CAMBRIDGE
International Examinations

Cambridge
IGCSE

SYLLABUS

Cambridge IGCSE®
Physical Science

0652

For examination in November 2017 and 2018

Cambridge Secondary 2

Version 1

Changes to syllabus for 2017 and 2018

The syllabus has been revised. You are advised to read the whole of the syllabus before planning your teaching programme. 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

The practical option Paper 4: Coursework has been withdrawn.

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

Core candidates will now take Paper 1: Multiple Choice (Core), Paper 3: Theory (Core) and either

Paper 5: Practical Test or Paper 6: Alternative to Practical.

Extended candidates will now take Paper 2: Multiple Choice (Extended), Paper 4: Theory (Extended), and either Paper 5: Practical Test or Paper 6: Alternative to Practical.

Changes to other sections of the syllabus

1. Introduction
   In the introductory section, some small changes have been made to wording to align this syllabus with the equivalent section in the IGCSEs for Physics and Chemistry.
2. Syllabus content at a glance
   This section has been revised.
5. Syllabus aims and assessment objectives
   This section has been updated to align this syllabus with the other science IGCSEs and are to ensure coherence across the IGCSE science suite.

   The syllabus aims have been amended to more fully reflect the skills and knowledge promoted by study of the course.

   The assessment objectives have been revised slightly for clarity. The meaning of the assessment objectives remains unchanged.
6. Syllabus content
   Topic 3.2 (b) of P3 (Physics) has been updated on page 30.
7. Practical assessment
   The wording of this section has been revised to align this syllabus with the equivalent sections in the other science IGCSEs.
8. Appendix
   A table of electrical symbols and notes on presentation of data have been added to align this syllabus with the equivalent sections in the other IGCSE science syllabuses.

Contents

1. Introduction 2
   1.1 Why choose Cambridge?
   1.2 Why choose Cambridge IGCSE?
   1.3 Why choose Cambridge IGCSE Physical Science?
   1.4 Cambridge ICE (International Certificate of Education)
   1.5 How can I find out more?

2. Teacher support 5
   2.1 Support materials
   2.2 Endorsed resources
   2.3 Training

3. Syllabus content at a glance 6

4. Assessment at a glance 7

5. Syllabus aims and assessment objectives 9
   5.1 Syllabus aims
   5.2 Assessment objectives
   5.3 Relationship between assessment objectives and components
   5.4 Grade descriptions
   5.5 Conventions (e.g. signs, symbols, terminology and nomenclature)

6. Syllabus content 14
   6.1 Chemistry
   6.2 Physics

7. Practical assessment 37
   7.1 Teaching experimental skills
   7.2 Description of Components, Paper 5: Practical Test and Paper 6: Alternative to Practical

8. Appendix 42
   8.1 Symbols, units and definitions of physical quantities
   8.2 Electrical symbols
   8.3 Safety in the laboratory
   8.4 Notes for use in qualitative analysis
   8.5 The Periodic Table of Elements
   8.6 Mathematical requirements
   8.7 Presentation of data
   8.8 Glossary of terms used in science papers

9. Other information 51

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 recognised by the world's best universities and employers, giving students a wide range of options in their education and career. As a not-for-profit organisation, we devote our resources to delivering high-quality educational programmes that can unlock learners' potential.

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

Cambridge learners

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

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

Recognition

Cambridge IGCSE is recognised 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 learners in Cambridge schools. Resources suit a variety of teaching methods in different international contexts. Through subject discussion forums and training, teachers can access the expert advice they need for teaching our qualifications. More details can be found in Section 2 of this syllabus and at **www.cie.org.uk/teachers**

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 programmes for learners aged 5 to 19 are certified as meeting the internationally recognised standard for quality management, ISO 9001:2008. Learn more at **www.cie.org.uk/ISO9001**

1.2 Why choose Cambridge IGCSE?

Cambridge IGCSEs are international in outlook, but retain a local relevance. The syllabuses provide opportunities for contextualised 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 aim is to balance knowledge, understanding and skills in our programmes and qualifications to enable students to become effective learners and to provide a solid foundation for their continuing educational journey.

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

Cambridge 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 programmes, such as the US Advanced Placement program and the International Baccalaureate Diploma programme. Learn more about Cambridge IGCSEs at **www.cie.org.uk/cambridgesecondary2**

Guided learning hours

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

1.3 Why choose Cambridge IGCSE Physical Science?

Cambridge IGCSE Physical Science gives learners the opportunity to study chemistry and physics within a scientifically coherent syllabus and is accepted by universities and employers as proof of essential knowledge and ability. As well as a subject focus, the physical science syllabus enables learners to:

- better understand the technological world, with an informed interest in scientific matters
- recognise 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.

Prior learning

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

Progression

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

Candidates who are awarded grades C to A* in Cambridge IGCSE Physical Science are well prepared to follow courses leading to Cambridge International AS Level Physical Science, or the equivalent.

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 recognising the achievements of learners who pass examinations in a number of different subjects.

Learn more about Cambridge ICE at **www.cie.org.uk/cambridgesecondary2**

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 organisation can register to become a Cambridge school.

2. Teacher support

2.1 Support materials

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

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

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

2.2 Endorsed resources

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

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

2.3 Training

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

3. Syllabus content at a glance

The syllabus content that follows is divided into two sections: Chemistry (C1–C11) and Physics (P1–P5). **Candidates must study both sections.**

Candidates can either follow the Core syllabus only, or they can follow the Extended syllabus which includes both the Core and the Supplement. Candidates aiming for grades A* to C should follow the Extended syllabus.

It is important that, throughout this course, teachers should make candidates aware of the relevance of the concepts studied to everyday life, and to the natural and man-made worlds.

Chemistry

C1. The particulate nature of matter
C2. Experimental techniques
C3. Atoms, elements and compounds
C4. Stoichiometry
C5. Chemical reactions
C6. Acids, bases and salts
C7. The Periodic Table
C8. Metals
C9. Air and water
C10. Lime and limestone
C11. Organic chemistry

Physics

P1. General physics, including motion, mass, forces and energy
P2. Thermal physics
P3. Properties of waves, including light and sound
P4. Electricity and magnetism
P5. Atomic physics

4. Assessment at a glance

All candidates must enter for three papers.

<table>
<tr><th>Core candidates take:</th><th></th><th>Extended candidates take:</th></tr>
<tr><td>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.</td><td></td><td>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.</td></tr>
<tr><th>and:</th><th></th><th>and:</th></tr>
<tr><td>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.</td><td></td><td>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.</td></tr>
</table>

<table>
<tr><th colspan="2">All candidates take:</th></tr>
<tr><th>either:</th><th>or:</th></tr>
<tr><td>Paper 5 1 hour 30 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.
30 marks
This paper will be weighted at 20% of the final total mark.</td><td>Paper 6 1 hour
Alternative to Practical
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.
60 marks
This paper will be weighted at 20% of the final total mark.</td></tr>
</table>

Candidates who have studied the Core syllabus content, or who are expected to achieve a grade D or below, should be entered for Paper 1, Paper 3 and either Paper 5 or Paper 6. 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 6. These candidates will be eligible for grades A* to G.

Availability

This syllabus is examined in the November examination series.

This syllabus is available to private candidates.

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

Combining this with other syllabuses

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

- syllabuses with the same title at the same level
- 0620 Cambridge IGCSE Chemistry
- 0625 Cambridge IGCSE Physics
- 0653 Cambridge IGCSE Combined Science
- 0654 Cambridge IGCSE Co-ordinated Sciences (Double Award)
- 5054 Cambridge O Level Physics
- 5070 Cambridge O Level Chemistry
- 5129 Cambridge O Level Combined Science

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

5. Syllabus aims and assessment objectives

5.1 Syllabus aims

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

The aims are:

1. to provide an enjoyable and worthwhile educational experience for all learners, whether or not they go on to study science beyond this level
2. to enable learners 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 learners to recognise 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 science
   - 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 science such as:
   - concern for accuracy and precision
   - objectivity
   - integrity
   - enquiry
   - initiative
   - inventiveness
6. to enable learners 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 assessment 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, organise and present information from a variety of sources
2. translate information from one form to another
3. manipulate numerical and other data
4. use information to identify patterns, report trends and draw inferences
5. present reasoned explanations for phenomena, patterns and relationships
6. make predictions and hypotheses
7. solve problems, 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 summarised in the table below.

Assessment objective	Papers 1 and 2	Papers 3 and 4	Papers 5 and 6	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 synthesise 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
- analyse 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
- analyse 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 to 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
- analyse 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)

Syllabuses and question papers will conform with generally accepted international practice. In particular, attention is drawn to the following documents, published in the UK, which will be used as guidelines.

Reports produced by the Association for Science Education (ASE):

SI Units, Signs, Symbols and Abbreviations (1981)

Chemical Nomenclature, Symbols and Terminology for use in school science (1985)

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

Litre/dm^3

To avoid any confusion concerning the symbol for litre, $\mathbf{dm^3}$ will be used in place of l or litre.

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. Syllabus content

The syllabus content that follows is divided into two sections: Chemistry (C1–C11) and Physics (P1–P5). **Candidates must study both sections.**

Candidates can either follow the Core syllabus only, or they can follow the Extended syllabus which includes both the Core and the Supplement. Candidates aiming for grades A* to C should follow the Extended syllabus.

Note:

1. The syllabus content is designed to provide guidance to teachers as to what will be assessed in the overall evaluation of the candidate. It is not meant to limit, in any way, the teaching programme of any particular school or college.
2. The content is set out in topic areas within chemistry and physics. Each topic area is divided into a number of sections. The left-hand column provides amplification of the Core content, which all candidates must study. The right-hand column outlines the Supplement content, which should be studied by candidates following the Extended syllabus.

The syllabus content below is a guide to the areas on which candidates are assessed.

It is important that, throughout this course, teachers should make candidates aware of the relevance of the concepts studied to everyday life, and to the natural and man-made worlds.

In particular, attention should be drawn to:

- the finite nature of the world's resources, the impact of human activities on the environment, and the need for recycling and conservation
- economic considerations for agriculture and industry, such as the availability and cost of raw materials and energy
- the importance of natural and man-made materials, including chemicals, in both industry and everyday life.

Specific content has been limited in order to encourage this approach, and to allow flexibility in the design of teaching programmes. Cambridge provides science schemes of work which teachers may find helpful; these are available from Teacher Support. Go to **http://teachers.cie.org.uk**

6.1 Chemistry

Core	Supplement
C1. The particulate nature of matter	
1 describe the states of matter and explain their interconversion in terms of kinetic particle theory 2 describe diffusion and Brownian motion in terms of kinetic theory	
C2. Experimental techniques	
1 name appropriate apparatus for the measurement of time, temperature, mass and volume, including burettes, pipettes and measuring cylinders 2 describe paper chromatography (including the use of locating agents) and interpret simple chromatograms 3 recognise that mixtures melt and boil over a range of temperatures 4 describe methods of purification by the use of a suitable solvent, filtration, crystallisation and distillation (including use of a fractionating column). Please see the fractional distillation of crude oil (petroleum – section 11.2) and fermented liquor (section 11.6)	

Core	Supplement
C3. Atoms, elements and compounds	
3.1 Atomic structure and the Periodic Table	
1 state the relative charge and approximate relative mass of a proton, a neutron and an electron 2 define *atomic (proton) number* and *mass (nucleon) number* 3 use atomic (proton) number and the simple structure of atoms to explain the basis of the Periodic Table (sections 7.1 to 7.4), with special reference to the elements with atomic (proton) numbers 1 to 20 4 use the notation $^{A}_{Z}X$ for an atom 5 describe the build-up of electrons in 'shells' and understand the significance of the noble gas electronic structures and of outer electrons (The ideas of the distribution of electrons in s- and p-orbitals and in d-block elements are not required.) (A copy of the Periodic Table will be provided in Papers 1 and 3.) 6 define *isotope*	(A copy of the Periodic Table will be provided in Papers 2 and 4.)
3.2 Bonding: the structure of matter	
1 describe the differences between *elements*, *mixtures* and *compounds*, and between *metals* and *non-metals* (section 7.1) 2 describe *alloys*, such as brass, as mixtures of a metal with other elements	3 explain how alloying affects the properties of metals (see 3.2(d))
3.2(a) Ions and ionic bonds	
Core	**Supplement**
1 describe the formation of *ions* by electron loss or gain and describe the formation of ionic bonds between the alkali metals and the halogens	2 describe the formation of ionic bonds between metallic and non-metallic elements

Core	Supplement
3.2(b) Molecules and covalent bonds	
1 describe the formation of single covalent bonds in H_2, Cl_2, H_2O, CH_4 and HCl as the sharing of pairs of electrons leading to the noble gas configuration 3 describe the differences in volatility, solubility and electrical conductivity between ionic and covalent compounds	2 describe the electron arrangement in more complex covalent molecules such as N_2, C_2H_4, CH_3OH and CO_2
3.2(c) Macromolecules	
1 describe the structure of graphite and of diamond	2 relate these structures to melting point, conductivity and hardness
3.2(d) Metallic bonding	
	1 describe metallic bonding as a lattice of positive ions in a 'sea of electrons' and use this to explain the electrical conductivity and malleability of metals
C4. Stoichiometry	
1 use the symbols of the elements and write the formulae of simple compounds	2 determine the formula of an ionic compound from the charges on the ions present
3 deduce the formula of a simple compound from the relative numbers of atoms present 5 construct word equations and simple balanced chemical equations 6 define *relative atomic mass*, A_r	4 deduce the balanced equation of a chemical reaction, given relevant information
7 define *relative molecular mass*, M_r, and calculate it as the sum of the relative atomic masses (the term *relative formula mass* or M_r will be used for ionic compounds)	8 calculate stoichiometric reacting masses and volumes of gases and solutions, solution concentrations expressed in g/dm^3 and mol/dm^3. (Calculations based on 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.)

Core	Supplement
C5. Chemical reactions	
5.1 Production of energy	
1 describe the production of heat energy by burning fuels 2 describe hydrogen as a fuel 3 describe radioactive isotopes, such as ^{235}U, as a source of energy	
5.2 Energetics of a reaction	
1 describe the meaning of *exothermic* and *endothermic* reactions 2 describe bond breaking as endothermic and bond forming as exothermic	
5.3 Rate of reaction	
1 describe the effects of concentration, particle size, catalysts (including enzymes) and temperature on the rates of reactions	2 show awareness that light can provide the energy needed for a chemical reaction to occur
3 state that organic compounds that catalyse organic reactions are called enzymes	4 state that photosynthesis leads to the production of glucose from carbon dioxide and water in the presence of chlorophyll and sunlight (energy)
5 describe the application of the above factors to the danger of explosive combustion with fine powders (e.g. flour mills) and gases (e.g. mines)	6 describe the use of silver salts in photography (i.e. reduction of silver ions to silver)
5.4 Redox	
1 define *oxidation* and *reduction* in terms of oxygen gain / loss	

Core	Supplement
C6. Acids, bases and salts	
6.1 The characteristic properties of acids and bases	
1 describe the characteristic properties of acids as reactions with metals, bases, carbonates and effect on litmus 3 describe neutrality, relative acidity and alkalinity in terms of pH (whole numbers only) measured using Universal Indicator paper 5 describe and explain the importance of the use of lime in controlling acidity in soil	2 define *acids* and *bases* in terms of proton transfer, limited to aqueous solutions 4 use these ideas to explain specified reactions as acid/base
6.2 Types of oxides	
1 classify oxides as either acidic or basic, related to the metallic and non-metallic character of the element forming the oxide	2 classify other oxides as neutral or amphoteric
6.3 Preparation of salts	
1 describe the preparation, separation and purification of salts as examples of some of the techniques specified in section 2 and the reactions specified in section 6.1	2 suggest a method of making a given salt from suitable starting materials, given appropriate information, including precipitation
6.4 Identification of ions	
1 describe the use of the following tests to identify: – *aqueous cations:* ammonium, copper(II), iron(II), iron(III) and zinc, using aqueous sodium hydroxide and aqueous ammonia as appropriate. (Formulae of complex ions are **not** required.) – *anions:* carbonate (by reaction with dilute acid and then limewater), chloride (by reaction under acidic conditions with aqueous silver nitrate), nitrate (by reduction with aluminium to ammonia) and sulfate (by reaction under acidic conditions with aqueous barium ions)	

Core	Supplement
6.5 Identification of gases	
1 describe the use of the following tests to identify: ammonia (using damp red litmus paper), carbon dioxide (using limewater), chlorine (using damp litmus paper), hydrogen (using a lighted splint), oxygen (using a glowing splint)	
C7. The Periodic Table	
1 describe the Periodic Table as a method of classifying elements and describe its use in predicting properties of elements	
7.1 Periodic trends	
1 describe the change from metallic to non-metallic character across a period	2 describe the relationship between group number and the number of outer electrons
7.2 Group properties	
1 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 2 predict the properties of other elements in the group given data, where appropriate 3 describe chlorine, bromine and iodine in Group VII as a collection of diatomic non-metals showing a trend in colour, and state their reaction with other halide ions 4 predict the properties of other elements in the group, given data where appropriate	5 identify trends in other groups, given data about the elements concerned
7.3 Transition elements	
1 describe the transition elements as a collection of metals having high densities, high melting points and forming coloured compounds, and which, as elements and compounds, often act as catalysts	

Core	Supplement
7.4 Noble gases	
1 describe the noble gases as being unreactive 2 describe the uses of the noble gases in providing an inert atmosphere (e.g. argon in lamps and helium for filling weather balloons)	
C8. Metals	
8.1 Properties of metals	
1 compare the general physical and chemical properties of metals with those of non-metals	
8.2 Reactivity series	
1 place in order of reactivity: potassium, sodium, calcium, magnesium, zinc, iron, hydrogen and copper, by reference to the reactions, if any and where relevant, of the metals with: – water or steam – dilute hydrochloric acid (equations not required) – the aqueous ions of other metals 3 deduce an order of reactivity from a given set of experimental results	2 account for the apparent unreactivity of aluminium in terms of the oxide layer adhering to the metal
8.3(a) Extraction of metals	
1 describe the ease in obtaining metals from their ores by relating the elements to the reactivity series 3 name metals that occur 'native', including copper and gold 4 name the main ores of aluminium, copper and iron	2 describe the essential reactions in the extraction of iron from hematite

Core	Supplement
8.3(b) Uses of metal	
1 describe the idea of changing the properties of iron by the controlled use of additives to form steel alloys 3 name the uses of mild steel (car bodies and machinery) and stainless steel (chemical plant and cutlery) 4 name the uses of zinc for galvanising and making brass	2 name the uses, related to their properties, of copper (electrical wiring and in cooking utensils) and of aluminium (aircraft parts and food containers)
C9. Air and water	
1 describe a chemical test for water 2 show understanding that hydration may be reversible (e.g. by heating hydrated copper(II) sulfate or hydrated cobalt(II) chloride) 3 describe, in outline, the purification of the water supply in terms of filtration and chlorination 4 name some of the uses of water in industry and in the home 5 describe the composition of clean air as being approximately 78% nitrogen, 21% oxygen and the remainder as being a mixture of noble gases, water vapour and carbon dioxide 6 name the common pollutants in the air as being carbon monoxide, sulfur dioxide, oxides of nitrogen and lead compounds 7 state the source of each of these pollutants: – 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 and lead compounds from car exhausts	8 explain the catalytic removal of nitrogen oxides from car exhaust gases

<table>
<tr><th>Core</th><th>Supplement</th></tr>
<tr><td>9 state the adverse effect of common pollutants on buildings and on health
10 describe the separation of oxygen and nitrogen from liquid air by fractional distillation
11 name the uses of oxygen in oxygen tents in hospitals, and with acetylene (a hydrocarbon) in welding
12 describe methods of rust prevention:
– paint and other coatings, to exclude oxygen
– galvanising
14 describe the need for nitrogen-, phosphorous- and potassium-containing fertilisers
15 describe the formation of carbon dioxide:
– 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</td><td>13 explain galvanising in terms of the reactivity of zinc and iron</td></tr>
<tr><th colspan="2">C10. Lime and limestone</th></tr>
<tr><td>1 describe the manufacture of calcium oxide (lime) from calcium carbonate (limestone) in terms of the chemical reactions involved
2 name some uses of lime and calcium hydroxide (slaked lime), such as treating acidic soil and neutralising acidic industrial waste products</td><td></td></tr>
</table>

Core	Supplement
C11. Organic chemistry	
11.1 Names of compounds	
1 name, and draw, the structures of methane, ethane, ethene, ethanol, ethanoic acid and the products of the reactions stated in sections 11.4 to 11.6 2 state the type of compound present, given a chemical name ending in -*ane*, -*ene*, -*ol*, or -*oic* acid or a molecular structure	
11.2 Fuels	
1 name the fuels coal, natural gas and petroleum 2 name methane as the main constituent of natural gas 3 describe petroleum as a mixture of hydrocarbons and its separation into useful fractions by fractional distillation 4 name the uses of the fractions: – petrol fraction as fuel in cars – paraffin fraction for oil stoves and aircraft fuel – diesel fraction for fuel in diesel engines – lubricating fraction for lubricants and making waxes and polishes – bitumen for making roads	
11.3 Homologous series	
1 describe the concept of homologous series as a 'family' of similar compounds with similar properties due to the presence of the same functional group	
11.4 Alkanes	
1 describe the properties of alkanes (exemplified by methane) as being generally unreactive, except in terms of burning	

Core	Supplement
11.5 Alkenes	
1 describe the properties of alkenes in terms of addition reactions with bromine, hydrogen and steam 3 distinguish between *saturated* and *unsaturated* hydrocarbons from molecular structures, by simple chemical tests 4 describe the formation of poly(ethene) as an example of addition polymerisation of monomer units	2 describe the manufacture of alkenes and of hydrogen by cracking
11.6 Alcohols	
1 name the uses of ethanol: as a solvent, as a fuel and as a constituent of wine and beer	2 describe the formation of ethanol by fermentation and by the catalytic addition of steam to ethene

6.2 Physics

Throughout this section, attention should be paid to showing the relevance of concepts to the student's everyday life and to the natural and man-made world.

Core	Supplement
P1. General physics	
1.1 Length and time	
1 use and describe the use of rules and measuring cylinders to determine a length or a volume	2 use and describe the use of a mechanical method for the measurement of a small distance
3 use and describe the use of clocks and devices for measuring an interval of time	4 measure and describe how to measure a short interval of time (including the period of a pendulum)
1.2 Speed, velocity and acceleration	
1 define *speed* and calculate speed from $\frac{\textit{total distance}}{\textit{total time}}$	2 distinguish between *speed* and *velocity*
3 plot and interpret a speed-time graph	4 recognise linear motion for which the acceleration is constant and calculate the acceleration
5 recognise from the shape of a speed-time graph when a body is: – at rest – moving with constant speed – moving with changing speed	6 recognise motion for which the acceleration is not constant
7 calculate the area under a speed-time graph to determine the distance travelled for motion with constant acceleration	
8 demonstrate an understanding that acceleration is related to changing speed	
9 state that the acceleration of free fall for a body near to the Earth is constant	10 describe qualitatively the motion of bodies falling in a uniform gravitational field with and without air resistance (including reference to terminal velocity)

Core	Supplement
1.3 Mass and weight	
1 show familiarity with the idea of the mass of a body 3 state that weight is a force 4 calculate the weight of a body from its mass	2 demonstrate an understanding that mass is a property which 'resists' change in motion
5 demonstrate an understanding that weights (and hence masses) may be compared using a balance	6 describe and use the concept of weight as the effect of a gravitational field on a mass
1.4 Density	
1 describe an experiment to determine the density of a liquid and of a regularly shaped solid, and make the necessary calculation	2 describe the determination of the density of an irregularly shaped solid by the method of displacement
1.5 Forces	
1.5(a) Effects of forces	
1 state that a force may produce a change in the size and shape of a body	2 take readings from and interpret extension-load graphs (Hooke's law, as such, is **not** required)
3 plot extension-load graphs and describe the associated experimental procedure	4 recognise the significance of the term *limit of proportionality* for an extension-load graph and use proportionality in simple calculations
5 describe the ways in which a force may change the motion of a body	6 recall and use the relation between force, mass and acceleration (including the direction), $F = ma$
1.5(b) Turning effect	
1 describe the moment of a force as a measure of its turning effect, and give everyday examples	2 perform and describe an experiment (involving vertical forces) to verify that there is no net moment on a body in equilibrium
1.5(c) Centre of mass	
1 calculate the moment of a force, given the necessary information 2 perform and describe an experiment to determine the position of the centre of mass of a plane lamina 3 describe qualitatively the effect of the position of the centre of mass on the stability of simple objects	

Core	Supplement
1.6 Energy, work and power	
1.6(a) Energy	
1 give examples of energy in different forms, its conversion and conservation, and apply the principle of energy conservation to simple examples	2 describe energy transfer in terms of work done and make calculations involving $F \times d$
3 show some understanding of energy of motion and energy of position (i.e. gravitational and strain)	4 use the terms *kinetic* and *potential energy* in context 5 recall and use the expressions: k.e. = $\frac{1}{2}mv^2$ p.e. = mgh
1.6(b) Major sources of energy and alternative sources of energy	
1 describe processes by which energy is converted from one form to another, including reference to: – chemical/fuel energy (a regrouping of atoms) – energy from water (hydroelectric energy, waves, tides) – geothermal energy – solar energy – nuclear energy (fission of heavy atoms) – wind energy (e.g. wind turbines, windmills, sailing boats and ships)	2 describe the process of energy conversion by the fusion of nuclei of atoms in the Sun as a source of solar energy 3 recall and use the equation that relates energy to mass $E = mc^2$ 4 express a qualitative understanding of efficiency
1.6(c) Work	
1 relate, without calculation, work done to the magnitude of a force and distance moved	2 recall and use $\Delta W = F \times d = \Delta E$
1.6(d) Power	
1 relate, without calculation, power to work done and time taken, using appropriate examples	2 recall and use the equation $P = E / t$ in simple systems

Core	Supplement
P2. Thermal physics	
2.1 Thermal properties	
2.1(a) Thermal expansion of solids, liquids and gases	
1 describe qualitatively the thermal expansion of solids, liquids and gases 3 identify and explain some of the everyday applications and consequences of thermal expansion	2 show an appreciation of the relative order of magnitude of the expansion of solids, liquids and gases
2.1(b) Measurement of temperature	
1 recall and describe how a physical property which varies with temperature may be used for the measurement of temperature and state examples of such properties 4 recognise the need for and identify a fixed point 5 describe the structure and action of liquid-in-glass thermometers	2 apply a given property to the measurement of temperature 3 demonstrate understanding of *sensitivity*, *range* and *linearity* 6 describe the structure and action of a thermocouple, and show understanding of its use for measuring high temperatures and those which vary rapidly
2.1(c) Melting and boiling	
1 describe *melting* and *boiling* in terms of energy input without a change in temperature 3 state the meaning of *melting point* and *boiling point*	2 distinguish between *boiling* and *evaporation*
2.2 Transfer of thermal energy	
2.2(a) Conduction	
1 describe experiments to demonstrate the properties of good and bad conductors of heat	2 give a simple molecular account of heat transfer in solids
2.2(b) Convection	
1 relate convection in fluids to density changes and describe experiments to illustrate convection	

Core	Supplement
2.2(c) Radiation	
1 identify infra-red radiation as part of the electromagnetic spectrum	2 describe experiments to show the properties of good and bad emitters and good and bad absorbers of infra-red radiation
2.2(d) Consequences of energy transfer	
1 identify and explain some of the everyday applications and consequences of conduction, convection and radiation	
P3. Properties of waves, including light and sound	
3.1 General wave properties	
1 describe what is meant by *wave motion* as illustrated by vibration in ropes, springs and by experiments using water waves 2 use the term *wavefront* 3 give the meaning of *speed*, *frequency*, *wavelength* and *amplitude* 5 describe the use of water waves to show – reflection at a plane surface – refraction due to a change of speed	4 recall and use the equation $v = f\lambda$ 6 interpret reflection, refraction and diffraction using wave theory
3.2 Light	
3.2(a) Reflection of light	
1 describe the formation, and give the characteristics, of an optical image formed by a plane mirror 3 use the law *angle of incidence* = *angle of reflection*	2 perform simple constructions, measurements and calculations
3.2(b) Refraction of light	
1 describe the refraction, including angle of refraction, in terms of the passage of light through a parallel-sided glass block 3 identify and describe internal and total internal reflection 4 state the meaning of *critical angle*	2 determine and calculate refractive index using $n = \sin i / \sin r$ 5 describe the action of optical fibres, particularly in medicine and communications

Core	Supplement
3.2(c) Thin converging lens	
1 describe the action of a thin converging lens on a beam of light 2 use the terms *principal focus* and *focal length* 3 draw ray diagrams to illustrate the formation of a real image by a single lens	4 describe the difference between a real image and a virtual image 5 use and describe the use of a single lens as a magnifying glass
3.2(d) Electromagnetic spectrum	
1 describe the main features of the electromagnetic spectrum, and state that all electromagnetic waves travel with the same high speed *in vacuo*	2 state the approximate value of the speed of electromagnetic waves 3 use the term *monochromatic*
3.3 Sound	
1 describe the production of sound by vibrating sources 2 state the approximate range of audible frequencies 3 show an understanding that a medium is required in order to transmit sound waves	
P4. Electricity and magnetism	
4.1 Simple phenomena of magnetism	
1 state the properties of magnets 2 give an account of induced magnetism 3 distinguish between ferrous and non-ferrous materials 4 describe an experiment to identify the pattern of field lines around a bar magnet 5 distinguish between the magnetic properties of iron and steel 6 distinguish between the design and use of permanent magnets and electromagnets	
4.2 Electrostatics	
1 describe simple experiments to show the production and detection of electrostatic charges	

Core	Supplement
4.2(a) Electric charge	
1 state that there are positive and negative charges 3 state that unlike charges attract and that like charges repel	2 state that charge is measured in coulombs
4.3 Electricity	
1 state that current is related to the flow of charge	2 show understanding that a current is a rate of flow of charge, and recall and use the equation $I = Q/t$
4.3(a) Current	
1 use and describe the use of an ammeter	
4.3 (b) Electromotive force (e.m.f.)	
1 state that the e.m.f. of a source of electrical energy is measured in volts	2 show understanding that e.m.f. is defined in terms of energy supplied by a source in driving charge around a complete circuit
4.3(c) Potential difference (p.d.)	
1 state that the potential difference across a circuit component is measured in volts 2 use and describe the use of a voltmeter	
4.3(d) Resistance	
1 recall and use the equation $V = IR$ 3 describe an experiment to determine resistance using a voltmeter and an ammeter 4 relate (without calculation) the resistance of a wire to its length and to its diameter	2 recall and use quantitatively the proportionality between resistance and the length, and the inverse proportionality between resistance and the cross-sectional area of a wire
4.3(e) *V* / *I* characteristic graphs	
1 sketch the *V* / *I* characteristic graphs for metallic (ohmic) conductors	

Core	Supplement
4.4 Electric circuits	
1 draw and interpret circuit diagrams containing sources, switches, resistors (fixed and variable), ammeters, voltmeters, magnetising coils, bells, fuses, relays	2 draw and interpret circuit diagrams containing diodes as rectifiers
3 understand that the current at every point in a series circuit is the same	4 recall and use the fact that the sum of the p.d.s across the components in a series circuit is equal to the total p.d. across the supply
5 give the combined resistance of two or more resistors in series	
6 state that, for a parallel circuit, the current from the source is larger than the current in each branch	7 recall and use the fact that the current from the source is the sum of the currents in the separate branches of a parallel circuit
8 state that the combined resistance of two resistors in parallel is less than that of either resistor by itself	9 calculate the effective resistance of two resistors in parallel
4.5 Practical electric circuitry	
4.5(a) Uses of electricity	
1 describe the uses of electricity in heating, lighting (including lamps in parallel) and motors	2 recall and use the equations $P = IV$ and $E = IVt$ and their alternative forms
4.5(b) Safety considerations	
1 state the hazards of – damaged insulation – overheating of cables – damp conditions	
4.6 Electromagnetic effects	
4.6(a) Electromagnetic induction	
	1 describe an experiment which shows that a changing magnetic field can induce an e.m.f. in a circuit 2 state the factors affecting the magnitude of the induced e.m.f. 3 show understanding that the direction of an induced e.m.f. opposes the change causing it

Core	Supplement
4.6(b) a.c. generator	
	1 describe a rotating-coil generator and the use of slip rings 2 show understanding of the nature of an alternating current (a.c.) 3 sketch a graph of voltage output against time for a simple a.c. generator
4.6(c) d.c. motor	
1 state that a current-carrying coil in a magnetic field experiences a turning effect, and that the effect is increased by increasing the number of turns on the coil 3 relate this turning effect to the action of an electric motor	2 describe the effect of increasing the current
4.6(d) Transformer	
	1 describe the construction of a basic iron-cored transformer as used for voltage transformations 2 show an understanding of the principle of operation of a transformer 3 use the equation $(V_p / V_s) = (N_p / N_s)$ 4 recall and use the equation $V_p I_p = V_s I_s$ (for 100% efficiency) 5 show understanding of energy loss in cables (calculation not required) 6 describe the use of the transformer in high-voltage transmission of electricity 7 give the advantages of high-voltage transmission
4.7 Cathode rays and the cathode-ray oscilloscope (c.r.o.)	
4.7(a) Cathode rays	
1 describe the production and detection of cathode rays 3 describe their deflection in electric fields and magnetic fields 4 deduce that the particles emitted in thermionic emission are negatively charged 5 state that the particles emitted in thermionic emission are electrons	2 distinguish between the direction of electron current and conventional current

Core	Supplement
4.7(b) Simple treatment of cathode-ray oscilloscope	
1 describe in outline the basic structure, and action, of a cathode-ray oscilloscope (detailed circuits are **not** required) 3 use and describe the use of a cathode-ray oscilloscope to display waveforms	2 use and describe the use of a cathode ray oscilloscope (c.r.o.) to measure p.d.s and short intervals of time (detailed circuits are **not** required)
P5. Atomic physics	
5.1 Radioactivity	
5.1(a) Detection of radioactivity	
1 show awareness of the existence of background radioactivity 2 describe the detection of alpha-particles, beta-particles and gamma-rays	
5.1(b) Characteristics of the three kinds of emission	
1 state that radioactive emissions occur randomly over space and time 2 state, for radioactive emissions: – their nature – their relative ionising effects – their relative penetrating abilities 3 describe their deflection in electric fields and magnetic fields	
5.1(c) Radioactive decay	
1 state the meaning of *radioactive decay*, using word equations to represent changes in the composition of the nucleus when particles are emitted	
5.1(d) Half-life	
1 use the term *half-life* in simple calculations which might involve information in tables or decay curves	
5.1(e) Safety precautions	
1 describe how radioactive materials are handled, used and stored in a safe way	

Core	Supplement
5.2 The nuclear atom	
5.2(a) Nucleus	
1 describe the composition of the nucleus in terms of protons and neutrons 2 use the term *atomic (proton) number, Z* 3 use the term *mass (nucleon) number, A* 4 use the term *nuclide* and nuclide notation $^{A}_{Z}X$ 5 use the nuclide notation in equations to show alpha and beta decay	
5.2(b) Isotopes	
1 use the term *isotope*	2 give and explain examples of practical applications of isotopes

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 science 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 6: Alternative to Practical (written paper).

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.

Calculators may be used in all parts of the assessment.

7.1 Teaching experimental skills

The best preparation for these papers is for learners 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 learners 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.

Experimental work

Experimental work is an essential component of all science and should form a key part of teachers' delivery plans for this syllabus.

Experimental work within science education:

- gives candidates first-hand experience of phenomena
- enables candidates to acquire practical skills
- provides candidates with the opportunity to plan and carry out investigations into practical problems.

Note on taking readings

When approximate volumes are used, e.g. about 2 cm^3, it is expected that candidates will estimate this and not use measuring devices.

A measuring instrument should be used to its full precision. Thermometers may be marked in 1 °C intervals but it is often appropriate to interpolate between scale divisions and record a temperature to the nearest 0.0 °C or 0.5 °C. Measurements using a rule require suitable accuracy of recording, such as 15.0 cm rather than 15 cm; the use of millimetres when appropriate should be encouraged. Similarly, when measuring current, it is often more appropriate to use milliamperes rather than amperes.

Apparatus list

The list below details the apparatus expected to be generally available for both the teaching and the examination of Paper 5. The list is not exhaustive: in particular, some items that are commonly regarded as standard equipment in a science laboratory are not included.

The *Confidential Instructions*, provided to Centres prior to the examination of Paper 5, will give the detailed requirements for each examination.

- rulers capable of measuring to 1 mm
- metre rule
- means of writing on glassware
- beakers, 100 cm^3, 250 cm^3
- a polystyrene or other plastic beaker of approximate capacity 150 cm^3
- test-tubes (Pyrex or hard glass), approximately 125 mm × 16 mm
- test-tubes, approximately 125 mm × 16 mm
- boiling tubes, approximately 150 mm × 25 mm
- delivery tubes
- conical flasks, within the range 150 cm^3 to 250 cm^3
- measuring cylinders, 100 cm^3, 50 cm^3, 25 cm^3, 10 cm^3
- dropping pipettes
- white tiles
- large containers (e.g. plastic bowl) to hold cold water
- thermometers, –10 °C to +110 °C with 1 °C graduations
- stopclocks (or wall clock or wrist-watch), to measure to an accuracy of 1 s
- glass rods
- spatulas
- wooden splints
- indicators (e.g. litmus paper, Universal Indicator paper, full range Universal Indicator)
- common reagents for tests (e.g. limewater test)
- burettes, 50 cm^3
- pipettes, 25 cm^3
- pipette fillers
- filter funnels and filter paper
- wash bottle

- an ammeter FSD 1 A, 2A
- voltmeter FSD 1 V, 5 V
- electrical cells (batteries) and holders to enable several cells to be joined
- connecting leads and crocodile clips
- d.c. power supply, variable to 12 V
- low-voltage filament lamps in holders
- various resistors and resistance wire
- switches
- good supply of masses and holders
- 2 cm expendable springs
- clamps and stands
- pendulum bobs
- newton meters
- Plasticine or modelling clay
- wooden boards
- converging lens with f = 15 cm
- glass or Perspex block, rectangular and semi-circular
- glass or Perspex prism, triangular
- optics pins
- plane mirrors
- ray box

7.2 Description of Components, Paper 5: Practical Test and Paper 6: Alternative to Practical

These papers are based on testing experimental skills. The questions do not assess specific syllabus content from Section 6: Syllabus 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 and Paper 6: Alternative to Practical

Questions may be set requiring candidates to:

- carefully follow a sequence of instructions
- describe, explain or comment on experimental arrangements and techniques
- select the most appropriate apparatus or method for a task and justify the choice made
- draw, complete or label diagrams of apparatus
- perform simple arithmetical calculations
- take readings from an appropriate measuring device or from an image of the device (e.g. thermometer, rule, protractor, measuring cylinder, ammeter, stopwatch), including:
  - reading analogue and digital scales with accuracy and appropriate precision
  - interpolating between scale divisions when appropriate
  - correcting for zero errors when appropriate

- plan to take a sufficient number and range of measurements, repeating where appropriate to obtain an average value
- describe or explain precautions taken in carrying out a procedure to ensure safety or the accuracy of observations and data, including the control of variables and repetition of measurements
- identify key variables and describe how, or explain why, certain variables should be controlled
- record observations systematically, for example in a table, using appropriate units and to a consistent and appropriate degree of precision
- process data, using a calculator where necessary
- present and analyse data graphically, including the use of best-fit lines where appropriate, interpolation and extrapolation, and the determination of a gradient, intercept or intersection
- interpret and evaluate observations and experimental data
- draw an appropriate conclusion, justifying it by reference to the data and using an appropriate explanation
- comment critically on a procedure or point of practical detail, and suggest an appropriate improvement
- evaluate the quality of data, identifying and dealing appropriately with any anomalous results
- identify possible causes of uncertainty, in data or in a conclusion
- make estimates or describe outcomes which demonstrate their familiarity with an experiment, procedure or technique
- plan an experiment or investigation, including making reasoned predictions of expected results and suggesting suitable apparatus and techniques.

Chemistry

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 and energetics
- problems of an investigatory nature, possibly including suitable organic compounds
- filtration
- electrolysis
- identification of ions and gases
- metals and the reactivity series
- acids, bases, oxides and preparation of salts
- redox reactions and rusting.

Physics

Candidates may be asked questions on the following experimental contexts:

- measurement of physical quantities such as length or volume or force or density
- cooling and heating
- springs and balances
- timing motion or oscillations
- electrical circuits, circuit diagrams and electrical symbols
- optics equipment such as mirrors, prisms and lenses
- procedures using simple apparatus, in situations where the method may not be familiar to the candidate.

- use or describe the use of common techniques, apparatus and materials, e.g. ray-tracing equipment or the connection of electric circuits
- explain the manipulation of the apparatus to obtain observations or measurements, e.g.:
  - when determining a derived quantity, such as the extension per unit load for a spring
  - when testing/identifying the relationship between two variables, such as between the p.d. across a wire and its length
  - when comparing physical quantities, such as two masses, using a balancing method.

8. Appendix

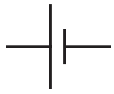
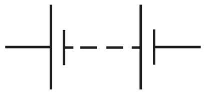
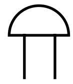
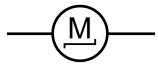
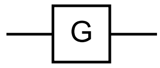
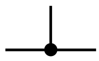
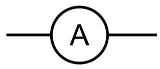
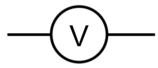
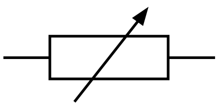
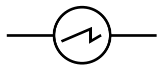
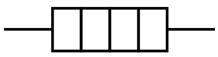
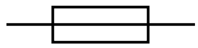
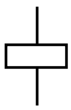
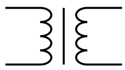
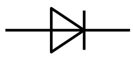
8.1 Symbols, units and definitions of physical quantities

Candidates should be able to state the symbols for the following physical quantities and, where indicated, state the units in which they are measured. Candidates should be able to define those items indicated by an asterisk (*). The list for the Extended syllabus content includes both the Core and the Supplement.

Core			Supplement		
Quantity	**Symbol**	**Unit**	**Quantity**	**Symbol**	**Unit**
length	*l*, *h*	km, m, cm, mm			
area	*A*	m^2, cm^2			
volume	*V*	m^3, dm^3, cm^3			
weight	*W*	N			N*
mass	*m*, *M*	kg, g			mg
density*	*d*, *ρ*	kg/m^3, g/cm^3			
time	*t*	h, min, s			ms
speed*	*u*, *v*	km/h, m/s, cm/s	velocity*		km/h, m/s, cm/s
acceleration	*a*		acceleration*		m/s^2
acceleration of free fall	*g*				
force	*F*, *P*	N	force*		N*
work done	*W*, *E*	J	work done by a force*		J*
energy	*E*	J			J*, kWh
power	*P*	W	power*		W*
temperature	*θ*, *T*	°C			
frequency	*f*	Hz	frequency*	*f*	Hz*
wavelength	*λ*	m, cm	wavelength*	*λ*	m, cm
focal length	*f*	cm, mm			
angle of incidence	*i*	degree (°)			
angle of reflection*, refraction	*r*	degree (°)			
critical angle*	*c*	degree (°)			
potential difference/ voltage*	*V*	V, mV	potential difference*		V*
current	*I*	A, mA	current*		
e.m.f.	*E*	V	e.m.f.*		
resistance*	*R*	Ω			
			mole*	*n*	mol
			concentration	*c*	mol/dm^3
			charge	*Q*	C

8.2 Electrical symbols

Candidates are expected to be able to recall and use the standard electrical symbols listed below.

Core			
cell		switch	
battery of cells	 or 	electric bell	
power supply		motor	
a.c. power supply		generator	
junction of conductors		ammeter	
fixed resistor		voltmeter	
variable resistor		oscilloscope	
heater		fuse	
relay coil			
transformer			
diode			

8.3 Safety in the laboratory

Responsibility for safety matters rests with Centres. Further information can be found in the following UK associations, websites, publications and regulations.

Associations

CLEAPSS is an advisory service providing support in practical science and technology, primarily for UK schools. International schools and post-16 colleges can apply for associate membership, which includes access to the CLEAPSS publications listed below.

http://www.cleapss.org.uk

Websites

http://www.ncbe.reading.ac.uk/NCBE/SAFETY/menu.html

http://www.microbiologyonline.org.uk/teachers/safety-information

Publications

Safeguards in the School Laboratory, ASE, 11th edition, 2006

Topics in Safety, ASE, 3rd edition, 2001

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

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

Safety in Science Education, DfES, HMSO, 1996

Hazardous Chemicals Manual, SSERC, 1997

Hazardous Chemicals. An interactive manual for science education, SSERC, 2002 (CD)

UK Regulations

Control of Substances Hazardous to Health Regulations (COSHH) 2002 and subsequent amendment in 2004
http://www.legislation.gov.uk/uksi/2002/2677/contents/made
http://www.legislation.gov.uk/uksi/2004/3386/contents/made

A brief guide may be found at
http://www.hse.gov.uk/pubns/indg136.pdf

8.4 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.
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.

Tests for aqueous cations

cation	effect of aqueous sodium hydroxide	effect of aqueous ammonia
ammonium (NH_4^+)	ammonia produced on warming	–
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	green ppt., insoluble in excess
iron(III) (Fe^{3+})	red-brown ppt., insoluble in excess	red-brown ppt., insoluble in excess
zinc (Zn^{2+})	white ppt., soluble in excess, giving a colourless solution	white ppt., soluble in excess, giving a colourless solution

Tests for gases

gas	test and test result
ammonia (NH_3)	turns damp red litmus paper blue
carbon dioxide (CO_2)	turns limewater milky
chlorine (Cl_2)	bleaches damp litmus paper
hydrogen (H_2)	'pops' with a lighted splint
oxygen (O_2)	relights a glowing splint

Flame tests for metal ions

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

8.5 The Periodic Table of Elements

Key

atomic number
atomic symbol
name
relative atomic mass

Group																	
I	II											III	IV	V	VI	VII	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 –		114 Fl flerovium –		116 Lv livermorium –		

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.)

8.6 Mathematical requirements

Calculators may be used in all parts of the assessment.

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
- recognise 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 gradient and intercept of a graph
- select suitable scales and axes for graphs
- make approximate evaluations of numerical expressions
- recognise and use the relationship between length, surface area and volume and their units on metric scales
- 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.

8.7 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 labelled 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 penalised. 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 gradient 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.

8.8 Glossary of terms used in science papers

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

1. *Define* (the term(s) ...) is intended literally, only a formal statement or equivalent paraphrase being required.
2. *What do you understand by/ What is meant by* (the term(s) ...) normally implies that a definition should be given, together with some relevant comment on the significance or context of the term(s) concerned, especially where two or more terms are included in the question. The amount of supplementary comment intended should be interpreted in the light of the indicated mark value.
3. *State* implies a concise answer with little or no supporting argument (e.g. a numerical answer that can 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. *Explain* may imply reasoning or some reference to theory, depending on the context.
6. *Describe* requires the candidate to state in words (using diagrams where appropriate) the main points of the topic. It is often used with reference either to particular phenomena or to particular experiments. In the former instance, the term usually implies that the answer should include reference to (visual) observations associated with the phenomena.

   In other contexts, *describe* should be interpreted more generally (i.e. the candidate has greater discretion about the nature and the organisation of the material to be included in the answer). *Describe and explain* may be coupled, as may *state and explain*.
7. *Discuss* requires the candidate to give a critical account of the points involved in the topic.
8. *Outline* implies brevity (i.e. restricting the answer to giving essentials).

9. *Predict* implies that the candidate is not expected to produce the required answer by recall but by making a logical connection between other pieces of information. Such information may be wholly given in the question or may depend on answers extracted in an earlier part of the question.

   Predict also implies a concise answer with no supporting statement required.
10. *Deduce* is used in a similar way to *predict* except that some supporting statement is required (e.g. reference to a law, principle, or the necessary reasoning is to be included in the answer).
11. *Suggest* is used in two main contexts: either to imply that there is no unique answer (e.g. in chemistry, two or more substances may satisfy the given conditions describing an 'unknown'), or to imply that candidates are expected to apply their general knowledge to a 'novel' situation, one that may be formally 'not in the syllabus'.
12. *Find* is a general term that may variously be interpreted as *calculate, measure, determine*, etc.
13. *Calculate* is used when a numerical answer is required. In general, working should be shown, especially where two or more steps are involved.
14. *Measure* implies that the quantity concerned can be directly obtained from a suitable measuring instrument (e.g. length, using a rule; or mass, using a balance).
15. *Determine* often implies that the quantity concerned cannot be measured directly but is obtained by calculation, substituting measured or known values of other quantities into a standard formula (e.g. resistance or the formula of an ionic compound).
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 or 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.

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 aim of avoiding direct and indirect discrimination.

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

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

Information on access arrangements is found in the *Cambridge Handbook* which can be downloaded from the website **www.cie.org.uk/examsofficers**

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*.

Cambridge International Examinations
1 Hills Road, Cambridge, CB1 2EU, United Kingdom
Tel: +44 (0)1223 553554 Fax: +44 (0)1223 553558
Email: info@cie.org.uk www.cie.org.uk

* 6 8 2 5 0 5 7 0 6 8 *

A DIVISION OF
CAMBRIDGE ASSESSMENT