Cambridge Assessment International Education

Syllabus

Cambridge O Level

Combined Science 5129

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

This syllabus is **not** available in all administrative zones.
Please check the syllabus page at **www.cambridgeinternational.org/5129** to see if this syllabus is available in your administrative zone.

Version 2

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

Cambridge Pathway

Why choose Cambridge International?

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

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

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

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

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

School feedback: 'We think the Cambridge curriculum is superb preparation for university.'
Feedback from: Christoph Guttentag, Dean of Undergraduate Admissions, Duke University, USA

Quality management

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

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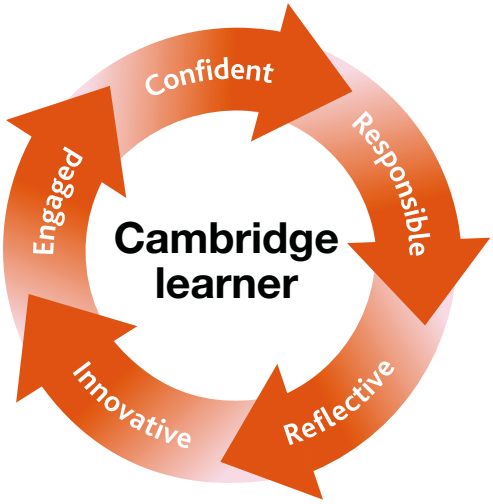
Important: Changes to this syllabus

For information about changes to this syllabus for 2026, 2027 and 2028, go to page 63.

1 Why choose this syllabus?

Key benefits

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



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

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

Our approach in Cambridge O Level Combined Science encourages learners to be:

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

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

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

innovative, solving unfamiliar problems confidently and creatively

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

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

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

International recognition and acceptance

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

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

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

Supporting teachers

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

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

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

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

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

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

Professional development

Find the next step on your professional development journey.

- Introductory Professional Development – An introduction to Cambridge programmes and qualifications.
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Find out more at:
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Supporting exams officers

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

2 Syllabus overview

Aims

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

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

The aims are to enable students to:

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

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

Content overview

Candidates study the following topics:

Biology

1 Cells
2 Enzymes
3 Plant nutrition and transport
4 Human nutrition
5 Human gas exchange
6 Respiration
7 Transport in humans
8 Drugs and their effects
9 Coordination and control
10 Development of organisms and continuity of life
11 Biotechnology and genetic modification
12 Relationships of organisms with one another and with the environment

Chemistry

13 States of matter
14 Atoms, elements and compounds
15 Stoichiometry
16 Chemical energetics
17 Chemical reactions
18 Acids, bases and salts
19 The Periodic Table
20 Metals
21 Chemistry of the environment
22 Organic chemistry

Physics

23 Motion, forces and energy
24 Thermal physics
25 Waves
26 Electricity
27 Nuclear physics

Assessment overview

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

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

AND

Practical assessment

Paper 3: Experimental Skills and Investigations	
1 hour	
40 marks	20%
Questions will be based on the experimental skills in section 4	
Externally assessed	

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

Assessment objectives

The assessment objectives (AOs) are:

AO1 Knowledge with understanding

Candidates should be able to demonstrate knowledge and understanding of:

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

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

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

AO2 Handling information and problem-solving

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

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

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

AO3 Experimental skills and investigations

Candidates should be able to:

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

Weighting for assessment objectives

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

Assessment objectives as a percentage of the qualification

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

Assessment objectives as a percentage of each component

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

3 Subject content

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

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

Practical work helps students to:

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

Please note that in this syllabus, 'understand' is taken to mean 'state, describe and explain'.

Biology

1 Cells

1.1 Cell structure and function

1 Identify on diagrams, photomicrographs or electron micrographs, the mitochondria, nucleus, cytoplasm and cell membrane in an animal cell

2 Identify on diagrams, photomicrographs or electron micrographs, the mitochondria, chloroplasts, nucleus, sap vacuole, cytoplasm, cell membrane and cellulose cell wall in a plant cell

3 Describe the functions of the above structures in animal and plant cells

4 Understand that cells can become specialised and that their structures are related to their specific functions, as illustrated by examples covered in the syllabus

1.2 Movement into and out of cells

1 Describe the role of water as a solvent in organisms with reference to digestion, excretion and transport

2 Understand diffusion as the net movement of molecules or ions from a region of their higher concentration to a region of their lower concentration (i.e. down a concentration gradient), as a result of their random movement

3 Describe how the rate of diffusion is affected by surface area, temperature, concentration gradients and distance

4 Understand osmosis as the net movement of water molecules from a region of higher water potential to a region of lower water potential, through a partially permeable membrane (calculations of water potential are **not** required)

5 Describe the effects of osmosis on plant and animal tissues and explain the importance of water potential gradient and osmosis in the uptake and loss of water

6 Investigate and explain the effects on plant tissues of immersing them in solutions of different concentrations, using the terms turgid, turgor pressure, plasmolysis and flaccid

2 Enzymes

2.1 Enzyme action

1 Describe a catalyst as a substance that increases the rate of a chemical reaction and is not changed by the reaction

2 Describe enzymes as proteins that function as biological catalysts

3 Understand that most enzymes act within the cell that produces them and that this is how the cell controls its metabolic activities

4 Explain enzyme action with reference to the substrate, active site, enzyme-substrate complex, and product

5 Explain the specificity of enzymes in terms of the complementary shape and fit of the active site with the substrate

6 Investigate and explain the effects of changes of temperature and pH on enzyme activity in terms of kinetic energy, shape and fit, denaturation and the frequency of effective collisions

3 Plant nutrition and transport

3.1 Photosynthesis

1 Understand that photosynthesis is the process by which plants make carbohydrates from raw materials using energy from light

2 State the word equation and balanced chemical equation for photosynthesis

3 State that chlorophyll is a green pigment that is found in chloroplasts

4 State that chlorophyll transfers light energy into chemical energy for the formation of glucose and other carbohydrates

5 Outline the subsequent use and storage of the carbohydrates made in photosynthesis, limited to:
   (a) starch as an energy store
   (b) cellulose to build cell walls
   (c) glucose used in respiration to provide energy
   (d) sucrose for transport through the plant
   (e) glucose and mineral ions to synthesise other biological molecules e.g. proteins

6 Investigate and explain the effect of varying light intensity on the rate of photosynthesis using submerged aquatic plants

3.2 Leaf structure

1 State that most leaves have a large surface area and are thin, and explain how these features are adaptations for photosynthesis

2 Identify and label the cuticle, cellular and tissue structures of a dicotyledonous leaf, as seen in diagrams or photomicrographs, and explain how these structures are adaptations for photosynthesis and gas exchange, limited to:
   (a) stomata and guard cells
   (b) spongy and palisade mesophyll cells
   (c) air spaces
   (d) vascular bundles (xylem and phloem)
   (e) distribution of chloroplasts

3.3 Transport in flowering plants

1 Relate the structure of root hair cells to their function of water and mineral ion uptake

2 Explain the importance of:
   (a) nitrate ions for making amino acids, required for the production of proteins
   (b) magnesium ions for making chlorophyll

3 Outline the pathway taken by water through the root, stem and leaf, limited to: root hair cells, root cortex cells, xylem and mesophyll cells

4 Describe transpiration as the evaporation of water from the surfaces of the mesophyll cells into air spaces and then the diffusion of the water vapour out of the leaves through the stomata

5 Describe translocation as the movement of sucrose and amino acids in the phloem from parts of plants that produce them (sources) to parts of plants that use or store them (sinks)

4 Human nutrition

4.1 Diet

1 List the chemical elements that make up:
   (a) carbohydrates
   (b) lipids (fats and oils)
   (c) proteins
2 State that starch, cellulose and glycogen are made from glucose, proteins from amino acids and lipids from glycerol and fatty acids
3 Describe and be able to do chemical tests for:
   (a) starch (iodine solution)
   (b) glucose and maltose (Benedict's solution)
   (c) protein (biuret test)
   (d) lipids (ethanol emulsion test)
4 List the principal sources of, and describe the dietary importance of carbohydrates, lipids, proteins, vitamins (C and D only), mineral ions (calcium and iron only), fibre (roughage) and water
5 Understand the concept of a balanced diet
6 Describe the signs of Type 2 diabetes (limited to increased blood glucose concentration and glucose in urine) and its treatment by diet, exercise and/or administration of insulin

4.2 Human digestive system

1 Identify the main regions of the digestive system: mouth, salivary glands, oesophagus, stomach, small intestine (duodenum and ileum), pancreas, liver and large intestine (colon, rectum and anus)
2 Explain why most foods must be digested before they can be absorbed
3 Describe physical digestion as the breakdown of food into smaller pieces without chemical change to the food molecules
4 State that physical digestion increases the surface area of food for the action of enzymes in chemical digestion
5 Describe chemical digestion as the breakdown of large molecules into small molecules
6 Describe the functions of the main regions of the digestive system, limited to:
   (a) mouth – ingestion, physical digestion, chemical digestion of starch by amylase
   (b) salivary glands – secretion of saliva containing amylase
   (c) stomach – physical digestion, chemical digestion of protein by protease, presence of hydrochloric acid in gastric secretions
   (d) small intestine (duodenum and ileum) – chemical digestion of starch by amylase, maltose by maltase, protein by protease and lipids by lipase
   (e) liver – storage of glycogen, breakdown of excess amino acids to produce urea which is excreted by the kidneys
   (f) pancreas – alkaline secretion containing amylase, protease and lipase
   (g) ileum and colon – absorption
   (h) rectum and anus – egestion

4.2 Human digestive system continued

7 Describe the functions of amylase, maltase, protease and lipase, listing the substrates and products, limited to:
   (a) amylase breaks down starch to maltose
   (b) maltase breaks down maltose to glucose
   (c) protease breaks down protein to amino acids
   (d) lipase breaks down lipids to fatty acids and glycerol
8 Describe the function of hydrochloric acid in the stomach as killing ingested bacteria
9 Understand that the different proteases present in the stomach and the duodenum work best at different pH levels

4.3 Absorption and assimilation

1 State that the small intestine is the region where nutrients are absorbed
2 Understand that absorption is the movement of nutrients from the intestines into cells lining the digestive system and then into the blood
3 Understand that assimilation is the uptake and use by cells of nutrients from the blood
4 Explain the significance of villi in increasing the internal surface area of the ileum
5 Understand that water is absorbed from the lumen of the small intestine and the colon, but that most absorption of water happens in the small intestine
6 State the function of the hepatic portal vein as the route taken to the liver by most of the nutrients absorbed from the ileum

5 Human gas exchange

5.1 Human gas exchange

1 State and explain the differences between inspired and expired air
2 Identify, on diagrams and images, the larynx, trachea, lungs, bronchi, bronchioles, alveoli and associated capillaries
3 State that the alveoli are sites where oxygen passes into the blood and where carbon dioxide passes out of the blood and that these transfers occur by diffusion
4 Investigate and explain the effect of physical activity on the rate and depth of breathing

6 Respiration

6.1 Respiration

1 Describe respiration as the chemical reactions in all living cells that release energy from glucose

6.2 Aerobic and anaerobic respiration

1 Describe aerobic respiration as the release of a relatively large amount of energy by the breakdown of glucose in the presence of oxygen
2 State the word equation and balanced chemical equation for aerobic respiration
3 State that carbon dioxide is a waste product of respiration, which is excreted through the lungs in humans
4 Describe anaerobic respiration as the release of a relatively small amount of energy by the breakdown of glucose without using oxygen
5 State the word equation for anaerobic respiration in humans
6 Explain why lactic acid builds up in muscles and blood during vigorous exercise causing an 'oxygen debt'
7 Outline how the oxygen debt is removed after exercise, limited to:
   (a) continuation of fast heart rate to transport lactic acid in blood from muscles to the liver
   (b) continuation of deeper and faster breathing to supply oxygen for the breakdown of lactic acid in the liver

7 Transport in humans

7.1 Circulatory system

1 Describe the circulatory system as a system of blood vessels with a pump and valves to ensure one-way flow of blood
2 Identify on diagrams and photographs the structures of the mammalian heart, limited to: the muscular wall, the septum, the left and right ventricles and atria, atrioventricular and semilunar valves and coronary arteries
3 Explain the relative thickness:
   (a) of the muscle walls of the left and right ventricles
   (b) of the muscle walls of the atria compared to those of the ventricles
4 Describe the functioning of the heart in terms of the contraction of muscles of the atria and ventricles and the action of the valves in a heartbeat
5 Investigate and explain the effect of physical activity on heart rate
6 Describe coronary heart disease in terms of the blockage of coronary arteries and state the possible risk factors including diet, sedentary lifestyle, stress, smoking, genetic predisposition, age and gender
7 Discuss the role of diet and exercise in reducing the risk of coronary heart disease

7.2 Blood vessels

1 Name the main blood vessels that carry blood to and from the heart, lungs and liver, limited to: aorta, vena cava, pulmonary artery, pulmonary vein, hepatic artery, hepatic vein and hepatic portal vein

2 Describe, and identify on diagrams and photomicrographs, the structure of arteries, veins and capillaries, limited to:
   (a) relative thickness of wall
   (b) composition of wall (muscle and elastic tissue)
   (c) diameter of lumen
   (d) presence of valves

3 Explain how the structure of arteries, veins and capillaries is related to the pressure of the blood that they transport

7.3 Blood

1 Identify red and white blood cells (lymphocytes and phagocytes) as seen in diagrams and photomicrographs

2 State the functions of the components of blood:
   (a) red blood cells – oxygen transport
   (b) white blood cells – antibody production by lymphocytes and engulfing pathogens by phagocytes
   (c) platelets – clotting to prevent blood loss and the entry of pathogens (clotting mechanism is **not** required)
   (d) plasma (consisting mainly of water) – transport, limited to: blood cells, ions, glucose, amino acids, hormones, carbon dioxide, urea, vitamins and antibodies

8 Drugs and their effects

8.1 Drugs and their effects

1 Describe a drug as any substance taken into the body that modifies or affects chemical reactions in the body

2 Describe the use of antibiotics for the treatment of bacterial infection

3 State that the development of antibiotic-resistant bacteria can be minimised by using antibiotics only when essential

4 Describe the effects of excessive consumption of alcohol: reduced self-control, depressant, effect on reaction times, damage to liver and social implications

5 Describe the effects of tobacco smoke and its major toxic components (nicotine, tar and carbon monoxide): strong association with bronchitis, emphysema, lung cancer, heart disease, and the association between smoking during pregnancy and reduced birth weight of the baby

9 Coordination and control

9.1 Human nervous system and hormones

1 State that the nervous system (brain, spinal cord and nerves) coordinates and regulates body functions

2 Describe the human nervous system in terms of:

(a) the central nervous system (CNS) consisting of the brain and the spinal cord

(b) the peripheral nervous system (PNS) consisting of the nerves outside the brain and spinal cord

3 State that sensory receptors detect changes in the environment to which the body can respond via the nervous system

4 Describe simple reflex arcs in terms of receptor, sensory neurone, relay neurone, motor neurone and effector (muscles and glands)

5 Describe a reflex action as a rapid and automatic response to a stimulus

6 Describe a hormone as a chemical substance, e.g. insulin, produced by a gland and carried by the blood, which alters the activity of one or more specific target organs

10 Development of organisms and continuity of life

10.1 Nuclear division

1 Understand that chromosomes contain DNA (deoxyribonucleic acid), which carries genetic information in the form of genes

2 State that a gene is a specific section of DNA carrying the code needed to make a specific protein, which is usually an enzyme

3 State that most cells contain a diploid nucleus containing two sets of chromosomes and that human cells contain 23 pairs of chromosomes

4 Describe mitosis as nuclear division giving rise to genetically identical cells in which the chromosome number is maintained (detail of stages are **not** required)

5 Outline the role of mitosis in growth, repair of damaged tissues and replacement of dying cells

6 State that meiosis is involved in the production of gametes and in humans occurs only in the testes and ovaries

7 Describe meiosis as a reduction division in which the chromosome number is halved from diploid to haploid resulting in genetically different cells (details of stages are **not** required)

10.2 Sexual reproduction in humans

1 Identify, on diagrams of the male reproductive system: the testes, scrotum, sperm ducts, prostate gland, urethra and penis, and describe their functions
2 Identify, on diagrams of the female reproductive system: the ovaries, oviducts, uterus, cervix and vagina, and describe their functions
3 Compare male and female gametes in terms of size, structure, numbers and motility
4 Describe fertilisation as the fusion of the nuclei from a male gamete (sperm) and a female gamete (egg cell) to form a zygote which develops into an embryo
5 Describe the menstrual cycle in terms of development and release of an egg and changes in the lining of the uterus (knowledge of hormones is **not** required)
6 Describe how the human immunodeficiency virus (HIV) is transmitted
7 Understand that HIV infection may lead to Acquired Immune Deficiency Syndrome (AIDS)
8 Describe the methods by which HIV may be controlled

11 Biotechnology and genetic modification

11.1 Biotechnology and genetic modification

1 Describe genetic modification as changing the genetic material of an organism by removing, inserting or changing individual genes
2 Understand that bacteria are useful in biotechnology and genetic modification due to:
   (a) their rapid reproduction rate
   (b) their ability to make complex molecules
   (c) no ethical concerns over their manipulation and growth
3 Understand that the gene that controls the production of human insulin is inserted into bacterial DNA for commercial production of insulin
4 State that crop plants can be genetically modified so that they:
   (a) are resistant to herbicides
   (b) are resistant to insect pests
   (c) can produce additional vitamins

12 Relationships of organisms with one another and with the environment

12.1 Nutrient cycles and energy flow

1 Understand that the Sun is the principal source of energy input to most biological systems
2 Explain why most forms of life are completely dependent on photosynthesis
3 Describe the flow of energy through food chains including energy from light and energy in living organisms and its eventual transfer to the environment
4 Explain why it is more energy efficient for humans to eat crop plants than to eat livestock that have been fed on crop plants
5 Understand that the growth of the human population is increasing the demand for global resources
6 Describe the carbon cycle, limited to:
   (a) photosynthesis
   (b) respiration
   (c) feeding
   (d) decomposition and the role of decomposers
   (e) formation of fossil fuels
   (f) combustion

12.2 Effects of humans on ecosystems

1 Outline the causes and describe the consequences of deforestation, limited to its effects on biodiversity, extinction, loss of soil, flooding and concentration of carbon dioxide in the atmosphere
2 Describe the impacts humans have through:
   (a) over-harvesting of plant and animal species
   (b) introducing a non-native species to an ecosystem
   (c) water pollution by untreated sewage and nitrogen-containing fertilisers, limited to the reduction in dissolved oxygen and death of organisms
   (d) non-biodegradable plastics in the environment, in both aquatic and terrestrial ecosystems

Chemistry

13 States of matter

13.1 Solids, liquids and gases

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

14 Atoms, elements and compounds

14.1 Elements, compounds and mixtures

1 Describe the differences between elements, molecules, compounds and mixtures
2 Describe a:
   (a) solvent as a substance that dissolves a solute
   (b) solute as a substance that is dissolved in a solvent
   (c) solution as a mixture composed of one or more solutes dissolved in a solvent
3 Describe how to use paper chromatography to separate mixtures of soluble substances, using a suitable solvent
4 Interpret simple chromatograms to identify:
   (a) unknown substances by comparison with known substances
   (b) pure and impure substances

14.2 Atomic structure and the Periodic Table

1 Describe the structure of the atom as a central nucleus containing neutrons and protons surrounded by electrons in shells
2 State the relative charges and relative masses of a proton, a neutron and an electron
3 Define proton number/atomic number as the number of protons in the nucleus of an atom
4 Define mass number/nucleon number as the total number of protons and neutrons in the nucleus of an atom
5 Determine the electronic configuration of elements with proton number 1 to 20, e.g. 2,8,3
6 State that:
   (a) Group VIII, the noble gases, are unreactive monatomic gases, with a full outer shell, e.g. 2,8
   (b) the number of outer shell electrons is equal to the group number in Groups I to VII
   (c) the number of occupied electron shells is equal to the period number

14.3 Ions and ionic bonds

1 Describe the formation of positive ions, known as cations, and negative ions, known as anions, with noble gas electronic configurations
2 Describe the giant lattice structure of ionic compounds as a regular arrangement of alternating positive and negative ions
3 State that an ionic bond is a strong electrostatic attraction between oppositely charged ions
4 Describe the formation of ionic bonds between ions of metallic and non-metallic elements, including between sodium and chlorine to form $NaCl$ and magnesium and chlorine to form $MgCl_2$
5 Use dot-and-cross diagrams to show the formation of ionic bonds
6 Describe and explain in terms of structure and bonding the properties of ionic compounds:
   (a) high melting points and boiling points
   (b) good electrical conductivity when aqueous or molten and poor when solid

14.4 Simple molecules and covalent bonds

1 State that a covalent bond is formed when a pair of electrons is shared between two atoms leading to noble gas electronic configurations
2 Describe the formation of covalent bonds in simple molecules, including H_2, Cl_2, H_2O, CH_4, NH_3, HCl, O_2 and CO_2. Use dot-and-cross diagrams to show the electronic configurations in these and similar molecules.
3 Describe and explain in terms of structure and bonding the properties of simple molecular compounds:
   (a) low melting points and boiling points in terms of weak intermolecular forces (specific types of intermolecular forces are **not** required)
   (b) poor electrical conductivity

15 Stoichiometry

15.1 Formulae

1 State the formulae of the elements and compounds named in the subject content
2 Define the molecular formula of a compound as the number and type of different atoms in one molecule
3 Deduce the formula of a simple compound from the relative numbers of atoms or ions present in a model or a diagrammatic representation
4 Construct word equations and symbol equations to show how reactants form products, including state symbols
5 Deduce the symbol equation for a chemical reaction, given relevant information

15.2 Relative masses of atoms and molecules

1 Define relative molecular mass, *M*r, as the sum of the relative atomic masses. Relative formula mass, *M*r, will be used for ionic compounds.
2 Calculate relative molecular mass and relative formula mass
3 Calculate stoichiometric reacting masses
4 Calculate concentration as the mass of solute dissolved in a given volume of solution, measured in g/dm^3
5 Use volumetric pipettes, volumetric flasks and balances to prepare solutions of known concentration

16 Chemical energetics

16.1 Exothermic and endothermic reactions

1 State that an exothermic reaction transfers thermal energy to the surroundings leading to an increase in the temperature of the surroundings
2 State that neutralisation and combustion are exothermic reactions
3 State that an endothermic reaction transfers thermal energy from the surroundings leading to a decrease in the temperature of the surroundings
4 State that dissolving ammonium nitrate and cracking are endothermic reactions
5 Interpret data, including graphs, from temperature changes in endothermic and exothermic reactions

17 Chemical reactions

17.1 Physical and chemical changes

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

17.2 Rate of reaction

1 Describe the effect on the rate of reactions of
   (a) changing the concentration of solutions
   (b) changing the surface area of solids
   (c) changing the temperature
   (d) adding or removing catalysts
2 Explain that a catalyst is unchanged at the end of a reaction
3 Describe, use and evaluate practical methods for investigating the rate of a reaction, including the formation of a gas
4 Interpret data, including graphs, from rate of reaction experiments

17.3 Redox

1 Define redox reactions as involving simultaneous reduction and oxidation
2 Define oxidation in terms of gain of oxygen
3 Define reduction in terms of loss of oxygen
4 Identify redox reactions as reactions involving gain and loss of oxygen
5 Describe and use a test to identify oxygen gas, O_2, using a glowing splint

18 Acids, bases and salts

18.1 The characteristic properties of acids and bases

1 State that aqueous solutions of acids contain H^+ ions and aqueous solutions of alkalis contain OH^- ions
2 State that bases are oxides or hydroxides of metals and that alkalis are soluble bases
3 Describe the characteristic properties of acids in terms of their reactions with:
   (a) some metals
   (b) bases
   (c) carbonates
4 Describe and use tests to identify the gases:
   (a) carbon dioxide, CO_2, using limewater
   (b) hydrogen, H_2, using a lighted splint
5 Describe the characteristic properties of bases in terms of their reactions with:
   (a) acids
   (b) ammonium salts
6 Describe and use damp red litmus paper to identify ammonia gas, NH_3
7 State that a neutralisation reaction occurs between an acid and a base
8 Describe the reaction between an acid and an alkali to produce water as a neutralisation reaction
9 Describe acids and alkalis in terms of their effects on:
   (a) universal indicator
   (b) litmus
10 Describe how and be able to compare neutrality, relative acidity and relative alkalinity in terms of colour and pH using universal indicator
11 State that acids and alkalis may be corrosive

18.2 Preparation of salts

1 Describe the preparation of soluble salts by reaction of an acid with:
   (a) excess metal
   (b) excess insoluble base
   (c) excess insoluble carbonate
2 Describe the preparation of insoluble salts by precipitation (knowledge of solubility of compounds is **not** required)
3 Describe and explain methods of separation and purification using:
   (a) a suitable solvent
   (b) filtration
   (c) crystallisation
4 Describe a:
   (a) residue as a substance that remains after evaporation, filtration or any similar process
   (b) filtrate as a liquid or solution that has passed through a filter

19 The Periodic Table

19.1 Arrangement of elements

1 Describe the Periodic Table as an arrangement of elements in periods and groups and in order of increasing proton number/atomic number
2 Describe the change from metallic to non-metallic character across a period
3 Describe the relationship between group number and the charge on ions formed from elements in that group
4 Explain similarities in the chemical properties of elements in the same group of the Periodic Table in terms of their electronic configuration
5 Explain how the position of an element in the Periodic Table can be used to predict its properties

19.2 Group I properties

1 Describe the Group I alkali metals, lithium, sodium and potassium, as relatively soft metals with general trends down the group, limited to:
   (a) decreasing melting point
   (b) increasing reactivity with water
2 Describe Group I metals as flammable
3 Describe and use flame tests to identify Group I cations, limited to:
   (a) lithium, Li^+, red
   (b) sodium, Na^+, yellow
   (c) potassium, K^+, lilac
4 Predict the properties of other elements in Group I, given information about the elements

19.3 Group VII properties

1 Describe the Group VII halogens, chlorine, bromine and iodine, as diatomic non-metals with general trends down the group, limited to:
   (a) increasing density
   (b) decreasing reactivity
2 State the appearance of the halogens at r.t.p. as:
   (a) chlorine, a pale yellow-green gas
   (b) bromine, a red-brown liquid
   (c) iodine, a grey-black solid
3 Describe chlorine, Cl_2, and bromine, Br_2, as toxic
4 Describe how to use damp litmus paper to identify chlorine gas, Cl_2
5 Describe and explain the displacement reactions of halogens with other halide ions and use these reactions to place the halogens in order of reactivity
6 State the appearance of the halogens in aqueous solution as:
   (a) chlorine, colourless
   (b) bromine, orange
   (c) iodine, brown

19.3 Group VII properties continued

7 Describe the reactions of the halide ions with acidified aqueous silver nitrate to form insoluble silver halides, limited to
   (a) AgC*l*, white
   (b) AgBr , cream
   (c) AgI, pale yellow
8 Predict the properties of other elements in Group VII, given information about the elements

19.4 Identification of ions

1 Do tests and use information provided on the reactions of aqueous anions to identify:
   (a) carbonate, CO_3^{2-} , by reaction with dilute acid and then testing for carbon dioxide gas
   (b) chloride, Cl^-, bromide, Br^-, and iodide, I^-, by acidifying with dilute nitric acid then adding aqueous silver nitrate
   (c) sulfate, SO_4^{2-} , by reaction with aqueous barium nitrate and dilute nitric acid
2 Do tests and use information provided on the reactions of aqueous cations with aqueous sodium hydroxide and aqueous ammonia to identify:
   (a) aluminium, Al^{3+}
   (b) ammonium, NH_4^+
   (c) calcium, Ca^{2+}
   (d) chromium(III), Cr^{3+}
   (e) copper(II), Cu^{2+}
   (f) iron(II), Fe^{2+}
   (g) iron(III), Fe^{3+}
   (h) zinc, Zn^{2+}

20 Metals

20.1 Properties and uses of metals

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

20.2 Reactivity series

1 State that the reactivity series is an arrangement of metals in decreasing order of their reactivity

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

3 Deduce an order of reactivity by using a given set of experimental results from:

(a) reactions of metals to displace hydrogen from cold water, steam and dilute hydrochloric acid

(b) displacement reactions of metals

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

21 Chemistry of the environment

21.1 Water

1 Describe distillation as the separation of a liquid by evaporation and condensation

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

3 State that water needs to be treated to make it suitable for drinking

4 Describe the treatment of the domestic water supply in terms of:

(a) sedimentation and filtration to remove insoluble solids

(b) use of carbon to remove tastes and odours

(c) chlorination to kill microbes

5 Describe desalination as a process to obtain drinking water from sea water

21.2 Air quality and climate

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

2 State the source of each of these air pollutants:
   (a) carbon dioxide from the complete combustion of carbon-containing fuels
   (b) carbon monoxide and particulates from the incomplete combustion of carbon-containing fuels
   (c) methane from the decomposition of vegetation and waste gases from digestion in animals
   (d) gases from the burning of plastics

3 State the adverse effect of these air pollutants:
   (a) carbon dioxide: higher levels of carbon dioxide leading to increased global warming, which leads to climate change
   (b) carbon monoxide: toxic gas
   (c) particulates: increased risk of respiratory problems and cancer
   (d) methane: higher levels of methane leading to increased global warming, which leads to climate change
   (e) gases from the burning of plastics: toxic

4 State and explain strategies to reduce global warming, limited to increasing use of renewable energy, decreasing use of fossil fuels, limiting deforestation and reduction in livestock farming

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

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

22 Organic chemistry

22.1 Names and formulae of organic compounds

1 State that a structural formula is an unambiguous description of the way the atoms in a molecule are arranged

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

3 Name, draw and interpret the structural and displayed formulae of unbranched:
   (a) alkanes
   (b) alkenes

   containing up to three carbon atoms per molecule

4 State the type of compound present given the chemical name ending in –ane or -ene, or from a molecular, structural or displayed formula

22.2 Fuels

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

22.3 Alkanes

1 State that the bonding in alkanes is single covalent and that alkanes are saturated hydrocarbons
2 Describe the properties of alkanes as being generally unreactive, except in terms of combustion

22.4 Alkenes

1 State that the bonding in alkenes includes a double carbon–carbon covalent bond and that alkenes are unsaturated hydrocarbons
2 Describe the manufacture of alkenes and hydrogen by the cracking of large alkane molecules using a high temperature, and a catalyst
3 Describe the reasons for the cracking of large alkane molecules
4 Describe the test to distinguish between saturated and unsaturated hydrocarbons by their reaction with aqueous bromine
5 State that in an addition reaction only one product is formed
6 Describe the formation of poly(ethene) from ethene by addition polymerisation, identifying the repeat unit
7 State that poly(ethene) is a widely used plastic

Physics

23 Motion, forces and energy

23.1 Physical quantities and measurement techniques

1 Describe how and be able to measure a variety of lengths with appropriate precision using tapes and rulers

2 Describe how and be able to use a measuring cylinder to measure the volume of a liquid and to determine the volume of a solid by displacement

3 Describe how and be able to measure a variety of time intervals using clocks and digital timers

23.2 Motion

1 Define speed as distance travelled per unit time

2 Recall and use the equation

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

$$v = \frac{s}{t}$$

3 Recall and use the equation

$$\text{average speed} = \frac{\text{total distance travelled}}{\text{total time taken}}$$

4 Define acceleration as change in speed per unit time; recall and use the equation

$$\text{acceleration} = \frac{\text{change in speed}}{\text{time taken}}$$

$$a = \frac{\Delta v}{\Delta t}$$

5 State what is meant by and describe examples of uniform acceleration and non-uniform acceleration

6 Sketch, plot and interpret distance–time and speed–time graphs

7 Determine from the shape of a distance–time graph when an object is:

(a) at rest

(b) moving with constant speed

(c) accelerating

(d) decelerating

8 Determine from the shape of a speed–time graph when an object is:

(a) at rest

(b) moving with constant speed

(c) moving with constant acceleration

(d) moving with changing acceleration

23.3 Mass and weight

1 Describe how and be able to determine mass using an electronic balance

2 Describe how and be able to measure weight using a force meter

3 Define gravitational field strength as force per unit mass; recall and use the equation

$$\text{gravitational field strength} = \frac{\text{weight}}{\text{mass}}$$

$$g = \frac{W}{m}$$

and know that this is equivalent to the acceleration of free fall

23.4 Density

1 Define density as mass per unit volume; recall and use the equation

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

$$\rho = \frac{m}{V}$$

2 Describe how and be able to determine the density of a liquid, of a regularly shaped solid and of an irregularly shaped solid which sinks in a liquid (volume by displacement), including appropriate calculations

23.5 Forces

23.5.1 Balanced and unbalanced forces

1 Identify and use different types of force, including weight (gravitational force), friction, drag, air resistance, tension (elastic force), electrostatic force, magnetic force, thrust (driving force) and contact force

2 State that a force may change the motion of an object by changing its direction or speed

3 Determine the resultant of two or more forces acting along the same straight line

4 Recall and use the equation

$$\text{resultant force} = \text{mass} \times \text{acceleration}$$

$$F = ma$$

23.5.2 Friction

1 Describe friction as a force that may impede motion and produce heating

23.5.3 Elastic deformation

1 Know that forces may produce a change in size and shape of an object

2 Define the spring constant as force per unit extension; recall and use the equation

$$\text{spring constant} = \frac{\text{force}}{\text{extension}}$$

$$k = \frac{F}{x}$$

3 Sketch, plot and interpret load-extension graphs for an elastic solid and describe the associated experimental procedures

23.5 Forces continued

23.5.4 Turning effect of forces

1 Describe the moment of a force as a measure of its turning effect and give everyday examples

2 Define the moment of a force as moment = force × perpendicular distance from the pivot; recall and use this equation

3 Describe and be able to do an experiment to verify the principle of moments

23.6 Energy, work and power

23.6.1 Energy

1 State that energy may be stored as: kinetic, gravitational potential, chemical, elastic (strain), nuclear, electrostatic and internal (thermal)

2 Describe how energy is transferred between stores during events and processes, including examples of transfer by forces (mechanical work done), electrical currents (electrical work done), heating and by electromagnetic, sound and other waves

3 Know the principle of the conservation of energy and apply this principle to the transfer of energy between stores during events and processes

23.6.2 Work

1 Recall and use the equation

work done = force × distance moved in the direction of the force

$W = Fd$

23.6 Energy, work and power continued

23.6.3 Energy resources

1 List renewable and non-renewable energy sources

2 Describe how useful energy may be obtained, or electrical power generated, from:

(a) chemical energy stored in fossil fuels

(b) chemical energy stored in biofuels

(c) hydroelectric resources

(d) solar radiation

(e) nuclear fuel

(f) geothermal resources

(g) wind

(h) tides

(i) waves in the sea

including references to a boiler, turbine and generator where they are used

3 Give advantages and disadvantages of each method limited to whether it is renewable, when and whether it is available, and its impact on the environment

24 Thermal physics

24.1 Kinetic particle model of matter

1 Describe qualitatively the particle structure of solids, liquids and gases, relating their properties to the forces and distances between particles and to the motion of the particles (atoms, molecules, ions and electrons)

24.2 Thermal expansion of solids, liquids and gases

1 Explain some of the applications and consequences of thermal expansion in the context of common examples, including the liquid-in-glass thermometer

2 Explain, in terms of the motion, arrangement and separation of particles, the thermal expansion of solids, liquids and gases

24.3 Transfer of thermal energy

1 Describe and be able to do experiments to distinguish between good and bad thermal conductors

2 Explain convection in liquids and gases in terms of density changes and describe experiments to illustrate convection

3 Describe and be able to do experiments to distinguish between good and bad emitters of infrared radiation

4 Describe and be able to do experiments to distinguish between good and bad absorbers of infrared radiation

5 Explain everyday applications using ideas about conduction, convection and radiation, including:

(a) heating objects such as kitchen pans

(b) heating a room by convection

(c) measuring temperature using an infrared thermometer

(d) using thermal insulation to maintain the temperature of a liquid and to reduce thermal energy transfer in buildings

25 Waves

25.1 General properties of waves

1 Know that waves transfer energy without transferring matter

2 Describe what is meant by wave motion as illustrated by vibrations in ropes and springs and by experiments using water waves

3 Define the terms:

(a) frequency as the number of wavelengths that pass a point per unit time

(b) wavelength as the distance between two consecutive, identical points such as two consecutive crests

(c) amplitude as the maximum distance from the mean position

4 Recall and use the equation

wave speed = frequency × wavelength

$v = f\lambda$

5 Know that for a transverse wave, the direction of vibration is at right-angles to the direction of the energy transfer, and give examples such as electromagnetic radiation, waves on the surface of water, and seismic S-waves (secondary)

6 Know that for a longitudinal wave, the direction of vibration is parallel to the direction of the energy transfer, and give examples such as sound waves, seismic P-waves (primary) and longitudinal waves in compressed helical springs e.g. slinky toys

25.2 Light

25.2.1 Reflection of light

1 Define and use the terms normal, angle of incidence and angle of reflection

2 Describe and be able to do experiments to illustrate the law of reflection

3 State that for reflection, the angle of incidence is equal to the angle of reflection and use this in constructions, measurements and calculations

25.2.2 Refraction of light

1 Define and use the terms normal, angle of incidence and angle of refraction

2 Describe and be able to do experiments to show refraction of light by transparent blocks of different shapes (refraction through lenses is **not** required)

25.3 Electromagnetic spectrum

1 Know the main regions of the electromagnetic spectrum in order of frequency and in order of wavelength

2 Know that the speed of all electromagnetic waves in:

(a) a vacuum is 3.0×10^8 m/s

(b) air is approximately the same as in a vacuum

3 Describe the role of the following regions in the stated applications:

(a) radio waves – radio and television communications

(b) microwaves –mobile (cell) phone, Bluetooth, microwave ovens

(c) infrared – household electrical appliances, remote controllers, thermal imaging

(d) visible light –photography, vision

(e) ultraviolet – security marking and sterilising water

(f) X-rays – hospital use in medical imaging, security scanners, killing cancerous cells

(g) gamma rays – medical treatment in detecting and killing cancerous cells, sterilising food and medical equipment, engineering applications such as detecting cracks in metal

26 Electricity

26.1 Electrical quantities

26.1.1 Electrical charge

1 State that there are positive and negative charges and that charge is measured in coulombs

2 State that unlike charges attract and like charges repel

3 Describe and be able to do experiments to show electrostatic charging by friction

4 Explain that the charging of solids by friction involves only a transfer of negative charge (electrons)

5 State examples of electrical conductors and insulators

6 Describe examples where electrostatic charge is a problem, including lightning and aircraft refuelling

7 Describe examples where electrostatic charge is helpful, including photocopiers, insecticide sprayers and spray painting

26.1.2 Electrical current

1 Define electric current as charge passing a point per unit time; recall and use the equation

$$\text{electric current} = \frac{\text{charge}}{\text{time}}$$

$$I = \frac{Q}{t}$$

2 Describe electrical conduction in metals in terms of the movement of free (delocalised) electrons

3 Describe the use of and be able to use ammeters (analogue and digital) with different ranges

26.1 Electrical quantities continued

26.1.3 Potential difference

1 Describe the use of and be able to use voltmeters (analogue and digital) with different ranges

2 Calculate the total voltage available from several sources arranged in series

26.1.4 Resistance

1 Recall and use the equation

$$\text{resistance} = \frac{\text{p.d.}}{\text{current}}$$

$$R = \frac{V}{I}$$

2 Describe and be able to do an experiment to determine resistance using a voltmeter and an ammeter and do the appropriate calculations

3 Calculate the combined resistance of two or more resistors in series

26.2 Electrical circuits

26.2.1 Circuit diagrams

1 Draw and interpret circuit diagrams with cells, batteries, power supplies, switches, resistors (fixed and variable), heaters, thermistors (NTC only), light-dependent resistors (LDRs), lamps, motors, ammeters, voltmeters, coils, fuses, diodes and light-emitting diodes (LEDS)

26.2.2 Series and parallel circuits

1 Recall and use in calculations, the fact that:

(a) the current at every point in a series circuit is the same

(b) the sum of the currents entering a junction in a parallel circuit is equal to the sum of the currents that leave the junction

(c) the total p.d. across the components in a series circuit is equal to the sum of the individual p.d.s across each component

(d) the p.d. across an arrangement of parallel resistances is the same as the p.d. across one branch in the arrangement of the parallel resistances

26.3 Practical electricity

26.3.1 Uses of electricity

1 State common uses of electricity, including heating, lighting, battery charging and powering motors and electronic systems

2 Recall and use the equation

power = current × voltage

$P = IV$

3 Recall and use the equation

energy = current × voltage × time

$E = IVt$

4 Define the kilowatt-hour (kW h) and calculate the cost of using electrical appliances where the energy unit is the kW h

26.3.2 Electrical safety

1 State the hazards of:

(a) damaged insulation

(b) overheating cables

(c) damp conditions

(d) excess current from overloading of plugs, extension leads, single and multiple sockets

when using a mains supply

2 Explain the use and operation of trip switches and fuses and choose appropriate fuse ratings and trip switch settings

3 Explain what happens when a live wire touches a metal case that is earthed

4 Explain why the outer casing of an electrical appliance must be either non-conducting (double insulated) or earthed

5 Know that a mains circuit consists of a live wire (line wire), a neutral wire and an earth wire and explain why a switch must be connected in to the live wire for the circuit to be switched off safely

6 Explain why fuses and circuit breakers are connected into the live wire

27 Nuclear physics

27.1 The nuclear model of the atom

1 Describe the structure of the atom in terms of a positively charged nucleus and negatively charged electrons in orbit around the nucleus

2 Describe the composition of the nucleus in terms of protons and neutrons

3 Define the terms

(a) proton number/atomic number, Z

(b) nucleon number/mass number, A

and be able to calculate the number of neutrons in a nucleus

4 Explain what is meant by an isotope and state that an element may have more than one isotope

27.2 Radioactivity

27.2.1 Detection of radioactivity

1 Describe the detection of alpha particles (α-particles) using a cloud chamber or spark counter, and the detection of beta particles (β-particles) (β-particles will be taken to refer to β^-) and gamma radiation (γ-radiation) by using a Geiger-Müller (GM) tube and counter

2 Use count rate measured in counts/s or counts/minute

3 Know what is meant by background radiation

27.2.2 The three types of emission

1 Know that radioactive decay is a change in an unstable nucleus that can result in the emission of α, β and γ radiation and know that these changes are spontaneous and random

2 Describe α-particles as two protons and two neutrons (helium nuclei), β-particles as high-speed electrons from the nucleus and γ-radiation as high-frequency electromagnetic waves

3 State, for α-particles, β-particles and γ-radiation:
   (a) their relative ionising effects
   (b) their relative penetrating powers

27.2.3 Half-life and uses of radioactive isotopes

1 Define the half-life of a particular isotope as the time taken for half the nuclei of that isotope in any sample to decay

2 Explain how the type of radiation emitted and the half-life of the isotope determine which isotope is used for applications including:
   (a) household fire (smoke) alarms
   (b) irradiating food to kill bacteria
   (c) sterilisation of equipment using gamma rays
   (d) measuring and controlling thicknesses with the choice of radiations used linked to penetration and absorption
   (e) diagnosis and treatment of cancer using gamma rays

27.2.4 Safety precautions

1 Explain how radioactive materials are moved, used and stored in a safe way, with reference to:
   (a) reducing exposure time
   (b) increasing distance between source and living tissue
   (c) use of shielding to absorb radiation

4 Details of the assessment

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

Paper 1: Multiple Choice
1 hour
40 marks
40 compulsory multiple-choice items of the four-choice type
This paper tests assessment objectives AO1 and AO2
Externally assessed

Paper 2: Theory
1 hour 45 minutes
80 marks
Compulsory short-answer and structured questions
This paper tests assessment objectives AO1 and AO2
Externally assessed

Practical assessment

Paper 3: Experimental Skills and Investigations
1 hour
40 marks
All items are compulsory
This paper tests assessment objective AO3
Notes for use in qualitative analysis are provided
Candidates will **not** be required to do experiments as part of this test
Externally assessed

The Experimental Skills and Investigations paper:

- requires experimental skills to be developed and learned
- requires an understanding of experimental contexts
- tests assessment objective AO3.

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

Biology

- simple quantitative experiments, including the measurement of:
  - volume of solutions/liquids
  - mass
  - temperature
  - time
  - length
- diffusion
- osmosis
- chemical tests on food

- rates of enzyme-catalysed reactions
- photosynthesis (rate and effect of light intensity)
- heart rate and breathing rate
- calculating the magnification of biological specimens
- procedures using simple apparatus, in situations where the method may not be familiar to the candidate.

Chemistry

- simple quantitative experiments, including the measurement of:
  - volume of gas or solution/liquid
  - mass
  - temperature
  - time
  - length
- rate of reaction
- salt preparation
- separation and purification techniques, including:
  - filtration
  - crystallisation
  - simple distillation
  - fractional distillation
  - chromatography
- identification of metal ions, non-metal ions and gases, including by flame tests
- pH and the use of litmus and universal indicator
- test-tube reactions of dilute acids
- displacement reactions of metals and halogens
- temperature changes during reactions
- procedures using simple apparatus, in situations where the method may not be familiar to the candidate.

Physics

- measurement of physical quantities including length, volume or force
- measurement of small distances or short intervals of time
- determining a derived quantity including the extension per unit load for a spring, the value of a known resistance or the acceleration of an object
- testing and identifying the relationship between two variables such as between the potential difference across a wire and its length
- comparing measured quantities such as angles of reflection
- comparing derived quantities such as density
- cooling and heating, including measurement of temperature
- experiments using springs and balances
- timing motion or oscillations
- electric circuits, including the connection and reconnection of these circuits, and the measurement of current and potential difference
- optics experiments using equipment such as optics pins, mirrors, prisms, glass or Perspex blocks (both rectangular and semi-circular), including the use of transparent, translucent and opaque substances to investigate the transmission of light
- procedures using simple apparatus, in situations where the method may not be familiar to the candidate.

Candidates may be required to do the following:

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

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

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

- **interpret and evaluate experimental observations and data:**
  - process data, including for use in further calculations or for graph plotting, using a calculator as appropriate
  - present data graphically, including the use of best-fit lines where appropriate
  - analyse and interpret observations and data, including data presented graphically
  - use interpolation and extrapolation graphically to determine a gradient or intercept
  - form conclusions justified by reference to observations and data and with appropriate explanation
  - evaluate the quality of observations and data, identifying any anomalous results and taking appropriate action
  - comment on and explain whether results are equal within the limits of experimental accuracy (assumed to be ± 10% at this level of study)

- **evaluate methods and suggest possible improvements:**
  - evaluate experimental arrangements, methods and techniques, including the control of variables
  - identify sources of error, including measurement error, random error and systematic error
  - identify possible causes of uncertainty in data or in a conclusion
  - suggest possible improvements to the apparatus, experimental arrangements, methods or techniques

Language of measurement

The following definitions have been taken or adapted from *The Language of Measurement* (2010), a guide from the Association for Science Education (ASE).
www.ase.org.uk

The definitions in the table below should be used by teachers during the course to encourage students to use the terminology correctly and consistently.

Candidates will **not** be required to recall the specific definition of these terms in the exams.

true value	the value that would be obtained in an ideal measurement
measurement error	the difference between a measured value and the true value of a quantity
accuracy	a measurement result is described as accurate if it is close to the true value
precision	how close the measured values of a quantity are to each other
repeatability	a measurement is repeatable if the same or similar result is obtained when the measurement is repeated under the same conditions, using the same method, within the same experiment
reproducibility	a measurement is reproducible if the same or similar result is obtained when the measurement is made under either different conditions or by a different method or in a different experiment
validity of experimental design	an experiment is valid if the experiment tests what it says it will test. The experiment must be a fair test where only the independent variable and dependent variable may change, and controlled variables are kept constant
range	the maximum and minimum value of the independent or dependent variables
anomaly	an anomaly is a value in a set of results that appears to be outside the general pattern of the results, i.e. an extreme value that is either very high or very low in comparison to others
independent variable	independent variables are the variables that are changed in a scientific experiment by the scientist. Changing an independent variable may cause a change in the dependent variable
dependent variable	dependent variables are the variables that are observed or measured in a scientific experiment. Dependent variables may change based on changes made to the independent variables

Apparatus and reagents

This list gives items that candidates should be familiar with using in preparation for the Experimental Skills and Investigations paper, Paper 3. The list is divided into general apparatus for use across the syllabus, and specific apparatus and materials for each of biology, chemistry and physics. Any queries on apparatus or materials can be sent to **info@cambridgeinternational.org**

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

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

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

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

General apparatus

- adhesive putty (e.g. Patafix, Blu Tack®)
- adhesive tape (e.g. Sellotape®)
- aluminium foil
- balances to measure up to 500 g, with precision of at least 0.1 g
- beakers, squat form with lip, 400 cm^3, 250 cm^3 and 100 cm^3
- beakers or cups made of an insulating material, approximately 200 cm^3
- boiling tubes / large test-tubes, approximately 150 mm × 25 mm
- Bunsen burners
- card
- filter paper
- funnels
- glass rods
- heat-proof mats, tripods and gauzes
- means of writing on glassware (e.g. wax pencils or water-resistant markers)
- measuring cylinders, 100 cm^3, 50 cm^3 or 25 cm^3, 10 cm^3 (ISO6706 or ISO4788 or grade B)
- pair of compasses
- racks for test-tubes and boiling tubes
- red and blue litmus paper
- retort stands, bosses and clamps
- ruler, 30 cm, graduated in mm
- S-hook
- scissors
- set square
- small dropping pipettes or teat pipettes
- stirring thermometers, –10 °C to +110 °C, with 1 °C graduations

- stoppers for test-tubes and boiling tubes / large test-tubes
- stoppers with delivery tubes to fit test-tubes and boiling tubes / large test-tubes
- stop-watches, reading to 0.1 s or better
- string
- syringes (without needles, various sizes, e.g. 1 cm^3, 5 cm^3, 10 cm^3)
- test-tube holders (to hold test-tubes or boiling tubes)
- test-tubes (Pyrex or hard glass), approximately 125 mm × 16 mm
- thread
- tracing paper
- universal indicator paper or solution
- wash bottles containing distilled or deionised water
- wooden board (rigid, 150 cm × 20 cm × 1.5 cm)

Biology

Biological materials

- locally available samples of food
- locally available terrestrial and aquatic plant material

Chemicals, reagents and indicators

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

- Benedict's solution **[MH]**
- biuret reagent (sodium or potassium hydroxide solution and copper sulfate solution) **[C]**
- buffer solutions (buffer tablets are commonly available)
- carbohydrates (starch, glucose, sucrose), proteins, lipids
- dilute acid **[C] [MH]**
- dilute alkali **[C] [MH]**
- enzymes (e.g. amylase, a protease, lipase) **[C] [HH] [MH]**
- ethanol **[F] [HH] [MH]**
- hydrogen peroxide solution **[C] [MH]**
- iodine in potassium iodide solution (iodine solution) **[MH] [N]**

Apparatus

- dishes (e.g. Petri dishes)
- electric lamp
- forceps
- hand lenses (at least ×6 magnification)
- means of cutting biological materials (e.g. scalpels or sharp knives)
- mortars and pestles (or access to a blender)
- mounted needles or seekers or long pins with large heads
- spotting tiles
- white tiles or other suitable cutting surfaces

Chemistry

Reagents

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

- dilute hydrochloric acid, 1.0 mol / dm^3 HCl
- dilute nitric acid, 1.0 mol / dm^3 HNO^3 **[C]**
- dilute sulfuric acid, 0.5 mol / dm^3 H_2SO_4 **[MH]**
- aqueous ammonia, 1.0 mol / dm^3 NH_3 **[MH][N]**
- aqueous sodium hydroxide, 1.0 mol / dm^3 NaOH **[C]**
- aqueous barium nitrate, 0.1 mol / dm^3 $Ba(NO_3)_2$
- aqueous silver nitrate, 0.05 mol / dm^3 $AgNO_3$
- limewater, saturated aqueous calcium hydroxide, $Ca(OH)_2$ **[MH]**
- aqueous potassium iodide, 0.1 mol / dm^3 KI

Apparatus

- conical flasks, within the range 50 cm^3 to 250 cm^3
- flame test wires or alternative apparatus
- pipette fillers
- spatulas
- volumetric flasks, 250 cm^3 (ISO1042 or grade B)
- volumetric pipettes, 25 cm^3 (ISO648 or grade B)

Physics

The following suggested equipment has been categorised, but equipment can be used in any topic.

Mechanics

- expendable steel springs, with spring constant of approx. 0.25 N / cm
- force meter, with maximum reading or full scale deflection of between 1.0 N and 10.0 N
- G-clamp
- glass ball (marble), ball bearing (approx. 10 mm in diameter) and table tennis ball
- half-metre rule, graduated in mm
- masses, 10 × 10 g, 10 × 100 g, including holders
- metre rule, graduated in mm
- modelling clay (e.g. Plasticine®)
- pendulum bob
- pivots (e.g. 15 cm nails, triangular wooden blocks)
- retort stand, boss and clamp
- single-wheel pulley, with facilities for attaching to a bench or to a clamp stand

Optics

- glass or Perspex 60° prism
- glass or Perspex blocks, rectangular and semicircular
- optics pins, minimum length 75 mm
- plane mirror, approx. 75 mm × 25 mm
- pin board
- protractor

Electricity

Candidates or centres may need to join components, meters and cells together to make circuits. Connectors used will be 3.5 mm or 4 mm in diameter.

- ammeter, with full scale deflection 1 A or 1.5 A and precision of at least 0.05 A (analogue, dedicated digital or multimeter)
- voltmeter, with full scale deflection 5 V and precision of at least 0.1 V (analogue, dedicated digital or multimeter)
- cells, 1.5 V, and holders to enable several cells to be joined
- connecting leads, 3.5 mm or 4 mm connectors
- crocodile clips
- d.c. power supply, variable to 12 V
- diodes, including LEDs
- filament lamp, 12 V, 24 W and holder
- filament lamps, low voltage (e.g. 2.5 V) and holders
- LDRs (suitable for use in 1 V–5 V circuits)
- selection of resistors, values within range 5 Ω to 50 Ω, power rating of 1 W to 2 W
- switches, including push switches
- thermistors (NTC only)
- wire, constantan (eureka), 0.38 mm diameter (28 swg), 0.32 mm diameter (30 swg)
- wire, nichrome, 0.38 mm diameter (28 swg), 0.32 mm diameter (30 swg)

Safety in the laboratory

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

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

Associations

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

Publications

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

CLEAPSS Hazcards, 2019 update of 2016 edition (available to CLEAPSS members only)

UK regulations

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

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

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

A brief guide may be found at

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

Notes for use in qualitative analysis

Tests for anions

anion	test	test result
carbonate, CO_3^{2-}	add dilute acid, then test for carbon dioxide gas	effervescence, carbon dioxide produced
chloride, Cl^- [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	white ppt.
bromide, Br^- [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	cream ppt.
iodide, I^- [in solution]	acidify with dilute nitric acid, then add aqueous silver nitrate	yellow ppt.
sulfate, SO_4^{2-} [in solution]	acidify with dilute nitric acid, then add aqueous barium nitrate	white ppt.

Tests for aqueous cations

cation	effect of aqueous sodium hydroxide	effect of aqueous ammonia
aluminium, Al^{3+}	white ppt., soluble in excess, giving a colourless solution	white ppt., insoluble in excess
ammonium, NH_4^+	ammonia produced on warming	—
calcium, Ca^{2+}	white ppt., insoluble in excess	no ppt. or very slight white ppt.
chromium(III), Cr^{3+}	green ppt., soluble in excess	green ppt., insoluble in excess
copper(II), Cu^{2+}	light blue ppt., insoluble in excess	light blue ppt., soluble in excess, giving a dark blue solution
iron(II), Fe^{2+}	green ppt., insoluble in excess, ppt. turns brown near surface on standing	green ppt., insoluble in excess, ppt. turns brown near surface on standing
iron(III), Fe^{3+}	red-brown ppt., insoluble in excess	red-brown ppt., insoluble in excess
zinc, Zn^{2+}	white ppt., soluble in excess, giving a colourless solution	white ppt., soluble in excess, giving a colourless solution

Tests for gases

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

Flame tests for metal ions

metal ion	flame colour
lithium, Li^+	red
sodium, Na^+	yellow
potassium, K^+	lilac

The Periodic Table of Elements

The Periodic Table of Elements

Key

atomic number
atomic symbol
name
relative atomic mass

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

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

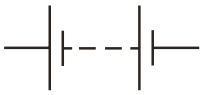
The volume of one mole of any gas is 24 dm^3 at room temperature and pressure (r.t.p.).

Electrical symbols

cell

battery of cells

or

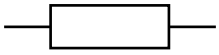


power supply

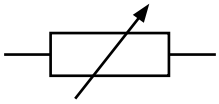
d.c. power supply

a.c. power supply

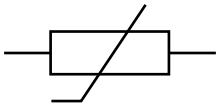
fixed resistor



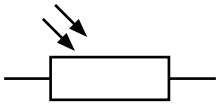
variable resistor



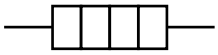
thermistor



light-dependent resistor



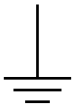
heater



coil

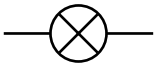
switch

earth or ground



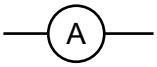
junction of conductors

lamp

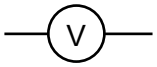


motor

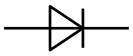
ammeter



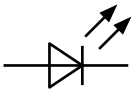
voltmeter



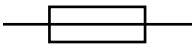
diode



light-emitting diode



fuse



Symbols and units for physical quantities

Candidates should be able to give the symbols for the following physical quantities and, where indicated, state the units in which they are measured.

Candidates should be able to use the following multipliers: G giga, M mega, k kilo, d deci, c centi, m milli, μ micro, n nano

Quantity	***Usual symbol***	***Usual unit***
length	*l, h, d, s, x*	km, m, cm, mm, μm
area	*A*	m^2, cm^2
volume	*V*	m^3, cm^3, dm^3
weight	*W*	N
mass	*m, M*	kg, g, mg
time	*t*	h, min, s, ms, μs
density	*ρ*	g/cm^3, kg/m^3
speed	*u, v*	km/h, m/s, cm/s
acceleration	*a*	m/s^2
force	*F*	N
gravitational field strength	*g*	N/kg
spring constant	*k*	N/m, N/cm
moment of a force		N m
work done	*W*	J, kJ, MJ
energy	*E*	J, kJ, MJ, kWh
power	*P*	W, kW, MW
temperature	*θ*, *T*	°C
specific heat capacity	*c*	J/(g °C), J/(kg °C)
frequency	*f*	Hz, kHz
wavelength	*λ*	m, cm, nm
angle of incidence	*i*	degree (°)
angle of reflection	*r*	degree (°)
angle of refraction	*r*	degree (°)
potential difference/voltage	*V*	V, mV, kV
current	*I*	A, mA
resistance	*R*	Ω
charge	*Q*	C
count rate		counts/s, counts/minute
half-life		s, minutes, h, days, weeks, years

Mathematical requirements

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

Calculators may be used in all parts of the examination.

Numerical answers should be written as decimals (or percentages if appropriate).

Number

- add, subtract, multiply and divide
- use decimals, fractions, percentages, ratios and reciprocals
- convert between decimals, fractions and percentages
- calculate and use percentages and percentage change
- understand and use the symbols: =, <, >
- understand the meaning of sum, difference and product
- use standard form (scientific notation)
- understand that only the final answer in a calculation should be rounded
- use decimal places and significant figures appropriately
- make approximations and estimates to obtain reasonable answers

Algebra

- use positive, whole number indices in algebraic expressions
- substitute values of quantities into equations, using consistent units
- solve simple algebraic equations for any one term when the other terms are known
- recognise and use direct and inverse proportion
- set up simple algebraic equations as mathematical models of physical situations and to represent information given in words
- use Δ (delta) in algebraic expressions and equations to represent a change in a variable

Geometry and measurements

- understand the meaning of angle, curve, circle, radius, diameter, circumference, square, parallelogram, rectangle and diagonal
- recall and use the equation for the circumference of a circle
- recall and use the equations for the area of a rectangle, area of a triangle and area of a circle
- recall and use the equations for the volume of a rectangular block and volume of a cylinder
- select and use the most appropriate units for recording data and the results of calculations
- convert between units, including μm, mm, cm and m; cm^3 and dm^3; mg, g and kg; J and kJ
- understand surface area and use Surface Area : Volume ratio
- use scale diagrams
- apply Pythagoras' theorem to the calculation of a side of a right-angled triangle
- understand that a right angle is 90° and that the sum of the angles on a straight line is 180°
- use sine and inverse sine
- use mathematical instruments (ruler, pair of compasses, protractor, set square)
- recognise and use the points of the compass (N, S, E, W) and clockwise and anticlockwise directions

Graphs, charts and statistics

- draw graphs and charts from data
- interpret graphs and charts, including interpolation and extrapolation of data
- determine the gradient (slope) of a line on a graph, including by drawing a tangent to a curve
- determine the intercept of the line on a graph, extending the line graphically (extrapolating) where appropriate
- select suitable scales and axes for graphs
- understand that $y = mx + c$ represents a linear relationship
- recognise direct and inverse proportionality from a graph
- use and interpret Venn diagrams to show groupings and sets
- calculate and use the average (mean) and range of a set of values
- use simple probability

Presentation of data

Taking readings

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

Recording readings

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

Graphs

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

Drawings

- These should be drawn using a sharp pencil to give fine lines that are clear and unbroken.
- These should use most of the available space and show all the features observed in the specimen, with no shading.
- Label lines should be drawn with a ruler and touch the object or feature labelled.

Charts

- Pie charts are generally used to show percentage or proportional data.
- Bar charts should be drawn for categorical or discrete data. They should have bars of equal width that do not touch.
- Histograms should be drawn for continuous data. They should have bars that touch.

Further guidance can be found in the following publications:

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

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

https://www.ase.org.uk/mathsinscience

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

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

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

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

The traditional names sulfate, sulfite, nitrate, nitrite, sulfuric acid and nitric acid will be used in question papers. Candidates will be credited for traditional or systematic names in their answers.

Decimal markers

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

Numbers

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

Variables

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

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

Units

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

In practical work, candidates will be expected to use SI units or, where appropriate, units approved for use with the SI (e.g. minute). A list of SI units and units approved for use with the SI may be found at **http://www.bipm.org**

The use of imperial/customary units such as the inch and degree Fahrenheit is not acceptable and should be discouraged. In all examinations, where data is supplied for use in questions, candidates will be expected to use units that are consistent with the units supplied and should not attempt conversion to other systems of units unless this is a requirement of the question.

Command words

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

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

5 What else you need to know

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

Before you start

Previous study

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

Guided learning hours

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

Availability and timetables

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

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

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

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

Combining with other syllabuses

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

- Cambridge IGCSE Biology (0610)
- Cambridge IGCSE Chemistry (0620)
- Cambridge IGCSE Physics (0625)
- Cambridge IGCSE Physical Science (0652)
- Cambridge IGCSE Combined Science (0653)
- Cambridge IGCSE Co-ordinated Sciences (Double Award) (0654)
- Cambridge IGCSE (9–1) Biology (0970)
- Cambridge IGCSE (9–1) Chemistry (0971)
- Cambridge IGCSE (9–1) Physics (0972)
- Cambridge IGCSE (9–1) Co-ordinated Sciences (Double Award) (0973)

- Cambridge O Level Physics (5054)
- Cambridge O Level Chemistry (5070)
- Cambridge O Level Biology (5090)
- syllabuses with the same title at the same level.

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

Making entries

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

Exam administration

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

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

Support for exams officers

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

Retakes

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

Language

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

Accessibility and equality

Syllabus and assessment design

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

Access arrangements

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

Important:

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

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

After the exam

Grading and reporting

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

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

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

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

These letters do not appear on the certificate.

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

How students and teachers can use the grades

Assessment at Cambridge O Level has two purposes:

1 to measure learning and achievement

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

2 to show likely future success

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

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

Changes to this syllabus for 2026, 2027 and 2028

The syllabus has been updated. This is version 2, published December 2025.

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

Changes to version 2 of the syllabus, published December 2025

Other changes	• The weblink on page 59 has been updated.

Changes to version 1 of the syllabus, published September 2023

Changes to availability	• This syllabus is available to candidates in international centres in the November series only. Centres in Brunei can enter candidates in the June series also.

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

We are committed to making our documents accessible in accordance with the WCAG 2.1 Standard. We are always looking to improve the accessibility of our documents. If you find any problems or you think we are not meeting accessibility requirements, contact us at **info@cambridgeinternational.org** with the subject heading: Digital accessibility. If you need this document in a different format, contact us and supply your name, email address and requirements and we will respond within 15 working days.

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