

SYLLABUS

Cambridge IGCSE®
Chemistry (US)

0439

For examination in June and November 2016, 2017 and 2018

**This syllabus is available only to Centers participating in the
NCEE Excellence for All initiative in the USA.**

**If you have any questions about this syllabus, please contact Cambridge
at info@cie.org.uk quoting syllabus code 0439.**

Changes to syllabus for 2016

The syllabus has been revised. You are advised to read the whole of the syllabus before planning your teaching program. The most significant changes are outlined below.

| Significant changes to the syllabus are indicated by black vertical lines at the side of the text. |

Changes to the structure of the assessment

A new Multiple Choice paper for Extended candidates has been included. This paper is now Paper 2.

The papers are:

Paper 1: Multiple Choice (Core)

Paper 2: Multiple Choice (Extended)

Paper 3: Theory (Core)

Paper 4: Theory (Extended)

Paper 5: Practical Test

Paper 7: Coursework

Core candidates will now take Paper 1: Multiple Choice (Core), Paper 3: Theory (Core) and either Paper 5: Practical Test or Paper 7: Coursework.

Extended candidates will now take Paper 2: Multiple Choice (Extended), Paper 4: Theory (Extended) and either Paper 5: Practical Test or Paper 7: Coursework.

Changes to curriculum content

The curriculum content has been revised and updated to modernize and improve the relevance of the syllabus.

The wording of some learning outcomes has been changed for clarification.

Some material has been reordered, removed, moved between sections, or reclassified as either Core or Supplement material.

Minor changes have been made to the wording of the Syllabus Goals, Assessment Objectives and Grade Descriptions for clarity.

Changes to accreditation for Cambridge IGCSE coursework assessors

We have reviewed the current accreditation process. To ensure that all teachers involved in the marking of internally assessed components can benefit from the training materials provided by Cambridge, we are widening access to these materials and discontinuing the accreditation process after the November 2015 series.

The last exam series requiring teacher accreditation for the marking of certain Cambridge IGCSE components will be November 2015. Guidance on the delivery and assessment of Cambridge coursework and speaking tests will be available for all teachers on our Teacher Support site from January 2016.

Section 8 of this syllabus has been updated to provide more detail on the moderation process

Note

The subject content of this syllabus is the same as the international version. The alternative to practical paper is not included to ensure that coursework or the practical paper is a mandatory part of the syllabus.

Please read the Cambridge Glossary alongside this syllabus. This is available from our website.

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1. Introduction

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 recognized by the world's best universities and employers, giving students a wide range of options in their education and career. As a non-profit organization, we devote our resources to delivering high-quality educational programs that can unlock students' potential.

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

Cambridge Students

Cambridge programs and qualifications develop not only subject knowledge but also skills. We encourage Cambridge students 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 students, developing their ability to learn
- **innovative** and equipped for new and future challenges
- **engaged** intellectually and socially, ready to make a difference.

Recognition

Cambridge IGCSE is recognized by leading universities and employers worldwide, and is an international passport to progression and success. It provides a solid foundation for moving on to higher-level studies. Learn more at www.cie.org.uk/recognition

Support for Teachers

A wide range of materials and resources is available to support teachers and students 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

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

Our systems for managing the provision of international qualifications and education programs for students aged 5 to 19 are certified as meeting the internationally recognized standard for quality management, ISO 9001:2008. Learn more at www.cie.org.uk/ISO9001

1.2 Why Choose Cambridge IGCSE?

Cambridge IGCSEs are international in outlook but retain a local relevance. The syllabi provide opportunities for contextualized learning, and the content has been created to suit a wide variety of schools, avoid cultural bias, and develop essential lifelong skills, including creative thinking and problem solving.

Our goal is to balance knowledge, understanding, and skills in our programs 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 IGCSEs, we provide the tools to enable teachers to prepare students to the best of their ability and work with us in the pursuit of excellence in education.

Cambridge IGCSEs 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 programs, such as the US Advanced Placement program and the International Baccalaureate Diploma program. Learn more about Cambridge IGCSEs at **www.cie.org.uk/cambridgesecundary2**

Guided Learning Hours

Cambridge IGCSE syllabi are designed with the assumption that candidates 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 candidates' prior experience with the subject.

1.3 Why Choose Cambridge IGCSE Chemistry?

Cambridge IGCSE Chemistry is accepted by universities and employers as proof of essential knowledge and ability. As well as a subject focus, the chemistry syllabus enables learners to:

- better understand the technological world, with an informed interest in scientific matters
- recognize the usefulness (and limitations) of scientific method, and how to apply this to other disciplines and in everyday life
- develop relevant attitudes, such as a concern for accuracy and precision, objectivity, integrity, enquiry, initiative and inventiveness
- develop an interest in, and care for, the environment
- better understand the influence and limitations placed on scientific study by society, economy, technology, ethics, the community and the environment
- develop an understanding of the scientific skills essential for both further study and everyday life.

Prerequisites

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

Progression

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

Candidates who are awarded grades A* to C for this qualification are well prepared to follow courses leading to Level 3 AS and A Level GCE Chemistry, Cambridge Pre-U Chemistry, IB Certificates in Chemistry or the Cambridge International AS and A Level Chemistry.

1.4 Cambridge ICE (International Certificate of Education)

Cambridge ICE is a group award for Cambridge IGCSE. It gives schools the opportunity to benefit from offering a broad and balanced curriculum by recognizing the achievements of candidates who pass examinations in a number of different subjects.

Learn more about Cambridge ICE at **www.cie.org.uk/cambridgesecundary2**

1.5 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 organization can register to become a Cambridge school.

2. Teacher Support

2.1 Support Materials

We send Cambridge syllabi, 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/igcse** to download current and future syllabi 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 syllabi is available from Teacher Support, our secure online support for Cambridge teachers. Go to **<http://teachers.cie.org.uk>** (username and password required).

2.2 Resource Lists

We work with publishers providing a range of resources for our syllabi 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 that can be filtered to show all resources, or just those that 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** for further information.

3. Curriculum Content at a Glance

Candidates study the following topics.

1. The particulate nature of matter
2. Experimental techniques
2.1 Measurement
2.2.1 Criteria of purity
2.2.2 Methods of purification
3. Atoms, elements and compounds
3.1 Atomic structure and the Periodic Table
3.2.1 Bonding: the structure of matter
3.2.2 Ions and ionic bonds
3.2.3 Molecules and covalent bonds
3.2.4 Macromolecules
3.2.5 Metallic bonding (Extended candidates only)
4. Stoichiometry
4.1 Stoichiometry
4.2 The mole concept (Extended candidates only)
5. Electricity and chemistry
6. Chemical energetics
6.1 Energetics of a reaction
6.2 Energy transfer
7. Chemical reactions
7.1 Physical and chemical changes
7.2 Rate (speed) of reaction
7.3 Reversible reactions
7.4 Redox
8. Acids, bases and salts
8.1 The characteristic properties of acids and bases
8.2 Types of oxides
8.3 Preparation of salts
8.4 Identification of ions and gases

9. The Periodic Table

- 9.1 The Periodic Table
- 9.2 Periodic trends
- 9.3 Group properties
- 9.4 Transition elements
- 9.5 Noble gases

10. Metals

- 10.1 Properties of metals
- 10.2 Reactivity series
- 10.3 Extraction of metals
- 10.4 Uses of metals

11. Air and water

- 11.1 Water
- 11.2 Air
- 11.3 Nitrogen and fertilizers
- 11.4 Carbon dioxide and methane

12. Sulfur**13. Carbonates****14. Organic chemistry**

- 14.1 Names of compounds
- 14.2 Fuels
- 14.3 Homologous series
- 14.4 Alkanes
- 14.5 Alkenes
- 14.6 Alcohols
- 14.7 Carboxylic acids
- 14.8.1 Polymers
- 14.8.2 Synthetic polymers
- 14.8.3 Natural polymers

4. Assessment at a Glance

All candidates must enter for three papers.

Core candidates take:

Paper 1 45 minutes

A multiple-choice paper consisting of 40 items of the four-choice type.

This paper will test assessment objectives AO1 and AO2. Questions will be based on the Core syllabus content.

This paper will be weighted at 30% of the final total mark.

and:

Paper 3 1 hour 15 minutes

A written paper consisting of short-answer and structured questions.

This paper will test assessment objectives AO1 and AO2. Questions will be based on the Core syllabus content.

80 marks

This paper will be weighted at 50% of the final total mark.

Extended candidates take:

Paper 2 45 minutes

A multiple-choice paper consisting of 40 items of the four-choice type.

This paper will test assessment objectives AO1 and AO2. Questions will be based on the Extended syllabus content (Core and Supplement).

This paper will be weighted at 30% of the final total mark.

and:

Paper 4 1 hour 15 minutes

A written paper consisting of short-answer and structured questions.

This paper will test assessment objectives AO1 and AO2. Questions will be based on the Extended syllabus content (Core and Supplement).

80 marks

This paper will be weighted at 50% of the final total mark.

All candidates take

either:

Paper 5 1 hour 15 minutes

Practical Test

This paper will test assessment objective AO3. Questions will be based on the experimental skills in Section 7.

The paper is structured to assess grade ranges A*–G.

40 marks

This paper will be weighted at 20% of the final total mark.

or:

Paper 7

Coursework

This paper will test assessment objective AO3. The paper is structured to assess grade ranges A*–G.

48 marks

This paper will be weighted at 20% of the final total mark.

Candidates who have studied the Core syllabus content, or who are expected to achieve a grade D or above should be entered for Paper 1, Paper 3 and either Paper 5 or Paper 7. These candidates will be eligible for grades C to G.

Candidates who have studied the Extended syllabus content (Core and Supplement), and who are expected to achieve a grade C or above should be entered for Paper 2, Paper 4 and either Paper 5 or Paper 7. These candidates will be eligible for grades A* to G.

Availability

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

Detailed timetables are available from **www.cie.org.uk/examsofficers**

Combining This With Other Syllabi

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

- syllabi 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 Award)
- 5129 Cambridge O Level Combined Science

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

5. Syllabus Goals and Assessment Objectives

5.1 Goals

The syllabus goals listed below describe the educational purposes of a course based on this syllabus. These goals are not intended as assessment criteria but outline the educational context in which the syllabus content should be viewed. These goals are the same for all students and are not listed in order of priority. Some of these goals may be delivered by the use of suitable local, international or historical examples and applications, or through collaborative experimental work.

The goals are:

1. to provide an enjoyable and worthwhile educational experience for all students, whether or not they go on to study science beyond this level
2. to enable students to acquire sufficient knowledge and understanding to:
 - become confident citizens in a technological world and develop an informed interest in scientific matters
 - be suitably prepared for studies beyond Cambridge IGCSE
3. to allow students to recognize that science is evidence based and understand the usefulness, and the limitations, of scientific method
4. to develop skills that:
 - are relevant to the study and practice of chemistry
 - are useful in everyday life
 - encourage a systematic approach to problem solving
 - encourage efficient and safe practice
 - encourage effective communication through the language of science
5. to develop attitudes relevant to chemistry such as:
 - concern for accuracy and precision
 - objectivity
 - integrity
 - enquiry
 - initiative
 - inventiveness
6. to enable students to appreciate that:
 - science is subject to social, economic, technological, ethical and cultural influences and limitations
 - the applications of science may be both beneficial and detrimental to the individual, the community and the environment

5.2 Assessment Objectives

AO1: Knowledge with understanding

Candidates should be able to demonstrate knowledge and understanding of:

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 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.

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.

Questions testing this objective will often begin with one of the following words: *define, state, describe, explain (using your knowledge and understanding) or outline* (see the *Glossary of terms used in science papers*).

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:

1. locate, select, organize 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, 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.

Questions testing these skills will often begin with one of the following words: *predict, suggest, calculate or determine* (see the *Glossary of terms used in science papers*).

AO3: Experimental skills and investigations

Candidates should be able to:

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

5.3 Relationship Between Assessment Objectives and Components

The approximate weightings allocated to each of the assessment objectives are summarized in the table below.

Assessment objective	Papers 1 and 2	Papers 3 and 4	Papers 5 and 7	Weighting of AO in overall qualification
AO1: Knowledge with understanding	63%	63%	–	50%
AO2: Handling information and problem solving	37%	37%	–	30%
AO3: Experimental skills and investigations	–	–	100%	20%
Weighting of paper in overall qualification	30%	50%	20%	

5.4 Grade Descriptions

The scheme of assessment is intended to encourage positive achievement by all candidates.

A **Grade A** candidate will be able to:

- recall and communicate precise knowledge and display comprehensive understanding of scientific phenomena, facts, laws, definitions, concepts and theories
- apply scientific concepts and theories to present reasoned explanations of familiar and unfamiliar phenomena, to solve complex problems involving several stages, and to make reasoned predictions and hypotheses
- communicate and present complex scientific ideas, observations and data clearly and logically, independently using scientific terminology and conventions consistently and correctly
- independently select, process and synthesize information presented in a variety of ways, and use it to draw valid conclusions and discuss the scientific, technological, social, economic and environmental implications
- devise strategies to solve problems in complex situations which may involve many variables or complex manipulation of data or ideas through multiple steps
- analyze data to identify any patterns or trends, taking account of limitations in the quality of the data and justifying the conclusions reached select, describe, justify and evaluate techniques for a large range of scientific operations and laboratory procedures.

A **Grade C** candidate will be able to:

- recall and communicate secure knowledge and understanding of scientific phenomena, facts, laws, definitions, concepts and theories
- apply scientific concepts and theories to present simple explanations of familiar and some unfamiliar phenomena, to solve straightforward problems involving several stages, and to make detailed predictions and simple hypotheses
- communicate and present scientific ideas, observations and data using a wide range of scientific terminology and conventions
- select and process information from a given source, and use it to draw simple conclusions and state the scientific, technological, social, economic or environmental implications
- solve problems involving more than one step, but with a limited range of variables or using familiar methods
- analyze data to identify a pattern or trend, and select appropriate data to justify a conclusion
- select, describe and evaluate techniques for a range of scientific operations and laboratory procedures.

A **Grade F** candidate will be able to:

- recall and communicate limited knowledge and understanding of scientific phenomena, facts, laws, definitions, concepts and theories
- apply a limited range of scientific facts and concepts to give basic explanations of familiar phenomena, to solve straightforward problems and make simple predictions
- communicate and present simple scientific ideas, observations and data using a limited range of scientific terminology and conventions
- select a single piece of information from a given source, and use it to support a given conclusion, and to make links between scientific information and its scientific, technological, social, economic or environmental implications
- solve problems involving more than one step if structured help is given
- analyze data to identify a pattern or trend
- select, describe and evaluate techniques for a limited range of scientific operations and laboratory procedures.

5.5 Conventions (e.g. Signs, Symbols, Terminology and Nomenclature)

Syllabi 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).

Liter/dm³

To avoid any confusion concerning the symbol for liter, **dm³** will be used in place of *l* or liter.

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 whole numbers, e.g. 4 256 789.

6. Curriculum Content

All candidates should be taught the Core syllabus content. Candidates who are only taught the Core syllabus content can achieve a maximum of grade C. Candidates aiming for grades A* to C should be taught the Extended syllabus content. The Extended syllabus content includes both the Core and the Supplement.

In delivering the course, teachers should aim to show the relevance of concepts to the students' everyday lives and to the world around them. The syllabus content has been designed so as to allow teachers to develop flexible programs which meet all of the general goals of the syllabus while drawing on appropriate local and international contexts.

Scientific subjects are, by their nature, experimental. Wherever possible, students should pursue a fully integrated course which allows them to develop their practical skills by carrying out practical work and investigations within all of the topics listed.

1. The particulate nature of matter

Core

- State the distinguishing properties of solids, liquids and gases
- Describe the structure of solids, liquids and gases in terms of particle separation, arrangement and types of motion
- Describe changes of state in terms of melting, boiling, evaporation, freezing, condensation and sublimation
- Describe qualitatively the pressure and temperature of a gas in terms of the motion of its particles
- Show an understanding of the random motion of particles in a suspension (sometimes known as Brownian motion) as evidence for the kinetic particle (atoms, molecules or ions) model of matter
- Describe and explain diffusion

Supplement

- Explain changes of state in terms of the kinetic theory
- Describe and explain Brownian motion in terms of random molecular bombardment
- State evidence for Brownian motion
- Describe and explain dependence of rate of diffusion on molecular mass

2. Experimental techniques

2.1 Measurement

Core

- Name appropriate apparatus for the measurement of time, temperature, mass and volume, including burets, droppers and graduated cylinders

<p>2.2.1 Criteria of purity</p> <p>Core</p> <ul style="list-style-type: none"> • Demonstrate knowledge and understanding of paper chromatography • Interpret simple chromatograms • Identify substances and assess their purity from melting point and boiling point information • Understand the importance of purity in substances in everyday life, e.g. foodstuffs and drugs 	<p>Supplement</p> <ul style="list-style-type: none"> • Interpret simple chromatograms, including the use of R_f values • Outline how chromatography techniques can be applied to colorless substances by exposing chromatograms to substances called locating agents (Knowledge of <i>specific</i> locating agents is not required.)
<p>2.2.2 Methods of purification</p> <p>Core</p> <ul style="list-style-type: none"> • Describe and explain methods of purification by the use of a suitable solvent, filtration, crystallization and distillation (including use of fractionating column). (Refer to the fractional distillation of petroleum in section 14.2 and products of fermentation in section 14.6.) • Suggest suitable purification techniques, given information about the substances involved 	
<p>3. Atoms, elements and compounds</p>	
<p>3.1 Atomic structure and the Periodic Table</p> <p>Core</p> <ul style="list-style-type: none"> • State the relative charges and approximate relative masses of protons, neutrons and electrons • Define <i>proton number</i> (atomic number) as the number of protons in the nucleus of an atom • Define <i>nucleon number</i> (mass number) as the total number of protons and neutrons in the nucleus of an atom • Use proton number and the simple structure of atoms to explain the basis of the Periodic Table (see section 9), with special reference to the elements of proton number 1 to 20 • Define <i>isotopes</i> as atoms of the same element which have the same proton number but a different nucleon number • State the two types of isotopes as being radioactive and non-radioactive • State one medical and one industrial use of radioactive isotopes • Describe the build-up of electrons in 'shells' and understand the significance of the noble gas electronic structures and of the outer shell electrons (The ideas of the distribution of electrons in s and p orbitals and in d block elements are not required.) <p>Note: a copy of the Periodic Table, as shown in the Appendix, will be available in Papers 1, 2, 3 and 4.</p>	<p>Supplement</p> <ul style="list-style-type: none"> • Understand that isotopes have the same properties because they have the same number of electrons in their outer shell

<p>3.2.1 Bonding: the structure of matter</p> <p>Core</p> <ul style="list-style-type: none"> Describe the differences between elements, mixtures and compounds, and between metals and nonmetals Describe an alloy, such as brass, as a mixture of a metal with other elements 	
<p>3.2.2 Ions and ionic bonds</p> <p>Core</p> <ul style="list-style-type: none"> Describe the formation of ions by electron loss or gain Describe the formation of ionic bonds between elements from Groups I and VII 	<p>Supplement</p> <ul style="list-style-type: none"> Describe the formation of ionic bonds between metallic and nonmetallic elements Describe the lattice structure of ionic compounds as a regular arrangement of alternating positive and negative ions
<p>3.2.3 Molecules and covalent bonds</p> <p>Core</p> <ul style="list-style-type: none"> Describe the formation of single covalent bonds in H_2, Cl_2, H_2O, CH_4, NH_3 and HCl as the sharing of pairs of electrons leading to the noble gas configuration Describe the differences in volatility, solubility and electrical conductivity between ionic and covalent compounds 	<p>Supplement</p> <ul style="list-style-type: none"> Describe the electron arrangement in more complex covalent molecules such as N_2, C_2H_4, CH_3OH and CO_2 Explain the differences in melting point and boiling point of ionic and covalent compounds in terms of attractive forces
<p>3.2.4 Macromolecules</p> <p>Core</p> <ul style="list-style-type: none"> Describe the giant covalent structures of graphite and diamond Relate their structures to their uses, e.g. graphite as a lubricant and a conductor, and diamond in cutting tools 	<p>Supplement</p> <ul style="list-style-type: none"> Describe the macromolecular structure of silicon(IV) oxide (silicon dioxide) Describe the similarity in properties between diamond and silicon(IV) oxide, related to their structures
<p>3.2.5 Metallic bonding</p>	<p>Supplement</p> <ul style="list-style-type: none"> Describe metallic bonding as a lattice of positive ions in a 'sea of electrons' and use this to describe the electrical conductivity and malleability of metals

4. Stoichiometry

4.1 Stoichiometry

Core

- Use the symbols of the elements and write the formulae of simple compounds
- Deduce the formula of a simple compound from the relative numbers of atoms present
- Deduce the formula of a simple compound from a model or a diagrammatic representation
- Construct word equations and simple balanced chemical equations
- Define *relative atomic mass*, A_r , as the average mass of naturally occurring atoms of an element on a scale where the ^{12}C atom has a mass of exactly 12 units
- Define *relative molecular mass*, M_r , as the sum of the relative atomic masses (*Relative formula mass* or M_r will be used for ionic compounds.)
(Calculations involving reacting masses in simple proportions may be set. Calculations will **not** involve the mole concept.)

Supplement

- Determine the formula of an ionic compound from the charges on the ions present
- Construct equations with state symbols, including ionic equations
- Deduce the balanced equation for a chemical reaction, given relevant information

4.2 The mole concept

Supplement

- Define the *mole* and the *Avogadro constant*
- Use the molar gas volume, taken as 24 dm^3 at room temperature and pressure
- Calculate stoichiometric reacting masses, volumes of gases and solutions, and concentrations of solutions expressed in g/dm^3 and mol/dm^3
(Calculations involving the idea of limiting reactants may be set. Questions on the gas laws and the conversion of gaseous volumes to different temperatures and pressures will **not** be set.)
- Calculate empirical formulae and molecular formulae
- Calculate percentage yield and percentage purity

5. Electricity and chemistry

Core

- Define electrolysis as the breakdown of an ionic compound, molten or in aqueous solution, by the passage of electricity
- Describe the electrode products and the observations made during the electrolysis of:
 - molten lead(II) bromide
 - concentrated hydrochloric acid
 - concentrated aqueous sodium chloride
 - dilute sulfuric acid
 between inert electrodes (platinum or carbon)
- State the general principle that metals or hydrogen are formed at the negative electrode (cathode), and that nonmetals (other than hydrogen) are formed at the positive electrode (anode)
- Predict the products of the electrolysis of a specified binary compound in the molten state
- Describe the electroplating of metals
- Outline the uses of electroplating
- Describe the reasons for the use of copper and (steel-cored) aluminum in cables, and why plastics and ceramics are used as insulators

Supplement

- Relate the products of electrolysis to the electrolyte and electrodes used, exemplified by the specific examples in the Core together with aqueous copper(II) sulfate using carbon electrodes and using copper electrodes (as used in the refining of copper)
- Describe electrolysis in terms of the ions present and reactions at the electrodes in the examples given
- Predict the products of electrolysis of a specified halide in dilute or concentrated aqueous solution
- Construct ionic half-equations for reactions at the cathode
- Describe the transfer of charge during electrolysis to include:
 - the movement of electrons in the metallic conductor
 - the removal or addition of electrons from the external circuit at the electrodes
 - the movement of ions in the electrolyte
- Describe the production of electrical energy from simple cells, i.e. two electrodes in an electrolyte. (This should be linked with the reactivity series in section 10.2 and redox in section 7.4.)
- Describe, in outline, the manufacture of:
 - aluminum from pure aluminum oxide in molten cryolite (refer to section 10.3)
 - chlorine, hydrogen and sodium hydroxide from concentrated aqueous sodium chloride
 (Starting materials and essential conditions should be given but not technical details or diagrams.)

6. Chemical energetics

6.1 Energetics of a reaction

Core

- Describe the meaning of *exothermic* and *endothermic* reactions
- Interpret energy level diagrams showing exothermic and endothermic reactions

Supplement

- Describe bond breaking as an endothermic process and bond forming as an exothermic process
- Draw and label energy level diagrams for exothermic and endothermic reactions using data provided
- Calculate the energy of a reaction using bond energies

6.2 Energy transfer

Core

- Describe the release of heat energy by burning fuels
- State the use of hydrogen as a fuel
- Describe radioactive isotopes, such as ^{235}U , as a source of energy

Supplement

- Describe the use of hydrogen as a fuel reacting with oxygen to generate electricity in a fuel cell (Details of the construction and operation of a fuel cell are **not** required.)

7. Chemical reactions

7.1 Physical and chemical changes

Core

- Identify physical and chemical changes, and understand the differences between them

7.2 Rate (speed) of reaction

Core

- Describe and explain the effect of concentration, particle size, catalysts (including enzymes) and temperature on the rate of reactions
- Describe the application of the above factors to the danger of explosive combustion with fine powders (e.g. flour mills) and gases (e.g. methane in mines)
- Demonstrate knowledge and understanding of a practical method for investigating the rate of a reaction involving gas evolution
- Interpret data obtained from experiments concerned with rate of reaction

Note: Candidates should be encouraged to use the term *rate* rather than *speed*.

Supplement

- Devise and evaluate a suitable method for investigating the effect of a given variable on the rate of a reaction
- Describe and explain the effects of temperature and concentration in terms of collisions between reacting particles (An increase in temperature causes an increase in collision rate **and** more of the colliding molecules have sufficient energy (activation energy) to react whereas an increase in concentration only causes an increase in collision rate.)

cont.

<p>7.2 Rate (speed) of reaction continued</p>	<ul style="list-style-type: none"> Describe and explain the role of light in photochemical reactions and the effect of light on the rate of these reactions (This should be linked to section 14.4.) Describe the use of silver salts in photography as a process of reduction of silver ions to silver; and photosynthesis as the reaction between carbon dioxide and water in the presence of chlorophyll and sunlight (energy) to produce glucose and oxygen
<p>7.3 Reversible reactions</p> <p>Core</p> <ul style="list-style-type: none"> Understand that some chemical reactions can be reversed by changing the reaction conditions (Limited to the effects of heat and water on hydrated and anhydrous copper(II) sulfate and cobalt(II) chloride.) (Concept of equilibrium is not required.) 	<p>Supplement</p> <ul style="list-style-type: none"> Predict the effect of changing the conditions (concentration, temperature and pressure) on other reversible reactions Demonstrate knowledge and understanding of the concept of equilibrium
<p>7.4 Redox</p> <p>Core</p> <ul style="list-style-type: none"> Define <i>oxidation</i> and <i>reduction</i> in terms of oxygen loss/gain. (Oxidation state limited to its use to name ions, e.g. iron(II), iron(III), copper(II), manganate(VII).) 	<p>Supplement</p> <ul style="list-style-type: none"> Define <i>redox</i> in terms of electron transfer Identify redox reactions by changes in oxidation state and by the color changes involved when using acidified potassium manganate(VII), and potassium iodide. (Recall of equations involving KMnO_4 is not required.) Define <i>oxidizing agent</i> as a substance which oxidizes another substance during a redox reaction. Define <i>reducing agent</i> as a substance which reduces another substance during a redox reaction. Identify oxidizing agents and reducing agents from simple equations

8. Acids, bases and salts

8.1 The characteristic properties of acids and bases

Core

- Describe the characteristic properties of acids as reactions with metals, bases, carbonates and effect on litmus and methyl orange
- Describe the characteristic properties of bases as reactions with acids and with ammonium salts and effect on litmus and methyl orange
- Describe neutrality and relative acidity and alkalinity in terms of pH measured using Universal Indicator paper (whole numbers only)
- Describe and explain the importance of controlling acidity in soil

Supplement

- Define *acids* and *bases* in terms of proton transfer, limited to aqueous solutions
- Describe the meaning of weak and strong acids and bases

8.2 Types of oxides

Core

- Classify oxides as either acidic or basic, related to metallic and nonmetallic character

Supplement

- Further classify other oxides as neutral or amphoteric

8.3 Preparation of salts

Core

- Demonstrate knowledge and understanding of preparation, separation and purification of salts as examples of some of the techniques specified in section 2.2.2 and the reactions specified in section 8.1

Supplement

- Demonstrating knowledge and understanding of the preparation of insoluble salts by precipitation
- Suggest a method of making a given salt from a suitable starting material, given appropriate information

8.4 Identification of ions and gases

Core

- Describe the following tests to identify:

aqueous cations:

aluminum, ammonium, calcium, chromium(III), copper(II), iron(II), iron(III) and zinc (using aqueous sodium hydroxide and aqueous ammonia as appropriate) (Formulae of complex ions are **not** required.)

cations:

use of the flame test to identify lithium, sodium, potassium and copper(II)

anions:

carbonate (by reaction with dilute acid and then limewater), chloride, bromide and iodide (by reaction under acidic conditions with aqueous silver nitrate), nitrate (by reduction with aluminum), sulfate (by reaction under acidic conditions with aqueous barium ions) and sulfite (by reaction with dilute acids and then aqueous potassium manganate(VII))

gases:

ammonia (using damp red litmus paper), carbon dioxide (using limewater), chlorine (using damp litmus paper), hydrogen (using lighted splint), oxygen (using a glowing splint), and sulfur dioxide (using aqueous potassium manganate(VII))

9. The Periodic Table	
9.1 The Periodic Table Core <ul style="list-style-type: none"> Describe the Periodic Table as a method of classifying elements and its use to predict properties of elements 	
9.2 Periodic trends Core <ul style="list-style-type: none"> Describe the change from metallic to nonmetallic character across a period 	Supplement <ul style="list-style-type: none"> Describe and explain the relationship between Group number, number of outer shell electrons and metallic/nonmetallic character
9.3 Group properties Core <ul style="list-style-type: none"> Describe lithium, sodium and potassium in Group I as a collection of relatively soft metals showing a trend in melting point, density and reaction with water Predict the properties of other elements in Group I, given data, where appropriate Describe the halogens, chlorine, bromine and iodine in Group VII, as a collection of diatomic non-metals showing a trend in color and density and state their reaction with other halide ions Predict the properties of other elements in Group VII, given data where appropriate 	Supplement <ul style="list-style-type: none"> Identify trends in Groups, given information about the elements concerned
9.4 Transition elements Core <ul style="list-style-type: none"> Describe the transition elements as a collection of metals having high densities, high melting points and forming colored compounds, and which, as elements and compounds, often act as catalysts 	Supplement <ul style="list-style-type: none"> Know that transition elements have variable oxidation states
9.5 Noble gases Core <ul style="list-style-type: none"> Describe the noble gases, in Group VIII or 0, as being unreactive, monoatomic gases and explain this in terms of electronic structure State the uses of the noble gases in providing an inert atmosphere, i.e. argon in lamps, helium for filling balloons 	

10. Metals

10.1 Properties of metals

Core

- List the general physical properties of metals
- Describe the general chemical properties of metals e.g. reaction with dilute acids and reaction with oxygen
- Explain in terms of their properties why alloys are used instead of pure metals
- Identify representations of alloys from diagrams of structure

10.2 Reactivity series

Core

- Place in order of reactivity: potassium, sodium, calcium, magnesium, zinc, iron, (hydrogen) and copper, by reference to the reactions, if any, of the metals with:
 - water or steam
 - dilute hydrochloric acid
 and the reduction of their oxides with carbon
- Deduce an order of reactivity from a given set of experimental results

Supplement

- Describe the reactivity series as related to the tendency of a metal to form its positive ion, illustrated by its reaction, if any, with:
 - the aqueous ions
 - the oxides
 of the other listed metals
- Describe and explain the action of heat on the hydroxides, carbonates and nitrates of the listed metals
- Account for the apparent unreactivity of aluminum in terms of the oxide layer which adheres to the metal

10.3 Extraction of metals

Core

- Describe the ease in obtaining metals from their ores by relating the elements to the reactivity series
- Describe and state the essential reactions in the extraction of iron from hematite
- Describe the conversion of iron into steel using basic oxides and oxygen
- Know that aluminum is extracted from the ore bauxite by electrolysis
- Discuss the advantages and disadvantages of recycling metals, limited to iron/steel and aluminum

Supplement

- Describe in outline, the extraction of zinc from zinc blende
- Describe in outline, the extraction of aluminum from bauxite including the role of cryolite and the reactions at the electrodes

<p>10.4 Uses of metals</p> <p>Core</p> <ul style="list-style-type: none"> Name the uses of aluminum: <ul style="list-style-type: none"> in the manufacture of aircraft because of its strength and low density in food containers because of its resistance to corrosion Name the uses of copper related to its properties (electrical wiring and in cooking utensils) Name the uses of mild steel (car bodies and machinery) and stainless steel (chemical plant and cutlery) 	<p>Supplement</p> <ul style="list-style-type: none"> Explain the uses of zinc for galvanizing and for making brass Describe the idea of changing the properties of iron by the controlled use of additives to form steel alloys
<p>11. Air and water</p>	
<p>11.1 Water</p> <p>Core</p> <ul style="list-style-type: none"> Describe chemical tests for water using cobalt(II) chloride and copper(II) sulfate Describe, in outline, the treatment of the water supply in terms of filtration and chlorination Name some of the uses of water in industry and in the home 	<p>Supplement</p> <ul style="list-style-type: none"> Discuss the implications of an inadequate supply of water, limited to safe water for drinking and water for irrigating crops
<p>11.2 Air</p> <p>Core</p> <ul style="list-style-type: none"> State the composition of clean, dry air as being approximately 78% nitrogen, 21% oxygen and the remainder as being a mixture of noble gases and carbon dioxide Name the common pollutants in the air as being carbon monoxide, sulfur dioxide, oxides of nitrogen and lead compounds State the source of each of these pollutants: <ul style="list-style-type: none"> carbon monoxide from the incomplete combustion of carbon-containing substances sulfur dioxide from the combustion of fossil fuels which contain sulfur compounds (leading to 'acid rain') oxides of nitrogen from car engines lead compounds from leaded gasoline State the adverse effect of these common pollutants on buildings and on health and discuss why these pollutants are of global concern State the conditions required for the rusting of iron Describe and explain methods of rust prevention, specifically paint and other coatings to exclude oxygen 	<p>Supplement</p> <ul style="list-style-type: none"> Describe the separation of oxygen and nitrogen from liquid air by fractional distillation Describe and explain the presence of oxides of nitrogen in car engines and their catalytic removal Describe and explain sacrificial protection in terms of the reactivity series of metals and galvanizing as a method of rust prevention

<p>11.3 Nitrogen and fertilizers</p> <p>Core</p> <ul style="list-style-type: none"> Describe the need for nitrogen-, phosphorus- and potassium-containing fertilizers Describe the displacement of ammonia from its salts 	<p>Supplement</p> <ul style="list-style-type: none"> Describe and explain the essential conditions for the manufacture of ammonia by the Haber process including the sources of the hydrogen and nitrogen, i.e. hydrocarbons or steam and air
<p>11.4 Carbon dioxide and methane</p> <p>Core</p> <ul style="list-style-type: none"> State that carbon dioxide and methane are greenhouse gases and explain how they may contribute to climate change State the formation of carbon dioxide: <ul style="list-style-type: none"> as a product of complete combustion of carbon-containing substances as a product of respiration as a product of the reaction between an acid and a carbonate from the thermal decomposition of a carbonate State the sources of methane, including decomposition of vegetation and waste gases from digestion in animals 	<p>Supplement</p> <ul style="list-style-type: none"> Describe the carbon cycle, in simple terms, to include the processes of combustion, respiration and photosynthesis
<p>12. Sulfur</p>	
<p>Core</p> <ul style="list-style-type: none"> Name some sources of sulfur Name the use of sulfur in the manufacture of sulfuric acid State the uses of sulfur dioxide as a bleach in the manufacture of wood pulp for paper and as a food preservative (by killing bacteria) 	<p>Supplement</p> <ul style="list-style-type: none"> Describe the manufacture of sulfuric acid by the Contact process, including essential conditions and reactions Describe the properties and uses of dilute and concentrated sulfuric acid
<p>13. Carbonates</p>	
<p>Core</p> <ul style="list-style-type: none"> Describe the manufacture of lime (calcium oxide) from calcium carbonate (limestone) in terms of thermal decomposition Name some uses of lime and slaked lime such as in treating acidic soil and neutralizing acidic industrial waste products, e.g. flue gas desulfurization Name the uses of calcium carbonate in the manufacture of iron and cement 	

14. Organic chemistry

14.1 Names of compounds

Core

- Name and draw the structures of methane, ethane, ethene, ethanol, ethanoic acid and the products of the reactions stated in sections 14.4–14.6
- State the type of compound present, given a chemical name ending in *-ane*, *-ene*, *-ol*, or *-oic acid* or a molecular structure

Supplement

- Name and draw the structures of the unbranched alkanes, alkenes (not *cis-trans*), alcohols and acids containing up to four carbon atoms per molecule
- Name and draw the structural formulae of the esters which can be made from unbranched alcohols and carboxylic acids, each containing up to four carbon atoms

14.2 Fuels

Core

- Name the fuels: coal, natural gas and petroleum
- Name methane as the main constituent of natural gas
- Describe petroleum as a mixture of hydrocarbons and its separation into useful fractions by fractional distillation
- Describe the properties of molecules within a fraction
- Name the uses of the fractions as:
 - refinery gas for bottled gas for heating and cooking
 - gasoline fraction for fuel in cars
 - naphtha fraction for making chemicals
 - kerosene/paraffin fraction for jet fuel
 - diesel oil/gas oil for fuel in diesel engines
 - fuel oil fraction for fuel for ships and home heating systems
 - lubricating fraction for lubricants, waxes and polishes
 - bitumen for making roads

14.3 Homologous series

Core

- Describe the concept of homologous series as a 'family' of similar compounds with similar chemical properties due to the presence of the same functional group

Supplement

- Describe the general characteristics of an homologous series
- Recall that the compounds in a homologous series have the same general formula
- Describe and identify structural isomerism

14.4 Alkanes

Core

- Describe the properties of alkanes (exemplified by methane) as being generally unreactive, except in terms of burning
- Describe the bonding in alkanes

Supplement

- Describe substitution reactions of alkanes with chlorine

<p>14.5 Alkenes</p> <p>Core</p> <ul style="list-style-type: none"> Describe the manufacture of alkenes and of hydrogen by cracking Distinguish between saturated and unsaturated hydrocarbons: <ul style="list-style-type: none"> from molecular structures by reaction with aqueous bromine Describe the formation of poly(ethene) as an example of addition polymerization of monomer units 	<p>Supplement</p> <ul style="list-style-type: none"> Describe the properties of alkenes in terms of addition reactions with bromine, hydrogen and steam
<p>14.6 Alcohols</p> <p>Core</p> <ul style="list-style-type: none"> Describe the manufacture of ethanol by fermentation and by the catalytic addition of steam to ethene Describe the properties of ethanol in terms of burning Name the uses of ethanol as a solvent and as a fuel 	<p>Supplement</p> <ul style="list-style-type: none"> Outline the advantages and disadvantages of these two methods of manufacturing ethanol
<p>14.7 Carboxylic acids</p> <p>Core</p> <ul style="list-style-type: none"> Describe the properties of aqueous ethanoic acid 	<p>Supplement</p> <ul style="list-style-type: none"> Describe the formation of ethanoic acid by the oxidation of ethanol by fermentation and with acidified potassium manganate(VII) Describe ethanoic acid as a typical weak acid Describe the reaction of a carboxylic acid with an alcohol in the presence of a catalyst to give an ester
<p>14.8.1 Polymers</p> <p>Core</p> <ul style="list-style-type: none"> Define polymers as large molecules built up from small units (monomers) 	<p>Supplement</p> <ul style="list-style-type: none"> Understand that different polymers have different units and/or different linkages

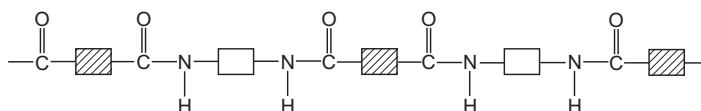
14.8.2 Synthetic polymers

Core

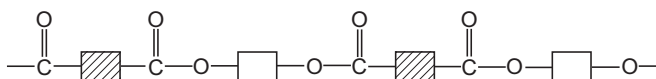
- Name some typical uses of plastics and of man-made fibers such as nylon and *Terylene*
- Describe the pollution problems caused by non-biodegradable plastics

Supplement

- Explain the differences between condensation and addition polymerization
- Deduce the structure of the polymer product from a given alkene and *vice versa*
- Describe the formation of nylon (a polyamide) and *Terylene* (a polyester) by condensation polymerization, the structure of nylon being represented as:



and the structure of *Terylene* as:



(Details of manufacture and mechanisms of these polymerizations are **not** required.)

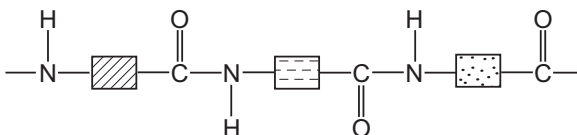
14.8.3 Natural polymers

Core

- Name proteins and carbohydrates as constituents of food

Supplement

- Describe proteins as possessing the same (amide) linkages as nylon but with different units
- Describe the structure of proteins as:



- Describe the hydrolysis of proteins to amino acids (Structures and names are **not** required.)
- Describe complex carbohydrates in terms of a large number of sugar units, considered as $\text{HO}-\square-\text{OH}$, joined together by condensation polymerization, e.g. $-\text{O}-\square-\text{O}-\square-\text{O}-\square-\text{O}-$
- Describe the hydrolysis of complex carbohydrates (e.g. starch), by acids or enzymes to give simple sugars
- Describe the fermentation of simple sugars to produce ethanol (and carbon dioxide) (Candidates will **not** be expected to give the molecular formulae of sugars.)
- Describe, in outline, the usefulness of chromatography in separating and identifying the products of hydrolysis of carbohydrates and proteins

7. Practical Assessment

Scientific subjects are, by their nature, experimental. It is therefore important that an assessment of a candidate's knowledge and understanding of chemistry should contain a practical component (see assessment objective AO3).

Schools' circumstances (e.g. the availability of resources) differ greatly, so two alternative ways of examining the practical component are provided. The alternatives are:

- Paper 5—Practical Test
- Paper 7—Coursework (internal assessment).

Whichever practical assessment route is chosen, the following points should be noted:

- the same assessment objectives apply
- the same practical skills are to be learned and developed
- the same sequence of practical activities is appropriate.

Candidates may not use textbooks in the practical component, nor any of their own records of laboratory work carried out during their course.

7.1 Teaching Experimental Skills

The best preparation for these papers is for candidates to pursue a course in which practical work is fully integrated so that it is a normal and natural part of the teaching.

Teachers are expected to identify suitable opportunities to embed practical techniques and investigative work throughout the course, rather than as an isolated aspect of preparation for examination. This approach will not only provide opportunities for developing experimental skills but will increase the appeal of the course, and the enjoyment of the subject. Practical work helps students to acquire a secure understanding of the syllabus topics and to appreciate how scientific theories are developed and tested. It also promotes important scientific attitudes such as objectivity, integrity, co-operation, enquiry and inventiveness.

7.2 Paper 5: Practical Test

This paper is based on testing experimental skills. The questions do not assess specific syllabus content from Section 6: Curriculum Content. Any information required to answer these questions is contained within the question paper or from the experimental context and skills listed below.

Questions are structured to assess across the grade range A*—G.

Experimental Skills Tested in Paper 5: Practical Test

Candidates may be asked questions on the following experimental contexts:

- simple quantitative experiments involving the measurement of volumes and/or masses
- rates (speeds) of reaction
- measurement of temperature based on a thermometer with 1°C graduations
- problems of an investigatory nature, possibly including suitable organic compounds
- filtration
- electrolysis
- identification of ions and gases.

Candidates may be required to do the following:

- take and record readings from apparatus, including:
 - reading a scale with appropriate accuracy and precision
 - interpolating between scale divisions
 - taking repeated measurements, where appropriate
- describe, explain or comment on experimental arrangements and techniques
- complete tables of data, and process data, using a calculator where necessary
- draw an appropriate conclusion, justifying it by reference to the data and using an appropriate explanation
- interpret and evaluate observations and experimental data
- plot graphs and/or interpret graphical information
- identify sources of error and suggest possible improvements in procedures
- plan an experiment or investigation, including making reasoned predictions of expected results and suggesting suitable apparatus and techniques.

Apparatus list

The list below details the apparatus expected to be generally available for both teaching and for examination of Paper 5. The list is not exhaustive: in particular, items that are commonly regarded as standard equipment in a chemical laboratory (such as Bunsen burners or tripods) are not included. The Confidential Instructions, provided to Centers prior to the examination of Paper 5, will give the detailed requirements for the examination.

- one buret, 50 cm³
- one volumetric pipet, 25 cm³
- a pipet filler
- two Erlenmeyer flasks, within the range 150 cm³ to 250 cm³
- graduated cylinder, 50 cm³, 25 cm³, 10 cm³
- a filter funnel

- beaker, squat form with lip, 250 cm³ and 100 cm³
- a thermometer, –10 °C to +110 °C at 1 °C graduations
- a styrofoam or other plastic beaker of approximate capacity 150 cm³
- 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 (Pyrex or hard glass), approximately 125 mm × 16 mm
- large test tubes, approximately 150 mm × 25 mm
- stirring rod.

7.3 Paper 7: Coursework

The experimental skills and abilities to be assessed are:

- AO3.1 Using and organizing techniques, apparatus, and materials
- AO3.2 Observing, measuring, and recording
- AO3.3 Handling experimental observations and data
- AO3.4 Planning and evaluating investigations

The four skills carry equal weighting.

All assessments must be based on experimental work carried out by the candidates.

It is expected that the teaching and assessment of experimental skills and abilities will take place throughout the course.

Teachers must ensure that they can make available to Cambridge evidence of **two** assessments of each skill for each candidate. For skills AO3.1 to AO3.4 inclusive, information about the tasks set and how the marks were awarded will be required. In addition, for skills AO3.2, AO3.3, and AO3.4, the candidate's written work will also be required.

The assessment scores finally recorded for each skill must represent the candidate's best performances.

For candidates who miss the assessment of a given skill through no fault of their own, for example, because of illness, and who cannot be assessed on another occasion, Cambridge procedure for special consideration should be followed. However, candidates who for no good reason absent themselves from an assessment of a given skill should be given a mark of zero for that assessment.

Criteria for Assessment of Experimental Skills and Abilities

Each skill must be assessed on a six-point scale, level 6 being the highest level of achievement. Each of the skills is defined in terms of three levels of achievement at scores of 2, 4, and 6.

A score of 0 is available if there is no evidence of positive achievement for a skill.

For candidates who do not meet the criteria for a score of 2, a score of 1 is available if there is some evidence of positive achievement.

A score of 3 is available for candidates who go beyond the level defined for 2, but who do not meet fully the criteria for 4.

Similarly, a score of 5 is available for those who go beyond the level defined for 4, but do not meet fully the criteria for 6.

Score	Skill AO3.1: Using and Organizing Techniques, Apparatus, and Materials
0	No evidence of positive achievement for this skill.
1	Some evidence of positive achievement, but the criteria for a score of 2 are not met.
2	Follows written, diagrammatic, or oral instructions to perform a single practical operation. Uses familiar apparatus and materials adequately, needing reminders on points of safety.
3	Is beyond the level defined for 2 but does not meet fully the criteria for 4.
4	Follows written, diagrammatic, or oral instructions to perform an experiment involving a series of step-by-step practical operations. Uses familiar apparatus, materials, and techniques adequately and safely.
5	Is beyond the level defined for 4 but does not meet fully the criteria for 6.
6	Follows written, diagrammatic, or oral instructions to perform an experiment involving a series of practical operations where there may be a need to modify or adjust one step in the light of the effect of a previous step. Uses familiar apparatus, materials, and techniques safely, correctly, and methodically.

Score	Skill AO3.2: Observing, Measuring, and Recording
0	No evidence of positive achievement for this skill.
1	Some evidence of positive achievement, but the criteria for a score of 2 are not met.
2	Makes observations or readings given detailed instructions. Records results in an appropriate manner given a detailed format.
3	Is beyond the level defined for 2 but does not meet fully the criteria for 4.
4	Makes relevant observations, measurements, or estimates given an outline format or brief guidelines. Records results in an appropriate manner given an outline format.
5	Is beyond the level defined for 4 but does not meet fully the criteria for 6.
6	Makes relevant observations, measurements, or estimates to a degree of accuracy appropriate to the instruments or techniques used. Records results in an appropriate manner given no format.

Score	Skill AO3.3: Handling Experimental Observations and Data
0	No evidence of positive achievement for this skill.
1	Some evidence of positive achievement, but the criteria for a score of 2 are not met.
2	Processes results in an appropriate manner given a detailed format. Draws an obvious qualitative conclusion from the results of an experiment.
3	Is beyond the level defined for 2 but does not meet fully the criteria for 4.
4	Processes results in an appropriate manner given an outline format. Recognizes and comments on anomalous results. Draws qualitative conclusions that are consistent with obtained results and deduces patterns in data.
5	Is beyond the level defined for 4 but does not meet fully the criteria for 6.
6	Processes results in an appropriate manner given no format. Deals appropriately with anomalous or inconsistent results. Recognizes and comments on possible sources of experimental error. Expresses conclusions as generalizations or patterns where appropriate.

Score	Skill AO3.4: Planning and Evaluating Investigations
0	No evidence of positive achievement for this skill.
1	Some evidence of positive achievement, but the criteria for a score of 2 are not met.
2	Suggests a simple experimental strategy to investigate a given practical problem. Attempts "trial and error" modification in the light of the experimental work carried out.
3	Is beyond the level defined for 2 but does not meet fully the criteria for 4.
4	Specifies a sequence of activities to investigate a given practical problem. In a situation where there are two variables, recognizes the need to keep one of them constant while the other is being changed. Comments critically on the original plan and implements appropriate changes in the light of the experimental work carried out.
5	Is beyond the level defined for 4 but does not meet fully the criteria for 6.
6	Analyzes a practical problem systematically and produces a logical plan for an investigation. In a given situation, recognizes that there are a number of variables and attempts to control them. Evaluates chosen procedures, suggests/implements modifications where appropriate, and shows a systematic approach in dealing with unexpected results.

Guidance on Candidate Assessment

The following notes are intended to provide teachers with information to help them make valid and reliable assessments of the skills and abilities of their candidates.

- The assessments should be based on the principle of positive achievement: candidates should be given opportunities to demonstrate what they understand and can do.
- It is expected that candidates will have had opportunities to acquire a given skill before assessment takes place.
- It is not expected that all of the practical work undertaken by a candidate will be assessed.
- Assessments can be carried out at any time during the course. However, at whatever stage assessments are done, the standards applied must be those expected at the end of the course, as exemplified in the criteria for the skills.
- Assessments should normally be made by the person responsible for teaching the candidates.
- A given practical task is unlikely to provide opportunities for all aspects of the criteria at a given level for a particular skill to be satisfied; for example, there may not be any anomalous results (Skill AO3.3). However, by using a range of practical work, teachers should ensure that opportunities are provided for all aspects of the criteria to be satisfied during the course.
- Extended experimental investigations are of great educational value. If such investigations are used for assessment purposes, teachers should make sure that the candidates have ample opportunity for displaying the skills and abilities required by the scheme of assessment.
- It is not necessary for all candidates within a teaching group, or within a Center, to be assessed on exactly the same practical work, although teachers can use work that is undertaken by all of their candidates.
- When assessing group work, teachers must ensure that each candidate's individual contribution is assessed.
- Skill AO3.1 might not generate a written product from the candidates; it will often be assessed by watching the candidates carrying out practical work.
- Skills AO3.2, AO3.3, and AO3.4 will usually generate a written product from the candidates; this will provide evidence for moderation.
- Raw scores for coursework must be recorded on the Individual Candidate Record Card produced by Cambridge. These forms, and the instructions for completing them, may be downloaded from **www.cie.org.uk/samples**. The database will ask you for the syllabus code (i.e. 0439) and your Center number, after which it will take you to the correct forms. Follow the instructions when completing each form.
- Raw scores for individual practical assessments may be given to candidates as part of the normal feedback from the teacher. The final, internally moderated, total score should **not** be given to the candidate.

Moderation

Internal Moderation

When several teachers in a Center are involved in internal assessment, arrangements must be made within the Center for all candidates to be assessed to the same standard. It is essential that the marks for each skill assigned within different teaching groups (or classes) are moderated internally for the whole Center entry. The Center assessments will then be moderated externally by Cambridge.

The internally moderated marks for all candidates must be recorded on the Coursework Assessment Summary Form. This form, and the instructions for completing it, may be downloaded from **www.cie.org.uk/samples**. The database will ask you for the syllabus code (i.e. 0439) and your Center number, after which it will take you to the correct form. Follow the instructions when completing the form.

External Moderation

External moderation of internal assessment is carried out by Cambridge. Centers must submit candidates' internally assessed marks to Cambridge. The deadlines and methods for submitting internally assessed marks are in the *Cambridge Administrative Guide* available on our website.

Once it has received the marks, Cambridge will draw up a list of sample candidates whose work will be moderated (a further sample may also be requested), and will ask the Center to immediately send every piece of work which has contributed toward these candidates' final marks. Individual Candidate Record Cards and Coursework Assessment Summary Forms must also be sent with the coursework. All remaining coursework and records should be kept by the Center until results are published.

Ideally, Centers should use loose-leaf letter-size filler paper for practical written work, as this is cheaper to send by mail. Original work is preferred for moderation, but authenticated photocopies can be sent if absolutely necessary.

Pieces of work for each skill should **not** be stapled together. Each piece of work should be clearly and securely labeled with:

- the skill being assessed
- the Center number
- the candidate's name and number
- the title of the experiment
- a copy of the mark scheme used
- the mark awarded.

7.4 Notes For Use in Qualitative Analysis

Tests for anions

anion	test	test result
carbonate (CO_3^{2-})	add dilute acid	effervescence, carbon dioxide produced
chloride (Cl^-) [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	white ppt.
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 aluminum foil; warm carefully	ammonia produced
sulfate (SO_4^{2-}) [in solution]	acidify, then add aqueous barium nitrate	white ppt.
sulfite (SO_3^{2-})	add dilute hydrochloric acid, warm gently and test for the presence of sulfur dioxide	sulfur dioxide produced will turn acidified aqueous potassium manganate(VII) from purple to colorless

Tests for aqueous cations

cation	effect of aqueous sodium hydroxide	effect of aqueous ammonia
aluminum (Al^{3+})	white ppt., soluble in excess giving a colorless 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	gray-green ppt., insoluble in excess
copper (Cu^{2+})	light blue ppt., insoluble in excess	light blue ppt., soluble in excess, giving a dark blue solution
iron(II) (Fe^{2+})	green ppt., insoluble in excess	green ppt., insoluble in excess
iron(III) (Fe^{3+})	red-brown ppt., insoluble in excess	red-brown ppt., insoluble in excess
zinc (Zn^{2+})	white ppt., soluble in excess, giving a colorless solution	white ppt., soluble in excess, giving a colorless 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 colorless

Flame tests for metal ions

metal ion	flame colour
lithium (Li^+)	red
sodium (Na^+)	yellow
potassium (K^+)	lilac
copper(II) (Cu^{2+})	blue-green

8. Appendix

8.1 The Periodic Table

DATA SHEET
The Periodic Table of the Elements

Group																			
I	II												III	IV	V	VI	VII	0	
								1 H Hydrogen 1											4 He Helium 2
7 Li Lithium 3	9 Be Beryllium 4												11 B Boron 5	12 C Carbon 6	14 N Nitrogen 7	16 O Oxygen 8	19 F Fluorine 9	20 Ne Neon 10	
23 Na Sodium 11	24 Mg Magnesium 12												27 Al Aluminum 13	28 Si Silicon 14	31 P Phosphorus 15	32 S Sulfur 16	35.5 Cl Chlorine 17	40 Ar Argon 18	
39 K Potassium 19	40 Ca Calcium 20	45 Sc Scandium 21	48 Ti Titanium 22	51 V Vanadium 23	52 Cr Chromium 24	55 Mn Manganese 25	56 Fe Iron 26	59 Co Cobalt 27	59 Ni Nickel 28	64 Cu Copper 29	65 Zn Zinc 30	70 Ga Gallium 31	73 Ge Germanium 32	75 As Arsenic 33	79 Se Selenium 34	80 Br Bromine 35	84 Kr Krypton 36		
85 Rb Rubidium 37	88 Sr Strontium 38	89 Y Yttrium 39	91 Zr Zirconium 40	93 Nb Niobium 41	96 Mo Molybdenum 42	98 Tc Technetium 43	101 Ru Ruthenium 44	103 Rh Rhodium 45	106 Pd Palladium 46	108 Ag Silver 47	112 Cd Cadmium 48	115 In Indium 49	119 Sn Tin 50	122 Sb Antimony 51	128 Te Tellurium 52	127 I Iodine 53	131 Xe Xenon 54		
133 Cs Caesium 55	137 Ba Barium 56	139 La Lanthanum 57	178 Hf Hafnium 72	181 Ta Tantalum 73	184 W Tungsten 74	186 Re Rhenium 75	190 Os Osmium 76	192 Ir Iridium 77	195 Pt Platinum 78	197 Au Gold 79	201 Hg Mercury 80	204 Tl Thallium 81	207 Pb Lead 82	209 Bi Bismuth 83	210 Po Polonium 84	210 At Astatine 85	222 Rn Radon 86		
Fr Francium 87	226 Ra Radium 88	227 Ac Actinium 89																	
*58-71 Lanthanoid series †90-103 Actinoid series																			
Key <div><div>aXb</div><div>a = relative atomic mass X = atomic symbol b = proton (atomic) number</div></div>		140 Ce Cerium 58	141 Pr Praseodymium 59	144 Nd Neodymium 60	147 Pm Promethium 61	150 Sm Samarium 62	152 Eu Europium 63	157 Gd Gadolinium 64	159 Tb Terbium 65	162 Dy Dysprosium 66	165 Ho Holmium 67	167 Er Erbium 68	169 Tm Thulium 69	173 Yb Ytterbium 70	175 Lu Lutetium 71				
		232 Th Thorium 90	234 Pa Protactinium 91	238 U Uranium 92	237 Np Neptunium 93	244 Pu Plutonium 94	247 Am Americium 95	251 Cm Curium 96	252 Bk Berkelium 97	258 Cf Californium 98	261 Es Einsteinium 99	267 Fm Fermium 100	271 Md Mendelevium 101	285 No Nobelium 102	289 Lr Lawrencium 103				

8.2 Safety in the Laboratory

Responsibility for safety matters rests with Centers. Further information can be found from the following associations, publications and regulations.

Associations

CLEAPSS is an advisory service providing support in practical science and technology.

<http://www.cleapss.org.uk>

Publications

CLEAPSS Laboratory Handbook, updated 2009 (available to CLEAPSS members only)

CLEAPSS Hazcards, 2007 update of 1995 edition (available to CLEAPSS members only)

8.3 Glossary of Terms Used in Science Papers

This glossary (which is relevant only to science subjects) will prove helpful to candidates as a guide, but 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 readily 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. (a) *Explain* may imply reasoning or some reference to theory, depending on the context. It is another way of asking candidates to give reasons. The candidate needs to leave the examiner in no doubt why something happens.
(b) *Give a reason/Give reasons* is another way of asking candidates to explain why something happens.
6. *Describe* requires the candidate to state in words (using diagrams where appropriate) the main points. *Describe* and *explain* may be coupled, as may *state* and *explain*.
7. *Discuss* requires the candidate to give a critical account of the points involved.
8. *Outline* implies brevity (i.e. restricting the answer to giving essentials).
9. *Predict* implies that the candidate is expected to make a prediction not by recall but by making a logical connection between other pieces of information.
10. *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.
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 of the subject to a 'novel' situation, one that may be formally 'not in the syllabus'—many data response and problem solving questions are of this type.

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 mass using a balance).
15. *Determine* often implies that the quantity concerned cannot be measured directly but is obtained from a graph or by calculation.
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).
In diagrams, *sketch* implies that simple, freehand drawing is acceptable; nevertheless, care should be taken over proportions and the clear exposition of important details.

8.4 Mathematical Requirements

Calculators may be used in all parts of the examination.

Candidates should be able to:

- add, subtract, multiply and divide
- use averages, decimals, fractions, percentages, ratios and reciprocals
- use standard notation, including both positive and negative indices
- understand significant figures and use them appropriately
- recognize and use direct and inverse proportion
- use positive, whole number indices in algebraic expressions
- draw charts and graphs from given data
- interpret charts and graphs
- determine the slope and intercept of a graph
- select suitable scales and axes for graphs
- make approximate evaluations of numerical expressions
- understand the meaning of angle, curve, circle, radius, diameter, circumference, square, rectangle and diagonal
- solve equations of the form $x = y + z$ and $x = yz$ for any one term when the other two are known.

8.5 Presentation of Data

The solidus (/) is to be used for separating the quantity and the unit in tables, graphs and charts, e.g. time/s, for time in seconds.

(a) Tables

- Each column of a table should be headed with the physical quantity and the appropriate unit, e.g. time/s.
- The column headings of the table can then be directly transferred to the axes of a constructed graph.

(b) Graphs

- 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).
- Each axis should be labeled with the physical quantity and the appropriate unit, e.g. time/s.
- 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.
- The graph is the whole diagrammatic presentation, including the best-fit line when appropriate. It may have one or more sets of data plotted on it.
- Points on the graph should be clearly marked as crosses (x) or encircled dots (⊙).
- Large 'dots' are penalized. Each data point should be plotted to an accuracy of better than one half of each of the smallest squares on the grid.
- A best-fit line (trend line) should be a single, thin, smooth straight-line or curve. 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.
- The slope of a straight line should be taken using a triangle whose hypotenuse extends over at least half of the length of the best-fit line, and this triangle should be marked on the graph.

(c) Numerical results

- Data should be recorded so as to reflect the precision of the measuring instrument.
- The number of significant figures given for calculated quantities should be appropriate to the least number of significant figures in the raw data used.

(d) Pie charts

- These should be drawn with the sectors in rank order, largest first, beginning at 'noon' and proceeding clockwise. Pie charts should preferably contain no more than six sectors.

(e) Bar charts

- These should be drawn when one of the variables is not numerical. They should be made up of narrow blocks of equal width that do **not** touch.

(f) Histograms

- These are drawn when plotting frequency graphs with continuous data. The blocks should be drawn in order of increasing or decreasing magnitude and they **should** touch.

8.6 ICT Opportunities

In order to play a full part in modern society, candidates need to be confident and effective users of ICT. The syllabus provides candidates with a wide range of opportunities to use ICT in their study of chemistry.

Opportunities for ICT include:

- gathering information from the internet, DVDs and CD-ROMs
- gathering data using sensors linked to data-loggers or directly to computers
- using spreadsheets and other software to process data
- using animations and simulations to visualize scientific ideas
- using software to present ideas and information on paper and on screen.

9. Other Information

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 goal 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 to 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**

Language

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

Grading and Reporting

Cambridge IGCSE results are shown by one of the grades A*, A, B, C, D, E, F, or G indicating the standard achieved, A* being the highest and G the lowest. “Ungraded” indicates that the candidate’s performance fell short of the standard required for grade G. “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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