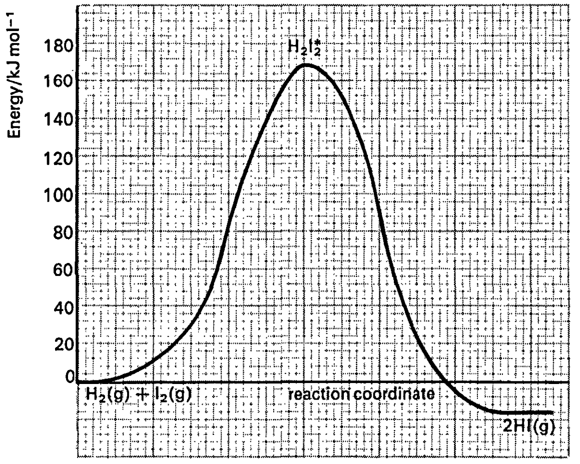


Figure 37

a What general name could be given to the stage of a reaction of which $H_2I_2^*$ is an example? 2

b What is the activation energy of this reaction? 3

c What is ΔH for the reaction:
$H_2(g) + I_2(g) \rightarrow 2HI(g)$?

State whether this reaction is

A exothermic

B endothermic

or C it is not possible to say from the information given *3*

d What is ΔH for the reaction:

$H_2I_2^* \rightarrow 2HI(g)$? **2**

***28** The seven items of information set out below are about an element X and its compounds. On the basis of some of this information it can be concluded that X is a d-block element.

a Classify each of these seven items into one of the two following categories:

A The item, when regarded by itself, fully supports the conclusion

B The item, when regarded by itself, is inconclusive *7*

b State briefly why you classified item (*vi*) as you did into A or B. *4*

i X is a solid at room temperature; its crystal structure is that of a body-centred cube, having a coordination number of 8

ii X exists in the following oxidation states in aqueous solution: +II blue solution, +III green solution, +VI yellow solution

iii X forms a soluble chloride

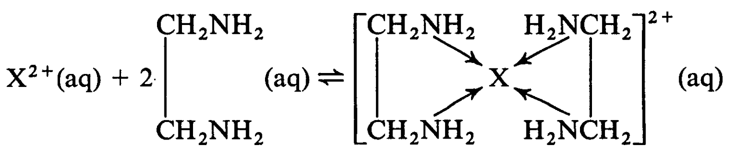
iv X reacts vigorously with chlorine:

$X(c) + 1\tfrac{1}{2}Cl_2(g) \rightarrow XCl_3(c)$

v X dissolves slowly in aqueous sodium hydroxide:

$X(c) + OH^-(aq) + 3H_2O(l) \rightarrow X(OH)_4^-(aq) + 1\tfrac{1}{2}H_2(g)$

vi X^{2+}(aq) undergoes the following changes:



(lg K = 9)

$X^{2+}(aq) + 6CN^-(aq) \rightarrow X(CN)_6^{4-}(aq)$ ($\Delta H = -276$ kJ)

vii X forms an oxide, XO_3, which dissolves readily in water to form an acidic solution

*29 The seven items of information set out below are about an element Y and its compounds. On the basis of some of this information it can be concluded that Y is a p-block element.

a Classify each of the seven items into one of the following categories:
A The item, when regarded by itself, fully supports the conclusion
B The item, when regarded by itself, is inconclusive *7*

b State briefly why you classified item (*vi*) as you did into A or B. *4*

i Y is a volatile solid at room temperature, and consists of tetratomic molecules
ii Y exists in various oxidation states from −III to +V, all colourless in aqueous solution
iii Y does not react with hydrochloric acid at room temperature
iv An atom of Y contains no electrons in d energy levels
v Compounds of Y are essential in the metabolism of many organisms
vi Y is less metallic in character than the element immediately below it in the Periodic Table
vii Y can exist in aqueous solution in the form of stable YO_3^- ions

*30

a Figure 38 represents a mass spectrometer. What is the purpose of each part labelled A to F on the diagram? *4*

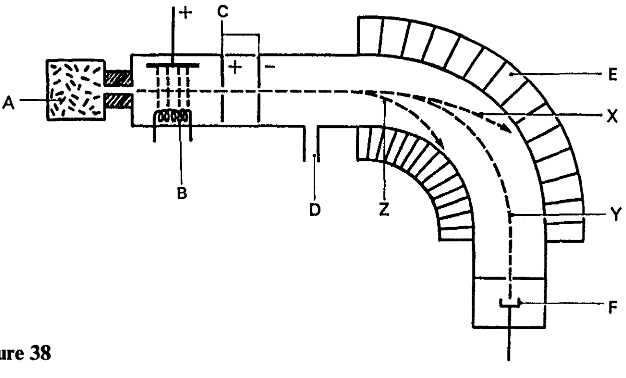


Figure 38

b The dotted lines X, Y, and Z represent the paths of particles when the specimen is a naturally occurring element. State briefly why X and Z differ from Y. **2**
What alteration must be made to the setting of the apparatus to bring the dotted arrow X nearer to the main dotted line Y? *1*

c Figure 39 represents the mass-spectrometer trace obtained for naturally occurring tungsten. Using values obtained from the trace, calculate the atomic weight of naturally occurring tungsten to four significant figures. *4*

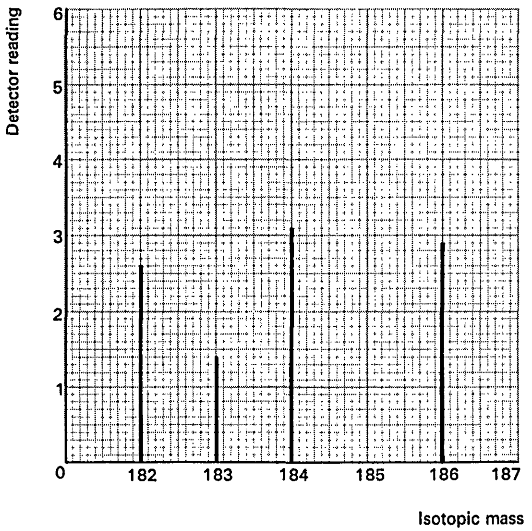


Figure 39

***31** Values for the atomic and ionic radii of the group II elements are shown in the following table:

Element	Atomic radius/nm	Ionic radius/nm
Beryllium	0.112	0.031
Magnesium	0.160	0.065
Calcium	0.197	0.099
Strontium	0.215	0.113
Barium	0.221	0.136

a Explain the increase in atomic radius in passing from beryllium to barium. 2

b Explain why the ion is, in every case, smaller than the atom from which it is formed. Write the formula of any ion which you would expect to be larger than its parent atom. *3*

c Which of the ions of the elements in group II would you expect to have the highest hydration energy? Give reasons for your answer. *3*

d Beryllium hydroxide is the only group II hydroxide which shows acidic as well as basic reactions.

i Write two equations to illustrate this behaviour.

ii Suggest a reason for this behaviour. *4*

***32** This question refers to the following thermochemical data. All values are given in kJ mol^{-1} (it may not be necessary to use all the data).

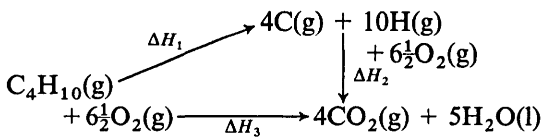
Bond energy term ($\bar{E}$) C—H	413
Bond energy term ($\bar{E}$) C—C	342
$\Delta H^\ominus$, $C(g) + O_2(g) \rightarrow CO_2(g)$	−1108
$\Delta H^\ominus$, $2H(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$	−721
$\Delta H^\ominus$, $C(s) + O_2(g) \rightarrow CO_2(g)$	−393
$\Delta H^\ominus$, $H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$	−285
$\Delta H^\ominus$, $H_2O(l) \rightarrow H_2O(g)$	44

Experimental value of $\Delta H^\ominus_{combustion}$ of methylpropane,

CH_3CHCH_3 (with CH_3 on the central carbon) −2857

a What is the standard enthalpy of formation of water? *1*

b Use the bond energy terms to deduce a theoretical standard enthalpy of atomization of methylpropane (ΔH_1, in the following energy cycle).



c Calculate from the above data ΔH_2 in the energy cycle. **2**

d From your answers to (b) and (c) deduce a theoretical value for $\Delta H^\ominus_{combustion}$ of methylpropane (ΔH_3 in the energy cycle). **2**

e Suggest one reason why the value of the experimental standard enthalpy of combustion of methylpropane differs from the theoretical standard enthalpy of combustion calculated in (d). **2**

***33**

a Give the structural formula for each of the following compounds. (The formulae should be abbreviated to the type: $CH_3CHClCH_2CH_3$.)

A sodium hexanoate
B 3-methylpenta-2,4-diene
C 4-bromo-2-methylpentan-1-ol
D 2-methylpentan-1,4-diol *4*

b Which one of the compounds would be the most likely starting point for the development of a new polymer? *1*

c Which one of the compounds would be most likely to leave a solid residue when it is strongly heated in air? *1*

d State briefly how C could be converted into D (the isolation of the product is not required). *2*

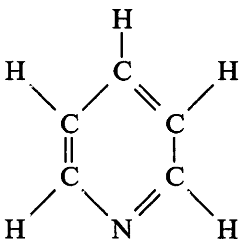
e *i* Which one of the compounds is most likely to be a solid at room temperature?

ii Briefly state the reasons for your answer. *3*

f If you were given unlabelled samples of B, C, and D, state briefly how you would quickly distinguish between them using the least number of tests and observations. *3*

***34** Cobalt(II) in aqueous solution can be determined by the following procedure:

i To the neutral solution add an excess of ammonium thiocyanate. Heat to boiling and add an excess of pyridine. The formula of ammonium thiocyanate is NH_4CNS and that of pyridine is



ii Stir the solution and cool to room temperature. Red crystals are precipitated.

iii The crystals are filtered by means of a porous crucible which has been previously weighed. They are then washed with a solution of pyridine and ammonium thiocyanate in water followed with solutions of pyridine in alcohol and ether.

iv The crystals in the crucible are dried in a vacuum desiccator and then weighed.

v The weight of cobalt is calculated using the formula of the crystals:
$[Co(C_5H_5N)_4](CNS)_2$

vi This determination of cobalt can be conducted in the presence of magnesium ions but not in the presence of copper ions.

Answer the questions which follow.

a What is the oxidation number of cobalt in the compound? *1*

b Through which atom and by what type of bond will the pyridine be attached to the cobalt? *2*

c Suggest a reason for the presence of pyridine in all the washing solutions. *2*

d What error might occur if ammonium thiocyanate were contained in the final washing solution? *2*

e Suggest a reason why the presence of copper ions in the original solution interferes with this determination and magnesium ions do not. *3*

***35**

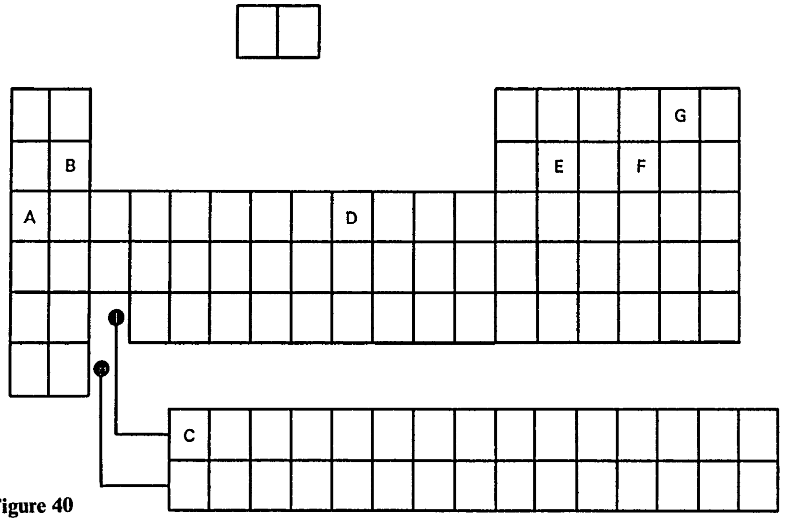


Figure 40

The positions of some elements are shown on the outline Periodic Table (figure 40) by letters: these letters are not the usual symbols for the elements.

a Classify the elements A, B, C, D, E, F, G into:
i s-block elements
ii p-block elements
iii d-block elements
iv f-block elements *3*

b The first eight ionization energies (kJ mol^{-1}) of one of the elements are:
999, 2253, 3386, 4539, 6939, 8485, 27 128, 31 768.
Which one of the elements, A, B, C, D, E, F, G is most likely to have these ionization energies? *1*
Briefly state the reasons for your choice. *3*

c For which one of the elements A, B, C, D, E, F, G is the following data most likely to be correct?
atomic number lies between 8 and 30
atomic radius = 0.125 nm
ionic radii = 0.063 nm and 0.078 nm *1*
Briefly give reasons for your choice. *3*

d Another element X has extreme oxidation states of −3 and +5. It forms stable hydrides in which it shows oxidation states of −2 and −3. Its hydrides form stronger hydrogen bonds with water than with each other.
In which position in the Periodic Table is this element most likely to be placed? **2**

e Two other elements, Y and Z, react together with a strongly exothermic reaction to form an ionic solid in which the proportions are 2 g-ions of Y to 1 g-ion of Z. Both Y and Z form hydrides; the hydride of Y is ionic but the hydride of Z is molecular with a large dipole moment.
In which position in the Periodic Table are these elements most likely to be placed? ***3***

***36** A student prepared some barium chromate by adding an excess of potassium chromate solution to a solution of barium chloride. Using the apparatus in figure 41, he filtered the precipitate, and washed it by running 1 cubic decimetre of water through it.

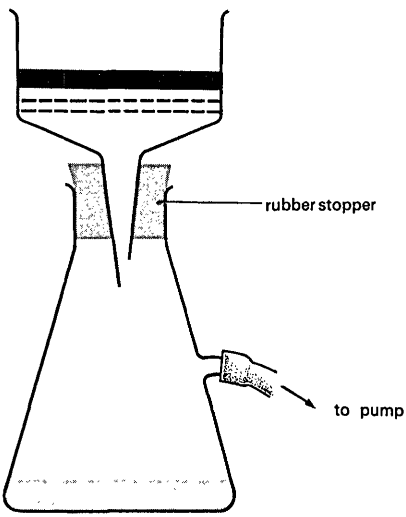


Figure 41

a Give one advantage of using this apparatus rather than gravity filtering. **2**

b Why is the stem of the filter funnel slightly tapered? **2**

c The student estimated that the washing process caused a loss in yield of 0.002 53 g (solubility product of $BaCrO_4 = 1 \times 10^{-10} mol^2\ dm^{-6}$ and 1 mole of $BaCrO_4$ weighs 253 g). Explain concisely why this was an overestimate. ***4***

c What change (if any) takes place in pressure when S_4 is formed from S_2, at constant volume and temperature? *1*

d Calculate the temperature at which $K_p = 1$. *1*

e Calculate K_p at 600 K. *2*

f Comment briefly, but critically, on the accuracy and limitations of the statement, 'At 1000 K sulphur vapour consists almost entirely of diatomic molecules.' *3*

***39** The protein salmin is obtained from certain salmon. The first step in the elucidation of its structure is hydrolysis followed by two-way paper chromatography of the resulting amino acids, the resulting chromatogram appearing as follows:

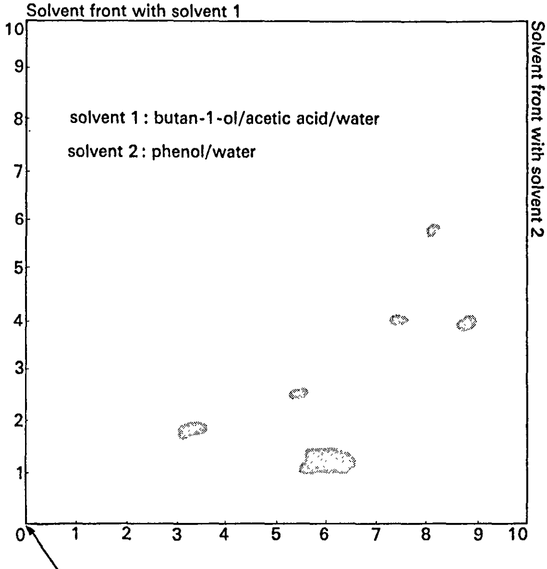


Figure 43

a Give a brief description of how the chromatogram was prepared, mentioning how the spots were made visible. *4*

b Using the following tables of R_f values for the two solvents, state which amino acids are present in the hydrolysate.

Amino acid	**Solvent 1**	**Solvent 2**
alanine	0.24	0.55
2-aminobutyric acid	0.28	0.58
arginine	0.13	0.60
glutamic acid	0.25	0.33
glycine	0.20	0.40
hydroxyproline	0.21	0.67
*iso*leucine	0.57	0.81
leucine	0.58	0.82
lysine	0.12	0.55
β-phenylalanine	0.50	0.86
proline	0.39	0.88
serine	0.19	0.34
taurine	0.12	0.33
threonine	0.21	0.49
tyrosine	0.38	0.62
valine	0.40	0.74

If you have reason to believe that a positive identification cannot reasonably be made in any instance, draw attention to this briefly. 5

Section C

Free response questions

These questions have been used either in the trial examinations or in the Nuffield A-level examinations; the latter (marked with asterisks) are reprinted by kind permission of the London University School Examinations Department.

1 'A typical covalent bond is that between the chlorine atoms in the chlorine molecule Cl_2; and a typical ionic compound is sodium chloride, Na^+Cl^-. Between these two extremes, however, there are a number of compounds with intermediate types of bond. In the case of most compounds, instead of speaking of *covalent* or *ionic* bonds, we should be more accurate in referring to the *degree of ionic or covalent character* of chemical bonds.'
Upon what evidence does the above statement depend?

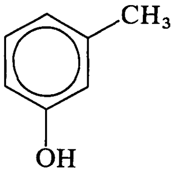
2 For any of the substances you have so far studied, describe one of its uses or applications which has interested you. Your choice may include the part played by the substance in human metabolism or in commerce or industry. As far as possible explain the principles involved in the application you describe.

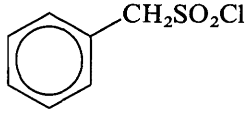
3 A student X suggests that an *alkali* is a substance that produces hydroxide ions, $OH^-(aq)$, on dissolving in water, while one of his colleagues, student Y, disagrees and insists that an alkali is any substance that will react with dissolved hydrogen ions.
Write a short script of the ensuing discussion between X and Y.

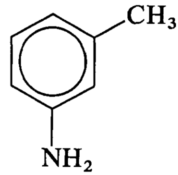
4 You will have spent a considerable time in studying the periodic classification (table) of the elements. Imagine that you have to convince a sceptical new entrant to sixth form chemistry that a study of the Periodic Table is *not* a waste of time. Describe how this study has helped you in your work in chemistry. Your answer should include some mention of the characteristics of *any* good classification, and you should give suitable examples of the usefulness of *this* classification.

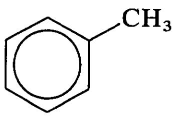
5 'Progress in chemistry owes as much to the engineers as progress in engineering owes to the chemists.'
In a few lines state concisely the implications which appear to lie behind this statement. Give an account of suitable evidence to *support* the statement.

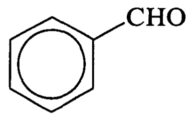
6 Suppose you were given the following five substances with no labels to identify them.

A 

B 

C 

D 

E 

Describe how you would establish the identity of each. There is no need to determine the formula of each, simply to distinguish between them. Choose a procedure which would enable you to identify each quickly. Lengthy analyses will not be suitable.
Outline the experimental procedure, state briefly what changes would take place, state what you would observe, and what inferences you would draw from the observations.

***7** 'The boiling point and molar heat of vaporization of molecular compounds increase with increasing molecular weight. This is because the forces between molecules increase with increasing molecular mass.'
Give a detailed opinion on the extent to which this is an accurate statement and explanation of the behaviour of molecular substances. Illustrate your answer with suitable examples.

***8** Phosphate ions (PO_4^{3-}), in the presence of chloride, bromide, and iodide ions, can be detected in aqueous solution by the following procedure:

a To the aqueous solution add dilute nitric acid and silver nitrate solution. Phosphate ions remain in solution.

b Centrifuge. Remove the supernatant liquid from any precipitate which has formed and place it in a narrow test-tube.

c Carefully add a solution of ammonia to the liquid. A pale yellow ring of silver phosphate, forming where the acidic and alkaline solutions meet, confirms the presence of phosphate ions.

With the aid of your *Book of data*, give a detailed explanation of what occurs in this test. At the end of your answer quote all the data which have a bearing on it. The solubility of silver phosphate is 0.000 65 g in 100 g of water at 20 °C.

***9** Describe the general principles of the way in which you investigated the chemistry of *either* nitrogen *or* sulphur. Give examples of some of the reactions you carried out, in each case stating clearly what you did, what you observed, and what deductions could be made from these observations.

***10** The applications and uses of several elements and their compounds are discussed in the *Students' book* (e.g. sodium, calcium, and magnesium; the halogens). *Either* choosing an element *or* choosing a group of elements (not necessarily a Periodic Table group) from those discussed in the *Students' book*, or that you have read about for yourself elsewhere, give an account of its (or their) applications or uses. Wherever possible you should include some description of the essential chemistry underlying the applications you describe.

***11** Suppose you had to investigate the rate of reaction of a single piece of natural limestone with a solution of carbon dioxide in water. This is a reaction which in nature requires many years for sufficient change to be observed. Describe how you would conduct an investigation – by experiment – of this reaction in a much shorter period of time.

***12** Use your *Book of data* to determine the lattice energy of strontium chloride. Show how you arrive at your answer.
A substance of formula $SrCl_3$ does not exist. What further energetics data would you need to explain this fact? Show how you would use the data.

***13** Solutions containing thiosulphate ions are said to be oxidized by bromine water according to the equation:

$$S_2O_3^{2-}(aq) + 4Br_2(aq) + 5H_2O(l) \rightarrow 2SO_4^{2-}(aq) + 8Br^-(aq) + 10H^+(aq)$$

You can assume you have the normal apparatus of a chemical laboratory available, but only the following substances:

sodium thiosulphate crystals, $Na_2S_2O_35H_2O$
bromine water
potassium iodide crystals
distilled water
starch solution
dilute sulphuric acid

Devise a scheme whereby you could show experimentally that the reaction is correctly (or otherwise) represented by the above equation, and give detailed instructions in the form in which you have usually been given them on undertaking an experiment (including the quantities to be used), to enable a student with roughly your experience to carry it out. You should indicate to him how the necessary calculations should be performed.

***14** One of the objectives of a modern chemistry course is that it should relate the study of the subject to its significance in everyday life. Discuss the extent to which you think that this objective has been achieved in the course you have followed.

Some aspects you might usefully consider are:

a The ways in which the investigational attitude might be of use to you in your ordinary life or work.

b The value that the knowledge you have gained might have as part of your general information as an educated adult.

c The extent to which knowledge of scientific method and materials can help people to understand better the technological civilization in which we live.

There may well be other aspects you would like to consider, and you may also wish to include discussion of ways in which the course could have achieved this objective more fully.

***15** The Ancients knew of the existence of very few of the elements; by 1831, 47 were known and now we are aware of 103. Use your *Book of data* as well as your own knowledge of chemistry, to discuss the reasons why man did not discover all the elements at roughly the same time. In your answer, attempt to generalize about the nature of the elements discovered at different periods of history.

***16** Use your *Book of data*, to discuss the extent to which a knowledge of the successive ionization energies of the elements can be of assistance to the chemist. In particular bring out the trends in various groups and discuss the sharp 'breaks' which occur in some sequences.

***17** Give a full account of an experiment you have performed to show that the route by which a chemical change is carried out makes no difference to the overall energy change involved.
Discuss the importance of this result for determination of standard enthalpies of formation of compounds, and explain the importance to the chemist of a knowledge of such values.

***18** Each item in the following list is an example of the way in which changes in matter can be brought about. Either by using some or all of the examples in the list, or by using your own examples, discuss precisely what you mean by a chemical reaction.

a The burning of magnesium in air
b The solution of zinc in dilute hydrochloric acid
c The interaction of hydrogen and iodine to form hydrogen iodide
d The addition of a little water to anhydrous copper sulphate
e The solution of hydrogen chloride in water
f The solution of hydrogen chloride in benzene
g The passage of an electric current through fused lead bromide
h The passage of an electric current through a copper wire
i The interaction of dilute solutions of barium chloride and sodium sulphate
j The melting of ice

***19** 'The motion before this House is that the scientists have been misleading us for the past 160 years. Matter is not particulate but continuous; there are no atoms and molecules but merely a continuum of matter throughout the universe.'

So reads the motion for a debate, and the chief points brought out by the Proposer are that:

a No one has ever seen an atom or a molecule.

b The wonderful photographs taken by electron microscopy (whatever that may be) and which the scientists say show the shadows of molecules, show merely a roughness of the surface of matter which anyone in their senses would expect when things are magnified so greatly.

c The scientists themselves are clearly confused about whether light is a wave motion or consists of little bundles of energy, whether electrons are particles or waves – why should we believe them to be right about the particulate nature of atoms and molecules?

d The scientist tells us to look at smoke particles under a microscope and asks us to believe that they move about because his molecules are knocking them about. Why should they not move about on their own as his atoms and molecules are supposed to?

e The scientists tell us that gases diffuse through space because of the rapid motion of the molecules, which increases with temperature. In the next breath they tell us that the sun is merely an immensely hot ball of gas. Why has this not diffused away centuries ago?

f They cloak their ignorance in ludicrously small dimensions like 0.000 000 01 cm, and fantastically large numbers like 602 000 000 000 000 000 000 000.

How can these values be measured or have any meaning to anyone?

g I could go on like this: the whole thing is a ludicrous fiction spread about by those know-alls who hide away in laboratories and think that they have solved the problems of the universe. I defy them to convince me or anyone else that matter is made up of particles. I know they will use long words to try to do so, but it is facts and evidence that I want to hear!

Write the leading speech for the Opposition.

***20** Describe how you would compare the rates of hydrolysis of chlorobenzene, C_6H_5Cl, and 1-phenyl-2-chloroethane, $C_6H_5{-}CH_2{-}CH_2Cl$. Predict the probable outcome of your investigation, explaining in detail the reasons for your prediction.

***21** Give a detailed explanation of the observations made in the experiment described below. You may discuss any aspects of the experiment or results which interest you, but your answer should include some mention of the changes which take place, the rate of the reaction, the type of reaction, and why the reaction took place. Use your *Book of data*.
Into each of four flasks 50 cm^3 of dilute acidified potassium dichromate ($K_2Cr_2O_7$) solution was put.

Each flask was treated as follows:

Flask	Treatment	Time for yellow colour to disappear	Temperature/°C
A	1 g of single piece of copper foil added and flask allowed to stand	24 hours	16
B	1 g of single piece of copper foil added and flask shaken continuously	1 hour	16
C	1 g of copper powder added and flask allowed to stand	15 minutes	16
D	1 g of copper powder added and flask shaken continuously	20 seconds	16

All four of the very pale blue solutions, which remained at the end of the experiments, could be shown to contain copper(II) ions.

***22** Describe a practical investigation in which you have shown that a reaction was of the first order with respect to one of its reactants. You may mention any matters which were of interest to you in the investigation, but your answer should include some account of

a The practical techniques, including any difficulties you may have encountered

b The nature of the reactions and how you followed their progress

c The results and how you used them to show that the reaction was of the first order.

***23** There has recently been some discussion on whether the *mole* should be accepted as one of the basic units of the International System of Units (SI units). Imagine that you had to state the case for the use of the mole as one of the basic SI units. You should explain in detail how the mole is defined and demonstrate its importance in its use in various aspects of chemistry.

***24** 'When an element in gaseous form is energized, it gives rise to a characteristic line emission spectrum.'
Describe the general form of the line emission spectrum of hydrogen. Explain the significance of the spectrum in terms of electron energy levels. Show how measurements of the spectrum of hydrogen can be used to calculate the ionization energy of hydrogen and compare your value for the ionization value with that given in the *Book of data*. You should use your *Book of data* and the following values for the Lyman Series of lines for atomic hydrogen:

Frequency/Hz
2.922×10^{15}
3.081×10^{15}
3.149×10^{15}
3.196×10^{15}
3.220×10^{15}
3.238×10^{15}
3.248×10^{15}

***25** 'The financial loss to the community (UK) caused by fires in 1965 is estimated at £413 000 000. Compounds of the halogen elements are playing a part in preventing or retarding fires and in extinguishing them once they have started.'
Describe how the compounds of the halogen elements do so, emphasizing the chemical principles which underlie their use in this role.

***26** You have been asked to advise on the production of a film loop. A film loop is a short film of up to about four minutes in length, usually silent, designed to give information about a single topic. It is usually accompanied by notes for the teacher which indicate suggested verbal comments to accompany each stage of the loop. Such loops are notably valuable for instruction in practical techniques and in this question you are asked to advise a technician on the production of a suitable loop for use in teaching students how to carry out one of the following operations:

a The purification of an organic liquid
b The purification of an organic solid
c The preparation and use of a thin-film chromatogram for the separation of a simple mixture of two coloured substances
d The determination of the molecular weight of a volatile liquid
e The setting-up and use of a hydrogen electrode.

You should divide your page(s) into three columns as follows:

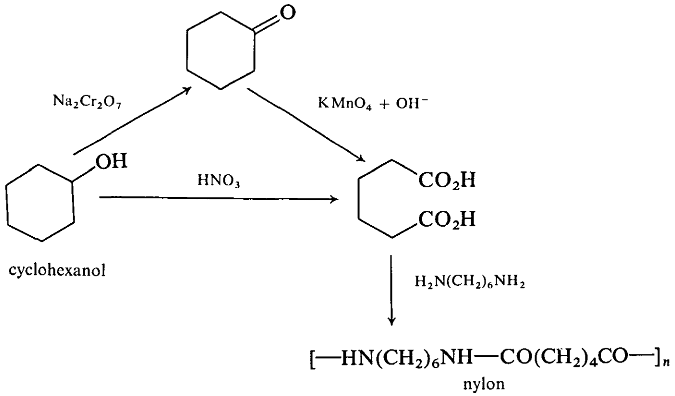
Time	Sequence to be shown visually	Outline notes for the teacher

At the end of each sequence you should rule a horizontal line right across the page and indicate the time. If you feel that the loop should be stopped at certain points for discussion of points of detail you should also indicate these.

***27** When the multistage synthesis of an organic compound is attempted in the laboratory many practical problems arise and in this question you are asked to discuss these problems in the case of ONE such synthesis. You will need to describe how the various operations are carried out, what difficulties there are and how they may be overcome, as well as the precautions that must be taken in order to ensure the maximum yield and a suitable degree of purity for the final product. You should indicate clearly the approximate quantities of materials used and the sizes of pieces of apparatus where this is appropriate.

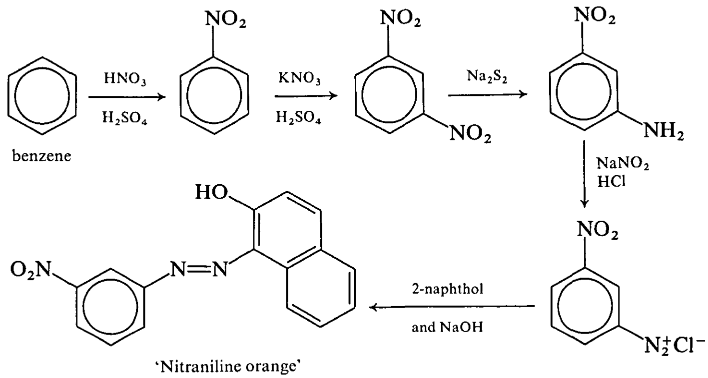
You may use as your example any one of the seven syntheses which are schematically outlined on the next two pages, or you may use an example of your own provided that it consists of at least two stages. If you choose your own example, you should precede your account with an outline scheme in a similar form to those which follow.

a



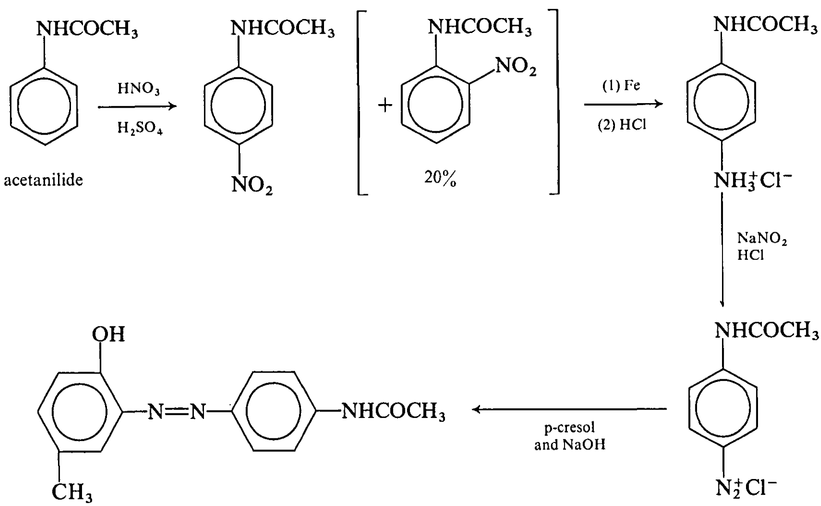
$Na_2Cr_2O_7$
$KMnO_4 + OH^-$
OH
HNO_3
CO_2H
CO_2H
cyclohexanol
$H_2N(CH_2)_6NH_2$
$[—HN(CH_2)_6NH—CO(CH_2)_4CO—]_n$
nylon

b



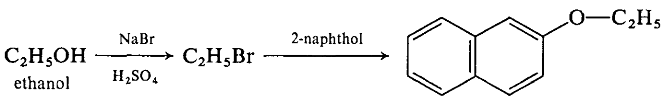
NO_2
HNO_3
H_2SO_4
KNO_3
H_2SO_4
Na_2S_2
NH_2
benzene
$NaNO_2$
HCl
HO
O_2N
N=N
2-naphthol
and NaOH
$N_2^+Cl^-$
'Nitraniline orange'

c



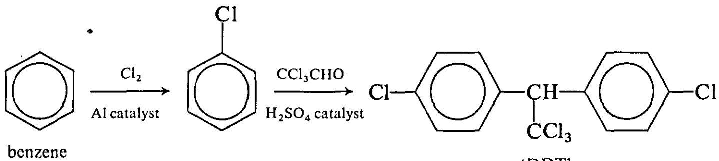
$NHCOCH_3$
HNO_3
H_2SO_4
NO_2
20%
(1) Fe
(2) HCl
acetanilide
$NH_3^+Cl^-$
$NaNO_2$
HCl
OH
N=N
p-cresol
and NaOH
CH_3
$N_2^+Cl^-$

d



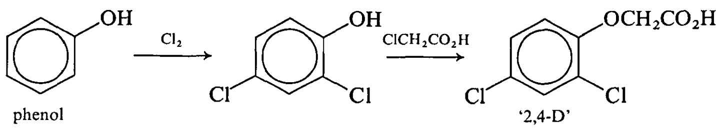
'Bromelia'

e



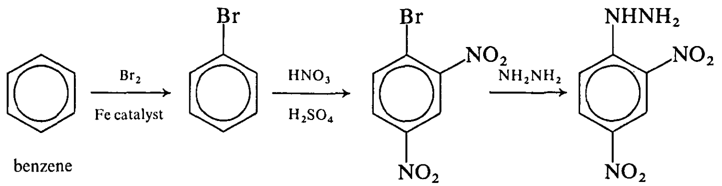
'DDT'

f



'2,4-D'

g



2,4-dinitrophenylhydrazine

***28** The following information describes experimental observations made on a white crystalline solid A. Use the observations to deduce what you can about the identity of A, and comment on each of the phrases in italics. Where possible you should indicate the precise nature of each change and relate it to the other changes described.

a A sample of A was heated strongly in a test-tube when a *colourless gas was evolved* and *a white solid residue* remained in the tube. After cooling, the residue was dissolved in water and the solution divided into two portions. Dilute sulphuric acid was added to the first portion when a *brownish gas was evolved* and *the solution became pale blue*: acidified potassium permanganate solution was added to the second portion and was *immediately decolorized.*

b A further sample of A was dissolved in water, made alkaline, and the solution boiled with aluminium powder when *a colourless gas was evolved*: this gas was mixed with an excess of air and passed over heated platinized asbestos which *continued to glow red even when the heat was removed.* The *brown gas formed on cooling the products of this reaction* was readily *absorbed by aqueous sodium hydroxide with the production of a colourless solution.*

***29** Use your *Book of data* to predict which reactions are possible and which are not between aqueous solutions containing bromine or bromide ions on the one hand and aqueous solutions of all the ions of compounds containing chromium on the other.
In each case you should show in detail how you decided whether or not a reaction was possible. Where reactions are possible, construct equations and show all the changes in oxidation state which take place. Indicate the limitation of your predictions and mention the other factors which can decide the possibility of a reaction taking place.

***30** The element zinc is sometimes considered as a d-block element and sometimes not. From your own knowledge of the properties of the d-block elements and their compounds and of the chemistry of zinc, discuss the extent to which its inclusion as a d-block element is justified. You will find at least 16 references to zinc in the *Book of data*, some of which will be helpful to you in your answer.

***31** One of the recommendations of the Government-sponsored Dainton Committee in 1968 was that 'Normally, all pupils should study mathematics until they leave school...' Imagine that you were being interviewed by a member of a similar committee for a future report on educational policy and had been asked 'Do you think that it would be desirable for us to recommend that all pupils should study chemistry until they leave school?' Decide how you would answer this question, giving a fully reasoned argument to support your answer.

Appendix 1

Specimen record cards for assessment of practical work

UNIVERSITY OF LONDON

(In association with all the G.C.E. Examining Boards)

GENERAL CERTIFICATE OF EDUCATION EXAMINATION

Nuffield Foundation Science Teaching Project

CHEMISTRY, ADVANCED LEVEL

Assessment of Practical Work

School Name .... Centre Number .... Name of Candidate .... Form and/or Set ....

Duration of course: September, 19 to July, 19

RECORD CARD NUMBER ....1.... of ....2....

ASSESSED EXPERIMENTS AND OTHER ASSESSMENTS	OBJECTIVES AND MARKS (SHOWING MAXIMUM)				
	1 OBSERVATION 25%	2 INTERPRETATION 15%	3 PLANNING 10%	4 MANIPULATION 30%	5 ATTITUDES 20%
2.2(c) Properties of chlorides	6/10	4/5			
5.3 Iodide/Iodate reaction				7/10 (accuracy)	
6.1(b) Reactions of some metallic elements	8/10	3/5			
7.2(b) Enthalpy of hydration			3/5 (Comment on sources of error)		
9.4(b) Preparation of phenyl benzoate				2/5 (yield) 4/5 (purity)	
General impression of manipulative skill (year end)				4/5 (speed) 3/5 (orderliness)	
General impression of attitudes to practical work (year end)					4/5 (routine) 4/5 (persistence)

SUMMARY

(Carried forward)	OBJECTIVES					TOTALS
	1	2	3	4	5	
MARKS						
SCALED MARKS						

....
Signature of teacher

Figure 44
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UNIVERSITY OF LONDON

(In association with all the G.C.E. Examining Boards)

GENERAL CERTIFICATE OF EDUCATION EXAMINATION

Nuffield Foundation Science Teaching Project

CHEMISTRY, ADVANCED LEVEL

Assessment of Practical Work

School Name .... Centre Number .... Name of Candidate .... Form and/or Set ....

Duration of course: September, 19 to July, 19

RECORD CARD NUMBER ....2.... of ....2....

ASSESSED EXPERIMENTS AND OTHER ASSESSMENTS	OBJECTIVES AND MARKS (SHOWING MAXIMUM)				
	1 OBSERVATION 25%	2 INTERPRETATION 15%	3 PLANNING 10%	4 MANIPULATION 30%	5 ATTITUDES 20%
10.2(a) Strength of hydrogen bond		3/5	5/10		
12.3 Solubility product of silver iodate				4/5 (accuracy)	
14.2 Rate of reaction			4/5 (recognition of errors)		
17.1 Reaction of thionyl chloride with hydrates	4/5	3/5			
17.3(a) Redox reactions	6/10		3/5 (prediction)		
18.3(a) Chromatographic separation of amino acids	4/5	2/5		3/5 (dexterity)	
General impression (year end)				4/5 (speed) 4/5 (orderliness)	4/5 (routine) 4/5 (enthusiasm)

SUMMARY

	OBJECTIVES					TOTALS
	1	2	3	4	5	
MARKS*	28/40	15/25	15/25	35/50	16/20	109/160
SCALED* MARKS	18/25	9/15	6/10	21/30	16/20	70/100

.... *Signature of teacher*

*Note: Marks should be totalled and scaled at the end of the course **only**, do **not** total and scale marks for each year and give the average scaled mark.

Figure 45

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Appendix 2

Specimen summary sheet for assessment of practical work

UNIVERSITY OF LONDON
(In association with all the G.C.E. Examining Boards)

GENERAL CERTIFICATE OF EDUCATION EXAMINATION
Nuffield Foundation Science Teaching Project
CHEMISTRY, ADVANCED LEVEL
Summary of Assessment of Practical Work

School .... Centre Number*.............. Form and/or Set..............................

Duration of Course: September, 19 to July, 19

Candidate Number*	Name and Initials	Total Mark /100

* Insert the University of London Centre or Candidate Number for the examination; these should be known at the time this form is submitted, otherwise the relevant spaces may be left blank.

Note: A separate form should be used for each teaching set.

Teacher's signature .... Date ....

Figure 46
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Appendix 3

Item analysis

It has been mentioned earlier that one of the advantages of objective tests is that they lend themselves to a quantitative analysis of the results. In the A-level examination itself items are pre-tested by trials on a sample of students. The results of the pre-tests are analysed by computer and the information so obtained is used by the examiners when they assemble Paper I in the A-level examination. Pre-testing is rarely worth while for internal tests devised by teachers themselves. What teachers can do, however, is to analyse the results of their tests, determine how each item and the test as a whole functioned, and then select those items which functioned well for use in future tests.

There are three main pieces of information which item analysis yields:

1 The facility of each item; that is the percentage of candidates who answered correctly.

2 The discrimination of each item; that is the degree to which the item discriminated between the good and not so good candidates.

3 The extent to which each incorrect response acted as a distractor.

The following table is an example of the analysis of an item given in Section A (multiple choice number 6).

Responses	A	B	C	D	E	Omits
Numbers	3	29	149	9	25	1
Proportion	0.014	0.134	0.690	0.042	0.116	0.005
Top fifth		1	41		2	
Next top fifth		4	35	1	3	
Middle fifth		6	29		7	1
Next bottom fifth	1	7	28	3	4	
Bottom fifth	2	11	16	5	9	

216 candidates divided into five groups of approximately equal size according to their performance in the whole test.

Facility Index 0.69 (69 per cent of the candidates chose the correct response C).

Discrimination Index Those who did well in the test as a whole (top fifth) also did well in this item and those who did badly in the test as a whole did badly in this item. Therefore, the item discriminates between candidates in the same way as the whole test does: there is a positive correlation between performance in the item and performance in the test.

There are several ways in which this correlation can be worked out. In the trial examinations and in the A-level examinations it is done by a rather complex formula called a biserial correlation. For the item used in the example the biserial correlation was +0.539.

A less complex formula, more suitable for use in internal tests, is to subtract the number of candidates in the *bottom third* who answered correctly from the number of candidates in the *top third* who answered correctly and then divide by one third of the total number of candidates. For the example quoted above this simplified discrimination correlation would be approximately: $\frac{58 - 30}{72} = +0.4$.

There are no firm rules for deciding the lowest discrimination coefficient which is acceptable, but a reasonable lower limit would be +0.2 for internal tests.

Non-functioning Responses It can be seen from the analysis table that only 3 of the 216 candidates chose response A. Response A did little towards its function as a distractor and, if the item were to be used again, it might be advisable to change it. It could be changed, for example, to barium iodate, but if this were done it would almost certainly change both the facility index and the discrimination index.

Index

The first part of this book contains a detailed account of the system of assessment used in the Nuffield Advanced Chemistry course, a system which involves several new techniques. It includes chapters on the purpose of assessment, the written examination, the assessment of practical work, and the construction of tests for internal use.

The second part of the book contains a large selection of the various types of questions, objective, structured, and free response, which are used in the assessment.

Organizer,
Advanced Chemistry
E.H.Coulson

Author of this book
J.C.Mathews

Published by Penguin Education

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