Cambridge Assessment International Education

Syllabus

Cambridge O Level

Chemistry 5070

Use this syllabus for exams in 2026, 2027 and 2028.
Exams are available in the June and November series.

This syllabus is **not** available in all administrative zones.
Please check the syllabus page at **www.cambridgeinternational.org/5070** to see if this syllabus is available in your administrative zone.

Version 1

For the purposes of screen readers, any mention in this document of Cambridge IGCSE refers to Cambridge International General Certificate of Secondary Education.

Cambridge Pathway

Why choose Cambridge International?

Cambridge International prepares school students for life, helping them develop an informed curiosity and a lasting passion for learning. We are part of the University of Cambridge.

Our Cambridge Pathway gives students a clear path for educational success from age 5 to 19. Schools can shape the curriculum around how they want students to learn – with a wide range of subjects and flexible ways to offer them. It helps students discover new abilities and a wider world, and gives them the skills they need for life, so they can achieve at school, university and work.

Our programmes and qualifications set the global standard for international education. They are created by subject experts, are rooted in academic rigour and reflect the latest educational research. They provide a strong platform for learners to progress from one stage to the next, and are well supported by teaching and learning resources. Learn more about our research at **www.cambridgeassessment.org.uk/our-research/**

We believe education works best when curriculum, teaching, learning and assessment are closely aligned. Our programmes develop deep knowledge, conceptual understanding and higher-order thinking skills, to prepare students for their future. Together with schools, we develop Cambridge learners who are confident, responsible, reflective, innovative and engaged – equipped for success in the modern world.

Every year, nearly a million Cambridge students from 10 000 schools in 160 countries prepare for their future with the Cambridge Pathway.

School feedback: 'We think the Cambridge curriculum is superb preparation for university.'

Feedback from: Christoph Guttentag, Dean of Undergraduate Admissions, Duke University, USA

Quality management

Cambridge International is committed to providing exceptional quality. In line with this commitment, our quality management system for the provision of international education programmes and qualifications for students aged 5 to 19 is independently certified as meeting the internationally recognised standard, ISO 9001:2015. Learn more at **www.cambridgeinternational.org/about-us/our-standards/**

Contents

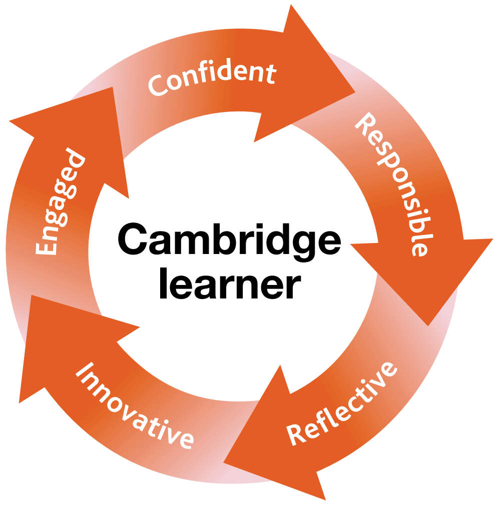
Important: Changes to this syllabus

The latest syllabus is version 1, published September 2023. There are no significant changes which affect teaching.

Any textbooks endorsed to support the syllabus for examination from 2023 are still suitable for use with this syllabus.

1 Why choose this syllabus?

Key benefits



Cambridge O Level is typically for 14 to 16 year olds and is an internationally recognised qualification. It has been designed especially for an international market and is sensitive to the needs of different countries. Cambridge O Level is designed for learners whose first language may not be English, and this is acknowledged throughout the examination process.

Our programmes promote a thorough knowledge and understanding of a subject and help to develop the skills learners need for their next steps in education or employment.

Cambridge O Level Chemistry develops a set of transferable skills including handling data, practical problem-solving and applying the scientific method. Learners develop relevant attitudes, such as concern for accuracy and precision, objectivity, integrity, enquiry, initiative and inventiveness. They acquire the essential scientific skills required for progression to further studies or employment.

Our approach in Cambridge O Level Chemistry encourages learners to be:

confident, interested in learning about science, questioning ideas and using scientific language to communicate their views and opinions

responsible, working methodically and safely when working alone or collaboratively with others

reflective, learning from their experiences and interested in scientific issues that affect the individual, the community and the environment

innovative, solving unfamiliar problems confidently and creatively

engaged, keen to develop scientific skills, curious about scientific principles and their application in the world.

School feedback: 'Cambridge O Level has helped me develop thinking and analytical skills which will go a long way in helping me with advanced studies.'

Feedback from: Kamal Khan Virk, former student at Beaconhouse Garden Town Secondary School, Pakistan, who went on to study Actuarial Science at the London School of Economics

International recognition and acceptance

Our expertise in curriculum, teaching and learning, and assessment is the basis for the recognition of our programmes and qualifications around the world. The combination of knowledge and skills in Cambridge O Level Chemistry gives learners a solid foundation for further study. Candidates who achieve grades A* to C are well prepared to follow a wide range of courses including Cambridge International AS & A Level Chemistry.

Cambridge O Levels are accepted and valued by leading universities and employers around the world as evidence of academic achievement. Cambridge students can be confident that their qualifications will be understood and valued throughout their education and career, in their home country and internationally. Many universities require a combination of Cambridge International AS & A Levels and Cambridge O Levels or equivalent to meet their entry requirements.

Learn more at **www.cambridgeinternational.org/recognition**

Supporting teachers

We believe education is most effective when curriculum, teaching and learning, and assessment are closely aligned. We provide a wide range of resources, detailed guidance, innovative training and targeted professional development so that you can give your students the best possible preparation for Cambridge O Level. To find out which resources are available for each syllabus go to our School Support Hub.

The School Support Hub is our secure online site for Cambridge teachers where you can find the resources you need to deliver our programmes. You can also keep up to date with your subject and the global Cambridge community through our online discussion forums.

Find out more at **www.cambridgeinternational.org/support**

Support for Cambridge O Level			
Planning and preparation	**Teaching and assessment**	**Learning and revision**	**Results**
• Syllabuses • Schemes of work • Specimen Question Papers and Mark Schemes • Teacher guides	• Endorsed resources • Online forums • Support for coursework	• Example candidate responses • Past papers and mark schemes • Specimen paper answers	• Candidate Results Service • Principal examiner reports for teachers

Sign up for email notifications about changes to syllabuses, including new and revised products and services, at **www.cambridgeinternational.org/syllabusupdates**

Syllabuses and specimen materials represent the final authority on the content and structure of all of our assessments.

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- Introductory Professional Development – An introduction to Cambridge programmes and qualifications.
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- Cambridge Professional Development Qualifications (PDQs) – Practice-based programmes that transform professional learning for practising teachers. Available at Certificate and Diploma level.

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www.cambridgeinternational.org/support-and-training-for-schools/professional-development/

Supporting exams officers

We provide comprehensive support and guidance for all Cambridge exams officers.
Find out more at: **www.cambridgeinternational.org/eoguide**

2 Syllabus overview

Aims

The aims describe the purposes of a course based on this syllabus.

You can deliver some of the aims using suitable local, international or historical examples and applications, or through collaborative experimental work.

The aims are to enable students to:

- acquire scientific knowledge and understanding of scientific theories and practice
- develop a range of experimental skills, including handling variables and working safely
- use scientific data and evidence to solve problems and discuss the limitations of scientific methods
- communicate effectively and clearly, using scientific terminology, notation and conventions
- understand that the application of scientific knowledge can benefit people and the environment
- enjoy science and develop an informed interest in scientific matters which support further study.

Cambridge Assessment International Education is an education organisation and politically neutral. The contents of this syllabus, examination papers and associated materials do not endorse any political view. We endeavour to treat all aspects of the exam process neutrally.

Content overview

Candidates study the following topics:

1 States of matter
2 Atoms, elements and compounds
3 Stoichiometry
4 Electrochemistry
5 Chemical energetics
6 Chemical reactions
7 Acids, bases and salts
8 The Periodic Table
9 Metals
10 Chemistry of the environment
11 Organic chemistry
12 Experimental techniques and chemical analysis

Assessment overview

All candidates take three components. Candidates will be eligible for grades A* to E.

Paper 1: Multiple Choice			Paper 2: Theory	
1 hour			1 hour 45 minutes	
40 marks	30%	**AND**	80 marks	50%
40 four-option multiple-choice questions			Short-answer and structured questions	
Externally assessed			Externally assessed	

Practical assessment

All candidates take one practical paper from a choice of two:

Paper 3: Practical Test			Paper 4: Alternative to Practical	
1 hour 30 minutes			1 hour	
40 marks	20%	**OR**	40 marks	20%
Questions will be based on the experimental skills in section 4			Questions will be based on the experimental skills in section 4	
Externally assessed			Externally assessed	

Information on availability is in the **Before you start** section.

Assessment objectives

The assessment objectives (AOs) are:

AO1 Knowledge with understanding

Candidates should be able to demonstrate knowledge and understanding of:

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

Subject content defines the factual material that candidates may be required to recall and explain.

Candidates will also be asked questions which require them to apply this material to unfamiliar contexts and to apply knowledge from one area of the syllabus to another.

AO2 Handling information and problem-solving

Candidates should be able, in words or using other written forms of presentation (i.e. symbolic, graphical and numerical), to:

- locate, select, organise and present information from a variety of sources
- translate information from one form to another
- manipulate numerical and other data
- use information to identify patterns, report trends and form conclusions
- present reasoned explanations for phenomena, patterns and relationships
- make predictions based on relationships and patterns
- solve problems, including some of a quantitative nature.

Questions testing these skills may be based on information that is unfamiliar to candidates, requiring them to apply the principles and concepts from the syllabus to a new situation, in a logical, deductive way.

AO3 Experimental skills and investigations

Candidates should be able to:

- demonstrate knowledge of how to select and safely use techniques, apparatus and materials (including following a sequence of instructions where appropriate)
- plan experiments and investigations
- make and record observations, measurements and estimates
- interpret and evaluate experimental observations and data
- evaluate methods and suggest possible improvements.

Weighting for assessment objectives

The approximate weightings allocated to each of the assessment objectives (AOs) are summarised below.

Assessment objectives as a percentage of the qualification

Assessment objective	Weighting in O Level %
AO1 Knowledge with understanding	50
AO2 Handling information and problem-solving	30
AO3 Experimental skills and investigations	20
Total	100

Assessment objectives as a percentage of each component

Assessment objective	Weighting in components %		
	Paper 1	**Paper 2**	**Papers 3 and 4**
AO1 Knowledge with understanding	63	63	0
AO2 Handling information and problem-solving	37	37	0
AO3 Experimental skills and investigations	0	0	100
Total	100	100	100

3 Subject content

This syllabus gives you the flexibility to design a course that will interest, challenge and engage your learners. Where appropriate you are responsible for selecting resources and examples to support your learners' study. These should be appropriate for the learners' age, cultural background and learning context as well as complying with your school policies and local legal requirements.

Scientific subjects are, by their nature, experimental. Learners should pursue a fully integrated course which allows them to develop their experimental skills by doing practical work and investigations.

Practical work helps students to:

- use equipment and materials accurately and safely
- develop observational and problem-solving skills
- develop a deeper understanding of the syllabus topics and the scientific approach
- appreciate how scientific theories are developed and tested
- transfer the experimental skills acquired to unfamiliar contexts
- develop positive scientific attitudes such as objectivity, integrity, cooperation, enquiry and inventiveness
- develop an interest and enjoyment in science.

1 States of matter

1.1 Solids, liquids and gases

1 State the distinguishing properties of solids, liquids and gases
2 Describe the structures of solids, liquids and gases in terms of particle separation, arrangement and motion
3 Describe and explain changes of state (melting, boiling, evaporating, freezing and condensing) in terms of kinetic particle theory
4 Interpret and explain heating and cooling curves in terms of kinetic particle theory
5 Describe and explain, in terms of kinetic particle theory, the effects of temperature and pressure on the volume of a gas

1.2 Diffusion

1 Describe and explain diffusion in terms of kinetic particle theory
2 Describe and explain the effect of relative molecular mass on the rate of diffusion of gases

2 Atoms, elements and compounds

2.1 Elements, compounds and mixtures

1 Describe the differences between elements, compounds and mixtures

2.2 Atomic structure and the Periodic Table

1 Describe the structure of the atom as a central nucleus containing neutrons and protons surrounded by electrons in shells

2 State the relative charges and relative masses of a proton, a neutron and an electron

3 Define proton number/atomic number as the number of protons in the nucleus of an atom

4 Define mass number/nucleon number as the total number of protons and neutrons in the nucleus of an atom

5 Determine the electronic configuration of elements and their ions with proton number 1 to 20, e.g. 2,8,3

6 State that:

(a) Group VIII noble gases have a full outer electron shell

(b) the number of outer shell electrons is equal to the group number in Groups I to VII

(c) the number of occupied electron shells is equal to the period number

2.3 Isotopes

1 Define isotopes as different atoms of the same element that have the same number of protons but different numbers of neutrons

2 State that isotopes of the same element have the same chemical properties because they have the same number of electrons and therefore the same electronic configuration

3 Interpret and use symbols for atoms, e.g. ${}^{12}_{6}C$, and ions, e.g. ${}^{35}_{17}Cl^{-}$

4 Calculate the relative atomic mass of an element from the relative masses and abundances of its isotopes

2.4 Ion and ionic bonds

1 Describe the formation of positive ions, known as cations, and negative ions, known as anions

2 Describe the giant lattice structure of ionic compounds as a regular arrangement of alternating positive and negative ions

3 State that an ionic bond is a strong electrostatic attraction between oppositely charged ions

4 Describe the formation of ionic bonds between ions of metallic and non-metallic elements, including the use of dot-and-cross diagrams

5 Describe and explain in terms of structure and bonding the properties of ionic compounds:

(a) high melting points and boiling points

(b) good electrical conductivity when aqueous or molten and poor when solid

2.5 Simple molecules and covalent bonds

1 State that a covalent bond is formed when a pair of electrons is shared between two atoms leading to noble gas electronic configurations

2 Describe the formation of covalent bonds in simple molecules, including H_2, Cl_2, H_2O, CH_4, NH_3, HCl, CH_3OH, C_2H_4, O_2, CO_2 and N_2. Use dot-and-cross diagrams to show the electronic configurations in these and similar molecules

3 Describe and explain in terms of structure and bonding the properties of simple molecular compounds:

(a) low melting points and boiling points in terms of weak intermolecular forces (specific types of intermolecular forces are **not** required)

(b) poor electrical conductivity

2.6 Giant covalent structures

1 Describe the giant covalent structures of graphite, diamond and silicon(IV) oxide, SiO_2

2 Relate the structures and bonding of graphite and diamond to their uses, limited to:

(a) graphite as a lubricant and as an electrode

(b) diamond in cutting tools

3 Describe the similarity in properties between diamond and silicon(IV) oxide, related to their structures

2.7 Metallic bonding

1 Describe metallic bonding as the electrostatic attraction between the positive ions in a giant metallic lattice and a 'sea' of delocalised electrons

2 Explain in terms of structure and bonding the properties of metals:

(a) good electrical conductivity

(b) malleability and ductility

3 Stoichiometry

3.1 Formulae

1 State the formulae of the elements and compounds named in the subject content

2 Define the molecular formula of a compound as the number and type of different atoms in one molecule

3 Define the empirical formula of a compound as the simplest whole number ratio of the different atoms or ions in a compound

4 Deduce the formula of a simple compound from the relative numbers of atoms or ions present in a model or a diagrammatic representation

5 Deduce the formula of an ionic compound from the charges on the ions

6 Construct word equations, symbol equations and ionic equations to show how reactants form products, including state symbols

7 Deduce the symbol equation with state symbols for a chemical reaction, given relevant information

3.2 Relative masses of atoms and molecules

1 Describe relative atomic mass, A_r, as the average mass of the isotopes of an element compared to 1/12th of the mass of an atom of ^{12}C

2 Define relative molecular mass, M_r, as the sum of the relative atomic masses. Relative formula mass, M_r, will be used for ionic compounds

3.3 The mole and the Avogadro constant

1 State that the mole, mol, is the unit of amount of substance and that one mole contains 6.02×10^{23} particles, e.g. atoms, ions, molecules; this number is the Avogadro constant

2 Use the relationship

amount of substance (mol) = $\frac{\text{mass (g)}}{\text{molar mass (g/mol)}}$

to calculate:

(a) amount of substance

(b) mass

(c) molar mass

(d) relative atomic mass or relative molecular/formula mass

(e) number of particles, using the value of the Avogadro constant

3 Use the molar gas volume, taken as $24\,dm^3$ at room temperature and pressure, r.t.p., in calculations involving gases

4 State that concentration can be measured in g/dm^3 or mol/dm^3

5 Calculate stoichiometric reacting masses, limiting reactants, volumes of gases at r.t.p., volumes of solutions and concentrations of solutions expressed in g/dm^3 and mol/dm^3, including conversion between cm^3 and dm^3

6 Use experimental data to calculate the concentration of a solution in a titration

7 Calculate empirical formulae and molecular formulae, given appropriate data

8 Calculate percentage yield, percentage composition by mass and percentage purity, given appropriate data

4 Electrochemistry

4.1 Electrolysis

1 Define electrolysis as the decomposition of an ionic compound, when molten or in aqueous solution, by the passage of an electric current

2 Identify in simple electrolytic cells:
- (a) the anode as the positive electrode
- (b) the cathode as the negative electrode
- (c) the electrolyte as the molten or aqueous substance that undergoes electrolysis

3 Describe the transfer of charge during electrolysis to include:
- (a) the movement of electrons in the external circuit
- (b) the loss or gain of electrons at the electrodes
- (c) the movement of ions in the electrolyte

4 Identify the products formed at the electrodes and describe the observations made during the electrolysis of:
- (a) molten lead(II) bromide
- (b) concentrated aqueous sodium chloride
- (c) dilute sulfuric acid

using inert electrodes made of platinum or carbon/graphite

5 Identify the products formed at the electrodes and describe the observations made during the electrolysis of aqueous copper(II) sulfate using inert carbon/graphite electrodes and when using copper electrodes

6 State that metals or hydrogen are formed at the cathode and that non-metals (other than hydrogen) are formed at the anode

7 Predict the identity of the products at each electrode for the electrolysis of a binary compound in the molten state

8 Predict the identity of the products at each electrode for the electrolysis of a halide compound in dilute or concentrated aqueous solution

9 Construct ionic half-equations for reactions at the anode (to show oxidation) and at the cathode (to show reduction)

10 State that metal objects are electroplated to improve their appearance and resistance to corrosion

11 Describe how metals are electroplated

4.2 Hydrogen–oxygen fuel cells

1 State that a hydrogen–oxygen fuel cell uses hydrogen and oxygen to produce electricity with water as the only chemical product

2 Describe the advantages and disadvantages of using hydrogen–oxygen fuel cells in comparison with gasoline/petrol engines in vehicles

5 Chemical energetics

5.1 Exothermic and endothermic reactions

1 State that an exothermic reaction transfers thermal energy to the surroundings leading to an increase in the temperature of the surroundings

2 State that an endothermic reaction takes in thermal energy from the surroundings leading to a decrease in the temperature of the surroundings

3 State that the transfer of thermal energy during a reaction is called the enthalpy change, ΔH, of the reaction. ΔH is negative for exothermic reactions and positive for endothermic reactions

4 Define activation energy, E_a, as the minimum energy that colliding particles must have to react

5 Draw, label and interpret reaction pathway diagrams for exothermic and endothermic reactions using information provided, to include:
- (a) reactants
- (b) products
- (c) enthalpy change of the reaction, ΔH
- (d) activation energy, E_a

6 State that bond breaking is an endothermic process and bond making is an exothermic process and explain the enthalpy change of a reaction in terms of bond breaking and bond making

7 Calculate the enthalpy change of a reaction using bond energies

6 Chemical reactions

6.1 Physical and chemical changes

1 Identify physical and chemical changes, and describe the differences between them

6.2 Rate of reaction

1 Describe collision theory in terms of:
- (a) number of particles per unit volume
- (b) frequency of collisions between particles
- (c) kinetic energy of particles
- (d) activation energy, E_a

2 State that a catalyst increases the rate of a reaction, decreases the activation energy, E_a, of a reaction and is unchanged at the end of a reaction

3 Describe and explain the effect on the rate of reactions of:
- (a) changing the concentration of solutions
- (b) changing the pressure of gases
- (c) changing the surface area of solids
- (d) changing the temperature
- (e) adding or removing a catalyst, including enzymes

using collision theory

4 Describe and evaluate practical methods for investigating the rate of a reaction, including change in mass of a reactant or a product and the formation of a gas

5 Interpret data, including graphs, from rate of reaction experiments

6.3 Reversible reactions and equilibrium

1 State that some chemical reactions are reversible as shown by the symbol $\rightleftharpoons$

2 Describe how changing the conditions can change the direction of a reversible reaction for:
   (a) the effect of heat on hydrated compounds
   (b) the addition of water to anhydrous compounds
   including copper(II) sulfate and cobalt(II) chloride

3 State that a reversible reaction in a closed system is at equilibrium when:
   (a) the rate of the forward reaction is equal to the rate of the reverse reaction
   (b) the concentrations of reactants and products are no longer changing

4 Predict and explain, for a reversible reaction, how the position of equilibrium is affected by:
   (a) changing temperature
   (b) changing pressure
   (c) changing concentration
   (d) using a catalyst
   using information provided

5 State the symbol equation for the production of ammonia in the Haber process,
   $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

6 State the sources of the hydrogen (methane) and nitrogen (air) in the Haber process

7 State the typical conditions in the Haber process as 450 °C, 20 000 kPa / 200 atm and an iron catalyst

8 State the symbol equation for the conversion of sulfur dioxide to sulfur trioxide in the Contact process,
   $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

9 State the sources of the sulfur dioxide (burning sulfur or roasting sulfide ores) and oxygen (air) in the Contact process

10 State the typical conditions for the conversion of sulfur dioxide to sulfur trioxide in the Contact process as 450 °C, 200 kPa / 2 atm and a vanadium(V) oxide catalyst

11 Explain, in terms of rate of reaction and position of equilibrium, why the typical conditions stated are used in the Haber process and in the Contact process, including safety considerations and economics

6.4 Redox

1 Use a Roman numeral to indicate the oxidation number of an element in a compound

2 Define redox reactions as involving simultaneous reduction and oxidation

3 Define oxidation in terms of:
- (a) gain of oxygen
- (b) loss of electrons
- (c) an increase in oxidation number

4 Define reduction in terms of:
- (a) loss of oxygen
- (b) gain of electrons
- (c) a decrease in oxidation number

5 Identify redox reactions as reactions involving gain and loss of oxygen, or gain and loss of electrons

6 Identify redox reactions by changes in oxidation number using:
- (a) the oxidation number of elements in their uncombined state is zero
- (b) the oxidation number of a monatomic ion is the same as the charge on the ion
- (c) the sum of the oxidation numbers in a compound is zero
- (d) the sum of the oxidation numbers in an ion is equal to the charge on the ion

7 Identify redox reactions by the colour changes involved when using acidified aqueous potassium manganate(VII) or aqueous potassium iodide

8 Define an oxidising agent as a substance that oxidises another substance and is itself reduced

9 Define a reducing agent as a substance that reduces another substance and is itself oxidised

10 Identify oxidation, oxidising agents, reduction and reducing agents in redox reactions

7 Acids, bases and salts

7.1 The characteristic properties of acids and bases

1 State that aqueous solutions of acids contain H^+ ions and aqueous solutions of alkalis contain OH^- ions

2 Define acids as proton donors and bases as proton acceptors

3 State that bases are oxides or hydroxides of metals and that alkalis are soluble bases

4 Describe the characteristic properties of acids in terms of their reactions with:
(a) metals
(b) bases
(c) carbonates

5 Describe the characteristic properties of bases in terms of their reactions with:
(a) acids
(b) ammonium salts

6 State that a neutralisation reaction occurs between an acid and a base

7 Describe the neutralisation reaction between an acid and an alkali to produce water,
$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

8 Describe acids and alkalis in terms of their effects on:
(a) litmus
(b) thymolphthalein
(c) methyl orange

9 Define a strong acid as an acid that is completely dissociated in aqueous solution and a weak acid as an acid that is partially dissociated in aqueous solution

10 State examples of strong acids, including hydrochloric acid, nitric acid and sulfuric acid and construct the symbol equations to show their complete dissociation, e.g. $HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$

11 State examples of weak acids, including carboxylic acids and construct the symbol equations to show their partial dissociation, e.g. for ethanoic acid, $CH_3COOH(aq) \rightleftharpoons H^+(aq) + CH_3COO^-(aq)$

12 Describe how to compare hydrogen ion concentration, neutrality, relative acidity and relative alkalinity in terms of colour and pH using universal indicator paper

7.2 Oxides

1 Describe amphoteric oxides as oxides that react with acids and bases to produce a salt and water

2 Classify oxides as acidic, including SO_2 and CO_2, basic, including CuO and CaO, or amphoteric, limited to Al_2O_3 and ZnO, related to metallic and non-metallic character

7.3 Preparation of salts

1 Describe the preparation, separation and purification of soluble salts by reaction of an acid with:
  (a) an alkali by titration
  (b) excess metal
  (c) excess insoluble base
  (d) excess insoluble carbonate

2 Describe the preparation of insoluble salts by precipitation

3 Describe the general solubility rule for salts:
  (a) sodium, potassium and ammonium salts are soluble
  (b) nitrates are soluble
  (c) chlorides are soluble, except lead and silver
  (d) sulfates are soluble, except barium, calcium and lead
  (e) carbonates are insoluble, except sodium, potassium and ammonium
  (f) hydroxides are insoluble, except sodium, potassium, ammonium and calcium (partially)

4 Define a hydrated substance as a substance that is chemically combined with water and an anhydrous substance as a substance containing no water

5 Define the term water of crystallisation as the water molecules present in hydrated crystals, including $CuSO_4 \bullet 5H_2O$ and $CoCl_2 \bullet 6H_2O$

8 The Periodic Table

8.1 Arrangement of elements

1 Describe the Periodic Table as an arrangement of elements in periods and groups and in order of increasing proton number / atomic number

2 Describe the change from metallic to non-metallic character across a period

3 Describe the relationship between group number and the charge of the ions formed from elements in that group

4 Explain similarities in the chemical properties of elements in the same group of the Periodic Table in terms of their electronic configuration

5 Explain how the position of an element in the Periodic Table can be used to predict its properties

6 Identify trends in groups, given information about the elements

8.2 Group I properties

1 Describe the Group I alkali metals, lithium, sodium and potassium, as relatively soft metals with general trends down the group, limited to:
  (a) decreasing melting point
  (b) increasing density
  (c) increasing reactivity

2 Predict the properties of other elements in Group I, given information about the elements

8.3 Group VII properties

1 Describe the Group VII halogens, chlorine, bromine and iodine, as diatomic non-metals with general trends down the group, limited to:
 (a) increasing density
 (b) decreasing reactivity

2 State the appearance of the halogens at r.t.p. as:
 (a) chlorine, a pale yellow-green gas
 (b) bromine, a red-brown liquid
 (c) iodine, a grey-black solid

3 Describe and explain the displacement reactions of halogens with other halide ions

4 Predict the properties of other elements in Group VII, given information about the elements

8.4 Transition elements

1 Describe the transition elements as metals that:
 (a) have high densities
 (b) have high melting points
 (c) have variable oxidation numbers
 (d) form coloured compounds
 (e) often act as catalysts as elements and in compounds

8.5 Noble gases

1 Describe the Group VIII noble gases as unreactive, monatomic gases and explain this in terms of electronic configuration

9 Metals

9.1 Properties of metals

1 Compare the general physical properties of metals and non-metals, including:
 (a) thermal conductivity
 (b) electrical conductivity
 (c) malleability and ductility
 (d) melting points and boiling points

2 Describe the general chemical properties of metals, limited to their reactions with:
 (a) dilute acids
 (b) cold water and steam
 (c) oxygen

9.2 Uses of metals

1 Describe the uses of metals in terms of their physical properties, including:
- (a) aluminium in the manufacture of aircraft because of its low density
- (b) aluminium in the manufacture of overhead electrical cables because of its low density and good electrical conductivity
- (c) aluminium in food containers because of its resistance to corrosion
- (d) copper in electrical wiring because of its good electrical conductivity and ductility

9.3 Alloys and their properties

1 Describe an alloy as a mixture of a metal with other elements, including:
- (a) brass as a mixture of copper and zinc
- (b) stainless steel as a mixture of iron and other elements such as chromium, nickel and carbon

2 Explain in terms of structure how alloys can be harder and stronger than the pure metals because the different sized atoms or ions in alloys mean the layers can no longer slide over each other

3 Describe the uses of alloys in terms of their physical properties, including stainless steel in cutlery because of its hardness and resistance to rusting

4 Identify representations of alloys from diagrams of structure

9.4 Reactivity series

1 State the order of the reactivity series as: potassium, sodium, calcium, magnesium, aluminium, carbon, zinc, iron, hydrogen, copper, silver, gold

2 Describe the relative reactivities of metals in terms of their tendency to form positive ions, by displacement reactions, if any, with the aqueous ions of magnesium, zinc, iron, copper and silver

3 Describe the reactions, if any, of:
- (a) potassium, sodium and calcium with cold water
- (b) magnesium with steam
- (c) magnesium, zinc, iron, copper, silver and gold with dilute hydrochloric acid

and explain these reactions in terms of the position of the metals in the reactivity series

4 Explain the apparent unreactivity of aluminium in terms of its oxide layer

5 Deduce an order of reactivity from a given set of experimental results

9.5 Corrosion of metals

1 State the conditions required for the rusting of iron and steel to form hydrated iron(III) oxide

2 Describe how barrier methods prevent rusting by excluding oxygen or water

3 State some common barrier methods, including painting, greasing and coating with plastic

4 Explain sacrificial protection in terms of the reactivity series and in terms of electron loss

5 Describe the use of zinc in galvanising as an example of a barrier method and sacrificial protection

9.6 Extraction of metals

1 Describe the ease of obtaining metals from their ores, related to the position of the metal in the reactivity series

2 Describe the extraction of iron from hematite in the blast furnace, including symbol equations for each step, limited to:

(a) the burning of carbon (coke) to provide heat and produce carbon dioxide

(b) the reduction of carbon dioxide to carbon monoxide

(c) the reduction of iron(III) oxide by carbon monoxide

(d) the thermal decomposition of calcium carbonate / limestone to produce calcium oxide

(e) the formation of slag

3 Describe the extraction of aluminium from purified bauxite / aluminium oxide, including:

(a) the role of cryolite

(b) why the carbon anodes need to be regularly replaced

(c) the reactions at the electrodes, including ionic half-equations

Details of the purification of bauxite are **not** required

10 Chemistry of the environment

10.1 Water

1 Describe chemical tests for the presence of water using anhydrous cobalt(II) chloride and anhydrous copper(II) sulfate

2 Describe how to test for the purity of water using melting point and boiling point

3 Explain that distilled water is used in practical chemistry rather than tap water because it contains fewer chemical impurities

4 State that water from natural sources may contain substances, including:
- (a) dissolved oxygen
- (b) metal compounds
- (c) plastics
- (d) sewage
- (e) harmful microbes
- (f) nitrates from fertilisers
- (g) phosphates from fertilisers and detergents

5 State that some of these substances are beneficial, including:
- (a) dissolved oxygen for aquatic life
- (b) some metal compounds provide essential minerals for life

6 State that some of these substances are potentially harmful, including:
- (a) some metal compounds are toxic
- (b) some plastics harm aquatic life
- (c) sewage contains harmful microbes which cause disease
- (d) nitrates and phosphates lead to deoxygenation of water and damage to aquatic life

Details of the eutrophication process are **not** required

7 Describe the treatment of the domestic water supply in terms of:
- (a) sedimentation and filtration to remove solids
- (b) use of carbon to remove tastes and odours
- (c) chlorination to kill microbes

10.2 Fertilisers

1 State that ammonium salts and nitrates are used as fertilisers

2 Describe the use of NPK fertilisers to provide the elements nitrogen, phosphorus and potassium for improved plant growth

10.3 Air quality and climate

1 State the composition of clean, dry air as approximately 78% nitrogen, N_2, 21% oxygen, O_2, and the remainder as a mixture of noble gases and carbon dioxide, CO_2

2 State the source of each of these air pollutants:
   - (a) carbon dioxide from the complete combustion of carbon-containing fuels
   - (b) carbon monoxide and particulates from the incomplete combustion of carbon-containing fuels
   - (c) methane from the decomposition of vegetation and waste gases from digestion in animals
   - (d) oxides of nitrogen from car engines
   - (e) sulfur dioxide from the combustion of fossil fuels which contain sulfur compounds

3 State the adverse effects of these air pollutants:
   - (a) carbon dioxide: higher levels of carbon dioxide leading to increased global warming, which leads to climate change
   - (b) carbon monoxide: toxic gas
   - (c) particulates: increased risk of respiratory problems and cancer
   - (d) methane: higher levels of methane leading to increased global warming, which leads to climate change
   - (e) oxides of nitrogen: acid rain, photochemical smog and respiratory problems
   - (f) sulfur dioxide: acid rain

4 Describe how the greenhouse gases carbon dioxide and methane cause global warming, limited to:
   - (a) the absorption, reflection and emission of thermal energy
   - (b) reducing thermal energy loss to space

5 State and explain strategies to reduce the effects of these environmental issues, limited to:
   - (a) climate change: planting trees, reduction in livestock farming, decreasing use of fossil fuels, increasing use of hydrogen and renewable energy, e.g. wind, solar
   - (b) acid rain: use of catalytic converters in vehicles, reducing emissions of sulfur dioxide by using low-sulfur fuels and flue gas desulfurisation with calcium oxide

6 Explain how oxides of nitrogen form in car engines and describe their removal by catalytic converters, e.g. $2CO + 2NO \rightarrow 2CO_2 + N_2$

7 Describe photosynthesis as the reaction between carbon dioxide and water to produce glucose and oxygen in the presence of chlorophyll and using energy from light

8 State the word equation and symbol equation for photosynthesis

11 Organic chemistry

11.1 Formulae, functional groups and terminology

1 State that a structural formula is an unambiguous description of the way the atoms in a molecule are arranged, including $CH_2{=}CH_2$, CH_3CH_2OH, CH_3COOCH_3

2 Draw and interpret the displayed formula of a molecule to show all the atoms and all the bonds

3 Write and interpret general formulae of compounds in the same homologous series, limited to:
- (a) alkanes, C_nH_{2n+2}
- (b) alkenes, C_nH_{2n}
- (c) alcohols, $C_nH_{2n+1}OH$
- (d) carboxylic acids, $C_nH_{2n+1}COOH$

4 Define structural isomers as compounds with the same molecular formula, but different structural formulae, including C_4H_{10} as $CH_3CH_2CH_2CH_3$ and $CH_3CH(CH_3)CH_3$ and C_4H_8 as $CH_3CH_2CH{=}CH_2$ and $CH_3CH{=}CHCH_3$

5 Identify a functional group as an atom or group of atoms that determine the chemical properties of a homologous series

6 Describe the general characteristics of a homologous series as:
- (a) having the same functional group
- (b) having the same general formula
- (c) differing from one member to the next by a $-CH_2-$ unit
- (d) displaying a trend in physical properties
- (e) sharing similar chemical properties

7 State that a saturated compound has molecules in which all carbon–carbon bonds are single bonds

8 State that an unsaturated compound has molecules in which one or more carbon–carbon bonds are not single bonds

11.2 Naming organic compounds

1 Name and draw the structural and displayed formulae of unbranched:
- (a) alkanes
- (b) alkenes, including but-1-ene and but-2-ene
- (c) alcohols, including propan-1-ol, propan-2-ol, butan-1-ol and butan-2-ol
- (d) carboxylic acids
- (e) the products of the reactions stated in sections 11.4–11.7

containing up to four carbon atoms per molecule

2 State the type of compound present given the chemical name ending in -ane, -ene, -ol, or -oic acid or from a molecular, structural or displayed formula

3 Name and draw the displayed formulae of the unbranched esters which can be made from unbranched alcohols and carboxylic acids, each containing up to four carbon atoms

11.3 Fuels

1 Name the fossil fuels: coal, natural gas and petroleum
2 Name methane as the main constituent of natural gas
3 State that hydrocarbons are compounds that contain hydrogen and carbon only
4 State that petroleum is a mixture of hydrocarbons
5 Describe the separation of petroleum into useful fractions by fractional distillation
6 Describe how the properties of fractions obtained from petroleum change from the bottom to the top of the fractionating column, limited to:
   (a) decreasing chain length
   (b) higher volatility
   (c) lower boiling points
   (d) lower viscosity
7 Name the uses of the fractions as:
   (a) refinery gas fraction for gas used in heating and cooking
   (b) gasoline / petrol fraction for fuel used in cars
   (c) naphtha fraction as a chemical feedstock
   (d) kerosene / paraffin fraction for jet fuel
   (e) diesel oil / gas oil fraction for fuel used in diesel engines
   (f) fuel oil fraction for fuel used in ships and home heating systems
   (g) lubricating oil fraction for lubricants, waxes and polishes
   (h) bitumen fraction for making roads

11.4 Alkanes

1 State that the bonding in alkanes is single covalent and that alkanes are saturated hydrocarbons
2 Describe the properties of alkanes as being generally unreactive, except in terms of combustion and substitution by chlorine
3 State that in a substitution reaction one atom or group of atoms is replaced by another atom or group of atoms
4 Describe the substitution reaction of alkanes with chlorine as a photochemical reaction, with ultraviolet light providing the activation energy, E_a, and draw the structural or displayed formulae of the products, limited to monosubstitution

11.5 Alkenes

1 State that the bonding in alkenes includes a double carbon–carbon covalent bond and that alkenes are unsaturated hydrocarbons

2 Describe the manufacture of alkenes and hydrogen by the cracking of larger alkane molecules using a high temperature and a catalyst

3 Describe the reasons for the cracking of larger alkane molecules

4 Describe the test to distinguish between saturated and unsaturated hydrocarbons by their reaction with aqueous bromine

5 State that in an addition reaction only one product is formed

6 Describe the properties of alkenes in terms of addition reactions with:
- (a) bromine or aqueous bromine
- (b) hydrogen in the presence of a nickel catalyst
- (c) steam in the presence of an acid catalyst

and draw the structural or displayed formulae of the products

11.6 Alcohols

1 Describe the manufacture of ethanol by:
- (a) fermentation of aqueous glucose at 25–35 °C in the presence of yeast and in the absence of oxygen
- (b) catalytic addition of steam to ethene at 300 °C and 6000 kPa / 60 atm in the presence of an acid catalyst

including a comparison of the advantages and disadvantages of the two methods

2 Describe the combustion of alcohols

3 State the uses of ethanol as:
- (a) a solvent
- (b) a fuel

11.7 Carboxylic acids

1 Describe the reactions of carboxylic acids with:
- (a) metals
- (b) bases
- (c) carbonates

including names and formulae of the salts produced

2 Describe the formation of ethanoic acid by the oxidation of ethanol:
- (a) with acidified aqueous potassium manganate(VII)
- (b) by bacterial oxidation during vinegar production

3 Describe the reaction of a carboxylic acid with an alcohol using an acid catalyst to form an ester

11.8 Polymers

1 Define polymers as large molecules built up from many smaller molecules called monomers

2 Identify the repeat units and/or linkages in addition polymers and in condensation polymers

3 Deduce the structure or repeat unit of an addition polymer from a given alkene and vice versa

4 Deduce the structure or repeat unit of a condensation polymer from given monomers and vice versa, limited to:
   (a) polyamides from a dicarboxylic acid and a diamine
   (b) polyesters from a dicarboxylic acid and a diol

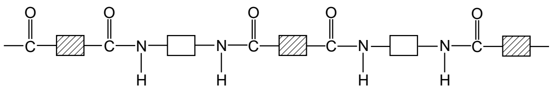
5 Describe the differences between addition and condensation polymerisation

6 State that plastics are made from polymers

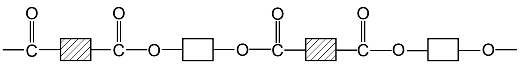
7 Describe how the properties of plastics have implications for their disposal

8 Describe the environmental challenges caused by plastics, limited to:
   (a) disposal in land fill sites
   (b) accumulation in oceans
   (c) formation of toxic gases from burning

9 Describe and draw the structure of:
   (a) nylon, a polyamide



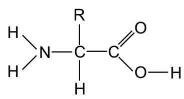
   (b) PET, a polyester



The full name for PET, polyethylene terephthalate, is **not** required

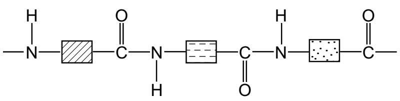
10 State that PET can be converted back into monomers and re-polymerised

11 Describe proteins as natural polyamides and that they are formed from amino acid monomers with the general structure:



where R represents different types of side-chain

12 Describe and draw the structure of proteins as:



12 Experimental techniques and chemical analysis

12.1 Experimental design

1 Name appropriate apparatus for the measurement of time, temperature, mass and volume, including:
   (a) stop-watches
   (b) thermometers
   (c) balances
   (d) burettes
   (e) volumetric pipettes
   (f) measuring cylinders
   (g) gas syringes

2 Suggest advantages and disadvantages of experimental methods and apparatus

3 Describe a:
   (a) solvent as a substance that dissolves a solute
   (b) solute as a substance that is dissolved in a solvent
   (c) solution as a mixture of one or more solutes dissolved in a solvent
   (d) saturated solution as a solution containing the maximum concentration of a solute dissolved in the solvent at a specified temperature
   (e) residue as a substance that remains after evaporation, distillation, filtration or any similar process
   (f) filtrate as a liquid or solution that has passed through a filter

12.2 Acid–base titrations

1 Describe an acid–base titration to include the use of a:
   (a) burette
   (b) volumetric pipette
   (c) suitable indicator

2 Describe how to identify the end-point of a titration using an indicator

12.3 Chromatography

1 Describe how paper chromatography is used to separate mixtures of soluble substances, using a suitable solvent

2 Describe the use of locating agents when separating mixtures containing colourless substances. Knowledge of specific locating agents is **not** required

3 Interpret simple chromatograms to identify:
   (a) unknown substances by comparison with known substances
   (b) pure and impure substances

4 State and use the equation for R_f:

$$R_f = \frac{\text{distance travelled by substance}}{\text{distance travelled by solvent}}$$

12.4 Separation and purification

1 Describe and explain methods of separation and purification using:
- (a) a suitable solvent
- (b) filtration
- (c) crystallisation
- (d) simple distillation
- (e) fractional distillation

2 Suggest suitable separation and purification techniques, given information about the substances involved

3 Identify substances and assess their purity using melting point and boiling point information

12.5 Identification of ions and gases

1 Describe tests to identify the anions:
- (a) carbonate, CO_3^{2-}, by reaction with dilute acid and then testing for carbon dioxide gas
- (b) chloride, Cl^-, bromide, Br^-, and iodide, I^-, by acidifying with dilute nitric acid then adding aqueous silver nitrate
- (c) nitrate, NO_3^-, by reduction with aluminium foil and aqueous sodium hydroxide and then testing for ammonia gas
- (d) sulfate, SO_4^{2-}, by acidifying with dilute nitric acid then adding aqueous barium nitrate
- (e) sulfite, SO_3^{2-}, by reaction with acidified aqueous potassium manganate(VII)

2 Describe tests using aqueous sodium hydroxide and aqueous ammonia to identify the aqueous cations:
- (a) aluminium, Al^{3+}
- (b) ammonium, NH_4^+
- (c) calcium, Ca^{2+}
- (d) chromium(III), Cr^{3+}
- (e) copper(II), Cu^{2+}
- (f) iron(II), Fe^{2+}
- (g) iron(III), Fe^{3+}
- (h) zinc, Zn^{2+}

3 Describe tests to identify the gases:
- (a) ammonia, NH_3, using damp red litmus paper
- (b) carbon dioxide, CO_2, using limewater
- (c) chlorine, Cl_2, using damp litmus paper
- (d) hydrogen, H_2, using a lighted splint
- (e) oxygen, O_2, using a glowing splint
- (f) sulfur dioxide, SO_2, using acidified aqueous potassium manganate(VII)

12.5 Identification of ions and gases continued

4 Describe the use of a flame test to identify the cations:

(a) lithium, Li^+

(b) sodium, Na^+

(c) potassium, K^+

(d) calcium, Ca^{2+}

(e) barium, Ba^{2+}

(f) copper(II), Cu^{2+}

4 Details of the assessment

All candidates take three papers. All papers assess grades A* to E.

Paper 1: Multiple Choice		Paper 2: Theory
1 hour 40 marks 40 compulsory multiple-choice items of the four-choice type This paper tests assessment objectives AO1 and AO2 Externally assessed	**AND**	1 hour 45 minutes 80 marks Compulsory short-answer and structured questions This paper tests assessment objectives AO1 and AO2 Externally assessed

Practical assessment

All candidates take one practical paper from a choice of two.

Paper 3: Practical Test		Paper 4: Alternative to Practical
1 hour 30 minutes 40 marks All items are compulsory This paper tests assessment objective AO3 Candidates will be required to do experiments in a laboratory as part of this test Externally assessed	**OR**	1 hour 40 marks All items are compulsory This paper tests assessment objective AO3 Candidates will not be required to do experiments in a laboratory as part of this test Externally assessed
Notes for use in qualitative analysis are provided for both Paper 3 and Paper 4.		

The Practical Test and Alternative to Practical:

- require the same experimental skills to be developed and learned
- require an understanding of the same experimental contexts
- test the same assessment objective, AO3.

Candidates are expected to be familiar with and may be asked questions on the following experimental contexts:

- simple quantitative experiments, including the measurement of:
  - volumes of gases or solutions / liquids
  - masses
  - temperatures
  - times
  - lengths

- rates of reaction
- salt preparation
- separation and purification techniques, including:
  - filtration
  - crystallisation
  - simple distillation
  - fractional distillation
  - chromatography
- electrolysis
- identification of metal ions, non-metal ions and gases
- chemical tests for water
- test-tube reactions of dilute acids, including ethanoic acid
- tests for oxidising and reducing agents
- heating and cooling curves
- titrations
- solubility
- melting points and boiling points
- displacement reactions of metals and halogens
- temperature changes during reactions
- conditions under which iron rusts or other metals corrode
- procedures using simple apparatus, in situations where the method may not be familiar to the candidate

Candidates may be required to do the following:

- **demonstrate knowledge of how to select and safely use techniques, apparatus and materials (including following a sequence of instructions where appropriate):**
  - identify apparatus from diagrams or descriptions
  - draw, complete or label diagrams of apparatus
  - use, or explain the use of, common techniques, apparatus and materials
  - select the most appropriate apparatus or method for the task and justify the choice made
  - describe tests (qualitative, gas tests, other tests)
  - describe and explain hazards and identify safety precautions
  - describe and explain techniques used to ensure the accuracy of observations and data

- **plan experiments and investigations:**
  - identify the independent variable and dependent variable
  - describe how and explain why variables should be controlled
  - suggest an appropriate number and range of values for the independent variable
  - suggest the most appropriate apparatus or technique and justify the choice made
  - describe experimental procedures
  - identify risks and suggest safety precautions
  - describe how to record the results of an experiment
  - describe how to process the results of an experiment to form a conclusion or to evaluate a prediction
  - make reasoned predictions of expected results

- **make and record observations, measurements and estimates:**
  - take readings from apparatus (analogue and digital) or from diagrams of apparatus
  - take readings with appropriate precision, reading to the nearest half-scale division where required
  - make observations, measurements or estimates that are in agreement with expected results or values
  - take sufficient observations or measurements, including repeats where appropriate
  - record qualitative observations from chemical tests and other tests
  - record observations and measurements systematically, for example in a suitable table, to an appropriate degree of precision and using appropriate units

- **interpret and evaluate experimental observations and data:**
  - process data, including for use in further calculations or for graph plotting, using a calculator as appropriate
  - present data graphically, including the use of best-fit lines where appropriate
  - analyse and interpret observations and data, including data presented graphically
  - use interpolation and extrapolation graphically to determine a gradient or intercept
  - form conclusions justified by reference to observations and data and with appropriate explanation
  - evaluate the quality of observations and data, identifying any anomalous results and taking appropriate action

- **evaluate methods and suggest possible improvements, including:**
  - evaluate experimental arrangements, methods and techniques, including the control of variables
  - identify sources of error
  - suggest possible improvements to the apparatus, experimental arrangements, methods or techniques

Apparatus and reagents

This list gives items that candidates should be familiar with using, whether they are taking the Practical Test or the Alternative to Practical.

These items should be available for use in the Practical Test. This list is not exhaustive and we may also require other items to be sourced for specific examinations. The Confidential Instructions we send before the Practical Test will give the detailed requirements for the examination.

Every effort is made to minimise the cost to and resources required by centres. Experiments will be designed around basic apparatus and materials which should be available in most school laboratories or are easily obtainable.

Hazard codes are used where relevant and in accordance with information provided by CLEAPSS (**www.cleapss.org.uk**). Students should be familiar with the meanings of these codes and terms but will **not** be assessed on them.

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

The attention of centres is also drawn to any national and local regulations relating to safety, first aid and disposal of chemicals. 'Hazard data sheets' should be available from your chemical supplier.

Appropriate safety equipment must be provided to students and should at least include eye protection.

- aluminium foil
- balances to measure up to 500 g, with precision of at least 0.1 g
- beakers or cups made of an insulating material such as polystyrene, approximate capacity 150 cm^3
- beakers, squat form with lip, 1 dm^3, 250 cm^3 and 100 cm^3
- boiling tubes, approximately 150 mm × 25 mm
- Bunsen burners
- burettes, 50 cm^3 (ISO385 or grade B)
- conical flasks, within the range 50 cm^3 to 250 cm^3
- delivery tubes
- filter funnels and filter papers
- flame test wires or alternative apparatus
- measuring cylinders, 100 cm^3, 50 cm^3, 25 cm^3, 10 cm^3 (ISO6706 or ISO4788 or grade B)
- pens for labelling glassware
- pipette fillers
- racks for test-tubes and boiling tubes
- red and blue litmus paper
- retort stands, bosses and clamps
- small droppers or teat pipettes
- small funnels for filling burettes
- spatulas

- stirring rods
- stirring thermometers, –10 °C to +110 °C, with 1 °C graduations
- stoppers for test-tubes and boiling tubes
- stop-watches to measure to an accuracy of 1 s
- test-tube holders (to hold test-tubes or boiling tubes)
- test-tubes (Pyrex or hard glass), approximately 125 mm × 16 mm
- tripods
- universal indicator paper
- volumetric pipettes, 25 cm^3 (ISO648 or grade B)
- wash bottles
- white tiles

Preparation of reagents

Detailed guidance on preparing the standard bench reagents and indicators listed here will **not** be given in the Confidential Instructions. The Confidential Instructions will refer supervisors to the preparations in this list.

Candidates are **not** expected to be familiar with the preparation of these reagents.

Please note, hazard symbols were accurate at the time of publication and may change.

Hazard	Label	Identify	Instructions
	dilute hydrochloric acid	1.0 mol / dm^3 HCl	Dilute 85 cm^3 of concentrated (35–37%; approximately 11 mol / dm^3) HCl **[C] [MH]** to 1 dm^3.
[C]	**dilute nitric acid**	1.0 mol / dm^3 HNO_3	Dilute 64 cm^3 of concentrated (70%) HNO_3 **[C] [O]** to 1 dm^3.
[MH]	**dilute sulfuric acid**	0.5 mol / dm^3 H_2SO_4	Cautiously pour 28 cm^3 of concentrated (98%) H_2SO_4 **[C]** into 500 cm^3 of distilled water with continuous stirring. Make the solution up to 1 dm^3 with distilled water. **Care:** concentrated H_2SO_4 is very corrosive.
[MH] [N]	**aqueous ammonia**	1.0 mol / dm^3 NH_3	Dilute 56 cm^3 of concentrated (35%) NH_3 **[C] [MH] [N]** to 1 dm^3.
[C]	**aqueous sodium hydroxide**	1.0 mol / dm^3 NaOH	Dissolve 40.0 g of NaOH **[C]** in each dm^3 of solution. **Care:** the process of solution is exothermic and any concentrated solution is very corrosive.
	aqueous barium nitrate	0.1 mol / dm^3 $Ba(NO_3)_2$	Dissolve 26.1 g of $Ba(NO_3)_2$ **[MH] [O]** in each dm^3 of solution.
	aqueous silver nitrate	0.05 mol / dm^3 $AgNO_3$	Dissolve 8.5 g of $AgNO_3$ **[C] [N] [O]** in each dm_3 of solution.
[MH]	**limewater**	saturated aqueous calcium hydroxide, $Ca(OH)_2$	Prepare fresh limewater by leaving distilled water to stand over solid $Ca(OH)_2$ **[C] [MH]** for several days, shaking occasionally. Decant or filter the solution.
	aqueous potassium iodide	0.1 mol / dm^3 KI	Dissolve 16.6 g of KI in each dm^3 of solution.
	aqueous potassium manganate(VII)	0.02 mol / dm^3 $KMnO_4$	Dissolve 3.16 g of $KMnO_4$ **[HH] [O] [MH] [N]** in each dm^3 of solution.
[MH]	**acidified aqueous potassium manganate(VII)**	0.01 mol / dm^3 $KMnO_4$ 0.5 mol / dm^3 H_2SO_4	Mix equal volumes of 0.02 mol / dm^3 $KMnO_4$ and 1.0 mol / dm^3 H_2SO_4 **[MH]**.
[C] [F] [HH] [MH] [N] [T]	**methyl orange indicator**	methyl orange indicator (pH range 3.1–4.4)	Use commercially produced solution or dissolve 0.4 g of solid methyl orange indicator **[C] [HH] [MH] [N] [T]** in 200 cm^3 of 95% ethanol **[F] [HH] [MH]** and make up to 1 dm^3 with distilled water.
[C] [HH] [MH] [N] [T]	**screened methyl orange indicator**	screened methyl orange indicator (pH range 3.2–4.2)	Use commercially produced solution or dissolve 1 g of solid methyl orange indicator **[C] [HH] [MH] [N] [T]** and 2.6 g of xylene cyanol **[HH] [MH] [N]** in 1 dm^3 of water.
[F] [HH] [MH]	**thymolphthalein indicator**	thymolphthalein indicator (pH range 9.3–10.5)	Use commercially produced solution or dissolve 2 g of solid thymolphthalein indicator in 1 dm^3 of 95% ethanol **[F] [HH] [MH]**.
	starch indicator	Freshly prepared aqueous starch indicator (approximately 2% solution)	Mix 2 g of soluble starch with a little cold water until a smooth paste is obtained. Add 100 cm^3 boiling water and stir. Boil until a clear solution is obtained (about 5 minutes).

Safety in the laboratory

Teachers should make sure that they do not contravene any school, education authority or government regulations. Responsibility for safety matters rests with centres.

Further information can be found from the following UK associations, publications and regulations.

Associations

CLEAPSS is an advisory service providing support in practical science and technology.
www.cleapss.org.uk

Publications

CLEAPSS Laboratory Handbook, updated 2015 (available to CLEAPSS members only)

CLEAPSS Hazcards, 2022 update of 2016 edition (available to CLEAPSS members only)

UK regulations

Control of Substances Hazardous to Health Regulations (COSHH) 2002 and subsequent amendment in 2004

www.legislation.gov.uk/uksi/2002/2677/contents/made

www.legislation.gov.uk/uksi/2004/3386/contents/made

A brief guide may be found at

www.hse.gov.uk/pubns/indg136.pdf

Notes for use in qualitative analysis

Tests for anions

anion	test	test result
carbonate, CO_3^{2-}	add dilute acid, then test for carbon dioxide gas	effervescence, carbon dioxide produced
chloride, Cl^- [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	white ppt.
bromide, Br^- [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	cream 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 with dilute nitric acid, then add aqueous barium nitrate	white ppt.
sulfite, SO_3^{2-}	add a small volume of acidified aqueous potassium manganate(VII)	the acidified aqueous potassium manganate(VII) changes colour from purple to colourless

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.
chromium(III), Cr^{3+}	green ppt., soluble in excess	green ppt., insoluble in excess
copper(II), 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, ppt. turns brown near surface on standing	green ppt., insoluble in excess, ppt. turns brown near surface on standing
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 manganate(VII) from purple to colourless

Flame tests for metal ions

metal ion	flame colour
lithium, Li^+	red
sodium, Na^+	yellow
potassium, K^+	lilac
calcium, Ca^{2+}	orange-red
barium, Ba^{2+}	light green
copper(II), Cu^{2+}	blue-green

The Periodic Table of Elements

Key

atomic number atomic symbol name relative atomic mass

Group I	Group II											Group III	Group IV	Group V	Group VI	Group VII	Group VIII
							1 H hydrogen 1										2 He helium 4
3 Li lithium 7	4 Be beryllium 9											5 B boron 11	6 C carbon 12	7 N nitrogen 14	8 O oxygen 16	9 F fluorine 19	10 Ne neon 20
11 Na sodium 23	12 Mg magnesium 24											13 Al aluminium 27	14 Si silicon 28	15 P phosphorus 31	16 S sulfur 32	17 Cl chlorine 35.5	18 Ar argon 40
19 K potassium 39	20 Ca calcium 40	21 Sc scandium 45	22 Ti titanium 48	23 V vanadium 51	24 Cr chromium 52	25 Mn manganese 55	26 Fe iron 56	27 Co cobalt 59	28 Ni nickel 59	29 Cu copper 64	30 Zn zinc 65	31 Ga gallium 70	32 Ge germanium 73	33 As arsenic 75	34 Se selenium 79	35 Br bromine 80	36 Kr krypton 84
37 Rb rubidium 85	38 Sr strontium 88	39 Y yttrium 89	40 Zr zirconium 91	41 Nb niobium 93	42 Mo molybdenum 96	43 Tc technetium –	44 Ru ruthenium 101	45 Rh rhodium 103	46 Pd palladium 106	47 Ag silver 108	48 Cd cadmium 112	49 In indium 115	50 Sn tin 119	51 Sb antimony 122	52 Te tellurium 128	53 I iodine 127	54 Xe xenon 131
55 Cs caesium 133	56 Ba barium 137	57–71 lanthanoids	72 Hf hafnium 178	73 Ta tantalum 181	74 W tungsten 184	75 Re rhenium 186	76 Os osmium 190	77 Ir iridium 192	78 Pt platinum 195	79 Au gold 197	80 Hg mercury 201	81 Tl thallium 204	82 Pb lead 207	83 Bi bismuth 209	84 Po polonium –	85 At astatine –	86 Rn radon –
87 Fr francium –	88 Ra radium –	89–103 actinoids	104 Rf rutherfordium –	105 Db dubnium –	106 Sg seaborgium –	107 Bh bohrium –	108 Hs hassium –	109 Mt meitnerium –	110 Ds darmstadtium –	111 Rg roentgenium –	112 Cn copernicium –	113 Nh nihonium –	114 Fl flerovium –	115 Mc moscovium –	116 Lv livermorium –	117 Ts tennessine –	118 Og oganesson –

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

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

Mathematical requirements

It is expected that these requirements will be covered as part of a mathematics curriculum at this level of study.

Calculators may be used in all parts of the examination.

Number

- add, subtract, multiply and divide
- use decimals, fractions, percentages, ratios and reciprocals
- use standard form
- understand that only the final answer in a calculation is rounded
- use decimal places and significant figures appropriately

Algebra

- use positive, whole number indices in algebraic expressions
- substitute values of quantities into equations, using consistent units
- solve simple algebraic equations for any one term when the other terms are known
- recognise and use direct and inverse proportion

Geometry and measurements

- understand the meaning of angle, curve, circle, radius, diameter, circumference, square, rectangle and diagonal
- select and use the most appropriate units for recording data and the results of calculations
- convert between units, including cm^3 and dm^3; mg, g and kg; J and kJ; Pa and kPa

Graphs, charts and statistics

- draw graphs and charts from data
- interpret graphs and charts, including interpolation and extrapolation of data
- determine the gradient (slope) of a line on a graph, including by drawing a tangent to a curve
- determine the intercept of the line on a graph, extending the line graphically (extrapolating) where appropriate
- select suitable scales and axes for graphs
- recognise direct proportionality from a graph
- calculate and use the average (mean) for a set of data

Presentation of data

Taking readings

- Data values should be read from an instrument to an accuracy of one half of one of the smallest divisions on the scale.
- Interpolation between scale divisions should be to an accuracy of one half of a division. That is, where a reading occurs between two scale marks, it should be interpolated to the nearest half division.

Recording readings

- Data should be recorded so as to reflect the precision of the measuring instrument, i.e. the smallest difference that can be detected on the measuring scale should be reflected by the number of decimal places and unit given in the measurement.
- A measurement or calculated quantity must be accompanied by a correct unit, where appropriate.
- Each column of a table should be headed with the name or symbol of the measured or calculated quantity and the appropriate unit, e.g. time / s. The solidus (/) is to be used for separating the quantity and the unit in tables, graphs and charts.
- Each reading should be repeated, where appropriate, and recorded.
- Units should not be included with data in the body of a table.
- The number of significant figures given for measured quantities should be appropriate to the measuring instrument used.
- The number of significant figures given for calculated quantities should be the same as the least number of significant figures in the raw data used in that specific calculation.
- A ratio should be expressed as $x : y$.

Graphs

- The column headings of a table can be directly transferred to the axes of a constructed graph.
- A graph should be drawn with a sharp pencil.
- The axes should be labelled with the name or symbol of the measured or calculated quantity and the appropriate unit, e.g. time / s.
- Unless instructed otherwise, the independent variable should be plotted on the x-axis (horizontal axis) and the dependent variable plotted on the y-axis (vertical axis).
- Unless instructed otherwise, the scales for the axes should allow more than half of the graph grid to be used in both directions, and be based on sensible ratios, e.g. 2 cm on the graph grid representing 1, 2 or 5 units of the variable (or 10, 20 or 50, etc.).
- Points on the graph should be clearly marked as crosses (×) or encircled dots (⊙) of appropriate size.
- Each data point should be plotted to an accuracy of one half of one of the smallest squares on the grid.
- A best-fit line (trend line) should be a single, thin, smooth straight-line or curve. Mathematical or least-squares methods of obtaining a best-fit line are **not** required. The line does not need to coincide exactly with any of the points; where there is scatter evident in the data, examiners would expect a roughly even distribution of points either side of the line over its entire length. Points that are clearly anomalous should be ignored when drawing the best-fit line.
- Candidates should be able to take readings from the graph by extrapolation or interpolation.
- Data values should be read from a line on a graph to an accuracy of one half of one of the smallest squares on the grid. The same accuracy should be used in reading off an intercept.
- The gradient of a straight line should be taken using a triangle whose hypotenuse extends over at least half the length of the candidate's best-fit line, and this triangle should be marked on the graph.

Further guidance can be found in the following publications:

ASE, *The Language of Mathematics in Science: A Guide for Teachers of 11–16 Science* (2016).

ASE, *The Language of Mathematics in Science: Teaching Approaches* (2016).

www.ase.org.uk/mathsinscience

Conventions (e.g. signs, symbols, terminology and nomenclature)

Candidates are expected to be familiar with the nomenclature used in the syllabus.

The syllabus and question papers conform with generally accepted international practice. In particular, the following document, produced by the Association for Science Education (ASE), should be used as a guideline.

Signs, Symbols and Systematics: The ASE Companion to 16–19 Science (2000).

The traditional names sulfate, sulfite, nitrate, nitrite, sulfuric acid and nitric acid will be used in question papers. Candidates will be credited for traditional or systematic names in their answers, except when specifically asked to use oxidation numbers to deduce or understand systematic names.

Decimal markers

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.

Numbers

Numbers from 1000 to 9999 will be printed without commas or spaces. Numbers greater than or equal to 10 000 will be printed without commas. A space will be left between each group of three digits, e.g. 4 256 789.

Variables

Independent variables are the variables that are changed in a scientific experiment by the scientist. Changing an independent variable may cause a change in the dependent variable.

Dependent variables are the variables that are observed or measured in a scientific experiment. Dependent variables may change based on changes made to the independent variables.

Units

To avoid any confusion concerning the symbol for litre, the equivalent quantity, the cubic decimetre (dm^3) will be used in place of l or litre.

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 at **www.bipm.org**

The use of imperial/customary units such as the inch and degree Fahrenheit are 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.

Command words

Command words and their meanings help candidates know what is expected from them in the exams. The table below includes command words used in the assessment for this syllabus. The use of the command word will relate to the subject context.

Command word	What it means
Analyse	examine in detail to show meaning, identify elements and the relationship between them
Calculate	work out from given facts, figures or information
Compare	identify/comment on similarities and/or differences
Consider	review and respond to given information
Contrast	identify/comment on differences
Deduce	conclude from available information
Define	give precise meaning
Demonstrate	show how or give an example
Describe	state the points of a topic / give characteristics and main features
Determine	establish an answer using the information available
Discuss	write about issue(s) or topic(s) in depth in a structured way
Evaluate	judge or calculate the quality, importance, amount, or value of something
Examine	investigate closely, in detail
Explain	set out purposes or reasons / make the relationships between things clear / say why and/or how and support with relevant evidence
Give	produce an answer from a given source or recall/memory
Identify	name/select/recognise
Justify	support a case with evidence/argument
Outline	set out the main points
Predict	suggest what may happen based on available information
Show (that)	provide structured evidence that leads to a given result
Sketch	make a simple freehand drawing showing the key features, taking care over proportions
State	express in clear terms
Suggest	apply knowledge and understanding to situations where there are a range of valid responses in order to make proposals / put forward considerations

5 What else you need to know

This section is an overview of other information you need to know about this syllabus. It will help to share the administrative information with your exams officer so they know when you will need their support. Find more information about our administrative processes at **www.cambridgeinternational.org/eoguide**

Before you start

Previous study

We recommend that learners starting this course should have studied a broad curriculum such as the Cambridge Lower Secondary programme or equivalent national educational framework.

Guided learning hours

We design Cambridge O Level syllabuses to require about 130 guided learning hours for each subject. This is for guidance only. The number of hours a learner needs to achieve the qualification may vary according to each school and the learners' previous experience of the subject.

Availability and timetables

All Cambridge schools are allocated to one of six administrative zones. Each zone has a specific timetable. Find your administrative zone at **www.cambridgeinternational.org/adminzone**. Cambridge O Levels are available to centres in administrative zones 3, 4 and 5.

You can enter candidates in the June and November exam series. You can view the timetable for your administrative zone at **www.cambridgeinternational.org/timetables**

Check you are using the syllabus for the year the candidate is taking the exam.

Private candidates can enter for this syllabus. For more information, please refer to the *Cambridge Guide to Making Entries*.

Combining with other syllabuses

Candidates can take this syllabus alongside other Cambridge International syllabuses in a single exam series. The only exceptions are:

- Cambridge IGCSE Chemistry (0620)
- Cambridge IGCSE (9–1) Chemistry (0971)
- Cambridge IGCSE Physical Science (0652)
- Cambridge IGCSE Combined Science (0653)
- Cambridge IGCSE Co-ordinated Sciences (Double Award) (0654)
- Cambridge IGCSE (9–1) Co-ordinated Sciences (Double Award) (0973)
- Cambridge O Level Combined Science (5129)
- syllabuses with the same title at the same level.

Cambridge O Level, Cambridge IGCSE™ and Cambridge IGCSE (9–1) syllabuses are at the same level.

Making entries

Exams officers are responsible for submitting entries to Cambridge International. We encourage them to work closely with you to make sure they enter the right number of candidates for the right combination of syllabus components. Entry option codes and instructions for submitting entries are in the *Cambridge Guide to Making Entries*. Your exams officer has access to this guide.

Exam administration

To keep our exams secure, we produce question papers for different areas of the world, known as administrative zones. We allocate all Cambridge schools to an administrative zone determined by their location. Each zone has a specific timetable.

Some of our syllabuses offer candidates different assessment options. An entry option code is used to identify the components the candidate will take relevant to the administrative zone and the available assessment options.

Support for exams officers

We know how important exams officers are to the successful running of exams. We provide them with the support they need to make entries on time. Your exams officer will find this support, and guidance for all other phases of the Cambridge Exams Cycle, at **www.cambridgeinternational.org/eoguide**

Retakes

Candidates can retake the whole qualification as many times as they want to. Information on retake entries is at **www.cambridgeinternational.org/retakes**

Language

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

Accessibility and equality

Syllabus and assessment design

At Cambridge International, we work to avoid direct or indirect discrimination in our syllabuses and assessment materials. We aim to maximise inclusivity for candidates of all national, cultural or social backgrounds and candidates with protected characteristics, which include special educational needs and disability, religion and belief, and characteristics related to gender and identity. We also aim to make our materials as accessible as possible by using accessible language and applying accessible design principles. This gives all candidates the fairest possible opportunity to demonstrate their knowledge, skills and understanding and helps to minimise the requirement to make reasonable adjustments during the assessment process.

Access arrangements

Access arrangements (including modified papers) are the principal way in which Cambridge International complies with our duty, as guided by the UK Equality Act (2010), to make 'reasonable adjustments' for candidates with special educational needs (SEN), disability, illness or injury. Where a candidate would otherwise be at a substantial disadvantage in comparison to a candidate with no SEN, disability, illness or injury, we may be able to agree pre-examination access arrangements. These arrangements help a candidate by minimising accessibility barriers and maximising their opportunity to demonstrate their knowledge, skills and understanding in an assessment.

Important:

Requested access arrangements should be based on evidence of the candidate's barrier to assessment and should also reflect their normal way of working at school. This is explained in the *Cambridge Handbook* **www.cambridgeinternational.org/eoguide**

- For Cambridge International to approve an access arrangement, we will need to agree that it constitutes a reasonable adjustment, involves reasonable cost and timeframe and does not affect the security and integrity of the assessment.
- Availability of access arrangements should be checked by centres at the start of the course. Details of our standard access arrangements and modified question papers are available in the *Cambridge Handbook* **www.cambridgeinternational.org/eoguide**
- Please contact us at the start of the course to find out if we are able to approve an arrangement that is not included in the list of standard access arrangements.
- Candidates who cannot access parts of the assessment may be able to receive an award based on the parts they have completed.

After the exam

Grading and reporting

Grades A*, A, B, C, D or E indicate the standard a candidate achieved at Cambridge O Level.

A* is the highest and E is the lowest. 'Ungraded' means that the candidate's performance did not meet the standard required for grade E. 'Ungraded' is reported on the statement of results but not on the certificate.

In specific circumstances your candidates may see one of the following letters on their statement of results:

- Q (PENDING)
- X (NO RESULT).

These letters do not appear on the certificate.

On the statement of results and certificates, Cambridge O Level is shown as GENERAL CERTIFICATE OF EDUCATION (GCE O LEVEL).

How students and teachers can use the grades

Assessment at Cambridge O Level has two purposes:

1 to measure learning and achievement

The assessment confirms achievement and performance in relation to the knowledge, understanding and skills specified in the syllabus.

2 to show likely future success

The outcomes help predict which students are well prepared for a particular course or career and/or which students are more likely to be successful.

The outcomes help students choose the most suitable course or career.

Changes to this syllabus for 2026, 2027 and 2028

The syllabus has been updated. This is version 1, published September 2023.

You must read the whole syllabus before planning your teaching programme. We review our syllabuses regularly to make sure they continue to meet the needs of our schools. In updating this syllabus, we have made it easier for teachers and students to understand, keeping the familiar features that teachers and schools value.

There are no substantial changes in this syllabus that would impact teaching.

Any textbooks endorsed to support the syllabus for examination from 2023 are still suitable for use with this syllabus.

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