Syllabus

Cambridge O Level Chemistry
Syllabus code 5070
For examination in June and November 2011

UNIVERSITY *of* CAMBRIDGE
International Examinations

Note for Exams Officers: Before making Final Entries, please check availability of the codes for the components and options in the E3 booklet (titled "Procedures for the Submission of Entries") relevant to the exam session. Please note that component and option codes are subject to change.

Contents

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1. Introduction

1.1 Why choose Cambridge?

University of Cambridge International Examinations (CIE) is the world's largest provider of international qualifications. Around 1.5 million students from 150 countries enter Cambridge examinations every year. What makes educators around the world choose Cambridge?

Developed for an international audience

International O Levels have been designed specially for an international audience and are sensitive to the needs of different countries. These qualifications are designed for students whose first language may not be English and this is acknowledged throughout the examination process. The curriculum also allows teaching to be placed in a localised context, making it relevant in varying regions.

Recognition

Cambridge O Levels are internationally recognised by schools, universities and employers as equivalent to UK GCSE. They are excellent preparation for A/AS Level, the Advanced International Certificate of Education (AICE), US Advanced Placement Programme and the International Baccalaureate (IB) Diploma. CIE is accredited by the UK Government regulator, the Qualifications and Curriculum Authority (QCA). Learn more at **www.cie.org.uk/recognition**.

Support

CIE provides a world-class support service for teachers and exams officers. We offer a wide range of teacher materials to Centres, plus teacher training (online and face-to-face) and student support materials. Exams officers can trust in reliable, efficient administration of exams entry and excellent, personal support from CIE Customer Services. Learn more at **www.cie.org.uk/teachers**.

Excellence in education

Cambridge qualifications develop successful students. They not only build understanding and knowledge required for progression, but also learning and thinking skills that help students become independent learners and equip them for life.

Not-for-profit, part of the University of Cambridge

CIE is part of Cambridge Assessment, a not-for-profit organisation and part of the University of Cambridge. The needs of teachers and learners are at the core of what we do. CIE invests constantly in improving its qualifications and services. We draw upon education research in developing our qualifications.

1. Introduction

1.2 Why choose Cambridge O Level Chemistry?

International O Levels are established qualifications that keep pace with educational developments and trends. The International O Level curriculum places emphasis on broad and balanced study across a wide range of subject areas. The curriculum is structured so that students attain both practical skills and theoretical knowledge.

Cambridge O Level Chemistry is recognised by universities and employers throughout the world as proof of knowledge and understanding. Successful Cambridge O Level Chemistry candidates gain lifelong skills, including:

- a better understanding of the technological world in which they live, and take an informed interest in science and scientific developments
- knowledge of the basic principles of Chemistry through a mix of theoretical and practical studies
- an understanding of the scientific skills essential for further study at A Level, skills which are useful in everyday life
- how science is studied and practised, and an awareness that the results of scientific research can have both good and bad effects on individuals, communities and the environment.

Candidates may also study for a Cambridge O Level in a number of other science subjects including Physics and Biology. In addition to Cambridge O Levels, CIE also offers Cambridge IGCSE and International A & AS Levels for further study in both Chemistry as well as other science subjects. See **www.cie.org.uk** for a full list of the qualifications you can take.

1.3 How can I find out more?

If you are already a Cambridge Centre

You can make entries for this qualification through your usual channels, e.g. your regional representative, the British Council or CIE Direct. If you have any queries, please contact us at **international@cie.org.uk**.

If you are not a Cambridge Centre

You can find out how your organisation can become a Cambridge Centre. Email either your local British Council representative or CIE at **international@cie.org.uk**. Learn more about the benefits of becoming a Cambridge Centre at **www.cie.org.uk**.

2. Assessment at a glance

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All candidates enter for **three** papers – Papers 1 and 2 and either 3 or 4.

Paper 1: Multiple choice	**1 hour**
40 compulsory multiple choice questions. A copy of the data sheet (see Appendix) is provided as part of this paper. 40 marks	

Paper 2: Theory	**1 hour 30 minutes**
This paper has two sections. Section A has a small number of compulsory, structured questions of variable mark value. 45 marks in total are available for this section. Section B has four questions to choose from and candidates must answer **three**. Each question is worth 10 marks. A copy of the data sheet (see Appendix) is provided as part of this paper. 75 marks	

Paper 3: Practical test	**1 hour 30 minutes**	**Paper 4: Alternative to practical**	**1 hour**
Details of the syllabus and requirements for this paper are given in the Appendix. Candidates may **not** refer to notebooks, textbooks or any other information during the practical examination. Qualitative Analysis Notes are provided. 40 marks scaled to a mark out of 30.		A written paper of compulsory short-answer and structured questions designed to test familiarity with laboratory practical procedures. Further details are given in the Appendix. Qualitative Analysis Notes are **not** provided. 60 marks scaled to a mark out of 30.	

3. Syllabus aims and assessment

3.1 Aims

The aims of the syllabus, which are not listed in order of priority, are to:

1. provide, through well designed studies of experimental and practical chemistry, a worthwhile educational experience for all students, whether or not they go on to study science beyond this level and, in particular, to enable them to acquire sufficient understanding and knowledge to
   - 1.1 become confident citizens in a technological world, able to take or develop an informed interest in matters of scientific import;
   - 1.2 recognise the usefulness, and limitations, of scientific method and to appreciate its applicability in other disciplines and in everyday life;
   - 1.3 be suitably prepared for studies beyond O/SC level in pure sciences, in applied sciences or in science-dependent vocational courses.
2. develop abilities and skills that:
   - 2.1 are relevant to the study and practice of science;
   - 2.2 are useful in everyday life;
   - 2.3 encourage efficient and safe practice;
   - 2.4 encourage effective communication.
3. develop attitudes relevant to science such as:
   - 3.1 concern for accuracy and precision;
   - 3.2 objectivity;
   - 3.3 integrity;
   - 3.4 enquiry;
   - 3.5 initiative;
   - 3.6 inventiveness.
4. stimulate interest in and care for the local and global environment.
5. promote an awareness that:
   - 5.1 the study and practice of science are co-operative and cumulative activities, and are subject to social, economic, technological, ethical and cultural influences and limitations;
   - 5.2 the applications of sciences may be both beneficial and detrimental to the individual, the community and the environment.

3.2 Assessment objectives

The three assessment objectives in Cambridge O Level Chemistry are:

A: Knowledge with understanding

Candidates should be able to demonstrate knowledge and understanding in relation to

1. scientific phenomena, facts, laws, definitions, concepts and theories
2. scientific vocabulary, terminology and conventions (including symbols, quantities and units)
3. scientific instruments and apparatus, including techniques of operation and aspects of safety
4. scientific quantities and their determination
5. scientific and technological applications with their social, economic and environmental implications.

Curriculum content defines the factual material that candidates may be required to recall and explain. Questions testing these objectives will often begin with one of the following words: *define, state, describe, explain* or *outline* (see Glossary of Terms).

B: Handling information and solving problems

Candidates should be able, in words or using symbolic, graphical and numerical forms of presentation, to

1. locate, select, organise and present information from a variety of sources
2. translate information from one form to another
3. manipulate numerical and other data
4. use information to identify patterns, report trends and draw inferences
5. present reasoned explanations for phenomena, patterns and relationships
6. make predictions and hypotheses
7. solve problems.

These assessment objectives cannot be precisely specified in the subject content because questions testing such skills may be based on information that is unfamiliar to the candidate. In answering such questions, candidates are required to use principles and concepts that are within the syllabus and apply them in a logical, deductive or reasoned manner to a new situation.
Questions testing these skills will often begin with one of the following words: *predict, suggest, calculate* or *determine*. (See the Glossary of Terms.)

C: Experimental skills and investigations

Candidates should be able to

1. follow a sequence of instructions
2. use techniques, apparatus and materials
3. make and record observations, measurements and estimates
4. interpret, evaluate and report upon observations and experimental results
5. design/plan an investigation, select techniques, apparatus and materials
6. evaluate methods and suggest possible improvements.

The apparatus and techniques that candidates should be familiar with are given in Section 1 of the curriculum content and in the descriptions of Papers 3 and 4. See also Appendix.

3.3 Weighting of Assessment objectives

Theory papers (Papers 1 and 2)

A: Knowledge with understanding is weighted at approximately 65% of the marks with approximately half allocated to recall.

B: Handling information and solving problems is weighted at approximately 35% of the marks.

Practical assessment (Papers 3 and 4)

This is designed to test appropriate skills in **C: Experimental skills and investigations** and carries approximately 20% of the marks for the subject.

3.4 Exam combinations

Candidates can combine this syllabus in an exam session with any other CIE syllabus, except:

- syllabuses with the same title at the same level
- 0620 Chemistry
- 0652 Physical Science
- 0653 Combined Science
- 0654 Co-ordinated Sciences (Double Award)
- 5124 Science (Physics, Chemistry)
- 5126 Science (Chemistry, Biology)
- 5129 Combined Science
- 5130 Additional Combined Science

Please note that O Level, Cambridge International Level 1/Level 2 Certificates and IGCSE syllabuses are at the same level.

3.5 Nomenclature, units and significant figures

Nomenclature

The proposals in 'Signs, Symbols and Systematics' (The Association for Science Education Companion to 16–19 Science)' will generally be adopted, although the traditional names sulfate, sulfite, nitrate, nitrite, sulfurous and nitrous acids will be used in question papers. Sulfur (and all compounds of sulfur) will be spelt with f, not ph.

To avoid difficulties arising out of the use of *l* as the symbol for litre, use of $\mathbf{dm^3}$ in place of *l* or litre will be made.

In chemistry, full *structural formulae (displayed formulae)* in answers should show in detail both the relative placing of atoms and the number of bonds between atoms. Hence $–CONH_2$ and $–CO_2H$ are not satisfactory as full structural formulae, although either of the usual symbols for the benzene ring is acceptable.

Units, significant figures

Candidates should be aware that misuse of units and/or significant figures, i.e. failure to quote units where necessary, the inclusion of units in quantities defined as ratios or quoting answers to an inappropriate number of significant figures, is liable to be penalised.

4. Curriculum content

Most of the objectives specified below relate to *Knowledge with understanding*, although some indication has been given as to where the skills of *Handling information and solving problems* may be developed. Teachers are reminded that, in the written papers, some of the marks are allocated to these higher 'thinking' skills. In almost every section, candidates should be given practice at dealing with unfamiliar situations so that these higher thinking skills can be developed.

It is important that, throughout the course, attention should be drawn to:

(i) the finite life of the world's resources and economic and environmental issues relating to recycling, renewable energy and conservation;

(ii) economic considerations in the chemical industry, such as the availability and cost of raw materials and energy;

(iii) the social, environmental, health and safety issues relating to the use of chemicals in the laboratory, in the home and in industry;

(iv) the importance of chemicals in industry and in everyday life.

Asterisks (*) placed alongside learning objectives indicate areas of the syllabus where it is anticipated that teachers might use applications of IT, as appropriate.

1 EXPERIMENTAL CHEMISTRY

Content

1.1 Experimental design

1.2 Methods of purification and analysis

1.3 Identification of ions and gases

It is expected that any course in Chemistry will be based on experimental work. Teachers are encouraged to develop appropriate practical work for their students to facilitate a greater understanding of the subject. Candidates should be aware of the hazards and appropriate safety precautions to follow when handling the reagents mentioned in this section.

Learning Outcomes

Candidates should be able to:

1.1 Experimental design

(a) name appropriate apparatus for the measurement of time, temperature, mass and volume, including burettes, pipettes, measuring cylinders and gas syringes

(b) suggest suitable apparatus, given relevant information, for a variety of simple experiments, including collection of gases and measurement of rates of reaction

4. Curriculum content

1.2 Methods of purification and analysis

(a) describe methods of purification by the use of a suitable solvent, filtration and crystallisation, distillation and fractional distillation, with particular references to the fractional distillation of crude oil, liquid air and fermented liquor

(b) suggest suitable methods of purification, given information about the substances involved

(c) describe paper chromatography and interpret chromatograms including comparison with 'known' samples and the use of R_f values

(d) explain the need to use locating agents in the chromatography of colourless compounds

(e) deduce from the given melting point and boiling point the identities of substances and their purity

(f) explain that the measurement of purity in substances used in everyday life, e.g. foodstuffs and drugs, is important

1.3 Identification of ions and gases

(a) describe the use of aqueous sodium hydroxide and aqueous ammonia to identify the following aqueous cations: aluminium, ammonium, calcium, copper(II), iron(II), iron(III) and zinc (formulae of complex ions are **not** required)

(b) describe tests to identify the following anions: carbonate (by the addition of dilute acid and subsequent use of limewater); chloride (by reaction of an aqueous solution with nitric acid and aqueous silver nitrate); iodide (by reaction of an aqueous solution with nitric acid and aqueous lead(II) nitrate); nitrate (by reduction with aluminium and aqueous sodium hydroxide to ammonia and subsequent use of litmus paper) and sulfate (by reaction of an aqueous solution with nitric acid and aqueous barium nitrate)

(c) describe tests to identify the following gases: ammonia (using damp red litmus paper); carbon dioxide (using limewater); chlorine (using damp litmus paper); hydrogen (using a burning splint); oxygen (using a glowing splint) and sulfur dioxide (using acidified potassium dichromate(VI))

(d) describe a chemical test for water

4. Curriculum content

2 THE PARTICULATE NATURE OF MATTER

Content

2.1 Kinetic particle theory

2.2 Atomic structure

2.3 Structure and properties of materials

2.4 Ionic bonding

2.5 Covalent bonding

2.6 Metallic bonding

Learning Outcomes

Candidates should be able to:

2.1 Kinetic particle theory

(a) *describe the solid, liquid and gaseous states of matter and explain their interconversion in terms of the kinetic particle theory and of the energy changes involved

(b) *describe and explain evidence for the movement of particles in liquids and gases (the treatment of Brownian motion is not required)

(c) explain everyday effects of diffusion in terms of particles, e.g. the spread of perfumes and cooking aromas; tea and coffee grains in water

(d) *state qualitatively the effect of molecular mass on the rate of diffusion and explain the dependence of rate of diffusion on temperature

2.2 Atomic structure

(a) state the relative charges and approximate relative masses of a proton, a neutron and an electron

(b) *describe, with the aid of diagrams, the structure of an atom as containing protons and neutrons (nucleons) in the nucleus and electrons arranged in shells
(energy levels) (no knowledge of s, p, d and f classification will be expected; a copy of the Periodic Table will be available in Papers 1 and 2)

(c) define proton number and nucleon number

(d) interpret and use symbols such as ${}^{12}_{6}C$

(e) define the term *isotopes*

(f) deduce the numbers of protons, neutrons and electrons in atoms and ions from proton and nucleon numbers

(g) state that some isotopes are radioactive

2.3 Structure and properties of materials

(a) describe the differences between elements, compounds and mixtures

(b) *compare the structure of molecular substances, e.g. methane; iodine, with those of giant molecular substances, e.g. poly(ethene); sand; diamond; graphite in order to deduce their properties

(c) *compare the bonding and structures of diamond and graphite in order to deduce properties such as electrical conductivity, lubricating or cutting action (candidates will not be required to draw the structures)

(d) deduce the physical and chemical properties of substances from their structures and bonding and vice versa

2.4 Ionic bonding

(a) *describe the formation of ions by electron loss/gain in order to obtain the electronic configuration of an inert gas

(b) *describe the formation of ionic bonds between metals and non-metals, e.g. $NaCl$; $MgCl_2$

(c) *state that ionic materials contain a giant lattice in which the ions are held by electrostatic attraction, e.g. $NaCl$ (candidates will not be required to draw diagrams of ionic lattices)

(d) deduce the formulae of other ionic compounds from diagrams of their lattice structures, limited to binary compounds

(e) relate the physical properties (including electrical property) of ionic compounds to their lattice structure

2.5 Covalent bonding

(a) *describe the formation of a covalent bond by the sharing of a pair of electrons in order to gain the electronic configuration of an inert gas

(b) describe, using ‘dot-and-cross’ diagrams, the formation of covalent bonds between non-metallic elements, e.g. H_2; Cl_2; O_2; HCl; N_2; H_2O; CH_4; C_2H_4; CO_2

(c) deduce the arrangement of electrons in other covalent molecules

(d) relate the physical properties (including electrical properties) of covalent compounds to their structure and bonding

2.6 Metallic bonding

(a) *describe metals as a lattice of positive ions in a ‘sea of electrons’

(b) *relate the malleability of metals to their structure and the electrical conductivity of metals to the mobility of the electrons in the structure

4. Curriculum content

3 FORMULAE, STOICHIOMETRY AND THE MOLE CONCEPT

Candidates should be able to:

(a) state the symbols of the elements and formulae of the compounds mentioned in the syllabus

(b) deduce the formulae of simple compounds from the relative numbers of atoms present and *vice versa*

(c) deduce the formulae of ionic compounds from the charges on the ions present and *vice versa*

(d) interpret and construct chemical equations, with state symbols, including ionic equations

(e) define relative atomic mass, A_r

(f) define relative molecular mass, M_r, and calculate relative molecular mass (and relative formula mass) as the sum of relative atomic masses

(g) calculate the percentage mass of an element in a compound when given appropriate information

(h) calculate empirical and molecular formulae from relevant data

(i) *calculate stoichiometric reacting masses and volumes of gases (one mole of gas occupies 24 dm^3 at room temperature and pressure); calculations involving the idea of limiting reactants may be set (questions on the gas laws and the calculations of gaseous volumes at different temperatures and pressures will not be set)

(j) *apply the concept of solution concentration (in mol/dm^3 or g/dm^3) to process the results of volumetric experiments and to solve simple problems (appropriate guidance will be provided where unfamiliar reactions are involved)

(k) calculate % yield and % purity

4 ELECTROLYSIS

Candidates should be able to:

(a) *describe electrolysis as the conduction of electricity by an ionic compound (an electrolyte), when molten or dissolved in water, leading to the decomposition of the electrolyte

(b) *describe electrolysis as evidence for the existence of ions which are held in a lattice when solid but which are free to move when molten or in solution

(c) describe, in terms of the mobility of ions present and the electrode products, the electrolysis of molten lead bromide, using inert electrodes

(d) predict the likely products of the electrolysis of a molten binary compound

(e) apply the idea of selective discharge (linked to the reactivity series for cations, see 9.2) to deduce the electrolysis of concentrated aqueous sodium chloride, aqueous copper(II) sulfate and dilute sulfuric acid using inert electrodes

(f) predict the likely products of the electrolysis of an aqueous electrolyte, given relevant information

(g) construct ionic equations for the reactions occurring at the electrodes during the electrolysis of the substances mentioned in the syllabus

(h) *describe the electrolysis of purified aluminium oxide dissolved in molten cryolite as the method of extraction of aluminium (see 9.5(a))

(i) *describe the electrolysis of aqueous copper(II) sulfate with copper electrodes as a means of purifying copper

(j) *describe the electroplating of metals, e.g. copper plating, and recall one use of electroplating

(k) describe the production of electrical energy from simple cells (i.e. two electrodes in an electrolyte) linked to the reactivity series (see 9.2)

5 ENERGY FROM CHEMICALS

Candidates should be able to:

(a) describe the meaning of enthalpy change in terms of exothermic (ΔH negative) and endothermic (ΔH positive) reactions

(b) *represent energy changes by energy profile diagrams, including reaction enthalpy changes and activation energies (see 6.1(c))

(c) describe bond breaking as an endothermic process and bond making as an exothermic process

(d) *explain overall enthalpy changes in terms of the energy changes associated with the breaking and making of covalent bonds

(e) describe combustion of fuels as exothermic, e.g. wood; coal; oil; natural gas; hydrogen

(f) describe hydrogen, derived from water or hydrocarbons, as a potential fuel for use in future, reacting with oxygen to generate electricity directly in a fuel cell (details of the construction and operation of a fuel cell are **not** required) and discuss the advantages and disadvantages of this

(g) name natural gas, mainly methane, and petroleum as sources of energy

(h) describe petroleum as a mixture of hydrocarbons and its separation into useful fractions by fractional distillation

(i) name the following fractions and state their uses

- (i) petrol (gasoline) as a fuel in cars
- (ii) naphtha as feedstock for the chemical industry
- (iii) paraffin (kerosene) as a fuel for heating and cooking and for aircraft engines
- (iv) diesel as a fuel for diesel engines
- (v) lubricating oils as lubricants and as a source of polishes and waxes
- (vi) bitumen for making road surfaces

(j) describe photosynthesis as the reaction between carbon dioxide and water in the presence of chlorophyll, using sunlight (energy) to produce glucose and explain how this can provide a renewable energy source.

6 CHEMICAL REACTIONS

Content

6.1 Speed of reaction

6.2 Redox

6.3 Reversible reactions

Learning Outcomes

Candidates should be able to:

6.1 Speed of reaction

(a) *describe the effect of concentration, pressure, particle size and temperature on the speeds of reactions and explain these effects in terms of collisions between reacting particles

(b) define the term *catalyst* and describe the effect of catalysts (including enzymes) on the speeds of reactions

(c) *explain how pathways with lower activation energies account for the increase in speeds of reactions

(d) state that transition elements and their compounds act as catalysts (see 8.3) in a range of industrial processes and that enzymes are biological catalysts

(e) suggest a suitable method for investigating the effect of a given variable on the speed of a reaction

(f) *interpret data obtained from experiments concerned with speed of reaction

6.2 Redox

(a) define oxidation and reduction (redox) in terms of oxygen/hydrogen gain/loss

(b) define redox in terms of electron transfer and changes in oxidation state

(c) identify redox reactions in terms of oxygen/hydrogen, and/or electron, gain/loss, and/or changes in oxidation state

(d) describe the use of aqueous potassium iodide, and acidified potassium manganate(VII) and acidified potassium dichromate(VI) in testing for oxidising and reducing agents from the resulting colour changes

6.3 Reversible reactions

(a) describe the idea that some chemical reactions can be reversed by changing the reaction conditions

(b) describe the idea that some reversible reactions can reach dynamic equilibrium and predict the effect of changing the conditions

7 THE CHEMISTRY AND USES OF ACIDS, BASES AND SALTS

Content

7.1 The characteristic properties of acids and bases

7.2 Preparation of salts

7.3 Properties and uses of ammonia

7.4 Sulfuric acid

Learning Outcomes

Candidates should be able to:

7.1 The characteristic properties of acids and bases

(a) describe the meanings of the terms acid and alkali in terms of the ions they contain or produce in aqueous solution and their effects on Universal Indicator paper

(b) describe how to test hydrogen ion concentration and hence relative acidity using Universal Indicator paper and the pH scale

(c) describe the characteristic properties of acids as in reactions with metals, bases and carbonates

(d) describe qualitatively the difference between strong and weak acids in terms of the extent of ionisation

(e) describe neutralisation as a reaction between hydrogen ions and hydroxide ions to produce water, $H^+ + OH^- \rightarrow H_2O$

(f) describe the importance of controlling the pH in soils and how excess acidity can be treated using calcium hydroxide

(g) describe the characteristic properties of bases in reactions with acids and with ammonium salts

(h) classify oxides as acidic, basic or amphoteric, based on metallic/non-metallic character

7.2 Preparation of salts

(a) *describe the techniques used in the preparation, separation and purification of salts as examples of some of the techniques specified in Section 1.2(a)

(methods for preparation should include precipitation and titration together with reactions of acids with metals, insoluble bases and insoluble carbonates)

(b) describe the general rules of solubility for common salts to include nitrates, chlorides (including silver and lead), sulfates (including barium, calcium and lead), carbonates, hydroxides, Group I cations and ammonium salts

(c) suggest a method of preparing a given salt from suitable starting materials, given appropriate information

7.3 Properties and uses of ammonia

- *(a)* describe the use of nitrogen, from air, and hydrogen, from cracking oil, in the manufacture of ammonia
- *(b)* state that some chemical reactions are reversible (e.g. manufacture of ammonia)
- *(c)* *describe the essential conditions for the manufacture of ammonia by the Haber process
- *(d)* describe the use of nitrogenous fertilisers in promoting plant growth and crop yield
- *(e)* compare nitrogen content of salts used for fertilisers by calculating percentage masses
- *(f)* describe eutrophication and water pollution problems caused by nitrates leaching from farm land and explain why the high solubility of nitrates increases these problems
- *(g)* describe the displacement of ammonia from its salts and explain why adding calcium hydroxide to soil can cause the loss of nitrogen from added nitrogenous fertiliser

7.4 Sulfuric acid

- *(a)* describe the manufacture of sulfuric acid from the raw materials sulfur, air and water in the contact process
- *(b)* state the use of sulfur dioxide as a bleach, in the manufacture of wood pulp for paper and as a food preservative (by killing bacteria)
- *(c)* state the uses of sulfuric acid in the manufacture of detergents and fertilisers; and as a battery acid

8 THE PERIODIC TABLE

Content

8.1 Periodic trends

8.2 Group properties

8.3 Transition elements

Learning Outcomes

Candidates should be able to:

8.1 Periodic trends

- *(a)* describe the Periodic Table as an arrangement of the elements in the order of increasing proton (atomic) number
- *(b)* *describe how the position of an element in the Periodic Table is related to proton number and electronic structure
- *(c)* *describe the relationship between Group number and the ionic charge of an element
- *(d)* explain the similarities between the elements in the same Group of the Periodic Table in terms of their electronic structure

(e) describe the change from metallic to non-metallic character from left to right across a period of the Periodic Table

(f) *describe the relationship between Group number, number of valency electrons and metallic/non-metallic character

(g) *predict the properties of elements in Group I, VII and the transition elements using the Periodic Table

8.2 Group properties

(a) describe lithium, sodium and potassium in Group I (the alkali metals) as a collection of relatively soft, low density metals showing a trend in melting point and in their reaction with water

(b) describe chlorine, bromine and iodine in Group VII (the halogens) as a collection of diatomic non-metals showing a trend in colour, state and their displacement reactions with solutions of other halide ions

(c) describe the elements in Group 0 (the noble gases) as a collection of monatomic elements that are chemically unreactive and hence important in providing an inert atmosphere, e.g. argon and neon in light bulbs; helium in balloons; argon in the manufacture of steel

(d) describe the lack of reactivity of the noble gases in terms of their electronic structures

8.3 Transition elements

(a) describe the central block of elements (transition metals) as metals having high melting points, high density, variable oxidation state and forming coloured compounds

(b) state the use of these elements and/or their compounds as catalysts, e.g. iron in the Haber process; vanadium(V) oxide in the Contact process; nickel in the hydrogenation of alkenes, and how catalysts are used in industry to lower energy demands and hence are economically advantageous and help conserve energy sources

9 METALS

Content

9.1 Properties of metals

9.2 Reactivity series

9.3 Extraction of metals

9.4 Iron

9.5 Aluminium

Learning Outcomes

Candidates should be able to:

9.1 Properties of metals

(a) describe the general physical properties of metals (as solids having high melting and boiling points; malleable; good conductors of heat and electricity) in terms of their structure

(b) describe alloys as a mixture of a metal with another element, e.g. brass; stainless steel

(c) identify representations of metals and alloys from diagrams of structures

(d) explain why alloys have different physical properties to their constituent elements

9.2 Reactivity series

(a) place in order of reactivity calcium, copper, (hydrogen), iron, lead, magnesium, potassium, silver, sodium and zinc by reference to

(i) the reactions, if any, of the metals with water, steam and dilute hydrochloric acid,

(ii) the reduction, if any, of their oxides by carbon and/or by hydrogen

(b) describe the reactivity series as related to the tendency of a metal to form its positive ion, illustrated by its reaction with

(i) the aqueous ions of the other listed metals

(ii) the oxides of the other listed metals

(c) deduce the order of reactivity from a given set of experimental results

(d) describe the action of heat on the carbonates of the listed metals and relate thermal stability to the reactivity series

9.3 Extraction of metals

(a) describe the ease of obtaining metals from their ores by relating the elements to their positions in the reactivity series

(b) describe metal ores as a finite resource and hence the need to recycle metals

(c) discuss the social, economic and environmental advantages and disadvantages of recycling metals e.g. aluminium and copper

9.4 Iron

- *(a)* describe and explain the essential reactions in the extraction of iron using haematite, limestone and coke in the blast furnace
- *(b)* describe steels as alloys which are a mixture of iron with carbon or other metals and how controlled use of these additives changes the properties of the iron, e.g. high carbon steels are strong but brittle whereas low carbon steels are softer and more easily shaped
- *(c)* state the uses of mild steel (e.g. car bodies; machinery) and stainless steel (e.g. chemical plant; cutlery; surgical instruments)
- *(d)* describe the essential conditions for the corrosion (rusting) of iron as the presence of oxygen and water; prevention of rusting can be achieved by placing a barrier around the metal (e.g. painting; greasing; plastic coating; galvanising)
- *(e)* describe the sacrificial protection of iron by a more reactive metal in terms of the reactivity series where the more reactive metal corrodes preferentially (e.g. underwater pipes have a piece of magnesium attached to them)

9.5 Aluminium

- *(a)* outline the manufacture of aluminium from pure aluminium oxide dissolved in cryolite (starting materials and essential conditions, including identity of electrodes should be given together with equations for the electrode reactions but no technical details or diagrams are required)
- *(b)* explain the apparent lack of reactivity of aluminium
- *(c)* state the uses of aluminium and relate the uses to the properties of this metal and its alloys, e.g. the manufacture of aircraft; food containers; electrical cables

10 ATMOSPHERE AND ENVIRONMENT

Content

10.1 Air

10.2 Water

Learning Outcomes

Candidates should be able to:

10.1 Air

- *(a)* describe the volume composition of gases present in dry air as 79% nitrogen, 20% oxygen and the remainder being noble gases (with argon as the main constituent) and carbon dioxide
- *(b)* describe the separation of oxygen, nitrogen and the noble gases from liquid air by fractional distillation
- *(c)* state the uses of oxygen (e.g. in making steel; oxygen tents in hospitals; together with acetylene, in welding)
- *(d)* name some common atmospheric pollutants (e.g. carbon monoxide; methane; nitrogen oxides (NO and NO_2); ozone; sulfur dioxide; unburned hydrocarbons)

(e) state the sources of these pollutants as
- *(i)* carbon monoxide from incomplete combustion of carbon-containing substances
- *(ii)* methane from bacterial decay of vegetable matter
- *(iii)* nitrogen oxides from lightning activity and internal combustion engines
- *(iv)* ozone from photochemical reactions responsible for the formation of photochemical smog
- *(v)* sulfur dioxide from volcanoes and combustion of fossil fuels
- *(vi)* unburned hydrocarbons from internal combustion engines

(f) describe the reactions used in possible solutions to the problems arising from some of the pollutants named in *(d)*
- *(i)* the redox reactions in catalytic converters to remove combustion pollutants
- *(ii)* the use of calcium carbonate to reduce the effect of 'acid rain' and in flue gas desulfurisation

(g) discuss some of the effects of these pollutants on health and on the environment
- *(i)* the poisonous nature of carbon monoxide
- *(ii)* the role of nitrogen dioxide and sulfur dioxide in the formation of 'acid rain' and its effects on respiration and buildings

(h) discuss the importance of the ozone layer and the problems involved with the depletion of ozone by reaction with chlorine containing compounds, chlorofluorocarbons (CFCs)

(i) *describe the carbon cycle in simple terms, to include
- *(i)* the processes of combustion, respiration and photosynthesis
- *(ii)* how the carbon cycle regulates the amount of carbon dioxide in the atmosphere

(j) state that carbon dioxide and methane are greenhouse gases and may contribute to global warming, give the sources of these gases and discuss the possible consequences of an increase in global warming

10.2 Water

(a) state that water from natural sources contains a variety of dissolved substances
- *(i)* naturally occurring (mineral salts; oxygen; organic matter)
- *(ii)* pollutant (metal compounds; sewage; nitrates from fertilisers; phosphates from fertilisers and detergents; harmful microbes)

(b) discuss the environmental effects of the dissolved substances named in *(a)*
- *(i)* beneficial, e.g. oxygen and mineral salts for aquatic life
- *(ii)* pollutant, e.g. hazards to health; eutrophication

(c) outline the purification of the water supply in terms of
- *(i)* filtration to remove solids
- *(ii)* use of carbon to remove tastes and odours
- *(iii)* chlorination to disinfect the water

(d) state that seawater can be converted into drinkable water by desalination

11 ORGANIC CHEMISTRY

Content

11.1 Alkanes

11.2 Alkenes

11.3 Alcohols

11.4 Carboxylic acids

11.5 Macromolecules

*The use of molecular models is recommended to enable students to appreciate the three-dimensional structures of molecules

Learning Outcomes

Candidates should be able to:

(a) state that the naphtha fraction from crude oil is the main source of hydrocarbons used as the feedstock for the production of a wide range of organic compounds

(b) describe the issues relating to the competing uses of oil as an energy source and as a chemical feedstock

11.1 Alkanes

(a) describe an homologous series as a group of compounds with a general formula, similar chemical properties and showing a gradation in physical properties as a result of increase in the size and mass of the molecules, e.g. melting and boiling points; viscosity; flammability

(b) describe the alkanes as an homologous series of saturated hydrocarbons with the general formula C_nH_{2n+2}

(c) *draw the structures of branched and unbranched alkanes, C1 to C4 and name the unbranched alkanes, methane to butane

(d) define isomerism and identify isomers

(e) describe the properties of alkanes (exemplified by methane) as being generally unreactive except in terms of burning and substitution by chlorine

11.2 Alkenes

(a) describe the alkenes as an homologous series of unsaturated hydrocarbons with the general formula C_nH_{2n}

(b) *draw the structures of branched and unbranched alkenes, C2 to C4 and name the unbranched alkenes, ethene to butene

(c) describe the manufacture of alkenes and hydrogen by cracking hydrocarbons and recognise that cracking is essential to match the demand for fractions containing smaller molecules from the refinery process

(d) describe the difference between saturated and unsaturated hydrocarbons from their molecular structures and by using aqueous bromine

(e) describe the properties of alkenes in terms of combustion, polymerisation and their addition reactions with bromine, steam and hydrogen

(f) state the meaning of *polyunsaturated* when applied to food products

(g) describe the manufacture of margarine by the addition of hydrogen to unsaturated vegetable oils to form a solid product

11.3 Alcohols

(a) describe the alcohols as an homologous series containing the –OH group

(b) *draw the structures of alcohols, C1 to C4 and name the unbranched alcohols, methanol to butanol

(c) describe the properties of alcohols in terms of combustion and oxidation to carboxylic acids

(d) describe the formation of ethanol by the catalysed addition of steam to ethene and by fermentation of glucose

(e) state some uses of ethanol, e.g. as a solvent; as a renewable fuel; as a constituent of alcoholic beverages

11.4 Carboxylic acids

(a) describe the carboxylic acids as an homologous series containing the $–CO_2H$ group

(b) *draw the structures of carboxylic acids, methanoic acid to butanoic acid and name the unbranched acids, methanoic to butanoic acids

(c) describe the carboxylic acids as weak acids, reacting with carbonates, bases and some metals

(d) describe the formation of ethanoic acid by the oxidation of ethanol by atmospheric oxygen or acidified potassium dichromate(VI)

(e) describe the reaction of ethanoic acid with ethanol to form the ester, ethyl ethanoate

(f) state some commercial uses of esters, e.g. perfumes; flavourings; solvents

11.5 Macromolecules

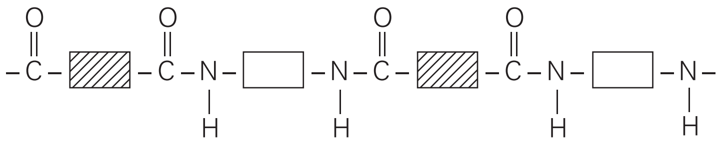
(a) *describe macromolecules as large molecules built up from small units, different macromolecules having different units and/or different linkages

(b) describe the formation of poly(ethene) as an example of addition polymerisation of ethene as the monomer

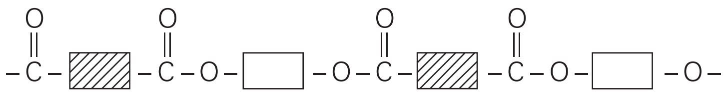
(c) state some uses of poly(ethene) as a typical plastic, e.g. plastic bags; clingfilm

(d) deduce the structure of the polymer product from a given monomer and vice versa

(e) describe nylon, a polyamide, and *Terylene*, a polyester, as condensation polymers, the partial structure of nylon being represented as



and the partial structure of *Terylene* as



(details of manufacture and mechanisms of these polymerisations are **not** required)

(f) state some typical uses of man-made fibres such as nylon and *Terylene*, e.g. clothing; curtain materials; fishing line; parachutes; sleeping bags

(g) describe the pollution problems caused by the disposal of non-biodegradable plastics

(h) identify carbohydrates, proteins and fats as natural macromolecules

(i) describe proteins as possessing the same amide linkages as nylon but with different monomer units

(j) describe fats as esters possessing the same linkages as *Terylene* but with different monomer units

(k) describe the hydrolysis of proteins to amino acids and carbohydrates (e.g. starch) to simple sugars

5. Appendix

5.1 Mathematical requirements

Calculators may be used in all parts of the examination providing they are in accordance with the regulations stated in the *UCLES Handbook for Centres (General Certificate of Education)*.
Candidates should be able to:

- add, subtract, multiply and divide
- use averages, decimals, fractions, percentages, ratios and reciprocals
- recognise and use standard notation
- use direct and inverse proportion
- use positive, whole number indices
- draw charts and graphs from given data
- interpret charts and graphs
- select suitable scales and axes for graphs
- make approximate evaluations of numerical expressions
- recognise and use the relationship between length, surface area and volume and their units on metric scales
- solve equations of the form $x = yz$ for any one term when the other two are known.
- understand and use the symbols/notations $<$, $>$, $\approx$, /, $\propto$;
- understand how to handle numerical work so that significant figures are neither lost unnecessarily nor used beyond what is justified.

5.2 Data sheet: The Periodic Table of the Elements

Group																	
I	II											III	IV	V	VI	VII	0
							1 **H** Hydrogen 1										4 **He** Helium 2
7 **Li** Lithium 3	9 **Be** Beryllium 4											11 **B** Boron 5	12 **C** Carbon 6	14 **N** Nitrogen 7	16 **O** Oxygen 8	19 **F** Fluorine 9	20 **Ne** Neon 10
23 **Na** Sodium 11	24 **Mg** Magnesium 12											27 **Al** Aluminium 13	28 **Si** Silicon 14	31 **P** Phosphorus 15	32 **S** Sulfur 16	35.5 **Cl** Chlorine 17	40 **Ar** Argon 18
39 **K** Potassium 19	40 **Ca** Calcium 20	45 **Sc** Scandium 21	48 **Ti** Titanium 22	51 **V** Vanadium 23	52 **Cr** Chromium 24	55 **Mn** Manganese 25	56 **Fe** Iron 26	59 **Co** Cobalt 27	59 **Ni** Nickel 28	64 **Cu** Copper 29	65 **Zn** Zinc 30	70 **Ga** Gallium 31	73 **Ge** Germanium 32	75 **As** Arsenic 33	79 **Se** Selenium 34	80 **Br** Bromine 35	84 **Kr** Krypton 36
85 **Rb** Rubidium 37	88 **Sr** Strontium 38	89 **Y** Yttrium 39	91 **Zr** Zirconium 40	93 **Nb** Niobium 41	96 **Mo** Molybdenum 42	**Tc** Technetium 43	101 **Ru** Ruthenium 44	103 **Rh** Rhodium 45	106 **Pd** Palladium 46	108 **Ag** Silver 47	112 **Cd** Cadmium 48	115 **In** Indium 49	119 **Sn** Tin 50	122 **Sb** Antimony 51	128 **Te** Tellurium 52	127 **I** Iodine 53	131 **Xe** Xenon 54
133 **Cs** Caesium 55	137 **Ba** Barium 56	139 **La** Lanthanum 57 *	178 **Hf** Hafnium 72	181 **Ta** Tantalum 73	184 **W** Tungsten 74	186 **Re** Rhenium 75	190 **Os** Osmium 76	192 **Ir** Iridium 77	195 **Pt** Platinum 78	197 **Au** Gold 79	201 **Hg** Mercury 80	204 **Tl** Thallium 81	207 **Pb** Lead 82	209 **Bi** Bismuth 83	**Po** Polonium 84	**At** Astatine 85	**Rn** Radon 86
Fr Francium 87	226 **Ra** Radium 88	227 **Ac** actinium 89 †															

*58–71 Lanthanoid series
†90–103 Actinoid series

140 **Ce** Cerium 58	141 **Pr** Praseodymium 59	144 **Nd** Neodymium 60	**Pm** Promethium 61	150 **Sm** Samarium 62	152 **Eu** Europium 63	157 **Gd** Gadolinium 64	159 **Tb** Terbium 65	163 **Dy** Dysprosium 66	165 **Ho** Holmium 67	167 **Er** Erbium 68	169 **Tm** Thulium 69	173 **Yb** Ytterbium 70	175 **Lu** Lutetium 71
232 **Th** Thorium 90	**Pa** Protactinium 91	238 **U** Uranium 92	**Np** Neptunium 93	**Pu** Plutonium 94	**Am** Americium 95	**Cm** Curium 96	**Bk** Berkelium 97	**Cf** Californium 98	**Es** Einsteinium 99	**Fm** Fermium 100	**Md** Mendelevium 101	**No** Nobelium 102	**Lr** Lawrencium 103

Key

a **X** b

a = relative atomic mass
X = atomic symbol
b = proton (atomic) number

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.)

5. Appendix

5.3 Practical assessment

Scientific subjects are, by their nature, experimental. So it is important that an assessment of a candidate's knowledge and understanding of Chemistry should contain a component relating to practical work and experimental skills. Two alternative means of assessment are provided:

- Paper 3 – Coursework
- Paper 4 – Alternative to Practical (written paper).

Both papers assess the skills outlined in Assessment objective C.

5.4 Paper 3: Practical test

The questions in the practical paper may include:

(a) a volumetric analysis problem, based on one set of titrations.
Knowledge of acid/alkali titrations using methyl orange or screened methyl orange will be assumed. Simple titrations involving other reagents may be set but full instructions and other necessary information will be given.

(b) an experiment that may involve the determination of some quantity, e.g. a temperature change or the rate of a reaction. Such experiments will depend on the use of usual laboratory apparatus.

(c) an observational problem in which the candidate will be asked to investigate, by specified experiments, an unknown substance or mixture. The exercise may include simple chromatography, tests for oxidising and reducing agents and filtration.

Systematic analysis will **not** be required but it will be assumed that candidates will be familiar with the reactions of the following cations with aqueous sodium hydroxide and aqueous ammonia (aluminium, ammonium, calcium, copper, iron(II), iron(III) and zinc), and with the tests for the anions (carbonate, chloride, iodide, nitrate, and sulfate) and gases (ammonia, carbon dioxide, chlorine, hydrogen, oxygen and sulfur dioxide) as detailed in the Qualitative Analysis Notes which will be included with the question paper and are reproduced in this appendix.

Exercises involving organic substances and ions not on the list above may be set but candidates will only be required to record observations and to draw general conclusions.

Candidates are **not** allowed to refer to note books, text books or any other information in the Practical Examination.

Candidates may also be required to carry out simple calculations as detailed in the theory syllabus.

5.5 Paper 4: Alternative to practical paper

This paper is designed for those Centres for whom the preparation and execution of the Practical Test is impracticable. The best preparation for this paper is a thorough course in experimental Chemistry. Candidates are unlikely to demonstrate their full potential on this paper unless they have become fully familiar with the techniques and apparatus involved by doing experiments for themselves. The examiners expect the same degree of detail as for Paper 3 and candidates should be taught to adopt practices which satisfy the same general marking points.

Questions may be set requiring candidates to:

- record readings from diagrams of apparatus;
- describe, explain, comment on or suggest experimental arrangements, techniques and procedures;
- complete tables of data and/or plot graphs;
- interpret, draw conclusions from and evaluate observations and experimental (including graphical) data;
- describe tests for gases, ions, oxidising and reducing agents and/or draw conclusions from such tests.

Candidates may also be required to perform simple calculations.
The Qualitative Analysis Notes are **not** provided.

Practical Techniques
The following notes are intended to give schools and candidates an indication of the accuracy that is expected in quantitative exercises and general instructions for qualitative exercises.

(a) Candidates should normally record burette readings to the nearest 0.1 cm^3 and they should ensure that they have carried out a sufficient number of titrations, e.g. in an experiment with a good end-point, two titres within 0.2 cm^3.

(b) Candidates should normally record: temperature readings to the nearest 0.5 °C,
times to the nearest second.

(c) In qualitative exercises candidates should use approximately 1 cm depth of a solution (1–2 cm^3) for each test and add reagents slowly, ensuring good mixing, until no further change is seen. Candidates should indicate at what stage a change occurs.

Answers should include details of colour changes and precipitates formed and the names and chemical tests for any gases evolved. Equations are **not** required and marks for deductions or conclusions can only be gained if the appropriate observations are recorded.

5. Appendix

5.6 Apparatus list

This list given below has been drawn up in order to give guidance to schools concerning the apparatus that is expected to be generally available for examination purposes. The list is not intended to be exhaustive, in particular, items (such as Bunsen burners, tripods) that are commonly regarded as standard equipment in a chemical laboratory are not included. The rate of allocation is 'per candidate'.

- one burette, 50 cm^3
- one pipette, 25 cm^3
- a pipette filler
- two conical flasks within the range 150 cm^3 to 250 cm^3
- a measuring cylinder, 50 cm^3 or 25 cm^3
- a filter funnel
- a beaker, squat form with lip: 250 cm^3
- a thermometer, –10 °C to +110 °C at 1 °C
- a polystyrene, or other plastic beaker of approximate capacity 150 cm^3
- clocks (or wall-clock) to measure to an accuracy of about 1s (Where clocks are specified, candidates may use their own wrist watch if they prefer.)
- wash bottle
- test-tubes (some of which should be Pyrex or hard glass), approximately 125 mm × 16 mm boiling-tubes, approximately 150 mm × 25 mm
- stirring rod

5. Appendix

5.7 Reagents list

This list given below has been drawn up in order to give guidance to schools concerning the standard reagents that are expected to be generally available for examination purposes. The list is not intended to be exhaustive and the 'Instructions to Supervisors' issued several weeks in advance of the examination will give a full list of all the reagents that are required for each practical examination. These instructions also contain advice about colour-blind candidates.

- aqueous sodium hydroxide (approximately 1.0 mol dm^{-3})
- aqueous ammonia (approximately 1.0 mol dm^{-3})
- hydrochloric acid (approximately 1.0 mol dm^{-3})
- nitric acid (approximately 1.0 mol dm^{-3})
- sulfuric acid (approximately 0.5 mol dm^{-3})
- aqueous silver nitrate (approximately 0.05 mol dm^{-3})
- aqueous barium nitrate or aqueous barium chloride (approximately 0.2 mol dm^{-3})
- aqueous lead(II) nitrate (approximately 0.2 mol dm^{-3})
- limewater (a saturated solution of calcium hydroxide)
- aqueous potassium dichromate(VI) (approximately 0.1 mol dm^{-3})
- aqueous potassium manganate(VII) (approximately 0.02 mol dm^{-3})
- aqueous potassium iodide (approximately 0.1 mol dm^{-3})
- aluminium foil
- red and blue litmus paper or Universal Indicator paper

Supervisors are reminded of their responsibilities for supplying the examiners with the information specified in the instructions. Failure to supply such information may cause candidates to be unavoidably penalised.

Please refer to the *Handbook for Centres* which contains a section on science syllabuses which includes information about arrangements for practical examinations.

5. Appendix

5.8 Qualitative Analysis Notes

Tests for anions

anion	***test***	***test result***
carbonate (CO_3^{2-})	add dilute acid	effervescence, carbon dioxide produced
chloride (Cl^-) [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	white ppt.
iodide (I^-) [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	yellow ppt.
nitrate (NO_3^-) [in solution]	add aqueous sodium hydroxide, then aluminium foil; warm carefully	ammonia produced
sulfate (SO_4^{2-}) [in solution]	acidify, then add aqueous barium nitrate	white ppt.

Tests for aqueous cations

cation	***effect of aqueous sodium hydroxide***	***effect of aqueous ammonia***
aluminium (Al^{3+})	white ppt., soluble in excess giving a colourless solution	white ppt., insoluble in excess
ammonium (NH_4^+)	ammonia produced on warming	–
calcium (Ca^{2+})	white ppt., insoluble in excess	no ppt. or very slight white ppt.
copper (Cu^{2+})	light blue ppt., insoluble in excess	light blue ppt., soluble in excess, giving a dark blue solution
iron(II) (Fe^{2+})	green ppt., insoluble in excess	green ppt., insoluble in excess
iron(III) (Fe^{3+})	red-brown ppt., insoluble in excess	red-brown ppt., insoluble in excess
zinc (Zn^{2+})	white ppt., soluble in excess, giving a colourless solution	white ppt., soluble in excess, giving a colourless solution

Tests for gases

gas	***test and test result***
ammonia (NH_3)	turns damp red litmus paper blue
carbon dioxide (CO_2)	turns limewater milky
chlorine (Cl_2)	bleaches damp litmus paper
hydrogen (H_2)	'pops' with a lighted splint
oxygen (O_2)	relights a glowing splint
sulfur dioxide (SO_2)	turns acidified aqueous potassium dichromate(VI) from orange to green

5. Appendix

5.9 Glossary of terms used in science papers

It is hoped that the glossary (which is relevant only to chemistry subjects) will prove helpful to candidates as a guide, i.e. it is neither exhaustive nor definitive. The glossary has been deliberately kept brief not only with respect to the number of terms included but also to the descriptions of their meanings. Candidates should appreciate that the meaning of a term must depend in part on its context.

1. *Define (the term(s)…)* is intended literally, only a formal statement or equivalent paraphrase being required.
2. *What do you understand by/What is meant by (the term(s)…)* normally implies that a definition should be given, together with some relevant comment on the significance or context of the term(s) concerned, especially where two or more terms are included in the question. The amount of supplementary comment intended should be interpreted in the light of the indicated mark value.
3. *State* implies a concise answer with little or no supporting argument, e.g. a numerical answer that can be obtained 'by inspection'.
4. *List* requires a number of points, generally each of one word, with no elaboration. Where a given number of points is specified, this should not be exceeded.
5. *Explain* may imply reasoning or some reference to theory, depending on the context.
6. *Describe* requires candidates to state in words (using diagrams where appropriate) the main points of the topic. It is often used with reference either to particular phenomena or to particular experiments. In the former instance, the term usually implies that the answer should include reference to (visual) observations associated with the phenomena.
   In other contexts, *describe and give an account* of should be interpreted more generally, i.e. the candidate has greater discretion about the nature and the organisation of the material to be included in the answer. *Describe and explain* may be coupled in a similar way to *state and explain*.
7. *Discuss* requires candidates to give a critical account of the points involved in the topic.
8. *Outline* implies brevity, i.e. restricting the answer to giving essentials.
9. *Predict* or *deduce* implies that the candidate is not expected to produce the required answer by recall but by making a logical connection between other pieces of information. Such information may be wholly given in the question or may depend on answers extracted in an early part of the question.
10. *Comment* is intended as an open-ended instruction, inviting candidates to recall or infer points of interest relevant to the context of the question, taking account of the number of marks available.
11. *Suggest* is used in two main contexts, i.e. either to imply that there is no unique answer (e.g. in chemistry, two or more substances may satisfy the given conditions describing an 'unknown'), or to imply that candidates are expected to apply their general knowledge to a 'novel' situation, one that may be formally 'not in the syllabus'.
12. *Find* is a general term that may variously be interpreted as calculate, measure, determine etc.
13. *Calculate* is used when a numerical answer is required. In general, working should be shown, especially where two or more steps are involved.

14. *Measure* implies that the quantity concerned can be directly obtained from a suitable measuring instrument, e.g. length, using a rule, or angle, using a protractor.
15. *Determine* often implies that the quantity concerned cannot be measured directly but is obtained by calculation, substituting measured or known values of other quantities into a standard formula, e.g. relative molecular mass.
16. *Estimate* implies a reasoned order of magnitude statement or calculation of the quantity concerned, making such simplifying assumptions as may be necessary about points of principle and about the values of quantities not otherwise included in the question.
17. *Sketch*, when applied to graph work, implies that the shape and/or position of the curve need only be qualitatively correct, but candidates should be aware that, depending on the context, some quantitative aspects may be looked for, e.g. passing through the origin, having an intercept, asymptote or discontinuity at a particular value.

    In diagrams, *sketch* implies that a simple, freehand drawing is acceptable: nevertheless, care should be taken over proportions and the clear exposition of important details.
18. *Construct* is often used in relation to chemical equations where a candidate is expected to write a balanced equation, not by factual recall but by analogy or by using information in the question.

Special Note

Units, significant figures. Candidates should be aware that misuse of units and/or significant figures, i.e. failure to quote units where necessary, the inclusion of units in quantities defined as ratios or quoting answers to an inappropriate number of significant figures, is liable to be penalised.

5. Appendix

5.10 Resource list

Books endorsed by CIE for use with this syllabus

These books have been through an independent quality assurance process and match the syllabus content closely.

Author	Title	Date	Publisher	ISBN
R. Harwood	**Chemistry (Edition 2)* (Also suitable for use with the IGCSE Chemistry syllabus)	2003	Cambridge University Press The Edinburgh Building Shaftesbury Road Cambridge CB2 2RU UK **uk.cambridge.org/education/international/cie**	0521530938
	Chemistry GCE O Level Past Papers with Answer Guides	2004	Foundation Books 4764/2A Ansari Road Daryaganj New Delhi-110 002, India **fbindia.com**	8175961791

Suggested textbooks and other books for students

The following books are all suitable for use with this syllabus. Content of the books does not necessarily match the CIE syllabus closely and examples may be British in focus.

Author	Title	Publisher	ISBN
A. Clegg	*Chemistry for IGCSE*	Heinemann, Harcourt Education Ltd, Halley Court, Jordan Hill, Oxford, OX2 8EJ, United Kingdom **www.heinemann.co.uk**	0435966758
B. Earl & L.D. Wilford	*IGCSE Chemistry*	John Murray, Hodder Murray, 338 Euston Road, London, NW1 3BH, UK **www.johnmurray.co.uk**	0719586178
G. Hill	*Chemistry Counts*	Hodder and Stoughton, Hodder Headline, 338 Euston Road, London, NW1 3BH, United Kingdom **www.hodderheadline.co.uk**	0340639342
Lewis & Waller	*Thinking Chemistry (GCSE Edition)*	Oxford University Press, Great Clarendon Street, Oxford, OX2 6DP, United Kingdom **www4.oup.co.uk/**	0199142572

5. Appendix

These titles represent some of the texts available at the time of printing this booklet. Teachers are encouraged to choose texts for class use which they feel will be of interest to their students and will support their own teaching style.

The book marked with an asterisk is also available from Cambridge University Press in a Low Priced Edition (ISBN 0-521-66662-7) from their local distributors in Africa, The Caribbean, Bangladesh, India, Nepal, Pakistan and Sri Lanka. For a full list, or details of distributors in your local area, please contact Mark Ellwood at CUP (**mellwood@cambridge.org**, tel: +44 1223 312393, fax: +44 1223 315052).

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