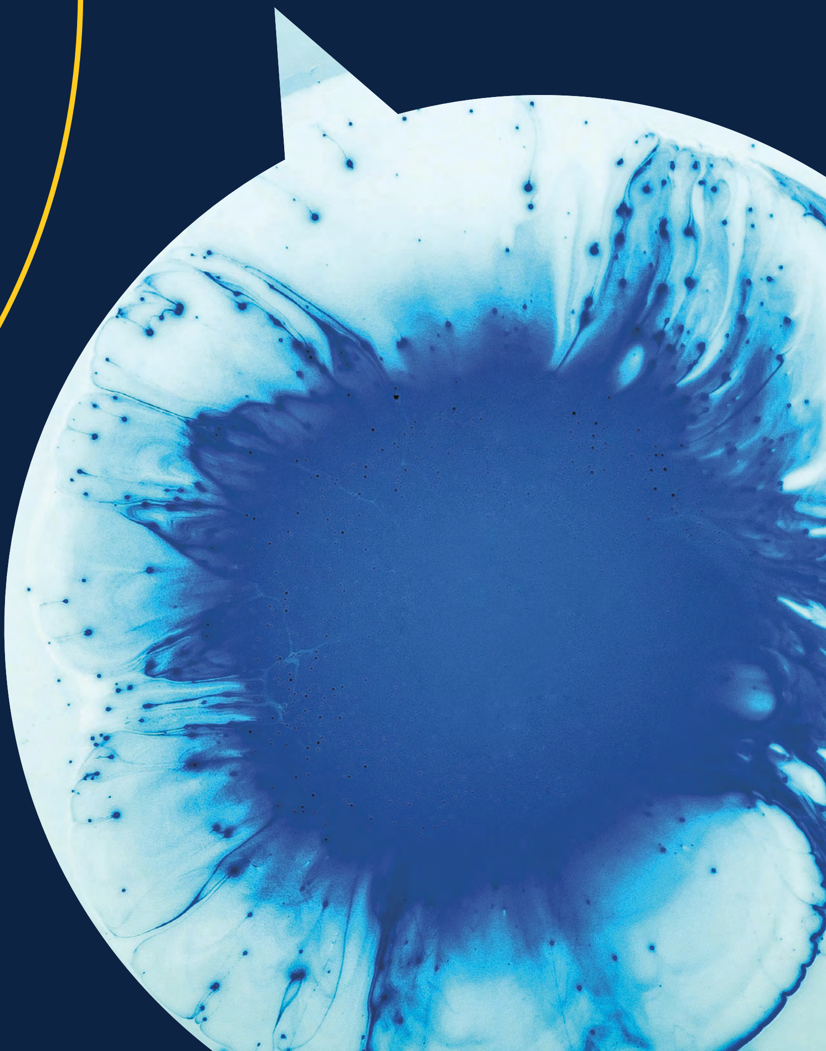
OXFORD AQA
INTERNATIONAL QUALIFICATIONS

International GCSE

Combined Science Double Award

(9204) Specification



For teaching from September 2016 onwards

For exams May/June 2018 onwards

For teaching and examination outside the United Kingdom

Contents

Are you using the latest version of this specification?

- You will always find the most up-to-date version of this specification on our website at **oxfordaqa.com/9204**
- We will write to you if there are significant changes to the specification.

1 Introduction

1.1 Why choose OxfordAQA International GCSEs?

Our International qualifications enable schools that follow a British curriculum to benefit from the best education expertise in the United Kingdom (UK).

Our International GCSEs offer the same rigour and high quality as GCSEs in the UK and are relevant and appealing to students worldwide. They reflect a deep understanding of the needs of teachers and schools around the globe and are brought to you by Oxford University Press and AQA, the UK's leading awarding body.

Providing valid and reliable assessments, these qualifications are based on over 100 years of experience, academic research and international best practice. They have been independently validated as being to the same standard as the qualifications accredited by the UK examinations regulator, Ofqual. They reflect the latest changes to the British system, enabling students to progress to higher education with up-to-date qualifications.

You can find out about OxfordAQA at **oxfordaqa.com**

1.2 Why choose our International GCSE Combined Science Double Award?

In developing this specification we have consulted widely with teachers and science advisers to produce content and assessments that will both stimulate students' interest in and enthusiasm for science and provide an excellent grounding for further study. This specification contains a broad range of topics that are designed to engage students whilst providing the knowledge and understanding required for progression to Level 3 qualifications.

Science is an enquiry-based discipline involving practical and investigational skills as well as knowledge. The specification emphasises scientific knowledge, the application of science and the scientific process. Section 3 gives the fundamental ideas behind scientific enquiry that should be delivered through teaching of the content. The experimental and investigative skills that will be assessed in this specification are listed in Section 6.1. There are a number of required practicals identified in the specification, which students will need to cover as part of the content of the specification. These practicals will be assessed during the lifetime of the specification. These are summarised in Section 6.2.

The content is a subset of the separate sciences so they are co-teachable.

The terminal assessment model is designed to ensure the maximum amount of time for teaching.

You can find out about all our International GCSE Combined Science Double Award qualifications at **oxfordaqa.com/science**

1.3 Recognition

OxfordAQA meet the needs of international students. Please refer to the published timetables on the exams administration page of our website (**oxfordaqa.com/exams-administration**) for up to date exam timetabling information. They are an international alternative and comparable in standard to the Ofqual regulated qualifications offered in the UK.

Our qualifications have been independently benchmarked by UK NARIC, the UK national agency for providing expert opinion on qualifications worldwide. They have confirmed they can be considered ‘comparable to the overall GCE A-level and GCSE standard offered in the UK’. Read their report at **oxfordaqa.com/recognition**

To see the latest list of universities who have stated they accept these international qualifications, visit **oxfordaqa.com/recognition**

1.4 Support and resources to help you teach

We know that support and resources are vital for your teaching and that you have limited time to find or develop good quality materials. That’s why we’ve worked with experienced teachers to provide resources that will help you confidently plan, teach and prepare for exams.

Teaching resources

You will have access to:

- sample schemes of work to help you plan your course with confidence
- training courses to help you deliver our qualifications
- student textbooks that have been checked and approved by us
- engaging worksheets and activities developed by teachers, for teachers
- command words with exemplars
- science vocabulary with definitions
- a handbook to support practical work.

Preparing for exams

You will have access to the support you need to prepare for our exams, including:

- specimen papers and mark schemes
- exemplar student answers with examiner commentaries
- a searchable bank of past AQA exam questions mapped to these new International qualifications.

Analyse your students' results with Enhanced Results Analysis (ERA)

After the first examination series, you can use this tool to see which questions were the most challenging, how the results compare to previous years and where your students need to improve. ERA, our free online results analysis tool, will help you see where to focus your teaching.

Information about results, including maintaining standards over time, grade boundaries and our post-results services, will be available on our website in preparation for the first examination series.

Help and support

Visit our website for information, guidance, support and resources at **oxfordaqa.com/9204**

You can contact the subject team directly at **science@oxfordaqa.com** or call us on +44 (0)161 696 5995 (option 1 and then 1 again).

Please note: We aim to respond to all email enquiries within two working days.

Our UK office hours are Monday to Friday, 8am – 5pm.

2 Specification at a glance

The title of the qualification is:

- OxfordAQA International GCSE Combined Science Double Award.

This qualification is linear. Linear means that students will sit all their exams at the end of the course.

Exams will be available May/June and in November.

The guided learning hours (GLH) for this qualification is 240 as it is a Double Award. These figures are for guidance only and may vary according to local practice and the learner's prior experience of the subject.

2.1 Subject content

Biology

Organisation

All organisms are constituted of one or more cells. Multi–cellular organisms have cells that are differentiated according to their function. All the basic functions of life are the result of what happens inside the cells which make up an organism. Growth is the result of multiple cell divisions.

- Cell structure
- Principles of organisation
- Animal tissues, organs and organ systems
- Plant tissues, organs and systems
- Transport in cells

Bioenergetics and Ecology

Food provides materials and energy for organisms to carry out the basic functions of life and to grow. Some plants and bacteria are able to use energy from the Sun to generate complex food molecules. Animals obtain energy by breaking down complex food molecules and are ultimately dependent on green plants for energy. In any ecosystem there is competition among species for the energy and materials they need to live and reproduce.

Bioenergetics

- Photosynthesis
- Circulation in humans
- Digestion
- Breathing
- Respiration

Ecology

- Energy transferred in ecosystems
- Adaptations, interdependence and competition
- Decay and the carbon cycle

Organisms' interaction with the environment

Changes in environmental conditions may be biotic or abiotic and can result in responses from an organism which protect the organism from harm and support maintenance of the species. Such responses may impact on the internal stability of the organism or promote certain behaviours to protect it.

- The human nervous system
- Homeostasis
- Temperature control
- Control of blood glucose
- Behaviour
- Infection and response

Inheritance

Genetic information in a cell is held in the chemical DNA in the form of a four letter code. Genes determine the development and structure of organisms. In asexual reproduction all the genes in the offspring come from one parent. In sexual reproduction half of the genes come from each parent.

- Reproduction
- Cell division
- Genetic variation
- Genetic disorders
- Genetic manipulation

Variation and Evolution

All life today is directly descended from a universal common ancestor that was a simple one-celled organism. Over countless generations changes resulted from natural diversity within a species which makes possible the selection of those individuals best suited to survive under certain conditions. Organisms not able to respond sufficiently to changes in their environment become extinct.

- Variation
- Natural selection

Chemistry

Atomic structure and the Periodic Table

Atoms are the building blocks of all materials and knowledge of atomic structure and the periodic table are fundamental to the learning associated with all the following sections.

- Solids liquids and gases
- A simple model of the atom
- The periodic table

Structure, bonding and the properties of matter

This section examines how atoms interact to form chemical bonds and how these bonds determine the properties and uses of materials.

- Chemical bonds: ionic, covalent and metallic
- How bonding and structure are related to the properties of substances
- Structure and bonding of carbon

Chemical changes

The group of materials known as metals are explored in more detail including how atoms are rearranged to form new substances in chemical reactions.

- Metals
- The reactivity series
- Metal carbonates
- Electrolysis

Chemical analysis

This section focuses on developing practical skills in chemistry which identify substances and reinforces the idea of a pure substance as consisting of one substance only.

- Purity and chromatography
- Identification of ions

Acids, bases and salts

This section looks in greater detail at the properties and applications of acids and bases.

- The properties of acids and bases
- Preparation of salts

Quantitative chemistry

- Conservation of mass including the quantitative interpretation of chemical equations
- Use of amount of substance in relation to masses of pure substances
- The mole concept
- Using molar concentrations of solutions

Trends within the periodic table

This section looks to both describe and explain trends within the periodic table along with more detailed knowledge and understanding of identified groups.

- Group properties

The rate of chemical change

- Rate of reaction

Energy changes

This section highlights that chemical reactions involve changes which require energy to make them happen. This is a fundamental concept which links to key ideas in biology and physics. The section also involves developing mathematical skills and also application of knowledge.

- Exothermic and endothermic reactions
- Calculating and explaining energy change

Organic chemistry

- Crude oil
- Hydrocarbons
- Obtaining useful substances from crude oil
- Synthetic and naturally occurring polymers
- Organic compounds – their structure and reactions

Physics

Forces and their effects

This topic explores the interactions (forces) between objects that can change their shape or the way they are moving. Mathematical relationships can predict the resultant motion of an object and applications illustrate how forces can be used to achieve certain outcomes and avoid others.

- Forces and their interactions
- Motion
- Resultant forces
- Safety in public transport

Energy

This topic starts with the principles of energy transfer and then explores it in various contexts, such as heating. It considers the idea that energy is never destroyed but may end up so dissipated that it is of little use.

- Forces and energy
- Energy transfers, conservation and dissipation of energy
- Energy resources

Waves

Waves, both transverse and longitudinal, carry energy from a source and can be detected by a receiver. This topic explores the properties of waves and their application to contexts such as information communication and sight.

- General properties of waves
- The electromagnetic spectrum
- Sound
- Reflection

Particle model of matter

The properties of materials can be understood in terms of constituent particles, their motions and interactions.

- Kinetic theory
- Energy transfers and particle motion

Electricity and Magnetism

Electricity is convenient because it is easily transmitted over distances and can be easily transferred in a range of different ways. By controlling the flow of current and understanding the factors that affect this flow it can be used to make a range of applications work. Electricity is also a good context for considering how energy is transferred. Magnetism provides a connection with forces through the study of fields and the way it can produce and be produced by electricity.

- Electrical circuits
- Magnetism and electromagnetism

Generating and distributing electricity and household use

In this topic magnetism and electromagnetism are studied in the context of their uses in using current to cause motion and vice versa and in changing the voltages of an ac supply. In so doing the big ideas of field forces and energy transfer are also used.

- Using electricity in the home
- The motor effect
- Transferring electrical energy

Nuclear physics

The structure of material is used to model what an atom consists of, what might happen when atoms break apart and when they fuse together. This provides ways of actually or potentially generating power and explains processes at the centre of stars.

- Atomic structure
- Ionizing radiation from the nucleus
- Nuclear fission

Space physics

Space physics uses ideas about forces and motion, energy transfer, atomic structure and fields to develop explanations about the start and end of the universe and about how the Earth receives energy from the Sun. Space was one of the first challenges that civilisation tried to explain in its attempts to account for day, season, year and the appearance of the night sky and remains one of the most challenging due to its scale and complexity.

- Life cycle of a star
- Solar system and orbital motion

2.2 Assessments

The title of the qualification is:

- OxfordAQA International GCSE Combined Science Double Award.

This qualification is linear, with three question papers to be taken in the same examination series.

Students must take the same tier of paper for biology, chemistry and physics. Mixed tiering is prohibited.

Biology (Paper 1)	+	Chemistry (Paper 2)	+	Physics (Paper 3)
What's assessed Content from any part of the biology section of the specification may be assessed.		What's assessed Content from any part of the chemistry section of the specification may be assessed.		What's assessed Content from any part of the physics section of the specification may be assessed.
How it's assessed Written exam: 1 hour and 45 minutes 100 marks		How it's assessed Written exam: 1 hour and 45 minutes 100 marks		How it's assessed Written exam: 1 hour and 45 minutes 100 marks
Questions Structured and open questions.		Questions Structured and open questions.		Questions Structured and open questions.

3 Subject content

Through the teaching of this combined science syllabus, students will develop knowledge and understanding of the subject content of combined science, the practices of science and how science as a discipline develops. Students will develop their ability to work as a scientist.

Working as a scientist involves being able to observe, question, hypothesise and carry out various types of scientific enquiry to further scientific knowledge, and to be able to use models and arguments to support explanations and decision making. It also involves following established procedures to ensure that new scientific knowledge can be validated.

Working this way requires knowledge and understanding of the practices of science and how science as a discipline develops.

Knowledge of the subject content in isolation does **not** provide the knowledge, understanding and skills required for progression to higher qualifications or develop the knowledge, understanding and skills required for students to be future scientists or scientifically literate citizens.

There are three dimensions to working as a scientist:

- Subject content
- The practices of science
- How science as a discipline develops.

Subject content

The established facts, concepts, ideas and theories.

The assessed subject content is presented as a series of topic areas listing the statements students need to know, understand and apply. Expansion of the content and clarification of what may be examined is given in *italics*.

In this specification there is additional content for Extension Tier students.

This is denoted in the subject content in **bold type**.

The practices of science

How observation and experimentation is carried out to obtain evidence. The assessment requirements are detailed in the specification appendices 6.1 and 6.2.

Students should develop an understanding of how the following elements relate to the subject content and practices of science.

Students should be able to:

- suggest, describe and explain experimental and investigative procedures
- justify the choice of experimental or investigative procedure and the use of apparatus
- identify possible hazards, the risks associated with these hazards, and methods of minimising the risks
- recognise and explain the need to manipulate and control variables, including the use of control groups where necessary
- assess whether sufficient measurements have been taken with appropriate precision, and appreciate when it is appropriate to calculate a mean

- recognise and identify the causes of anomalous results and suggest what should be done about them
- present, analyse and interpret data in tabular and graphical forms, identifying patterns and correlations (which may be causal or non-causal)
- recognise and identify the causes of random and systematic errors
- evaluate data, considering its validity, repeatability and reproducibility in supporting conclusions
- evaluate working methods, suggesting advantages and disadvantages of approaches used.

How science as a discipline develops

The defining features that characterise the nature of the subject and how new scientific knowledge is established.

The defining features of how science knowledge and understanding develops over time:

- Predictions are tested to support or refute a new scientific idea or explanation.
- Scientific claims are supported by evidence and scientific reasoning, and should be able to be confirmed by other scientists.
- Evidence and creative thinking is used to develop new scientific ideas and explanations.
- Different conclusions may be drawn from available evidence and can be influenced by personal background, experience or interests.
- New technologies and practical techniques can lead to new investigations and discoveries, and advance scientific knowledge and understanding.
- New evidence can lead to new lines of enquiry and changes in scientific ideas and explanations.
- Models are used to support scientific explanations with limits to what they can and cannot explain.
- Accepted scientific ideas and explanations can take a long time to be abandoned even if new evidence disagrees with predictions based upon them.
- Science often involves collaboration in interdisciplinary teams, often from several countries.

The scientific terms used in this specification are clearly defined by the ASE in *The Language of Measurement: Terminology used in school science investigations* (Association for Science Education, 2010).

Teachers should ensure that they and their students are familiar with these terms. Definitions of the terms will **not** be required in assessments, but students will be expected to use them correctly.

Biology

3.1 Organisation

All organisms are constituted of one or more cells. Multicellular organisms have cells that are differentiated according to their function. All the basic functions of life are the result of what happens inside the cells which make up an organism. Growth is the result of multiple cell divisions.

3.1.1 Cell structure

a. Most animal cells (eukaryotic cells) have the following parts:

- a nucleus, which controls the activities of the cell
- cytoplasm, in which most of the chemical reactions take place
- a cell membrane, which controls the passage of substances into and out of the cell
- mitochondria, which is where most energy is released in respiration
- ribosomes, which is where protein synthesis occurs.

b. In addition to the above, plant cells (eukaryotic cells) often have:

- chloroplasts, which absorb light energy to make food
- a permanent vacuole filled with cell sap.

Plant and algal cells also have a cell wall made of cellulose, which strengthens the cell.

c. A bacterial cell (prokaryotic cell) consists of cytoplasm and a membrane surrounded by a cell wall; the genes are not in a distinct nucleus; some of the genes are located in circular structures called plasmids.

d. Cells may be specialised to carry out a particular function.

Students should be able, when provided with appropriate information, to relate the structure of different types of cell to their function in a tissue, an organ, or the whole organism.

3.1.2 Principles of organisation

a. Large multicellular organisms develop systems for exchanging materials. During the development of a multicellular organism, cells differentiate so that they can perform different functions.

b. A tissue is a group of cells with similar structure and function.

c. Organs are made of tissues. One organ may contain several tissues.

d. Organ systems are groups of organs that perform a particular function.

Students should develop an understanding of size and scale in relation to cells, tissues, organs and systems.

3.1.3 Animal tissues, organs and systems

a. Examples of animal tissues include:

- muscular tissue, which can contract to bring about movement
- glandular tissue, which can produce substances such as enzymes and hormones
- epithelial tissue, which covers some parts of the body.

b. An example of an animal organ is the stomach, which contains:

- muscular tissue, to allow contents to move through the digestive system
- glandular tissue, to produce digestive juices
- epithelial tissue, to cover the outside and the inside of the stomach.

c. An example of an animal organ system is the digestive system, a system in which humans and other mammals exchange substances with the environment. The digestive system includes:

- glands, such as the pancreas and salivary glands, which produce digestive juices
- the stomach and small intestine, where digestion occurs
- the liver, which produces bile
- the small intestine, where the absorption of soluble food occurs
- the large intestine, where water is absorbed from the undigested food, producing faeces.

3.1.4 Plant tissues, organs and systems

a. Examples of plant tissues include:

- epidermal tissues, which cover the plant
- palisade mesophyll, which carries out photosynthesis
- spongy mesophyll, which has air spaces to facilitate diffusion of gases
- xylem and phloem, which transport substances around the plant.

b. Plant organs include stems, roots and leaves.

Details of the internal structure of these organs are limited to the leaf and to the position of the xylem and phloem in a dicotyledonous primary root and primary stem.

3.1.5 Transport in cells

The movement of substances into and out of cells.

a. Diffusion is the spreading of the particles of any substance in solution, or particles of a gas, resulting in a net movement from an area of higher concentration to an area of lower concentration. The greater the difference in concentration, the faster the rate of diffusion.

b. Dissolved substances can move into and out of cells by diffusion.

c. Oxygen required for respiration passes through cell membranes by diffusion.

d. Osmosis is the diffusion of water from a dilute to a more concentrated solution through a selectively permeable membrane that allows the passage of water molecules.

e. Differences in the concentrations of the solutions inside and outside a cell cause water to diffuse into or out of the cell by osmosis.

   Students should be familiar with experiments related to diffusion and osmosis as well as the terms isotonic, hypertonic, turgor and plasmolysis.

f. Substances are sometimes absorbed against a concentration gradient. This requires the use of energy from respiration. The process is called active transport.

g. Active transport enables plants to absorb ions from very dilute solutions, eg by root hair cells. Similarly, sugar may be absorbed from low concentrations in the intestine and from low concentrations in the kidney tubules.

h A single-celled organism has a relatively large surface area to volume ratio. All the necessary exchanges occur across its surface membrane.

   The increased size and complexity of an organism increases the difficulty of exchanging materials.

i. In multicellular organisms many organ systems are specialised for exchanging materials. The effectiveness of an exchange surface is increased by:

   - having a large surface area that is thin, to provide a short diffusion path
   - (in animals) having an efficient blood supply
   - (in animals, for gaseous exchange) being ventilated.

   Students should be able to explain how the small intestine and lungs in mammals, and the roots and leaves in plants, are adapted for exchanging materials.

j. Gas and solute exchange surfaces in humans and other organisms are adapted to maximise effectiveness.

   Students should be able to explain how gas and solute exchange surfaces are adapted to maximise effectiveness.

3.2 Bioenergetics

Food provides materials and energy for organisms to carry out the basic functions of life and to grow. Some plants and bacteria are able to use energy from the Sun to generate complex food molecules. Animals obtain energy by breaking down complex food molecules and are ultimately dependent on green plants for energy.

3.2.1 Photosynthesis

a. Photosynthesis is summarised by the equations:

$$\text{carbon dioxide} + \text{water} \xrightarrow{\text{light}} \text{glucose} + \text{oxygen}$$

$$6CO_2 + 6H_2O \xrightarrow{\text{light}} C_6H_{12}O_6 + 6O_2$$

b. During photosynthesis:

- light is absorbed by a green substance called chlorophyll, which is found in chloroplasts in some plant cells and in algae
- light is used to convert carbon dioxide (from the air) and water (from the soil) into sugar (glucose)
- oxygen is released as a by-product.

c. The rate of photosynthesis may be limited by:

- low temperature
- shortage of carbon dioxide
- shortage of light.

These factors interact and any one of them may be the factor that limits photosynthesis.

Students should be able to relate the principle of limiting factors to the economics of enhancing the following conditions in greenhouses:

- *temperature*
- *carbon dioxide concentration*
- *light intensity.*

Required practical:
Investigate how variables affect the rate of photosynthesis.

d. The glucose produced in photosynthesis may be used as a source of chemical energy or converted to larger molecules for storage and use later. The glucose can be:

- used for respiration
- converted into insoluble starch for storage
- used to produce fat or oil for storage
- used to produce cellulose, which strengthens the cell wall
- used to produce proteins.

e. To produce proteins, plants also use nitrate ions that are absorbed from the soil.

3.2.2 Circulation in humans

a. Substances are transported from where they enter the body to the cells, or from the cells to where they are removed from the body, by the circulatory system (the heart, the blood vessels and the blood).

b. The heart is an organ that pumps blood around the body in a double circulatory system. Much of the wall of the heart is made from muscle tissue.

c. The heart has four main chambers (right and left atria and right and left ventricles).

d. Blood enters the atria of the heart. The atria contract and force blood into the ventricles. The ventricles contract and force blood out of the heart. Valves in the heart ensure that blood flows in the correct direction.

   Knowledge of the names of the heart valves is not required.

e. Blood flows from the heart to the organs through arteries and returns through veins. There are two separate circulation systems, one for the lungs and one for all other organs of the body.

   Knowledge of the blood vessels associated with the heart is limited to aorta, vena cava, pulmonary artery, pulmonary vein and coronary arteries.

f. Arteries have thick walls containing muscle and elastic fibres. Veins have thinner walls and often have valves to prevent back-flow of blood.

g. In the organs, blood flows through very narrow, thin-walled blood vessels called capillaries. Substances needed by the cells in body tissues pass out of the blood and substances produced by the cells pass into the blood, through the walls of the capillaries.

h. Blood is a tissue consisting of a fluid called plasma, in which the white blood cells, platelets and red blood cells are suspended.

i. Blood plasma transports:

   - carbon dioxide from the organs to the lungs
   - soluble products of digestion from the small intestine to other organs
   - urea from the liver to the kidneys.

j. Red blood cells have no nucleus. They are packed with a red pigment called haemoglobin. Red blood cells transport oxygen from the lungs to the organs. In the lungs haemoglobin combines with oxygen to form oxyhaemoglobin. In other organs oxyhaemoglobin splits up into haemoglobin and oxygen.

k. White blood cells have a nucleus. They form part of the body's defence system against microorganisms.

l. Platelets are small fragments of cells. They have no nucleus. Platelets help blood to clot at the site of a wound.

m. Blood clotting is a series of enzyme-controlled reactions, resulting in the change of fibrinogen to fibrin, which forms a network of fibers trapping blood cells and forming a clot.

n. Antigens are proteins on the surface of cells.

3.2.3 Digestion

a. Starch (a carbohydrate), proteins and fats are insoluble. They are broken down into soluble substances so that they can be absorbed into the bloodstream in the wall of the small intestine. In the large intestine much of the water mixed with the food is absorbed into the bloodstream. The indigestible food which remains makes up the bulk of the faeces. Faeces leave the body via the anus.

   Students should be able to recognise the following on a diagram of the digestive system: salivary glands, oesophagus, stomach, liver, gall bladder, pancreas, duodenum, small intestine, large intestine, anus.

b. Enzymes help the breakdown of food in the digestive system.

   - Enzymes are large proteins that act as biological catalysts. Catalysts increase the rate of chemical reactions and are utilized in the digestive process to speed up the breakdown of large molecules to small molecules for absorption into the bloodstream.
   - The shape of an enzyme is vital for the enzyme's function. High temperatures denature the enzyme, changing the shape of the active site.
   - Different enzymes work best at different pH values.
   - Some enzymes work outside the body cells. The digestive enzymes are produced by specialised cells in glands and in the lining of the gut. The enzymes then pass out of the cells into the gut, where they come into contact with food molecules. They catalyse the breakdown of large molecules into smaller molecules.

c. Digestive enzymes.

   - The enzyme amylase is produced in the salivary glands, the pancreas and the small intestine. Amylase catalyses the breakdown of starch into sugars in the mouth and small intestine.
   - Protease enzymes are produced by the stomach, the pancreas and the small intestine. These enzymes catalyse the breakdown of proteins into amino acids in the stomach and the small intestine.
   - Lipase enzymes are produced by the pancreas and small intestine. These enzymes catalyse the breakdown of lipids into fatty acids and glycerol in the small intestine.
   - The stomach also produces hydrochloric acid. The enzymes in the stomach work most effectively in acid conditions.
   - The liver produces bile, which is stored in the gall bladder before being released into the small intestine. Bile neutralises the acid that was added to food in the stomach. This provides alkaline conditions in which enzymes in the small intestine work most effectively.
   - Bile also emulsifies fats (breaks large drops of fats into smaller droplets). This increases the surface area of fats for lipase enzymes to act upon.

3.2.4 Breathing

a. The respiratory (breathing) system takes air into and out of the body so that oxygen from the air can diffuse into the bloodstream and carbon dioxide can diffuse out of the bloodstream into the air. The lungs are in the upper part of the body (thorax), protected by the ribcage and separated from the lower part of the body (abdomen) by the diaphragm.

   Students should be able to recognise the following on a diagram of the respiratory system: ribs, intercostal muscles, diaphragm, lungs, trachea, bronchi, bronchioles, alveoli.

b. To inhale:

   - the intercostal muscles contract, pulling the ribcage upwards
   - at the same time the diaphragm muscles contract, causing the diaphragm to flatten
   - these two movements cause an increase in the volume of the thorax
   - the consequent decrease in pressure to below that of the air surrounding the body results in atmospheric air entering the lungs.

   To exhale:

   - the intercostal muscles relax, allowing the rib cage to move downwards
   - at the same time the diaphragm muscles relax, allowing the diaphragm to resume its domed shape
   - these two movements cause a reduction in the volume of the thorax
   - the consequent increase in pressure results in air leaving the lungs.

c. The alveoli provide a very large surface area, richly supplied with blood capillaries, so that gases can readily diffuse into and out of the blood.

3.2.5 Respiration

a. Respiration in cells can take place aerobically (using oxygen) or anaerobically (without oxygen), to transfer energy.

b. During aerobic respiration chemical reactions occur that use glucose (a sugar) and oxygen and transfer energy.

c. Aerobic respiration is summarised by the equations:

glucose + oxygen → carbon dioxide + water (+ energy)
$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ (+ energy)

d. Aerobic respiration takes place continuously in both plants and animals.

e. Most of the reactions in aerobic respiration take place inside mitochondria.

f. The energy that is transferred during respiration may be used by the organism in a variety of ways:

- to build larger molecules from smaller ones
- in animals, to enable muscles to contract
- in mammals and birds, to maintain a steady body temperature in colder surroundings
- in plants, to build up sugars, nitrates and other nutrients into amino acids, which are then built up into proteins.

g. During exercise the human body needs to react to the increased demand for energy. A number of changes take place:

- the heart rate increases, increasing blood flow to the muscles
- the rate and depth of breathing increase
- glycogen stored in the muscles is converted back to glucose.

h. These changes increase the supply of glucose and oxygen to, and increase the rate of removal of carbon dioxide from, the muscles.

i. If insufficient oxygen is reaching the muscles, energy is transferred by anaerobic respiration.

glucose → lactic acid
$\mathbf{C_6H_{12}O_6 \rightarrow 2C_3H_6O_3}$

j. Anaerobic respiration in muscles is the incomplete breakdown of glucose, which causes a build-up of lactic acid. **An oxygen debt needs to be repaid to oxidise the lactic acid to carbon dioxide and water**.

k. As the breakdown of glucose is incomplete, much less energy is transferred in anaerobic respiration than during aerobic respiration.

l. During long periods of vigorous activity muscles become fatigued and stop contracting efficiently. One cause of muscle fatigue is the build-up of lactic acid in the muscles. Blood flowing through the muscles eventually removes the lactic acid.

Required practical:
Investigate the effects of exercise on the human body.

m. Anaerobic respiration in plant cells and in some microorganisms results in the production of ethanol and carbon dioxide.

3.3 Ecology

Materials including carbon and water are continually recycled by the living world, being released through respiration of animals, plants and decomposing microorganisms and taken up by plants in photosynthesis. All species live in ecosystems composed of complex communities of animals and plants dependent on each other and that are adapted to particular conditions, both abiotic and biotic.

3.3.1 Energy transferred in ecosystems

a. Radiation from the Sun is the source of energy for most communities of living organisms. Plants and algae transfer about 1 % of the incident energy from light for photosynthesis. This energy is stored in the substances that make up the cells of the plants.

b. Only approximately 10 % of the biomass from each trophic level is transferred to the level above it because:

- some materials and energy are always lost in the organisms' waste materials
- respiration supplies all the energy needs for living processes, including movement. Much of this energy is eventually transferred to the surroundings.

Construction of food webs and chains, and of pyramids of numbers, is not required. An understanding of pyramids of numbers is not required.

c. The biomass at each stage can be drawn to scale and shown as a pyramid of biomass.

Students should be able to interpret pyramids of biomass and construct them from appropriate information.

3.3.2 Adaptations, interdependence and competition

a. To survive and reproduce, organisms require a supply of materials from their surroundings and from the other living organisms there.

b. Plants often compete with each other for light and space, and for water and nutrients from the soil.

c. Animals often compete with each other for food, mates and territory.

d. Organisms, including microorganisms, have features (adaptations) that enable them to survive in the conditions in which they normally live.

e. Some organisms live in environments that are very extreme, containing high levels of salt, high temperatures or high pressures. These organisms are called extremophiles.

f. Adaptations include:

- structural adaptations, eg the ways in which organisms are shaped, or coloured
- behavioural adaptations, eg migration, huddling together
- functional adaptations, related to processes *such as reproduction and metabolism*.

Students given appropriate information should be able to suggest how animals and plants are adapted to their environment.

3.3.3 Decay and the carbon cycle

a. Living organisms remove materials from the environment for growth and other processes. These materials are returned to the environment either in waste materials or when living things die and decay.

b. Materials decay because they are broken down (digested) by microorganisms. Microorganisms are more active and digest materials faster in warm, moist, aerobic conditions.

c. The decay process releases substances that plants need to grow.

d. In a stable community, the processes that remove materials are balanced by processes that return materials. The materials are part of a constant cycle.

e. The constant cycling of carbon is called the carbon cycle.

In the carbon cycle:

- carbon dioxide is removed from the environment by green plants and algae during photosynthesis
- the carbon from the carbon dioxide is used to make carbohydrates, fats and proteins, which make up the body of plants and algae
- when green plants and algae respire, some of this carbon becomes carbon dioxide and is released into the atmosphere
- when green plants and algae are eaten by animals and these animals are eaten by other animals, some of the carbon becomes part of the fats and proteins that make up the bodies of the consumers
- when animals respire, some of this carbon becomes carbon dioxide and is released into the atmosphere
- when plants, algae and animals die, some animals and microorganisms feed on their bodies
- carbon is released into the atmosphere as carbon dioxide when microorganisms respire
- by the time the microorganisms and detritus feeders have broken down the waste products and dead bodies of organisms in ecosystems and cycled the materials as plant nutrients, all the energy originally absorbed by green plants and algae has been transferred
- combustion of wood and fossil fuels releases carbon dioxide into the atmosphere.

Students should be able to apply the principles of the carbon cycle.

3.4 Organisms' interaction with the environment

Changes in environmental conditions can result in responses from an organism which protect the organism from harm and support maintenance of the species. Such responses may impact the internal stability of the organism or promote certain behaviours to protect it.

3.4.1 The human nervous system

a. The nervous system enables humans to react to their surroundings and to coordinate their behaviour.

b. Information from receptors passes along cells (neurones) as impulses to the central nervous system (CNS). The CNS is the brain and spinal cord. The brain coordinates the response.

c. Reflex actions are automatic and rapid. They often involve sensory, relay and motor neurones.

d. In a simple reflex action such as a pain-withdrawal reflex:

- impulses from a receptor pass along a sensory neurone to the CNS
- at a junction (synapse) between a sensory neurone and a relay neurone in the CNS, a chemical is released that causes an impulse to be sent along a relay neurone
- a chemical is then released at the synapse between a relay neurone and motor neurone in the CNS, causing impulses to be sent along a motor neurone to the effector
- the effector is either a muscle or a gland: a muscle responds by contracting and a gland responds by releasing (secreting) chemical substances.

e. Effectors include muscles and glands.

Students should be able, when provided with appropriate information, to analyse a particular given example of behaviour in terms of:

stimulus → receptor → coordinator → effector → response

3.4.2 Homeostasis

a. Automatic control systems in the body keep conditions inside the body relatively constant.

b. Control systems include:

- cells called receptors, which detect stimuli (changes in the environment)
- coordination centres that receive and process information from receptors
- effectors, which bring about responses.

c. Receptors are found in many organs, including:

- the eyes – sensitive to light
- the ears – sensitive to sound, and to changes in position (which enables us to keep our balance)
- the tongue and in the nose – sensitive to chemicals (enable us to taste and to smell)
- the skin – sensitive to touch, pressure, pain and to temperature changes
- the brain – sensitive to blood temperature and the concentration of water in the blood
- the pancreas – sensitive to the concentration of glucose in the blood.

*Knowledge and understanding of the structure and functions of sense organs such as the eye and the ear is **not** required.*

d. Coordination centres include the brain and spinal cord and the pancreas.

e. Internal conditions that are controlled include:

- temperature
- the water content of the body
- the ion content of the body
- blood glucose levels.

3.4.3 Temperature control

a. Body temperature is monitored and controlled by the thermoregulatory centre in the brain. The thermoregulatory centre has receptors sensitive to the temperature of the blood flowing through the brain.

*The name of the centre in the brain (hypothalamus) is **not** required.*

b. Temperature receptors in the skin send impulses to the thermoregulatory centre, giving information about skin temperature.

c. **If the core body temperature is too high:**

- **blood vessels supplying the skin capillaries dilate so that more blood flows through the capillaries and more energy is transferred from the skin to the environment**
- **sweat glands release more sweat, which cools the body as it evaporates.**

*Core Tier students are **not** expected to describe details of changes in the blood vessels when the core body temperature is too high, but should understand that the skin looks red when we are hot due to increased blood flow.*

d. Sweating helps to cool the body. More water is lost when it is hot, and more fluid has to be taken through drink or food to balance this loss.

If the core body temperature is too low:

- **blood vessels supplying the skin capillaries constrict to reduce the flow of blood through the capillaries**
- **muscles may 'shiver' – their contraction needs respiration, which transfers energy to warm the body.**

*Core Tier students are **not** expected to describe details of changes in the blood vessels when the core body temperature is too low.*

3.4.4 Control of blood glucose

a. The blood glucose concentration is monitored and controlled by the pancreas. Much of the glucose is stored as glycogen in the liver and muscles. When these stores are full, excess glucose is stored as lipid.

b. If blood glucose levels are too high, the pancreas produces the hormone insulin, which allows the glucose to move from the blood into the cells.

c. **When blood glucose levels fall, the pancreas produces a second hormone, glucagon. This causes glycogen to be converted into glucose and released into the blood.**

d. In Type 1 diabetes a person's blood glucose level may be too high because the pancreas does not produce enough of the hormone insulin. Type 1 diabetes may be controlled by careful diet, exercise, and by injecting insulin.

e. Type 2 diabetes develops when the body does not respond to its own insulin. Obesity is a significant factor in the development of Type 2 diabetes. Type 2 diabetes can be controlled by careful diet, exercise and by drugs that help the cells to respond to insulin.

3.4.5 Behaviour

Animals exhibit different behaviours.

a. Sexual reproduction requires the finding and selection of a suitable mate, and can involve courtship behaviours that advertise an individual's quality. Animals have different mating strategies, including:

- a mate for life
- several mates over a life time
- a mate for a breeding season
- several mates over one breeding season.

b. Some animals have developed special behaviours for rearing their young. Parental care can be a successful evolutionary strategy, including:

- increased chance of survival of offspring
- increased chance of parental genes being passed on by the offspring.

Students should be able to explain how, within the animal kingdom, parental care may involve risks to the parents.

c. The different behaviours displayed by animals include:

- innate behaviour
- imprinting
- habituation
- classic conditioning
- operant conditioning.

d. Humans can make use of conditioning when training captive animals for specific purposes, including:

- sniffer dogs
- police horses.

e. Methods of communication within the animal kingdom. Animals use a variety of types of signals to communicate.

Students should be able to describe the types of signals animals use to communicate eg sound, chemical, visual.

3.4.6 Infection and response

a. Microorganisms that cause infectious disease are called pathogens.

b. Bacteria and viruses may reproduce rapidly inside the body. Bacteria may produce poisons (toxins) that make us feel ill. Viruses live and reproduce inside cells, causing damage.

*Knowledge of the structure of viruses is **not** required.*

c. White blood cells help to defend against pathogens by:

- ingesting pathogens (phagocytosis)
- producing antibodies, which destroy particular bacteria or viruses
- producing antitoxins, which counteract the toxins released by the pathogens.

d. The immune system of the body produces specific antibodies to kill a particular pathogen. This leads to immunity from that pathogen. In some cases, dead or inactivated pathogens stimulate antibody production. If a large proportion of the population is immune to a pathogen, the spread of the pathogen is very much reduced.

e. People can be immunised against a disease by introducing small quantities of dead or inactive forms of the pathogen into the body (vaccination). Vaccines stimulate the white blood cells to produce antibodies that destroy the pathogen. This makes the person immune to future infections by the microorganism, because the body can respond by rapidly making the correct antibody, in the same way as if the person had previously had the disease. The MMR vaccine is used to protect children against measles, mumps and rubella.

Details of vaccination schedules and side effects associated with specific vaccines are not required.

Students should be able to evaluate the advantages and disadvantages of being vaccinated against a particular disease.

f. Antibiotics, such as penicillin, are medicines that help to cure bacterial disease by killing infective bacteria inside the body. It is important that specific bacteria should be treated by specific antibiotics. The use of antibiotics has greatly reduced deaths from infectious bacterial diseases.

g. Antibiotics cannot kill viral pathogens.

Students should be aware that it is difficult to develop drugs that kill viruses without also damaging the body's tissues.

h. Mutations of pathogens produce new strains. **Antibiotics kill individual pathogens of the non-resistant strain but individual resistant pathogens survive and reproduce, so the population of the resistant strain rises.** Antibiotics and vaccinations may no longer be effective against a new resistant strain of the pathogen. The new strain will then spread rapidly because people are not immune to it and there is no effective treatment.

Knowledge of development of resistance in bacteria is limited to the fact that pathogens mutate, producing resistant strains.

i. Many strains of bacteria, including MRSA, have developed resistance to antibiotics. Overuse and inappropriate use of antibiotics has increased the rate of development of antibiotic-resistant strains of bacteria. **Antibiotics are not currently used to treat non-serious infections such as mild throat infections, in order to slow down the rate of development of resistant strains.**

j. The development of antibiotic-resistant strains of bacteria necessitates the development of new antibiotics.

Required practical:
Investigate the effect of disinfectants and antibiotics on uncontaminated cultures of microorganisms.

3.5 Inheritance

Genetic information in a cell is held in the chemical DNA. Genes determine the development and structure of organisms. In asexual reproduction all the genes in the offspring come from one parent. In sexual reproduction half of the genes come from each parent.

3.5.1 Reproduction

There are two forms of reproduction:

- sexual reproduction – the joining (fusion) of male and female gametes. The mixture of the genetic information from two parents leads to variety in the offspring
- asexual reproduction – no fusion of gametes and only one individual is needed as the parent. There is no mixing of genetic information and so no genetic variation in the offspring. These genetically identical individuals are known as clones.

3.5.2 Cell division

a. The nucleus of a cell contains chromosomes. Chromosomes carry genes that control the characteristics of the body. Each chromosome carries a large number of genes.

b. Many genes have different forms called alleles, which may produce different characteristics.

c. In body cells the chromosomes are normally found in pairs.

d. Body cells divide by mitosis to produce additional cells during growth or to produce replacement cells.

e. When a body cell divides by mitosis:
   - copies of the genetic material are made
   - the cell then divides once to form two genetically identical body cells.

f. Cells in reproductive organs divide to form gametes.

g. A cell divides to form gametes by meiosis.

h. When a cell divides to form gametes:
   - copies of the genetic information are made
   - the cell then divides twice to form four gametes, each with a single set of chromosomes.

i. Gametes join at fertilisation to form a single body cell with new pairs of chromosomes. This cell repeatedly divides by mitosis to form many cells. As an organism develops, these cells differentiate to form different kinds of cells.

j. Most types of animal cell differentiate at an early stage whereas many plant cells retain the ability to differentiate throughout life. In mature animals, cell division is mainly restricted to repair and replacement.

k. Cells from human embryos and adult bone marrow, called stem cells, can be made to differentiate into many different types of human cell.

l. In therapeutic cloning an embryo is produced with the same genes as the patient. Stem cells from the embryo will not be rejected by the patient's body so they may be used for medical treatment.

m. Treatment with stem cells may be able to help conditions such as paralysis.

*Knowledge and understanding of stem cell techniques is **not** required.*

Students should be able, when provided with appropriate information, to make informed judgements about the social and ethical issues concerning the use of stem cells from adult bone marrow and embryos in medical research and treatments.

3.5.3 Genetic variation

a. Differences in the characteristics of individuals of the same kind may be due to differences in:

- the genes they have inherited (genetic causes)
- the conditions in which they have developed (environmental causes)
- a combination of genetic and environmental causes.

b. The information that results in plants and animals having similar characteristics to their parents is carried by genes, which are passed on in the sex cells (gametes) from which the offspring develop.

c. The nucleus of a cell contains chromosomes. Chromosomes carry genes that control the characteristics of the body. Chromosomes are normally found in pairs.

d. In human body cells, one of the 23 pairs of chromosomes carries the genes that determine sex. In females the sex chromosomes are the same (XX); in males the sex chromosomes are different (XY).

e. Different genes control the development of different characteristics of an organism. Some characteristics are controlled by a single gene. Each gene may have different forms called alleles.

Students should understand that genes operate at a molecular level to develop characteristics that can be seen.

f. If both chromosomes in a pair contain the same allele of a gene, the individual is homozygous for that gene. If the chromosomes in a pair contain different alleles of a gene, the individual is heterozygous for that gene.

g. An allele that controls the development of a characteristic when it is present on only one of the chromosomes is called a dominant allele. An allele that controls the development of a characteristic only if the dominant allele is not present is called a recessive allele.

Students should be familiar with principles used by Mendel in investigating monohybrid inheritance in peas. They should understand that Mendel's work preceded the work by other scientists which linked Mendel's 'inherited factors' with chromosomes.

Extension Tier students should be able to construct genetic diagrams of monohybrid crosses and to predict the outcomes of monohybrid crosses. They should be able to use the terms homozygous, heterozygous, phenotype and genotype.

*Core Tier students should be able to interpret genetic diagrams of monohybrid inheritance and sex inheritance, but will **not** be expected to construct genetic diagrams or use the terms homozygous, heterozygous, phenotype of genotype.*

Students should understand that genetic diagrams are biological models which can be used to predict the outcomes of crosses.

Students should be able to interpret genetic diagrams, including family trees.

h. Chromosomes are made up of large molecules of DNA. DNA contains the coded information that determines inherited characteristics.

i. A gene is a small section of DNA. **Each gene codes for a particular combination of amino acids, to make a specific protein.**

j. DNA is made of very long strands, twisted to form a double helix, which contain four different compounds, called bases.

   *Students are **not** expected to know the names of the four bases or how complementary pairs of bases enable DNA replication to take place.*

k. A sequence of three bases is the code for a particular amino acid. The order of bases controls the order in which amino acids are assembled to produce a particular protein.

3.5.4 Genetic disorders

Attention is drawn to the potential sensitivity needed in teaching about inherited disorders.

a. Some disorders are inherited.

   Students should be able to interpret data relating to genetic disorders such as polydactyly, cystic fibrosis and sickle cell anaemia.

b. Some inherited conditions are caused by inheritance of abnormal numbers of chromosomes, eg Down's Syndrome is caused by the presence of an extra chromosome.

3.5.5 Genetic manipulation

a. Modern cloning techniques include:

   - tissue culture – using small groups of cells from part of a plant
   - embryo transplants – splitting cells from a developing animal embryo before they become specialised, then transplanting the identical embryos into host mothers
   - adult cell cloning – the nucleus is removed from an unfertilised egg cell and the nucleus from an adult body cell, eg a skin cell, is inserted into the egg cell. An electric shock then acts as the catalyst for the egg cell to begin to divide to form embryo cells. These embryo cells contain the same genetic information as the adult skin cell. When the embryo has developed into a ball of cells, it is inserted into the womb of an adult female to continue its development.

b. **In genetic engineering, genes from the chromosomes of humans and other organisms can be 'cut out' and transferred to cells of other organisms:**

   - **enzymes are used to isolate the required gene**
   - **this gene is inserted into a vector, usually a bacterial plasmid or a virus**
   - **the vector is used to insert the gene into the required cells.**

c. Genes can also be transferred to the cells of animals, plants or microorganisms at an early stage in their development so that they develop with desired characteristics.

d. Crops that have had their genes modified in this way are called genetically modified (GM) crops. GM crops include ones that are resistant to insect attack or to herbicides.

e. GM crops generally show increased yields.

f. Concerns about GM crops include the effect on populations of wild flowers and insects, and uncertainty about the effects of eating GM crops on human health.

Students should be able, when provided with appropriate information, to interpret information about cloning techniques and genetic engineering techniques and to make informed judgements about issues concerning cloning and genetic engineering, including GM crops.

3.6 Variation and evolution

All life today is directly descended from a universal common ancestor that was a simple single-celled organism. Over countless generations changes resulted from natural diversity within a species which makes possible the selection of those individuals best suited to survive under certain conditions. Species not able to respond sufficiently to changes in their environment are at risk of becoming extinct.

3.6.1 Variation

The causes of variation include:

- genetic variation – different characteristics as a result of mutation or reproduction
- environmental variation – different characteristics caused by an organism's environmental (acquired characteristics).

3.6.2 Natural selection

a. Theories of how organisms have evolved include:

- the theory of evolution by natural selection
- other theories, including that of Lamarck, are based mainly on the idea that changes that occur in an organism during its lifetime can be inherited. We now know that in the vast majority of cases this type of inheritance cannot occur.

b. Evolution occurs via natural selection.

- Individual organisms within a particular species may show a wide range of variation because of differences in their genes.
- Individuals with characteristics most suited to the environment are more likely to survive to breed successfully.
- The genes that have enabled these individuals to survive are then passed on to the next generation.

Students should develop an understanding of the time scales involved in evolution.

c. New species arise as a result of:

- isolation: two populations of a species become separated, eg geographically
- genetic variation: each population has a wide range of alleles that control their characteristics
- natural selection: in each population, the alleles that control the characteristics which help the organism to survive are selected
- speciation: the populations become so different that successful interbreeding leading to fertile offspring, is no longer possible.

Chemistry

3.7 Atomic structure and the periodic table

Atoms are the building blocks of all materials and knowledge of atomic structure and the periodic table are fundamental to the learning associated with all the following sections.

3.7.1 Solids, liquids and gases

a. Matter can be classified in terms of the three states of matter.

Students should be familiar with states of matter and be able to name each inter-conversion process. They should be able to describe and explain their inter-conversion in terms of how the particles are arranged and their movement. They should understand the energy changes that accompany changes of state.

b. Evidence for the existence of particles can be obtained from simple experiments.

Students should be familiar with simple diffusion experiments such as Br_2/air, NH_3/HCl, $KMnO_4$/water.

3.7.2 A simple model of the atom

a. All substances are made of atoms. A substance that is made of only one sort of atom is called an element. There are about 100 different elements. Elements are shown in the periodic table.

b. Atoms of each element are represented by a chemical symbol, eg O represents an atom of oxygen.

Knowledge of the chemical symbols for elements other than those named in the specification is ***not*** *required.*

c. Atoms have a small central nucleus, made up of protons and neutrons, and around which there are electrons.

Students should be aware that the atomic model has changed over time.

d. The relative electrical charges are as shown:

Name of particle	Charge
Proton	+1
Neutron	0
Electron	–1

e. In an atom, the number of electrons is equal to the number of protons in the nucleus. Atoms have no overall electrical charge.

f. The number of protons in an atom of an element is its atomic number. The sum of the protons and neutrons in an atom is its mass number.

Students will be expected to calculate the numbers of each sub-atomic particle in an atom from its atomic number and mass number.

g. Atoms of the same element can have different numbers of neutrons; these atoms are called isotopes of that element.

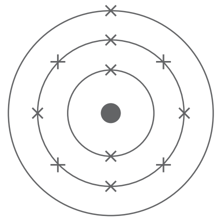
h. Atoms can be represented as shown in this example:

(Mass number) (Atomic number) $^{23}_{11}\text{Na}$

i. Electrons occupy particular energy levels. Each electron in an atom is at a particular energy level (in a particular shell). The electrons in an atom occupy the lowest available energy levels (innermost available shells).

Students may answer questions in terms of either energy levels or shells.

Students should be able to represent the electronic structure of the first twenty elements of the periodic table in the following forms:



sodium 2,8,1

j. The relative masses of protons, neutrons and electrons are:

Name of particle	Mass
Proton	1
Neutron	1
Electron	Very small

k. The relative atomic mass of an element (A_r) compares the mass of atoms of the element with the ^{12}C isotope. It is an average value for the isotopes of the element.

Students will not be expected to calculate relative atomic masses from isotopic abundances.

3.7.3 The Periodic Table

a. The periodic table is arranged in order of atomic (proton) number. Elements with similar properties are in columns, known as groups. The table is called a periodic table because similar properties occur at regular intervals.

Students should know that the current periodic table is based on the work of Mendeleev.

b. Elements in the same group in the periodic table have the same number of electrons in their highest energy level (outer electrons) and this gives them similar chemical properties.

Students should know that basing the periodic table on groups of elements with similar properties has allowed for the prediction of elements which were still to be discovered.

c. The elements in Group 0 of the periodic table are called the noble gases. They are unreactive because their atoms have stable arrangements of electrons.

Students should know that the noble gases have eight electrons in their outer energy level, except for helium, which has only two electrons.

3.8 Structure, bonding and the properties of matter

This section examines how atoms interact to form chemical bonds and how these bonds determine the properties and uses of materials.

3.8.1 Chemical bonds: ionic, covalent and metallic

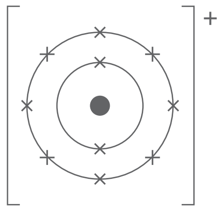
a. Compounds are substances in which atoms of two or more elements are chemically combined.

b. Chemical bonding involves either transferring or sharing electrons in the highest occupied energy levels (outer shells) of atoms in order to achieve the electron arrangement of a noble gas.

c. When atoms form chemical bonds by transferring electrons, they form ions. Atoms that lose electrons become positively charged ions. Atoms that gain electrons become negatively charged ions. Ions have the electron arrangement of a noble gas (Group 0). Compounds formed from metals and non-metals consist of ions.

   Students should know that metals form positive ions, whereas non-metals form negative ions.

   Students should be able to represent the electron arrangement of ions in the following form:

   for sodium ion (Na^+).

   Students should be able to relate the charge on simple ions to the group number of the element in the periodic table.

d. The elements in Group 1 of the periodic table, the alkali metals, all react with non-metal elements to form ionic compounds in which the metal ion has a single positive charge.

   Knowledge of the chemical properties of alkali metals is limited to their reactions with non-metal elements and water.

e. The elements in Group 7 of the periodic table, the halogens, all react with metals to form ionic compounds in which the halide ions have a single negative charge.

   Knowledge of the chemical properties of the halogens is limited to reactions with metals and displacement of less reactive halogens.

f. An ionic compound is a giant structure of ions. Ionic compounds are held together by strong electrostatic forces of attraction between oppositely charged ions. These forces act in all directions in the lattice and this is called ionic bonding.

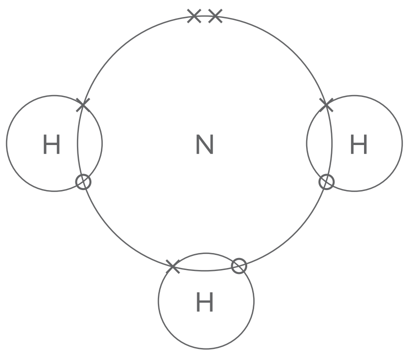
   *Students should be familiar with the structure of sodium chloride but do **not** need to know the structures of other ionic compounds.*

   Students given appropriate information, should be able to draw or complete diagrams to show how elements form ions and ionic compounds.

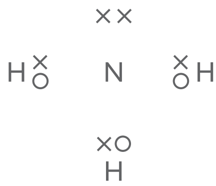
g. When atoms share pairs of electrons, they form covalent bonds. These bonds between atoms are strong. Some covalently bonded substances, such as H_2, Cl_2, O_2, N_2, HCl, H_2O, NH_3 and CH_4, consist of simple molecules. Others, such as diamond and silicon dioxide, have giant covalent structures (macromolecules).

Students should be able to represent the covalent bonds in molecules such as water, ammonia, hydrogen, hydrogen chloride, methane and oxygen in the following forms:

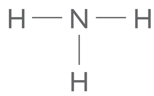
For ammonia (NH_3)



and/or



and/or



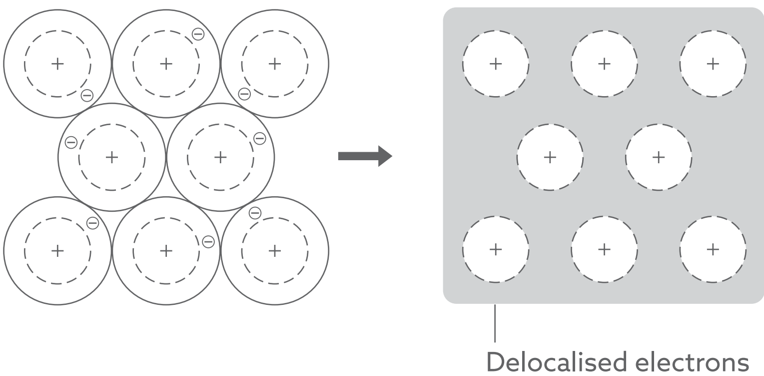
Students, given appropriate information, should be able to draw or complete diagrams to show how elements form covalent compounds by sharing electrons.

Students should be able to recognise other simple molecules and giant structures from diagrams that show their bonding.

h. Compounds formed from non-metals consist of molecules. In molecules, the atoms are held together by covalent bonds.

i. Metals consist of giant structures of atoms arranged in a regular pattern.

j. **The electrons in the highest occupied energy levels (outer shell) of metal atoms are delocalised and so free to move through the whole structure. This corresponds to a structure of positive ions with electrons between the ions holding them together by strong electrostatic attractions. The bonding in metals is represented in the following form:**



3.8.2 How bonding and structure are related to the properties of substances

a. Ionic compounds have regular structures (giant ionic lattices) in which there are strong electrostatic forces of attraction in all directions between oppositely charged ions.

These compounds have high melting points and high boiling points because of the large amounts of energy needed to break the many strong bonds.

b. When melted or dissolved in water, ionic compounds conduct electricity because the ions are free to move and carry the current.

*Knowledge of the structures of specific ionic compounds other than sodium chloride is **not** required.*

c. Substances that consist of simple molecules are gases, liquids or solids that have relatively low melting points and boiling points.

d. **Substances that consist of simple molecules have only weak forces between the molecules (intermolecular forces). It is these intermolecular forces that are overcome, not the covalent bonds, when the substance melts or boils.**

Students need to understand that intermolecular forces are weak compared with covalent bonds.

e. Substances that consist of simple molecules do not conduct electricity because the molecules do not have an overall electric charge.

f. Atoms that share electrons can also form giant structures or macromolecules. Diamond and graphite (forms of carbon) and silicon dioxide (silica) are examples of giant covalent structures (lattices) of atoms. All the atoms in these structures are linked to other atoms by strong covalent bonds and so they have very high melting points.

Students should be able to recognise other giant structures or macromolecules from diagrams showing their bonding.

g. **Metals conduct heat and electricity because of the delocalised electrons in their structures.**

Students should know that conduction depends on the ability of electrons to move through the metal.

3.8.3 Structure and bonding of carbon

a. The element carbon can form four covalent bonds.

b. In diamond, each carbon atom forms four covalent bonds with other carbon atoms in a giant covalent structure, so diamond is very hard.

c. In graphite, each carbon atom bonds to three others, forming layers. The layers are free to slide over each other because there are no covalent bonds between the layers and so graphite is soft and slippery.

Extension Tier students should be able to explain the properties of graphite in terms of weak forces between the layers.

d. **In graphite, one electron from each carbon atom is delocalised. These delocalised electrons allow graphite to conduct heat and electricity.**

Students should realise that graphite is similar to metals in that it has delocalised electrons.

e. **Carbon can also form fullerenes with different numbers of carbon atoms. Fullerenes can be used for drug delivery into the body, in lubricants, as catalysts, and in nanotubes for reinforcing materials, eg in tennis racquets.**

Students are only required to know that the structure of fullerenes is based on hexagonal rings of carbon atoms.

3.9 Chemical changes

The group of materials known as metals are explored in more detail including how atoms are rearranged to form new substances in chemical reactions.

3.9.1 Metals

a. Metals are useful materials because they are good conductors of heat and electricity. They can be bent or hammered into shape because the layers of atoms in metals are able to slide over each other.

b. An alloy is a mixture of at least two elements, at least one of which is a metal. Alloys often have properties that are different to the metals they contain. This makes them more useful than the pure metals alone. Steels are a mixture of iron with carbon and sometimes other metals.

Students may be given information on the composition of specific alloys so that they can evaluate their uses.

c. Copper is useful for electrical wiring and plumbing because it has the following properties:

- it is a good conductor of heat and electricity
- it can be bent but is hard enough to be used to make pipes or tanks
- it does not react with water.

3.9.1.1 The reactivity series

a. Metals can be arranged in an order of their reactivity from their reactions with water and dilute acids.

Students should be able to recall and describe the reactions, if any, of potassium, sodium, lithium, calcium, magnesium, zinc, iron and copper with water or dilute acids. Students should be able, where appropriate, to place them in order of reactivity.

b. Displacement reactions involving metals and their compounds in aqueous solution establish positions within the reactivity series.

Students should be able to describe displacement reactions in terms of oxidation and reduction, and to write the ionic equations.

c. Unreactive metals such as gold are found in the Earth as the metal itself but most metals are found as compounds that require chemical reactions to extract the metal.

d. Metals that are less reactive than carbon can be extracted from their oxides by reduction with carbon: for example, iron oxide is reduced in the blast furnace to make iron.

Knowledge and understanding are limited to the reduction of oxides using carbon.

Knowledge of reduction is limited to the removal of oxygen.

Students should understand that oxidation can be described as the gain of oxygen by a substance.

*Details of the blast furnace are **not** required, but students should know the raw materials used and explain the simple chemistry involved, including the use of equations.*

*Knowledge of the details of the extraction of other metals is **not** required. Examination questions may provide further information about specific processes for students to interpret or evaluate.*

e. Metals that are more reactive than carbon, such as aluminium, are extracted by electrolysis of molten compounds. The use of large amounts of energy in the extraction of these metals makes them expensive.

   *Knowledge of the details of industrial methods of electrolysis is **not** required, other than the detail required for aluminium (see Section 3.9.2).*

f. New ways of extracting copper from low-grade ores are being researched to limit the environmental impact of traditional mining.

   Copper can be extracted by phytomining, or by bioleaching.

   Students should know and understand that:

   - *phytomining uses plants to absorb metal compounds and that the plants are burned to produce ash that contains the metal compounds*
   - *bioleaching uses bacteria to produce leachate solutions that contain metal compounds.*

   *Further specific details of these processes are **not** required.*

g. Copper can be obtained from solutions of copper salts by electrolysis.

   Students should know the electrode material and be able to write the ionic half equations for the reactions occurring at both electrodes.

h. Copper can be obtained from solutions of copper salts by displacement using scrap iron.

   Students should be able to describe this in terms of oxidation and reduction, and to write the ionic equation.

i. We should recycle metals because extracting them uses limited resources, and is expensive in terms of energy and in terms of effects on the environment.

   *Students are **not** required to know details of specific examples of recycling, but should understand the benefits of recycling in the general terms specified here.*

3.9.1.2 Metal carbonates

a. The carbonates of magnesium, copper, zinc, calcium and lithium decompose on heating (thermal decomposition) in a similar way.

   Students should be aware that not all carbonates of metals in Group 1 of the periodic table decompose at the temperatures reached by a Bunsen burner.

b. Metal carbonates react with acids to produce carbon dioxide, a salt and water.

3.9.2 Electrolysis

a. When an ionic substance is melted or dissolved in water, the ions are free to move about within the liquid or solution.

b. Passing an electric current through ionic substances that are molten, eg lead bromide, or in solution breaks them down into elements. This process is called electrolysis and the substance broken down is called the electrolyte.

c. During electrolysis, positively charged ions move to the negative electrode (the cathode), and negatively charged ions move to the positive electrode (the anode).

d. Oxidation and reduction can be defined as the loss and gain of electrons respectively.

e. At the cathode, positively charged ions gain electrons; at the anode, negatively charged ions lose electrons.

f. Reactions at electrodes can be represented by half equations, for example:

$2Cl^- \rightarrow Cl_2 + 2e^-$
or
$2Cl^- - 2e^- \rightarrow Cl_2$

Students should be able to write half equations for the reactions occurring at the electrodes during electrolysis, and may be required to complete and balance supplied half equations.

g. If there is a mixture of ions:

- at the cathode, the products formed depend on the reactivity of the elements involved
- at the anode, the products formed also depend on the relative concentrations of the ions present.

h. Electrolysis is used to electroplate objects. This may be for reasons such as appearance, durability and prevention of corrosion. It includes copper plating and silver plating.

i. Aluminium is manufactured by the electrolysis of a molten mixture of aluminium oxide and cryolite. Aluminium forms at the negative electrode and oxygen at the positive electrode. The positive electrode is made of carbon, which reacts with the oxygen to produce carbon dioxide.

Students should understand why cryolite is used in this process.

Students should be aware that large amounts of energy are needed in the extraction process.

j. The electrolysis of sodium chloride solution produces hydrogen and chlorine. Sodium hydroxide solution is also produced. These are important reagents for the chemical industry, eg sodium hydroxide for the production of soap and chlorine for the production of bleach and plastics.

Students should be able to explain, using ideas related to reactivity, why each of these products is produced.

3.10 Chemical analysis

This section focuses on developing practical skills in chemistry which identify substances and reinforces the idea of a pure substance as consisting of one substance only.

3.10.1 Purity and chromatography

a. A pure element or compound contains only one substance, with no other substances mixed in.

Students should be able to identify substances and assess their purity from melting point and boiling point information.

b. Measures of purity are important in everyday substances such as foodstuffs and drugs.

c. A mixture consists of two or more elements or compounds not chemically combined together. The chemical properties of each substance in the mixture are unchanged. It is possible to separate the substances in a mixture by physical methods, including distillation, filtration and crystallisation.

d. Paper chromatography can be used to analyse substances present in a solution, eg food colourings and inks/dyes.

Students should be able to describe how to carry out paper chromatography separations and ***Extension Tier students should be able to describe how the components of a mixture can be identified using R_f values****. They have to be aware that solvents other than water can be used.*

e. Chromatography involves a stationary and a mobile phase and separation depends on the relative solubilities of the components.

Students should be able to suggest chromatographic methods for distinguishing pure from impure substances.

3.10.2 Identification of ions

a. Flame tests can be used to identify metal ions. Lithium, sodium, potassium, calcium and barium compounds produce distinctive colours in flame tests:

- lithium compounds result in a crimson flame
- sodium compounds result in a yellow flame
- potassium compounds result in a lilac flame
- calcium compounds result in a red flame
- barium compounds result in a green flame.

Required practical:
Identify the metal ion in an unknown compound using flame testing techniques.

b. Aluminium, calcium and magnesium ions form white precipitates with sodium hydroxide solution but only the aluminium hydroxide precipitate dissolves in excess sodium hydroxide solution.

c. Copper(II), iron(II) and iron(III) ions form coloured precipitates with sodium hydroxide solution. Copper(II) forms a blue precipitate, iron(II) a green precipitate and iron(III) a brown precipitate.

d. Carbonates react with dilute acids to form carbon dioxide. Carbon dioxide produces a white precipitate with limewater, which turns limewater cloudy white.

e. Halide ions in solution produce precipitates with silver nitrate solution in the presence of dilute nitric acid. Silver chloride is white, silver bromide is cream and silver iodide is yellow.

f. Sulfate ions in solution produce a white precipitate with barium chloride solution in the presence of dilute hydrochloric acid.

3.11 Acids, bases and salts

This section looks in greater detail at the properties and applications of acids and bases.

3.11.1 The properties of acids and bases

a. Metal oxides and hydroxides are bases. Soluble hydroxides are called alkalis.

b. Acids react with bases to form salts. These reactions are called neutralisation reactions.

c. The particular salt produced in any reaction between an acid and a base or alkali depends on:

- the acid used (hydrochloric acid produces chlorides, nitric acid produces nitrates, sulfuric acid produces sulfates)
- the metal in the base or alkali.

d. Ammonia dissolves in water to produce an alkaline solution. It is used to produce ammonium salts.

e. A solution of calcium hydroxide in water (limewater) reacts with carbon dioxide to produce calcium carbonate.

f. Hydrogen ions, H^+ (aq), make solutions acidic and hydroxide ions, OH^- (aq), make solutions alkaline. The pH scale is a measure of the acidity or alkalinity of a solution.

Students should be familiar with the pH scale from 0 to 14, and know that pH 7 is a neutral solution.

Students should be able to describe the use of universal indicator to measure the approximate pH of a solution.

g. In neutralisation reactions, hydrogen ions react with hydroxide ions to produce water. This reaction can be represented by the equation:

$H^+ (aq) + OH^- (aq) \rightarrow H_2O (l)$

3.11.2 Preparation of salts

a. Soluble salts can be made from acids by reacting them with:

- metals – not all metals are suitable; some are too reactive and others are not reactive enough
- insoluble bases – the base is added to the acid until no more will react and the excess solid is filtered off
- alkalis – an indicator can be used to show when the acid and alkali have completely reacted to produce a salt solution.

Students should be able to suggest methods to make a named soluble salt.

b. Salt solutions can be crystallised to produce solid salts.

c. Insoluble salts can be made by mixing appropriate solutions of ions so that a precipitate is formed. Precipitation can be used to remove unwanted ions from solutions: for example, in treating water for drinking or in treating effluent.

Students should be able to name the substances needed to make a named insoluble salt.

3.12 Quantitative chemistry

Conservation of mass is a key concept in chemistry and this is developed during this section. This is then used to develop a quantitative approach to chemical reactions, leading to many opportunities to develop experimental skills through practical work and mathematical skills.

3.12.1 Conservation of mass including the quantitative interpretation of chemical equations

a. Chemical reactions can be represented by word equations or by symbol equations.

Students should be able to write word and balanced symbol equations for reactions in the specification.

b. Information about the states of reactants and products can be included in chemical equations.

Students should be able to use the state symbols (g), (l), (s) and (aq) in equations where appropriate.

c. No atoms are lost or made during a chemical reaction so the mass of the products equals the mass of the reactants.

d. The masses of reactants and products can be calculated from balanced symbol equations.

Students should be able to calculate the mass of a reactant or product from information about the masses of the other reactants and products in the reaction and the balanced symbol equation.

e. Even though no atoms are gained or lost in a chemical reaction, it is not always possible to obtain the calculated amount of a product because:

- the reaction may not go to completion because it is reversible
- some of the product may be lost when it is separated from the reaction mixture
- some of the reactants may react in ways different from the expected reaction.

3.12.2 Use of amount of substance in relation to masses of pure substances

a. The relative formula mass (M_r) of a compound is the sum of the relative atomic masses of the atoms in the numbers shown in the formula.

Students are expected to use relative atomic masses in the calculations specified in the subject content. Students should be able to calculate the relative formula mass (M_r) of a compound from its formula.

b. The percentage by mass of an element in a compound can be calculated from the relative atomic mass of the element in the formula and the relative formula mass of the compound.

c. The empirical formula of a compound can be calculated from the masses or percentages of the elements in a compound.

Students should be able to calculate empirical formulae and molecular formulae.

3.12.3 The mole concept

a. The relative formula mass of a substance, in grams, is known as one mole of that substance.

Students should be able to use the relative formula mass of a substance to calculate the number of moles in a given mass of that substance and vice versa.

b. One mole contains 6.02×10^{23} atoms or molecules. This number is known as Avogadro's constant.

3.12.4 Molar concentrations

a. The concentration of a solution is related to the mass of the solute (in terms of number of moles) and the volume of the solution. The concentration of a solution is calculated as follows:

Concentration (mol/dm^3) = number of moles/volume of solution (in dm^3).

b. The volumes of acid and alkali solutions that react with each other can be measured by titration using a suitable indicator.

Students should be able to carry out titrations using strong acids and strong alkalis only (sulfuric, hydrochloric and nitric acids only).

Required practical:
Establish the concentration of an unknown strong acid through titration with a strong base.

c. If the concentration of one of the reactants is known, the results of a titration can be used to find the concentration of the other reactant.

Students should know how to carry out a titration and be able to calculate the chemical quantities in titrations involving concentrations in mol/dm^3 and in g/dm^3.

3.13 Trends within the periodic table

This section looks to both describe and explain trends within the periodic table along with more detailed knowledge and understanding of identified groups.

3.13.1 Group properties

a. The elements in Group 1 of the periodic table (known as the alkali metals):

- are metals with low density (the first three elements in the group are less dense than water)
- react with non-metals to form ionic compounds in which the metal ion carries a charge of +1. The compounds are white solids that dissolve in water to form colourless solutions
- react with water, releasing hydrogen
- form hydroxides that dissolve in water to give alkaline solutions.

b. In Group 1, the further down the group an element is, the more reactive the element.

c. The elements in Group 7 of the periodic table (known as the halogens) react with metals to form ionic compounds in which the halide ion carries a charge of –1.

d. In Group 7, the further down the group an element is:

- the less reactive the element
- the higher its melting point and boiling point.

e. A more reactive halogen can displace a less reactive halogen from an aqueous solution of its salt.

f. The trends in reactivity within groups in the periodic table can be explained because the higher the energy level of the outer electrons:

- the more easily electrons are lost
- the less easily electrons are gained.

Students should be able to explain the relative reactivities of the elements in Group 1 and 7.

3.14 The rate of chemical change

3.14.1 Rate of reaction

a. The rate of a chemical reaction can be found by measuring the amount of a reactant used or the amount of product formed over time:

$$\text{Rate of reaction} = \frac{\text{amount of reactant used}}{\text{time}}$$

$$\text{Rate of reaction} = \frac{\text{amount of product formed}}{\text{time}}$$

Students need to be able to interpret graphs showing the amount of product formed (or reactant used up) with time, in terms of the rate of the reaction.

*Knowledge of specific reactions other than those in the subject content is **not** required, but students will be expected to have studied examples of chemical reactions and processes in developing their skills during their study of this section.*

b. Chemical reactions can occur only when reacting particles collide with each other and with sufficient energy. The minimum amount of energy that particles must have to react is called the activation energy.

c. Increasing the temperature increases the speed of the reacting particles so that they collide more frequently and more energetically. This increases the rate of reaction.

d. Increasing the pressure of reacting gases increases the frequency of collisions and so increases the rate of reaction.

e. Increasing the concentration of reactants in solutions increases the frequency of collisions and so increases the rate of reaction.

f. Increasing the surface area of solid reactants increases the frequency of collisions and so increases the rate of reaction.

Required practical:
Investigate factors affecting the rate of a reaction.

g. Catalysts change the rate of chemical reactions but are not used up during the reaction. Different reactions need different catalysts.

*Knowledge of named catalysts other than those specified in the subject content is **not** required, but students should be aware of some examples of chemical reactions and processes that use catalysts.*

h. Catalysts are important in increasing the rates of chemical reactions used in industrial processes to reduce costs.

3.15 Energy changes

This section highlights that chemical reactions involve changes which require energy to make them happen. This is a fundamental concept which links to key ideas in biology and physics. The section also involves developing mathematical skills and also application of knowledge.

3.15.1 Exothermic and endothermic reactions

a. When chemical reactions occur, energy is transferred to or from the surroundings.

Knowledge of delta H (ΔH) conventions and enthalpy changes, including the use of positive values for endothermic reactions and negative values for exothermic reactions, is required.

b. An exothermic reaction is one that transfers energy to the surroundings. Examples of exothermic reactions include combustion, many oxidation reactions and neutralisation.

Students should be able to give examples of exothermic reactions including combustion, oxidation and neutralisation. Everyday uses of exothermic reactions include self-heating cans (eg for coffee) and hand warmers.

c. An endothermic reaction is one that takes in energy from the surroundings. Endothermic reactions include thermal decompositions. Some sports injury packs are based upon endothermic reactions.

d. In some chemical reactions, the products of the reaction can react to produce the original reactants. Such reactions are called reversible reactions and are represented as follows:

$A + B \rightarrow C + D$

For example:

hydrated copper sulfate (blue)	endothermic → exothermic	anhydrous copper sulfate (white)	+ water

e. The amount of energy produced by a chemical reaction in solution can be calculated from the measured temperature change of the solution when the reagents are mixed in an insulated container. This method can be used for reactions of solids with water or for neutralisation reactions.

3.15.2 Calculating and explaining energy changes

a. Simple energy level diagrams can be used to show the relative energies of reactants and products, the activation energy and the overall energy change of a reaction.

Students will be expected to understand simple energy level diagrams showing the relative energies of reactants and products, the activation energy and the overall energy change, with a curved arrow to show the energy as the reaction proceeds.

Students should be able to relate these to exothermic and endothermic reactions.

b. During a chemical reaction:

- energy must be supplied to break bonds
- energy is released when bonds are formed.

Students should be able to calculate the energy transferred in reactions and interpret simple energy level diagrams in terms of bond breaking and bond formation (including the idea of activation energy and the effect on this of catalysts).

c. In an exothermic reaction, the energy released from forming new bonds is greater than the energy needed to break existing bonds.

Students should be able to calculate the energy transferred in reactions using bond dissociation energies supplied.

d. In an endothermic reaction, the energy needed to break existing bonds is greater than the energy released from forming new bonds.

e. Catalysts provide a different pathway for a chemical reaction that has a lower activation energy.

Students should be able to represent the effect of a catalyst on an energy level diagram.

3.16 Organic chemistry

3.16.1 Carbon compounds as fuels

3.16.1.1 Crude oil

a. Crude oil is a mixture of a very large number of compounds.

b. Most of the compounds in crude oil are hydrocarbons, which are molecules made up of hydrogen and carbon atoms only.

c. The many hydrocarbons in crude oil may be separated into fractions, each of which contains molecules with a similar number of carbon atoms, by evaporating the oil and allowing it to condense at a number of different temperatures. This process is called fractional distillation.

Students should know and understand the main processes in continuous fractional distillation in a fractionating column.

Knowledge of the names of specific fractions or fuels is ***not*** *required.*

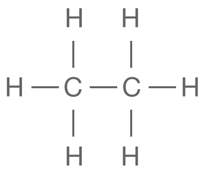
3.16.1.2 Hydrocarbons

a. Most of the hydrocarbons in crude oil are saturated hydrocarbons called alkanes. The general formula for the homologous series of alkanes is C_nH_{2n+2}

Students should know that in saturated hydrocarbons all the carbon–carbon bonds are single covalent bonds.

b. Alkane molecules can be represented in the following forms:

C_2H_6 or



Students should know that in displayed structures — represents a covalent bond.

Students should be able to recognise alkanes from their formulae in any of the forms, but do not need to know the names of specific alkanes other than methane, ethane and propane.

c. Some properties of hydrocarbons depend on the size of their molecules. These properties influence how hydrocarbons are used as fuels.

Knowledge and understanding of trends in properties of hydrocarbons is limited to:

- *boiling points*
- *viscosity*
- *flammability.*

d. Most fuels, including coal, contain carbon and/or hydrogen and may also contain some sulfur. The gases released into the atmosphere when a fuel burns may include carbon dioxide, water (vapour), carbon monoxide, sulfur dioxide and oxides of nitrogen. Solid particles (particulates) may also be released. Solid particles may contain soot (carbon) and unburnt fuels.

Sulfur dioxide and oxides of nitrogen cause acid rain, an increase in carbon dioxide may result in climate change, and solid particles cause global dimming.

Students should be able to relate products of combustion to the elements present in compounds in the fuel and to the extent of combustion (whether complete or incomplete).

No details of how the oxides of nitrogen are formed are required, other than the fact that they are formed at high temperatures.

e. The combustion of hydrocarbon fuels releases energy. During combustion, the carbon and hydrogen in the fuels are oxidised.

f. Biofuels, including biodiesel and ethanol, are produced from plant material, and are possible alternatives to hydrocarbon fuels.

Students should know and understand the benefits and disadvantages of biofuels in terms of:

- *use of renewable resources*
- *their impacts on land use*
- *their carbon footprint.*

Students should know that ethanol for use as a biofuel is produced from a dilute solution of ethanol obtained by the fermentation of plant materials at a temperature between 20 °C and 35 °C. Detailed knowledge of the methods used to produce other biofuels is ***not*** *required.*

3.16.1.3 Obtaining useful substances from crude oil

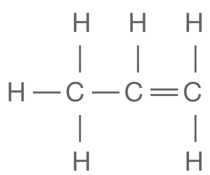
a. Hydrocarbons can be broken down (cracked) to produce smaller, more useful molecules. This process involves heating the hydrocarbons to vaporise them. The vapours are either passed over a hot catalyst or mixed with steam and heated to a very high temperature so that thermal decomposition reactions then occur.

b. The products of cracking include alkanes and unsaturated hydrocarbons called alkenes. The general formula for the homologous series of alkenes is C_nH_{2n}

Students should know that in unsaturated hydrocarbons some of the carbon–carbon bonds are double covalent bonds.

c. Unsaturated hydrocarbon molecules can be represented in the following forms:

C_3H_6 or



Students should know that in displayed structures $=$ *represents a double bond.*

Students should be able to recognise alkenes from their names or formulae, but do ***not*** *need to know the names of individual alkenes other than ethene and propene.*

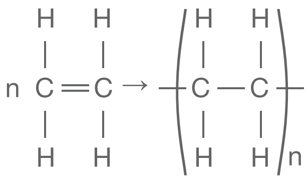
d. Alkenes react with bromine water, turning it from orange to colourless.

e. Some of the products of cracking are useful as fuels.

3.16.2 Synthetic and naturally occurring polymers

a. Alkenes can be used to make polymers such as poly(ethene) and poly(propene). In polymerisation reactions, many small molecules (monomers) join together to form very large molecules (polymers).

For example:



ethene poly(ethene)

Students should be able to recognise the molecules involved in these reactions in the forms shown in the subject content. They should be able to represent the formation of a polymer from a given alkene monomer.

*Further details of polymerisation are **not** required.*

b. The properties of polymers depend on what they are made from and the conditions under which they are made. For example, low-density (LD) and high-density (HD) poly(ethene) are produced using different catalysts and reaction conditions.

c. Thermosoftening polymers consist of individual, tangled polymer chains. Thermosetting polymers consist of polymer chains with cross-links between them so that they do not melt when they are heated.

Extension Tier students should be able to explain thermosoftening polymers in terms of intermolecular forces.

d. Polymers have many useful applications and new uses are being developed. Examples include: new packaging materials, waterproof coatings for fabrics, dental polymers, wound dressings, hydrogels, and smart materials (including shape memory polymers).

Students should consider the ways in which new materials are being developed and used, but will not need to recall the names of specific examples.

e. Many polymers are not biodegradable, ie they are not broken down by microbes. This can lead to problems with waste disposal.

*Knowledge of specific named examples is **not** required, but students should be aware of the problems that are caused in landfill sites and in litter.*

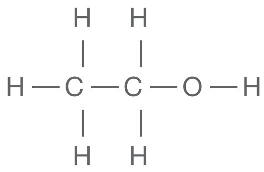
f. Plastic bags are being made from polymers and cornstarch so that they break down more easily. Biodegradable plastics made from cornstarch have been developed.

3.16.3 Organic compounds – their structure and reactions

3.16.3.1 Alcohols

a. Alcohols contain the functional group –OH. Methanol, ethanol and propanol are the first three members of a homologous series of alcohols. Alcohols can be represented in the following forms:

CH_3CH_2OH or



*Students should be able to recognise alcohols from their names or formulae, but do **not** need to know the names of individual alcohols other than methanol, ethanol and propanol.*

b. Methanol, ethanol and propanol:

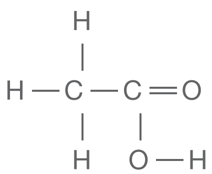
- dissolve in water to form a neutral solution
- react with sodium to produce hydrogen
- burn in air
- are used as fuels and solvents, and ethanol is the main alcohol in alcoholic drinks.

c. Ethanol can be oxidised to ethanoic acid, (a carboxylic acid) either by chemical oxidising agents or by microbial action. Ethanoic acid is the main acid in vinegar.

3.16.3.2 Carboxylic acids

a. Ethanoic acid is a member of the homologous series of carboxylic acids, which have the functional group –COOH. The structures of carboxylic acids can be represented in the following forms:

CH_3COOH or



*Students should be able to recognise carboxylic acids from their names or formulae, but do **not** need to know the names of individual carboxylic acids other than methanoic acid, ethanoic acid and propanoic acid.*

b. Carboxylic acids:

- dissolve in water to produce acidic solutions
- react with carbonates to produce carbon dioxide
- react with alcohols in the presence of an acid catalyst to produce esters
- do not ionise completely when dissolved in water and so are weak acids
- aqueous solutions of weak acids have a higher pH value than aqueous solutions of strong acids with the same concentration.

Students are expected to write balanced chemical equations for the reactions of carboxylic acids.

Physics

3.17 Forces and their effects

This topic explores the interactions (forces) between objects that can change their shape or the way they are moving. Mathematical relationships can predict the resultant motion of an object and applications illustrate how forces can be used to achieve certain outcomes and avoid others.

3.17.1 Forces and their interactions

a. Objects interact by non-contact (field) forces (including gravity, electrostatics, magnetism) and by contact forces (including friction, air resistance, tension and normal contact force).

b. Friction is a force between two surfaces, which impedes motion and may result in heating. Air resistance is a form of friction.

c. Pairs of objects interact to produce a force on each other, which can be represented as vectors.

d. Scalars are quantities that have magnitude only. Vectors are quantities that have direction as well as a magnitude. A vector quantity may be represented by an arrow. The length of the arrow represents the magnitude and the direction of the arrow represents the direction of the vector quantity.

   Students should be aware that distance, speed and time are examples of scalars and displacement, velocity, acceleration, force and momentum are examples of vectors.

e. Weight is the force acting on an object due to gravity. The weight of an object depends on the gravitational filed strength at the point where the object is. The weight of an object can be calculated using the equation:

   Weight (N) = mass (kg) × gravitational field strength (N/kg)
   $W = m \times g$

   *Students will **not** be expected to know the value of g; it will be given in any examination items.*

f. A force applied to an elastic object such as a spring will result in the object stretching and storing elastic potential energy.

g. For an object behaving elastically, the extension is directly proportional to the force applied, provided that the limit of proportionality is not exceeded. The relationship between the force, F, and the extension, e, is:

   $F = k \times e$

   where k is a constant.

h. Required practical:
   Investigate the relationship between force and extension for a spring.

3.17.2 Motion

a. If an object moves in a straight line, its distance from a certain point can be represented by a distance–time graph.

b. The speed of the object can be calculated from the gradient of a distance–time graph.

c. The velocity, v, of an object is its speed in a given direction and is given by the equation:

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

where s is the displacement and t is the time taken.

d. This equation can also be used to calculate the average speed of objects undergoing non-uniform motion.

3.17.3 Resultant forces

a. Whenever two objects interact, the forces they exert on each other are equal in magnitude and opposite in direction. This is Newton's Third Law.

b. A number of forces acting on an object may be replaced by a single force that has the same effect on the motion as all the original forces acting together. This single force is called the resultant force.

Students should be able to determine the resultant of opposite or parallel forces acting in a straight line and determine the resultant of two coplanar forces by scale drawing.

c. A non-zero resultant force acting on an object causes it to accelerate.

d. Acceleration is the rate of change of velocity. An object can accelerate by changing its direction even if it is going at a constant speed. Deceleration is a negative acceleration. The average acceleration, a, of an object is given by the equation:

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

where Δv is the change in velocity and t is the time taken for the object to accelerate.

e. **The acceleration of an object can be calculated from the gradient of the velocity–time graph.**

f. **The distance travelled by an object can be calculated from the area under a velocity–time graph.**

g. If the resultant force acting on an object is zero:

- a moving object will continue to move at the same velocity
- a stationary object will remain at rest.

This is Newton's First Law.

h. If the resultant force on an object is not zero, the object will accelerate in the direction of the resultant force. The relationship between the resultant force, F, acting on an object, its mass, m, and the acceleration caused, a, is:

$$F = m \times a$$

This is Newton's Second Law.

3.17.4 Safety in public transport

a. When a vehicle travels at a steady speed in a straight line the resistive forces are balancing the driving force.

b. The greater the speed of a vehicle the greater the braking force needed to stop it in a certain distance. The greater the braking force the greater the deceleration of the vehicle. Large decelerations may lead to brakes overheating and/or loss of control.

Students should understand that, for a given braking force, the greater the speed, the greater the stopping distance.

c. The stopping distance of a vehicle is the sum of the distance the vehicle travels during the driver's reaction time (thinking distance) and the distance it travels under the braking force (braking distance). A driver's reaction time can be affected by tiredness, distractions, drugs and alcohol.

d. When the brakes of a vehicle are applied, work done by the friction force between the brakes and the wheel reduces the kinetic energy of the vehicle and the temperature of the brakes increases.

e. A vehicle's braking distance can be affected by adverse road and weather conditions and poor condition of the vehicle.

Students should understand that 'adverse road conditions' includes wet or icy conditions. Poor condition of the car is limited to the car's brakes or tyres.

3.18 Energy

This topic starts with the principles of energy transfer and then explores it in various contexts, such as heating. It considers the idea that energy is never destroyed but may end up so dissipated that it is of little use.

3.18.1 Forces and energy

a. Work is done when a force causes an object to move through a distance. The relationship between work done, W, force, F, and distance, d, moved in the direction of the force is:

$$W = F \times d$$

b. Energy is transferred when work is done. Work done against frictional forces causes energy transfer by heating.

Students should be able to discuss the transfer of kinetic energy in particular situations, for example shuttle re-entry into the atmosphere or meteorites burning up in the atmosphere and braking systems on vehicles.

c. **The amount of elastic potential energy stored in a stretched spring (assuming the limit of proportionality has not been exceeded) can be calculated using the equation:**

$$\boldsymbol{E_e = \tfrac{1}{2} \times k \times e^2}$$

d. An object gains gravitational potential energy when it is raised vertically because work is done against the gravitational force. The relationship between gravitational potential energy, E_p, mass, m, gravitational field strength, g, and height, h, is:

$$E_p = m \times g \times h$$

e. The kinetic energy of a moving object depends on its mass and its velocity. The relationship between kinetic energy, E_k, mass, m and velocity, v, is:

$$E_k = \tfrac{1}{2} \times m \times v^2$$

Students should understand that when the mass of an object is doubled, if it is travelling at the same speed it will have twice the kinetic energy. They should understand that an object travelling at twice the speed of another object with the same mass will have four times the kinetic energy and should be able to apply this idea in the context of road safety.

f. Power is the rate at which energy is transferred or the rate at which work is done. The relationship between power, P, work done, W, or energy transferred, E, and time, t, is:

$$P = \frac{E}{t}$$

and

$$P = \frac{W}{t}$$

3.18.2 Energy transfers, conservation and dissipation of energy

a. When a system changes, energy is transferred. A system is an object or group of objects.

Students should be able to identify when and where energy has been transferred using concepts such as kinetic energy, gravitational potential energy and elastic potential energy.

b. Energy can be transferred usefully, stored or dissipated, but cannot be created or destroyed.

c. When energy is transferred only part of it may be usefully transferred; the rest is dissipated so that it is stored in less useful ways. This energy is often described as being 'wasted'.

d. Friction and air resistance are forces that dissipate energy by heating the surroundings.

e. The efficiency of a device can be calculated using:

$$\text{efficiency} = \frac{\text{useful energy out}}{\text{(total energy in)}} \quad (\times\ 100\ \%)$$

and

$$\text{efficiency} = \frac{\text{useful power out}}{\text{(total power in)}} \quad (\times\ 100\ \%)$$

Students may be required to calculate efficiency as a decimal or as a percentage.

f. The energy flow in a system can be represented using Sankey diagrams.

Students should be able to draw and interpret Sankey diagrams to show how the overall energy in a system is redistributed when the system is changed but there is no net change to the total energy.

3.18.3 Energy resources

a. Fuels are a useful store of energy; different fuels are suitable for different situations and are selected according to a range of factors, such as ease of storage, energy content and safety.

b. When a fuel is used, some energy is transferred to the surroundings. Some fuels are more efficient than others.

c. There is a range of energy sources used on a national and global scale. Their use has implications for society in terms of factors including renewability and the environmental impacts of extraction, use and disposal.

d. A range of technologies have been developed to provide energy in a renewable way, such as wave power, solar power and geothermal power.

Students should be aware of these and other examples and be able to identify advantages and drawbacks with their use.

3.19 Waves

Waves, both transverse and longitudinal, carry energy from a source and can be detected by a receiver. This topic explores the properties of waves and their application to contexts such as information communication and sight.

3.19.1 General properties of waves

a. A wave is a disturbance caused by an oscillating source that transfers energy and information in the direction of wave travel, without transferring matter.

b. In a transverse wave the oscillations are perpendicular to the direction of energy transfer.

c. In a longitudinal wave the oscillations are parallel to the direction of energy transfer. Longitudinal waves have areas of compression and rarefaction.

d. Electromagnetic waves and water waves are transverse, sound waves are longitudinal and mechanical waves may be either transverse or longitudinal.

e. Waves can be reflected, transmitted or absorbed (or a combination of these) at the boundary between two different materials.

f. Waves can undergo refraction due to a change in speed and diffraction through a narrow gap or at an edge.

Students should appreciate that for appreciable diffraction to take place the wavelength of the wave has to be comparable to the size of the obstacle or gap. Students may be required to apply these ideas to the reduction of diffraction in optical instruments, ultrasound waves in medicine and radio wave reception.

Required practical:
Investigate the refraction of light in glass blocks.

g. Wave motion can be described in terms of their frequency, wavelength, period, amplitude and wavefront.

Students should be able to explain the meaning of these terms.

h. The relationship between wave speed, v, frequency, f, and wavelength, λ, is:

$$v = f \times \lambda$$

3.19.2 The electromagnetic spectrum

a. Electromagnetic waves are transverse waves that transfer energy from the source of the waves to an absorber.

b. Electromagnetic waves form a continuous spectrum and all types of electromagnetic wave travel at the same speed through a vacuum (space).

Students should know the order of electromagnetic waves within the spectrum, grouped in terms of energy, frequency and wavelength. They should appreciate that the wavelengths of the electromagnetic spectrum range from 10^{-15} *m to* 10^{4} *m and beyond.*

c. Visible light is the part of the electromagnetic spectrum that is detected by our eyes; we see different wavelengths as different colours.

d. All objects emit and absorb infrared radiation. The hotter an object is the more infrared radiation it radiates in a given time.

- Dark, matt surfaces are good absorbers and good emitters of infrared radiation.
- Light, shiny surfaces are poor absorbers and poor emitters of infrared radiation.
- Light, shiny surfaces are good reflectors of infrared radiation.

e. Radio waves, microwaves, infrared and visible light can be used for communication.

f. Electromagnetic waves have many practical applications. For example:

- radio waves – television and radio systems (including Bluetooth)
- microwaves – mobile phones and satellite television systems
- infrared – TV remote controls, night vision devices, heating
- visible light – photography, fibre optic communications
- ultraviolet – security marking
- X-rays – medical imaging
- gamma rays – sterilising surgical instruments and killing harmful bacteria in food.

g. Excessive exposure of the human body to electromagnetic waves can be hazardous. Low energy waves have a heating effect and higher energy waves have enough energy to cause ionisation (remove an electron from an atom or molecule). For example:

- microwaves – heating of body tissue
- infrared – skin burns
- ultraviolet – skin cancer and blindness
- X-rays – high doses kill cells
- gamma rays – genetic mutations.

Students should be able to describe simple protection measures against risks.

h. X-rays are part of the electromagnetic spectrum. They have a very short wavelength, high energy and cause ionisation.

i. Properties of X-rays include:

- **they affect a photographic film in the same way as light**
- **they are absorbed strongly by metal and bone**
- **they are transmitted by healthy tissue.**

j. X-rays can be used to diagnose some medical conditions, for example in computed tomography (CT) scanning, bone fractures and dental problems. X-rays are also used to treat some conditions, for example in killing cancer cells.

k. The use of high energy ionising radiation can be dangerous, and precautions need to be taken to monitor and minimise the levels of radiation that people who work with it are exposed to.

3.19.3 Sound

a. Sound waves are longitudinal waves and cause vibrations in a medium, which are detected as sound. The range of human hearing is about 20 Hz to 20 000 Hz.

***No** details of the structure of the ear are required.*

b. The pitch of a sound is determined by the frequency of vibrations of the source. Its loudness is related to the size of the amplitude of the disturbance.

c. Sound waves can be reflected (echoes) and diffracted.

3.19.4 Reflection

a. When waves are reflected the angle of incidence is equal to the angle of reflection.

b. The normal is a construction line perpendicular to the reflecting surface at the point of incidence.

c. The image produced in a plane mirror is virtual, upright and laterally inverted.

Students will be expected to be able to construct ray diagrams to represent the changing path of reflected rays.

3.20 Particle model of matter

The properties of materials can be understood in terms of constituent particles, their motions and interactions.

3.20.1 Kinetic theory

a. Kinetic theory can be used to explain the different states of matter and their properties. The particles in solids, liquids and gases have different amounts of energy.

Students should be able to recognise, use and compare simple diagrams to represent key features of solids, liquids and gases.

b. The specific heat capacity of a substance is the amount of energy required to change the temperature of one kilogram of the substance by one degree Celsius. The relationship between energy, E, mass, m, specific heat capacity, c, and temperature change, $\Delta\theta$, is:

$$E = m \times c \times \Delta\theta$$

c. **The specific latent heat of vaporisation of a substance is the amount of energy required to change the state of one kilogram of the substance from a liquid to a vapour with no change in temperature. The relationship between energy, E, mass, m, and specific latent heat of vaporization, L_V , is:**

$$E = m \times L_V$$

d. **The specific latent heat of fusion of a substance is the amount of energy required to change the state of one kilogram of the substance from a solid to a liquid with no change in temperature. The relationship between energy, E, mass, m, and specific latent heat of fusion, L_F , is:**

$$E = m \times L_F$$

e. The melting point of a solid and the boiling point of a liquid are affected by impurities.

Throughout Section 3.19, students should be able to explain the shape of the temperature–time graph for a substance that is either cooled or heated through changes in state.

3.20.2 Energy transfers and particle motion

a. Energy may be transferred by conduction and convection.

Students should be able to explain, in terms of particles, how these energy transfers take place. They should understand in simple terms how the arrangement and movement of particles determine whether a material is a conductor or an insulator and understand the role of free electrons in conduction through a metal. They should be able to use the idea of particles moving apart to make a fluid less dense, to explain and apply the concept of convection.

b. **Energy may be transferred by evaporation and condensation.**

Students should be able to explain evaporation, and the cooling effect this causes, using kinetic theory. Students should be able to discuss the factors that affect the rate of evaporation.

c. The rate at which an object transfers energy by heating depends on:

- its surface area and volume
- the material from which the object is made
- the nature of the surface with which the object is in contact.

Students should be able to explain the design of devices in terms of energy transfer, for example cooling fins, and should be able to explain animal adaptations in terms of energy transfer, for example relative ear size of animals in cold and warm climates.

d. The bigger the temperature difference between an object and its surroundings, the faster the rate at which energy is transferred by heating.

e. Most substances expand when heated.

Students should understand that the expansion of substances on heating may be a hazard (for example, the expansion of roofs and bridges) or useful (for example, the bi-metallic strip thermostat).

3.21 Electricity and magnetism

Electricity is convenient because it is easily transmitted over distances and can be easily transferred in a range of different ways. By controlling the flow of current and understanding the factors that affect this flow it can be used to make a range of applications work. Electricity is also a good context for considering how energy is transferred. Magnetism provides a connection with forces through the study of fields and the way it can produce and be produced by electricity.

3.21.1 Electrical circuits

a. Electrical charges can move easily through some substances; for example metals have many charges (electrons) that are free to move.

b. Electric current is the rate of flow of electric charge. Charge flow, Q, current, I, and time, t, are linked by the equation:

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

c. The voltage of a source is the energy supplied by a source in driving charges round a complete circuit and is measured in volts.

d. Potential difference across a component measures the energy transfer by charges and is measured in volts.

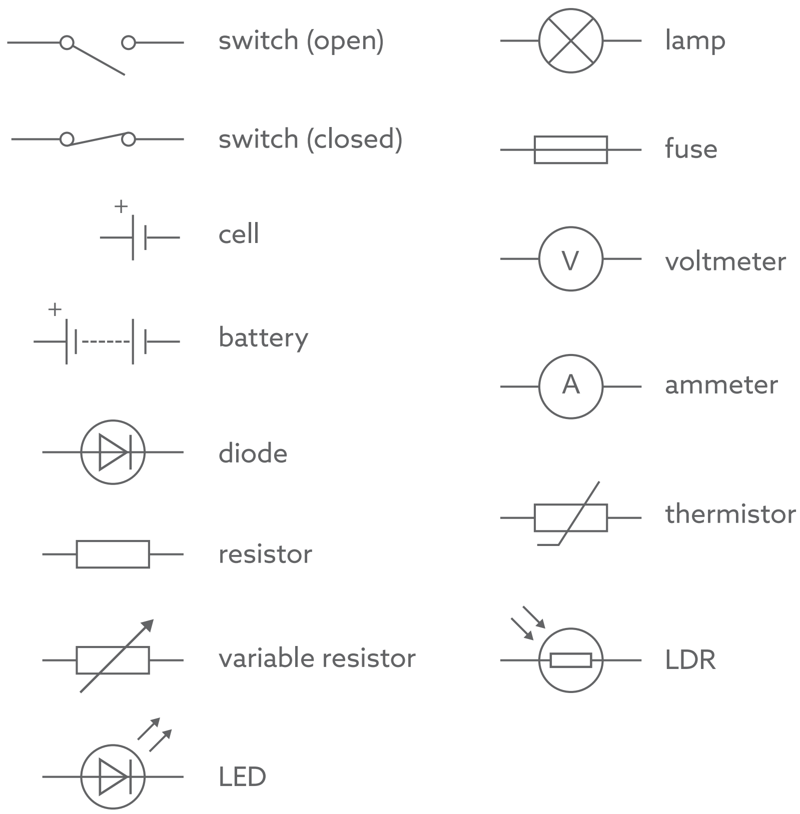
e. **The relationship between potential difference, V, energy transferred, E, and charge, Q, is:**

$$V = \frac{E}{Q}$$

Teachers can use either of the terms potential difference or voltage. Questions will be set using the term potential difference. Students will gain credit for the correct use of either term.

f. Circuit diagrams use standard symbols.

Students will be required to interpret and draw circuit diagrams. Students should know the following standard symbols:



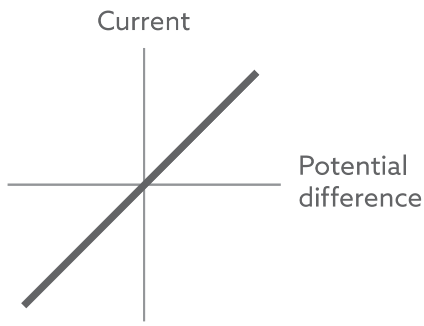
Students should understand the use of thermistors in circuits, for example thermostats.

Students should understand the use of light-dependent resistors (LDRs) in circuits, for example switching lights on when it gets dark.

g. Components resist the flow of charge through them. The greater the resistance the smaller the current for a given potential difference across the component. The resistance of a component can be found by measuring the current through and potential difference across, the component. The relationship between potential difference, V, current, I, and resistance, R, is:

$$V = I \times R$$

h. The current through a resistor (at a constant temperature) is directly proportional to the potential difference across the resistor. This means that the resistance remains constant as the current changes.



i. The resistance of components such as lamps, diodes, thermistors and LDRs is not constant; it changes with the current through the component.

j. **The resistance of a filament lamp increases as the temperature of the filament increases.**

Students should be able to explain change in resistance in terms of ions and electrons.

k. An LED emits light when a current flows through it in the forward direction.

Students should be aware that the use of LEDs for lighting is increasing, as they use a much smaller current than other forms of lighting.

l. The combined voltage of several sources in series is their sum.

m. There are two ways of joining electrical components: in series and in parallel. Some circuits include both series and parallel parts.

n. For components connected in series:

- the combined resistance is the sum of the resistance of each component
- the current is the same in each component
- the total potential difference of the power supply is shared between the components.

o. For components connected in parallel:

- the combined resistance is less than that of either component
- the current from the supply splits in the branches
- the potential difference across each component is the same.

p. **When an electrical charge flows through a resistor, the resistor gets hot because of collisions between moving charges and stationary atoms in the wire.**

Students should understand that a lot of energy is wasted in filament bulbs by heating. Less energy is wasted in power saving lamps such as Compact Fluorescent Lamps (CFLs). They should understand that there is a choice when buying new appliances in how efficiently they transfer energy.

3.21.2 Magnetism and electromagnetism

a. Magnetic forces are strongest at the poles of a magnet. When two magnets are brought close together they exert a force on each other. Two like poles repel each other and two unlike poles attract. Attraction and repulsion between two magnetic poles are examples of non-contact forces.

   Students should be able to predict the interaction between magnets given their physical arrangement.

b. The space around a magnet where a force acts on another magnet or on a magnetic material (iron, steel, cobalt, nickel) is called a magnetic field. The strength and direction of a magnetic field change from one point to another.

   Students should be able to recognise magnetic field patterns using one or two bar magnets. In a uniform magnetic field the lines of the magnetic field are parallel.

c. An induced magnet is a material that becomes a magnet when it is placed in a magnetic field. Induced magnetism always causes a force of attraction. When removed from the magnetic field an induced magnet loses most/all of its magnetism quickly.

   Students should be able to explain how a magnet attracts a magnetic object by inducing a magnetic field around it.

d. The earth has a magnetic field that is most concentrated at the magnetic north and south poles.

   Students should be able to explain how a plotting compass can be used to detect the earth's magnetic field and to assist in navigation.

e. A magnetic field is produced when an electric current flows through a wire. The magnetic field lines are concentric circles in a plane, perpendicular to the wire.

   - The field is stronger closer to the wire.
   - Increasing the current makes the magnetic field stronger.
   - Reversing the current reverses the direction of the magnetic field lines.

f. Shaping a wire to form a solenoid increases the strength of the magnetic field created by a current through the wire. The magnetic field inside a solenoid is strong and uniform.

g. The magnetic field around a solenoid has a similar shape to that of a bar magnet. Adding an iron core increases the magnetic field strength. An electromagnet consists of a solenoid with an iron core.

   Students should be familiar with some typical uses of electromagnets.

   Required practical:
   Investigate the factors that determine the strength of an electromagnet.

3.22 Electricity and household use

In this topic magnetism and electromagnetism are studied in the context of their uses in using current to cause motion and vice versa and in changing the voltages of an ac supply. In so doing the big ideas of field forces and energy transfer are also used.

3.22.1 Using electricity in the home

a. Cells and batteries supply current that always passes in the same direction. This is called direct current (dc).

b. An alternating current (ac) is one that is repeatedly changing direction.

Students should be able to determine the period, and hence the frequency, of a supply from diagrams. They should be able to compare and calculate potential differences of dc supplies and the peak potential differences of ac supplies from diagrams.

c. Mains electricity is an ac supply, which has a set frequency and voltage.

Knowledge of root mean square (rms) measurements and values are not required.

d. There are a number of safety features that can be incorporated in electrical systems and appliances. One of these is earthing: if the metal body of an appliance becomes live through a fault, the current is harmlessly conducted away.

e. If an electrical fault causes too great a current to flow, a fuse or a circuit breaker in the live wire disconnects the circuit. The current will cause the fuse wire to overheat and melt or the circuit breaker to switch off ('trip'). A circuit breaker operates much faster than a fuse and can be reset.

f. Appliances with metal cases are usually earthed. If a fault develops a large current flows from the live wire to earth. This melts the fuse and disconnects the live wire.

Students should be aware that some appliances are double insulated and therefore have no earth wire connection.

3.22.2 The motor effect

a. **A current carrying conductor has a magnetic field around the wire. When a current carrying conductor is placed in a magnetic field so that it cuts lines of magnetic force, the magnet and the conductor exert a force on each other. This is called the motor effect. The conductor will not experience a force if it is parallel to the magnetic field.**

b. **The size of the force can be increased by:**

- **increasing the strength of the magnetic field**
- **increasing the size of the current**
- **increasing the length of the conductor in the magnetic field.**

c. **The direction of the force is reversed if either the direction of the current or the direction of the magnetic field is reversed.**

Students should be able to identify the direction of the force using Flemings left-hand rule.

d. **A coil of wire carrying a current in a magnetic field tends to rotate. This is the basis of an electric motor.**

3.22.3 Transferring electrical energy

a. Electrical appliances are designed to transfer energy.

Students should be able to give examples of such devices and identify the energy transfers.

b. The rate at which energy is transferred by an appliance is called the power. The relationship between power, P, energy transferred, E, and time, t, is:

$$P = \frac{E}{t}$$

c. The power transfer, P, in any device is related to the current, I, flowing through it and potential difference, V, across it:

$$P = I \times V$$

Students should be able to calculate the current through an appliance from its power and the potential difference of the supply and from this determine the size of fuse needed.

d. **The relationship between energy transferred, E, potential difference, V, and charge, Q, is:**

$$\boldsymbol{E = V \times Q}$$

e. The amount of energy an appliance transfers depends on how long the appliance is switched on for and its power rating. It is often more convenient to measure energy transfers in domestic appliances in kWh instead of J due to the small size of the latter.

f. The relationship between energy transferred, E, from the mains, power, P, and time, t, is:

$$E(kWh) = P(kW) \times t(h)$$

*Students will **not** be required to convert between kilowatt-hours and joules.*

Students should be able to calculate the cost of mains electricity given the cost per kilowatt-hour and interpret and use electricity meter readings to calculate total cost over a period of time.

3.23 Nuclear physics

The structure of material is used to model what an atom consists of, what might happen when atoms break apart and when they fuse together. This provides ways of actually or potentially generating power and explains processes at the centre of stars.

3.23.1 Atomic structure

a. Atoms are very small, having a radius of about 10^{-10} metres. The simple model of an atom is a small central positively charged nucleus composed of protons and neutrons, surrounded by electrons. The radius of the nucleus is much smaller than that of the atom with almost all of the mass in the nucleus.

b. **The scattering of alpha particles by thin metal foil provides evidence of the distribution of mass in the atom.**

c. The relative masses and electric charges of protons, neutrons and electrons are as follows:

	Relative mass	Relative charge
Proton	1	1
Neutron	1	0
Electron	Very small	–1

d. In an atom the number of electrons is equal to the number of protons in the nucleus. The atom has no overall electrical charge.

e. In each atom its electrons are arranged at various distances from the nucleus. Atoms may lose or gain outer electrons to form charged particles called ions.

f. The atoms of a particular element always have the same number of protons, but have a different number of neutrons for each isotope. The total number of protons in an atom is called its proton number or atomic number. The total number of protons and neutrons in an atom is called its mass number. Atoms can be represented as shown:

(Mass number)
(Atomic number) $^{23}_{11}\mathrm{Na}$

3.23.2 Ionizing radiation from the nucleus

a. Some atomic nuclei are unstable. The nucleus emits particles or radiation and the nucleus changes to that of a different element and becomes more stable. This is a random process called radioactive decay.

b. Energy is emitted by changes in the nucleus.

c. Unstable nuclei emit alpha particles, beta particles, or neutrons, and electromagnetic radiation as gamma waves. Neither chemical nor physics processes affect this behaviour. These substances are said to be radioactive and although the general process follows a pattern this radioactive decay is a random process. It is impossible to predict when a particular atom might decay.

d. Background radiation is around us all of the time. It comes from a range of sources, such as radioactive substances in the environment, from space or from devices such as X-ray machines in hospitals.

e. An alpha particle consists of two neutrons and two protons (i.e. a Helium nucleus). A beta particle is a high speed electron ejected from the nucleus as a neutron turns into a proton. Gamma radiation is electromagnetic radiation from the nucleus.

f. **Nuclear equations are used to represent radioactive decay.**

   Students will be required to balance equations for single alpha and beta decay, limited to the completion of atomic number and mass number. The identification of daughter elements from such decays is not required.

g. Properties of the alpha, beta and gamma radiations are limited to their relative ionising power, their penetration through materials and their range in air.

3.23.3 Nuclear fission

a. Nuclear fission is the splitting of a large and unstable nucleus and the release of energy.

b. **For fission to occur the uranium-235 or plutonium-239 nucleus must first absorb a neutron to make the nucleus unstable. The nucleus undergoing fission splits into two smaller nuclei, releasing two or three neutrons and energy. The amount of energy released during nuclear fission is much greater than that released in a chemical reaction involving a similar mass of material.**

c. A chain reaction occurs when neutrons from the fission go on to cause further fission. In a nuclear reactor control rods absorb fission neutrons to ensure that on average only one neutron per fission goes on to produce further fission and energy transfer.

   Students should be able to sketch or complete a labelled diagram to illustrate how a chain reaction may occur.

d. Nuclear reactions produce waste which may be dangerous due to its radioactive nature and may remain so for a long time, depending upon its half life and products. The disposal of such waste needs to be managed with care and is a factor that may influence the use of nuclear power for the generation of electricity.

3.24 Space physics

Space physics uses ideas about forces and motion, energy transfer, atomic structure and fields to develop explanations about the start and end of the universe and about how the Earth receives energy from the Sun. Space was one of the first challenges that civilisation tried to explain in its attempts to account for day, season, year and the appearance of the night sky and remains one of the most challenging due to its scale and complexity.

3.24.1 Life cycle of a star

a. Stars form when enough dust and gas (mainly hydrogen and helium) from space are pulled together by gravitational attraction. Smaller masses may form and be attracted by a larger mass to become planets, or even stars.

b. During the ‘main sequence’ period of its life cycle, energy is released by the fusion of hydrogen nuclei to make helium nuclei in the core and a star is stable because the forces within it are balanced.

   The term ‘radiation pressure’ will ***not*** *be required.*

c. The core (centre) of a star is where the temperature and density are greatest and where most nuclear fusion takes place.

d. The more massive a star, the hotter its core and the heavier the nuclei it can create by fusion.

e. Stars change over time; they have a life cycle. This life cycle is determined by the mass of the star.

f. A main sequence star uses nuclear reactions to produce light and heat. When it runs out of hydrogen, what happens next in its life cycle depends upon its mass.

g. A larger star will swell to become a red supergiant, in which helium nuclei fuse to form carbon, followed by further fusion that produces heavier nuclei such as nitrogen and oxygen. It expands, cools and turns red. The outer layers then blast away as a supernova is formed. The core then collapses and depending upon mass, it forms either a neutron star or a black hole.

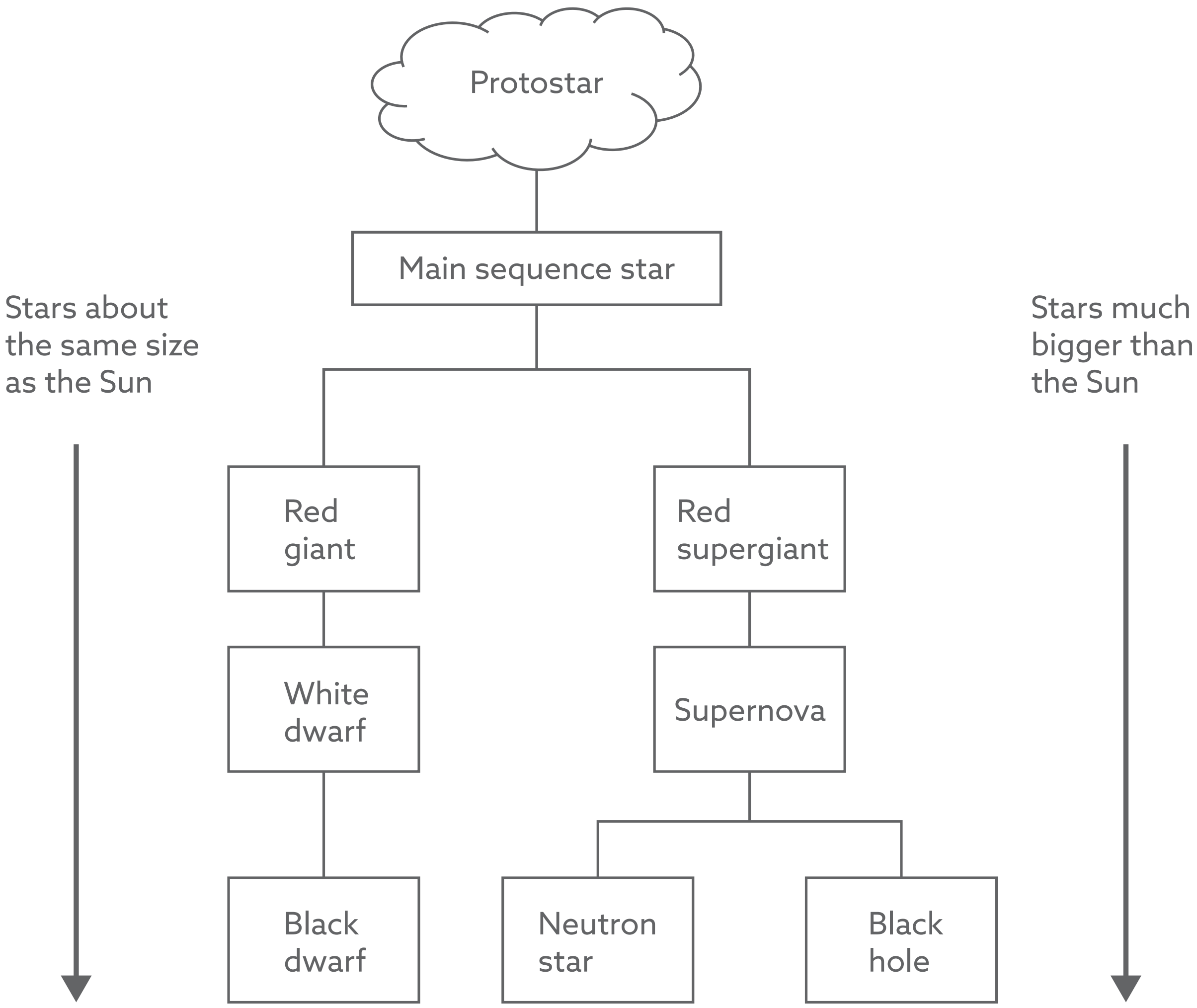
h. A smaller star, similar to our Sun, follows a different sequence, expanding to become a red giant. It then sheds out layers of gas, exposing the core as a white dwarf and finally cools to become a black dwarf.

Students should be familiar with charts that show the life cycles of stars.

i. Fusion processes in stars are the source of energy and produce all of the naturally occurring elements. These elements may be distributed throughout the universe by the explosion of a massive star (supernova) at the end of its life.

Students should be able to explain how stars are able to maintain their energy output for millions of years, why the early universe contained only hydrogen but now contains a large variety of different elements and that elements heavier than iron are formed in a supernova.

j.



3.24.2 Solar system and orbital motion

a. The Earth is one of eight planets orbiting the Sun (a medium sized star), which together with other smaller objects (asteroids, dwarf planets, comets) and moons orbiting several planets, make up the solar system.

Students should be able to describe the principal differences between planets, moons, the Sun, comets and asteroids in terms of relative size and motion.

b. Our universe is made up of:

- thousands of millions of galaxies that are each made up of thousands of millions of stars
- our Sun is one of thousands of millions of stars in our galaxy called the Milky Way.

c. Planets orbit the Sun and a moon is a natural satellite of a planet. Artificial satellites orbit the Earth and can be in geostationary or low polar orbits.

d. Gravity provides the centripetal force that keeps planets and satellites (both natural and artificial) in orbit.

e. **The force of gravity acts towards the centre of the orbit. This unbalanced force causes acceleration towards the centre of the orbit, changing the direction of motion of the body (its velocity) but not its speed.**

The equation for calculating centripetal force is not required.

f. **The centripetal force due to gravity decreases as the separation of orbiting masses increases, resulting in lower orbital speeds.**

g. **At a particular separation of the masses, the centripetal force results in a particular orbital speed. To stay in a stable orbit at a particular distance, the planet or satellite moves at a particular speed. A change in orbital speed results in a change in orbital radius.**

Students should be able to explain the motion of moons and artificial satellites and be able to apply this to the design of satellite placing where the speed will determine the radius of the satellite's final position.

4 Scheme of assessment

Find mark schemes, and specimen papers for new courses, on our website at **oxfordaqa.com/9204**

This is a linear qualification. In order to achieve the award, students must complete all assessments at the end of the course and in the same series.

Our International GCSE exams and certification for this specification are available for the first time in May/June 2018 and then every May/June and November for the life of the specification.

All materials are available in English only.

Our International GCSE exams in Combined Science Double Award include questions that allow students to demonstrate their ability to:

- recall the knowledge and understanding developed through the substantive content of the course
- apply their knowledge and understanding gained in discussing, evaluating and suggesting implications of data and evidence in both familiar and unfamiliar situations
- understand the scientific process while working scientifically and the skills developed while carrying out practical investigations.

The content is assessed through three 1 hour and 45 minutes written papers. Papers are tiered Core and Extension.

In all written papers, questions will be set that examine application of the knowledge and understanding gained in discussing, evaluating and suggesting implications of data and evidence in both familiar and unfamiliar situations. All applications will use the knowledge and understanding developed through the substantive content.

Questions may be taken from any part of the substantive content.

4.1 Aims and learning outcomes

Our International GCSE Combined Science Double Award should encourage students to be inspired, motivated and challenged by following a broad, coherent, practical, satisfying and worthwhile course of study. It should encourage students to develop their curiosity about the living world, enable students to engage with science in their everyday lives in order to make informed choices about further study in science and related disciplines.

Our International GCSE Combined Science Double Award should enable students to:

- develop their knowledge and understanding of biology, chemistry and physics
- develop and apply their knowledge and understanding of the scientific process
- develop their understanding of the relationships between hypotheses, evidence, theories and explanations

- develop and apply their observational, practical, modelling, enquiry and problem-solving skills, and their understanding in laboratory, field and other learning environments
- develop their ability to evaluate claims based on science through critical analysis of the methodology, evidence and conclusions both qualitatively and quantitatively
- develop their skills in reporting and presenting information clearly and logically in different formats
- develop their skills in communication, mathematics and the use of technology in scientific contexts.

4.2 Assessment Objectives

The exams will measure how students have achieved the following Assessment Objectives.

AO1: Knowledge and understanding of scientific principles.

AO2: Application of knowledge and understanding of scientific principles and concepts in both familiar and novel contexts.

AO3: Ability to describe, analyse, interpret and evaluate scientific information presented in different forms.

AO4: Ability to select, describe and evaluate scientific procedures.

4.2.1 Assessment Objective weightings for International GCSE

Assessment Objectives (AOs)	Component weightings (approx %)			Overall weighting (approx %)
	Biology	Chemistry	Physics	
AO1	30	30	30	30
AO2	40	40	40	40
AO3	20	20	20	20
AO4	10	10	10	10
Overall weighting of components (%)	100	100	100	100

4.3 Assessment weightings

Each paper is equally weighted.

Component	Maximum mark
Paper 1	100
Paper 2	100
Paper 3	100
Total mark:	300

5 General administration

We are committed to delivering assessments of the highest quality and have developed practices and procedures that support this aim. To ensure that all students have a fair experience, we have worked with other awarding bodies in England to develop best practice for maintaining the integrity of exams. This is published through the Joint Council for Qualifications (JCQ). We will maintain the same high standard through their use for OxfordAQA.

More information on all aspects of administration is available at **oxfordaqa.com/exams-administration**

For any immediate enquiries please contact **info@oxfordaqa.com**

Please note: We aim to respond to all email enquiries within two working days.

Our UK office hours are Monday to Friday, 8am – 5pm local time.

5.1 Entries and codes

You only need to make one entry for each qualification – this will cover all the question papers and certification.

Qualification title	OxfordAQA entry code
OxfordAQA International GCSE Combined Science Double Award Core Tier	9204/C
OxfordAQA International GCSE Combined Science Double Award Extension Tier	9204/E

Please check the current version of the Entry Codes book and the latest information about making entries on **oxfordaqa.com/exams-administration**

Exams will be available May/June and in November.

5.2 Overlaps with other qualifications

This specification overlaps with the AQA UK GCSE Combined Science: Trilogy (8464) and GCSE Combined Science: Synergy (8465). This specification overlaps with the OxfordAQA International GCSE Biology (9201), GCSE Chemistry (9202) and GCSE Physics (9203). Entry to this specification and OxfordAQA International GCSE Biology (9201), GCSE Chemistry (9202) or GCSE Physics (9203) is **not** permitted in the same series.

5.3 Awarding grades and reporting results

As this qualification is a double award, students will be awarded two identical grades eg 4–4, 7–7.

In line with UK GCSEs, this qualification will be graded on a nine-point scale: 1–1 to 9–9 – where 9–9 is the best grade. Students who fail to reach the minimum standard for grade 1–1 will be recorded as U (unclassified) and will not receive a qualification certificate.

To find out more about the new grading system, visit our website at **oxfordaqa.com**

A student taking Core assessments will be awarded a grade within the range of 1–1 to 5–5. Students who fail to reach the minimum standard for grade 1–1 will be recorded as U (unclassified) and will not receive a qualification certificate.

A student taking Extension assessments will be awarded a grade within the range of 4–4 to 9–9. A student sitting the Extension who just fails to achieve grade 4–4 will be awarded and allowed grade 3–3. Students who fail to reach the minimum standard for the allowed grade 3–3 will be recorded as U (unclassified) and will not receive a qualification certificate.

5.4 Resits

Candidates can re-take the whole qualification as many times as they wish. This is a traditional linear specification, individual components cannot be re-sat.

You only need to make one entry for each qualification – this will cover all the question papers and certification.

5.5 Previous learning and prerequisites

There are no previous learning requirements. Any requirements for entry to a course based on this specification are at the discretion of schools.

5.6 Access to assessment: equality and inclusion

Our general qualifications are designed to prepare students for a wide range of occupations and further study whilst assessing a wide range of competences.

The subject criteria have been assessed to ensure they test specific competences. The skills or knowledge required do not disadvantage particular groups of students.

Exam access arrangements are available for students with disabilities and special educational needs.

We comply with the *UK Equality Act 2010* to make reasonable adjustments to remove or lessen any disadvantage that affects a disabled student. Information about access arrangements will be issued to schools when they become OxfordAQA centres.

5.7 Working with OxfordAQA for the first time

You will need to apply to become an OxfordAQA centre to offer our specifications to your students. Find out how at **oxfordaqa.com/centreapprovals**

5.8 Private candidates

Centres may accept private candidates for examined units/components only with the prior agreement of OxfordAQA. If you are an approved OxfordAQA centre and wish to accept private candidates, please contact OxfordAQA at: **info@oxfordaqa.com**

As some of the marks in the GCSE papers will relate to practical work, students undertaking this specification must carry out the required practical activities in section 6.2 of the specification.

Centres accepting private candidates must ensure they have carried out this minimum requirement. Private candidates may also enter for examined only units via the British Council; please contact your local British Council office for details.

6 Appendices

6.1 Experimental and investigative skills

During this course, students should be encouraged to develop their understanding of the scientific process and the skills associated with scientific enquiry. Students will be assessed on aspects of the skills listed below, and may be required to read and interpret information from scales given in diagrams and charts, present data in appropriate formats, design investigations and evaluate information that is presented to them.

Scientific process and skill	
Designing a practical procedure	Design a practical procedure to answer a question, solve a problem or test a hypothesis.
	Comment on/evaluate plans for practical procedures.
	Select suitable apparatus for carrying out experiments accurately and safely.
Control	Appreciate that, unless certain variables are controlled, experimental results may not be valid.
	Recognise the need to choose appropriate sample sizes, and study control groups where necessary.
Risk assessment	Identify possible hazards in practical situations, the risks associated with these hazards, and methods of minimising the risks.
Collecting data	Make and record observations and measurements with appropriate precision and record data collected in an appropriate format (such as a table, chart or graph).
Analysing data	Recognise and identify the cause of anomalous results and suggest what should be done about them.
	Appreciate when it is appropriate to calculate a mean, calculate a mean from a set of at least three results and recognise when it is appropriate to ignore anomalous results in calculating a mean.
	Recognise and identify the causes of random errors and systematic errors.
	Recognise patterns in data, form hypotheses and deduce relationships.
	Use and interpret tabular and graphical representations of data.
Making conclusions	Draw conclusions that are consistent with the evidence obtained and support them with scientific explanations.
Evaluation	Evaluate data, considering its repeatability, reproducibility and validity in presenting and justifying conclusions.
	Evaluate methods of data collection and appreciate that the evidence obtained may not allow a conclusion to be made with confidence.
	Suggest ways of improving an investigation or practical procedure to obtain extra evidence to allow a conclusion to be made.

6.2 Required practicals

The table below summaries the nine required practicals, three biology, three chemistry and three physics.

Specification	Required practicals
1. Bioenergetics 3.2.1 Photosynthesis	Investigate how variables affect the rate of photosynthesis.
2. Bioenergetics 3.2.6 Respiration	Investigate the effects of exercise on the human body.
3. Organisms interaction with the environment 3.4.6 Infection and response	Investigate the effect of disinfectants and antibiotics on uncontaminated cultures of microorganisms.
4. Chemical analysis 3.10.2 Identification of ions	Identify the metal ion in an unknown compound using flame testing techniques.
5. Quantitative chemistry 3.12.4 Molar concentrations	Establish the concentration of an unknown strong acid through titration with a strong base.
6. The rate of chemical change 3.14.1 Rate of reaction	Investigate factors affecting the rate of a reaction.
7. Forces and their effects 3.17.1 Forces and their interactions	Investigate the relationship between force and extension for a spring.
8. Waves 3.19.1 General properties of waves	Investigate the refraction of light in glass blocks.
9. Electricity and magnetism 3.21.2 Magnetism and electromagnetism	Investigate the factors that determine the strength of an electromagnet.

Opportunities to develop experimental and investigative skills during the teaching and learning of the required practicals are identified in the table below.

Scientific process and skill	Rate of photosynthesis	Exercise	Microbes
Designing a practical procedure	✓	✓	x
Control	✓	x	✓
Risk assessment	✓	✓	✓
Collecting data	✓	✓	✓
Analysing data	✓	✓	✓
Making conclusions	✓	✓	✓
Evaluation	✓	✓	✓

Scientific process and skill	Flame tests	Titration	Rates of reaction
Designing a practical procedure	✓	✓	✓
Control	x	✓	✓
Risk assessment	✓	✓	✓
Collecting data	✓	✓	✓
Analysing data	✓	✓	✓
Making conclusions	✓	✓	✓
Evaluation	✓	✓	✓

Scientific process and skill	Hooke's Law	Refraction	Electromagnet
Designing a practical procedure	✓	x	✓
Control	✓	x	✓
Risk assessment	✓	✓	✓
Collecting data	✓	✓	✓
Analysing data	✓	✓	✓
Making conclusions	✓	✓	✓
Evaluation	✓	✓	✓

6.3 Mathematical requirements

This specification provides learners with the opportunity to develop their skills in communication, mathematics and the use of technology in scientific contexts. In order to deliver the mathematical element of this outcome, assessment materials for this specification contain opportunities for students to demonstrate scientific knowledge using appropriate mathematical skills.

The areas of mathematics that arise naturally from the science content are listed below. This is not a checklist for each question paper, but assessments reflect these mathematical requirements, covering the full range of mathematical skills over a reasonable period of time.

Students are permitted to use calculators in all assessments.

Students are expected to use units appropriately. However, not all questions reward the appropriate use of units.

All students should be able to:

1. Understand number size and scale and the quantitative relationship between units.

2. Understand when and how to use estimation.

3. Carry out calculations involving +, –, x, ÷, either singly or in combination, decimals, fractions, percentages and positive whole number powers.

4. Provide answers to calculations to an appropriate number of significant figures.

5. Understand and use the symbols =, <, >, ~

6. Understand and use direct proportion and simple ratios.

7. Calculate arithmetic means.

8. Understand and use common measures and simple compound measures such as speed.

9. Plot and draw graphs (line graphs, bar charts, pie charts, scatter graphs, histograms) selecting appropriate scales for the axes.

10. Substitute numerical values into simple formulae and equations using appropriate units.

11. Translate information between graphical and numeric form.

12. Extract and interpret information from charts, graphs and tables.

13. Understand the idea of probability.

14. Calculate area, perimeters and volumes of simple shapes.

15. Interpret order and calculate with numbers written in standard form.

16. Carry out calculations involving negative powers (only –1 for rate).

17. Change the subject of an equation.

18. Understand and use inverse proportion.

19. Understand and use percentiles and deciles.

Units, symbols and nomenclature

Units, symbols and nomenclature used in examination papers will normally conform to the recommendations contained in the following:

- *The Language of Measurement: Terminology used in school science investigations.* Association for Science Education (ASE), 2010. ISBN 978 0 86357 424 5.
- *Signs, Symbols and Systematics – the ASE companion to 16–19 Science*. Association for Science Education (ASE), 2000. ISBN 978 0 86357 312 5.
- *Signs, Symbols and Systematics – the ASE companion to 5–16 Science*. Association for Science Education (ASE), 1995. ISBN 0 86357 232 4.

6.4 Physics equation sheet

$v = \frac{s}{t}$	v s t	velocity displacement time
$a = \frac{\Delta v}{t}$	a Δv t	acceleration change in velocity time taken
$F = m \times a$	F m a	force mass acceleration
$W = m \times \mathrm{g}$	W m g	weight mass gravitational field strength
$F = k \times e$	F k e	force spring constant extension
$W = F \times d$	W F d	work done force distance moved in the direction of the force
$P = \frac{W}{t}$	P W t	power work done time
$P = \frac{E}{t}$	P E t	power energy transferred time
$E_{\mathrm{p}} = m \times g \times h$	E_{p} m g h	change in gravitational potential energy mass gravitational field strength (acceleration of free fall) height
$E_{\mathrm{k}} = \frac{1}{2} \times m \times v^2$	E_{k} m v	kinetic energy mass velocity
$E_{\mathrm{e}} = \frac{1}{2} \times k \times e^2$	E_{e} k e	elastic potential energy spring constant extension
$v = f \times \lambda$	v f λ	speed frequency wavelength
$E = m \times c \times \Delta\theta$	E m c $\Delta\theta$	energy mass specific heat capacity temperature change

$E = m \times L_V$	E energy m mass L_V specific latent heat of vaporisation
$E = m \times L_F$	E energy m mass L_F specific latent heat of fusion
$\text{efficiency} = \dfrac{\text{useful energy out}}{\text{total energy in}} \ (\times 100\%)$	
$\text{efficiency} = \dfrac{\text{useful power out}}{\text{total power in}} \ (\times 100\%)$	
$I = \dfrac{Q}{t}$	I current Q charge flow t time
$V = \dfrac{E}{Q}$	V potential difference E energy transferred Q charge
$V = I \times R$	V potential difference I current R resistance
$P = I \times V$	P power I current V potential difference

6.5 Units of physical quantities

The table gives details of units that students are expected to know.

Where a unit is given, eg second (s), students should be familiar with relevant subdivisions of the unit, eg millisecond (ms) and microsecond (μs).

In addition, where appropriate, students should be aware of larger units where the basic unit is given, eg joule (J) and kilojoule (kJ).

What the unit measures	Unit	Symbol
length	metre	m
area	square metre	m^2
volume	cubic metre	m^3
time	second hour	s h
speed	metres per second velocity kilometres per hour	m/s or km/h
acceleration	metres per second squared	m/s^2
mass	kilogram	kg
weight force	newton	N
moment of a force	newton metre	Nm
momentum	kilogram metre per second	kg m/s
pressure	pascal newtons per square metre	Pa N/m^2
power	watt	W
energy	joule kilowatt-hours	J kWh
current	ampere (amp)	A
charge	coulomb	C
potential difference	volt	V
resistance	ohm	Ω
temperature	degree Celsius	°C
specific heat capacity	joules per kilogram degree Celsius	J/(kg°C)
specific latent heat of vaporisation	joules per kilogram	J/kg
specific latent heat of fusion	joules per kilogram	J/kg
frequency	hertz	Hz

6.6 Periodic table

Key

relative atomic mass **atomic symbol** name atomic (proton) number

1	2											3	4	5	6	7	0
							1 **H** hydrogen 1										4 **He** helium 2
7 **Li** lithium 3	9 **Be** beryllium 4											11 **B** boron 5	12 **C** carbon 6	14 **N** nitrogen 7	16 **O** oxygen 8	19 **F** fluorine 9	20 **Ne** neon 10
23 **Na** sodium 11	24 **Mg** magnesium 12											27 **Al** aluminium 13	28 **Si** silicon 14	31 **P** phosphorus 15	32 **S** sulfur 16	35.5 **Cl** chlorine 17	40 **Ar** argon 18
39 **K** potassium 19	40 **Ca** calcium 20	45 **Sc** scandium 21	48 **Ti** titanium 22	51 **V** vanadium 23	52 **Cr** chromium 24	55 **Mn** manganese 25	56 **Fe** iron 26	59 **Co** cobalt 27	59 **Ni** nickel 28	63.5 **Cu** copper 29	65 **Zn** zinc 30	70 **Ga** gallium 31	73 **Ge** germanium 32	75 **As** arsenic 33	79 **Se** selenium 34	80 **Br** bromine 35	84 **Kr** krypton 36
85 **Rb** rubidium 37	88 **Sr** strontium 38	89 **Y** yttrium 39	91 **Zr** zirconium 40	93 **Nb** niobium 41	96 **Mo** molybdenum 42	[98] **Tc** technetium 43	101 **Ru** ruthenium 44	103 **Rh** rhodium 45	106 **Pd** palladium 46	108 **Ag** silver 47	112 **Cd** cadmium 48	115 **In** indium 49	119 **Sn** tin 50	122 **Sb** antimony 51	128 **Te** tellurium 52	127 **I** iodine 53	131 **Xe** xenon 54
133 **Cs** caesium 55	137 **Ba** barium 56	139 **La*** lanthanum 57	178 **Hf** hafnium 72	181 **Ta** tantalum 73	184 **W** tungsten 74	186 **Re** rhenium 75	190 **Os** osmium 76	192 **Ir** iridium 77	195 **Pt** platinum 78	197 **Au** gold 79	201 **Hg** mercury 80	204 **Tl** thallium 81	207 **Pb** lead 82	209 **Bi** bismuth 83	[209] **Po** polonium 84	[210] **At** astatine 85	[222] **Rn** radon 86
[223] **Fr** francium 87	[226] **Ra** radium 88	[227] **Ac*** actinium 89	[261] **Rf** rutherfordium 104	[262] **Db** dubnium 105	[266] **Sg** seaborgium 106	[264] **Bh** bohrium 107	[277] **Hs** hassium 108	[268] **Mt** meitnerium 109	[271] **Ds** darmstadtium 110	[272] **Rg** roentgenium 111	[285] **Cn** copernicium 112	[286] **Uut** ununtrium 113	[289] **Fl** flerovium 114	[289] **Uup** ununpentium 115	[293] **Lv** livermorium 116	[294] **Uus** ununseptium 117	[294] **Uuo** ununoctium 118

* The Lanthanides (atomic numbers 58 – 71) and the Actinides (atomic numbers 90 – 103) have been omitted.

Relative atomic masses for **Cu** and **Cl** have not been rounded to the nearest whole number.

6.7 Glossary of subject specific terminology

The following subject specific vocabulary provides definitions of key terms used in our International GCSE science specifications.

Wherever possible we have used the definitions derived from a booklet created in a joint project of the Association for Science Education and the Nuffield Foundation:

The Language of Measurement: Terminology used in school science investigations. Association for Science Education (ASE), 2010. ISBN 978 0 86357 424 5.

This list is **draft** and subject to change.

Accuracy

A measurement result is considered accurate if it is judged to be close to the true value.

Calibration

Marking a scale on a measuring instrument.

This involves establishing the relationship between indications of a measuring instrument and standard or reference quantity values, which must be applied.

For example, placing a thermometer in melting ice to see whether it reads zero, in order to check if it has been calibrated correctly.

Data

Information, either qualitative or quantitative, that has been collected.

Errors

See also uncertainty.

Measurement error: the difference between a measured value and the true value.

Anomalies: these are values in a set of results which are judged not to be part of the variation caused by random uncertainty.

Random error: these cause readings to be spread about the true value, due to results varying in an unpredictable way from one measurement to the next. Random errors are present when any measurement is made, and cannot be corrected. The effect of random errors can be reduced by making more measurements and calculating a new mean.

Systematic error: these cause readings to differ from the true value by a consistent amount each time a measurement is made. Sources of systematic error can include the environment, methods of observation or instruments used. Systematic errors cannot be dealt with by simple repeats. If a systematic error is suspected, the data collection should be repeated using a different technique or a different set of equipment, and the results compared.

Zero error: any indication that a measuring system gives a false reading when the true value of a measured quantity is zero, eg the needle on an ammeter failing to return to zero when no current flows. A zero error may result in a systematic uncertainty.

Evidence

Data which has been shown to be valid.

Fair test

A fair test is one in which only the independent variable has been allowed to affect the dependent variable.

Hypothesis

A proposal intended to explain certain facts or observations.

Interval

The quantity between readings, eg a set of 11 readings equally spaced over a distance of 1 metre would give an interval of 10 centimetres.

Precision

Precise measurements are ones in which there is very little spread about the mean value.

Precision depends only on the extent of random errors – it gives no indication of how close results are to the true value.

Prediction

A prediction is a statement suggesting what will happen in the future, based on observation, experience or a hypothesis.

Range

The maximum and minimum values of the independent or dependent variables; important in ensuring that any pattern is detected.

For example a range of distances may be quoted as either: ‘From 10 cm to 50 cm’ or ‘From 50 cm to 10 cm’.

Repeatable

A measurement is repeatable if the original experimenter repeats the investigation using same method and equipment and obtains the same results.

Reproducible

A measurement is reproducible if the investigation is repeated by another person, or by using different equipment or techniques, and the same results are obtained.

Resolution

This is the smallest change in the quantity being measured (input) of a measuring instrument that gives a perceptible change in the reading.

Sketch graph

A line graph, not necessarily on a grid, that shows the general shape of the relationship between two variables. It will not have any points plotted and although the axes should be labelled they may not be scaled.

True value

This is the value that would be obtained in an ideal measurement.

Uncertainty

The interval within which the true value can be expected to lie, with a given level of confidence or probability, eg ‘the temperature is 20 °C ± 2 °C, at a level of confidence of 95 %’.

Validity

Suitability of the investigative procedure to answer the question being asked. For example, an investigation to find out if the rate of a chemical reaction depended upon the concentration of one of the reactants would not be a valid procedure if the temperature of the reactants was not controlled.

Valid conclusion

A conclusion supported by valid data, obtained from an appropriate experimental design and based on sound reasoning.

Variables

These are physical, chemical or biological quantities or characteristics.

Categoric: categoric variables have values that are labels eg names of plants or types of material.

Continuous: continuous variables can have values (called a quantity) that can be given a magnitude either by counting (as in the case of the number of shrimp) or by measurement (eg light intensity, flow rate etc).

Control: a control variable is one which may, in addition to the independent variable, affect the outcome of the investigation and therefore has to be kept constant or at least monitored.

Dependent: the dependent variable is the variable of which the value is measured for each and every change in the independent variable.

Independent: the independent variable is the variable for which values are changed or selected by the investigator.

Terms no longer used

The term ‘discrete variable’ will no longer be used as this has been subsumed by the definition of ‘continuous variable’.

The terms ‘reliable’ and ‘reliability’ will no longer be used. Instead, the terms ‘repeatable’ or ‘repeatability’ and ‘reproducible’ or ‘reproducibility’ will be used.

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