Scottish Certificate of Education

Standard Grade Revised Arrangements in Chemistry

General and Credit Levels in and after 1999

STANDARD GRADE ARRANGEMENTS IN CHEMISTRY

Publication date: April 2000

Published by the Scottish Qualifications Authority

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Introduction

This document sets out the arrangements for examinations in Standard Grade Chemistry which have been developed in the light of a two-stage consultation exercise carried out between November 1995 and February 1997. The consultation initially sought the views of interested bodies and presenting centres on a range of alternative models for assessment of Practical Abilities in the sciences and latterly on proposed amended arrangements.

Examinations in Chemistry at General and Credit Levels based on these Arrangements will be offered in and after 1999.

Section 1

Aims and Course Objectives

1 Aims and Course Objectives

1 1 Aims

Standard Grade Chemistry is a course designed for a wide ability range of pupils. The course contributes to their general education by helping to make them aware of the applications of chemistry/science in everyday life. An additional aim is to provide a suitable base for further study, for training or for work. It is hoped to develop positive pupil attitudes through success and enjoyment in the subject.

The essence of scientific enquiry is problem solving. Thus, in common with the other sciences, the course aims to develop the skills necessary to find solutions to problems.

1 2 Course Objectives

1 2 1 To fulfill the aims of the course, the following objectives have been identified.

1 2 2 Knowledge and Understanding

Pupils should be able to demonstrate their knowledge and understanding of:

- some chemical facts, ideas and techniques
- some applications of Chemistry in society.

1 2 3 Problem Solving

Pupils should be able to demonstrate their abilities in problem solving in Chemistry by:

- handling and processing information
- evaluating procedures and information, making predictions, and drawing conclusions.

1 2 4 Practical Abilities

Pupils should be able to demonstrate:

- basic abilities
- procedural abilities
- investigative abilities.

1 2 5 Attitudes

Pupils should:

- be open-minded and willing to recognise alternative points of view
- develop an interest in science, in themselves and in their environment
- be aware that they can take decisions which affect the well-being of themselves and others, and the quality of their environment.

Section 2

The Course

2 The Course

2 1 Course Structure

Standard Grade Chemistry is described in terms of a number of topics, as shown below.

Topics

1 Chemical Reactions
2 Speed of Reactions
3 Atoms and the Periodic Table
4 How Atoms Combine
5 Fuels
6 Structures and Reactions of Hydrocarbons
7 Properties of Substances
8 Acids and Alkalis
9 Reactions of Acids
10 Making Electricity
11 Metals
12 Corrosion
13 Plastics and Synthetic Fibres
14 Fertilisers
15 Carbohydrates and Related Substances

Whilst the topics are listed in one logical learning sequence, teachers may modify this as they wish.

Guidance on the Chemistry content of the topics is given by the Learning Outcomes in Section 6.

It is assumed that the teaching time for the two-year Chemistry syllabus is at least 60 weeks, with a minimum weekly allocation of 160 minutes, ie a total of 160 hours. The amount of content of the course is limited to help teachers develop in pupils the skills and practices required by Standard Grade courses and also to allow adequate time for both informal and formal assessment.

The Learning Outcomes, which describe the Knowledge and Understanding content of the course, are written at two Levels. Pupils' ability should not be pre-judged at the start of the course. Initially, therefore, all pupils should be given the opportunity to tackle Learning Outcomes at both Levels. As pupils progress through the course, decisions may be required about whether or not to confine some pupils only to the General Level Outcomes.

2 2 Consequences for Teaching: Methods, Organisation and Resources

2 2 1 Methods

The course has a wide range of objectives, to cater for pupils of widely varying abilities who will learn in a range of different ways; because of this, variety in teaching and learning approaches and resources becomes almost a necessity. It is hoped that Chemistry laboratories will become (or remain) bright, busy and cheerful places featuring appropriate (and changing) visual wall displays, regular use of molecular models, the microcomputer as a familiar tool, audio and video tapes, and games and simulations.

2 2 1 *(continued)*

The course followed by each pupil should be sufficiently challenging to develop his or her abilities but should be appropriately tailored to give regular experience of successful achievement. The demands of this requirement on the professional skills of Chemistry teachers are recognised. Some of these demands could, in part at least, be satisfied by the support to be found in various forms of cooperative teaching, including working alongside teachers with special expertise in the area of learning difficulties.

It will, of course, be for teachers and schools to decide how the new course is to be presented. Nevertheless, the aim should be to place emphasis on the pupils being agents of their own learning; consequently, teachers should devise a variety of tasks and problems which pupils will find worthwhile. The study of Chemistry offers many opportunities to use support materials and equipment of all kinds to set up a resource base for pupil use. This does not imply that pupils should usually work on their own; there is considerable merit in encouraging groups of two or three pupils to cooperate with each other in a learning situation, and class presentations and discussions could make valuable contributions.

Nevertheless, if pupils from a wide range of abilities are to be catered for, the teaching of Standard Grade Chemistry will need to be distinguished by certain key features; none of these is new and each currently contributes to enterprising teaching. These features which are concerned with the acquisition of knowledge of content, the use of language and the nature of practical activities are as follows.

a) Content

Standard Grade Chemistry contains chemical content that is considered worth knowing; the course does not underestimate the importance of that content. However, the content is not to be received, and then to lie inert in the recipient's head; it has to be used in a variety of ways. In particular, the learner should be asked to make use of the content in acquiring the scientific skills involved in problem solving and practical experimentation.

b) Language

Chemistry teachers have shown an ever-increasing awareness of the importance of language in teaching and learning. The continued development of this concern for language is strongly encouraged. In teaching Standard Grade Chemistry, it is hoped that teachers will use language which facilitates pupil understanding, plan to encourage purposeful pupil talking and listening, and give due emphasis to reading and writing both within the class and as part of any homework set.

c) Practical activity

Standard Grade Chemistry should involve a grate deal of pupil activity. This does not mean that pupils are always to be physically active; much appropriate activity is mental. However, one of the features of the study of chemistry has always been the essential place it gives to practical, experimental work. The value of such work in stimulating interest and enjoyment in the subject is well recognised. Some of the other reasons for doing practical work are: to clarify and promote understanding; to develop hand skills, to test hypotheses; and to encourage both creative and critical thinking.

2 2 1 *(continued)*

The assessment of practical abilities for certification (see 4 7) is intended to enhance the status of experimental skills in the learning of Chemistry at school level. However, it is not expected that all practical work will be assessed.

Three different types of practical work which should be included are as follows.

i Illustrative experiments

The purpose of these is to make knowledge more memorable or understanding more likely. They could be pupil experiments, pupil demonstrations to other pupils, or pupil-assisted demonstrations by the teacher. In addition, there remains a place for skilfully presented teacher demonstrations; on occasion this is the safest, most economical and most effective approach.

ii Techniques

The purpose of these is to familiarise pupils with a type of practical activity that has a clear and important place within the normal study of Chemistry and to develop abilities such as following an extended set of instructions. These are familiar experiments where pupils receive guidance. An essential feature is that the procedures or instructions are given. It is important not to undervalue the abilities required to follow a chemical procedure safely, with skill and to a satisfactory conclusion.

iii Investigations

Pupils should be encouraged to exercise initiative by carrying out some experiments which demand more than just "recipe following". Practical problem-solving exercises of this type may be short-lived and could be based on modifications of existing illustrative experiments. They can motivate and involve pupils of all abilities. At a basic level, for example, pupils might be asked to identify "unknown" samples by chemical tests or compare the neutralising power of antacid tablets. Such experiments will typically involve them in selecting or designing appropriate procedures, deciding what to record and drawing conclusions. More protracted and structured investigations, of factors affecting the rates or outcomes of chemical reactions, for example, will involve pupils in a broader range of scientific skills including hypothesising, controlling variables, handling and presenting data, evaluating and reporting. It is through these more extended studies that pupils' investigative skills will be formally assessed, but opportunities for investigative tasks at all levels should be injected regularly throughout the course to increase variety and interest and to ensure adequate practice in the relevant skills.

2 2 2 Organisation

In every class there will be pupils of different abilities and pupils who achieve success in learning at different rates; in some classes the differences may be very great. Teachers will be free to decide how this matter can be addressed effectively, but this must be done within a framework which best meets the needs and interests of individual pupils.

The content of the course has been divided into 15 short topics. One purpose of the short topic format is to allow teachers the opportunity to adopt short-term, self-pacing methods where they believe that these are more appropriate to the topic. A measure of resource-based learning is desirable in order to cater for different needs and speeds of learning.

The major aim should be to ensure a planned variety of teaching approaches throughout the course. Interactions between pupils and teacher should include opportunities to explore an individual pupil's understanding, to stress and interlink key concepts and to emphasize everyday applications of Chemistry. Integrated formal/informal assessment of practical abilities may help to avoid the need to have mass practical assessment with consequent effect on pupils' attitudes towards practical work.

2 2 3 Resources

Initiating a resource-based approach involves substantial costs and is very demanding on both staff and technician time.

As far as apparatus and chemicals are concerned, it is not anticipated that Standard Grade Chemistry will require a substantial increase in the financial allocation for apparatus and chemicals, although some forms of resource-based learning are more expensive in this regard than others. It is desirable that micro-computers should be used more extensively for learning, for teaching, for assessment and for the production of teaching materials; this would have cost consequences. The other major additional costs in a move to more independent learning will be in the areas of storage, paper, printing and reprographic facilities.

2 2 4 Support materials

Teachers are referred to the following memoranda, which are available from the Scottish Consultative Council on the Curriculum, (formerly from the Scottish Curriculum Development Service) and are still relevant and helpful.

Memorandum No 37	Units, Symbols and Terminology for Science and Engineering.
Memorandum No 43	Language in Chemistry.
Curriculum Support Series booklet No 5	Nomenclature.
Memorandum No 64	Resource-based Learning.

The Central Support Group on Chemistry, together with Local Authority working groups, has provided a wide range of materials to support teachers in the implementation of Standard Grade Chemistry, including pupil materials, teachers' guides and exemplar items for assessment.

Section 3

Assessable Elements

3 Assessable Elements

3 1 Knowledge and Understanding

The structure of the presentation of course content for Knowledge and Understanding is set out under topic headings. Each topic is described in detail in Section 6 using the following format.

3 1 1 Introduction

This provides a brief description of, and justification for, the chemistry of each topic. It highlights opportunities to relate the content to everyday life and draws attention to aspects of teaching methods.

3 1 2 Learning Outcomes

These describe, in terms of pupil performance, the knowledge and understanding required at General and Credit Levels. The Learning Outcomes are a compromise between a large number of specific objectives and a few general statements; because of this, teaching should not be limited to a literal interpretation. In other words, the Learning Outcomes should not be seen as prescribing the experiences to which the pupils should be exposed throughout the course, but rather as indicating the knowledge and understanding expected at each Level.

The action words used, eg "state" or "explain", are intended for teachers' guidance, to build up a picture of expected performance. Thus "state" is a signal that pupils would be expected to find words for themselves if questioned about their knowledge and/or their understanding of that particular section of the course. This should help teachers to structure appropriate learning tasks; pupils should not be asked to learn by rote Learning Outcomes introduced by the requirement "state".

For example, in Topic 6 "Structures and Reactions of Hydrocarbons", one of the Learning Outcomes is:

"state that fractional distillation of crude oil yields more long chain hydrocarbons than are useful for present-day industrial purposes."

This could be assessed in a number of ways, for example:

- pupils could be given information about the industrial process and be expected to use the words "fractional distillation" in their answers
- pupils could be told that cracking is an important process in the oil industry used to produce small useful molecules from the products of fractional distillation and asked why this is necessary
- pupils could be asked if fractional distillation in itself supplies all the products the oil industry needs.

The examples given are not intended to be exhaustive: other variations are possible.

3 1 3 Symbols, Formulae and Equations

For each topic, opportunities for developing the skills of using chemical symbols are provided.

These opportunities are not tied to particular Learning Outcomes and they serve only as indication of where this work is carried out. Teachers will wish to take every opportunity to consolidate these aspects during classroom work. Attention is drawn to the SCCC Curriculum Support Series booklet No 5: "Nomenclature".

3 1 4 Activities

Activities are listed to relate to the course objectives to be assessed, ie Knowledge and Understanding, Problem Solving and Practical Abilities, and each activity is cross-referenced to a particular Learning Outcome or Outcomes. These Activities are only suggestions, and teachers may supplement these with activities of their own choosing, or substitute appropriate alternatives.

Where teachers elect to introduce an activity not listed, they should seek opportunities to overtake a very important aim of the course which is to make pupils aware of the social and industrial applications of Chemistry in everyday life. It is hoped that teachers will feel free to draw on features which reflect the pupils' environment and be prepared to modify their presentations as important social aspects change, eg the possible disappearance of lead form petrol. In the external question papers some open-ended questions may be set to give pupils opportunities to display their awareness of the importance of Chemistry in their own locality.

Activities for Problem Solving and Practical Abilities should also contribute to the development of Knowledge and Understanding.

3 1 5 Development of Knowledge and Understanding

The importance of introducing a variety of teaching and learning approaches which encourage pupils to take responsibility for their learning, has been emphasised in 2 2 1. Chemistry teachers have long been aware that knowledge and understanding can be extended or consolidated through practical work, including practical investigations, and it will be appropriate for aspects of this element to be developed in the context of the other two.

3 2 Problem Solving

3 2 1 Abilities

One of the stated objectives of the course is that pupils should develop the skill of applying Knowledge and Understanding to solve problems. An analysis of what pupils need to be able to do for success in Problem Solving is presented as a list of abilities. Situations set up to develop or assess these abilities will require candidates to consider evidence, make judgements and come to decisions. The abilities set out below are common to both Levels.

Selecting information

1 selecting relevant information from different sources, including data books, picture keys, flowcharts, tables, bar and line graphs, pie charts, or diagrams;

Presenting information

2 constructing tables of data and suggesting appropriate headings

3 constructing bar and line graphs when scales and axes are not given

4 selecting a suitable format for the presentation of data;

Selecting procedures

5 choosing an appropriate procedure from a given selection

6 suggesting, using words or labelled diagrams, an appropriate experimental procedure

7 choosing, from a given selection, a factor which might affect the fairness of a test

8 identifying factors which might affect the fairness of a test;

Concluding and explaining

9 drawing an appropriate conclusion from chemical information, including experimental results

10 deducing valid explanations of results and conclusions;

Predicating and generalising

11 using a conclusion to predict what might happen in a related situation

12 deducing an appropriate generalisation.

3 2 2 Rationale for the Approach Adopted

The initial attempts to state Extended Grade Related Criteria for Chemistry in terms of the abilities identified foundered for two reasons. Since it proved impossible to write easy or difficult questions for each ability, the abilities of themselves could not be allocated satisfactorily to one Level or the other; for example, although choosing a procedure from a given selection appeared initially to be easier than suggesting a procedure, in practice the context established the level of difficulty. Similarly, attempts to refine individual abilities by adding a qualifying phrase, such as “in a familiar context”, failed to function effectively. Questions devised to assess the ability proved to be differentiated by a range of qualifying phrases, eg assessing the ability to draw a conclusion can be made easier or more difficult by varying differentiating criteria such as the familiarity of the context, the number of steps involved and the complexity of the information.

3 2 2 *(continued)*

It became clear therefore that the abilities could only be grade related if they were considered alongside a list of differentiating criteria. The combination of an ability with one or more of these criteria forms the Extended Grade Related Criteria for this element (see 5 9).

3 2 3 It is acknowledged that the tasks being presented to the teacher are challenging but the in-service provision and the materials to be supplied as a result of the work of the Central Support Group for Chemistry will assist teachers in implementing this aspect of the course.

3 3 Practical Abilities

Details of the various abilities and the techniques which enable these to be assessed are set out in 4 7 (page ?).

Section 4

Assessment for Certification

4 Assessment for Certification

4 1 Certification

A grade for attainment in each element will be recorded on the Certificate, together with an overall grade awarded for the course derived from the mean of the element grades with a weighting of 2:2:1 in favour of the externally assessed elements.

For Chemistry, grades will be awarded on the scale 5 to 1, with Grade 1 denoting the highest performance. Grade 6 is not available for an element, but may be gained in the overall aggregate award. Grade 7 is available (see 4 5 below).

4 2 Assessment Scheme

The assessment of pupil performance in the three elements Knowledge and Understanding, Problem Solving and Practical Abilities will be carried out with reference to the Extended Grade Related Criteria defined for each of these elements.

Knowledge and Understanding, and Problem Solving will be assessed externally by a written examination.

Practical Abilities will be internally assessed, with external moderation.

4 3 External Assessment

Two external papers will be offered, designated General, assessing Grades 4 and 3, and Credit, assessing Grades 2 and 1. 1½ hours will be allowed for each paper.

The number of questions in each paper will be approximately equally distributed between Knowledge and Understanding and Problem Solving. Both papers may contain multiple-choice items, grid questions, short-answer questions and extended-answer questions. Grade 5 will be awarded to candidates who narrowly fail to meet the criteria for General Level.

Marks will be allocated to each question and a total mark obtained for the appropriate element. The two grades associated with each Level will be distinguished by setting two cut-off scores. The lower score (in the region of 40-50%) will reflect a satisfactory overall standard of performance, the upper score (in the region of 70-80%), a high overall standard of performance.

4 4 Presentations for External Papers

Candidates may attempt papers at both Levels, but are not obliged to do so. However, they should be made aware that, other than as the result of an appeal, they can only be awarded for the Knowledge and Understanding and Problem Solving one of the grades assessed by the paper(s) attempted, or Grade 5 or 7.

Candidates who attempt papers at both Levels will be given the better of the two grades achieved on the external papers. Performance at one Level will **not** be taken into account in grading at the other Level.

4 5 Grade 7 and No Overall Award

For any element, Grade 7 will indicate that the candidate has, in the element concerned, completed the course but has not fulfilled the requirements for Grade 5 or better.

The Scottish Qualifications Authority (SQA) will regard the submission of an estimate grade for an externally assessed element as evidence that the course has been completed in that element.

Candidates who have not complied with the assessment requirements in any element (eg due to unauthorised absence from the external examination) will be deemed not to have completed the course in that element. Such candidates **will not receive a grade** for that element and hence **will not receive an overall award** for the subject. In such cases, however, if a grade is gained for any other element, that grade will be recorded on the Certificate.

4 6 Internal Assessment and Estimates

4 6 1 Introduction

Candidates should be assessed in each of the three assessable elements at appropriate points throughout the course, with greatest weight given to work done towards the end of the course.

For the SQA's purposes, centres will be required to provide:

- an estimate of performance for each of Knowledge and Understanding and Problem Solving; and
- a grade for Practical Abilities.

4 6 2 Estimates for Knowledge and Understanding and for Problem Solving

Presenting centres must submit to the SQA, by 31 March of the year of the examination, an estimate grade for each candidate for each of Knowledge and Understanding and Problem Solving. The teacher should determine the estimate grades on the basis of each candidate's actual work. Estimates may be used by the SQA for its internal procedures, including such cases as absence from external examinations, adverse circumstances and appeals. Evidence in support of these estimates should be retained by centres for submission to the SQA if required.

It is for each centre to decide which testing procedure or combination of procedures should be used to provide the estimates of performance in the two elements.

4 7 Internal Assessment of Practical Abilities

It is anticipated that candidates embarking on a Standard Grade Chemistry course will have a well-established repertoire of basic practical skills. These basic skills have been identified as observing, recording, following instructions, measuring, manipulating and procedural skills.

4 7 *(continued)*

Within Standard Grade Chemistry, there are two categories of practical ability, namely:

a) techniques;

b) investigations.

4 8 Techniques

For assessment purposes, ten techniques, considered to be the most appropriate vehicles for the assessment of the key abilities, have been grouped as shown in the table below.

Group A	Group B	Group C	Group D	Group E
1 Bubbling gases into solutions and observing changes	1 Filtration	1 Mixing substances and observing changes	1 Titrations	1 Preparing compounds by neutralis-ation and evaporation
2 Electrolysing solutions	2 Collecting a sample of gas over water, when the gas has been produced by chemical reaction	2 Carrying out solubility tests		2 Distillation
3 Heating solids and observing changes				

It should be noted that the SQA will not accept the substitution of techniques as alternatives to those listed. However, chemicals different from those indicated in the support package distributed by the Scottish Consultative Council on the Curriculum may be used.

While opportunities should be given throughout the course to experience techniques, for certification purposes only, **one** technique from each of Groups A-E should be undertaken by candidates. Assessment of individual techniques can take place at any appropriate time during the course.

4 8 *(continued)*

The relationships of the ten specified techniques to the key abilities are shown in the following table.

	Techniques									
	A1	A2	A3	B1	B2	C1	C2	D1	E1	E2
	Bubbling gases into solutions and observing changes	Electrolysing solutions	Heating solids and observing changes	Filtration	Collecting a sample of gas over water, when the gas has been produced by chemical reaction	Mixing substances and observing changes	Carrying out solubility tests	Titrations	Preparing compounds by neutralisation and evaporation	Distillation
Abilities										
1 Following instructions	–	–	–	–	–	–	–	–	–	–
2 Selecting all the required items of apparatus	–	–	–	–	–	–	–	–	–	–
3 Setting up all the apparatus safely	–	–	–	–	–	–	–	–	–	–
4 Carrying out any necessary calibrations and zeroings								–		
5 Manipulating apparatus correctly and safely	–	–	–	–	–	–	–	–	–	–
6 Making observations and measurements	–	–	–			–	–	–		
7a Recording observations and measurements in an appropriate format – writing	–	–	–						–	
7b Recording observations and measurements in an appropriate format – constructing tables of data						–	–	–		
7c Recording observations and measurements in an appropriate format – drawing labelled diagrams	–	–	–	–	–					–
8 Supplying and using common units of measurement								–		
9 Measuring with precision appropriate to the technique								–		
10 Completing calculations								–		

4 9 Guidance on the Assessment of Techniques

4 9 1 General points

The following general points relating to the undertaking of techniques should be noted:

- candidates should be encouraged to draw clear sectional, labelled diagrams. The quality of drawing can be assessed in conjunction with the question – "Would the experiment work as drawn?" Rulers and/or stencils must be used. Cut-out diagrams are not acceptable
- tabled of results must have appropriate headings
- experiments should be written up in class
- all colour changes should include original and final colours
- while undertaking techniques for assessment purposes, candidates must not have access to teachers' checklists
- candidates must wear eye protection when carrying out techniques.

4 9 2 Specific points

The following notes of specific guidance relate to each of the ten techniques.

A1 **Bubbling gases into solutions and observing changes**

There is no need to identify the gas(es). One gas passed into two test solutions or two gases passed into a test solution would be acceptable.

A2 **Electrolysing solutions**

The diagram (key ability 7c) should be labelled to show positive and negative electrodes. The products, which need not be named, should be described either by noting on the diagram or in the written account.

A3 **Heating solids and observing changes**

Two changes must be observed eg heating copper carbonate and noting the colour change of the solid and the effect of the gas produced on lime water. Alternatively heating two compounds (eg copper carbonate and cobalt chloride) and noting the colour in each solid.

B1 **Filtration**

The diagram (key ability 7c), as a minimum, should be labelled to show residue, filtrate, funnel and paper. The residue and filtrate need not be named.

B2 **Collecting a sample of gas over water, when the gas has been produced by chemical reaction**

The diagram (key ability 7c) should show the reaction vessel, the method of delivery and the method of collecting the gas. The reactant(s) should be named.

C1 **Mixing substances and observing changes**

Three distinct experiments should be conducted. Chemicals which react at room temperature may be used.

C2 **Carrying out solubility tests**

The candidates should test three chemicals. Careful choice of chemicals is necessary. The results should be recorded as "soluble" or "insoluble" rather than as a rank order of solubility.

D1 **Titrations**

Candidates should be provided with standardised solutions. It is advisable to use a strong base/strong acid reaction.

The table of results should show the rough titre and titration necessary to achieve concordancy (within ± 0.2 cm^3 of the actual value).

Rogue results should be discarded.

Key ability 10 – "Completing calculations" – is satisfied by the subtraction of the initial and final volumes and averaging. Appropriate units should be used.

Two titration of accuracy to ± 0.2 cm^3 of each other should be obtained.

In order to ensure this level of accuracy, it may be helpful to have adequate volumes of standardised solutions stored in small bottles.

E1 **Preparing compounds by neutralisation and evaporation**

Candidates should provide a written report to include the neutralisation, filtration and evaporation stages.

The candidate should name the reagents used and their products and describe any crystals produced. The description should include colour and shape.

E2 **Distillation**

It is recommended that distillation should be carried out on a solution of a food dye. This will make it easier to assess the effectiveness of the distillation. Candidates should build the apparatus required from a kit.

4 9 3 Marking

For each of the techniques in Groups A, B and C a maximum of 6 marks can be awarded. For each technique in Groups D and E a maximum of 9 marks can be awarded. Thus, a total of 36 marks is available for assessment of Techniques.

In each of the techniques, safety should count for 1 mark and should cover the wearing of goggles and clearing up any spills without having to be so instructed. The remaining marks available for the different techniques should be awarded on the following basis.

For techniques in Groups A, B and C, 3 marks are allotted to the manipulative aspects such as collecting, setting up and manipulating the apparatus and 2 marks are available for the write-up.

For techniques in Groups D and E, 5 marks are allotted to the manipulative aspects and 3 marks are available for the write-up.

Single marks should be deducted for each error or omission. It should be noted that there is no barrier to the techniques being repeated if desired.

Evidence to substantiate the marks awarded should include candidate material which identifies the techniques assessed and the key abilities demonstrated within each. Supporting materials in the form of records and results for each candidate should also be retained. Candidate-generated reports should be dated and initialised by the teacher. It should be noted that teachers' checklists alone will not constitute adequate evidence. Evidence should be retained for possible submission to the SQA in connection with moderation procedures.

Evidence submitted by a centre may be based on the same techniques for all candidates. Some presenting centres may have good organisational reasons for restricting the range of techniques used for formal assessment purposes, whereas other centres will have arrangements which allow assessment of individual candidates on different techniques.

4 10 Investigations

4 10 1 The investigative skills objectives are grouped under four headings, as follows:

i Generative Skills (G);

ii Experimentation Skills (E);

iii Evaluation Skills (Ev);

iv Recording and Reporting Skills (RR).

Two investigations, each covering all of the investigative skills objectives should be submitted for the purpose of assessment for certification. At least one of the investigations must involve a continuous variable.

The investigative skills objectives, together with the related assessment criteria and mark allocations for Standard Grade Chemistry, are set out in the table which follows.

Investigative Skills Objectives and Assessment Criteria

TAPS Investigative Skills Objective The candidate should be able to:	**Assessment Criteria and available marks**	**Marks Total**
G1 demonstrate understanding of the problem posed;	Following group discussion, the candidate individually identifies and records an investigable aspect of the problem (1,0)	1
G2 state the aim of the investigation;	Clearly identifies the aim of the investigation in terms of the two relevant variables (1,0)	1
G3 articulate a testable hypothesis;	Articulates a testable hypothesis in terms of the two relevant variables; this should be directional if a continuous variable is chosen (1,0)	1
G4 suggest a broad strategy to adopt;	The strategy gives sufficient detail by description and/or diagram to indicate: *a)* how the chosen independent variable will be altered (1,0) *b)* that the candidate has considered what will have to be measured (1,0)	2
E1 adopt appropriate and safe procedures;	Adopts appropriate and safe procedures (1,0)	1
E2 identify the independent variable to be used and alter it over a suitable range;	*a)* Provides a working definition of the independent variable (1,0) *b)* Alters the independent variable over an appropriate range taking account of a suitable number of types or values (1,0)	2
E3 control all relevant variables as necessary;	*a)* Makes a written statement of the variables which need to be actively controlled by the candidate (1,0) *b)* Controls these variables in practice (1,0)	2
E4 make valid, reliable measurement of the dependent variable;	*a)* Uses a valid method of measuring the dependent variable (1,0) *b)* Evidence is provided of a form of repeat/replicate testing which improves the reliability of the results **or** a valid written justification is given for not repeating/ replicating measurements (1,0)	2
RR1 tabulate results with appropriate headings and units of measurement;	*a)* Values (or types) with appropriate headings for independent, dependent (and any derived) variable are entered in the table (1,0) *b)* Appropriate units or their correct abbreviations are entered in the table (1,0)	2

Investigative Skills Objectives and Assessment Criteria *(continued)*

TAPS Investigative Skills Objective The candidate should be able to:	**Assessment Criteria and available marks**	**Marks Total**
RR2 present the results on a graph or chart;	*a)* A graph or chart of a suitable size and scale is produced (1,0) *b)* Both axes have appropriate labels and units (1,0) *c)* Plots all the points/bars accurately (1,0) *d)* Draws line/curve of best fit or joins up the points as appropriate when the independent variable is continuous **or** draws a bar chart when independent variable is not continuous (1,0)	4
Ev1 draw a valid conclusion inter-relating the appropriate variables;	Draws a conclusion which inter-relates the appropriate variables or states that no firm conclusion can be drawn (1,0)	1
Ev2 use results to evaluate the original hypothesis;	Confirms hypothesis if appropriate **or** refutes hypothesis and replaces it with appropriate substitute **or** states that no conclusion can be drawn (1,0)	1
RR3 describe how the investigation was carried out.	The description includes: *a)* a labelled diagram and/or statement of the apparatus used; (1,0) *b)* an account of the procedure adopted to measure the dependent variable; (1,0) *c)* an account of how the independent variable was altered; (1,0) *d)* an indication of how variables which were the investigators' responsibility to control were kept constant (1,0)	4

4 10 2 Structure of investigations

During the course, candidates should be given opportunities to undertake a number of investigations, each of which involves demonstration of the thirteen specified skills objectives. Investigations for certification purposes should be carried out and written up in class time. The progress and achievement in investigations should be recorded in the investigation booklet issued by the SQA. **That booklet must be used for all investigations conducted for the purposes of assessment for certification.**

4 10 3 Conduct of investigations

It is expected that at the outset of the investigation teachers will stimulate class or group discussion. Subsequent to the discussion, if the candidate is unable to meet the criterion for G1, the teacher should give assistance to enable the pupil to proceed but will not award the mark allocated to this Objective. In the case of a candidate who identifies a relevant investable aspect which cannot be investigated within the constraints of the school situation, the candidate should be directed to other alternatives without penalty. Should a candidate fail to meet a criterion associated with Objective G2, G3 or G4, it is permissible for the teacher to intervene and give sufficient support to enable the candidate to proceed, but the mark allocated **to the relevant criterion** will not be awarded.

After the generative phase (Objectives G1, G2, G3 and G4), candidates must be left to pursue the investigation independently. Teacher intervention in the post-generative phase is permitted only when the candidate fails to adopt standard, safe laboratory practice. In such a case, the mark allocated to the criterion for Objective E1 is forfeited.

Investigations undertaken by candidates should be assessed on the basis of the above mark scheme. In awarding marks for each objective, only those marks indicated in the mark scheme may be given. For certification purposes, the final mark should be the sum of the scores for the candidate's **two** best investigations to give a score out of 48.

4 10 4 Grade for Practical Abilities

For each candidate, **a total score for Practical Abilities should be determined by multiplying the mark awarded for techniques by 2 and adding it to the mark awarded for investigations**. The overall grade for the element should then be determined by reference to the following table.

Marks range	Grade
106-120	1
91-105	2
78-90	3
66-77	4
53-65	5

Candidates for whom there is evidence in support of at least one technique or investigation and who achieve an overall total of less than 53 marks should be awarded a Grade 7 for Practical Abilities.

Annually, the SQA will provide presenting centres with details of the arrangements for the submission of internal assessments of Practical Abilities for all candidates.

4 11 Moderation of Internal Assessments

To ensure the uniform application of the Extended Grade Related Criteria for Practical Abilities, each year a sample of presenting centres will be required to submit to the SQA evidence in support of internal assessments for a sample of candidates. Where a centre's internal assessments cannot be confirmed, the centre will be required to carry out assessment as necessary.

Section 5

Grade Related Criteria

5 Grade Related Criteria

5 1 Definition

Grade Related Criteria (GRC) are descriptions of performance against which a candidate's achievement is measured. Direct comparisons are not made between the performance of one candidate and that of another.

5 2 Application of GRC

For each element, GRC are defined at two Levels of performance: General and Credit. Two grades are distinguished at each Level, Grades 4 and 3 at General Level and Grades 2 and 1 at Credit.

Grade 5 is available for candidates who narrowly fail to reach the standard of performance required for Grade 4. Grade 7 will be awarded to candidates who have completed the course but have not fulfilled the requirements for Grade 5 or better. Grade 6 will not be available for an element.

5 3 Types of GRC

Summary GRC are broad descriptions of performance. They are published as an aid to the interpretation of the profile of attainment by candidates, parents, employers and other users of the Certificate.

Extended GRC are more detailed descriptions of performance. They are intended to assist teachers in making their assessments for each element, and to be used by examiners when conducting external assessment.

5 4 Knowledge and Understanding – Summary GRC

General Level (Grades 4, 3)

The candidate has demonstrated knowledge and understanding of chemical facts, ideas, terminology, symbols, equations, chemical structure, and of some related applications of chemistry in society.

Credit Level (Grades 2, 1)

The candidate has demonstrated knowledge and understanding of complex chemical facts, ideas and terminology, of symbols, equations and chemical structure, of some theoretical generalisations and of related applications of chemistry in society.

5 5 Problem Solving – Summary GRC

General Level (Grades 4, 3)

The candidate has demonstrated ability to solve problems by obtaining and presenting information, drawing conclusions, explaining, predicating and generalising. Each skill involves choosing an appropriate procedure and using few thinking stages.

5 5 *(continued)*

Credit Level (Grades 2, 1)

The candidate has demonstrated ability to solve problems by obtaining and presenting information, drawing conclusions, explaining, predicting and generalising. Each skill involves choosing an appropriate procedure and using several thinking stages.

5 6 Practical Abilities – Summary GRC

General Level (Grades 4, 3)

The candidate has demonstrated ability to carry out a range of practical chemical techniques and to carry out chemical investigations with a degree of competence.

Credit Level (Grades 2, 1)

The candidate has demonstrated ability to carry out a wide range of practical chemical techniques and to carry out chemical investigations with a high degree of competence.

5 7 Descriptions of Grades

These describe performance within Levels. They apply to all elements.

Grade 5 Judged by the criteria for General Level, the candidate has demonstrated a significant but not satisfactory overall standard of performance.

Grade 4 The candidate has met the criteria for General Level, demonstrating a satisfactory overall standard of performance.

Grade 3 The candidate has met the criteria for General Level, demonstrating a high overall standard of performance.

Grade 2 The candidate has met the criteria for Credit Level, demonstrating a satisfactory overall standard of performance.

Grade 1 The candidate has met the criteria for Credit Level, demonstrating a high overall standard of performance.

5 8 Knowledge and Understanding – Extended GRC

General Level (Grades 4, 3)	Credit Level (Grades 2, 1)
Knowledge and understanding are recognised by the candidate being able to attain a majority of the General Level Learning Outcomes.	Knowledge and understanding are recognised by the candidate being able to attain a majority of the Credit Level Learning Outcomes.

Descriptions of grades are given in **5 7**.

5 9 Problem Solving – Extended GRC

The combination of the abilities listed and accompanying differentiating criteria are the Extended GRC for this element

THE ABILITIES ASSESSED ARE AS FOLLOWS:

Selecting information

1 selecting relevant information from different sources, including data books, picture keys, flowcharts, tables, bar and line graphs, pie charts, or diagrams;

Presenting information

2 constructing tables of data and suggesting appropriate headings
3 constructing bar and line graphs when scales and axes are not given
4 selecting a suitable format for the presentation of data;

Selecting procedures

5 choosing an appropriate procedure from a given selection
6 suggesting, using words or labelled diagrams, an appropriate experimental procedure
7 choosing, from a given selection, a factor which might affect the fairness of a test
8 identifying factors which might affect the fairness of a test;

Concluding and explaining

9 drawing an appropriate conclusion from chemical information, including experimental results
10 deducing valid explanations of results and conclusions;

Predicting and generalising

11 using a conclusion to predict what might happen in a related situation
12 deducing an appropriate generalisation.

At General Level, candidates should be able to demonstrate these abilities when one or more of the following differentiating criteria are involved:

A the level of knowledge and understanding is based on General Level Learning Outcomes

B the amount of data/ information is small

C the data/information are simple

D the data/information are presented in a way that does not require re-ordering

E the number of steps required to show the ability is small

F the data/information are set in a familiar context

G the number of dependent variables is small

H the relationship between the variables is easy to recognise

I some guidance is given.

At Credit Level, candidates should be able to demonstrate these abilities when one or more of the following differentiating criteria are involved:

A the level of knowledge and understanding may be based on General or Credit Level Learning Outcomes

B the amount of data/ information is large

C the data/information are complex

D the data/information are presented in a way that require re-ordering

E the number of steps required to show the ability is large

F the data/information are set in an unfamiliar context

G the number of dependent variables is large

H the relationship between these variables may be difficult to recognise

I guidance may not be required.

Descriptions of grades are given in **5 7**.

5 10 Practical Abilities – Extended GRC

	Abilities	General Level (Grades 4, 3)	Credit Level (Grades 2, 1)
		The candidate has demonstrated these abilities by being able to:	The candidate has demonstrated these abilities by being able to:
a)	Carry out techniques	carry out successfully a proportion of the specified techniques.	carry out successfully a high proportion of the specified techniques.
b)	Carry out chemical investigations	carry out chemical investigations, demonstrating competence in a proportion of the specified skills objectives.	carry out chemical investigations, demonstrating competence in a high proportion of the specified skills objectives.

Descriptions of grades are given in **5 7**.

Section 6

Learning Outcomes

6 Learning Outcomes

The following are the outcomes related to symbols, formulae and equations which are to be developed throughout the course.

GENERAL LEVEL (Grades 4, 3)	CREDIT LEVEL (Grades 2, 1)
Pupils should be able to:	and in addition to:
1 write correct formulae from models or given molecular pictures	work out formulae for compounds involving at least one of the following complexities:
2 work out formulae for compounds, using the Data Book, eg NaC1, $AlBr_3$, Al_2S_3 including • compounds with prefixes mono-, di-, tri-, tetra- • compounds involving groups but not requiring brackets, eg Na_2SO_4	work out formulae for compounds involving at least one of the following complexities: • using brackets where appropriate • working from Roman numerals eg for $Fe_2(SO_4)_3$
3 identify state symbols applied to species	using ion changes where appropriate
4 apply state symbols to species	
5 write an equation using symbols and formulae from a sentence description or a word equation with sufficient information to have all the reactants and products but not balancing the equation	write balanced equations
6	calculate the mass of a reactant or production in a reaction, using balanced equations
7	identify spectator ions in equations and rewrite omitting these ions, eg $H^+ (aq) + OH^- (aq) \rightarrow H_2O (l)$.

Topic 1: Chemical Reactions

Introduction

This introductory topic should contain regular reference to, and observation of, "real-life" chemistry. Our world is a chemical world; all materials in that world are chemicals. Chemical reactions are commonplace everyday occurrences: the burning of gas in a cooker, the rusting of cars, the hardening of glues, the digestion of food and so on. Reference should also be made to the work of chemists in developing materials which affect our way of life, although great care needs to be exercised in widening pupils' view of Chemistry from the experience in this topic. Reference to lists of materials produced by chemistry-based industries may serve to confuse rather than elucidate.

An understanding of the nature of chemical reaction should be developed through appropriate practical work: chemical reactions are identified through changes in appearance and detectable energy changes and involved the formation of one or more new substances.

The distinction between compounds and mixtures should be made and the concept of solution introduced in simple terms.

There should be a gradual introduction of the chemical nomenclature of elements and compounds, and of the symbols for elements.

Topic 1: Chemical Reactions **Learning Outcomes**

GENERAL LEVEL (Grades 4, 3)	CREDIT LEVEL (Grades 2, 1)
Pupils should be able to: 1 identify a chemical reaction by a change in appearance of substance 2 identify a chemical reaction by a detectable energy change 3 state that all chemical reactions involve the formation of one or more new substances 4 give examples of chemical reactions which occur in our day-to-day lives 5 state that everything in the world is made from about 100 elements 6 state that each element has a name and a symbol 7 state that compunds are formed when elements react together 8 state that mixtures occur when two or more substances come together without reacting 9 state that a solution is formed when a solute dissolves in a solvent 10 apply the general rules: the compounds with the name ending in "ide" contain the two elements indicated, and that the ending "ite" or "ate" indicates the additional element oxygen.	
<u>Symbols, formulae, equations</u> *a)* Awareness of the use of symbols for elements. Teachers should take account of the differing types of symbols eg H, N, O, S compared with Mg, Cr, Zn compared with Na, K, Ag. *b)* For particular reactions, word equations might help with the concept of chemical reaction, eg carbon + oxygen → carbon (di)oxide	

ACTIVITIES

Activities to assist the development of knowledge and understanding

4 Present audio-visual material, highlighting the importance of commonplace chemical reactions in the production of everyday materials.

5, 6 Examine Periodic Chart showing a photograph of each element.

5, 6 Examine samples of as many elements as possible.

Activities to develop skills of problem solving

4 Carry out library project on the variety of uses/economic importance of particular compounds.

5, 6 Obtain and present information from Data Book, book, wall chart or computer file.

8 Prepare list of some everyday substances which are mixtures.

9 Prepare a list of some everyday solutions.

Opportunities to develop practical abilities

1, 4 Carry out a selection of experiments, eg burn magnesium, heat copper carbonate, react calcium with water, react iron filings with copper sulphate solution, add dilute hydrochloric acid to a suitable metal or carbonate. Some everyday examples should be included, eg epoxy resin glues, striking a match, sherbet.

1, 4 Long-term exposure of iron, aluminum or copper to the air (see Topic 12).

2 Repeat some of the above, noting temperature changes. Include a reaction where there is a temperature change but no change in appearance, eg add dilute acid to a dilute alkali.

7 Investigate reacting elements, eg carbon, iron, with oxygen.

8 Investigate some mixtures, eg iron and sulphur, salt and sand.

9 Prepare dilute, concentrated and saturated solutions of, eg, copper sulphate, alums.

9 Determine quantitatively the solubility of a substance.

Topic 2: Speed of Reactions

Introduction

This topic should be based firmly on practical experiments in which variables that affect the speed of chemical reactions are investigated: particle size, concentration and temperature. These variables should be discussed in relation to real-life examples which are familiar to pupils. The concept of catalysis is introduced.

As in the previous topic, appropriate practical skills should be encouraged and good at-the-bench techniques established. There is a clear place for a practical investigation.

Topic 2: Speed of Reactions **Learning Outcomes**

GENERAL LEVEL (Grades 4, 3)	CREDIT LEVEL (Grades 2, 1)
Pupils should be able to: 1 describe how the following affect the speed of a reaction: • particle size • concentration • temperature 2 give examples of reactions (both laboratory and everyday) affected by the following: • particle size • concentration • temperature 3 state that catalysts are substances which: • speed up some reactions • are not used up during the reaction • can be recovered chemically unchanged 4 give everyday examples of uses of catalysts, eg transition metals in car exhaust systems.	

ACTIVITIES

Activities to assist the development of knowledge and understanding

1 Demonstrate a wide range of reactions which occur at a variety of speeds, eg the effect of particle size on burning of wood (block, stick and sawdust); reaction of iron in flame as metal bar, steel wool, filings.

Relate common everyday reactions such as making toast, making wine, rusting, formation of oil, firing caps for toy guns.

2 Discuss a wide range of chemical reactions including everyday examples; low temperature food storage, pressure cooking, rusting of car exhausts compared to underside of car.

Activities to develop skills of problem solving

1, 2 Obtain and present information on factors which influence the speed of a chemical reaction.

2, 3 Present experimental data in the form of tables and graphs.

4 Obtain and present information on use of catalysts in the motor car and other industries.

Opportunities to develop practical abilities

1 Carry out a range of experiments which occur at a variety of speeds, eg acid + metal; acid + carbonate; heating carbonates (copper carbonate); precipitations.

1 Use micro computer in comparing graphs of concentration and particle size.

2 Investigate the effect of particle size, temperature and concentration in the reaction of dilute acid on calcium carbonate. The control of variables should be emphasised.

3 Investigate the effect of a catalyst on the rate of reaction, eg decomposition of hydrogen peroxide with/without manganese dioxide.

Topic 3: Atoms and the Periodic Table

Introduction

This topic should further encourage pupils' awareness of the wide variety of chemicals that make up our material world; chemists have identified more than six million compounds which are made from only about one hundred elements.

The activities suggested should develop pupils' knowledge of different methods of classification and their usefulness.

At General Level, the Learning Outcomes are based on:

- the application of certain terms
- Periodic Table, period, group, atom, ion, the classification of elements in different ways according to their properties
- the allocation of the elements to the Periodic Table based on their Atomic Number
- the idea of gradation in size and mass of atoms
- some understanding of electron arrangement.

At Credit Level, in addition, the Learning Outcomes require knowledge of certain sub-atomic particles, Mass Number, electron arrangement, isotopy and the ability to manipulate Atomic Number, Mass Number and nuclide notation in terms of numbers of neutrons, protons and electrons.

GENERAL LEVEL (Grades 4, 3)	CREDIT LEVEL (Grades 2, 1)
Pupils should be able to:	and in addition to:
1 classify elements in different ways, eg naturally occurring/made by scientists; solid/liquid/gas; metal/non-metal	
2 state that chemists have classified elements by arranging them in the Periodic Table	
3 state that a group is a column of elements in the Periodic Table	
4 state that elements in one group of the Periodic Table show similar chemical properties	
5 identify the following families of elements: • the halogens • the alkali metals • the noble gases • the transition metals	
6 state that noble gases are a family of very unreactive elements	
7 state that every element is made up of very small particles called atoms	
8 describe the atom as having a vary small positively charged nucleus with negatively charged electrons moving around outside the nucleus	describe the location and charge of the proton, neutron and electron
9	state the relative masses of the proton, neutron and electron
10 state that an atom is neutral because the positive charge of the nucleus is equal to the sum of the negative charges of the electrons	state that an atom is neutral because the numbers of protons and electrons are equal
<u>Symbols, formulae, equations</u> Listing groups of "similar" elements using names and symbols.	

Topic 3 *(continued)*

ACTIVITIES

Activities to assist the development of knowledge and understanding

1, 2 View appropriate audio-visual material on Periodic Table; prepare Periodic Table showing physical state of elements.

4 Demonstrate reaction of Group 1 metals with water and air, eg Na and Li.

Activities to develop skills of problem solving

1, 5 Obtain and present information on classification of elements; use of Periodic Table in Data Book.

4, 5 Predict, given the properties of an unknown element, the position of that element in the Periodic Table.

8 Use computer assisted learning programme (CAL) for information retrieval to assist in compiling the Periodic Table.

7, 8 Obtain and present information on Rutherford's scattering equipment.

Opportunity to develop practical abilities

2 Use flame tests to identify elements.

Topic 3: Atoms and the Periodic Table *(continued)*

GENERAL LEVEL (Grades 4, 3)	CREDIT LEVEL (Grades 2, 1)
11 state that atoms of different elements are different and have a different number on the Periodic Table called the atomic number	state that atoms of different elements have a different number of protons, called the atomic number
12	state that the electrons in an atom are arranged in energy levels
13 state the electron arrangements of the first 20 elements	
14 explain the structure of the Periodic Table in terms of the atomic number and chemical properties of the elements	
15 state that elements with the same number of outer electrons have similar chemical properties	
16	state that an atom has a mass number which equals the number of protons plus neutrons
17	calculate the number of n, p and e from the mass number and atomic number, and vice versa
18	calculate the number of n, p and e from nuclide notation, including ions, eg $^{37}_{17}Cl^-$
19	state that most elements exist as a mixture of isotopes
20	state what is meant by isotopes
21 state that atoms of different elements vary in size and in mass	state what is meant by relative atomic mass
22	explain why the average atomic mass of an element is rarely a whole number.

ACTIVITIES

Activity to assist the development of knowledge and understanding

14 Use appropriate audio-visual material on Periodic Table.

Activities to develop skills of problem solving

11, 16 Use computer assisted learning programme (CAL) on structure of the atom, n, p and e.

11, 16 Draw and label diagram of atoms showing distribution of sub-atomic particles.

17, 18 Carry out exercises based on recognising isotopes and use of nuclide notation.

21 Find relative atomic masses in Data Book.

Opportunities to develop practical abilities

21, 22 Carry out analogy experiment, eg weighing a number of similar objects, such as adjacent sized rubber bungs; note that difference in masses of individual isotopes leads to the adoption of a weighted average number for the unit mass.

Topic 4: How Atoms Combine

Introduction

This topic requires extensive and imaginative use of models, pictures and audio-visual material. Pupils need help to understand that atoms are held together by bonds, and that the breaking of some bonds and the forming of new ones account for chemical change. Opportunities should be provided to write simple formulae for two-element compounds; this activity could flow from familiar practical work, from molecular models, and from information in the Data Book.

At General Level, the idea of covalent bonding between atoms is developed, leading to molecules and formulae.

At Credit Level, in addition, some knowledge of forces of attraction is required and the ability to represent diagrammatically the covalent bond and the shape of simple two element molecules.

GENERAL LEVEL (Grades 4, 3)	CREDIT LEVEL (Grades 2, 1)
Pupils should be able to:	and in addition to:
1 state that atoms can be held together by bonds	state that atoms can achieve a stable electron arrangement
2 describe the covalent bond in terms of atoms sharing pairs of electrons	
3 state that a molecule is a group of atoms held together by covalent bonds	explain the covalent bond as a situation in which two positive nuclei are held together by their common attraction for the shared pair of electrons
4 state that the chemical formula gives the number of atoms of each element in a molecule of a covalent substance	
5 state that (usually) only atoms of non-metal elements bond to form molecules	
6 state that a diatomic molecule is made up of two atoms	
7 give examples of elements which exists as diatomic molecules	
8	draw a diagram to show how the outer electrons form a covalent bond
9	draw diagrams to show the shape of simple two-element molecules.

Symbols, formulae, equations

a) For many pupils, this topic will provide the first opportunity to represent compound material in chemical symbols. Some rules about combining-ratio are required. Concrete support should be given by the use of molecular modules.

b) The idea of state symbols may be introduced.

ACTIVITIES

Activities to assist the development of knowledge and understanding

1, 2 Use models, eg ring magnets, balloons, etc.

4 Write formulae of covalent molecules eg HC1, H_2O, NH_3, CH_4.

Activities to develop skills of problem solving

3, 4 Use molecular models to illustrate the relationship between formula and structure.

8 Use diagrams to show how outer electrons form covalent bonds.

9 Use diagrams to show the shape of simple two element molecule, eg HC1, etc.

Topic 5: Fuels

Introduction

This topic is concerned with fossil fuels and, because of its international importance, the emphasis has been placed on oil, including its formation, refining and uses. The topic has been described in chemists' terms but teachers are urged to make every effort, in this topic above all others, to create a learning context which reflects the importance of the oil industry in Scotland. On the principle that bad news makes good copy, the media have often given publicity to adverse aspects of oil product consumption, eg oil spillage or the pollution from the products of combustion. As chemists, teachers should grasp the opportunity to highlight the outstanding positive contribution oil technology has made to the quality of our lives; teachers should also illustrate how chemists have often solved problems when the social will was there to provide the financial support.

At General Level, the Learning Outcomes are based on:

understanding of the ideas of fuel and combustion; awareness of the finite nature of fossil fuels, understanding how to separate crude oil into useful fractions; understanding the reasons for some types of pollution and possible solutions to this.

At Credit Level, in addition, understanding of combustion and fractional distillation at a molecular level is required.

Topic 5: Fuels Learning Outcomes

GENERAL LEVEL (Grades 4, 3)	CREDIT LEVEL (Grades 2, 1)
Pupils should be able to: 1 state that a fuel is a chemical which burns giving out energy 2 state that combustion is a reaction of a substance with oxygen, giving out energy 3 state the test for oxygen 4 state that the main components of air are oxygen and nitrogen in proportion of 1:4 5 state that an exothermic reaction is one in which energy is released 6 state what is meant by finite resource and fuel crisis in relation to the amount of coal, oil and natural gas in the earth 7 state what is meant by a fossil fuel 8 describe the formation of coal, oil and natural gas 9 give examples of the pollution problems associated with oil and coal and explain their occurrence	and in addition to:

Symbols, formulae, equations

a) A study of combustion leads to the equation:

$$C + O_2 \rightarrow CO_2$$

The change from element to compound provides further opportunity to compare atom and molecule.

b) The idea of the balanced equation may be introduced:

$$CH_4 + O_2 \rightarrow CO_2 + H_2O$$
$$+ O_2 \quad + H_2O$$

ACTIVITIES

Activities to assist the development of knowledge and understanding

5 Illustrate bond making, bond-breaking steps, using models.

6, 8 Invite a speaker; use audio-visual material to illustrate formation of crude oil, discuss finite resources of fossil fuels, the importance of conservation, economic aspects.

9 Demonstrate mixing crude oil and water.

Activities to develop skills of problem solving

6, 7 Obtain and present information from written or other sources on coal, oil and natural gas.

9 Present, in a variety of ways, information on pollution associated with crude oil.

Opportunity to develop practical abilities

1 Demonstrate the burning of coal (Arculus).

Topic 5: Fuels *(continued)*

GENERAL LEVEL (Grades 4, 3)	CREDIT LEVEL (Grades 2, 1)
10 state that crude oil is a mixture of compounds	
11 state that substances have specific melting points and boiling points	
12 state that a fraction is a group of compounds with boiling points within a given range	
13 state that fractional distillation is the process used to separate crude oil into fractions	
14 explain why fractions can be separated by distillation	
15 state what is meant by: • flammability • viscosity	
16 give examples of how the products of fractional distillation of crude oil can be used	state the typical range sof chain length of the molecules in each fraction and relate this to their use
17 describe how each of the following varies for fractions of different boiling points: • evaporation • flammability • viscosity	explain in terms of molecular size the change in each of the following: • boiling point • flammability • viscosity
18 state that the chemical compounds which are found in oil and natural gas are mainly hydrocarbons	
19 state that a hydrocarbon is a compound which contains hydrogen and carbon only	
20 state the tests for carbon dioxide and water	

ACTIVITIES

<u>Activity to assist the development of knowledge and understanding</u>

10-18 Use appropriate audio-visual material on oil industry to illustrate industrial production and the variety of oil products.

<u>Activity to develop skills of problem solving</u>

10-18 Obtain and present information on fractional distillation using table, graphs or diagrams; draw diagram of fractionating column.

<u>Opportunity to develop practical abilities</u>

12, 17 Investigate fractional distillation of simulated crude oil; test fraction; compare (i) evaporation rate, (ii) flammability, (iii) viscosity.

Topic 5: Fuels *(continued)*

GENERAL LEVEL (Grades 4, 3)		CREDIT LEVEL (Grades 2, 1)
21	state that hydrocarbons burn completely to produce only carbon dioxide and water	explain why the production of carbon dioxide and water, on burning, indicates the presence of carbon and hydrogen in the original fuel
22	state that carbon, and carbon monoxide, a poisonous gas, are produced when the hydrocarbons burn in a supply of oxygen which is insufficient for complete combustion	
23	state that the burning of some fuels releases sulphur dioxide, a poisonous gas, to the atmosphere	
24	state that removing sulphur compounds reduces air pollution	
25	state that nitrogen and oxygen from the air react inside a car engine to form nitrogen oxides (poisonous gases)	
26	state that lead compounds which are added to petrol cause pollution	
27	state that air pollution from the burning of hydrocarbons can be reduced by special exhaust systems or by altering the fuel to air ratio	explain that transition metal catalysts can convert the pollutant gases to harmless gases
28		explain that decreasing the fuel to air ratio improves the efficiency of combustion thus decreasing pollution.

ACTIVITIES

Activity to assist the development of knowledge and understanding

21 Carry out standard experiment to show that CO_2 and H_2O are produced on burning methane and/or a candle.

Activities to develop skills of problem solving

22-28 Obtain and present information about pollution from burning of fossil fuels.

25-28 Obtain and present information on some of these hazards of the internal combustion engine, leading to discussion of various attempts to reduce pollution, eg lead -free petrol and catalysts in exhaust systems.

Opportunities to develop practical abilities

22 Use Bunsen flames with air-hole open and closed, to demonstrate difference in products of combustion of methane (a hydrocarbon) in sufficient and insufficient air.

25 Demonstrate the sparking of nitrogen in air.

Topic 6: Structures and Reactions of Hydrocarbons

Introduction

As for Topic 5, teachers should take every opportunity to place the chemical theory of this topic in a context which relates to current industrial applications and their social implications. Thus the theory of cracking and its importance should be seen by pupils of all abilities as an industrial response to market demands. Similarly, the servicing role which the oil refineries provide for the plastics industry should be discussed along with the consequences for our day-to-day existence.

At General Level, the Learning Outcomes are based on:

- understanding and usage of the terms alkane and alkene
- knowledge of the various types of formulae
- understanding of the ideas of addition reaction and cracking.

At Credit Level, in addition, knowledge of cycloalkane, homologous series and isomer is required.

Topic 6: Structures and Reactions of Hydrocarbons **Learning Outcomes**

GENERAL LEVEL (Grades 4, 3)		CREDIT LEVEL (Grades 2, 1)
Pupils should be able to:		and in addition to:
1	state that the alkanes are a subset of the set of hydrocarbons	state what is meant by a homologous series
2	identify an alkane from the -ane ending	explain that the alkane family is an example of a homologous series
3	state the name for each alkane up to octane	
4	give examples of uses of alkanes	
5	for straight chain alkanes, (C_1 to C_8), work out the names from molecular formulae, shortened and full structural formulae	
6	for straight chain alkanes (C_1 to C_8), construct full and shortened structural formulae and molecular formulae given the name	
7	for alkanes, use the general formula to work out the molecular formulae	derive a general formula for alkanes
8		explain in terms of increasing molecular size why the boiling point increases as the number of carbon atoms in an alkane increases
9		state the name of each cycloalkane up to cyclohexane
10		explain that the cycloalkane family is an example of a homologous series
11		state what is meant by isomers
12	state that the alkanes are a subset of the set of hydrocarbons	
13	identify an alkene from the – ene ending	
14	state the name for each alkene up to hexene (isomers are not required, eg only butene is expected not but-1-ene, etc)	explain that the alkene family is an example of a homologous series
15	for alkenes, (C_1 to C_6), work out names from molecular, shortened or full structural formulae	
<u>Symbols, formulae, equations</u>		
a)	The various representations of alkanes and alkenes can be examined. Decisions will be required about when, and if, to cease writing full structural formulae if molecular formulae will suffice.	
b)	In writing equations for addition reactions, it may be better for some pupils to avoid the use of molecular formulae, so that the "double-bond" is always shown: $CH_3CH = CH_2 + H_2 \rightarrow CH_3\ CH_2\ CH_3$	

Topic 6 *(continued)*

ACTIVITIES	
Activities to assist the development of knowledge and understanding	
5, 6, 7	Use molecular models to illustrate structure of hydrocarbons; derive general formula of a homologous series from models; write formulae for alkanes (C_1 to C_8).
5	Draw 3-D models in two dimensions.
11, 18	Identify and write formulae for isomers.
Activities to develop skills of problem solving	
4	Obtain and present information on the structure and uses of hydrocarbons from newspapers, magazines, oil company booklets.
8	Relate structure of alkanes to boiling point, present information in form of a graph or table; Data Book exercise on boiling point of alkanes related to structure.

Topic 6: Structures and Reactions of Hydrocarbons *(continued)*

	GENERAL LEVEL (Grades 4, 3)	CREDIT LEVEL (Grades 2, 1)
16	for alkenes, C_1 to C_6 construct full and shortened structural formulae and molecular formulae given the name	
17	for alkenes, us a general formula to work out molecular formulae	derive a general formula for alkenes
18	identify from a structural formula the following types of compound: alkanes and alkenes	for simple organic molecules, including alkanes, alkenes and clycloalkanes, construct appropriate isometric forms, given a molecular formula
19	state what is meant by a saturated hydrocarbon	
20	explain that the alkanes are saturated hydrocarbons	
21	state what is meant by an unsaturated hydrocarbon	
22	explain that the alkenes are a sub-set of the set of unsaturated hydrocarbons	
23	state that it is possible to distinguish an unsaturated hydrocarbon from a saturated hydrocarbon using bromine (solution)	
24	state the name of the alkane formed by the reaction of an alkene with hydrogen	
25	state what is meant by an addition reaction	
26	explain that the reactions of alkenes with bromine and hydrogen are addition reactions	
27	state that fractional distillation of crude oil yields more long chain hydrocarbons than are useful for present-day industrial purposes	
28	state that cracking is an industrial method for producing smaller, more useful molecules	
29		state that the catalyst allows the reaction to take place at a lower temperature
30	state that the cracking produces smaller hydrocarbons, some of which are unsaturated	explain why cracking produces a mixture of saturated and unsaturated products.

Topic 6 *(continued)*

ACTIVITIES	
<u>Activities to assist the development of knowledge and understanding</u>	
24, 26	Illustrate addition reactions of alkenes using molecular models.
30	Illustrate cracking of long chain hydrocarbons using molecular models.
<u>Activities to develop skills of problem solving</u>	
27	Extract information on % yield of fractions from crude oil; relate % yield of fractions to demand; present information in form of graphs, bar charts, pie charts, etc.
30	Obtain and present information on cracking in the oil industry.
30	Introduce the use of state symbols with formulae.
<u>Opportunities to develop practical abilities</u>	
23	Test for saturation/unsaturation using a bromine solution.
30	Study the cracking of liquid (medicinal) paraffin; test gaseous product for unsaturation.

Topic 7: Properties of Substances

Introduction

Electrical conductivity can be a powerful tool in chemistry. This topic uses electrical conductivity to investigate elements and compounds and hence to develop a basis for ionic theory. The "theory" properties of ionic compounds are dealt with.

At General Level, the Learning Outcomes require:

- awareness that there are conducting and non-conducting elements and compounds
- that ionic solids conduct when molten or in aqueous solution
- that ionic compounds are changed by electrolysis
- knowledge of the existence of covalent and ionic compounds as molecular and network materials.

At Credit Level, in addition, the Learning Outcomes require ability to give more detailed explanations of electrolyses and of the state in which substances normally exist in terms of their bonding.

GENERAL LEVEL (Grades 4, 3)	CREDIT LEVEL (Grades 2, 1)
Pupils should be able to:	and in addition to:
1 state that metal elements and carbon (graphite) are conductors of electricity and that most non-metal elements are non-conductors of electricity	
2 state that covalent compounds (solid, liquid, solution) do not conduct electricity	
3 state that compounds made from metal elements do not conduct electricity in solid state, and that these compounds do conduct electricity when dissolved in water or when molten	
4 state that electric current is a flow of charged particles	
5 state that electrons flow through metals and that ions flow through solutions	
6 state that electrical energy chemically changes a solution which conducts	state that a d.c. supply must be used if the products are to be identified
7 describe the formation of ions in terms of atoms losing and gaining electrons	
8 state that solid compounds can be ionic or covalent and that compounds which exist as liquids or gases at room temperature are covalent	
9 state that ionic solids exist as networks/lattices of oppositely charged ions	explain why ionic and covalent network substances are solid, and why covalent substances can be solid, liquid or gas
<u>Symbols, formulae, equations</u> *a)* Writing ion-electron equations $M^+ + e \rightarrow M$ $X^- \rightarrow X + e$ should help to establish the idea of ion. *b)* Writing of chemical formulae for ionic compounds may be introduced here. The different representations of covalent and ionic materials, eg $CC1_4$ and Na^+ C1, can be related to their structural models.	

Topic 7 *(continued)*

ACTIVITIES

Activities to assists the development of knowledge and understanding

3, 13 Demonstrate electrolysis of a melt.

8, 9 Write appropriate formulae to represent ionic and covalent compounds.

9 Use models to illustrate formation of an ionic lattice or audio-visual material to illustrate lattice formation.

9 Draw and label diagrams to represent ionic and covalent compounds.

Opportunities to develop practical abilities

1 Test electrical conductivity of metals and non-metals.

2, 3 Compare conductivity of crystalline ionic solids and solutions with covalent compounds (solid, liquid, solutions).

6, 13 Electrolyse an ionic solution, eg copper chloride solution.

7 Test acidic and alkaline solutions, and water for electrical condition.

Topic 7: Properties of Substances *(continued)*

GENERAL LEVEL (Grades 4, 3)		CREDIT LEVEL (Grades 2, 1)
10	give examples of covalent substances which are insoluble in water but which dissolve in other solvents	
11	state that when ionic compounds dissolve in water, the lattice breaks up completely	
12	identify the elements which are formed when an ionic solution is changed by electrical energy, explaining the products at each electrode, in terms of positive metal ions being attracted to the negative electrode and negative non-metal ions being attracted to the positive electrode	explain the formation of atoms/molecules at each electrode in terms of positive ions gaining electrons and negative ions losing electrons
13	state that electrical energy chemically changes a molten ionic compound	
14	explain why the melt conducts but the solid does not	
15	state what is meant by an electrolyte	
16	state what is meant by electrolysis	
17	relate the colour of an ionic compound to the colour of the positive and/or negative ions	explain why the process is only applicable to ionic compounds.
18	explain the results of experiments involving the migration of coloured ions	

ACTIVITIES

<u>Activities to assist the development of knowledge and understanding</u>

14 Draw and label a circuit diagram for the electrolysis of an aqueous ionic solution, or a melt.

17, 18 Present information on colour of ions, in form of a table or as theme of a piece of writing.

<u>Activities to develop skills of problem solving</u>

10 Discuss hazards associated with certain solvents.

11 Carry out Data Book exercise on solubility of named compounds.

17 Examine a large number of ionic solids and relate colour to ions present.

18 Conduct experiments on migration of ions in gels and aqueous solutions.

Topic 8: Acids and Alkalis

Introduction

The importance of acids and alkalis in everyday life and in industry should be emphasised. In this topic, these compounds are distinguished by their pH. Some time should be devoted to dealing with some of the effects of acid rain and possible causes.

At General Level, the Learning Outcomes are based on:

- knowledge of the pH scale as a measure of acidity and alkalinity and of acid and alkali solutions in terms of the presence of hydrogen ions and hydroxide ions respectively
- awareness of the debate about effects of acid rain
- knowledge of the mole as the gram formula mass of any substance and of solution concentrations expressed in mo1/1 (mo1/dm³).

At Credit Level, in addition, the Learning Outcomes require a deeper understanding of acidity and alkalinity in terms of the balance of hydrogen ions and hydroxide ions and the ability to carry out calculations involving interconversion of masses and moles both for pure substances and for solutions in terms of the units of concentration mo1/1 (mo1/dm^3).

GENERAL LEVEL (Grades 4, 3)	CREDIT LEVEL (Grades 2, 1)
Pupils should be able to:	and in addition to:
1 state that non-metal oxides which dissolve in water produce acid solutions	
2 state that sulphur dioxide reacts with water in the atmosphere to produce acid rain	
3 give examples of the damaging effects of acid rain on buildings, other structures, soils and plant and animal life	
4 state that the pH scale is a continuous range	
5 state that: • acids have a pH of less than 7 • alkalis have a pH of more than 7 • pure water and neutral solutions have a pH equal to 7	
6 give examples of common acids and alkalis used in the laboratory and in the home	
7 state that: • ions are present in an acid solution • ions are present in an alkali solution • the concentration of ions in water is small	state that in water and a neutral solution, the concentration of $H^+(aq)$ and $OH^-(aq)$ ions is the same
8 state the test for hydrogen	

Symbols, formulae, equations

a) The writing of formulae for ions containing more than one atom is required.

b) By the end of this topic, pupils should be aware that writing formulae such as HC1(aq) for hydrochloric acid is a shorthand form which is a simplistic descriptor of what is present in the substance, viz: $H^+(aq)$ and $C1^-(aq)$.

Topic 8 *(continued)*

ACTIVITIES

Activities to assist the development of knowledge and understanding

1 Write equations for reaction of non-metal oxides with water.

2 Demonstrate chemical reaction of SO_2 with water.

3 View audio-visual material on acid rain, followed by class discussion of the social and economic issues involved.

6 View audio-visual material on commercial use of acids and alkalis.

5,6 Write formulae for common acids and alkalis.

Activities to develop skills of problem solving

3 Investigate acid rain issue using eg extended writing, book exercise, library project, newspaper/ media search; present information in the form of graphs, flow charts, pie charts, etc.

5, 6 Obtain and present information on the pH scale; relate the pH of common household substance to the pH scale; present information if the form of table, charts, etc.

Opportunities to develop practical abilities

1 Test the pH of some non-metal oxide solutions.

3 Investigate the effect of acid on building materials such as limestone, marble, iron and steel.

5 Measure pH of a variety of solutions using broad and narrow range indicator, and pH meter.

Topic 8: Acids and Alkalis *(continued)*

GENERAL LEVEL (Grades 4, 3)		CREDIT LEVEL (Grades 2, 1)
9	state that an acidic solution is one which contains hydrogen ions ($H^+(aq)$)	explain that an acidic solution contains more $H^+(aq)$ ions than does pure water
10	state that an alkaline solution is one which contains hydroxide ions ($OH^-(aq)$)	explain that an alkaline solution contains more $OH^-(aq)$ ions than does pure water
11	state that metal oxides or hydroxides which dissolve in water produce alkaline solutions	
12	for an acid and an alkali, describe the effect of dilution on: • the acidity or alkalinity • the pH	explain dilution in terms of the decreasing concentration of hydrogen and hydroxide ions
13		calculate the formula mass of a substance
14		state that the gram formula mass of any substance is known as one mole
15		state that the concentration of a solution is expressed in mo1/1 (mo1/dm³)
16		calculate moles to mass and masses to moles
17		carry out calculations involving mass from mo1/1 and mass per volume for a requested concentration.

ACTIVITIES

Activities to develop skills of handling information and applying knowledge

10	Obtain and present information on range of pH of common alkalis, present information on use of alkalis in the household.
11	Carry out Data Book exercise on solubility of metal hydroxides and metal oxides.
11	Write equations for the reaction of metal oxides with water.
13, 14	Carry out calculations based on the mole.

Activities to develop practical abilities

9	Electrolyse dilute H_2SO_4 to release $H_2(g)$, relate to presence of $H^+(aq)$.
9, 10	Test pH of a wide variety of acids and alkalis; test pH of common household substances.
11	Investigate solubility of a selection of metal oxides and metal hydroxides; test pH of resulting solution.
12	Investigate the effect of dilution on the acidity or alkalinity of a solution and on the pH number.
15-17	Prepare standard solutions of common acids and alkalis; titrate to check accuracy.

Topic 9: Reactions of Acids

Introduction

This topic extends the work of Topic 8 to develop further the theme of acids and alkalis. The significance of everyday examples should be stressed. The important concept of neutralisation is introduced.

At General Level, the Learning Outcomes are based on:

- an understanding of the idea of neutralisation
- some knowledge of the reactions of acids with alkalis, carbonates and metals
- awareness of the idea of precipitation as the result of mixing appropriate solutions.

At Credit Level, in addition, the Learning Outcomes require an understanding of the chemical theory underlying the reactions of acids; knowledge of the concepts of "base" and "salt" and of the methods of salt preparation; the ability to carry out calculations relating to acid/alkali volumetric titration.

GENERAL LEVEL (Grades 4, 3)	CREDIT LEVEL (Grades 2, 1)
Pupils should be able to:	and in addition to:
1 state that neutralisation is the reaction of acids with neutralisers	
2 give everyday examples of neutralisation, including: • reducing acidity in soil by adding lime • the use of lime to reduce acidity in lakes caused by rain • treatment of acid indigestion	
3 state that neutralisation moves the pH of an acid toward 7	
4 state that the reaction of acids with alkalis is an example of neutralisation	
5 state that neutralisation moves the pH of an alkali towards 7	
6 state that the reaction of $H^+(aq)$ to form water is an example of neutralisation	state that the reaction of hydrogen ions and hydroxide ions form water
7 name the products formed in the reaction of a neutraliser with dilute hydrochloric, nitric or sulphuric acid	define a salt as a substance in which the hydrogen ion of an acid has been replaced by a metal ion (or the ammonium ion).
Symbols, formulae, equations *a)* For pupils to develop an ability to name the products of neutralisation reactions, the equation writing should be supported by experience of the actual reactions. *b)* The opportunity exists in this topic to allow some pupils to reach an understanding of the following representation: $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$ $2H^+(aq) + CH_3^{2-}(aq) \rightarrow CO_2(g) + H_2O(l)$ $2H^+(aq) + M(s) \rightarrow H_2(g) + M^{2+}(aq)$.	

ACTIVITIES

Activities to assist the development of knowledge and understanding

1, 3 Demonstrate an acid/alkali titration (syringe method) to establish cancelling out of alkali by acid; use of indicator to determine end point.

2 View audio-visual material on process and applications of neutralisation to include reducing acidity in soil and lakes, treatment of acid indigestion, etc.

7 Demonstrate volumetric titration using burettes, pipettes, etc.

Activities to develop skills of problem solving

2 Obtain and present information on everyday applications of neutralisation.

2 Interpret data, eg bar charts, line graphs, flow charts, on acidification and suggest corrective measures.

7 Extract and present information on preparation of a salt by neutralisation.

7 Use Data Book to predict most appropriate method of preparing a salt.

Opportunities to develop practical abilities

1 Carry out neutralisation experiment.

2 Investigate neutralising effect of indigestion tablets.

2 Test pH of soil samples and suggest corrective measures; investigate neutralisation by the addition of lime.

7 Prepare sodium chloride.

7 Prepare salts by volumetric titration.

Topic 9: Reactions of Acids *(continued)*

GENERAL LEVEL (Grades 4, 3)		CREDIT LEVEL (Grades 2, 1)
8	state that an acid reacts with a metal carbonate to give off carbon dioxide	state that the reaction of hydrogen ions and carbonate ions forms water and carbon dioxide
9		explain why, in the preparation of a given salt, it is often easier to use an insoluble metal carbonate or metal oxide as the neutraliser
10	explain the effect of acid rain on buildings and carbonate rocks	
11		define a base as a substance which neutralises an acid
12		state that bases which dissolve in water form alkalis
13	state that an acid reacts with some metals to give off hydrogen gas	
14	state that in the reaction, hydrogen ions form hydrogen molecules	
15	name the products formed when dilute hydrochloric or sulphuric acid reacts with a metal	
16	explain the effect of acid rain on structures made from iron	
17	state that precipitation is the reaction of two solutions to form an insoluble product called a precipitate	state that insoluble salts can be formed by precipitation
18	name the insoluble product formed by the reaction of two solutions	
19		carry out calculations to find the concentration of acids/alkalis from volumetric titration.

ACTIVITIES

Activities to assist the development of knowledge and understanding

17 Discuss effects of acid rain on naturally occurring carbonates (eg chalk). Relate to use of carbonates as building materials (eg limestone, marble) – long term effects of acid rain on these.

Activities to develop skills of problem solving

16 Obtain and present information on effects of acid rain on structures made of iron.

19 Carry out calculations to find the concentration of acids/alkalis from volumetric analysis.

Opportunities to develop practical abilities

17, 18 React:
eg $Pb^{2+}(aq)$ with $I^-(aq)$
$Ba^{2+}(aq)$ with $SO_4^{2-}(aq)$ and $Ba^{2+}(aq)$ with $SO_3^{2-}(aq)$.

17, 18 Filter, wash and air-dry precipitates.

19 Use conductivity changes to follow process of neutralisation.

Topic 10: Making Electricity

Introduction

This topic deals with batteries as storage devices for chemical energy and as changers of chemical to electrical energy. The word battery has been used deliberately to help pupils link the work done to everyday experiences. Teachers should encourage pupils to use the word cell, in addition to battery, as progress is made through the topic. Pupils should be made aware that "battery technology" is a developing aspect of chemistry and that this section only touches on the general background. The concepts of oxidation and reduction are introduced.

At General Level, the Learning Outcomes require:

- a knowledge of the importance and use of batteries in everyday life
- some understanding of cells
- an awareness of the idea of an electrochemical series.

At Credit Level, in addition, the Learning Outcomes require a deeper understanding of the idea, and uses of, an electrochemical series; an awareness of the idea of oxidation/reduction and redox reactions; the ability to apply the terms oxidation and reduction to ion-electron equations.

Topic 10: Making Electricity **Learning Outcomes**

GENERAL LEVEL (Grades 4, 3)	CREDIT LEVEL (Grades 2, 1)
Pupils should be able to: 1 state that, in a battery, electricity comes from a chemical reaction 2 state that electricity passing along metal wires is a flow of electrons 3 explain the need to replace batteries in terms of the chemicals being used up in the reaction 4 state that some batteries are rechargeable, eg the lead-acid battery 5 explain that ammonium chloride in a cell is an example of an electrolyte 6 explain that the purpose of the electrolyte is to complete the circuit 7 state that electricity can be produced by connecting different metals together (with an electrolyte) to form a cell 8 state that the voltage between different pairs of metals varies and that this leads to the electrochemical series	and in addition to:
Symbols, formulae, equations *a)* The Electrochemical Series table in the Data Book provides a ready source of ion-electron equations that may be used by pupils in their work in this topic. *b)* Development of the idea of redox can be supported by frequent use of this table.	

Topic 10 *(continued)*

ACTIVITIES

Activities to assist the development of knowledge and understanding

1	Examine a wide variety of batteries, including a car battery.
1, 2, 3	Set up a cell; use it to ring a bell.
4	Charge a car battery; discuss safety factors and charging conditions, eg voltage and use of direct current.
5	Examine the composition of a typical cell in everyday use.

Activities to develop skills of problem solving

1, 7	Obtain information on composition and uses of a wide range of batteries in everyday use; present the information in a variety of ways, eg graphs, pie charts, extended writing, draw conclusions from given information.
3, 8	Carry out book exercise to investigate the historical development of cells, eg Galvani and frogs' legs.
8	Use Data Book to evaluate information on cells.

Opportunities to develop practical abilities

1, 4	Investigate a home-made lead-acid cell (lead foil/dil H_2SO_4 in beaker) before and after charging.
7	Make a lemon cell.
8	Use voltmeter to measure the voltage of various metal couples.

Topic 10: Making Electricity *(continued)*

	GENERAL LEVEL (Grades 4, 3)	CREDIT LEVEL (Grades 2, 1)
9	use an electrochemical series showing metals only to explain why displacement reactions occur and describe the experimental observations	use an electrochemical series to predict whether or not displacement reactions occur; and predict the experimental observations
10		state that the reactions of metals with acids can establish the position of hydrogen in an electrochemical series
11	state that electricity can be produced in a cell by connecting two different metals in solutions of their metal ions	state that electricity can be produced in a cell when at least one of the half-cells does not involve metal atoms
12	state that the purpose of the "ion bridge" is to complete the circuit	explain that the movement of ions in the ion bridge is to provide ions to complete the circuit
13	compare batteries and mains electricity sources in relation to ease of transport, safety, costs and uses of finite resources	
14		state that a metal element reacting to form a compound is an example of oxidation
15		state that oxidation is a loss of electrons by a reactant in any reaction
16		state that a compound reacting to form a metal element is an example of reduction
17		state that reduction is a gain of electrons by a reactant in any reaction
18		state that, in a redox reaction, reduction and oxidation go on together
19		apply terms oxidation and reduction to more complex ion-electron equations, eg SO_4^{2-}/SO_3^{2-}.

ACTIVITIES

Activities to develop skills of problem solving

9 Use a modified electrochemical series to predict whether or not displacement reactions will occur.

15 Write ion-electron equations for cell reactions.

19 Use Data Book for ion-electron equations for oxidation and reduction.

Activities to develop practical abilities

9 Use wet filter paper technique with different metals/some metals/metal and non-metal pairs.

9 Displacement reactions – find out which displaces which, by experiment.

10 Investigate reaction of lead with acid.

Topic 11: Metals

Introduction

Pupils should be encouraged to identify the presence and use of metals in the world around them. The social and industrial importance of the metal industry should be discussed, including the finite nature of metal sources and the need for re-cycling. Pupils should be aware that over three-quarters of the chemical elements are metals; this topic deals with some properties, uses and reactions of the more common metals and considers why some are found uncombined while others have to be extracted from ores.

At General Level, the Learning Outcomes are based on:

- some understanding of the macroscopic features of metal chemistry
- an awareness of the idea of reactivity in metals
- knowledge of ways of extracting metals from ores
- knowledge of the changes brought about by alloying.

At Credit Level, in addition, the Learning Outcomes require knowledge that some metal oxides can be reduced by heating with other substances; the ability to carry out calculations involving percentage composition.

Topic 11: Metals Learning Outcomes

GENERAL LEVEL (Grades 4, 3)	CREDIT LEVEL (Grades 2, 1)
Pupils should be able to:	and in addition to:
1 state that metals conduct electricity when solid or liquid	
2 relate specific properties of metals, eg density, thermal and electrical conductivity, malleability, strength, to their uses	
3 explain the need for recycling metals in terms of the finite nature of the metal resources	
4 describe the reactions of different metals with oxygen, water and dilute acid	
5 state that these reactions give an indication of the reactivity of the metal	
6 state that ores are naturally-occurring compounds of metals	
7 state that the less reactive metals are found uncombined in the earth's crust and that the more reactive metals have to be extracted from ores	
8	explain that the extract of a metal from its ore is an example of reduction
9 explain why the inactive metals were among the first to be discovered	
<u>Symbols, formulae, equations</u> The idea of reactivity can be used to develop equation-writing skills. The differing reactants and products provide opportunities to describe in symbols various reactions that are carried out in the study of metals: $M^{2+}O^{2-} + C \rightarrow M + CO_2$ $M^{2+}O^{2-} + H_2 \rightarrow M + H_2O$ $M^{2+}O^{2-} + CO \rightarrow M + CO_2$	

Topic 11 *(continued)*

ACTIVITIES

Activities to assist the development of knowledge and understanding

1 View audio-visual material on properties of metals and alloys.

2 Examine a series of metals.

4 Demonstrate more reactive metals with water.

Activities to develop skills of problem solving

2 Use Data Book, eg compare melting point, boiling point, density.

2, 3 Obtain and present information on metal resources from books, graphs, bar charts, pie charts, etc, eg percentage of metals on earth's crust, years of reserves left, percentage of metals recycled, world demand for different metals.

6 Carry out library/newspaper project on economic importance/prices of ores and metals.

7 Obtain and present information on extraction of metals from their ores.

8 Obtain information on the reduction of metal ores.

Opportunities to develop practical abilities

1 Test metals/non-metals for electrical conduction.

4 Investigate reaction of metals with oxygen, water and acid.

Topic 11: Metals *(continued)*

GENERAL LEVEL (Grades 4, 3)		CREDIT LEVEL (Grades 2, 1)
10	give examples of social and industrial factors which resulted in large scale extraction of more reactive metals	
11	state that some metals can be obtained from metal oxides by heat alone; some by heating with carbon; and some need other methods	explain in terms of the reactivity of the metal why some metals can be obtained from metal oxides by heat alone; and why some metal oxides need to be heated with other substances, eg carbon or carbon monoxide; and why some metals cannot be obtained by these methods
12	state that iron is produced from iron ore in the blast furnace	
13	state the two key reactions which take place in the blast furnace: • production of carbon monoxide • reduction of iron oxide	
14	state that an alloy is a mixture of metals or of metals with non-metals	
15	give examples of the important uses of alloys, eg brass, solder, "stainless" steel	
16		work out empirical (or molecular) formulae from masses or percentage composition
17		work out percentage masses of elements in compounds from their names or formulae

ACTIVITIES

<u>Activities to assist the development of knowledge and understanding</u>

11 Demonstrate effect of heat on Ag_2O.

13 View audio-visual material on the blast furnace.

<u>Activities to develop skills of problem solving</u>

10 Research date of discovery and large scale extraction of metals; relate to reactivity of metal, and to social and industrial developments which made feasible large scale production of a wider range of metals.

13 Carry out book exercise on blast furnace.

14, 15 Carry out library project on composition and uses of alloys; present information in a variety of forms, eg graphs, tables, pie charts.

16, 17 Calculate percentage composition from formulae, and vice versa.

<u>Opportunity to develop practical abilities</u>

11 Investigate metal oxide reductions with powdered carbon.

Topic 12: Corrosion

Introduction

This topic is concerned with the corrosion of metals and in particular the rusting of iron. The effect of salt, eg from road "gritting", on the rate of corrosion of iron is given prominence as an everyday example. Prevention of corrosion should be dealt with through real, everyday examples to which pupils can relate.

At General Level, the Learning Outcomes required:

- some understanding of the macroscopic aspects of corrosion, and its prevention
- knowledge that rusting is a change from iron atoms to iron ions, and that an indicator exists which can detect this change
- comprehension of the ways of preventing this oxidation.

At Credit Level, in addition, the Learning Outcomes require an awareness of the operation of a cell in rusting, and knowledge of the redox reactions involved. The scratched tinplate effect on the rate of rusting is dealt with at this Level.

Topic 12: Corrosion Learning Outcomes

GENERAL LEVEL (Grades 4, 3)	CREDIT LEVEL (Grades 2, 1)
Pupils should be able to:	and in addition to:
1 state that corrosion is a chemical reaction which involves the surface of a metal changing from an element to a compound	
2 give examples to show that different metals corrode at different rates	
3	explain that corrosion is an example of oxidation
4 apply the term rusting to the corrosion of iron	
5 state that both water and oxygen (from the air) are required for rusting	state that water, oxygen and dissolved carbon dioxide, or another electrolyte, are required for rusting
6 state that when iron rusts, initially the iron atoms lose two electrons to form Fe^{2+} ions	state that the iron (II) ions can be further oxidised to give iron (III) ions
7	state the that electrons lost by the iron during rusting are accepted by the water and oxygen to form hydroxide ions
8 state that ferroxyl indicator for $Fe^{2+}(aq)$ can be used to show the extent of the rusting process	
9 state that salt spread on roads increases the rate of corrosion on car bodywork	
10 explain that salt acts as an electrolyte	

<u>Symbols, formulae, equations</u>

The rusting of iron as an oxidation of the metal, shown in an ion-electron equation:

$Fe(s) \rightarrow Fe^{2+}(aq) + 2e.$

For some pupils, the corresponding reduction equation will be:

$2H_2O(l) + 0_2(g) + 4e \rightarrow 4OH^-(aq).$

In sacrificial protection, electrons become available from a more easily-oxidised metal:

$M(s) \rightarrow M^{2+}(aq) + 2e.$

Topic 12 *(continued)*

ACTIVITIES

Activities to assist the development of knowledge and understanding

1, 5 View audio-visual material on corrosion.

1, 2, 3 Examine different metals/materials left exposed to the atmosphere.

Activities to develop the skills of problem solving

9 Obtain information on costs to the community of corrosion effects.

Opportunities to develop practical abilities

5 Carry out test tube experiment, eg Fe nails in dry air, air, water and air-free water; suspend a nail in damp air, over NaOH (2 mol/l).

6 Carry out test for $Fe^{2+}(aq)$ and $Fe^{3+}(aq)$.

8, 14 Use ferroxyl indicator to test for $OH^-(aq)$ and $Fe^{2+}(aq)$; use ferroxyl indicator to show the effect of acid and salt on rusting.

Topic 12: Corrosion *(continued)*

GENERAL LEVEL (Grades 4, 3)		CREDIT LEVEL (Grades 2, 1)
11	state that iron does not rust when attached to the negative terminal of a battery	
12	state that electrons flowing to the iron prevents rusting	
13		explain the reaction at the iron in an iron/carbon cell using the colour change of Fe^{2+} indicator and direction of electron flow
14	state that with metals higher in the electrochemical series, electrons flow to the iron, and with metals lower in the series, electrons flow from the iron	explain the reactions in a cell using the colour change Fe^{2+} indicator and the direction of electron flow
15	explain what is meant by the following: • electroplating • galvanising • tin-plating	
16	explain that a surface barrier to air and water can provide physical protection against corrosion, eg • painting • greasing • electroplating • galvanising • tin-plating • coating with plastic	
17	explain the effect of sacrificial protection in terms of electron flow (eg galvanising, scrap magnesium)	explain the effect of scratching tinplate in increasing the rate of rusting of iron.
18	give everyday examples of anti-corrosion methods in 15, 16 and 17 above	

ACTIVITIES

<u>Activity to assist the development of knowledge and understanding</u>

16 Examine rack of objects left exposed to the weather.

<u>Activities to develop skills of problem solving</u>

14 Predict the direction and electron flow and the colour changes of ferroxyl indicator in cells.

16, 17 Carry out book exercise on corrosion prevention; compare corrosion data at different sites/atmospheres.

17 Identify and correct sources of error in corrosion experiments.

<u>Opportunities to develop practical abilities</u>

12 Use Fe nails as electrodes in ferroxyl indicator (9V battery with nail attached to negative terminal).

13 Set up cells – Fe/carbon, Fe/Mg, Fe/Cu; use ferroxyl indicator and meter to indicate direction of electron flow.

14 Add ferroxyl indicator to solution/gels with Mg/Fe, Zn/Fe, Fe, Cu/Fe, Ag/Fe.

16, 17 Electroplate an object with nickel.

Topic 13: Plastics and Synthetic Fibres

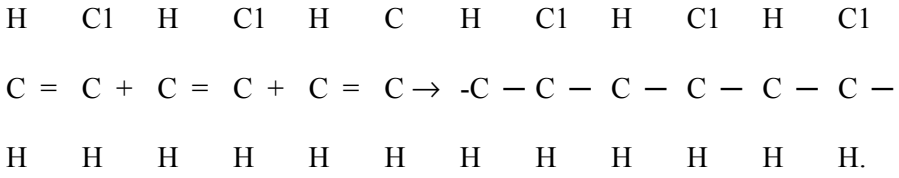
Introduction

This topic should be developed from the wide variety of everyday uses of plastic and synthetic fibres; the necessary development of these materials to meet the needs of modern society; their impact on our environment; and the economic relationship between the cost of oil and the cost of plastics and synthetic fibres. There is a considerable amount of audio-visual and printed material in addition to samples of plastics and synthetic fibres which could be used to good effect.

At General Level, the Learning Outcomes are based on:

- an awareness of the connection between oil and most plastics and synthetic fibres
- knowledge that plastics and synthetic fibres are made by joining smaller molecules together
- awareness of the relationship between the structure and properties of these materials
- realisation that most plastics are not biodegradable, and that combustion may produce toxic fumes. Naming of monomers and the resulting polymer is restricted to addition polymerisation and the use of full structural formulae to ethene/polythene.

At Credit Level, in addition, the Learning Outcomes require more detailed knowledge of addition polymerisation; the ability to relate the structure of the monomer to the polymer and to identify the repeating unit given the polymer structure.

GENERAL LEVEL (Grades 4, 3)	CREDIT LEVEL (Grades 2, 1)
Pupils should be able to: 1 state that most plastics and synthetic fibres are made from oil 2 state what is meant by synthetic as used in "synthetic fibre" 3 give examples of how the properties of plastics, eg lightness, durability and insulation are related to their uses 4 give examples of advantages and disadvantages of natural and synthetic materials 5 state what is meant by biodegradable 6 state that most plastics are not biodegradable and that their durability can cause environmental problems 7 state that some plastics burn or smoulder to give off toxic fumes 8 state that a thermoplastic plastic is one which can be melted or reshaped; and that a thermosetting plastic is one which cannot be shaped in this way 9 give examples of uses of thermosetting plastics	and in addition to: relate the toxic gases given off, during burning or smouldering, to the elements present in the plastic, eg carbon monoxide, hydrogen chloride (PVC), hydrogen cyanide (polyurethanes)
<u>Symbols, formulae, equations</u> Ability to represent the addition polymerisation of simple monomers can be acquired by careful teaching, maintaining the full structural formulae to assist easier identification of repeating units:  The idea of condensation polymerisation may need to be approached initially using simplified structures.	

Topic 13 *(continued)*

ACTIVITIES

Activities to assist the development of knowledge and understanding

1, 4 Use suitable audio-visual material on plastics and derivatives of crude oil.

3 Make a collection of everyday items made of named plastics.

4 Make a collection of natural and synthetic materials used for the same purpose.

Activities to develop skills of problem solving

1, 4 Obtain and present information on the properties and uses of plastics and of natural materials.

7 Obtain information on poisonous fumes hazard when plastics burn; collect statistics on fatalities and serious fire hazards from newspaper articles and present in form of graphs, tables or charts.

8, 9 Obtain and present information on properties and characteristics of thermosetting and thermoplastic plastics.

Opportunity to develop practical abilities

3 Carry out various tests on samples of plastics, eg conductivity of heat and electricity, physical strength, effect of solvents.

Topic 13: Plastics and Synethetic Fibres *(continued)*

GENERAL LEVEL (Grades 4, 3)		CREDIT LEVEL (Grades 2, 1)
10	state what is meant by: • monomer • polymer • polymerisation	
11	state that plastics are examples of polymers	describe how the small unsaturated molecules join together by the opening of the carbon to carbon double bond
12	state that many plastics are made from small unsaturated molecules produced by cracking	
13	give examples of plastics formed from alkenes	state what is meant by addition polymerisation
14	explain that the making of plastics is an example of polymerisation	explain that the making of polyalkenes (and substitutes) are an example of addition polymerisation
15	given the name of a monomer, state the name of the addition polymer	
16	state that fibres, both natural and synthetic, are examples of polymers	
17	explain, using full structural formulae, how ethene forms polythene	given the structure of an addition monomer, construct the polymer
18		given the structure of an addition polymer, work out the repeating unit and monomer structures.

ACTIVITIES

<u>Activities to develop skills of problem solving</u>

12, 13 Obtain and present information on the range of plastics possible from alkenes or substituted alkenes.

16 Compare the characteristics and uses of a natural fibre (wool) with a synthetic fibre (nylon).

17 Given the monomer, draw the repeating unit and the structure of an addition polymer.

<u>Opportunity to develop practical abilities</u>

16 Carry out the preparation of nylon.

Topic 14: Fertilisers

Introduction

This topic should be developed from an exploration of the need for greater food production (because of the increasing world population) and the importance of synthetic fertilisers (because of insufficient quantities of natural fertilisers to satisfy the demands of modern intensive farming).

The opportunity should be taken to build on and reinforce the chemistry from previous topics of the course.

At General Level, the Leaning Outcomes are based on:

- knowledge that plants require nutrients
- that these can become available from a number of sources (including the synthetic fertiliser industry)
- that there are essential elements
- knowledge that ammonia and nitric acid can be used to make fertilisers
- awareness of the Haber and Ostwald Processes, and of the properties of ammonia and nitric acid.

At Credit Level, in addition, the Learning Outcomes require awareness of the different nutrient needs of plants; more detailed knowledge of the Haber and Ostwald process and of ammonia.

GENERAL LEVEL (Grades 4, 3)	CREDIT LEVEL (Grades 2, 1)
Pupils should be able to:	and in addition to:
1 state that the increasing world population has led to a need for more efficient food production	
2 state that growing plants require nutrients, including compounds of phosphorus and potassium as well as nitrogen	state that different crops need fertilisers containing different proportions of nitrogen, phosphorus and potassium
3	work out percentage mass of elements in compounds from formulae
4 state that nitrogen-fixing bacteria in root nodules of some plants can convert atmospheric nitrogen into nitrogen compounds	
5 explain the importance of such plants in increasing soil fertility	
6 state that fertilisers are substances which restore the essential elements for plant growth to the soil	
7 give examples of the effect of artificial fertilisers on lochs and rivers	
8 explain the importance of the decomposition of plant and animal protein in the recycling of nitrogen	state that bacterial methods of fixing nitrogen are cheaper than chemical methods
9 explain in terms of solubility and essential elements why the following are useful, synthetic fertilisers: • ammonium salts • potassium salts • nitrates • phosphates	

<u>Symbols, formulae, equations</u>

a) Appreciation of the nature of synthetic fertilisers will be helped by representing them as ionic compounds

eg $(NH_4^+)_2SO_4^{2-}$.

b) Aqueous ammonia can be looked on as a neutraliser.

$H^+(aq) + NH_3(aq) \rightarrow NH_4^+(aq)$.

Topic 14 *(continued)*

ACTIVITIES

Activities to assist the development of knowledge and understanding

6, 11, 12 View suitable audio-visual material on fertilisers and the nitrogen cycle.

9 Display a range of packets of garden fertilisers.

Activities to develop skills of problem solving

1, 6 Calculate the percentage composition of some fertilisers.

6 Obtain information on the nitrogen cycle, nitrifying bacteria and crop rotation; present the information in a variety of ways to include flow chart, bar charts, pie charts, etc.

9 Extract information on composition of fertilisers from empty packets or magazine advertisements.

9 Use Data Book to suggest suitably soluble compounds for use as fertilisers.

9 Evaluate the procedure used in 9 below.

Opportunities to develop practical abilities

4, 8 Examine some plant roots with, and some without, suitable bacterial colonies.

9 Devise a suitable procedure to test the solubility of some compounds used as fertilisers (eg urea, ammonium phosphate).

Topic 14: Fertilisers *(continued)*

GENERAL LEVEL (Grades 4, 3)	CREDIT LEVEL (Grades 2, 1)
10 describe the nitrogen cycle in terms of recycling of nitrogen between plants and animals	
11 describe the various pathways by which nitrogen is gained and lost in the nitrogen cycle	
12 state that ammonia and nitric acid are nitrogen compounds which are used to make fertilisers	
13 describe the industrial manufacture of ammonia from nitrogen and hydrogen (Haber Process)	explain why the reaction is carried out at moderately high temperature
14	explain why all the nitrogen and hydrogen are not converted to ammonia
15 state that ammonia can be converted to an ammonium compound	
16	state that ammonia can be prepared in the laboratory by the reaction of ammonium compound with alkali
17 describe the following properties of ammonia: • appearance • smell • solubility • effect on damp pH paper/universal indicator	
18 state that nitric acid is formed when nitrogen dioxide, in the presence of air, dissolves in water	
19 state that nitrogen gas is not very reactive	

ACTIVITIES

<u>Activities to assist the development of knowledge and understanding</u>

10 Use wall charts or suitable audio-visual material on the nitrogen cycle.

17 Demonstrate fountain experiment (using safety screen, etc, to protect against implosion).

<u>Activities to develop skills of problem solving</u>

12 Evaluate the procedure used to prepare an ammonium salt listed in 12 below.

13 Obtain and present information on the Haber Process.

<u>Opportunities to develop practical abilities</u>

12 Devise a suitable technique to prepare a sample of ammonium nitrate, ammonium sulphate or ammonium chloride.

17 Test the physical and chemical properties of ammonia gas, including a mini-fountain experiment.

Topic 14: Fertilisers *(continued)*

GENERAL LEVEL (Grades 4, 3)	CREDIT LEVEL (Grades 2, 1)
20 State that nitrogen dioxide is produced in the air during lightning storms	
21 explain in energy terms why nitrogen and oxygen can combine during lightning storms or in a car engine	
22 explain the effect of nitrogen oxides in rain in terms of: • replacing nitrogen compounds in the soil • increasing the acidity of the soil	
23 state that the combination of nitrogen and oxygen does not provide an economic industrial route to nitric acid	
24 describe the catalytic oxidation of ammonia to form nitrogen dioxide – a step in the industrial manufacture of nitric acid (Ostwald Process)	explain why the reaction is carried out at a moderately high temperature
25 state that the catalytic oxidation of ammonia can be carried out in the laboratory	explain why it is not necessary to continue to supply heat once the catalytic oxidation of ammonia has started.

ACTIVITIES

<u>Activities to assist the development of knowledge and understanding</u>

20 Demonstrate sparking of nitrogen in air.

25 Demonstrate catalytic oxidation of ammonia (Ostwald Process) to nitrogen dioxide.

<u>Activities to develop skills of problem solving</u>

23 Select an appropriate procedure for the preparation of a salt using information from the Data Book and knowledge of reactions of acids; make critical comment on the suitability or otherwise of a given procedure.

24, 25 Obtain and present information on the Ostwald Process.

Topic 15: Carbohydrates and Related Substances

Introduction

The study of photosynthesis and respiration is fundamental to any appreciation of the relationship of Chemistry to life, in particular, the role of both processes in maintaining the balance of gases in the atmosphere, and the importance of photosynthesis in food production.

This topic introduces (or revises) these processes and extends chemical knowledge and understanding of the synthesis and breakdown of carbohydrates. The production of alcohol by fermentation is studied.

At General Level, the Learning Outcomes are based on:

- ability to apply the terms photosynthesis and respiration and explain their role in carbon dioxide/oxygen balance
- knowledge of distinguishing tests for glucose and starch
- awareness that starch is a polymer and of its breakdown into smaller molecules (glucose)
- knowledge of the role of enzymes as biological catalysts
- knowledge that ethanol is produced by fermentation.

At Credit Level, in addition, the Learning Outcomes require an understanding of hydrolysis (of starch); knowledge of the existence of simple carbohydrates other than glucose; the idea of functional group in alkanols and the ability to write formulae for monosaccharides and disaccharides (molecular only).

GENERAL LEVEL (Grades 4, 3)	CREDIT LEVEL (Grades 2, 1)
Pupils should be able to:	and in addition to:
1 state that photosynthesis is the process by which plants make carbohydrates from carbon dioxide and water, using light energy in the presence of chlorophyll; oxygen is released in the process	
2 state that the role of chlorophyll in photosynthesis is to absorb light energy	
3 state that the carbohydrates made in plants during photosynthesis are an important food for animals	
4 state that respiration is the process by which animals **and** plants obtain a supply of energy by breaking down carbohydrates (using oxygen) to give carbon dioxide and water	
5 state that carbohydrates release energy, producing carbon dioxide and water when burned	explain why the production of carbon dioxide and water, on burning, indicates the presence of carbon and hydrogen in a carbohydrate
6 give examples of how energy can be used by animals	
7 explain the importance of respiration and photosynthesis in maintaining the balance of carbon dioxide and oxygen in the air	
8 explain why the extensive clearing of forests could present dangers to life on earth	
9 give examples of carbohydrates to include glucose, sucrose and starch	explain why glucose/fructose and maltose/ sucrose are pairs of isomers

<u>Symbols, formulae, equations</u>

a) For many of the illustrations of reactions of the carbohydrates simplified structures can be used in equations. Thus, for condensation and hydrolysis only the -CH(OH) need be looked at.

b) The absence of a full structural representation for the saccharides may mean that the use of some form of molecular model is very important in this topic (in sugar chemistry, refer to monosaccharide, disaccharides and polysaccharides).

Topic 15 *(continued)*

ACTIVITIES

Activities to assist the development of knowledge and understanding

4 Prepare diagram or wall chart showing interdependence of photosynthesis and respiration.

5 Demonstrate flour, custard powder or icing sugar explosion.

7 Discuss the effect on the balance of carbon dioxide and oxygen in the air of the combustion of fossil fuels.

Activities to develop skills of problem solving

3 Obtain information on photosynthesis, eg the importance to the environment and to food production, and present in written form or in flow chart.

7, 8 Identify key points from a piece of writing on photosynthesis/respiration/greenhouse effect/deforestation.

Opportunities to develop practical abilities

4 Compare amounts of CO_2 in inhaled and exhaled air.

5 Burn samples of carbohydrates and test for CO_2 and observe evidence of formation of water.

Topic 15: Carbohydrates and Related Substances *(continued)*

GENERAL LEVEL (Grades 4, 3)		CREDIT LEVEL (Grades 2, 1)
10	state that carbohyradtes contain the elements carbon, hydrogen and oxygen	
11	state that glucose is sweet and dissolves in water and that starch is not sweet and does not dissolve well in water	
12	explain what is seen when a beam of light is passed through: • glucose solution • starch in water	
13	state that it is possible to distinguish starch from other carbohydrates using iodine solution	
14	state that Benedict's or Fehling's Reagent is used to test for glucose but not for sucrose	state that Benedict's or Fehling's Reagent is used to test for glucose, fructose, maltose and other sugars but not for sucrose
15	state that glucose is a carbohydrate built up in photosynthesis	
16	state that starch is a polymer made in plants from glucose monomer units	state that the glucose molecules join together with loss of water
17	explain that the joining up of glucose molecules to form starch is an example of polymerisation	explain that the joining up of glucose molecules to form starch is an example of condensation polymerisation
18	state that during digestion starch molecules are broken down in the body into small glucose molecules which can pass through the gut wall	
19	state that the breakdown of starch can be carried out in the laboratory using acid or amylase	state that starch molecules break down by reacting with water molecules
20		state what is meant by hydrolysis
21		explain that the breakdown of starch and sucrose are examples of hydrolysis
22	state the enzymes, eg amylase, act as biological catalysts in the breakdown of complex food molecules into smaller ones in the digestive system	

Topic 15 *(continued)*

ACTIVITIES

Activities to assist the development of knowledge and understanding

11, 12	Carry out Tyndall beam experiment on glucose solution and starch in water.
16, 17	Prepare "Polyglucose" model of starch using paper clips or poppet beads to represent glucose.
16	Draw simplified structures to represent the jointing up of monosaccharide to form a polymer.

Activities to develop skills of problem solving

19, 22	Obtain and present information on digestion from various tests.

Opportunities to develop practical abilities

11	Carry out solubility tests on carbohydrates; make a "solution" of starch.
14	Carry out starch/iodine test and Fehling's or Benedict's test for a reducing sugar.
18	Carry out visking tubing experiment.
19	Hydrolyse starch using (i) acid, (ii) enzyme; test product for a reducing sugar.
19-21	Carry out thin layer or paper chromatography.
21	Hydrolyse sucrose; test product for a reducing sugar.

Topic 15: Carbohydrates and Related Substances *(continued)*

GENERAL LEVEL (Grades 4, 3)		CREDIT LEVEL (Grades 2, 1)
23		write the molecular formulae for mono-saccharides and disaccharides
24	state that glucose is the carbohydrate which reacts with oxygen during respiration	
25	state that alcoholic drinks can be made from any fruit or vegetable which is a source of starch or sugars	
26	give examples to show that the type of alcoholic drink varies with the plant source of the carbohydrate	
27	state that an enzyme produced by yeast, a living organism, acts as a catalyst for the reaction	
28	state that fermentation is the breakdown of glucose to form alcohol and carbon dioxide	describe the effect of changes in pH and temperature on the optimum efficiency of an enzyme
29		
30	state that distillation is a method of increasing the alcohol concentration of fermentation products	explain why there is a limit to the alcohol concentration of fermentation products.
31	explain why water and alcohol can be separated by distillation	
32	state that alcohol is a member of the alkanol family and is called ethanol	

ACTIVITIES

<u>Activities to assist the development of knowledge and understanding</u>

25, 31 Use appropriate audio-visual material on production of alcoholic drinks by fermentation.

30, 31 Demonstrate a distillation to separate a mixture of alcohol and water.

<u>Activities to develop skills of problem solving</u>

25, 26 Obtain and present information on fermentation of fruit or vegetable material.

31 Find boiling point of water and alcohol in Data Book.

<u>Opportunity to develop practical abilities</u>

27-29 Carry out fermentation of a glucose solution.

Appendix

Assessment of Practical Abilities

Appendix I

(append to Arrangements issued August 1997)

Assessment of Practical Abilities

Standard Grade Biology, Chemistry, Physics and Science

In August 1997 SQA issued revised arrangements for the assessment of Practical Abilities in all of the science subjects specified above. These revised arrangements were implemented for the first time in 1999.

Following central moderation of the internal assessment of these subjects, SQA has decided that the following additional guidance should be provided to centres. This additional guidance does not change any requirements of the published Arrangements documents and should be read in conjunction with these documents.

General Comments

1 The assessment of candidate performance is carried out with reference to the Extended Grade Related Criteria (EGRC) that are included in Arrangements documents. Across the science subjects, the EGRC for Practical Abilities at Foundation, General and Credit Levels detail requirements for *both* techniques and investigations. In addition, the Summary GRC for Practical Abilities confirm that both techniques *and* investigations are required at all levels.

To be awarded any grade other than 7 in Practical Abilities, candidate evidence must be consistent with the EGRC and so must cover **both techniques and investigations**. For example, to be awarded any grade between 1 and 6 for Practical Abilities in Standard Grade Science, in achieving the minimum mark specified in the Arrangements document, candidates must:

- carry out at least one practical technique
  and
- achieve at least one Investigative Skill objective.

All of the Arrangements documents for science Standard Grades include statements of the type:

"Candidates for whom there is evidence in support of at least one technique or investigation and who achieve an overall total of less than X marks should be awarded a Grade 7 for Practical Abilities."

These statements apply only to the award of Grade 7. A small number of schools have inferred, incorrectly, that these statements also apply to the award of grades other than 7. As indicated above, this inference is consistent neither with the EGRC nor the Summary GRC.

A candidate who attempts neither techniques nor investigations will be deemed not to have completed the course in the Practical Abilities element. Such a candidate will not receive a grade for this element and hence will not receive an overall grade for the subject.

2 **To comply with the EGRC**, investigations undertaken by candidates **must** be relevant to the subject eg investigation of:

- the period of a pendulum is inappropriate for Chemistry or Biology candidates
- lathering is inappropriate for Physics candidates.

Science candidates may undertake an investigation in any science subject. All candidates should have a clear understanding of the science content of their investigations.

3 Investigations carried out for certification purposes **must** provide opportunities for candidates to demonstrate **all** of the thirteen skills objectives. During the generative phase it is in order for the teacher to direct candidates away from trivial or other investigations that will not permit candidates to demonstrate particular skills. For example a candidate might want to investigate the rate of reaction of copper with dilute acids. This would result in a graph where all of the points would be on one of the axes. This investigation is not appropriate for certification purposes as it would not permit the candidate to demonstrate skills in relation to criteria *a*, *c* and *d* of objective *RR2*. The candidate should be directed to alternatives **without penalty**.

4 The booklets supplied by SQA must be used. No change is permitted to the text of the booklets, or to the sequence. The following modifications **are permitted**:

- addition of school or class details to the front page
- reproduction in A4 or other format
- alteration of font size
- highlighting the boxes for marks awarded by direct observation
- photocopying graph paper into the booklet.

5 To facilitate assessment and moderation, candidates should provide evidence in the appropriate places in the Investigation Booklet. For example, evidence relevant to criterion *G1* should normally be written in the space following instruction number 1. Where marks are awarded for evidence written elsewhere in the booklet, this must be clearly recorded by the assessor.

6 Candidates should be encouraged to avoid the use of the term 'amount' where other terms, eg mass, volume, weight, are more appropriate. Use of 'amount' usually results in loss of marks, as responses are misleading and/or ambiguous.

7 At least one investigation must have a continuous independent variable to ensure that all candidates have the opportunity to draw a line graph.

8 To aid moderation, the teacher should indicate briefly in the booklet why a candidate has not been awarded marks for one or more of the criteria *G1*, *G2*, *G3* or *G4*. Similarly, the teacher should indicate briefly why marks dependent on direct observation (criteria *E1*, *E3b* and *E4a*) have not been awarded.

Investigative Skills Objective		Criterion	Wording in Investigation Booklet	Additional Guidance
The candidate should be able to:				
G1	demonstrate understanding of the problem posed;	Following group discussion, the candidate individually identifies and records an investigable aspect of the problem.	1 Having thought about the problem and talked about it with others in your class, write down the factor which you are going to investigate.	Where the dependent variable is given, the candidate must give an independent variable that is to be investigated. Where neither variable is given, the candidate could give **either** an independent or a dependent variable eg: • concentration of acid or rate of reaction • light intensity or number of seeds germinating • length of pendulum or period. A list of variables is not required. Candidates who make a list must indicate the variable they have chosen to investigate. If the candidate is *unable to meet this criterion*, the teacher should give assistance to enable the candidate to proceed but should *not award the mark* allocated to this objective. In the case of a candidate who identifies a relevant investigable aspect *that cannot be investigated within the constraints of the school situation* the candidate should be directed to alternatives **without penalty**. **Note:** The term 'constraints of the school situation' applies to any circumstance that would prevent the candidate from completing the investigation eg necessary equipment is not available, equipment that is available is insufficiently sensitive, length of school period is too short etc…

Investigative Skills Objective		Criterion	Wording in Investigation Booklet		Additional Guidance
The candidate should be able to:					
G2	state the aim of the investigation;	Clearly identifies the aim of the investigation in terms of the two relevant variables.	2	What is the aim of your investigation?	**Both** the independent and dependent variables must be mentioned eg to find out how: • *light intensity* affects the *germination* of seeds • the *length* of pendulum affects the *period* • the *concentration* of an acid affects *rate of reaction.* Candidates can use their own words – ie they do not have to use precise scientific terms to meet this criterion.
G3	articulate a testable hypothesis;	Articulates a testable hypothesis in terms of the two relevant variables; this should be directional if a continuous variable is chosen.	3	What is your hypothesis? (What do you expect to happen?)	Where a discontinuous variable is used, candidates should not be penalised for using the word 'change' eg the following are acceptable: • I expect voltage to change when I use electrodes made of different metals. • I expect height of rebound to change when I use different surfaces. When a continuous variable is used the direction of change **must** be mentioned eg I expect: • *more* seeds to germinate as temperature rises • current to *increase* as voltage increases. If the candidate is *unable to meet this criterion*, the teacher should give assistance to enable the candidate to proceed but should *not award the mark* allocated to this objective.

Investigative Skills Objective		Criterion	Wording in Investigation Booklet	Additional Guidance
The candidate should be able to:				
G4	suggest a broad strategy to adopt;	The strategy gives sufficient detail by description and/or diagram to indicate:	4 Describe briefly how you are going to carry out your investigation.	
		a) how the chosen independent variable will be altered.		*a)* It is not sufficient for candidates to say what they are going to change; they **must** state how they are going to effect the change eg I will change: • the voltage … by adding more batteries/by turning the voltage control on the power supply. ('by using a power supply' on its own is insufficient as many common power supplies have a single output voltage) • the temperature … by heating with a bunsen burner/water bath • light intensity … by putting one seed tray in a cupboard, one beside a window and one in a shaded part of the room. In each case the text after the ellipsis is essential. For investigations where candidates are provided with prepared samples of the independent variable (eg acids of different concentrations), they should indicate that they are using a different sample for each test.
		b) that the candidate has considered what will have to be measured.		*b)* Candidates do not require to state how they intend to measure the dependent variable. It is sufficient for candidates to state that they intend to measure it eg I will: • measure the volume of gas given off • measure the current • count the number of seeds that germinate. Where the independent variable requires to be measured, candidates should also state that they intend to measure this variable.

Investigative Skills Objective		Criterion	Wording in Investigation Booklet	Additional Guidance
The candidate should be able to:				
E1	adopt appropriate and safe procedures;	*Adopts appropriate and safe procedures. (Mark awarded by teacher observation)*	7 You should now carry out your investigation in a safe way.	**Both** appropriateness and safety are essential. Thus the mark allocated to this objective should not be awarded if the procedures followed by candidates: • do not allow successful completion of the investigation eg inappropriate method of measuring either variable • put themselves or anyone else at risk.
E2	identify the independent variable to be used and alter it over a suitable range;	*a)* Provides a working definition of the independent variable. *b)* Alters the independent variable over an appropriate range taking account of a suitable number of types or values.	5 State clearly what you are going to change. 8 Make a table of your results.	*a)* The candidate must refer to the **independent** variable. *b)* The minimum number of types of values must be **appropriate to the investigation.** While a minimum of three values will be appropriate in many investigations, this number would be insufficient for others. For example, the three pairs of values below could be obtained by candidates investigating *either* the variation of range with angle of projection (smooth curve with maximum at 45°) *or* variation of current with voltage (straight line through the origin for ohmic circuit). *Variable 1* 10 20 30 *Variable 2* 3.2 6.4 8.8 These three points on their own are insufficient to establish the relationship between these variables.

Investigative Skills Objective		Criterion	Wording in Investigation Booklet	Additional Guidance
The candidate should be able to:				
E3	control all the relevant variables as necessary;	*a)* Makes a written statement of the variables which need to be actively controlled by the candidate. *b) Controls these variables in practice.*	6 What variables are you going to keep the same?	*a)* The statement should include all variables that **must** be controlled by the candidate to ensure that the results of the investigation are valid. For example, if maintaining a constant temperature is crucial to the investigation, temperature must be included in the statement. However, if small variations in laboratory temperature do not have a significant effect on the measurements made, the candidate need not include temperature in the list. A candidate who omits any variable that must be controlled should not be awarded this mark. *b)* Candidates must **actively** control all of the variables included in their lists.
E4	make valid, reliable measurement of the dependent variable;	*a) Uses a valid method of measuring the dependent variable.*	7 You should now carry out your investigation in a safe way. Use the space below to note results or for rough notes.	*a)* Candidates must use a valid method to measure the dependent variable. (The method used by the candidate to measure the independent variable is irrelevant to this criterion. However, a candidate using an invalid method for measuring the independent variable would not be awarded the mark allocated to objective *E1*.)

Investigative Skills Objective		Criterion	Wording in Investigation Booklet	Additional Guidance
The candidate should be able to:				
E4 *(cont)*		*b)* Evidence is provided of a form of repeat/ replicate testing which improves the reliability of the results **or** a valid written justification is given for not repeating/ replicating measurements.	8 Make a table of your results.	*b)* In addition to taking more than one reading of the same measurement, repetition/replication may involve: • simultaneous experiments eg planting many seeds at the same time • measuring multiples eg the time for 10 swings of a pendulum. Pooling of results is not permitted. The purpose of replication is to **improve the reliability** of the results. Thus a candidate who calculates an average incorrectly should not be awarded the mark allocated to this criterion. Normal constraints of the school situation, eg insufficient apparatus, cost, length of period etc. are **not** valid justifications for repeat/replicate testing not being carried out. Candidates should have been directed to other investigable aspects without penalty (see comments for objective *G1*).
RR1	tabulate results with appropriate headings and units of measurement;	*a)* Values (or types) with appropriate headings for inde-pendent, dependent (and any derived) variable are entered in the table. *b)* Appropriate units or their correct abbreviations are entered in the table.	8 Make a table of your results.	*a)* Data must be presented in clearly discernible rows and columns. Headings should be clear and appropriate. Candidates should be encouraged to use a ruler when drawing tables. However, candidates should not be penalised for omitting table lines. Data errors, should be penalised, eg where it is apparent that the candidate has recorded incorrect readings for either variable. *b)* Units are required for **both** the independent and dependent variables. The units may appear in the table headings or in the body of the table. Where a table includes repeated measurements and an average value the units do not need to be repeated for each heading or entry eg: *Reading 1* *Reading 2* *Reading 3* *Average reading (units)* would be acceptable for one variable.

Investigative Skills Objective		Criterion	Wording in Investigation Booklet	Additional Guidance
The candidate should be able to:				
RR2	present the results on a graph or chart;		9 On square ruled paper or graph paper draw a graph or a chart based on your results. Staple the square ruled paper or graph paper to your booklet.	During the generative phase it is in order for the teacher to direct candidates away from investigations that will not permit the candidates to demonstrate these skills (see general comment 3 on page 101).
		a) A graph or chart of suitable size and scale is produced.		*a)* The decision about *suitability* of size of a graph should relate to the quality of the communication, ie does the graph communicate findings clearly? A graph that is difficult to read or interpret does not meet this criterion. Numerical scales must rise in equal increments (eg 0, 2, 4, 6, 8 ... **not** 0, 2, 5, 11, 23 ...).
		b) Both axes have appropriate labels and units.		*b)* Any error in labelling or units should be penalised *unless* the candidate has already been penalised for the error under criterion *RR1a* or *RR1b*. Line graph scales do not need to begin at zero. However, candidates using such scales will have to exercise great care when drawing conclusions. For bar charts, the y-axis should begin at zero.
		c) Plots all the points/bars accurately.		*c)* Plotting either average values or all replicates is acceptable. The points plotted should be consistent with the data in the table produced by the candidate. Incorrect data (penalised under criterion *RR1a*) plotted correctly should not be penalised again here.

Investigative Skills Objective		Criterion	Wording in Investigation Booklet	Additional Guidance
The candidate should be able to:				
RR2 *(cont)*		*d)* Draws line/curve of best fit or joins up the points as appropriate when the independent variable is continuous **or** draws a bar chart when independent variable is not continuous.		*d)* A line/curve of best fit must be drawn where this is appropriate eg in physics investigations. Joining of points with a series of straight lines should be accepted only if this is appropriate to the investigation. Inappropriate extrapolation should be penalised eg straight line extended well beyond highest/lowest values without supporting data. Vertical solid lines (spikes) should be penalised in line graphs. In a bar chart adjacent bars may be separate or touching. Candidates should be encouraged to use bars of equal width and to avoid using spikes.
Ev1	draw a valid conclusion inter-relating the appropriate variables;	Draws a conclusion which inter-relates the appropriate variables or states that no firm conclusion can be drawn.	10 What conclusion can you draw from your results?	The conclusion should relate to the aim of the investigation (*G2*) and should reflect the findings. It should be more than a simple restatement of the results. acceptable: "The higher the temperature the more seeds germinated." not acceptable: "Half the seeds germinated at 5°C and all the seeds germinated at 25°C." Where a valid conclusion can be made that is directional, the direction of change must be included in the candidate's conclusion. acceptable: "The longer the pendulum string the greater the period." unacceptable: "The period of the pendulum changes as the string gets longer." Candidates do not have to use precise scientific terms to meet this criterion ie candidates may answer in their own words.

Investigative Skills Objective		Criterion	Wording in Investigation Booklet	Additional Guidance
The candidate should be able to:				
Ev2	use results to evaluate the original hypothesis;	Confirms the hypothesis if appropriate **or** refutes hypothesis and replaces it with appropriate substitute **or** states that no conclusion can be drawn.	11 What can you say about your hypothesis? (Circle A or B or C below. If your circle B complete the sentence.) A My hypothesis in part 3 is correct. B My hypothesis in part 3 should be changed to … C My results do not allow me to choose A or B.	If the candidate is unable to meet the criterion for skill objective *G3*, the teacher should give assistance so that the candidate has an opportunity to gain the mark for objective *Ev2*. Where this is the case the teacher should record an appropriate comment on page 2 in the candidate's investigation booklet.

Investigative Skills Objective		Criterion	Wording in Investigation Booklet	Additional Guidance
The candidate should be able to:				
RR3	describe how the investigation was carried out.	The description includes: *a)* a labelled diagram and/or statement of the apparatus used; *b)* an account of the procedure adopted to measure the dependent variable; *c)* an account of how the independent variable was altered; *d)* an indication of how variables which were the investigator's responsibility to control were kept constant.	12 Describe clearly how you set up and carried out your investigation.	*a)* Key apparatus must appear in the text or in a labelled diagram. A list of apparatus is not required. *b)* This account should describe the procedure actually used by the candidate. *c)* This account should describe the procedure actually used by the candidate. The procedure used may be different from the procedure indicated for objective *G4* eg a candidate may have planned to change temperature using a bunsen burner but may actually have used an immersion heater. *d)* Candidates should indicate how they controlled **all** of the variables specified in their statement for criterion *E3a*. Some of the information required may be communicated by a clearly labelled diagram eg diagram could show that temperature was controlled by immersion of apparatus in crushed ice.