

# SYLLABUS

Cambridge O Level  
Chemistry

**5070**

For examination in June and November 2017, 2018 and 2019

### Changes to syllabus for 2017, 2018 and 2019

The following learning outcomes have been removed:

2.2 (g) state that some isotopes are radioactive

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

The test for sulfur dioxide has been removed from the Qualitative Analysis Notes. The test will no longer be used in the Practical Test though is still present in section 1.3 (c) of the Syllabus content.

This syllabus has been updated. Significant changes to the syllabus are indicated by black vertical lines either side of the text.

**You are advised to read the whole syllabus before planning your teaching programme.**

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# 1. Introduction

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## 1.1 Why choose Cambridge?

Cambridge International Examinations is part of the University of Cambridge. We prepare school students for life, helping them develop an informed curiosity and a lasting passion for learning. Our international qualifications are recognised by the world's best universities and employers, giving students a wide range of options in their education and career. As a not-for-profit organisation, we devote our resources to delivering high-quality educational programmes that can unlock learners' potential.

Our programmes set the global standard for international education. They are created by subject experts, are rooted in academic rigour, and provide a strong platform for progression. Over 10 000 schools in 160 countries work with us to prepare nearly a million learners for their future with an international education from Cambridge.

### Cambridge learners

Cambridge programmes and qualifications develop not only subject knowledge but also skills. We encourage Cambridge learners to be:

- **confident** in working with information and ideas – their own and those of others
- **responsible** for themselves, responsive to and respectful of others
- **reflective** as learners, developing their ability to learn
- **innovative** and equipped for new and future challenges
- **engaged** intellectually and socially, ready to make a difference.

### Recognition

Cambridge O Level is internationally recognised by schools, universities and employers as equivalent in demand to Cambridge IGCSE<sup>®</sup> (International General Certificate of Secondary Education). There are over 700 000 entries a year in nearly 70 countries. Learn more at [www.cie.org.uk/recognition](http://www.cie.org.uk/recognition)

### Support for teachers

A wide range of materials and resources is available to support teachers and learners in Cambridge schools. Resources suit a variety of teaching methods in different international contexts. Through subject discussion forums and training, teachers can access the expert advice they need for teaching our qualifications. More details can be found in Section 2 of this syllabus and at [www.cie.org.uk/teachers](http://www.cie.org.uk/teachers)

### Support for exams officers

Exams officers can trust in reliable, efficient administration of exams entries and excellent personal support from our customer services. Learn more at [www.cie.org.uk/examsOfficers](http://www.cie.org.uk/examsOfficers)

Our systems for managing the provision of international qualifications and education programmes for learners aged 5 to 19 are certified as meeting the internationally recognised standard for quality management, ISO 9001:2008. Learn more at [www.cie.org.uk/ISO9001](http://www.cie.org.uk/ISO9001)

## 1.2 Why choose Cambridge O Level?

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

Our aim is to balance knowledge, understanding and skills in our programmes and qualifications to enable students to become effective learners and to provide a solid foundation for their continuing educational journey.

Through our professional development courses and our support materials for Cambridge O Levels, we provide the tools to enable teachers to prepare learners to the best of their ability and work with us in the pursuit of excellence in education.

Cambridge O Levels are considered to be an excellent preparation for Cambridge International AS and A Levels, the Cambridge AICE (Advanced International Certificate of Education) Group Award, Cambridge Pre-U, and other education programmes, such as the US Advanced Placement program and the International Baccalaureate Diploma programme. Learn more about Cambridge O Levels at [www.cie.org.uk/cambridgesecundary2](http://www.cie.org.uk/cambridgesecundary2)

### Guided learning hours

Cambridge O Level syllabuses are designed on the assumption that learners have about 130 guided learning hours per subject over the duration of the course, but this is for guidance only. The number of hours required to gain the qualification may vary according to local curricular practice and the learners' prior experience of the subject.

## 1.3 Why choose Cambridge O Level Chemistry?

Cambridge O Levels are established qualifications that keep pace with educational developments and trends. The Cambridge 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 Cambridge International A Level, and 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, Cambridge also offers Cambridge IGCSE and Cambridge International AS & A Levels for further study in both chemistry as well as other science subjects. See [www.cie.org.uk](http://www.cie.org.uk) for a full list of the qualifications you can take.

## Prior learning

We recommend that candidates who are beginning this course should have previously studied a science curriculum such as that of the Cambridge Lower Secondary Programme or equivalent national educational frameworks. Candidates should also have adequate mathematical skills for the content contained in this syllabus.

## Progression

Cambridge O Levels are general qualifications that enable candidates to progress either directly to employment, or to proceed to further qualifications.

Candidates who are awarded grades C to A\* in Cambridge O Level Chemistry are well prepared to follow courses leading to Cambridge International AS and A Level Chemistry, or the equivalent.

## 1.4 How can I find out more?

### If you are already a Cambridge school

You can make entries for this qualification through your usual channels. If you have any questions, please contact us at **info@cie.org.uk**

### If you are not yet a Cambridge school

Learn about the benefits of becoming a Cambridge school at **www.cie.org.uk/startcambridge**. Email us at **info@cie.org.uk** to find out how your organisation can register to become a Cambridge school.

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## 2. Teacher support

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### 2.1 Support materials

We send Cambridge syllabuses, past question papers and examiner reports to cover the last examination series to all Cambridge schools.

You can also go to our public website at **[www.cie.org.uk/olevel](http://www.cie.org.uk/olevel)** to download current and future syllabuses together with specimen papers or past question papers and examiner reports from one series.

For teachers at registered Cambridge schools a range of additional support materials for specific syllabuses is available online from Teacher Support, our secure online support for Cambridge teachers. Go to **<http://teachers.cie.org.uk>** (username and password required).

### 2.2 Endorsed resources

We work with publishers providing a range of resources for our syllabuses including print and digital materials. Resources endorsed by Cambridge go through a detailed quality assurance process to ensure they provide a high level of support for teachers and learners.

We have resource lists which can be filtered to show all resources, or just those which are endorsed by Cambridge. The resource lists include further suggestions for resources to support teaching.

### 2.3 Training

We offer a range of support activities for teachers to ensure they have the relevant knowledge and skills to deliver our qualifications. See **[www.cie.org.uk/events](http://www.cie.org.uk/events)** for further information.

### 3. Assessment at a glance

For the Cambridge O Level in chemistry, candidates take **three** components: Paper 1 **and** Paper 2 and either Paper 3 **or** Paper 4.

<b>Paper 1: Multiple Choice</b>		<b>1 hour</b>
40 compulsory multiple-choice questions. A copy of the Periodic Table is provided as part of this paper (see Appendix).		
40 marks		
<b>Paper 2: Theory</b>		<b>1 hour 30 minutes</b>
This paper has two sections.		
Section A has 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 <b>three</b> . Each question is worth 10 marks.		
A copy of the Periodic Table is provided as part of this paper (see Appendix).		
75 marks		
<b>Paper 3: Practical Test</b>	<b>1 hour 30 minutes</b>	<b>Paper 4: Alternative to Practical</b>
<b>1 hour</b>		
Details of the syllabus and requirements for this paper are given in section 6.		A written paper of compulsory short-answer and structured questions designed to test familiarity with laboratory practical procedures. Further details are given in section 6.
Candidates may <b>not</b> refer to notebooks, textbooks or any other information during the practical examination.		
Qualitative Analysis Notes are provided.		Qualitative Analysis Notes are <b>not</b> provided.
40 marks scaled to a mark out of 30		60 marks scaled to a mark out of 30

#### Availability

This syllabus is examined in the June and November examination series.

This syllabus is available to private candidates. However, it is expected that private candidates learn in an environment where practical work is an integral part of the course. Candidates will not be able to perform well in this assessment or progress successfully to further study without this necessary and important aspect of science education.

Detailed timetables are available from [www.cie.org.uk/examsOfficers](http://www.cie.org.uk/examsOfficers)

Cambridge O Levels are available to Centres in Administrative Zones 3, 4 and 5. Centres in Administrative Zones 1, 2 or 6 wishing to enter candidates for Cambridge O Level examinations should contact Cambridge Customer Services.



## Combining this with other syllabuses

Candidates can combine this syllabus in an examination series with any other Cambridge syllabus, except:

- syllabuses with the same title at the same level
- 0652 Cambridge IGCSE Physical Science
- 0653 Cambridge IGCSE Combined Science
- 0654 Cambridge IGCSE Co-ordinated Sciences (Double)
- 5129 Cambridge O Level Combined Science

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

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## 4. Syllabus aims and assessment objectives

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### 4.1 Syllabus 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 Cambridge O 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.

## 4.2 Assessment objectives

The assessment objectives describe the knowledge, skills and abilities that candidates are expected to demonstrate at the end of the course. They reflect those aspects of the aims that are assessed.

### AO1 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.

Syllabus 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 the glossary of terms in section 7.3).

### AO2 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 syllabus 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 in section 7.3).

### AO3 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 part 1 of the syllabus content and in the section on practical assessment. See also Appendix.

## 4.3 Weighting of assessment objectives

### Theory papers (Papers 1 and 2)

AO1 Knowledge with understanding is weighted at approximately 65% of the marks for each paper, with approximately half allocated to recall.

AO2 Handling information and solving problems is weighted at approximately 35% of the marks for each paper.

### Practical assessment (Papers 3 and 4)

This is designed to test appropriate skills in assessment objective AO3 and carries approximately 20% of the marks for the qualification.

## 4.4 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  $\text{dm}^3$  in place of *l* or litre will be made.

In accordance with current ASE convention, decimal markers in examination papers will be a single dot on the line. Candidates are expected to follow this convention in their answers.

### Units, significant figures

In practical work, candidates will be expected to use SI units or, where appropriate, units approved by the BIPM for use with the SI (e.g. minute). A list of SI units and units approved for use with the SI may be found in the SI brochure at <http://www.bipm.org>. The use of imperial/customary units such as the inch and degree Fahrenheit is not acceptable and should be discouraged. In all examinations, where data is supplied for use in questions, candidates will be expected to use units that are consistent with the units supplied, and should not attempt conversion to other systems of units unless this is a requirement of the question.

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.

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## 5. Syllabus content

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Most of the objectives specified below relate to AO1, although some indication has been given as to where the skills of AO2 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.

# 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 candidates 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

### 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, chromium(III), 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 silver nitrate); nitrate (by reduction with aluminium and aqueous sodium hydroxide to ammonia and subsequent use of litmus paper), sulfate (by reaction of an aqueous solution with nitric acid and aqueous barium nitrate), and sulfite (by warming with dilute acid)
- (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 manganate(VII))
- (d) describe a chemical test for water

## 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
- (e) state qualitatively and explain the effects of temperature and pressure on the volumes of gases

#### 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  $^{12}_6\text{C}$
- (e) define the term *isotopes*
- (f) deduce the numbers of protons, neutrons and electrons in atoms and ions from proton and nucleon numbers

#### 2.3 Structure and properties of materials

- (a) describe the differences between elements, compounds and mixtures
- (b) compare the structure of simple molecular substances, e.g. methane, iodine, with those of giant covalent substances, e.g. 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.  $\text{NaCl}$ ;  $\text{MgCl}_2$
- (c) state that ionic materials contain a giant lattice in which the ions are held by electrostatic attraction, e.g.  $\text{NaCl}$  (candidates will not be required to draw diagrams of ionic lattices)
- (d) 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.  $\text{H}_2$ ;  $\text{Cl}_2$ ;  $\text{O}_2$ ;  $\text{HCl}$ ;  $\text{N}_2$ ;  $\text{H}_2\text{O}$ ;  $\text{CH}_4$ ;  $\text{C}_2\text{H}_4$ ;  $\text{CO}_2$
- (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 metallic bonding as the electrostatic attraction between positive ions in a lattice and 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



### 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; use Avogadro's law in calculations involving gas volume (one mole of gas occupies  $24 \text{ dm}^3$  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  $\text{mol/dm}^3$  or  $\text{g/dm}^3$ ) 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 compound
- (e) apply the idea of selective discharge (linked to the reactivity series for cations, see 9.2) to deduce the electrolysis products of aqueous solutions; describe 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 equations for the reactions occurring at each electrode (anode and cathode) during electrolysis
- (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, including 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 ( $\Delta H$  negative) and endothermic ( $\Delta H$  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 and 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 (crude oil) as sources of energy
- (h) describe petroleum (crude oil) 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 Rate of reaction
- 6.2 Redox
- 6.3 Reversible reactions

### Learning outcomes

Candidates should be able to:

#### 6.1 Rate of reaction

- (a) describe the effect of concentration, pressure, particle size and temperature on the rates 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 rates of reactions
- (c) explain how pathways with lower activation energies account for the increase in rates 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 rate of a reaction
- (f) interpret data obtained from experiments concerned with rate 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
- (c) identify redox reactions in terms of oxygen/hydrogen, and/or electron, gain/loss (calculation of oxidation numbers is **not** required)
- (d) describe the use of aqueous potassium iodide in testing for oxidising agents and acidified potassium manganate(VII) in testing for 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 and explain the effect of changing the conditions (see 7.3(b) and 7.3(c))

## 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 dissociation
- (e) describe neutralisation as a reaction between hydrogen ions and hydroxide ions to produce water,  $\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$
- (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
- (d) describe the meanings of the terms hydrated, anhydrous and water of crystallisation

#### 7.3 Properties and uses of ammonia

- (a) describe the use of nitrogen, from air, and hydrogen, from cracking hydrocarbons, in the manufacture of ammonia
- (b) state that some chemical reactions are reversible (e.g. manufacture of ammonia)
- (c) describe and explain 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 configuration
- (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 configuration
- (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 VIII (the noble gases, also known as Group 0) 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 from their constituent elements

#### 9.2 Reactivity series

- (a) place in order of reactivity: aluminium (see also 9.5(b)) calcium, copper, (hydrogen), iron, lead, magnesium, potassium, silver, sodium and zinc by reference to
  - (i) the reactions, if any, of the metals with water, oxygen, 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 78% nitrogen, 21% 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; in welding)
- (d) name some common atmospheric pollutants (e.g. carbon monoxide; methane; nitrogen oxides (NO and NO<sub>2</sub>); 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 organisms 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) describe how 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 petroleum (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 a 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
- (b) describe the alkanes as a 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 a 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 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

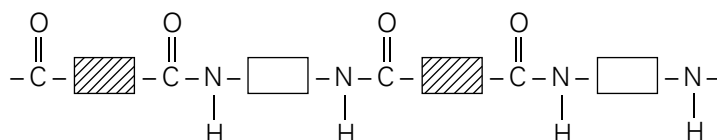
- describe the alcohols as a homologous series containing the  $-OH$  group
- draw the structures of alcohols, C1 to C4, and name the unbranched alcohols, methanol to butanol
- describe the properties of alcohols in terms of combustion and oxidation to carboxylic acids
- describe the formation of ethanol by the catalysed addition of steam to ethene and by fermentation of glucose
- state some uses of ethanol, e.g. as a solvent; as a renewable fuel; as a constituent of alcoholic beverages

### 11.4 Carboxylic acids

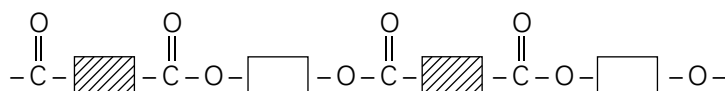
- describe the carboxylic acids as a homologous series containing the  $-CO_2H$  group
- draw the structures of carboxylic acids, methanoic acid to butanoic acid, and name the unbranched acids, methanoic to butanoic acids
- describe the carboxylic acids as weak acids, reacting with carbonates, bases and some metals
- describe the formation of ethanoic acid by the oxidation of ethanol by atmospheric oxygen or acidified potassium manganate(VII)
- describe the reaction of carboxylic acids from C1 to C4 with alcohols from C1 to C4 to form esters
- draw the structures of and name the esters formed from carboxylic acids (see 11.4 (b)) and alcohols (see 11.3 (b))
- state some commercial uses of esters, e.g. perfumes; flavourings; solvents

### 11.5 Polymers

- describe polymers as large molecules made from many small units called monomers, different polymers having different units and/or different linkages
- describe the formation of poly(ethene) as an example of addition polymerisation of ethene as the monomer
- state some uses of poly(ethene) as a typical plastic, e.g. plastic bags; clingfilm
- 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)

- state some typical uses of synthetic fibres such as nylon and *Terylene*, e.g. clothing; curtain materials; fishing line; parachutes; sleeping bags
- deduce the partial structure of the polymer product from a given monomer and vice versa
- describe the pollution problems caused by the disposal of non-biodegradable plastics
- identify proteins and complex carbohydrates (polysaccharides, e.g. starch) as natural polymers
- describe proteins as possessing the same amide linkages as nylon but with different monomer units
- describe fats as esters possessing the same linkages as *Terylene* but with different monomer units
- describe the hydrolysis of proteins to amino acids and complex carbohydrates (polysaccharides, e.g. starch) to simple sugars

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## 6. Practical assessment

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

Both papers assess the skills outlined in Assessment Objective AO3.

### 6.1 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, chromium(III), copper(II), 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 may also be required to carry out simple calculations as detailed in the theory syllabus.

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

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 section on science syllabuses in the *Cambridge Handbook*, which includes information about arrangements for practical examinations.

## 6.2 Paper 4: Alternative to Practical

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.

## 6.3 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  $0.1 \text{ cm}^3$  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  $0.2 \text{ cm}^3$ .
- (b) Candidates should normally record: temperature readings to the nearest  $0.5^\circ\text{C}$  and times to the nearest second.
- (c) In qualitative exercises candidates should use approximately 1 cm depth of a solution ( $1\text{--}2 \text{ cm}^3$ ) 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.

## 6.4 Apparatus

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<sup>3</sup>
- one pipette, 25 cm<sup>3</sup>
- a pipette filler
- two conical flasks within the range 150 cm<sup>3</sup> to 250 cm<sup>3</sup>
- measuring cylinders, 25 cm<sup>3</sup> and 10 cm<sup>3</sup>
- a filter funnel
- a beaker, squat form with lip: 250 cm<sup>3</sup>
- a thermometer, -10 °C to +110 °C at 1 °C intervals
- a polystyrene, or other plastic beaker of approximate capacity 150 cm<sup>3</sup>
- clocks (or wall clock) to measure to an accuracy of 1 s (where clocks are specified candidates may use their own wristwatch 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
- teat/dropping pipettes
- spatula

## 6.5 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  $1.0 \text{ mol dm}^{-3}$ )
- aqueous ammonia (approximately  $1.0 \text{ mol dm}^{-3}$ )
- hydrochloric acid (approximately  $1.0 \text{ mol dm}^{-3}$ )
- nitric acid (approximately  $1.0 \text{ mol dm}^{-3}$ )
- sulfuric acid (approximately  $0.5 \text{ mol dm}^{-3}$ )
- aqueous silver nitrate (approximately  $0.05 \text{ mol dm}^{-3}$ )
- aqueous barium nitrate or aqueous barium chloride (approximately  $0.2 \text{ mol dm}^{-3}$ )
- limewater (a saturated solution of calcium hydroxide)
- acidified aqueous potassium manganate (VII) (approximately  $0.01 \text{ mol dm}^{-3}$  in  $0.5 \text{ mol dm}^{-3}$  sulfuric acid)
- aqueous potassium manganate(VII) (approximately  $0.02 \text{ mol dm}^{-3}$ )
- aqueous potassium iodide (approximately  $0.1 \text{ mol dm}^{-3}$ )
- aluminium foil
- red and blue litmus paper or Universal Indicator paper
- methyl orange or screened methyl orange indicator
- starch solution

Detailed guidance on preparing standard bench reagents and indicators will **not** be given in the Confidential Instructions. The Confidential Instructions will refer Supervisors to the guidance notes in section 6.6 of this syllabus document.

The following hazard codes are used where relevant and are in accordance with information provided by CLEAPSS\* at the time of publication of this syllabus. Centres should be aware that the United Nations Global Harmonised System for hazard classification and compatible labelling (2015) is in the process of being implemented and therefore Centres are advised to make full use of the 'Safety Data Sheets' supplied with chemicals for current hazard information. The attention of Centres is also drawn to any local regulations relating to safety, first-aid and disposal of chemicals.

- C** = corrosive  
**MH** = moderate hazard  
**HH** = health hazard  
**T** = acutely toxic  
**F** = flammable  
**O** = oxidising  
**N** = hazardous to the aquatic environment

\* An advisory service providing support in practical science and technology for schools and colleges,  
[www.cleapss.org.uk](http://www.cleapss.org.uk)

## 6.6 Guidance for the preparation of reagents

Hazard	Label	Identity	Instructions
	<b>dilute hydrochloric acid</b>	1.0 mol dm <sup>-3</sup> HCl	Dilute 85 cm <sup>3</sup> of concentrated (35–37%; approximately 11 mol dm <sup>-3</sup> ) hydrochloric acid <b>[C] [MH]</b> to 1 dm <sup>3</sup> .
<b>[C]</b>	<b>dilute nitric acid</b>	1.0 mol dm <sup>-3</sup> HNO <sub>3</sub>	Dilute 64 cm <sup>3</sup> of concentrated (70% w/v) nitric acid <b>[C] [O]</b> to 1 dm <sup>3</sup> .
<b>[MH]</b>	<b>dilute sulfuric acid</b>	0.5 mol dm <sup>-3</sup> H <sub>2</sub> SO <sub>4</sub>	Cautiously pour 28 cm <sup>3</sup> of concentrated (98%) sulfuric acid <b>[C]</b> into 500 cm <sup>3</sup> of distilled water with continuous stirring. Make the solution up to 1 dm <sup>3</sup> with distilled water. <b>Care:</b> concentrated H <sub>2</sub> SO <sub>4</sub> is very corrosive.
<b>[MH]</b>	<b>aqueous ammonia</b>	1.0 mol dm <sup>-3</sup> NH <sub>3</sub>	Dilute 66 cm <sup>3</sup> of concentrated (35%) ammonia <b>[C] [MH] [N]</b> to 1 dm <sup>3</sup> .
<b>[C]</b>	<b>aqueous sodium hydroxide</b>	1.0 mol dm <sup>-3</sup> NaOH	Dissolve 40.0 g of NaOH <b>[C]</b> in each dm <sup>3</sup> of solution. <b>Care:</b> the process of solution is exothermic and any concentrated solution is very corrosive.
<b>[MH]</b>	<b>0.1 mol dm<sup>-3</sup> barium chloride</b> or <b>0.1 mol dm<sup>-3</sup> barium nitrate</b>	0.1 mol dm <sup>-3</sup> barium chloride or 0.1 mol dm <sup>-3</sup> barium nitrate	Dissolve 24.4 g of BaCl <sub>2</sub> · 2H <sub>2</sub> O <b>[T]</b> in each dm <sup>3</sup> of solution or dissolve 26.1 g of Ba(NO <sub>3</sub> ) <sub>2</sub> <b>[MH] [O]</b> in each dm <sup>3</sup> of solution.
	<b>0.05 mol dm<sup>-3</sup> silver nitrate</b>	0.05 mol dm <sup>-3</sup> silver nitrate	Dissolve 8.5 g of AgNO <sub>3</sub> <b>[C] [N] [O]</b> in each dm <sup>3</sup> of solution.
<b>[MH]</b>	<b>limewater</b>	saturated aqueous calcium hydroxide, Ca(OH) <sub>2</sub>	Prepare fresh limewater by leaving distilled water to stand over solid calcium hydroxide <b>[C] [MH]</b> for several days, shaking occasionally. Decant or filter the solution.
	<b>0.1 mol dm<sup>-3</sup> potassium iodide</b>	0.1 mol dm <sup>-3</sup> KI	Dissolve 16.6 g of KI in each dm <sup>3</sup> of solution.
	<b>0.02 mol dm<sup>-3</sup> potassium manganate(VII)</b>	0.02 mol dm <sup>-3</sup> KMnO <sub>4</sub>	Dissolve 3.16 g of KMnO <sub>4</sub> <b>[O] [C] [MH] [N]</b> in each dm <sup>3</sup> of solution.
<b>[MH]</b>	<b>acidified aqueous potassium manganate(VII)</b>	0.01 mol dm <sup>-3</sup> KMnO <sub>4</sub> 0.5 mol dm <sup>-3</sup> sulfuric acid	Mix equal volumes of 0.02 mol dm <sup>-3</sup> KMnO <sub>4</sub> and 1.0 mol dm <sup>-3</sup> H <sub>2</sub> SO <sub>4</sub> <b>[MH]</b> .
<b>[F] [HH]</b>	<b>methyl orange indicator</b>	methyl orange indicator (pH range 2.9 to 4.6)	Use commercially produced solution or dissolve 0.4 g of solid indicator <b>[T]</b> in 200 cm <sup>3</sup> of ethanol (IDA) <b>[F] [MH] [HH]</b> and make up to 1 dm <sup>3</sup> with distilled water.
	<b>starch indicator</b>	freshly prepared aqueous starch indicator (approx 2% solution w/v)	Mix 2 g of <b>soluble starch</b> with a little cold water until a smooth paste is obtained. Add 100 cm <sup>3</sup> boiling water and stir. Boil until a clear solution is obtained (about 5 minutes).



## 7. Appendix

### 7.1 Qualitative Analysis Notes

#### Tests for anions

anion	test	test result
carbonate ( $\text{CO}_3^{2-}$ )	add dilute acid	effervescence, carbon dioxide produced
chloride ( $\text{Cl}^-$ ) [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	white ppt.
iodide ( $\text{I}^-$ ) [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	yellow ppt.
nitrate ( $\text{NO}_3^-$ ) [in solution]	add aqueous sodium hydroxide, then add aluminium foil; warm carefully	ammonia produced
sulfate ( $\text{SO}_4^{2-}$ ) [in solution]	acidify with dilute nitric acid, then add aqueous barium nitrate	white ppt., insoluble in excess dilute nitric acid

#### Tests for aqueous cations

cation	effect of aqueous sodium hydroxide	effect of aqueous ammonia
aluminium ( $\text{Al}^{3+}$ )	white ppt., soluble in excess giving a colourless solution	white ppt., insoluble in excess
ammonium ( $\text{NH}_4^+$ )	ammonia produced on warming	–
calcium ( $\text{Ca}^{2+}$ )	white ppt., insoluble in excess	no ppt.
chromium(III) ( $\text{Cr}^{3+}$ )	green ppt., soluble in excess, giving a green solution	green ppt., insoluble in excess
copper(II) ( $\text{Cu}^{2+}$ )	light blue ppt., insoluble in excess	light blue ppt., soluble in excess, giving a dark blue solution
iron(II) ( $\text{Fe}^{2+}$ )	green ppt., insoluble in excess	green ppt., insoluble in excess
iron(III) ( $\text{Fe}^{3+}$ )	red-brown ppt., insoluble in excess	red-brown ppt., insoluble in excess
zinc ( $\text{Zn}^{2+}$ )	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 ( $\text{NH}_3$ )	turns damp red litmus paper blue
carbon dioxide ( $\text{CO}_2$ )	turns limewater milky
chlorine ( $\text{Cl}_2$ )	bleaches damp litmus paper
hydrogen ( $\text{H}_2$ )	'pops' with a lighted splint
oxygen ( $\text{O}_2$ )	relights a glowing splint

## 7.2 The Periodic Table of Elements

Group																	
I	II	III										IV	V	VI	VII	VIII	
3 <b>Li</b> lithium 7	4 <b>Be</b> beryllium 9	1 <b>H</b> hydrogen 1										5 <b>B</b> boron 11	6 <b>C</b> carbon 12	7 <b>N</b> nitrogen 14	8 <b>O</b> oxygen 16	9 <b>F</b> fluorine 19	10 <b>Ne</b> neon 20
11 <b>Na</b> sodium 23	12 <b>Mg</b> magnesium 24	Key atomic number atomic symbol name relative atomic mass										13 <b>Al</b> aluminium 27	14 <b>Si</b> silicon 28	15 <b>P</b> phosphorus 31	16 <b>S</b> sulfur 32	17 <b>Cl</b> chlorine 35.5	18 <b>Ar</b> argon 40
19 <b>K</b> potassium 39	20 <b>Ca</b> calcium 40	21 <b>Sc</b> scandium 45	22 <b>Ti</b> titanium 48	23 <b>V</b> vanadium 51	24 <b>Cr</b> chromium 52	25 <b>Mn</b> manganese 55	26 <b>Fe</b> iron 56	27 <b>Co</b> cobalt 59	28 <b>Ni</b> nickel 59	29 <b>Cu</b> copper 64	30 <b>Zn</b> zinc 65	31 <b>Ga</b> gallium 70	32 <b>Ge</b> germanium 73	33 <b>As</b> arsenic 75	34 <b>Se</b> selenium 79	35 <b>Br</b> bromine 80	36 <b>Kr</b> krypton 84
37 <b>Rb</b> rubidium 85	38 <b>Sr</b> strontium 88	39 <b>Y</b> yttrium 89	40 <b>Zr</b> zirconium 91	41 <b>Nb</b> niobium 93	42 <b>Mo</b> molybdenum 96	43 <b>Tc</b> technetium –	44 <b>Ru</b> ruthenium 101	45 <b>Rh</b> rhodium 103	46 <b>Pd</b> palladium 106	47 <b>Ag</b> silver 108	48 <b>Cd</b> cadmium 112	49 <b>In</b> indium 115	50 <b>Sn</b> tin 119	51 <b>Sb</b> antimony 122	52 <b>Te</b> tellurium 128	53 <b>I</b> iodine 127	54 <b>Xe</b> xenon 131
55 <b>Cs</b> caesium 133	56 <b>Ba</b> barium 137	57–71 lanthanoids	72 <b>Hf</b> hafnium 178	73 <b>Ta</b> tantalum 181	74 <b>W</b> tungsten 184	75 <b>Re</b> rhenium 186	76 <b>Os</b> osmium 190	77 <b>Ir</b> iridium 192	78 <b>Pt</b> platinum 195	79 <b>Au</b> gold 197	80 <b>Hg</b> mercury 201	81 <b>Tl</b> thallium 204	82 <b>Pb</b> lead 207	83 <b>Bi</b> bismuth 209	84 <b>Po</b> polonium –	85 <b>At</b> astatine –	86 <b>Rn</b> radon –
87 <b>Fr</b> francium –	88 <b>Ra</b> radium –	89–103 actinoids	104 <b>Rf</b> rutherfordium –	105 <b>Db</b> dubnium –	106 <b>Sg</b> seaborgium –	107 <b>Bh</b> bohrium –	108 <b>Hs</b> hassium –	109 <b>Mt</b> meitnerium –	110 <b>Ds</b> darmstadtium –	111 <b>Rg</b> roentgenium –	112 <b>Cn</b> copernicium –	113 <b>Nh</b> nihonium –	114 <b>Fl</b> flerovium –	115 <b>Mc</b> moscovium –	116 <b>Lv</b> livermorium –	117 <b>Ts</b> tennessine –	118 <b>Og</b> oganeson –

lanthanoids	57 <b>La</b> lanthanum 139	58 <b>Ce</b> cerium 140	59 <b>Pr</b> praseodymium 141	60 <b>Nd</b> neodymium 144	61 <b>Pm</b> promethium –	62 <b>Sm</b> samarium 150	63 <b>Eu</b> europium 152	64 <b>Gd</b> gadolinium 157	65 <b>Tb</b> terbium 159	66 <b>Dy</b> dysprosium 163	67 <b>Ho</b> holmium 165	68 <b>Er</b> erbium 167	69 <b>Tm</b> thulium 169	70 <b>Yb</b> ytterbium 173	71 <b>Lu</b> lutetium 175
actinoids	89 <b>Ac</b> actinium –	90 <b>Th</b> thorium 232	91 <b>Pa</b> protactinium 231	92 <b>U</b> uranium 238	93 <b>Np</b> neptunium –	94 <b>Pu</b> plutonium –	95 <b>Am</b> americium –	96 <b>Cm</b> curium –	97 <b>Bk</b> berkelium –	98 <b>Cf</b> californium –	99 <b>Es</b> einsteinium –	100 <b>Fm</b> fermium –	101 <b>Md</b> mendelevium –	102 <b>No</b> nobelium –	103 <b>Lr</b> lawrencium –

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

### 7.3 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, e.g. 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.

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## 8. Other information

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### Equality and inclusion

Cambridge International Examinations has taken great care in the preparation of this syllabus and assessment materials to avoid bias of any kind. To comply with the UK Equality Act (2010), Cambridge has designed this qualification with the aim of avoiding direct and indirect discrimination.

The standard assessment arrangements may present unnecessary barriers for candidates with disabilities or learning difficulties. Arrangements can be put in place for these candidates to enable them to access the assessments and receive recognition of their attainment. Access arrangements will not be agreed if they give candidates an unfair advantage over others or if they compromise the standards being assessed.

Candidates who are unable to access the assessment of any component may be eligible to receive an award based on the parts of the assessment they have taken.

Information on access arrangements is found in the *Cambridge Handbook* which can be downloaded from the website **[www.cie.org.uk/examsOfficers](http://www.cie.org.uk/examsOfficers)**

### Language

This syllabus and the associated assessment materials are available in English only.

### Grading and reporting

Cambridge O Level results are shown by one of the grades A\*, A, B, C, D or E, indicating the standard achieved, A\* being the highest and E the lowest. 'Ungraded' indicates that the candidate's performance fell short of the standard required for grade E. 'Ungraded' will be reported on the statement of results but not on the certificate. The letters Q (result pending), X (no results) and Y (to be issued) may also appear on the statement of results but not on the certificate.

### Entry codes

To maintain the security of our examinations, we produce question papers for different areas of the world, known as 'administrative zones'. Where the component entry code has two digits, the first digit is the component number given in the syllabus. The second digit is the location code, specific to an administrative zone. Information about entry codes can be found in the *Cambridge Guide to Making Entries*.

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