CAMBRIDGE
International Examinations

Cambridge
International
AS & A Level

SYLLABUS

Cambridge International AS Level
Physical Science

8780

For examination in November 2016

Cambridge Advanced

Changes to syllabus for 2016

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

The following learning outcomes have been deleted from the syllabus (2015 references)

C3(e)

C7(a) ionic radius

C7(b) ionic radius

C9(d)(ii)

C10(c)

C10(h)

C12(c)

C12(d)

Work done on/by a gas $W = p\Delta V$ (Data Booklet)

Safety notice regarding the use of chemicals

- identification of lead(II), Pb^{2+}(aq) has been removed
- identification of chromate(VI), CrO_4^{2-} has been removed
- use of lead, Pb^{2+}(aq), has been removed for identification of chloride, bromide, iodide and sulfate
- identification of sulfur dioxide is now to be carried out using potassium manganate(VII)

Teachers are advised to read the whole of the syllabus before planning their teaching programme.

If there are any further changes to this syllabus, Cambridge will write to Centres to inform them. This syllabus is also on the Cambridge website **www.cie.org.uk**. The version of the syllabus on the website should always be considered as the definitive version.

Copies of Cambridge International AS Level syllabuses can be downloaded from our website **www.cie.org.uk**

Contents

1. Introduction

1.1 Why choose Cambridge?

Recognition

Cambridge International Examinations is the world's largest provider of international education programmes and qualifications for learners aged 5 to 19. We are part of Cambridge Assessment, a department of the University of Cambridge, trusted for excellence in education. Our qualifications are recognised by the world's universities and employers.

Cambridge International AS and A Levels are recognised around the world by schools, universities and employers. The qualifications are accepted as proof of academic ability for entry to universities worldwide, though some courses do require specific subjects.

Cambridge International A Levels typically take two years to complete and offer a flexible course of study that gives learners the freedom to select subjects that are right for them.

Cambridge International AS Levels often represent the first half of an A Level course, but may also be taken as a freestanding qualification. The content and difficulty of a Cambridge International AS Level examination is equivalent to the first half of a corresponding Cambridge International A Level. Cambridge AS Levels are accepted in all UK universities and carry half the weighting of an A Level. University course credit and advanced standing is often available for Cambridge International AS and A Levels in countries such as the USA and Canada.

Learn more at **www.cie.org.uk/recognition**

Excellence in education

Our mission is to deliver world-class international education through the provision of high-quality curricula, assessment and services.

More than 9000 schools are part of our Cambridge learning community. We support teachers in over 160 countries who offer their learners an international education based on our curricula and leading to our qualifications. Every year, thousands of learners use Cambridge qualifications to gain places at universities around the world.

Our syllabuses are reviewed and updated regularly so that they reflect the latest thinking of international experts and practitioners and take account of the different national contexts in which they are taught.

Cambridge programmes and qualifications are designed to support learners in becoming:

- **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.

Support for teachers

A wide range of support materials and resources is available for 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 exam entries and excellent personal support from our customer services. Learn more at **www.cie.org.uk/examsofficers**

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

We are a not-for-profit organisation where the needs of the teachers and learners are at the core of what we do. We continually invest in educational research and respond to feedback from our customers in order to improve our qualifications, products and services.

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 International AS and A Level?

Cambridge International AS and A Levels 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 candidates to become effective learners and to provide a solid foundation for their continuing educational journey. Cambridge International AS and A Levels give learners building blocks for an individualised curriculum that develops their knowledge, understanding and skills.

Schools can offer almost any combination of 60 subjects, and learners can specialise or study a range of subjects, ensuring a breadth of knowledge. Giving learners the power to choose helps motivate them throughout their studies.

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

Cambridge International AS and A Levels have a proven reputation for preparing learners well for university, employment and life. They help develop the in-depth subject knowledge and understanding, which are so important to universities and employers.

Learners studying Cambridge International AS and A Levels have the opportunities to:

- acquire an in-depth subject knowledge
- develop independent thinking skills
- apply knowledge and understanding to new as well as familiar situations
- handle and evaluate different types of information sources
- think logically and present ordered and coherent arguments
- make judgements, recommendations and decisions
- present reasoned explanations, understand implications and communicate them clearly and logically
- work and communicate in English.

Guided learning hours

Cambridge International A Level syllabuses are designed on the assumption that learners have about 360 guided learning hours per subject over the duration of the course. Cambridge International AS Level syllabuses are designed on the assumption that learners have about 180 guided learning hours per subject over the duration of the course. This is for guidance only and 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 International AS Level Physical Science?

Cambridge International AS Level Physical Science is accepted by universities and employers as proof of essential knowledge and ability. The syllabus has been designed to give students a thorough understanding and ability to apply scientific concepts and principles. Successful students will:

- acquire the factual knowledge associated with scientific quantities, units and measurement techniques and their social, economic and environmental implications
- learn how to find, organise and present presentation scientific information and apply scientific hypotheses and theories to novel situations
- develop confidence in a technological world and the ability to take an informed interest in matters of scientific importance
- understand the use of experimental methods and techniques.

Cambridge International AS Level Physical Science is one of a number of science syllabuses that Cambridge offers – for details of other syllabuses at Cambridge IGCSE, Cambridge O Level and Cambridge International AS and A Level visit the Cambridge website at **www.cie.org.uk**

Prior learning

We recommend that candidates who are beginning this course should have previously completed a Cambridge O Level or Cambridge IGCSE course in Physical Science or both Physics and Chemistry or the equivalent.

Progression

Cambridge International AS Level Physical Science provides a suitable foundation for the study of Physical Science or related courses in higher education. Depending on local university entrance requirements, it may permit or assist progression directly to university courses in Physical Science or some other subjects. It is also suitable for candidates intending to pursue careers in Physical Science, or further study as part of a course of general education.

1.4 Cambridge AICE (Advanced International Certificate of Education) Diploma

Cambridge AICE Diploma is the group award of the Cambridge International AS and A Level. It gives schools the opportunity to benefit from offering a broad and balanced curriculum by recognising the achievements of candidates who pass examinations in three different curriculum groups:

- Mathematics and Science (Group 1)
- Languages (Group 2)
- Arts and Humanities (Group 3)

A Cambridge International A Level counts as a double-credit qualification and a Cambridge International AS Level counts as a single-credit qualification within the Cambridge AICE Diploma award framework.

To be considered for an AICE Diploma, a candidate must earn the equivalent of six credits by passing a combination of examinations at either double credit or single credit, with at least one course coming from each of the three curriculum groups.

Cambridge AS Level Physical Science (8780) is in Group 1, Mathematics and Sciences.

Credits gained from Cambridge AS Level Global Perspectives (8987) or Cambridge Pre-U Global Perspectives and Independent Research (9766) can be counted towards the Cambridge AICE Diploma, but candidates must also gain at least one credit from each of the three curriculum groups to be eligible for the award.

Learn more about the Cambridge AICE Diploma at **www.cie.org.uk/qualifications/academic/uppersec/aice**

The Cambridge AICE Diploma is awarded from examinations administered in the June and November series each year.

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

Cambridge syllabuses, past question papers and examiner reports to cover the last examination series are on the *Syllabus and Support Materials* DVD, which we send to all Cambridge schools.

You can also go to our public website at **www.cie.org.uk/alevel** 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 Resource lists

We work with publishers providing a range of resources for our syllabuses including textbooks, websites, CDs, etc. Any endorsed, recommended and suggested resources are listed on both our public website and on Teacher Support.

The resource lists can be filtered to show all resources or just those which are endorsed or recommended by Cambridge. Resources endorsed by Cambridge go through a detailed quality assurance process and are written to align closely with the Cambridge syllabus they support.

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 is divided into physics and chemistry sections.

All candidates study the following topics:

Physics	Chemistry
General physics	**General chemistry**
P1. Physical quantities and units	C1. Atoms, molecules and stoichiometry
P2. Measurement techniques	C2. Atomic structure
Newtonian mechanics	C3. Chemical bonding
P3. Kinematics	C4. Chemical energetics
P4. Dynamics	C5. Equilibria
P5. Forces	C6. Reaction kinetics
P6. Work, energy, power	**Inorganic chemistry**
Matter	C7. The Periodic Table: chemical periodicity
P7. Phases of matter	C8. Group II
Oscillations and waves	C9. Group VII
P8. Waves	C10. Nitrogen and sulfur
P9. Superposition	**Industrial processes**
Electricity and magnetism	C11. Industrial processes
P10. Electric fields	**Organic chemistry**
P11. Current electricity	C12 Introductory topics
P12. Circuits	C13 Hydrocarbons
Modern physics	C14 Halogen derivatives
P13. Physics of the atom	C15 Alcohols, aldehydes, ketones and carboxylic acids
	C16. Polymerisation

4. Assessment at a glance

All candidates take four papers, which are taken at a single examination series.

Paper 1

Multiple choice **40 minutes**

This paper consists of 30 questions; 15 from the physics syllabus content and 15 from the chemistry syllabus content.

There are 20 questions of the four-option type and 10 questions of the multiple-statement type.

30 marks

Weighted at 15% of the total marks available.

Paper 2

Short response **40 minutes**

This paper consists of a variable number of short-response questions, with 15 marks from the physics syllabus content and 15 marks from the chemistry syllabus content. Candidates answer all questions on the question paper provided.

30 marks

Weighted at 15% of the total marks available.

Paper 3

Structured questions **1 hour 30 minutes**

This paper consists of a variable number of structured questions. 40 marks come from the physics syllabus content and 40 marks from the chemistry syllabus content. Candidates answer all questions on the question paper provided.

80 marks

Weighted at 50% of the total marks available.

Paper 4

Advanced practical skills **1 hour 30 minutes**

Candidates are assessed on their experimental skills by carrying out two tasks. One task is broadly based on the physics syllabus content and one task is broadly based on the chemistry syllabus content. For each task, candidates have a maximum of 45 minutes to use the apparatus provided. Candidates answer on the question paper provided.

30 marks

Weighted at 20% of the total marks available.

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**

Centres in the UK that receive government funding are advised to consult the Cambridge website **www.cie.org.uk** for the latest information before beginning to teach this syllabus.

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
- 9701 AS/A Level Chemistry
- 9702 AS/A Level Physics

5. Syllabus aims and assessment objectives

5.1 Syllabus aims

The aims of a course based on this syllabus should be to:

1. provide, through well-designed studies of experimental and practical science, a worthwhile educational experience for all students, whether or not they go on to study science beyond this level and, in particular, to enable them to
   - 1.1 acquire sufficient understanding and knowledge to become confident citizens in a technological world and able to take or develop an informed interest in matters of scientific import
   - 1.2 recognise the usefulness, and limitations, of scientific method and to appreciate its applicability in other disciplines and in everyday life
   - 1.3 be suitably prepared for studies beyond Cambridge International AS Level Physical Science.

2. develop abilities and skills that
   - 2.1 are relevant to the study and practice of science
   - 2.2 are useful in everyday life
   - 2.3 encourage efficient and safe practice
   - 2.4 encourage effective communication.

3. develop attitudes relevant to science such as
   - 3.1 concern for accuracy and precision
   - 3.2 objectivity
   - 3.3 integrity
   - 3.4 the skills of enquiry
   - 3.5 initiative
   - 3.6 insight.

4. stimulate interest in, and care for, the environment in relation to the environmental impact of science and its applications.

5. promote an awareness that
   - 5.1 the study and practice of science are co-operative and cumulative activities, and are subject to social, economic, technological, ethical and cultural influences and limitations
   - 5.2 the implications of science may be both beneficial and detrimental to the individual, the community and the environment
   - 5.3 the use of information technology is important for communication, as an aid to experiments and as a tool for the interpretation of experimental and theoretical results.

6. stimulate students, create and sustain their interest in science, understand its relevance to society.

5.2 Assessment objectives

The three assessment objectives in Cambridge AS Level Physical Science are:

A: Knowledge and understanding

B: Handling, applying and evaluating information

C: Experimental skills and investiations

A: Knowledge with understanding

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

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

The syllabus content defines the factual knowledge that candidates may be required to recall and explain. Questions testing these objectives will often begin with one of the following words: *define*, *state*, *describe*, or *explain*. (See Glossary of terms used in Physical Science papers.)

B: Handling, applying and evaluating information

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

- locate, select, organise and present information from a variety of sources
- handle information, distinguishing the relevant from the extraneous
- manipulate numerical and other data and translate information from one form to another
- analyse and evaluate information to identify patterns, report trends, draw inferences and report conclusions
- make predictions and put forward hypotheses
- apply knowledge, including principles, to novel situations
- evaluate information and hypotheses
- demonstrate an awareness of the limitations of physical theories and models.

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

C: Experimental skills and investigations

Candidates should be able to:

- follow a detailed set or sequence of instructions and plan investigations
- use techniques, apparatus, measuring devices and materials safely and effectively
- make and record observations, measurements and estimates, with due regard for precision, accuracy and units
- interpret and evaluate observations and experimental data
- select techniques, apparatus, measuring devices and materials
- evaluate methods and techniques, and suggest possible improvements.

5.3 Relationship between assessment objectives and components

Assessment objective	Paper 1	Paper 2	Paper 3	Paper 4	Weighting (%)
A: Knowledge with understanding	✓	✓	✓	×	45
B: Handling, applying and evaluating information	✓	✓	✓	×	35
C: Experimental skills and investigations	×	×	×	✓	20

The balance of assessment objectives A, B and C on each paper may vary slightly and candidates are expected to demonstrate knowledge of experimental skills and investigations in a range of contexts.

Teachers should bear in mind that there is a greater weighting for skills (including handling information, solving problems, practical, experimental and investigative skills) compared to the weighting for knowledge and understanding. Teachers' schemes of work and the sequence of leareted for the assessment.

5.4 Symbols, signs, abbreviations and nomenclature

Symbols, signs, abbreviations and nomenclature

Wherever symbols, signs and abbreviations are used in examination papers, the recommendation made in the Association for Science Education (ASE) publication *Signs, Symbols and Systematics: The ASE Companion to 16–19 Science* (2000) will be followed.

See also the Association for Science Education publication *SI Units, Signs, Symbols and Abbreviations for use in School Science* (1981).

The traditional names of sulfite, nitrite, sulfur trioxide, sulfurous acid and nitrous acid will be used in question papers. Sulfur and all compounds of sulfur will be spelled with f, not ph.

Data Booklet

A *Data Booklet* is available for use in Papers 1, 2 and 3. The booklet is reprinted in the appendix of the syllabus. Copies of the booklet can be ordered from the *Publications Office* at Cambridge using the appropriate order form.

Litre / dm^3

To avoid any confusion concerning the symbol for litre, **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 of the Cambridge International AS Level Physical Science is divided into two sections: Physics and Chemistry.

Each part of the syllabus is specified by:

- content
- assumed knowledge (where appropriate)
- learning outcomes.

In some sections there is also an overview of the topics.

In order to specify the syllabus as precisely as possible and to emphasise the importance of skills other than recall, learning outcomes have been used throughout. The assumed knowledge section of the syllabus provides the basis for the content of the syllabus and may be examined.

It must be emphasised that the syllabus is not intended to be used as a teaching syllabus, nor is it intended to represent a teaching order.

It is recognised that there is overlap in some content such as Kinetic Theory; Atoms; Packing Theory, and Radioactivity.

Teachers should incorporate social, environmental, economic and technological aspects of Physical Science, where relevant, throughout the syllabus (see syllabus aims 4 and 5).

6.1 Physics

General physics

P1. Physical quantities and units

Content

1.1 Physical quantities

1.2 SI Units

1.3 Scalars and vectors

Assumed knowledge
Candidates should be aware of the nature of a physical measurement, in terms of a magnitude and a unit. They should have experience of making and recording such measurements in the laboratory.

Candidates should be able to:

(a) show an understanding that all physical quantities consist of a numerical magnitude and a unit

(b) recall the following *SI* base quantities and their units: mass (kg), length (m), time (s), current (A)

(c) distinguish scalar and vector quantities and give examples of each.

Learning outcomes
Candidates should be able to:

(d) recall the *SI* base quantity and unit: temperature (K)

(e) express derived units as products or quotients of the *SI* base units and use the named units listed in this syllabus as appropriate

(f) use *SI* base units to check the homogeneity of physical equations

(g) show an understanding of and use the conventions for labelling graph axes and table columns as set out in the ASE publication *SI Units, Signs, Symbols and Abbreviations for use in School Science* (1981), except where these have been superseded by *Signs, Symbols and Systematics: The ASE Companion to 16–19 Science* (2000)

(h) use the following prefixes and their symbols to indicate decimal sub-multiples or multiples of both base and derived units: pico (p), nano (n), micro (μ), milli (m), centi (c), deci (d), kilo (k), mega (M), giga (G), tera (T)

(i) make reasonable estimates of physical quantities included within the syllabus

(j) add and subtract coplanar vectors, using vector diagrams.

P2. Measurement techniques

Content

2.1 Measurements

2.2 Errors and uncertainties

Assumed knowledge

Candidates should be able to:

(a) use techniques for the measurement of length, volume, angle, mass, time, temperature and electrical quantities appropriate to the ranges of magnitude implied by the relevant parts of the syllabus.

Learning outcomes

Candidates should be able to:

(b) use techniques for the measurement of length, volume, angle, mass, time, temperature and electrical quantities appropriate to the ranges of magnitude implied by the relevant parts of the syllabus.

In particular, candidates should be able to:

- (i) measure lengths using a ruler, and a mechanical method for measuring small distances (e.g. callipers and micrometers)
- (ii) measure weight and hence mass using spring and lever balances
- (iii) measure an angle using a protractor
- (iv) measure time intervals using clocks, stopwatches and the calibrated time-base of a cathode-ray oscilloscope (c.r.o.)
- (v) measure temperature using a thermometer as a sensor
- (vi) use ammeters and voltmeters with appropriate scales
- (vii) use a cathode-ray oscilloscope (c.r.o.)

(c) estimate the uncertainty when making measurements and recognise that all measurements have an inherent uncertainty

(d) use both analogue scales and digital displays

(e) use calibration curves

(f) show an understanding of the distinction between systematic errors (including zero errors) and random errors

(g) show an understanding of the distinction between precision and accuracy

(h) show an understanding of linearity, range and sensitivity

(i) assess the uncertainty in a derived quantity by simple addition of actual, and percentage uncertainties (a rigorous statistical treatment is not required).

Newtonian mechanics

P3. Kinematics

Content

3.1 Linear motion

3.2 Non-linear motion

Assumed knowledge
Candidates should be able to:

(a) describe the action of a force on a body

(b) describe the motion of a body and recognise acceleration and constant speed

(c) recall and use the relationship *average speed = distance / time*

(d) define and use displacement, speed, velocity and acceleration

(e) solve problems using equations that represent uniformly accelerated motion in a straight line, including the motion of bodies in a uniform gravitational field without air resistance

(f) use graphical methods to represent displacement, speed, velocity and acceleration

(g) recall that the weight of a body is equal to the product of its mass and the acceleration of free fall.

Learning outcomes
Candidates should be able to:

(g) describe the motion of bodies falling in a uniform gravitational field with air resistance

(h) demonstrate an understanding that a force applied to a body at a right angles to the velocity of the body causes a change in direction of the body

(i) demonstrate an understanding of circular motion including centripetal acceleration.

P4. Dynamics

Content

4.1 Newton's laws of motion

4.2 Linear momentum and its conservation

Assumed knowledge
Candidates should be able to:

(a) describe and use the concept of weight as the effect of a gravitational field on a mass.

Learning outcomes
Candidates should be able to:

(b) show an understanding that mass is the property of a body which resists change in motion

(c) define linear momentum as the product of mass and velocity

(d) define and use force as rate of change of momentum

(e) recall and solve problems using the relationship $F = ma$, appreciating that acceleration and force are always in the same direction

(f) understand the difference between elastic and inelastic collisions

(g) apply the principle of conservation of momentum to solve simple problems including elastic and inelastic interactions between two bodies in one dimension (knowledge of the concept of coefficient of restitution is not required).

P5. Forces

Content

5.1 Types of force

5.2 Equilibrium of forces

5.3 Centre of gravity

5.4 Turning effects of forces

Assumed knowledge

Candidates should be able to:

(a) show a qualitative understanding of frictional forces including air resistance.

Learning outcomes

Candidates should be able to:

(b) describe the forces on mass and charge in uniform gravitational and electric fields, as appropriate

(c) use a vector triangle to represent forces in equilibrium

(d) show an understanding that the weight of a body may be taken as acting at a single point known as its centre of gravity

(e) show an understanding that a *couple* is a pair of forces which tends to produce rotation only

(f) define and apply the moment of a force and the torque of a couple

(g) show an understanding that, when there is no resultant force and no resultant torque, a system is in equilibrium

(h) apply the principle of moments.

P6. Work, energy, power

Content

6.1 Energy conversion and conservation

6.2 Work

6.3 Potential energy, kinetic energy and internal energy

6.4 Power

Assumed knowledge

Candidates should be able to:

(a) give examples of energy in different forms, its conversion and conservation, and apply the principle of energy conservation to simple examples

(b) show an understanding of the concept of work in terms of the product of a force and displacement in the direction of the force

(c) define power as work done per unit time.

Learning outcomes

Candidates should be able to:

(d) recall and apply the formula $E_k = ½\,mv^2$

(e) understand the concepts of gravitational potential energy, electric potential energy and elastic potential energy

(f) show an understanding of and use the work done when a force moves its point of application in a uniform field is equal to the potential energy charge

(g) derive the formula $\Delta E_p = mg\Delta h$ for potential energy changes near the Earth's surface, from the defining equation $\Delta W = F\Delta s$

(h) recall and use the formula $\Delta E_p = mg\Delta h$ for potential energy changes near the Earth's surface

(i) show an understanding of the concept of internal energy

(j) show an appreciation of the implications of energy losses in practical devices and use the concept of efficiency to solve problems, e.g. motors, transformers, electric transmission

(k) derive power as the product of force and velocity

(l) solve problems using the relationships *power* = *work done per unit time* and *power* = *force* × *velocity*.

Matter

P7. Phases of matter

Content

7.1 Density

7.2 Solids, liquids, gases

7.3 Pressure in fluids

7.4 Application of the kinetic theory

Assumed knowledge

Candidates should be able to:

(a) describe matter in terms of particles, with a qualitative understanding of their behaviour

(b) define and use the term *density*

(c) describe a simple kinetic model for solids, liquids and gases.

Learning outcomes

Candidates should be able to:

(d) relate the difference in structures and densities of solids, liquids and gases to simple ideas of the spacing, ordering, including simple packing structure, and motion the of molecules

(e) show an understanding that the mean speed of molecules increases with increasing temperature, including qualitative idea of the Boltzmann distributions at different temperatures

(f) define *pressure* and use the kinetic model to explain the pressure exerted by gases, and derive, from the definitions of pressure and density, the equation $p = \rho gh$

(g) use the equation $p = \rho gh$

(h) distinguish between the processes of melting, boiling and evaporation in terms of kinetic theory

(i) describe, using a kinetic-molecular model, the liquid state, melting and vaporisation.

Oscillations and waves

P8. Waves

Content

8.1 Progressive waves

8.2 Transverse and longitudinal waves

8.3 Determination of speed, frequency and wavelength

8.4 Electromagnetic spectrum

Assumed knowledge

Candidates should be able to:

(a) describe basic wave behaviour, gained through a study of optics

(b) show an understanding of the basic ideas of reflection and refraction in light

(c) describe what is meant by wave motion as illustrated by vibration in ropes, springs and ripple tanks

(d) recognise transverse and longitudinal waves.

Learning outcomes

Candidates should be able to:

(e) show an understanding of and use the terms *displacement*, *amplitude*, *phase difference*, *period*, *frequency*, *wavelength* and *speed*

(f) deduce, from the definitions of speed, frequency and wavelength, the equation $v = f\lambda$

(g) show an understanding that energy is transferred by a progressive wave

(h) recall and use the relationship, *intensity is proportional to (amplitude)*^{2}

(i) analyse and interpret graphical representations of transverse and longitudinal waves

(j) determine the frequency of sound using a calibrated cathode-ray oscilloscope (c.r.o.)

(k) state that all electromagnetic waves travel with the same speed in free space and recall the orders of magnitude of the wavelengths of the principal radiations from radio waves to γ-rays

(l) recognise that higher frequency electromagnetic radiation has energy to initiate reactions which lower frequency radiation cannot initiate.

P9. Superposition

Content

9.1 Diffraction

9.2 Interference

9.3 Two-source interference patterns

Learning outcomes

Candidates should be able to:

(a) explain the meaning of the term *diffraction*

(b) show an understanding of experiments which demonstrate diffraction including the diffraction of water waves in a ripple tank with both a wide gap and a narrow gap

(c) explain and use the principle of superposition in simple applications

(d) show an understanding of the terms *interference* and *coherence*

(e) show an understanding of experiments which demonstrate two-source interference using sound, water, light and microwaves

(f) show an understanding of the conditions required if two-source interference fringes are to be observed.

Electricity and magnetism

P10. Electric fields

Content

10.1 Concept of an electric field

10.2 Uniform electric fields

Assumed knowledge

Candidates should be able to:

(a) recall the two types of charge

(b) recall the laws of electrostatics

(c) distinguish between conductors and insulators using a simple electron model.

Learning outcomes

Candidates should be able to:

(d) show an understanding of the concept of an electric field as an example of a field of force and define electric field strength as force per unit positive charge

(e) represent an electric field by means of field lines

(f) understand and use $E = V/d$ to calculate the field strength of the uniform field between charged parallel plates in terms of potential difference and separation

(g) calculate the forces on charges in uniform electric fields

(h) describe the effect of a uniform electric field on the motion of charged particles and apply to the cathode-ray oscilloscope (c.r.o.)

P11. Current electricity

Content

11.1 Electric current

11.2 Potential difference

11.3 Resistance

11.4 Sources of electromotive force

Learning outcomes

Candidates should be able to:

(a) show an understanding that electric current is the rate of flow of charged particles

(b) define the coulomb

(c) recall and solve problems using the equation $Q = It$

(d) define potential difference and the volt

(e) recall and solve problems using $V = W/Q$

(f) recall and solve problems using $P = VI$, $P = I^2R$

(g) define resistance and the ohm

(h) recall and solve problems using $V = IR$

(i) sketch and explain the I-V characteristics of:

(i) a metallic conductor at constant temperature

(ii) a semiconductor diode

(iii) a filament lamp

(iv) a thermistor (thermistors will be assumed to be of the negative temperature-coefficient type).

P12. Circuits

Content

12.1 Practical circuits

12.2 Conservation of charge and energy

12.3 Use of the potential divider

Assumed knowledge

Candidates should be able to:

(a) recall and use appropriate circuit symbols as set out in the ASE publication *Signs, Symbols and Systematics: The ASE Companion to 16–19 Science* (2000)

(b) draw and interpret circuit diagrams containing sources, switches, resistors, ammeters, voltmeters, and/or any other type of component referred to in the syllabus.

Learning outcomes

Candidates should be able to:

(c) recall Kirchhoff's first law and appreciate the link to conservation of charge

(d) recall Kirchhoff's second law and appreciate the link to conservation of energy

(e) derive a formula for the combined resistance of two or more resistors in series, using Kirchhoff's laws

(f) solve problems using the formula for the combined resistance of two or more resistors in series

(g) derive a formula for the combined resistance of two or more resistors in parallel, using Kirchhoff's laws

(h) solve problems using the formula for the combined resistance of two or more resistors in parallel

(i) apply Kirchhoff's laws to solve simple circuit problems

(j) show an understanding of the use of a potential divider circuit as a source of variable potential difference (p.d.)

Modern physics

P13. Physics of the atom

Content

13.1 The nucleus

13.2 Isotopes

13.3 Nuclear processes

13.4 The nucleus of the atom: neutrons and protons, isotopes, proton and nucleon numbers

Assumed knowledge

Candidates should be able to:

(a) identify and describe protons, neutrons and electrons in terms of their relative charges and relative masses.

Learning outcomes

Candidates should be able to:

(b) describe the historical steps which led to the development of the Rutherford model from the Thomson 'plum-pudding' model of the atom:
   (i) describe the principles of the α-particle scattering experiment
   (ii) infer from the α-particle scattering experiment the Rutherford model of the atom including the existence of and the small size of the nucleus
   (iii) outline the development of the Bohr model of the atom (see Chemistry section C2)

(c) describe a simple model for the nuclear atom to include protons, neutrons and orbital electrons

(d) distinguish between nucleon number (mass number) and proton number (atomic number)

(e) show an understanding that an element can exist in various isotopic forms each with a different number of neutrons

(f) use the usual notation for the representation of nuclides

(g) appreciate that nucleon number, proton number, are conserved in nuclear processes

(h) represent simple nuclear reactions by nuclear equations of the form $^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}H$

(i) use nuclear equations to solve problems where there are two or more decays in a chain

(j) show an appreciation of the spontaneous and random nature of nuclear decay

(k) infer the random nature of radioactive decay from the fluctuations in count rate

(l) show an understanding of the nature and properties of α-, β- and γ-radiation including their deflection in electric fields (β^+ is not included and β–radiation will be taken to refer to β^-)

(m) deduce the behaviour of beams of protons, neutrons and electrons in electric fields

(n) describe the distribution of mass and charges within an atom

(o) deduce the numbers of protons, neutrons and electrons present in both atoms and ions given proton and nucleon numbers (and charge)

(p) describe the contribution of protons and neutrons to atomic nuclei in terms of proton number and nucleon number

(q) distinguish between isotopes on the basis of different numbers of neutrons present.

6.2 Chemistry

General chemistry

C1. Atoms, molecules and stoichiometry

Content

1.1 Relative masses of atoms and molecules

1.2 The mole, the Avogadro constant

1.3 The determination of relative atomic masses A_r and relative molecular masses M_r from mass spectra

1.4 The calculation of empirical and molecular formulae

1.5 Reacting masses and volumes (of solutions and gases)

1.6 The gaseous state: $pV = nRT$ (and its use in determining a value for M_r)

Assumed knowledge

Candidates should be able to:

(a) define and use the terms *relative atomic*, *isotopic*, *molecular* and *formula masses*, based on the ^{12}C scale.

Learning outcomes

[the term *relative formula mass* or M_r will be used for ionic compounds]

Candidates should be able to:

(b) define and use the term *mole* in terms of the Avogadro constant

(c) analyse simple mass spectra of uniatomic species in terms of m/e values (knowledge of the working of the mass spectrometer is not required)

(d) calculate the relative atomic mass of an element given the relative abundances of its isotopes, or its mass spectrum

(e) define and use the terms *empirical* and *molecular formulae*

(f) calculate empirical and molecular formulae, using combustion data, composition by mass or percentage by mass

(g) write balanced equations

(h) perform calculations, including use of the mole concept, involving:

- (i) reacting masses (from formulae and equations)
- (ii) volumes of gases using the ideal gas equation, $pV = nRT$
- (iii) volumes and concentrations of solutions

(i) deduce stoichiometric relationships from calculations such as those in (h).

C2. Atomic structure

Content

2.1 Electrons: electronic energy levels, ionisation energies, atomic orbitals, electron arrangements

Assumed knowledge

It will be assumed that candidates will be familiar with the content of 'Physics of the atom' from the Physics section P13.

Learning outcomes

Candidates should be able to:

(a) describe the number and relative energies of the s, p and d orbitals for the principal quantum numbers 1, 2 and 3 and also the 4s and 4p orbitals

(b) describe the shapes of s and p orbitals

(c) state the electronic configuration of atoms and ions for elements 1 to 36 using the convention $1s^2 2s^2 2p^6$ etc.

(d) explain and use the term *ionisation energy*

(e) explain the factors influencing the ionisation energies of elements

(f) explain the trends in ionisation energy across Period 3 and down the groups of the Periodic Table of Elements (see also section C7).

C3. Chemical bonding

Content

3.1 Ionic (electrovalent) bonding

3.2 Covalent bonding and co-ordinate (dative covalent) bonding

3.3 The shapes of simple molecules and ions

3.4 Trends in electronegativity

3.5 Bond energies, bond lengths and bond polarities

3.6 Intermolecular forces, including hydrogen bonding

3.7 Metallic bonding

3.8 Bonding and physical properties

3.9 Lattice structures

3.10 Redox processes: electron transfer and changes in oxidation number (oxidation state)

Assumed knowledge

Candidates should be able to:

(a) describe ionic (electrovalent) bonding, as in sodium chloride and magnesium oxide, including the use of 'dot-and-cross' diagrams.

Learning outcomes

Candidates should be able to:

(b) describe covalent bonding as involving a shared pair of electrons including co-ordinate (dative covalent) bonding, as for example in the formation of the ammonium ion and in the Al_2Cl_6 molecule

(c) explain the shapes of, and bond angles in, molecules and ions by using the qualitative model of electron-pair repulsion (including lone pairs), using simple examples such as CO_2 (linear), BF_3 (trigonal planar), CH_4 (tetrahedral), NH_3 (pyramidal), H_2O (bent or V shaped), PCl_5 (trigonal bipyramidal), SF_6 (octahedral), together with other species of similar shapes to these

(d) describe covalent bonding in terms of orbital overlap, giving σ and π bonds

(e) (i) explain and use the term *electronegativity*

(ii) explain the factors influencing the electronegativity of elements

(iii) explain the trends in electronegativity across Period 3 and down Group VII of the Periodic Table of Elements (see also section C7)

(f) explain the terms *bond energy*, *bond length* and *bond polarity* (attributed to difference in electronegativity) and use them to compare the reactivity of covalent bonds (see also sections C4 and C14)

(g) describe hydrogen bonding (attributed to a large difference in electronegativity), using ammonia and water as simple examples of molecules containing N-H and O-H groups

(h) outline the importance of hydrogen bonding to the physical properties of substances, including ethanol and water

(i) describe the intermolecular forces based on permanent dipoles and induced dipoles as in $CHCl_3$(l), Br_2(l) and the liquid noble gases

(j) describe metallic bonding in terms of the attraction between a lattice of positive ions and delocalised electrons

(k) describe, in simple terms, the lattice structure of a crystalline solid which is:

(i) ionic, as in sodium chloride, magnesium oxide

(ii) simple molecular, as in iodine

(iii) giant molecular, as in graphite; diamond; silicon(IV) oxide

(iv) metallic, as in copper

(the concept of unit cell is not required)

(l) describe, interpret and/or predict the effect of different types of bonding (ionic bonding, covalent bonding, hydrogen bonding, other intermolecular interactions, metallic bonding) on the physical properties of substances

(m) suggest, from quoted physical data, the type of structure and bonding present in a substance from given information

(n) show understanding of chemical reactions in terms of energy transfers associated with the breaking and making of chemical bonds

(o) explain redox reactions in terms of electron transfer and the changes in oxidation numbers (states) of atoms

(p) describe and explain the formation of salts from their elements as redox processes in terms of electron transfer and/or of changes in oxidation number (state).

C4. Chemical energetics

Content

4.1 Enthalpy changes: ΔH of formation, combustion, bond energy

4.2 Hess' Law

Learning outcomes

Candidates should be able to:

(a) explain that some chemical reactions are accompanied by energy changes, principally in the form of heat energy; the energy changes can be exothermic (ΔH negative) or endothermic (ΔH positive)

(b) explain and use the terms:
  (i) standard conditions
  (ii) enthalpy change of reaction, with particular reference to formation and combustion
  (iii) bond energy (ΔH positive, i.e. bond breaking)

(c) calculate enthalpy changes from appropriate experimental results, including the use of the relationship for thermal energy change $q = mc\Delta T$

(d) state and apply Hess' Law to construct simple energy cycles, and carry out calculations involving such cycles and relevant energy terms, with particular reference to:
  (i) determining enthalpy changes that cannot be found by direct experiment, e.g. an enthalpy change of formation from enthalpy changes of combustion
  (ii) average bond energies

(e) construct and interpret a reaction pathway diagram (reaction profile), in terms of the enthalpy change of the reaction and of the activation energy (see section C6).

C5. Equilibria

Content

5.1 Chemical equilibria: reversible reactions, dynamic equilibrium and factors affecting chemical equilibria

5.2 Ionic equilibria: Brønsted-Lowry theory of acids and bases

Learning outcomes

Candidates should be able to:

(a) explain, in terms of rates of the forward and reverse reactions, and of concentration, what is meant by a *reversible reaction* and a *dynamic equilibrium*

(b) state Le Chatelier's Principle and apply it to deduce qualitatively (from appropriate information) the effects of changes in temperature, concentration or pressure, on a system at equilibrium

(c) show understanding of and use the Brønsted-Lowry theory of acids and bases

(d) explain qualitatively the differences in behaviour between strong and weak acids and bases and the pH values of their aqueous solutions in terms of the extent of dissociation.

C6. Reaction kinetics

Content

6.1 Effect of temperature on rate; the concept of activation energy

6.2 Catalysis

6.3 The Boltzmann distribution applied to changes in temperature and the use of a catalyst

Learning outcomes

Candidates should be able to:

(a) explain and use the terms: rate of reaction, activation energy, catalysis

(b) explain qualitatively, in terms of collisions, the effect of concentration changes on the rate of a reaction

(c) show understanding, including reference to the Boltzmann distribution, of what is meant by the term *activation energy*

(d) explain qualitatively, in terms of the significance of changes to the Boltzmann distribution compared to changes in collision frequency, the effect of temperature change on the rate of a reaction

(e) (i) explain that, in the presence of a catalyst, a reaction has a different mechanism, i.e. one of lower activation energy

(ii) interpret this catalytic effect in terms of the Boltzmann distribution.

Inorganic chemistry

Overview

It is intended that the study should:

- be concerned primarily with aspects of selected ranges of elements and their compounds
- be based on a study of the patterns:
  (i) across Period 3 of the Periodic Table of Elements
  (ii) down Groups II and VII
- introduce the more important everyday aspects of nitrogen, sulfur and their compounds
- apply unifying themes to inorganic chemistry, such as structure (section C2), chemical bonding (section C3), redox (section C3), the reactions of ions, acid-base behaviour
- include:
  (i) the representation of reactions by means of balanced equations (molecular and/or ionic equations, together with state symbols)
  (ii) the interpretation of redox reactions in terms of changes in oxidation state of the specific atoms in the species involved.

C7. The Periodic Table: chemical periodicity

Content

7.1 Periodicity of physical properties of the elements: variation with proton number across the Period 3 (sodium to argon) of:

- 7.1.1 Atomic radius
- 7.1.2 Melting point
- 7.1.3 Electrical conductivity
- 7.1.4 Ionisation energy (see section C2)
- 7.1.5 Electronegativity (see section C3)

7.2 Periodicity of chemical properties of the elements in Period 3

- 7.2.1 Reaction of the elements with oxygen and water
- 7.2.2 Reactions of these oxides with water
- 7.2.3 Acid/base behaviour of these oxides and the corresponding hydroxides

Learning outcomes

Candidates should, for Period 3 (sodium to argon), be able to:

(a) describe qualitatively (and indicate the periodicity in) the variations in atomic radius, melting point and electrical conductivity of the elements

(b) explain qualitatively the variation in atomic radius

(c) interpret the variation in melting point and in electrical conductivity in terms of the presence of simple molecular, giant molecular or metallic bonding in the elements

(d) explain the variation in first ionisation energy (see section C2)

(e) explain the variation in electronegativity (see section C3)

(f) describe the reactions of the elements with:

- (i) oxygen (to give Na_2O; MgO; Al_2O_3; P_4O_{10}; SO_2; SO_3)
- (ii) water (Na and Mg only)

(g) describe the reactions, if any, of the oxides with water (treatment of peroxides and superoxides is not required)

(h) describe and explain the acid/base behaviour of oxides and hydroxides, including, where relevant, amphoteric behaviour in reaction with sodium hydroxide (only) and acids

(i) interpret the variations and trends in (f), (g) and (h) in terms of bonding and electronegativity

(j) suggest the types of chemical bonding present in oxides from observations of their chemical and physical properties

(k) predict the characteristic properties of an element in Group II and Group VII by using knowledge of chemical periodicity.

C8. Group II

Content

8.1 Similarities and trends in the properties of the Group II metals magnesium to barium and their compounds

8.2 Some uses of Group II compounds

Learning outcomes

Candidates should be able to:

(a) describe the reactions of the elements with oxygen, water and dilute acids

(b) describe the behaviour of the oxides, hydroxides and carbonates with water and with dilute acid

(c) describe the thermal decomposition of the nitrates and carbonates

(d) interpret, and make predictions from, the trends in physical and chemical properties of the elements and their compounds

(e) describe and explain the use of lime in agriculture and in building construction.

C9. Group VII

Content

9.1 The similarities and trends in the physical and chemical properties of chlorine, bromine and iodine

9.2 Characteristic physical properties

9.3 The relative reactivity of the elements as oxidising agents

9.4 Some reactions of the halide ions

9.5 The reactions of chlorine with water and with cold aqueous sodium hydroxide

9.6 The important uses of the halogens and of halogen compounds (see also section C15)

Learning outcomes

Candidates should be able to:

(a) describe the colours of and the trend in volatility of chlorine, bromine and iodine

(b) interpret the volatility of the elements in terms of van der Waals' forces

(c) describe and explain the relative reactivity of the elements as oxidising agents

(d) describe and explain the reactions of halide ions F^-(aq), Cl^-(aq), Br^-(aq) and I^-(aq) with:

  (i) aqueous solutions of the halogens Cl_2(aq), Br_2(aq) and I_2(aq)

  (ii) aqueous silver ions followed by aqueous ammonia

(e) describe and interpret in terms of changes of oxidation number the reaction of chlorine with water and with cold aqueous sodium hydroxide

(f) state the industrial importance and environmental significance of the halogens and their compounds, (e.g. for bleaches; PVC; halogenated hydrocarbons as solvents, refrigerants, in aerosols and in water purification) (see also section C14).

C10. Nitrogen and sulfur

Content

10.1 Nitrogen

- 10.1.1 Its unreactivity
- 10.1.2 Ammonia, the ammonium ion, nitric acid and fertilisers
- 10.1.3 The environmental impact of nitrogen oxides and nitrates

10.2 Sulfur

- 10.2.1 The formation of atmospheric sulfur dioxide, its role in acid rain formation
- 10.2.2 Sulfuric acid

Learning outcomes

Candidates should be able to:

(a) explain the lack of reactivity of nitrogen

(b) describe and explain:

- (i) the structure of the ammonium ion and its formation by an acid-base reaction
- (ii) the displacement of ammonia from its salts

(c) state the environmental consequences of the uncontrolled use of nitrate fertilisers

(d) state and explain the natural and man-made occurrences of oxides of nitrogen and their catalytic removal from the exhaust gases of internal combustion engines

(e) describe the formation of atmospheric sulfur dioxide from the combustion of sulfur contaminated carbonaceous fuels

(f) state that sulfur dioxide is involved in the formation of acid-rain and describe the main environmental consequences of acid-rain

Industrial processes

C11. Industrial processes

Content

11.1 Extraction of iron and the manufacture of steel

11.2 Electrolysis, industrial uses of electrolysis

11.3 The Haber process

11.4 The Contact process

Learning outcomes

Candidates should be able to:

(a) (i) describe the essential reactions in the extraction of iron from hematite

(ii) describe the conversion of iron into steel using magnesium (to remove sulfur), basic oxides and oxygen in the BOS (basic oxygen steelmaking) process

(iii) understand that the properties of iron may be changed by the controlled use of additives to form steel alloys

(b) name the uses of mild steel (car bodies and machinery) and stainless steel (chemical plant and cutlery)

(c) explain, including the electrode reactions, the industrial processes of:

(i) the extraction of aluminium from molten aluminium oxide/cryolite

(ii) the electrolytic purification of copper

(d) describe the Haber process for the manufacture of ammonia from its elements, giving essential operating conditions, and interpret these conditions (qualitatively) in terms of the principles of kinetics and equilibria (see also sections C5 and C6)

(e) state the industrial importance of ammonia and nitrogen compounds derived from ammonia

(f) describe the Contact process for the manufacture of sulfuric acid from SO_2, giving essential operating conditions, and interpret these conditions (qualitatively) in terms of the principles of kinetics and equilibria (see also sections C5 and C6).

Organic chemistry

Overview

Although there are features of organic chemistry topics that are distinctive, it is intended that appropriate cross-references with other sections/topics in the syllabus should be made.

When describing preparative reactions, candidates will be expected to quote the reagents, e.g. aqueous NaOH, the essential practical conditions, e.g. reflux, and the identity of each of the major products. Detailed knowledge of practical procedures is not required, however, candidates may be expected to suggest (from their knowledge of the reagents, essential conditions and products) what steps may be needed to purify/extract a required product from the reaction mixture. In equations for organic redox reactions, the symbols O and H are acceptable.

C12. Introductory topics

In each of the sections, C12 to C16, candidates will be expected to be able to predict the reaction products of a given compound in reactions that are chemically similar to those specified.

Content

12.1 Molecular, structural and empirical formulae

12.2 Functional groups and the naming of organic compounds

12.3 Characteristic organic reactions

12.4 Shapes of organic molecules σ and π bonds

12.5 Isomerism: structural; cis-trans

Learning outcomes

Candidates should be able to:

(a) interpret, and use the nomenclature, general formulae, structural formulae and displayed formulae of the following classes of compound:
- (i) alkanes, alkenes
- (ii) halogenoalkanes
- (iii) alcohols (including primary, secondary and tertiary)
- (iv) aldehydes and ketones
- (v) carboxylic acids
- (vi) amines (primary only), nitriles

(b) interpret, and use the following terminology associated with organic reactions:
- (i) functional group
- (ii) homolytic and heterolytic fission
- (iii) free radical, initiation, propagation, termination
- (iv) nucleophile, electrophile
- (v) addition, substitution, elimination, hydrolysis
- (vi) oxidation and reduction

(c) decribe and explain the shapes of the ethane, ethene molecules in terms of σ and π carbon-carbon bonds

(d) describe structural isomerism in terms of molecules that have the same molecular formula, but different structural formulae

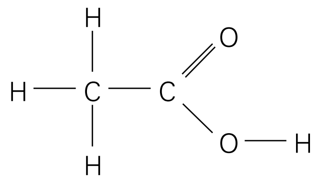
(e) describe cis-trans isomerism in alkenes, and explain its presence or absence in terms of restricted rotation, due to the presence of π bonds, and the atoms/groups attracted to the C=C atoms

(f) deduce the possible isomers for an organic molecule of known molecular formula
(g) identify cis-trans isomerism in a molecule of given structural formula.

General formulae
A general formula should show the functional group attached to an alkyl group, R, e.g. RCOOH for a carboxylic acid.

Structural formulae
In candidates' answers, an acceptable response to a request for a structural formula will be to give the minimal detail, using conventional groups, for an unambiguous structure, e.g. $CH_3CH_2CH_2OH$ for propan-1-ol, **not** C_3H_7OH and $CH_3CH{=}CHCH_3$ or $CH_3CHCHCH_3$ for butene, **not** C_4H_8.

Displayed formulae
A displayed formula should show both the relative placing of atoms and the number of bonds between them, e.g. for ethanoic acid:



C13. Hydrocarbons

Content
13.1 Alkanes
  13.1.1 Free-radical reactions
  13.1.2 Crude oil and 'cracking'
13.2 Alkenes
  13.2.1 Addition reactions
  13.2.2 Industrial importance
13.3 Hydrocarbons as fuels

Assumed knowledge
Candidates should be able to:

(a) explain the use of crude oil as a source of hydrocarbons

Learning outcomes
Candidates should be able to:

(b) show awareness of the general unreactivity of alkanes, including towards polar reagents
(c) describe the chemistry of alkanes involved in:
  (i) combustion
  (ii) substitution by chlorine and by bromine
(d) describe the mechanism of free-radical substitution with particular reference to the initiation, propagation and termination stages
(e) describe the chemistry of alkenes as exemplified, where relevant, by the following reactions:
  (i) addition of hydrogen, steam, hydrogen halides and halogens
  (ii) addition polymerisation (see section C16)

(f) describe the mechanism of electrophilic addition in symmetrical alkenes, to include the reaction of bromine with ethene and other symmetrical alkenes

(g) suggest how 'cracking' can be used to obtain more useful and valuable alkanes and alkenes of lower M_r from larger hydrocarbon molecules (no details of either the thermal cracking or catalytic cracking processes are required)

(h) describe and explain how the combustion reactions of alkanes lead to their use as fuels in industry, in the home and in transport

(i) recognise the environmental consequences of carbon monoxide, oxides of nitrogen and unburnt hydrocarbons arising from the internal combustion engine and of their catalytic removal (see section C10).

C14. Halogen derivatives

Content

14.1 Halogenoalkanes

- 14.1.1 Nucleophilic substitution
- 14.1.2 Hydrolysis
- 14.1.3 Formation of nitriles, primary amines
- 14.1.4 Elimination

14.2 Relative strength of the C-Hal bond

Learning outcomes

Candidates should be able to:

(a) recall the chemistry of halogenoalkanes as exemplified by:

- (i) the following nucleophilic substitution reactions of bromoethane; hydrolysis; formation of nitriles; formation of primary amines by reaction with ammonia
- (ii) the elimination of hydrogen bromide from 2-bromopropane

(b) describe the S_N2 mechanism of nucleophilic substitution in halogenoalkanes

C15. Alcohols, aldehydes, ketones and carboxylic acids

Content

15.1 Alcohols (exemplified by ethanol)

15.1.1 Reactions to include oxidation; dehydration

15.2 Aldehydes (exemplified by ethanal)

15.2.1 Characteristic tests for aldehydes

15.2.2 Oxidation to carboxylic acid

15.2.3 Reduction to primary alcohol

15.3 Ketones (exemplified by propanone)

15.3.1 Characteristic tests for ketones

15.3.2 Reduction to secondary alcohol

15.4 Carboxylic acids (exemplified by ethanoic acid)

15.4.1 Formation from primary alcohols, aldehydes and nitriles

15.4.2 Salt formation

Learning outcomes

Candidates should be able to:

(a) recall the chemistry of alcohols, exemplified by ethanol:
   (i) combustion
   (ii) oxidation to carbonyl compounds and carboxylic acids
   (iii) dehydration to alkenes

(b) classify hydroxy compounds into primary, secondary and tertiary alcohols:
   (i) suggest characteristic distinguishing reactions, e.g. mild oxidation
   (ii) the resistance of tertiary alcohols to oxidation using $Cr_2O_7^{2-}/H^+$ explained in terms of the absence of a hydrogen atom on the central carbon atom

(c) describe the formation of aldehydes and ketones from primary and secondary alcohols respectively using $Cr_2O_7^{2-}/H^+$

(d) compare the production of ethanol by fermentation, and by the catalytic addition of steam to ethene, in terms of conditions, rate, purity of product and required technology

(e) (i) describe the use of 2,4-dinitrophenylhydrazine (2,4-DNPH) reagent to detect the presence of carbonyl compounds
   (ii) describe the reduction of aldehydes and ketones, e.g. using $NaBH_4$

(f) deduce the nature (aldehyde or ketone) of an unknown carbonyl compound from the results of simple tests (i.e. Fehling's and Tollens' reagents; ease of oxidation)

(g) describe the formation of carboxylic acids from alcohols, aldehydes and nitriles

(h) describe the reactions of carboxylic acids in the formation of salts.

C16. Polymerisation

Content

16.1 Addition polymerisation

Learning outcomes

Candidates should be able to:

(a) describe the characteristics of addition polymerisation as exemplified by poly(ethene) and PVC

(b) write equations for the polymerisation of a given alkene monomer

(c) identify the monomer or monomers used in the formation of a given poly(alkene)

(d) recognise the difficulty of the disposal of poly(alkene)s, i.e. non-biodegradability and harmful combustion products.

7. Practical assessment

7.1 Introduction

Candidates should be directed towards the practice of experimental skills throughout the whole period of their course of study. As a guide, candidates should expect to spend at least 20% of their time doing practical work either individually or in small groups. This 20% does not include the time spent observing teacher demonstrations of experiments.

The practical work that candidates do during their course should aim to:

- provide learning opportunities so that candidates develop the skills they need to carry out experimental and investigative work
- reinforce the learning of the theoretical subject content of the syllabus
- instil an understanding of the interplay of experiment and theory in scientific method
- prove enjoyable, contributing to the motivation of candidates.

Candidates' experimental skills are assessed in Paper 4. The examiners are not strictly bound by the subject content of the syllabus in setting questions. Where appropriate, candidates are told exactly what to do and how to do it; only knowledge of theory and experimental skills within the syllabus are expected.

7.2 Paper 4: Advanced practical skills

Paper 4 is a timetabled, laboratory-based practical paper focusing on the following experimental skills:

- manipulation, measurement and observation (MMO)
- presentation of data and observations (PDO)
- analysis, conclusions and evaluation (ACE).

Each paper will consist of two questions, each of 45 minutes and each of 15 marks. One question will be based on the physics section of the syllabus, and one question will be based on the chemistry section.

7.3 Mark scheme for Paper 4

Paper 4 is marked based on using the generic mark scheme, for each 15-mark question. There are 30 marks overall. The expectations for each mark category are listed in the sections that follow.

Practical skill	Minimum mark allocation (for each question)
Manipulation, measurement and observation (MMO)	4 marks
Presentation of data and observations (PDO)	2 marks
Analysis, conclusions and evaluation (ACE)	4 marks

The remaining 5 marks for each 15 mark question, will be allocated across the skills and their allocation may vary from series to series.

Manipulation, measurement and observation (MMO)

Successful collection of data and observations
Candidates should be able to:

- set up apparatus correctly
- follow instructions given in the form of written instructions or diagrams or circuit diagrams
- use their apparatus to collect an appropriate quantity of data or observations, including subtle differences in colour, solubility or quantity of materials
- repeat readings where appropriate
- make measurements using common laboratory apparatus such as millimetre scales, protractors, stopwatches, top pan balances, newton meters, analogue and digital electrical meters, pipettes, burettes, measuring cylinders, thermometers
- use both analogue and digital scales.

Some candidates may be unable to set up their apparatus without help. Such candidates may ask for assistance from the supervisor. Supervisors will be given clear instructions on what assistance may be given to candidates, but this assistance should never go beyond the minimum necessary to enable candidates to take some readings. Under no circumstances should help be given with presentation of data, analysis, or evaluation sections. All assistance must be reported to the examiners, and candidates who require assistance will not be able to score full marks for the successful collection of data.

Systematic analysis and a knowledge of traditional methods of separation will not be required. It will be assumed that candidates are familiar with:

(i) the reactions of the following cations: NH_4^+; Mg^{2+}; Al^{3+}; Ca^{2+}; Cr^{3+}; Fe^{2+}; Fe^{3+}; Cu^{2+}; Zn^{2+}; Ba^{2+}; Pb^{2+};

(ii) the reactions of the following anions: CO_3^{2-}; NO_3^-; NO_2^-; SO_4^{2-}; SO_3^{2-}; Cl^-; Br^-; I^-;

(iii) tests for the following gases: NH_3; CO_2; Cl_2; H_2; O_2; SO_2, as detailed in the qualitative analysis notes which will be included with the question paper and are reproduced at the end of the section.

The substances to be investigated may contain ions not included in the above list: in such cases, candidates are not expected to identify the ions but only to draw conclusions of a general nature.

Candidates should not attempt tests other than those specified, except when it is appropriate to test for a gas.

Exercises requiring a knowledge of simple organic reactions, e.g. test-tube reactions indicating the presence of unsaturated, alcoholic and carboxylic groups may also be set, but this would be for the testing of observation skills and drawing general conclusions only.

A knowledge of volumetric determination of acids and alkalis using the materials listed in section 8.2 will be expected. Simple titrations involving other reagents may also be set but, where appropriate, sufficient working details will be given.

Candidates should normally record burette readings to the nearest 0.05 cm^3 and temperature readings to the nearest 0.5 °C when using a thermometer calibrated in 1 °C intervals and to the nearest 0.1 °C where the interval is 0.2 °C.

Quality of measurements or observations
Candidates should be able to:

- make accurate and consistent measurements and observations.

Marks are awarded for measured data in which the values obtained are reasonable. Marks will be awarded for consistency and accuracy of readings. In some cases, the candidate's data may be compared with information supplied by the supervisor or known to the examiners. The examiners only consider the extent to which the candidate has affected the quality of the data. Allowances are made where the quality of data is limited by the experimental method required or by the apparatus used.

In other cases, the award of the mark is based on the scatter of points on a graph.

In qualitative experiments, precise descriptions and comparisons of colour or other observations are expected.

In a titration with a good end-point, candidates are expected to record two titres within 0.10 cm^3.

Range and distribution of values
Candidates should be able to:

- make measurements that span the largest possible range of values within the limits either of the equipment provided or of the instructions given
- make measurements whose values are appropriately distributed within this range.

In most experiments, including those involving straight-line graphs, a regularly-spaced set of measurements will be appropriate. For other experiments, such as those requiring the peak value of a curved graph to be determined, it may be appropriate for the measurements to be concentrated in one part of the range investigated. Candidates are expected to be able to identify the most appropriate distribution of values.

Decisions relating to measurements or observations
Candidates should be able to:

- decide how many tests or observations to perform
- make measurements that span a range and have a distribution appropriate to the experiment
- decide how long to leave experiments running before making readings
- identify where repeated readings or observations are appropriate and calculate means where necessary
- identify where confirmatory tests are appropriate and the nature of such tests
- choose reagents to distinguish between given ions.

Candidates may need to choose how many tests, measurements and observations can be made in the time available. Candidates are expected to be able to identify the most appropriate range and distribution of values. In some experiments a regularly-spaced set of measurements is appropriate.

Repeated readings of particular quantities are often necessary in physical science in order to obtain accurate mean values and minimise experimental error. Individual readings or observations should be repeated where they appear to be anomalous.

In qualitative analysis experiments, candidates are expected to identify appropriate confirmatory tests.

Presentation of data and observations (PDO)

Table of results: layout

Candidates should be able to:

- present numerical data and values in a single table of results
- draw up the table in advance of taking readings so that they do not have to copy up their results
- include in the table of results columns for raw data and for values calculated from them
- use column headings that include both the quantity and the unit and that conform to accepted scientific conventions.

As an example of accepted practice in column headings, if the quantity being measured is current in milliamperes, then 'I/mA' would be the usual way to write the column heading, but 'I in mA' or 'I (mA)' would be allowed. Headings such as 'I mA' or just 'mA' are not acceptable. The quantity or the unit, or both, may be written in words rather than symbols. Conventional symbols or abbreviations, such as p.d. (for potential difference), may be used without explanation.

Table of results: raw data

Candidates should be able to:

- record raw readings of a quantity to the same degree of precision.

For example, if one measurement of length in a column of raw data is given to the nearest millimetre, then all the lengths in that column should be given to the nearest millimetre. The degree of precision used should be compatible with the measuring instrument used: it would be inappropriate to record a distance measured on a millimetre scale as '2 cm'.

Table of results: calculated quantities

Candidates should be able to:

- calculate other quantities from their raw data
- use the correct number of significant figures for these calculated quantities.

Except where they are produced by addition or subtraction, calculated quantities should be given to the same number of significant figures as (or one more than) the measured quantity of least accuracy. For example, if values of a potential difference and of a current are measured to 2 and 4 significant figures respectively, then the corresponding resistance should be given to 2 or 3 significant figures, but not 1 or 4.

Data layout

Candidates should be able to:

- use the appropriate presentation medium to produce a clear presentation of the data
- select which variables to plot against which and decide whether the graph should be drawn as a straight line or a curve
- plot appropriate variables on clearly labelled x- and y-axes
- choose suitable scales for graph axes
- plot all points or bars to an appropriate accuracy
- follow the ASE recommendations for putting lines on graphs.

Graph: layout

Candidates should be able to:

- choose a suitable and clear method of presenting the data, e.g. tabulations, graph or mixture of methods of presentation
- plot the independent variable on the *x*-axis and the dependent variable on the *y*-axis, except where the variables are conventionally plotted the other way around
- clearly label graph axes with both the quantity and the unit, following accepted scientific conventions
- choose scales for graph axes such that the data points occupy at least half of the graph grid in both *x*- and *y*-directions
- use a false origin where appropriate
- choose scales for the graph axes that allow the graph to be read easily, such as 1, 2 or 5 units to a 2 cm square
- place regularly-spaced numerical labels along the whole of each axis.

The accepted scientific conventions for labelling the axes of a graph are the same as for the column headings in a table of results.

Graph: plotting of points

Candidates should be able to:

- plot all their data points on their graph grid to an accuracy of better than 1 mm
- points should be finely drawn with a sharp pencil, but must still be visible. A fine cross or an encircled dot is suitable; a thick pencil blob is not.

Graph: trend line

Candidates should be able to:

- identify when the trend of a graph is linear or curved
- draw straight lines of best fit or curves to show the trend of a graph
- draw tangents to curved trend lines
- draw a trend line to show an even distribution of points on either side of the line along its whole length; lines should be finely drawn and should not contain kinks or breaks
- draw two curves or lines and find the intersection
- find an unknown value by using co-ordinates or intercepts on a graph
- determine the gradient of a straight-line graph or of a tangent to a curve
- determine the *y*-intercept of a straight-line graph or of a tangent to a curve, including where these are on graphs with a false origin
- evaluate the effectiveness of control variables.

Display of calculation and reasoning

Candidates should be able to:

- show their working in calculations, and the key steps in their reasoning
- justify the number of significant figures in a calculated quantity.

Analysis, conclusions and evaluation (ACE)

Interpretation of data or observations and identifying sources of error

Candidates should be able to:

- describe the patterns and trends shown by graphs and tables
- relate straight-line graphs to equations of the form $y = mx + c$, and hence to derive expressions that equate to the gradient or the y-intercept of their graphs
- read the co-ordinates of points on the trend line of a graph
- interpret the gradient of a straight-line graph or of a tangent to a curve
- interpret the y-intercept of a straight-line graph or of a tangent to a curve, including where these are on graphs with a false origin
- describe and summarise the key points of a set of observations
- calculate other quantities from data, or calculate the mean from repeated values, or make other appropriate calculations
- identify the most significant sources of error in an experiment
- estimate, quantitatively, the uncertainty in quantitative measurements
- express such uncertainty in a measurement as an absolute.

When a gradient is to be determined, the points on the line chosen for the calculation should be separated by at least half of the length of the line drawn.

In cases where the y-intercept cannot be read directly from the y-axis, it is expected that the co-ordinates of a point on the line and the gradient will be substituted into $y = mx + c$.

Candidates should be used to looking at experiments and assessing the relative importance of errors in measurement or in making observations so that they can judge which sources of error are most important. Candidates should be familiar with simple means of estimating error, such as the errors intrinsic in measuring devices or in the observer's ability to observe, or in experiments where limitations of the method introduce errors (e.g. energy loss when trying to assess enthalpy change). They should be able to express these errors in standard forms such as length = 73 mm ± 1 mm, or temperature increase = 14 °C ± 4 °C.

Candidates should be able to suggest which of the sources of error described are likely to be systematic errors such as those resulting from thermometers that consistently read 1 °C above actual temperature, or candidates who read volumes to the wrong part of the meniscus, as well as those which are likely to be random errors due to variability of materials, or random variations in room temperature.

Drawing conclusions

Candidates should be able to:

- draw conclusions from an experiment, including determining the values of constants, considering whether experimental data supports a given hypothesis, and making predictions
- draw conclusions from an experiment, giving an outline description of the main features of the data, considering whether experimental data supports a given hypothesis, and making further predictions
- draw conclusions from interpretations of observations, data and calculated values
- make scientific explanations of the data, observations and conclusions that they have described.

Hypotheses that are being tested in the practical paper will be given, although hypothesis formulation is in assessment objective B, and thus may be tested in the theory components. Conclusions may be expressed in terms of support for, or refutation of, hypotheses, or in terms of the deductions or inductions that can logically be made from the data, observations or calculated values.

Simple scientific explanations form a part of such conclusions and therefore form a part of this practical assessment, in which the candidates will be expected to refer to knowledge and understanding gained in their theory part of the course in order to provide explanations of their practical conclusions.

Suggesting improvements
Candidates should be able to:

- suggest modifications to an experimental arrangement that will improve the accuracy of the experiment or the accuracy of the observations that can be made
- describe such modifications clearly in words or diagrams.

Candidates' suggestions should be realistic, so that in principle they are achievable in practice, although they may include the use of apparatus that is not available to the candidate (e.g. a colorimeter). The suggestions may relate either to the apparatus used, to the experimental procedure followed or to the nature of the observations or the means used to make them. Candidates may include improvements that they have actually made while carrying out the experiment, such as repeating readings. The suggested modifications may relate to sources of error identified by the candidate or to other sources of error. Extensions of the investigation should not be confused with improvements to the investigation.

Estimating uncertainties
Candidates should be able to:

- estimate, quantitatively, the uncertainty in their measurements
- express the uncertainty in a measurement as an actual, fractional or percentage uncertainty, and translate between these forms.

Identifying limitations
Candidates should be able to:

- identify and describe the limitations in an experimental procedure
- identify the most significant sources of uncertainty in an experiment
- show an understanding of the distinction between systematic errors (including zero errors) and random errors.

Display of calculation and reasoning
Candidates should be able to:

- show their working in calculations, and the key steps in their reasoning
- use the correct number of significant figures for calculated quantities.

Where calculations are done, all of the key stages in the calculation should be recorded by candidates, so the credit can be given for correctly displaying working. Similarly, where observations form the basis for logical deduction (e.g. the concentration of a solution or the identity of an unknown substance), the steps in making the deduction should be shown. Again, where inductive thought processes are used to build up a general prediction or to support a general theory, from specific observations, the sequence of steps used should be reported.

Calculated quantities should be given to the same number of significant figures (or one more than) the measured quantity of least accuracy. For example, if titre volume is measured to four significant figures, e.g. 23.45 cm^3, then the corresponding molar concentration should be given to four significant figures, e.g. 1.305 mol dm^{-3} or 0.9876 mol dm^{-3}.

7.4 Administration of Paper 4

Detailed regulations on the administration of Cambridge practical examinations are contained in the *Cambridge Handbook*, which can be downloaded from **www.cie.org.uk**

A document called the Confidential Instructions will be despatched to Centres, usually about six weeks before the date of the examination. The Confidential Instructions detail the apparatus that will be required and how it should be laid out for candidates, and contain sufficient details to allow testing of the apparatus. Centres should contact the Despatch Department at Cambridge if they believe the Instructions have not been received.

Access to the question paper itself is not permitted in advance of the examination. It is essential that absolute confidentiality be maintained in advance of the examination date: the contents of the Confidential Instructions must **not** be revealed either directly or indirectly to candidates.

The Confidential Instructions contain a Supervisor's Report Form. A copy of this form must be completed and enclosed in each envelope of scripts. Centres are required to provide a sample set of results for both practical tasks and give details of any local difficulties with apparatus.

Preparation
Details of the specific requirements for apparatus and materials for a particular examination are given in the Confidential Instructions which are sent to Centres several weeks prior to the examination. These Instructions also contain advice about colour-blind candidates.

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

The attention of Centres is drawn to the *Cambridge Handbook* which contains a section on Science Syllabuses which includes information about arrangements for practical examinations.

Detailed guidance on preparing the standard bench reagents and indicators will **not** be given in the Confidential Instructions. The Confidential Instructions will refer Supervisors to the following guidance notes in this syllabus document. The following hazard codes are used where relevant.

C = corrosive substance	**F** = highly flammable substance
H = harmful or irritating substance	**O** = oxidising substance
T = toxic substance	**N** = dangerous for the environment

The attention of Centres is drawn to any local regulations relating to safety, first-aid and disposal of chemicals. "Hazard Data Sheets" should be available from your chemical supplier.

8. Apparatus requirements

The apparatus requirements for Paper 4 vary from series to series. A complete list of apparatus and materials required for each question is given in the Confidential Instructions for each series. The Confidential Instructions should be followed very carefully. If there is any doubt about how the practical examinations should be set up or if a particular chemical is impossible to obtain, it is vital that Centres contact Cambridge as soon as possible.

To provide some variation in the questions set, some novel items of equipment or material may be required. The list of practical apparatus and materials at the end of this section gives details of the requirements that are frequently required. Centres should keep these in stock and candidates should be accustomed to using these.

Guidance for the preparation of reagents for qualitative analysis and titration indicators is given at the end of this section. These instructions will not be given in the Confidential Instructions; instead the Supervisor will be referred to the syllabus.

8.1 Physics apparatus and materials

The list below gives some of the items that are regularly used in the practical test. The list is not intended to be exhaustive; in particular, to instil some variation in the questions set, some novel items are usually required. If there is any doubt about the interpretation of the Confidential Instructions or the suitability of the apparatus available, enquiries should be sent to the Product Manager for Physical Science at Cambridge, using either e-mail (**info@cie.org.uk**) or fax (+44 1223 553558) or telephone (+44 1223 553554).

Ammeter: (digital or analogue) f.s.d. 100 mA and 1 A (digital multimeters are suitable)
Cells: 1.5 V
Lamp and holder: 6 V 60 mA; 2.5 V 0.3 A
Leads and crocodile clips
Power supply: variable up to 12 V d.c. (low resistance)
Rheostat/variable resistor
Switch
Voltmeter: (digital or analogue) f.s.d. 5 V, 10 V (digital multimeters are suitable)
Wire: constantan 26, 28, 30, 32, 34, 36, 38 s.w.g. or metric equivalents

Long stem thermometer: –10 °C to 110 °C × 1 °C
Means to heat water safely to boiling (e.g. an electric kettle)
Plastic or polystyrene cup 200 cm^3
Stirrer

Balance to 0.1 g (this item may often be shared between sets of apparatus)
Bar magnet
Bare copper wire: 18, 26 s.w.g.

Beaker: 100 cm^3, 200 cm^3 or 250 cm^3
Adhesive putty (Blu-Tack)
Card
Expendable steel spring
G-clamp

Magnadur ceramic magnets
Mass hanger
Newton-meter (1 N, 10 N)
Pendulum bob
Modelling clay (Plasticine)
Protractor
Pulley
Rule with a millimetre scale (1 m, 0.5 m, 300 mm)
Scissors
Sticky tape (Sellotape)
Slotted masses (100 g, 50 g, 20 g, 10 g) or alternative
Spring
Stand, boss and clamp
Stopwatch (candidates may use their wristwatches), reading to 0.1 s or better
Stout pin or round nail
String/thread/twine
Wire cutters
Wood or metal jaws

8.2 Chemistry apparatus and materials

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

Glassware should where possible conform to the quality specifications given, or Supervisors should otherwise satisfy themselves that the glassware used is of an appropriate accuracy.

Two burettes, 50 cm^3 (ISO385 or grade B)
Two pipettes, 25 cm^3 (ISO648 or grade B)
One pipette, 10 cm^3 (ISO648 or grade B)
Teat/squeeze/dropping pipettes
One pipette filler
Conical flasks: three within range 150 cm^3 to 250 cm^3
One-mark graduated volumetric flask, 250 cm^3 (ISO1042 or grade B)
Measuring cylinders, 10 cm^3, 25 cm^3 and 50 cm^3 (ISO6706 or ISO4788 or grade B)
Wash bottle
Two filter funnels
Porcelain crucible, approximately 15 cm^3, with lid
Evaporating basin, at least 30 cm^3
Beakers, squat form with lip: 100 cm^3, 250 cm^3
Thermometers: –10 °C to +110 °C at 1 °C; –5 °C to +50 °C at 0.2 °C
Plastic beaker, e.g. polystyrene, of approximate capacity 150 cm^3
Test-tubes (some of which should be Pyrex or hard glass) approximately 125 mm × 16 mm
Boiling tubes, approximately 150 mm × 25 mm
Clocks (or wall-clock) to measure to an accuracy of about 1s (Where clocks are specified, candidates may use their own wrist watches if they prefer.)
Balance, single-pan, direct reading, minimum accuracy 0.1 g (1 per 8–12 candidates) weighing to 300 g

It is suggested that the following chemicals be used in the Centre as part of the practical course. These chemicals may also be required for the practical examination. Practical examinations may also require chemicals that are not listed.

For titration

Acid/base titration
common laboratory acids (hydrochloric acid, sulfuric acid, nitric acid)
a weak acid such as ethanoic or propanoic acid
sodium hydroxide
sodium carbonate
methyl orange or screened methyl orange indicator or bromophenol blue indicator or thymol blue or thymathalein

For qualitative analysis

Bench reagents
aqueous ammonia (approximately 2.0 mol dm^{-3})
aqueous sodium hydroxide (approximately 2.0 mol dm^{-3})
hydrochloric acid (approximately 2.0 mol dm^{-3})
nitric acid (approximately 2.0 mol dm^{-3})
sulfuric acid (approximately 1.0 mol dm^{-3})
aqueous potassium dichromate(VI) (approximately 1.0 mol dm^{-3})
aqueous barium nitrate or aqueous barium chloride (approximately 0.1 mol dm^{-3})
aqueous lead(II) nitrate (approximately 0.1 mol dm^{-3})
aqueous silver nitrate (approximately 0.05 mol dm^{-3})
limewater (a saturated solution of calcium hydroxide) and the equipment normally used by the Centre to test for carbon dioxide
red and blue litmus paper
universl indicator paper
splints
aluminium foil

Inorganic analysis
the carbonates (where they exist), sulfates, nitrates and chlorides of the cations listed in the Qualitative Analysis Notes
the sodium and potassium salts of the anions listed in the Qualitative Analysis Notes

Organic analysis
the reagents necessary to perform the reactions of alcohols (primary, secondary, tertiary), aldehydes, ketones, and carboxylic acids listed in the theory syllabus

9. Appendix

9.1 Guidance for the preparation of reagents for qualitative analysis and indicators

Hazard	Label	Identity	Instructions
[H]	**dilute hydrochloric acid**	2.0 mol dm^{-3} HCl	Dilute 170 cm^3 of concentrated (35-37%; approximately 11 mol dm^{-3}) acid **[C]** to 1 dm^3.
[C]	**dilute nitric acid**	2.0 mol dm^{-3} HNO_3	Dilute 128 cm^3 of concentrated (70% w/v) acid **[C] [O]** to 1 dm^3.
[H]	**dilute sulfuric acid**	1.0 mol dm^{-3} H_2SO_4	Cautiously pour 55 cm^3 of concentrated (98%) sulfuric acid **[C]** into 500 cm^3 of distilled water with continuous stirring. Make the solution up to 1 dm^3 with distilled water. **Care –** *concentrated H_2SO_4 is very corrosive.*
[H]	**aqueous ammonia**	2.0 mol dm^{-3} NH_3	Dilute 112 cm^3 of concentrated (35%) ammonia **[C] [N]** to 1 dm^3.
[C]	**aqueous sodium hydroxide**	2.0 mol dm^{-3} NaOH	Dissolve 80.0 g of NaOH **[C]** in each dm^3 of solution. **Care –** *the process of solution is exothermic and any concentrated solution is very corrosive.*
[T] [H]	**aqueous barium chloride** **[*or* aqueous barium nitrate]**	0.1 mol dm^{-3} barium chloride [or 0.1 mol dm^{-3} barium nitrate]	Dissolve 24.4 g of $BaCl_2.2H_2O$ **[T]** (or 26.1 g of $Ba(NO_3)_2$ **[H] [O]**) in each dm^3 of solution.
[H] [N]	**aqueous silver nitrate**	0.05 mol dm^{-3} silver nitrate	Dissolve 8.5 g of $AgNO_3$ **[C] [N]** in each dm^3 of solution.
[T] [N]	**aqueous lead(II) nitrate**	0.1 mol dm^{-3} lead(II) nitrate	Dissolve 33.1 g of $Pb(NO_3)_2$ **[T] [O] [N]** in each dm^3 of solution.
[H]	**limewater**	saturated aqueous calcium hydroxide, $Ca(OH)_2$	Prepare fresh limewater by leaving distilled water to stand over solid calcium hydroxide **[H]** for several days, shaking occasionally. Decant or filter the solution.
[T] [N]	**acidified aqueous potassium dichromate(VI)**	0.05 mol dm^{-3} $K_2Cr_2O_7$, 0.05 mol dm^{-3} H_2SO_4	Dissolve 14.8 g of $K_2Cr_2O_7$ **[T] [N]** in 50 cm^3 of 1 mol dm^{-3} sulfuric acid **[H]**. Make the solution up to 1 dm^3 with distilled water. *The use of plastic gloves may be considered to prevent contact with skin.*
	methyl orange indicator	methyl orange indicator (pH range 2.9 to 4.6)	Use commercially produced solution or dissolve 0.4 g of solid indicator **[H]** in 200 cm^3 of ethanol (IMS) **[F]** and make up to 1 dm^3 with distilled water.
	bromophenol blue indicator	bromophenol blue indicator (pH range 3.0 to 4.5)	Dissolve 0.4 g of the solid indicator **[H]** in 200 cm^3 of ethanol (IMS) **[F]** and make up to 1 dm^3 with distilled water.

9.2 Qualitative analysis notes

[Key: ppt. = precipitate]

Reactions of aqueous cations

cation	reaction with	
	NaOH(aq)	NH_3(aq)
aluminium, Al^{3+}(aq)	white ppt. soluble in excess	white ppt. insoluble in excess
ammonium, NH_4^+(aq)	no ppt. ammonia produced on heating	–
barium, Ba^{2+}(aq)	no ppt. (if reagents are pure)	no ppt.
calcium, Ca^{2+}(aq)	white ppt. with high [Ca^{2+}(aq)]	no ppt.
chromium (III), Cr^{3+}(aq)	grey-green ppt. soluble in excess giving dark green solution	grey-green ppt. insoluble in excess
copper(II), Cu^{2+}(aq)	pale blue ppt. insoluble in excess	blue ppt. soluble in excess giving dark blue solution
iron(II), Fe^{2+}(aq)	green ppt. turning brown on contact with air insoluble in excess	green ppt. turning brown on contact with air insoluble in excess
iron(III), Fe^{3+}(aq)	red-brown ppt. insoluble in excess	red-brown ppt. insoluble in excess
magnesium, Mg^{2+}(aq)	white ppt. insoluble in excess	white ppt. insoluble in excess
manganese(II), Mn^{2+}(aq)	off-white ppt. rapidly turning brown on contact with air insoluble in excess	off-white ppt. rapidly turning brown on contact with air insoluble in excess
zinc, Zn^{2+}(aq)	white ppt. soluble in excess	white ppt. soluble in excess

Reactions of anions

ion	reaction
carbonate, CO_3^{2-}	CO_2 liberated by dilute acids
chloride, Cl^-(aq)	gives white ppt. with Ag^+(aq) (soluble in NH_3(aq))
bromide, Br^-(aq)	gives cream ppt. with Ag^+(aq) (partially soluble in NH_3 (aq))
iodide, I^-(aq)	gives yellow ppt. with Ag^+(aq) (insoluble in NH_3(aq))
nitrate, NO_3^-(aq)	NH_3 liberated on heating with OH^-(aq) and Al foil
nitrite, NO_2^-(aq)	NH_3 liberated on heating with OH^-(aq) and Al foil; NO liberated by dilute acids (colourless NO → (pale) brown NO_2 in air)
sulfate, SO_4^{2-}(aq)	gives white ppt. with Ba^{2+}(aq) (insoluble in excess dilute strong acids)
sulfite, SO_3^{2-}(aq)	SO_2 liberated with dilute acids; gives white ppt. with Ba^{2+}(aq) (soluble in excess dilute strong acids)

Tests for gases

gas	test and test result
ammonia, NH_3	turns damp red litmus paper blue
carbon dioxide, CO_2	gives a white ppt. with limewater (ppt. dissolves with excess CO_2)
chlorine, Cl_2	bleaches damp litmus paper
hydrogen, H_2	"pops" with a lighted splint
oxygen, O_2	relights a glowing splint
sulfur dioxide, SO_2	turns acidified aqueous potassium manganate(VII) from purple to colourless

9.3 Safety in the laboratory

Responsibility for safety matters rests with Centres. Attention is drawn to 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.secmbfr.htm

Websites
http://www.chemsoc.org/networks/learnnet/Safety.htm
http://www.ncbe.reading.ac.uk/NCBE/SAFETY/menu.html
http://www.microbiologyonline.org.uk/safety.html

Publications
Safeguards in the School Laboratory, ASE, 11th Edition, 2006
Topics in Safety, ASE, 3rd Edition, 2001
CLEAPSS Laboratory Handbook, updated 2005 (available to CLEAPSS members only)
CLEAPSS Hazcards, 2005 update of 1995 edition (available to CLEAPSS members only)
Safety in Science Education, DfES, HMSO, 1996
Safe Practices in Chemical Laboratories, the Royal Society of Chemistry, 1989
Safety in Science Laboratories, DES Safety Series, 2, HMSO, 1976
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,
http://www.opsi.gov.uk/SI/si2002/20022677.htm, a brief guide may be found at
http://www.hse.gov.uk/pubns/indg136.pdf

9.4 Mathematical requirements

It is assumed that candidates will be competent in the techniques described below.

(a) Make calculations involving addition, subtraction, multiplication and division of quantities

(b) Make approximate evaluations of numerical expressions

(c) Express small fractions as percentages, and vice versa

(d) Calculate an arithmetic mean

(e) Transform decimal notation to power of ten notation (standard form)

(f) Use tables or calculators to evaluate logarithms (for pH calculations), squares, square roots, and reciprocals

(g) Change the subject of an equation (most such equations involve only the simpler operations but may include positive and negative indices and square roots)

(h) Substitute physical quantities into an equation using consistent units so as to calculate one quantity; check the dimensional consistency of such calculations

(i) Solve simple algebraic equations

(j) Comprehend and use the symbols/notations $<$, $>$, $\approx$, /, Δ, $\equiv$, $\bar{x}$ (or $<x>$)

(k) Test tabulated pairs of values for direct proportionality by a graphical method or by constancy of ratio

(l) Select appropriate variables and scales for plotting a graph, especially to obtain a linear graph of the form $y = mx + c$

(m) Determine and interpret the gradient and intercept of a linear graph

(n) Choose by inspection a straight line that will serve as the 'least bad' linear model for a set of data presented graphically

(o) (i) understand the slope of a tangent to a curve as a measure of rate of change

(ii) understand the 'area' below a curve where the area has physical significance, e.g. Boltzmann distribution curves

(p) Comprehend how to handle numerical work so that significant figures are neither lost unnecessarily nor used beyond what is justified

(q) Estimate orders of magnitude.

Calculators

If calculators are to be used, it is suggested that they should have the following functions:
$+$, $-$, $\times$, $\div$, $\sqrt{x}$, x^2, x^y, $\log x$ and $\ln x$. A *memory* function may be useful but is not essential.

Arithmetic

Candidates should be able to:

(a) recognise and use expressions in decimal and standard form (scientific) notation

(b) use appropriate calculating aids (electronic calculator or tables) for addition, subtraction, multiplication and division. Find arithmetic means, powers (including reciprocals and square roots), sines, cosines, tangents (and the inverse functions)

(c) take account of accuracy in numerical work and handle calculations so that significant figures are neither lost unnecessarily nor carried beyond what is justified

(d) make approximate evaluations of numerical expressions (e.g. $\pi^2 \approx 10$) and use such approximations to check the magnitude of calculated resultss.

Algebra

Candidates should be able to:

(a) substitute physical quantities into physical equations using consistent units and check the dimensional consistency of such equations

(b) formulate simple algebraic equations as mathematical models of physical situations, and identify inadequacies of such models

(c) comprehend and use the symbols $<$, $>$, $\ll$, $\gg$, $\approx$, /, $\propto$, $<x>$, Σ, Δx, δx, $\sqrt{\ }$.

Geometry and trigonometry

Candidates should be able to:

(a) calculate areas of right-angled and isosceles triangles, circumference and area of circles, areas and volumes of rectangular blocks, cylinders and spheres

(b) use Pythagoras' theorem, similarity of triangles, the angle sum of a triangle

(c) use sines, cosines and tangents (especially for 0°, 30°, 45°, 60°, 90°)

(d) understand the relationship between degrees and radians (defined as arc/radius), translate from one to the other and use the appropriate system in context.

Vectors

Candidates should be able to:

(a) find the resultant of two coplanar vectors, recognising situations where vector addition is appropriate.

Graphs

Candidates should be able to:

(a) translate information between graphical, numerical, algebraic and verbal forms

(b) select appropriate variables and scales for graph plotting

(c) for linear graphs, determine the slope, intercept and intersection

(d) choose, by inspection, a straight line which will serve as the line of best fit through a set of data points presented graphically

(e) draw a curved trend line through a set of data points presented graphically, when the arrangement of these data points is clearly indicative of a non-linear relationship

(f) recall standard linear form $y = mx + c$ and rearrange relationships into linear form where appropriate

(g) sketch and recognise the forms of plots of common simple expressions such as $1/x$, x^2, $\sin x$, $\cos x$, e^{-x}

(h) understand, draw and use the slope of a tangent to a curve as a means to obtain the gradient, and use notation in the form $\mathrm{d}y/\mathrm{d}x$ for a rate of change

(i) understand and use the area below a curve where the area has physical significance.

9.5 Glossary of terms used in Physical Science papers

It is hoped that the glossary will prove helpful to candidates as a guide, although it is not exhaustive. 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. They should also note that the number of marks allocated for any part of a question is a guide to the depth of treatment required for the answer.

1. *Define (the term(s)* ...) is intended literally. Only a formal statement or equivalent paraphrase, such as the defining equation with symbols identified, being required.
2. *What is meant by* ... 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. *Explain* may imply reasoning or some reference to theory, depending on the context.
4. *State* implies a concise answer with little or no supporting argument, e.g. a numerical answer that can be obtained 'by inspection' or a definition or required periodic trend in properties.
5. *List* requires a number of points with no elaboration. Where a given number of points is specified, this should not be exceeded.
6. *Describe* requires candidates to state in words (using diagrams where appropriate) the main points of the topic. It is often used with reference either to particular phenomena or to particular experiments. In the former instance, the term usually implies that the answer should include reference to (visual) observations associated with the phenomena. The amount of description intended should be interpreted in the light of the indicated mark value.
7. *Discuss* requires candidates to give a critical account of the points involved in the topic.
8. *Deduce/Predict* implies that candidates are 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.
9. *Suggest* is used in two main contexts. It may either imply that there is no unique answer or that candidates are expected to apply their general knowledge to a 'novel' situation, one that formally may not be 'in the syllabus'.
10. *Calculate* is used when a numerical answer is required. In general, working should be shown.
11. *Measure* implies that the quantity concerned can be directly obtained from a suitable measuring instrument, e.g. length, using a rule, or angle, using a protractor.
12. *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. the Young modulus, relative molecular mass.
13. *Show* is used where a candidate is expected to derive a given result. It is important that the terms being used by candidates are stated explicitly and that all stages in the derivation are stated clearly.
14. *Estimate* implies a reasoned order of magnitude statement or calculation of the quantity concerned. Candidates should make such simplifying assumptions as may be necessary about points of principle and about the values of quantities not otherwise included in the question.
15. *Sketch*, when applied to graph work, implies that the shape and/or position of the curve need only be qualitatively correct. However, candidates should be aware that, depending on the context, some quantitative aspects may be looked for, e.g. passing through the origin, having an intercept, asymptote or discontinuity at a particular value. On a sketch graph it is essential that candidates clearly indicate what is being plotted on each axis.
16. *Sketch*, when applied to diagrams, implies that a simple, freehand drawing is acceptable: nevertheless, care should be taken over proportions and the clear exposition of important details.
17. *Compare* requires candidates to provide both similarities and differences between things or concepts.

9.6 Key quantities, symbols and units

The list below is intended as a guide to the more important quantities which might be encountered in teaching and used in question papers. The list is not exhaustive.

Quantity	Usual symbols	Usual units
Base quantities		
mass	m	kg
length	l	m
time	t	s
electric current	I	A
thermodynamic temperature	T	K
amount of substance	n	mol
Other quantities		
acceleration	a	$\mathrm{m\,s^{-2}}$
acceleration of free fall	g	$\mathrm{m\,s^{-2}}$
activity of radioactive source	A	Bq
angle	θ	°, rad
area	A	$\mathrm{m^2}$
atomic mass	m_a	kg, u
Avogadro constant	N_A	$\mathrm{mol^{-1}}$
bond energy	–	$\mathrm{kJ\,mol^{-1}}$
Celsius temperature	θ	°C
change of internal energy	ΔU	J
concentration	c	$\mathrm{mol\,dm^{-3}}$
density	ρ	$\mathrm{kg\,m^{-3}}$, $\mathrm{g\,dm^{-3}}$, $\mathrm{g\,cm^{-3}}$
distance	d	m
displacement	s, x	m
electric charge	Q	C
electric field strength	E	$\mathrm{N C^{-1}}$, $\mathrm{V m^{-1}}$
electric potential	V	V
electric potential difference	V	V
electron affinity	–	$\mathrm{kJ\,mol^{-1}}$
electron mass	m_e	kg, u
elementary charge	e	C
e.m.f. (electromotive force)	E	V
energy	E, U, W	J
enthalpy change of reaction	ΔH	J, kJ
frequency	f	Hz
force	F	N
gravitational field strength	g	$\mathrm{N\,kg^{-1}}$
half-life	$t_{1/2}$	s
heating	q, Q	J
ionisation energy	I, ΔE	$\mathrm{kJ\,mol^{-1}}$
kinetic energy	E_k	J
molar gas constant	R	$\mathrm{J\,mol^{-1}\,K^{-1}}$
molar mass	M	$\mathrm{kg\,mol^{-1}}$
momentum	p	N s
nucleon number	A	
neutron mass	m_n	kg, u
neutron number	N	

number	*N*, *n*, *m*	
number density (number per unit volume)	*n*	m^{-3}
period	*T*	s
pH	pH	–
potential energy	E_p	J
power	*P*	W
pressure	*p*	Pa
proton mass	m_p	kg, *u*
proton number	*Z*	
relative atomic isotopic mass	A_r	
relative molecular mass	M_r	
resistance	*R*	Ω
specific heat capacity	*c*	$J\,kg^{-1}\,K^{-1}$
specific latent heat	*L*	$J\,kg^{-1}$
speed	*u*, *v*, *c*	$m\,s^{-1}$
speed of electromagnetic waves	*c*	$m\,s^{-1}$
standard enthalpy change of reaction	$\Delta H^{\ominus}$	$J\,mol^{-1}$, $kJ\,mol^{-1}$
torque	*T*	N m
velocity	*u*, *v*, *c*	$m\,s^{-1}$
volume	*V*, *v*	m^3, dm^3
wavelength	*λ*	m, mm, nm
weight	*W*	N
work	*W*	J

9.7 Data Booklet, including the Periodic Table of Elements

Additional copies of this booklet can be ordered from the *Publications Office* at Cambridge.

Cambridge
International
AS Level

Data Booklet

Cambridge International AS Level in Physical Science (8780)

For use from 2016 in all papers for the above syllabus, except practical examination.

CAMBRIDGE
International Examinations

Important values, constants and standards

molar gas constant	R	$= 8.31\ \mathrm{J\ K^{-1}\ mol^{-1}}$
the Avogadro constant	N_A, L	$= 6.02 \times 10^{23}\ \mathrm{mol^{-1}}$
speed of light in a vacuum	c	$= 3.00 \times 10^{8}\ \mathrm{m\ s^{-1}}$
rest mass of electron,	m_e	$= 9.11 \times 10^{-31}\ \mathrm{kg}$
elementary charge	e	$= -1.60 \times 10^{-19}\ \mathrm{C}$
specific heat capacity of water		$= 4.18\ \mathrm{kJ\ kg^{-1}\ K^{-1}}$ $= 4.18\ \mathrm{J\ g^{-1}\ K^{-1}}$
acceleration of free fall	g	$= 9.81\ \mathrm{m\ s^{-2}}$

Formulae

uniformly accelerated motion	s	$= ut + ½at^2$
	v^2	$= u^2 + 2as$
hydrostatic pressure	p	$= \rho gh$
resistors in series	R	$= R_1 + R_2 + ...$
resistors in parallel	$1/R$	$=1/R_1 + 1/R_2 + ...$

Ionisation energies (1st, 2nd, 3rd and 4th) of selected elements, in kJ mol^{-1}

	Proton Number	First	Second	Third	Fourth
H	1	1310	–	–	–
He	2	2370	5250	–	–
Li	3	519	7300	11800	–
Be	4	900	1760	14800	21000
B	5	799	2420	3660	25000
C	6	1090	2350	4610	6220
N	7	1400	2860	4590	7480
O	8	1310	3390	5320	7450
F	9	1680	3370	6040	8410
Ne	10	2080	3950	6150	9290
Na	11	494	4560	6940	9540
Mg	12	736	1450	7740	10500
Al	13	577	1820	2740	11600
Si	14	786	1580	3230	4360
P	15	1060	1900	2920	4960
S	16	1000	2260	3390	4540
Cl	17	1260	2300	3850	5150
Ar	18	1520	2660	3950	5770
K	19	418	3070	4600	5860
Ca	20	590	1150	4940	6480
Sc	21	632	1240	2390	7110
Ti	22	661	1310	2720	4170
V	23	648	1370	2870	4600
Cr	24	653	1590	2990	4770
Mn	25	716	1510	3250	5190
Fe	26	762	1560	2960	5400
Co	27	757	1640	3230	5100
Ni	28	736	1750	3390	5400
Cu	29	745	1960	3350	5690
Zn	30	908	1730	3828	5980
Ga	31	577	1980	2960	6190
Ge	32	762	1540	3300	4390
Br	35	1140	2080	3460	4850
Sr	38	548	1060	4120	5440
Sn	50	707	1410	2940	3930
I	53	1010	1840	2040	4030
Ba	56	502	966	3390	–
Pb	82	716	1450	3080	4080

Bond energies

(a) Diatomic molecules

Bond	Energy/kJ mol^{-1}
H—H	436
D—D	442
N≡N	944
O=O	496
F—F	158
C*l*—C*l*	242
Br—Br	193
I—I	151
H—F	562
H—C*l*	431
H—Br	366
H—I	299

(b) Polyatomic molecules

Bond	Energy/kJ mol^{-1}
C—C	350
C=C	610
C≡C	840
C┄C (benzene)	520
C—H	410
C—C*l*	340
C—Br	280
C—I	240
C—O	360
C=O	740
C—N	305
C=N	610
C≡N	890
N—H	390
N—N	160
N=N	410
O—H	460
O—O	150
Si—C*l*	359
Si—H	320
Si—O	444
Si—Si	222
S—C*l*	250
S—H	347
S—S	264

The Periodic Table of Elements

Key

relative atomic mass
atomic symbol
name
atomic number

Group																	
I	II											III	IV	V	VI	VII	0
							1.0 H hydrogen 1										4.0 He helium 2
6.9 Li lithium 3	9.0 Be beryllium 4											10.8 B boron 5	12.0 C carbon 6	14.0 N nitrogen 7	16.0 O oxygen 8	19.0 F fluorine 9	20.2 Ne neon 10
23.0 Na sodium 11	24.3 Mg magnesium 12											27.0 Al aluminium 13	28.1 Si silicon 14	31.0 P phosphorus 15	32.1 S sulfur 16	35.5 Cl chlorine 17	39.9 Ar argon 18
39.1 K potassium 19	40.1 Ca calcium 20	45.0 Sc scandium 21	47.9 Ti titanium 22	50.9 V vanadium 23	52.0 Cr chromium 24	54.9 Mn manganese 25	55.8 Fe iron 26	58.9 Co cobalt 27	58.7 Ni nickel 28	63.5 Cu copper 29	65.4 Zn zinc 30	69.7 Ga gallium 31	72.6 Ge germanium 32	74.9 As arsenic 33	79.0 Se selenium 34	79.9 Br bromine 35	83.8 Kr krypton 36
85.5 Rb rubidium 37	87.6 Sr strontium 38	88.9 Y yttrium 39	91.2 Zr zirconium 40	92.9 Nb niobium 41	95.9 Mo molybdenum 42	– Tc technetium 43	101.1 Ru ruthenium 44	102.9 Rh rhodium 45	106.4 Pd palladium 46	107.9 Ag silver 47	112.4 Cd cadmium 48	114.8 In indium 49	118.7 Sn tin 50	121.8 Sb antimony 51	127.6 Te tellurium 52	126.9 I iodine 53	131.3 Xe xenon 54
132.9 Cs caesium 55	137.3 Ba barium 56	lanthanoids 57–71	178.5 Hf hafnium 72	180.9 Ta tantalum 73	183.8 W tungsten 74	186.2 Re rhenium 75	190.2 Os osmium 76	192.2 Ir iridium 77	195.1 Pt platinum 78	197.0 Au gold 79	200.6 Hg mercury 80	204.4 Tl thallium 81	207.2 Pb lead 82	209.0 Bi bismuth 83	– Po polonium 84	– At astatine 85	– Rn radon 86
– Fr francium 87	– Ra radium 88	actinoids 89–103	– Rf rutherfordium 104	– Db dubnium 105	– Sg seaborgium 106	– Bh bohrium 107	– Hs hassium 108	– Mt meitnerium 109	– Ds darmstadtium 110	– Rg roentgenium 111	– Cn copernicium 112		– Fl flerovium 114		– Lv livermorium 116		

lanthanoids	138.9 La lanthanum 57	140.1 Ce cerium 58	140.9 Pr praseodymium 59	144.4 Nd neodymium 60	– Pm promethium 61	150.4 Sm samarium 62	152.0 Eu europium 63	157.3 Gd gadolinium 64	158.9 Tb terbium 65	162.5 Dy dysprosium 66	164.9 Ho holmium 67	167.3 Er erbium 68	168.9 Tm thulium 69	173.1 Yb ytterbium 70	175.0 Lu lutetium 71
actinoids	– Ac actinium 89	232.0 Th thorium 90	231.0 Pa protactinium 91	238.0 U uranium 92	– Np neptunium 93	– Pu plutonium 94	– Am americium 95	– Cm curium 96	– Bk berkelium 97	– Cf californium 98	– Es einsteinium 99	– Fm fermium 100	– Md mendelevium 101	– No nobelium 102	– Lr lawrencium 103

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

Cambridge International AS Level results are shown by one of the grades a, b, c, d or e, indicating the standard achieved, 'a' being the highest and 'e' the lowest. 'Ungraded' indicates that the candidate's performance fell short of the standard required for grade 'e'. 'Ungraded' will be reported on the statement of results but not on the certificate. The letters Q (result pending), X (no results) and Y (to be issued) may also appear on the statement of results but not on the certificate.

If a candidate takes a Cambridge International A Level and fails to achieve grade E or higher, a Cambridge International AS Level grade will be awarded if both of the following apply:

- the components taken for the Cambridge International A Level by the candidate in that series included all the components making up a Cambridge International AS Level
- the candidate's performance on these components was sufficient to merit the award of a Cambridge International AS Level grade.

For languages other than English, Cambridge also reports separate speaking endorsement grades (Distinction, Merit and Pass), for candidates who satisfy the conditions stated in the syllabus.

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 for your administrative zone can be found in the *Cambridge Guide to Making Entries*.

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