Syllabus Snapshot

GCSE
Science - Gateway
Combined Science A

Exam Board: OCR

SCRIBBLE
RESOURCES

2 The specification overview

2a. OCR's GCSE (9–1) in Combined Science A (Gateway Science) (J250)

Learners are entered for either Foundation Tier (Papers 1, 2, 3, 4, 5 and 6) **or** Higher Tier (Papers 7, 8, 9, 10, 11 and 12). This qualification is worth two GCSEs.

Content Overview	Assessment Overview	
Foundation Tier, grades 5–5 to 1–1		
• Topic B1: Cell level systems • Topic B2: Scaling up • Topic B3: Organism level systems • Topic CS7: Practical skills (PAGs B1-B5)	Paper 1 (Biology) J250/01 1 hour 10 minutes 60 mark written paper	**16.7%** of total GCSE
• Topic B4: Community level systems • Topic B5: Interaction between systems • Topic B6: Global challenges • Topic CS7: Practical skills (PAGs B1-B5) With assumed knowledge of B1–B3	Paper 2 (Biology) J250/02 1 hour 10 minutes 60 mark written paper	**16.7%** of total GCSE
• Topic C1: Particles • Topic C2: Elements, compounds and mixtures • Topic C3: Chemical reactions • Topic CS7:Practical skills (PAGs C1-C5)	Paper 3 (Chemistry) J250/03 1 hour 10 minutes 60 mark written paper	**16.7%** of total GCSE
• Topic C4: Predicting and identifying reactions and products • Topic C5: Monitoring and controlling chemical reactions • Topic C6: Global challenges • Topic CS7: Practical skills (PAGs C1-C5) With assumed knowledge of C1–C3	Paper 4 (Chemistry) J250/04 1 hour 10 minutes 60 mark written paper	**16.7%** of total GCSE
• Topic P1: Matter • Topic P2: Forces • Topic P3: Electricity and magnetism • Topic CS7: Practical skills (PAGs P1-P6)	Paper 5 (Physics) J250/05 1 hour 10 minutes 60 mark written paper	**16.7%** of total GCSE
• Topic P4: Waves and radioactivity • Topic P5: Energy • Topic P6: Global challenges • Topic CS7: Practical skills (PAGs P1-P6) With assumed knowledge of P1–P3.	Paper 6 (Physics) J250/06 1 hour 10 minutes 60 mark written paper	**16.7%** of total GCSE

J250/02, J250/04 and J250/06 include synoptic assessment.

Content Overview	Assessment Overview	
Higher Tier, grades 9–9 to 4–4		
• Topic B1: Cell level systems • Topic B2: Scaling up • Topic B3: Organism level systems • Topic CS7: Practical skills (PAGs B1-B5)	Paper 7 (Biology) J250/07 1 hour 10 minutes 60 mark written paper	**16.7%** of total GCSE
• Topic B4: Community level systems • Topic B5: Interaction between systems • Topic B6: Global challenges • Topic CS7: Practical skills (PAGs B1-B5) With assumed knowledge of B1–B3	Paper 8 (Biology) J250/08 1 hour 10 minutes 60 mark written paper	**16.7%** of total GCSE
• Topic C1: Particles • Topic C2: Elements, compounds and mixtures • Topic C3: Chemical reactions • Topic CS7: Practical skills (PAGs C1-C5)	Paper 9 (Chemistry) J250/09 1 hour 10 minutes 60 mark written paper	**16.7%** of total GCSE
• Topic C4: Predicting and identifying reactions and products • Topic C5: Monitoring and controlling chemical reactions • Topic C6: Global challenges • Topic CS7: Practical skills (PAGs C1-C5) With assumed knowledge of C1–C3	Paper 10 (Chemistry) J250/10 1 hour 10 minutes 60 mark written paper	**16.7%** of total GCSE
• Topic P1: Matter • Topic P2: Forces • Topic P3: Electricity and magnetism • Topic CS7: Practical skill (PAGs P1-P6)	Paper 11 (Physics) J250/11 1 hour 10 minutes 60 mark written paper	**16.7%** of total GCSE
• Topic P4: Waves and radioactivity • Topic P5: Energy • Topic P6: Global challenges • Topic CS7: Practical skills (PAGs P1-P6) With assumed knowledge of P1–P3	Paper 12 (Physics) J250/12 1 hour 10 minutes 60 mark written paper	**16.7%** of total GCSE

J250/08, J250/10 and J250/12 include synoptic assessment.

2b. Content of GCSE (9–1) in Combined Science A (Gateway Science) (J250)

The GCSE (9–1) in Combined Science A (Gateway Science) specification content is specified in section 2c It is divided into 18 teaching topics B1-B6, C1-C6 & P1-P6 and a practical activity skills topic CS7.

Learning at GCSE (9–1) in Combined Science A (Gateway Science) is described in the tables that follow:

Overview of the content layout

Topic B/C/P1: Topic title

B1.1 sub-topic

Summary
A short overview of the sub-topic that will be assessed in the examinations.

Underlying knowledge and understanding
Underlying knowledge and understanding learners should be familiar with linked to the sub-topic

Common misconceptions
Common misconceptions students often have associated with this topic

Tiering
A brief summary of the tiering of the sub-topic

Reference	Mathematical learning outcomes	Mathematical skills (See appendix 5f)
OCRs mathematics reference code	This column defines the areas of mathematics that will need to be taught specifically within the context of this sub-topic. Questions in the examination will assess these learning outcomes within the context of the topic.	Mathematical skill code as indicated in Appendix 5e

Topic content			**Opportunities to cover:** Items that are contained within these columns are intended as a starting point for lesson planning.		**Practical suggestions** (See topic CS7)
Learning outcomes		**To include**	**Maths** (See appendix 5e)	**Working scientifically** (See appendix 5d)	
Spec. reference number	Column specifies the subject content that will be assessed in the examinations.	This column is included to provide further/specific advice on delivery of the learning outcome.	Mathematical skills will be assessed throughout the examination. This column highlights the mathematical skills that could be taught alongside the topic content.	Working scientifically will be assessed throughout the examination. This column highlights the working scientifically skills that could be taught alongside the topic content.	The compulsory practical skills covered by the Practical Activity Groups or PAGs are indicated in the tables in Topic CS7. Activities in this column can be used to supplement the PAGs using topic appropriate experiments

Biology key ideas

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Biology is the science of living organisms (including animals, plants, fungi and microorganisms) and their interactions with each other and the environment. The study of biology involves collecting and interpreting information about the natural world to identify patterns and relate possible cause and effect. Biological information is used to help humans improve their own lives and strive to create a sustainable world for future generations.

Learners should be helped to understand how, through the ideas of biology, the complex and diverse phenomena of the natural world can be described in terms of a small number of key ideas which are of universal application, and which can be illustrated in the separate topics set out below. These ideas include:

- life processes depend on molecules whose structure is related to their function
- the fundamental units of living organisms are cells, which may be part of highly adapted structures including tissues, organs and organ systems, enabling living processes to be performed effectively
- living organisms may form populations of single species, communities of many species and ecosystems, interacting with each other, with the environment and with humans in many different ways
- living organisms are interdependent and show adaptations to their environment
- life on Earth is dependent on photosynthesis in which green plants and algae trap light from the Sun to fix carbon dioxide and combine it with hydrogen from water to make organic compounds and oxygen
- organic compounds are used as fuels in cellular respiration to allow the other chemical reactions necessary for life
- the chemicals in ecosystems are continually cycling through the natural world
- the characteristics of a living organism are influenced by its genome and its interaction with the environment
- evolution occurs by a process of natural selection and accounts both for biodiversity and how organisms are all related to varying degrees.

Chemistry key ideas

Chemistry is the science of the composition, structure, properties and reactions of matter, understood in terms of atoms, atomic particles and the way they are arranged and link together. It is concerned with the synthesis, formulation, analysis and characteristic properties of substances and materials of all kinds.

Learners should be helped to appreciate the achievements of chemistry in showing how the complex and diverse phenomena of both the natural and man-made worlds can be described in terms of a small number of key ideas which are of universal application, and which can be illustrated in the separate topics set out below. These ideas include:

- matter is composed of tiny particles called atoms and there are about 100 different naturally occurring types of atoms called elements
- elements show periodic relationships in their chemical and physical properties these periodic properties can be explained in terms of the atomic structure of the elements
- atoms bond by either transferring electrons from one atom to another or by sharing electrons
- the shapes of molecules (groups of atoms bonded together) and the way giant structures are arranged is of great importance in terms of the way they behave
- there are barriers to reaction so reactions occur at different rates
- chemical reactions take place in only three different ways:
    - proton transfer
    - electron transfer
    - electron sharing
- energy is conserved in chemical reactions so can therefore be neither created or destroyed.

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Physics key ideas

Physics is the science of the fundamental concepts of field, force, radiation and particle structures, which are inter-linked to form unified models of the behaviour of the material universe. From such models, a wide range of ideas, from the broadest issue of the development of the universe over time to the numerous and detailed ways in which new technologies may be invented, have emerged. These have enriched both our basic understanding of, and our many adaptations to, our material environment.

Students should be helped to understand how, through the ideas of physics, the complex and diverse phenomena of the natural world can be described in terms of a small number of key ideas which are of universal application and which can be illustrated in the separate topics set out below. These ideas include:

- the use of models, as in the particle model of matter or the wave models of light and of sound
- the concept of cause and effect in explaining such links as those between force and acceleration, or between changes in atomic nuclei and radioactive emissions
- the phenomena of 'action at a distance' and the related concept of the field as the key to analysing electrical, magnetic and gravitational effects
- that differences, for example between pressures or temperatures or electrical potentials, are the drivers of change
- that proportionality, for example between weight and mass of an object or between force and extension in a spring, is an important aspect of many models in science
- that physical laws and models are expressed in mathematical form.

Summary of content for GCSE (9–1) in Combined Science A (Gateway Science) – Biology

Topic B1: Cell level systems	Topic B2: Scaling up	Topic B3: Organism level systems
B1.1 Cell structures B1.2 What happens in cells (and what do cells need)? B1.3 Respiration B1.4 Photosynthesis	B2.1 Supplying the cell B2.2 The challenges of size	B3.1 Coordination and control – the nervous system B3.2 Coordination and control – the endocrine system B3.3 Maintaining internal environments
Topic B4: Community level systems	**Topic B5: Genes, inheritance and selection**	**Topic B6: Global challenges**
B4.1 Ecosystems	B5.1 Inheritance B5.2 Natural selection and evolution	B6.1 Monitoring and maintaining the environment B6.2 Feeding the human race B6.3 Monitoring and maintaining health

CS7 is a practical-based topic which provides learners with the necessary skills to undertake the 15% practical content in the examinations.

Summary of content for GCSE (9–1) in Combined Science A (Gateway Science) – Chemistry

Topic C1: Particles	Topic C2: Elements, compounds and mixtures	Topic C3: Chemical reactions
C1.1 The particle model C1.2 Atomic structure	C2.1 Purity and separating mixtures C2.2 Bonding C2.3 Properties of materials	C3.1 Introducing chemical reactions C3.2 Energetics C3.3 Types of chemical reactions C3.4 Electrolysis
Topic C4: Predicting and identifying reactions and products	**Topic C5: Monitoring and controlling chemical reactions**	**Topic C6: Global challenges**
C4.1 Predicting chemical reactions	C5.1 Controlling reactions C5.2 Equilibria	C6.1 Improving processes and products C6.2 Interpreting and interacting with Earth systems

CS7 is a practical-based topic which provides learners with the necessary skills to undertake the 15% practical content in the examinations.

Summary of content for GCSE (9–1) in Combined Science A (Gateway Science) – Physics

Topic P1: Matter	Topic P2: Forces	Topic P3: Electricity and magnetism
P1.1 The particle model P1.2 Changes of state	P2.1 Motion P2.2 Newton's laws P2.3 Forces in action	P3.1 Static and Charge P3.2 Simple circuits P3.3 Magnets and magnetic fields
Topic P4: Waves and radioactivity	**Topic P5: Energy**	**Topic P6: Global challenges**
P4.1 Wave behaviour P4.2 The electromagnetic spectrum P4.3 Radioactivity	P5.1 Work done P5.2 Power and efficiency	P6.1 Physics on the move P6.2 Powering Earth

CS7 is a practical-based topic which provides learners with the necessary skills to undertake the 15% practical content in the examinations.

2c. Content of topics B1 to B6, C1 to C6 and P1 to P6

Topic B1: Cell level systems

B1.1 Cell structures

Summary
Cells are the fundamental units of living organisms. Cells contain many sub-cellular structures that are essential for the functioning of the cell as a whole. Microscopy is used to examine cells and sub-cellular structures.

Underlying knowledge and understanding
Learners should be familiar with cells as the fundamental unit of living organisms, and with the use of light microscopes to view cells. They should also be familiar with some sub-cellular structures, and the similarities and differences between plant and animal cells.

Common misconceptions
Learners commonly have difficulty understanding the concept of a cell as a 3D structure, so this should be addressed during the teaching of this topic.

Tiering
Statements shown in **bold** type will only be tested in the Higher Tier papers. All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
BM1.1i	demonstrate an understanding of number, size and scale and the quantitative relationship between units	M2a and M2h
BM1.1ii	use estimations and explain when they should be used	M1d
BM1.1iii	**calculate with numbers written in standard form**	**M1b**

Topic content		Opportunities to cover:		Practical suggestions
Learning outcomes	**To include**	**Maths**	**Working scientifically**	
B1.1a describe how light microscopes and staining can be used to view cells	lenses, stage, lamp, use of slides and cover slips, and the use of stains to view colourless specimens or to highlight different structures/tissues and calculation of the magnification used	M1d, M2a, M2h	WS1.2c, WS1.4c, WS1.4d, WS1.4e, WS2a, WS2b, WS2c, WS2d	Investigation of a range of cells using pictures, light micrographs and diagrams. Measure the size and magnification of the cells. (PAG B1) Preparation of cheek cell slides. (PAG B1, PAG B5) Preparation of onion epidermis cells slides. (PAG B1, PAG B4) Use of light microscopes to view plant and animal cells. (PAG B1, PAG B4, PAG B5)
B1.1b explain how the main sub-cellular structures of eukaryotic cells (plants and animals) and prokaryotic cells are related to their functions	nucleus, genetic material, chromosomes, plasmids, mitochondria (contain enzymes for cellular respiration), chloroplasts (contain chlorophyll) and cell membranes (contain receptor molecules, provides a selective barrier to molecules)		WS1.4a, WS2a, WS2b, WS2c, WS2d	Demonstrate the structure of plant and animal cells by constructing 3D models. Investigation of cytoplasmic streaming in Elodea spp. (PAG B1, PAG B4)
B1.1c explain how electron microscopy has increased our understanding of sub-cellular structures	to include increased resolution in a transmission electron microscope	M1b	WS1.1a, WS1.4c, WS1.4d	Comparison of a range of cells using pictures from light and electron micrographs. Comparison of the structures visible on light and electron micrographs.

B1.2 What happens in cells (and what do cells need)?

Summary
Life processes depend on biological molecules whose structure is related to their function. Inside every cell is genetic material and this is used as a code to make proteins. Enzymes are important proteins in biology.

Underlying knowledge and understanding
Learners should have a simple understanding of the double helix model of DNA. Learners should be familiar with the idea of enzymes as biological catalysts.

Common misconceptions
Learners commonly hold the misconception that DNA is made of protein or sugar. Learners also think that all enzymes have an optimum temperature of 37°C (human body temperature). The range of optimum temperatures of enzymes should be introduced through the teaching of this topic and further addressed when considering homeostatic mechanisms for controlling temperature.

Tiering
Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
BM1.2i	carry out rate calculations for chemical reactions	M1a and M1c

Topic content		Opportunities to cover:		Practical suggestions
Learning outcomes	To include	Maths	Working scientifically	
DNA and protein synthesis				
B1.2a describe DNA as a polymer			WS1.4a	Demonstrate of the structure of DNA by constructing 3D models.
B1.2b describe DNA as being made up of two strands forming a double helix				

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
B1.2c	describe experiments that can be used to investigate enzymatic reactions		M1a, M1c, M2g	WS1.1h, WS1.2b, WS1.2c, WS1.2e, WS1.3a, WS1.3b, WS1.3c, WS1.3d, WS1.3e, WS1.3f, WS1.3g, WS2a, WS2b, WS2c, WS2d	Investigations of enzyme activity, including numerical analysis of data and graphical representation of results. (PAG B3)
B1.2d	explain the mechanism of enzyme action	the role of enzymes in metabolism, the role of the active site, enzyme specificity (lock and key hypothesis) and factors affecting the rate of enzyme controlled reactions (pH, temperature, substrate and enzyme concentration)	M1a, M1c, M3d, M4b	WS2a, WS2b, WS2c, WS2d	Demonstration of the effect of amylase on a baby rice paste. (PAG B3) Investigation of enzyme controlled reactions. (PAG B3)

B1.3 Respiration

Summary
Metabolic processes such as respiration are controlled by enzymes. Organic compounds are used as fuels in cellular respiration to allow the other chemical reactions necessary for life.

Underlying knowledge and understanding
Learners should have some underpinning knowledge of respiration. This should include that respiration involves the breakdown of organic molecules to enable all the other chemical processes necessary for life. Learners should be able to recall the word equation for respiration.

Common misconceptions
Learners commonly hold the misconception that ventilation is respiration. They can also get confused between the terms breakup and breakdown.

Tiering
Statements shown in **bold** type will only be tested in the Higher Tier papers. All other statements will be assessed in both Foundation and Higher Tier papers.

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
B1.3a	describe cellular respiration as a universal chemical process, continuously occurring in all living cells that supply ATP			WS1.2a	
B1.3b	describe cellular respiration as an exothermic reaction			WS1.2b	Demonstration of an exothermic reaction (e.g. heat pack).
B1.3c	compare the processes of aerobic and anaerobic respiration	in plants/fungi and animals the different conditions, substrates, products and relative yields of ATP		WS2a, WS2b, WS2c, WS2d	Research into whether plants respire. (PAG B3, PAG B4) Investigation of fermentation in fungi. (PAG B3) Investigation of respiration in yeast using alginate beads to immobilize the fungus. (PAG B3)

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
B1.3d	explain the importance of sugars in the synthesis and breakdown of carbohydrates	to include use of the terms monomer and polymer			Demonstration of the synthesis and breakdown of biological molecules (e.g. using Lego bricks). Testing of biological molecules PAG B2
B1.3e	explain the importance of amino acids in the synthesis and breakdown of proteins	to include use of the terms monomer and polymer			Testing of biological molecules PAG B2
B1.3f	explain the importance of fatty acids and glycerol in the synthesis and breakdown of lipids				Testing of biological molecules PAG B2

B1.4 Photosynthesis

Summary

Life processes depend on photosynthesis. Green plants and algae trap light from the Sun to fix carbon dioxide with hydrogen from water making organic compounds.

Underlying knowledge and understanding

Learners should also have some underpinning knowledge of photosynthesis. They should have an understanding that plants make carbohydrates in their leaves by photosynthesis, and be able to recall the word equation for photosynthesis.

Common misconceptions

Learners often think that plants do not respire.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
BM1.4i	understand and use simple compound measures such as the rate of a reaction	M1a and M1c
BM1.4ii	translate information between graphical and numerical form	M4a
BM1.4iii	plot and draw graphs, selecting appropriate scales and axes	M4a and M4c
BM1.4iv	extract and interpret information from charts, graphs and tables	M2c and M4a
BM1.4v	**Understand and use inverse proportion – the inverse square law and light intensity in the context of factors affecting photosynthesis**	M1c

Topic content		Opportunities to cover:		Practical suggestions
Learning outcomes	**To include**	**Maths**	**Working scientifically**	
B1.4a describe photosynthetic organisms as the main producers of food and therefore biomass for life on Earth				Use of concept cartoons to start discussions about photosynthesis.
B1.4b describe the process of photosynthesis	reactants and products, two-stage process, location of the reaction (in the chloroplasts)		WS2a, WS2b, WS2c, WS2d	Investigation of photosynthesis e.g. the Priestley experiment using *Cabomba* to collect oxygen or the Ingenhousz experiment to show mass gain. (PAG B4)
B1.4c describe photosynthesis as an endothermic reaction			WS1.3b, WS1.3c, WS1.3e	Demonstrate an endothermic reaction (e.g. icepack).
B1.4d describe experiments to investigate photosynthesis			WS2a, WS2b, WS2c, WS2d	Experiments to show the consequences of light exclusion on photosynthesising plants (e.g. testing geraniums for starch). (PAG B4)
B1.4e explain the effect of temperature, light intensity and carbon dioxide concentration on the rate of photosynthesis		M1a, M1c, M2c, M4a, M4c, M1c	WS2a, WS2b, WS2c, WS2d	Investigation of photosynthesis in algae using alginate beads to immobilize the algae. (PAG B4)
B1.4f **explain the interaction of these factors in limiting the rate of photosynthesis**		M1a, M1c M2c, M4a, M1c	WS1.2b, WS1.2c, WS1.2e WS1.3a, WS1.3b, WS1.3c, WS1.3d, WS1.3f, WS1.3g, WS1.4e, WS2c, WS2d	

Topic B2: Scaling up

B2.1 Supplying the cell

Summary

Cells transport many substances across their membranes by diffusion, osmosis and active transport. Stem cells are found in both plants and animals. These stem cells can divide, differentiate and become specialised to form tissues, organs and organ systems.

Underlying knowledge and understanding

Learners should be familiar with the role of diffusion in the movement of materials in and between cells.

Common misconceptions

Learners commonly show some confusion regarding surface area to volume ratio, particularly how larger animals have a smaller surface area to volume ratio. They also show some confusion as to stem cells: where they are found and their roles. Care should be taken to give clear definitions when covering this content.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
BM2.1i	use percentiles and calculate percentage gain and loss of mass	M1c

Topic content		Opportunities to cover:		Practical suggestions
Learning outcomes	**To include**	**Maths**	**Working scientifically**	
B2.1a explain how substances are transported into and out of cells through diffusion, osmosis and active transport	examples of substances moved, direction of movement, concentration gradients and use of the term water potential (no mathematical use of water potential required)	M1c, M1d	WS2a, WS2b, WS2c, WS2d	Observation of osmosis in plant cells using a light microscope. Demonstration of ‘creaming yeast’ to show osmosis. (PAG B1, PAG B5) Investigation of changes in mass of vegetable chips when placed in sucrose/salt solutions of varying concentrations. (PAG B4)

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
B2.1b	describe the process of mitosis in growth, including the cell cycle	the stages of the cell cycle as DNA replication, movement of chromosomes, followed by the growth of the cell		WS2a, WS2b, WS2c, WS2d	Modelling of mitosis using everyday objects e.g. shoes, socks etc. Observation of mitosis in stained root tip cells. (PAG B1, PAG B4)
B2.1c	explain the importance of cell differentiation	the production of specialised cells allowing organisms to become more efficient and examples of specialised cells		WS2a, WS2b, WS2c, WS2d	Examination of a range of specialised cells using a light microscope. (PAG B1, PAG B4, PAG B5)
B2.1d	recall that stem cells are present in embryonic and adult animals and meristems in plants				Demonstration of cloning using cauliflower. (PAG B4)
B2.1e	describe the functions of stem cells	division to produce a range of different cell types for development, growth and repair		WS1.1e, WS1.1f, WS1.1h	
B2.1f	describe the difference between embryonic and adult stem cells in animals				Research into the different types of stem cells.

B2.2 The challenges of size

Summary

When organisms become multicellular, the need arises for highly adapted structures including gaseous exchange surfaces and transport systems, enabling living processes to be performed effectively.

Underlying knowledge and understanding

Learners should be familiar with the role of diffusion in the movement of materials in and between cells. They should also be familiar with the human gaseous exchange system.

Common misconceptions

Learners have a view that the slow flow of blood in capillaries is due to the narrow diameter, when in fact it is a function of the total cross-sectional area of the capillaries (1000 times greater than the aorta). When explaining the importance of the slow flow of blood in allowing time for exchange by diffusion, this misunderstanding should be considered.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
BM2.2i	calculate surface area:volume ratios	M1c
BM2.2ii	use simple compound measures such as rate	M1a and M1c
BM2.2iii	carry out rate calculations	M1a and M1c
BM2.2iv	plot, draw and interpret appropriate graphs	M4a, M4b, M4c and M4d

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
B2.2a	explain the need for exchange surfaces and a transport system in multicellular organisms in terms of surface area:volume ratio	to include surface area, volume and diffusion distances	M1c	WS1.4d, WS1.4e, WS1.4f, WS2a, WS2b, WS2c, WS2d	Investigation of surface area:volume ratio using hydrochloric acid and gelatine cubes stained with phenolphthalein or other suitable pH indicator. (PAG B4, PAG B5)

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
B2.2b	describe some of the substances transported into and out of a range of organisms in terms of the requirements of those organisms	oxygen, carbon dioxide, water, dissolved food molecules, mineral ions and urea			
B2.2c	describe the human circulatory system	to include the relationship with the gaseous exchange system, the need for a double circulatory system in mammals and the arrangement of vessels			Modelling of the human circulatory system.
B2.2d	explain how the structure of the heart and the blood vessels are adapted to their functions	the structure of the mammalian heart with reference to valves, chambers, cardiac muscle and the structure of blood vessels with reference to thickness of walls, diameter of lumen, presence of valves		WS2a, WS2b, WS2c, WS2d	Investigation of heart structure by dissection. Investigation of a blood smear using a light microscope. (PAG B1, PAG B5) Modelling of blood using sweets to represent the components.
B2.2e	explain how red blood cells and plasma are adapted to their transport functions in the blood			WS2a, WS2b, WS2c, WS2d	Examination of the gross structure of blood vessels using a light microscope. (PAG B1) Investigation of the elasticity of different blood vessels using hanging masses.

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
B2.2f	explain how water and mineral ions are taken up by plants, relating the structure of the root hair cells to their function			WS2a, WS2b, WS2c, WS2d	Examination of root hair cells using a light microscope. (PAG B1, PAG B4) Demonstration of the effectiveness of transpiration by trying to suck water from a bottle using a 10m straw. (PAG B4) Investigation of the position of the xylem/phloem in root, stem and leaf tissues using a light microscope. (PAG B1, PAG B4) Interpretation of experimental evidence of the movement of dissolved food materials in a plant. (PAG B1, PAG B4) Examining the position of the phloem in root, stem and leaf tissues using a light microscope. (PAG B1, PAG B4)
B2.2g	describe the processes of transpiration and translocation	the structure and function of the stomata		WS2a, WS2b, WS2c, WS2d	Measurement of plant stomatal density by taking an impression of the leaf using clear nail varnish or spray on plaster. (PAG B1,PAG B4)
B2.2h	explain how the structure of the xylem and phloem are adapted to their functions in the plant				

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
B2.2i	explain the effect of a variety of environmental factors on the rate of water uptake by a plant	light intensity, air movement, and temperature	M1a, M1c M1d	WS2a, WS2b, WS2c, WS2d	Interpretation of experimental evidence of investigations into environmental factors that affect water uptake. (PAG B4)
B2.2j	describe how a simple potometer can be used to investigate factors that affect the rate of water uptake		M1a, M1c, M1d, M4a, M4b, M4c, M4d	WS1.2b, WS1.2c, WS1.2e WS1.3a, WS1.3b, WS1.3c, WS1.3d, WS1.3e, WS1.3f, WS1.3g, WS2a, WS2b, WS2c, WS2d	Investigation of transpiration rates from a plant cutting. (PAG B4) Calculation of the rate of transpiration in volume of water/ time. (PAG B4)

Topic B3: Organism level systems

B3.1 Coordination and control – the nervous system

Summary
The human nervous system is an important part of how the body communicates with itself and also receives information from its surroundings.

Underlying knowledge and understanding
Learners should have a concept of the hierarchical organisation of multicellular organisms from cells to tissues to organs to systems to organisms.

Common misconceptions
Learners commonly think that their eyes see objects 'directly', like a camera, but the reality is that the image formed by the brain is based on the eye's and brain's interpretation of the light that comes into the eye i.e. different people will perceive the same object or image differently. Young learners also have the misconception that some sort of 'force' comes out of the eye, enabling it to see.

Tiering
Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
B3.1a	describe the structure of the nervous system	Central Nervous System, sensory and motor neurones and sensory receptors			Demonstration of the structure of a neurone by constructing 3D models.
B3.1b	explain how the components of the nervous system can produce a coordinated response	it goes to all parts of the body, has many links, has different sensory receptors and is able to coordinate responses			Demonstration (by video) of someone trying to do everyday tasks whilst being given mild electric shocks (BBC Brainiac). Demonstration of reaction time by getting a learner to catch a falling £5 note. Investigating the reaction time by ruler drop. (PAG B5)
B3.1c	explain how the structure of a reflex arc is related to its function			M1d, WS2a, WS2b, WS2c, WS2d	Research into reflexes. (PAG B5)

B3.2 Coordination and control – the endocrine system

Summary

Hormones are chemical messengers. In animals, hormones are transported around the body in the blood and affect target tissues and organs. Hormones have a variety of roles in the human body, including controlling reproduction. Plant hormones are chemicals that regulate plant growth and development. They can be used in agriculture to control the rate of growth.

Underlying knowledge and understanding

Learners should be aware of a number of hormones including adrenaline and the male and female sex hormones.

Common misconceptions

With regards to the menstrual cycle, research has shown that learners have problems relating the time of conception to the condition of the lining of the uterus.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
BM3.2i	extract and interpret data from graphs, charts and tables	M2c
BM3.2ii	translate information between numerical and graphical forms	M4a

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
B3.2a	describe the principles of hormonal coordination and control by the human endocrine system	use of chemical messengers, transport in blood, endocrine glands and receptors	H2g		
B3.2b	**explain the roles of thyroxine and adrenaline in the body**	**thyroxine as an example of a negative feedback system**			
B3.2c	describe the role of hormones in human reproduction including the control of the menstrual cycle	oestrogen, progesterone, FSH and testosterone		WS1.3b, WS1.3e	

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
B3.2d	**explain the interactions of FSH, LH, oestrogen and progesterone in the control of the menstrual cycle**		M2c, M4a		Analysis of relative hormone levels from raw data and graphically.
B3.2e	explain the use of hormones in contraception and evaluate hormonal and non-hormonal methods of contraception	the relative effectiveness of the different forms of contraception	M2c, M4a	WS1.1d, WS1.1e, WS1.1f	Discussion into the various methods of contraception and their effective/ethical use.
B3.2f	**explain the use of hormones in modern reproductive technologies to treat infertility**			WS1.1d, WS1.1e, WS1.1f, WS1.1h	Research into *Xenopus laevis* pregnancy testing to detect hCG by the stimulation of oogenesis. Research into hormonal treatments for infertility.

B3.3 Maintaining internal environments

Summary
Homeostasis is crucial to the regulation of internal environments and enables organisms to adapt to change, both internally and externally. Internal temperature, blood sugar levels and osmotic balance are regulated by a number of organs and systems working together.

Underlying knowledge and understanding
Learners will build on the knowledge and understanding gained in section 3.1 about coordination and control when considering the topics in this section.

Tiering
Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
BM3.3i	extract and interpret data from graphs, charts and tables	M2c

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
B3.3a	explain the importance of maintaining a constant internal environment in response to internal and external change	allowing metabolic reactions to proceed at appropriate rates		WS1.4a	Research into hypothermia.
B3.3b	explain how insulin controls blood sugar levels in the body		M2g		
B3.3c	**explain how glucagon interacts with insulin to control blood sugar levels in the body**		M2c	WS2a, WS2b, WS2c, WS2d	Investigations into the glucose content of fake urine to diagnose diabetes, using e.g. Clinistix. (PAG B5)
B3.3d	compare type 1 and type 2 diabetes and explain how they can be treated				

Topic B4: Community level systems

B4.1 Ecosystems

Summary

Microorganisms play an important role in the continuous cycling of chemicals in ecosystems. Biotic and abiotic factors interact in an ecosystem and have an effect on communities. Living organisms form populations of single species, communities of many species and are part of ecosystems. Living organisms are interdependent and show adaptations to their environment. Feeding relationships reflect the stability of an ecosystem and indicate the flow of biomass through the ecosystem.

Underlying knowledge and understanding

Learners should be familiar with the idea of a food web and the interrelationships associated with them and that variation allows living things to survive in the same ecosystem. They should also recognise that organisms affect their environment and are affected by it.

Common misconceptions

Research has shown that it is easier for a learner to explain the consequences on a food web if the producers are removed for some reason than if the top predators are taken away. It is also better to start off explaining ideas relating to food webs using small simple webs with animals and plants that learners are likely to know e.g. rabbits and foxes. Learners find arrows showing the flow of biomass from one trophic level to another quite challenging and often mistake it for the direction of predation. This makes problems relating to the manipulation of a food web quite difficult for some.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
BM4.1i	Calculate the percentage of mass	M1c
BM4.1ii	Plot and draw appropriate graphs selecting appropriate scales for the axes	M4a and M4c

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
B4.1a	recall that many different materials cycle through the abiotic and biotic components of an ecosystem	examples of cycled materials e.g. nitrogen and carbon			
B4.1b	explain the role of microorganisms in the cycling of materials through an ecosystem	the role of microorganisms in decomposition			Research into the range of ecosystems and examples of micro-organisms that act as decomposers within them. (PAG B1, PAG B2, PAG B3, PAG B5)
B4.1c	explain the importance of the carbon cycle and the water cycle to living organisms	maintaining habitats, fresh water flow of nutrients			
B4.1d	describe different levels of organisation in an ecosystem from individual organisms to the whole ecosystem		M1c		
B4.1e	explain how abiotic and biotic factors can affect communities	temperature, light intensity, moisture level, pH of soil, predators, food	M4a, M4c, M3a	WS1.3a, WS1.3b, WS1.3e WS1.3h, WS2a, WS2b, WS2c, WS2d	Identification of the biotic factors in an ecosystem using sampling techniques. (PAG B2)
B4.1f	describe the importance of interdependence and competition in a community	interdependence relating to predation, mutualism and parasitism		WS1.4a	Examination of the roots of a leguminous plant e.g. clover to observe the root nodules. (PAG B1) Investigation of the holly leaf miner or the horse-chestnut leaf miner (*Cameraria ohridella*). (PAG B1, PAG B2)

Topic B5: Genes, inheritance and selection

B5.1 Inheritance

Summary

Inheritance relies on the genetic information contained in the genome being passed from one generation to the next, whether sexually or asexually. The characteristics of a living organism are influenced by the genome and its interaction with the environment.

Underlying knowledge and understanding

Learners should be familiar with the idea of heredity as the process by which genetic information is passed from one generation to the next. They should have a simple model of chromosomes, genes and DNA.

Common misconceptions

Learners commonly struggle to appreciate the physical relationships between the nucleus, genetic material, the genome, chromosomes and genes. Accurate definitions of these terms will help learners' explanations in this topic. Learners often have well-developed (although not necessarily scientifically accurate) explanations for inheritance before undertaking GCSE study. Some examples include that intra-specific variation is as a result of defects in development or that acquired characteristics can be inherited. Care must also be taken with the concept of dominant and recessive alleles. Whether an allele is dominant or recessive does not affect the mechanism of inheritance of the allele, but is an observed pattern in the phenotype of organisms. Many learners assume that the dominant allele 'dominates' the recessive allele preventing its expression (which is not the case) or that the recessive allele is actually just an absence of the dominant allele (also not generally the case).

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
BM5.1i	understand and use direct proportions and simple ratios in genetic crosses	M1c
BM5.1ii	understand and use the concept of probability in predicting the outcome of genetic crosses	M2e
BM5.1iii	extract and interpret information from charts, graphs and tables	M2c and M4a

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
B5.1a	explain the following terms: gamete, chromosome, gene, allele/variant, dominant, recessive, homozygous, heterozygous, genotype and phenotype				Use of alleles to work out the phenotype of progeny.
B5.1b	describe the genome as the entire genetic material of an organism				
B5.1c	describe that the genome, and its interaction with the environment, influence the development of the phenotype of an organism	use of examples of discontinuous and continuous variation e.g. eye colour, weight and height			
B5.1d	recall that all variants arise from mutations, and that most have no effect on the phenotype, some influence phenotype and a very few determine phenotype				
B5.1e	explain the terms haploid and diploid				
B5.1f	explain the role of meiotic cell division in halving the chromosome number to form gametes	that this maintains diploid cells when gametes combine and is a source of genetic variation			
B5.1g	explain single gene inheritance	in the context of homozygous and heterozygous crosses involving dominant and recessive genes	M2c, M4a		Prediction of the probability of phenotype for genetic crosses. Investigation into probability by suitable example (e.g. coin toss or die roll).
B5.1h	predict the results of single gene crosses		M1c, M2c, M2e,M4a		
B5.1i	describe sex determination in humans using a genetic cross		M1c, M2c, M2e, M4a		
B5.1j	recall that most phenotypic features are the result of multiple genes rather than single gene inheritance				

B5.2 Natural selection and evolution

Summary

Variation in the genome and changes in the environment drive the process of natural selection, leading to changes in the characteristics of populations. Evolution accounts for both biodiversity and how organisms are all related to varying degrees. Key individuals have played important roles in the development of the understanding of genetics.

Underlying knowledge and understanding

Learners should appreciate that changes in the environment can leave some individuals, or even some entire species, unable to compete and reproduce leading to extinction.

Common misconceptions

Learners are used to hearing the term evolution in everyday life but it is often used for items that have been designed and gradually improved in order to fit a purpose. They therefore find it difficult to grasp the idea that evolution by natural selection relies on random mutations. Learners also tend to imply that individuals change by natural selection. Statements such as ‘a moth will change by natural selection in order to become better camouflaged’ include both of these common misconceptions.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		**To include**	**Maths**	**Working scientifically**	
B5.2a	state that there is usually extensive genetic variation within a population of a species				
B5.2b	describe the impact of developments in biology on classification systems	natural and artificial classification systems and use of molecular phylogenetics based on DNA sequencing		WS1.1b	
B5.2c	explain how evolution occurs through the natural selection of variants that have given rise to phenotypes best suited to their environment	the concept of mutation			
B5.2d	describe evolution as a change in the inherited characteristics of a population over time, through a process of natural selection, which may result in the formation of new species				
B5.2e	describe the evidence for evolution	fossils and antibiotic resistance in bacteria		WS1.1c WS1.1d WS1.1g	

Topic B6: Global challenges

This topic seeks to integrate learners' knowledge and understanding of biological systems and processes, with the aim of applying it to global challenges. Biological information is used to help people to improve their own lives and strive to create a sustainable world for future generations. This topic provides opportunities to draw together the concepts covered in earlier topics, allowing synoptic treatment of the subject.

6.1 Monitoring and maintaining the environment

Summary

Living organisms interact with each other, the environment and with humans in many different ways. If the variety of life is to be maintained we must actively manage our interactions with the environment. We must monitor our environment, collecting and interpreting information about the natural world, to identify patterns and relate possible cause and effect.

Underlying knowledge and understanding

From their study in topic 4, learners should be familiar with ecosystems and the various ways organisms interact. They should understand how biotic and abiotic factors influence communities. Learners should be familiar with the gases of the atmosphere from key stage 3.

Common misconceptions

It is important that in the study of this topic learners are given opportunities to explore both positive and negative human interactions within ecosystems.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers. All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
BM6.1i	calculate arithmetic means	M2b
BM6.1ii	plot and draw appropriate graphs selecting appropriate scales for the axes	M4a and M4c
BM6.1iii	understand and use percentiles	M1c
BM6.1iv	extract and interpret information from charts, graphs and tables	M2c and M4a
BM6.1v	understand the principles of sampling as applied to scientific data	M2d

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
B6.1a	explain how to carry out a field investigation into the distribution and abundance of organisms in a habitat and how to determine their numbers in a given area	sampling techniques (random and transects, capture-recapture), use of quadrats, pooters, nets, keys and scaling up methods	M1c, M2b, M2c M4a, M4c	WS1.2d, WS1.2b, WS1.2c, WS1.2e, WS1.3h, WS2a, WS2b, WS2c, WS2d	Investigation of ecological sampling methods. Use the symbols =, <, <<, >>, >, ∝ , ~ in your answer where appropriate. (PAG B2) Investigation of sampling using a suitable model (e.g. measuring the red sweets in a mixed selection).
B6.1b	describe both positive and negative human interactions within ecosystems and explain their impact on biodiversity	the conservation of individual species and selected habitats and threats from land use and hunting		WS2a, WS2b, WS2c, WS2d	Investigation into the effectiveness of germination in different strengths of acid rain. (PAG B4) Investigation into the effects of pollution on lichen distribution. (PAG B2)
B6.1c	explain some of the benefits and challenges of maintaining local and global biodiversity	the difficulty in gaining agreements for and the monitoring of conservation schemes along with the benefits of ecotourism			

B6.2 Feeding the human race

Summary
The human population is increasing rapidly and with this comes a need for more food. Biologists are seeking to tackle this increased demand, which will lead to an improvement in the lives of many people around the world. However, there are many things to consider in achieving this aim, not least the impact on ecosystems. There is much debate surrounding the use of gene technology as a potential solution to the problem of food security.

Underlying knowledge and understanding
Learners should be familiar with the content of a healthy human diet and the consequences of imbalances in a healthy daily diet. Their knowledge and understanding from topics 1, 4 and 5 will also be drawn together in this topic. This includes the organisation of DNA, what plants require enabling them to photosynthesise, interactions between species and the idea of variability within species and subsequent selection of characteristics.

Common misconceptions
Learners can often think that genetic engineering leads to the increased use of pesticides.

Tiering
Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
BM6.2	extract and interpret information from charts, graphs and tables	M2c and M4a

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
B6.2a	explain the impact of the selective breeding of food plants and domesticated animals		M2c, M4a	WS1.1c	Research into the *Rothamsted Research Broadbalk experiment*.
B6.2b	describe genetic engineering as a process which involves modifying the genome of an organism to introduce desirable characteristics				

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
B6.2c	**describe the main steps in the process of genetic engineering**	**restriction enzymes, sticky ends, vectors e.g. plasmids, ligase, host bacteria and selection using antibiotic resistance markers**			Production of a storyboard describing the processes for genetic engineering.
B6.2d	explain some of the possible benefits and risks of using gene technology in modern agriculture	to include practical and ethical considerations		WS1.1c WS1.1d, WS1.1e, WS1.1f, WS1.1g, WS1.1h, WS1.3i	Research into the advantages and disadvantages of selective breeding and genetic engineering.

B6.3 Monitoring and maintaining health

Summary

Diseases affect the health of populations of both humans and plants. Scientists are constantly on the lookout for ways of preventing and combating disease. The prevention of disease in plants is important so that we are able to grow healthy plants enabling us to feed ourselves and enhance our environment. The understanding of how disease is spread, how our bodies defend themselves against disease and how immunity is achieved is essential to enable us to combat potentially fatal diseases spreading throughout whole populations. Non-communicable diseases also have an impact on the health of the population. The prevention of these diseases is frequently discussed in the media, with advice being given to us on how to reduce our risk of contracting these diseases through our life-style choices and discussion of new technologies.

Underlying knowledge and understanding

Learners should be familiar with the effects of 'recreational' drugs (including substance misuse) on behaviour, health and life processes, the impact of exercise, asthma and smoking on the gas exchange system and the consequences of imbalances in the diet, including obesity, starvation and deficiency diseases.

Common misconceptions

Research has shown that learners tend to view all micro-organisms as being non-beneficial. They tend to consider health as just physical and do not consider mental health. Learners also confuse which diseases are inherited and which are caught. They see cancer as a genetic disease.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers. All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
BM6.3i	translate information between graphical and numerical forms	M4a
BM6.3ii	construct and interpret frequency tables and diagrams, bar charts and histograms	M2c
BM6.3iii	understand the principles of sampling as applied to scientific data	M2d
BM6.3iv	use a scatter diagram to identify a correlation between two variables	M2g
BM6.3v	calculate cross-sectional areas of bacterial cultures and clear agar jelly using πr^2	M5c

Topic content		Opportunities to cover:		Practical suggestions
Learning outcomes	**To include**	**Maths**	**Working scientifically**	
B6.3a describe the relationship between health and disease				
B6.3b describe different types of diseases	communicable and non-communicable diseases			
B6.3c describe the interactions between different types of disease	HIV and tuberculosis, and HPV and cervical cancer	M4a		
B6.3d explain how communicable diseases (caused by viruses, bacteria, protists and fungi) are spread in animals and plants	scientific quantities, number of pathogens, number of infected cases, estimating the number of cases	M2c	WS1.4b	
B6.3e explain how the spread of communicable diseases may be reduced or prevented in animals and plants	detection of the antigen, DNA testing, visual identification of the disease	M2c	WS1.4b	
B6.3f describe a minimum of one common human infection, one plant disease and sexually transmitted infections in humans including HIV/AIDS	plant diseases: virus tobacco mosaic virus, fungal *Erysiphe graminis* barley powdery mildew, bacterial *Agrobacterium tumafaciens* crown gall disease			
B6.3g explain how white blood cells and platelets are adapted to their defence functions in the blood				
B6.3h describe the non-specific defence systems of the human body against pathogens				
B6.3i explain the role of the immune system of the human body in defence against disease				
B6.3j explain the use of vaccines and medicines in the prevention and treatment of disease	antibiotics, antivirals and antiseptics		WS1.1g, WS1.1h	Research into whether children should be routinely vaccinated.

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
B6.3k	describe the processes of discovery and development of potential new medicines	preclinical and clinical testing	M2d, M5c, M3d	WS1.1d, WS2a, WS2b, WS2c, WS2d	Investigation into the growth of bacterial cultures using aseptic techniques. (PAG B1)
B6.3l	recall that many non-communicable human diseases are caused by the interaction of a number of factors	cardiovascular diseases, many forms of cancer, some lung (bronchitis) and liver (cirrhosis) diseases and diseases influenced by nutrition, including type 2 diabetes			
B6.3m	evaluate some different treatments for cardiovascular disease	lifestyle, medical and surgical			
B6.3n	analyse the effect of lifestyle factors on the incidence of non-communicable diseases at local, national and global levels	lifestyle factors to include exercise, diet, alcohol and smoking	M2d, M2g, M4a		
B6.3o	describe cancer as the result of changes in cells that lead to uncontrolled growth and division				
B6.3p	discuss potential benefits and risks associated with the use of stem cells in medicine	tissue transplantation and rejection		WS1.1c, WS1.1d, WS1.1e, WS1.1f, WS1.1g, WS1.1h WS1.1j	
B6.3q	explain some of the possible benefits and risks of using gene technology in medicine	practical and ethical considerations		WS1.1c, WS1.1d, WS1.1e WS1.1j	
B6.3r	discuss the potential importance for medicine of our increasing understanding of the human genome	the ideas of predicting the likelihood of diseases occurring and their treatment by drugs which are targeted to genomes		WS1.1c WS1.1d, WS1.1j	

Topic C1: Particles

C1.1 The particle model

Summary
This short section introduces the particle model and its explanation of different states of matter. A simple particle model can be used to represent the arrangement of particles in the different states of matter and to explain observations during changes in state. It does not, however, explain why different materials have different properties. This explanation is that the particles themselves and how they are held together must be different in some way. Elements are substances that are made up of only one type of atom and atoms of different elements can combine to make compounds.

Underlying knowledge and understanding
Learners should be familiar with the different states of matter and their properties. They should also be familiar with changes of state in terms of the particle model. Learners should have sufficient grounding in the particle model to be able to apply it to unfamiliar materials and contexts.

Common misconceptions
Learners commonly intuitively adhere to the idea that matter is continuous. For example, they believe that the space between gas particles is filled or non-existent, or that particles expand when they are heated. The notion that empty space exists between particles is problematic because this lacks supporting sensory evidence. They also show difficulty understanding the concept of changes in state being reversible; this should be addressed during the teaching of this topic.

Tiering
Statements shown in **bold** type will only be tested in the Higher Tier papers. All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
CM1.1i	represent three-dimensional shapes in two dimensions and vice versa when looking at chemical structures e.g. allotropes of carbon	M5b

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C1.1a	describe the main features of the particle model in terms of states of matter and change of state		M5b	WS1.1a, WS1.1b	
C1.1b	explain in terms of the particle model the distinction between physical changes and chemical changes				
C1.1c	**explain the limitations of the particle model in relation to changes of state when particles are represented by inelastic spheres (e.g. like bowling balls)**	**that it does not take into account the forces of attraction between particles, the size of particles and the space between them**	M5b	WS1.1c	Observations of change of state with comparison to chemical changes.

C1.2 Atomic structure

Summary

An atom is the smallest component of an element that gives an element its property. These properties can be explained by models of atomic structure. Current models suggest that atoms are made of smaller sub-atomic particles called protons, neutrons and electrons. They suggest that atoms are composed of a nucleus surrounded by electrons. The nucleus is composed of neutrons and protons. Atoms of each element have the same number of protons as electrons. Atoms of different elements have different numbers of protons. Atoms of the same element will have the same number of protons but may have different numbers of neutrons.

Underlying knowledge and understanding

Learners should be familiar with the simple (Dalton) atomic model.

Common misconceptions

Learners commonly have difficulty understanding the concept of isotopes due to the fact they think that neutral atoms have the same number of protons and neutrons. They also find it difficult to distinguish between the properties of atoms and molecules. Another common misconception is that a positive ion gains protons or a negative ion loses electrons i.e. that there is a change in the nucleus of the atom rather than a change in the number of electrons.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
CM1.2i	relate size and scale of atoms to objects in the physical world	M4a
CM1.2ii	estimate size and scale of atoms	M1c

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C1.2a	describe how and why the atomic model has changed over time	the models of Dalton, Thomson, Rutherford, Bohr, Geiger and Marsden		WS1.1a, WS1.1i, WS1.2b	Timeline of the atomic model.
C1.2b	describe the atom as a positively charged nucleus surrounded by negatively charged electrons, with the nuclear radius much smaller than that of the atom and with most of the mass in the nucleus			WS1.4a	
C1.2c	recall the typical size (order of magnitude) of atoms and small molecules	the concept that typical atomic radii and bond length are in the order of 10^{-10}m	M1c, M4a	WS1.1c, WS1.4b, WS1.4c, WS1.4d, WS1.4e, WS1.4f	
C1.2d	recall relative charges and approximate relative masses of protons, neutrons and electrons			WS1.4a, WS1.4b, WS1.4c	
C1.2e	calculate numbers of protons, neutrons and electrons in atoms and ions, given atomic number and mass number of isotopes	definitions of an ion, atomic number, mass number and an isotope, also the standard notation to represent these		WS1.3c, WS1.4b	

Topic C2: Elements, compounds and mixtures

C2.1 Purity and separating mixtures

Summary

In chemical terms elements and compounds are pure substances and mixtures are impure substances. Chemically pure substances can be identified using melting point. Many useful materials that we use today are mixtures. There are many methods of separating mixtures including filtration, crystallisation, distillation and chromatographic techniques.

Underlying knowledge and understanding

Learners should be familiar with the concept of pure substances. They should have met simple separation techniques of mixtures. The identification of pure substances in terms of melting point, boiling point and chromatography will also have been met before.

Common misconceptions

Learners commonly misuse the word pure and confuse it with natural substances or a substance that has not been tampered with. They think that when a substance dissolves that the solution is pure and not a mixture.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
CM2.1i	arithmetic computation, ratio, percentage and multistep calculations permeates quantitative chemistry	M1a, M1c, M1d
CM2.1ii	provide answers to an appropriate number of significant figures	M2a
CM2.1iii	change the subject of a mathematical equation	M3b, M3c
CM2.1iv	arithmetic computation and ratio when determining empirical formulae, balancing equations	M3b, M3c

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C2.1a	explain what is meant by the purity of a substance, distinguishing between the scientific and everyday use of the term 'pure'			WS1.4a	Purification of compounds. (PAG C3, PAG C4)
C2.1b	use melting point data to distinguish pure from impure substances		M1a, M1c, M1d, M2a		Measurement of melting point.
C2.1c	calculate relative formula masses of species separately and in a balanced chemical equation	the definition of relative atomic mass, relative molecular mass and relative formula mass	M3b, M3c	WS1.3c, WS1.4c	
C2.1d	deduce the empirical formula of a compound from the relative numbers of atoms present or from a model or diagram and vice versa		M3b, M3c	WS1.1b, WS1.4a	
C2.1e	explain that many useful materials are formulations of mixtures	alloys			
C2.1f	describe, explain and exemplify the processes of filtration, crystallisation, simple distillation, and fractional distillation	knowledge of the techniques of filtration, crystallisation, simple distillation and fractional distillation		WS1.2b, WS1.2c, WS2a, WS2b	Separation of mixtures and purification of compounds. (PAG C3, PAG C4) Distillation of mixtures (PAG C3)
C2.1g	describe the techniques of paper and thin layer chromatography			WS1.2b, WS1.2c, WS1.4a, WS2a, WS2b	Thin layer chromatography. (PAG C2)
C2.1h	recall that chromatography involves a stationary and a mobile phase and that separation depends on the distribution between the phases	identification of the mobile and stationary phases		WS1.4a	

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
C2.1i	interpret chromatograms, including measuring R_f values	the recall and the use of the formula	M3b, M3c	WS1.3c, WS1.4a	
C2.1j	suggest suitable purification techniques given information about the substances involved				
C2.1k	suggest chromatographic methods for distinguishing pure from impure substances	paper, thin layer (TLC) and gas chromatography		WS1.4a	Using chromatography to identify mixtures of dyes in an unknown ink. (PAG C2)

C2.2 Bonding

Summary

A simple electron energy level model can be used to explain the basic chemical properties of elements. When chemical reactions occur, they can be explained in terms of losing, gaining or sharing of electrons. The ability of an atom to lose, gain or share electrons depends on its atomic structure. Atoms that lose electrons will bond with atoms that gain electrons. Electrons will be transferred between the atoms to form a positive ion and a negative ion. These ions attract one another in what is known as an ionic bond. Atoms that share electrons can bond with other atoms that share electrons to form a molecule. Atoms in these molecules are held together by covalent bonds.

Underlying knowledge and understanding

Learners should be familiar with the simple (Dalton) atomic model.

Common misconceptions

Learners do not always appreciate that the nucleus of an atom does not change when an electron is lost, gained or shared. They also find it difficult to predict the numbers of atoms that must bond in order to achieve a stable outer level of electrons. Learners think that chemical bonds are physical things made of matter. They also think that pairs of ions such as Na^+ and Cl^- are molecules. They do not have an awareness of the 3D nature of bonding and therefore the shape of molecules.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
CM2.2i	estimate size and scale of atoms	M1c
CM2.2ii	represent three-dimensional shapes in two dimensions and vice versa when looking at chemical structures e.g. allotropes of carbon	M5b
CM2.2iii	translate information between diagrammatic and numerical forms	M4a

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C2.2a	describe metals and non-metals and explain the differences between them on the basis of their characteristic physical and chemical properties	physical properties, formation of ions and common reactions e.g. with oxygen to form oxides		WS1.3f, WS1.4a	
C2.2b	explain how the atomic structure of metals and non-metals relates to their position in the Periodic Table				
C2.2c	explain how the position of an element in the Periodic Table is related to the arrangement of electrons in its atoms and hence to its atomic number	group number and period number	M1c	WS1.4a	
C2.2d	describe and compare the nature and arrangement of chemical bonds in: i. ionic compounds ii. simple molecules iii. giant covalent structures iv. polymers v. metals		M5b, M4a	WS1.4a	Make ball and stick models of molecules.
C2.2e	explain chemical bonding in terms of electrostatic forces and the transfer or sharing of electrons			WS1.4a	
C2.2f	construct dot and cross diagrams for simple covalent and binary ionic substances		M4a	WS1.4a	

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
C2.2g	describe the limitations of particular representations and models	dot and cross diagrams, ball and stick models and two- and three-dimensional representations	M5b	WS1.1c	
C2.2h	explain how the reactions of elements are related to the arrangement of electrons in their atoms and hence to their atomic number			WS1.1b, WS1.3f, WS1.4a	
C2.2i	explain in terms of atomic number how Mendeleev's arrangement was refined into the modern Periodic Table			WS1.1a, WS1.4a	

C2.3 Properties of materials

Summary
This section explores the physical properties of elements and compounds and how the nature of their bonding is a factor in their properties.

Underlying knowledge and understanding
Learners will know the difference between an atom, element and compound.

Common misconceptions
Learners commonly have a limited understanding of what can happen during chemical reactions, for example, that substances may explode, burn, contract, expand or change state.

Tiering
Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
CM2.3i	represent three-dimensional shapes in two dimensions and vice versa when looking at chemical structures e.g. allotropes of carbon	M5b

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C2.3a	recall that carbon can form four covalent bonds			WS1.4a	
C2.3b	explain that the vast array of natural and synthetic organic compounds occur due to the ability of carbon to form families of similar compounds, chains and rings				
C2.3c	explain the properties of diamond, graphite, fullerenes and graphene in terms of their structures and bonding		M5b	WS1.4a	
C2.3d	use ideas about energy transfers and the relative strength of chemical bonds and intermolecular forces to explain the different temperatures at which changes of state occur			WS1.2a, WS1.3f, WS1.4a, WS1.4c	
C2.3e	use data to predict states of substances under given conditions	data such as temperature and how this may be linked to changes of state			
C2.3f	explain how the bulk properties of materials (ionic compounds; simple molecules; giant covalent structures; polymers and metals) are related to the different types of bonds they contain, their bond strengths in relation to intermolecular forces and the ways in which their bonds are arranged	recognition that the atoms themselves do not have the bulk properties of these materials		WS1.4a	

Topic C3: Chemical reactions

C3.1 Introducing chemical reactions

Summary

A chemical equation represents, in symbolic terms, the overall change in a chemical reaction. New materials are formed through chemical reactions but mass will be conserved. This can be explained by a model involving the rearrangement of atoms. Avogadro gave us a system of measuring the amount of a substance in moles.

Underlying knowledge and understanding

Learners should be familiar with chemical symbols and formulae for elements and compounds. They should also be familiar with representing chemical reactions using formulae. Learners will have knowledge of conservation of mass, changes of state and chemical reactions.

Common misconceptions

Although learners may have met the conservation of mass they still tend to refer to chemical reactions as losing mass. They understand that mass is conserved but not the number or species of atoms. They may think that the original substance vanishes 'completely and forever' in a chemical reaction.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
CM3.1i	arithmetic computation and ratio when determining empirical formulae, balancing equations	M1a, M1c
CM3.1ii	**calculations with numbers written in standard form when using the Avogadro constant**	**M1b**
CM3.1iii	provide answers to an appropriate number of significant figures	M2a
CM3.1iv	convert units where appropriate **particularly from mass to moles**	M1c

Topic content		Opportunities to cover:		Practical suggestions
Learning outcomes	**To include**	**Maths**	**Working scientifically**	
C3.1a use chemical symbols to write the formulae of elements and simple covalent and ionic compounds		M1a, M1c	WS1.4a	
C3.1b use the names and symbols of common elements and compounds and the principle of conservation of mass to write formulae and balanced chemical equations **and half equations**		M1a, M1c	WS1.4c	
C3.1c use the names and symbols of common elements from a supplied Periodic Table to write formulae and balanced chemical equations where appropriate	the first 20 elements, Groups 1, 7, and 0 and other common elements included within the specification			
C3.1d use the formula of common ions to deduce the formula of a compound		M1a, M1c		
C3.1e construct balanced ionic equations		M1a, M1c		
C3.1f describe the physical states of products and reactants using state symbols (s, l, g and aq)				
C3.1g describe tests to identify selected gases	oxygen, hydrogen, carbon dioxide and chlorine			
C3.1h recall and use the definitions of the Avogadro constant (in standard form) and of the mole	**the calculation of the mass of one atom/molecule**	M1b, M1c	WS1.4b, WS1.4c, WS1.4d, WS1.4f	

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
C3.1i	**explain how the mass of a given substance is related to the amount of that substance in moles and vice versa**		M1c, M2a	WS1.4b, WS1.4c	
C3.1j	**explain how the mass of a solute and the volume of the solution is related to the concentration of the solution**		M1b, M1c	WS1.3c, WS1.4a, WS1.4c	
C3.1k	recall and use the law of conservation of mass			WS1.4c	
C3.1l	explain any observed changes in mass in non-enclosed systems during a chemical reaction and explain them using the particle model			WS1.1b, WS1.4c	
C3.1m	**deduce the stoichiometry of an equation from the masses of reactants and products and explain the effect of a limiting quantity of a reactant**		M1c	WS1.3c, WS1.4c, WS1.4d, WS1.4f	
C3.1n	**use a balanced equation to calculate masses of reactants or products**		M1c	WS1.3c, WS1.4c	

C3.2 Energetics

Summary

Chemical reactions are accompanied by an energy change. A simple model involving the breaking and making of chemical bonds can be used to interpret and calculate the energy change.

Underlying knowledge and understanding

Learners should be familiar with exothermic and endothermic chemical reactions.

Common misconceptions

Learners commonly have the idea that energy is lost or used up. They do not grasp the idea that energy is transferred. Learners also wrongly think that energy is released when bonds break and do not link this release of energy with the formation of bonds. They also may think for example that a candle burning is endothermic because heat is needed to initiate the reaction.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
CM3.2i	interpretation of charts and graphs when dealing with reaction profiles	M4a
CM3.2ii	arithmetic computation when calculating energy changes	M1a

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C3.2a	distinguish between endothermic and exothermic reactions on the basis of the temperature change of the surroundings			WS1.4c	Measuring the temperature change in reactions. (PAG C5)
C3.2b	draw and label a reaction profile for an exothermic and an endothermic reaction	activation energy, energy change, reactants and products	M4a	WS1.3b, WS1.3c, WS1.3d, WS1.3e, WS1.3g, WS1.3h, WS1.4c	
C3.2c	explain activation energy as the energy needed for a reaction to occur			WS1.4c	
C3.2d	**calculate energy changes in a chemical reaction by considering bond making and bond breaking energies**		M1a	WS1.3c, WS1.4c	

C3.3 Types of chemical reactions

Summary

Chemical reactions can be classified according to changes at the atomic and molecular level. Examples of these include reduction, oxidation and neutralisation reactions.

Underlying knowledge and understanding

Learners should be familiar with combustion, thermal decomposition, oxidation and displacement reactions. They will be familiar with defining acids and alkalis in terms of neutralisation reactions. Learners will have met reactions of acids with alkalis to produce a salt and water and reactions of acids with metals to produce a salt and hydrogen.

Common misconceptions

Learners commonly intuitively adhere to the idea that hydrogen ions in an acid are still part of the molecule, not free in the solution. They tend to have little understanding of pH, for example, they tend to think that alkalis are less corrosive than acids. Learners also may think that the strength of acids and bases and concentration mean the same thing.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
CM3.3i	arithmetic computation, ratio, percentage and multistep calculations permeates quantitative chemistry	M1a, M1c, M1d

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C3.3a	explain reduction and oxidation in terms of loss or gain of oxygen, identifying which species are oxidised and which are reduced	the concept of oxidising agent and reducing agent		WS1.4a	
C3.3b	**explain reduction and oxidation in terms of gain or loss of electrons, identifying which species are oxidised and which are reduced**			WS1.4a	
C3.3c	recall that acids form hydrogen ions when they dissolve in water and solutions of alkalis contain hydroxide ions			WS1.4a	

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
C3.3d	describe neutralisation as acid reacting with alkali or a base to form a salt plus water			WS1.4a	Production of pure dry sample of salt. (PAG C4)
C3.3e	recognise that aqueous neutralisation reactions can be generalised to hydrogen ions reacting with hydroxide ions to form water			WS1.4a	
C3.3f	recall that carbonates and some metals react with acids and write balanced equations predicting products from given reactants			WS1.4a	
C3.3g	**use and explain the terms dilute and concentrated (amount of substance) and weak and strong (degree of ionisation) in relation to acids**	**ratio of amount of acid to volume of solution**	M1a, M1c, M1d	WS1.4a	
C3.3h	recall that relative acidity and alkalinity are measured by pH			WS1.4a	
C3.3i	**describe neutrality and relative acidity and alkalinity in terms of the effect of the concentration of hydrogen ions on the numerical value of pH (whole numbers only)**	**pH of titration curves**		WS1.4a	Neutralisation reactions.
C3.3j	**recall that as hydrogen ion concentration increases by a factor of ten the pH value of a solution decreases by a factor of one**		M1a, M1c, M1d	WS1.4a	
C3.3k	describe techniques and apparatus used to measure pH				Determining pH of unknown solutions. Use of pH probes.

C3.4 Electrolysis

Summary
Decomposition of a liquid during the conduction of electricity is a chemical reaction called electrolysis. This section explores the electrolysis of various molten ionic liquids and aqueous ionic solutions.

Underlying knowledge and understanding
Learners should be familiar with ionic solutions and solids.

Common misconceptions
A common misconception is that ionic solutions conduct because of the movement of electrons. Another common misconception is that ionic solids do not conduct electricity because electrons cannot move.

Tiering
Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
CM3.4i	arithmetic computation and ratio when determining empirical formulae, balancing equations	M1a, M1c

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		**To include**	**Maths**	**Working scientifically**	
C3.4a	recall that metals (or hydrogen) are formed at the cathode and non-metals are formed at the anode in electrolysis using inert electrodes	the terms cations and anions		WS1.4a	
C3.4b	predict the products of electrolysis of binary ionic compounds in the molten state	compounds such as NaCl	M1a, M1c	WS1.2a, WS1.2b, WS1.2c, WS1.4a, WS2a, WS2b	
C3.4c	describe competing reactions in the electrolysis of aqueous solutions of ionic compounds in terms of the different species present	the electrolysis of aqueous NaCl and $CuSO_4$ using inert electrodes	M1a, M1c	WS1.4a	Electrolysis of sodium chloride solution. (PAG C1) Electrolysis of copper sulfate solution. (PAG C1)
C3.4d	describe electrolysis in terms of the ions present and reactions at the electrodes		M1a, M1c		
C3.4e	describe the technique of electrolysis using inert and non-inert electrodes				

Topic C4: Predicting and identifying chemical products

C4.1 Predicting chemical reactions

Summary

Models of how substances react and the different types of chemical reactions that can occur enable us to predict the likelihood and outcome of a chemical reaction. The current Periodic Table was developed based on observations of the similarities and differences in the properties of elements. The way that the Periodic Table is arranged into groups and periods reveals the trends and patterns in the behaviour of the elements. The model of atomic structure provides an explanation for trends and patterns in the properties of elements. The arrangement of elements in groups and periods reveals the relationship between observable properties and how electrons are arranged in the atoms of each element.

Underlying knowledge and understanding

Learners should be familiar with the principles underpinning the Mendeleev Periodic Table; the Periodic Table: periods and groups; metals and non-metals; the varying physical and chemical properties of different elements; the chemical properties of metals and non-metals; the chemical properties of metal and non-metal oxides with respect to acidity and how patterns in reactions can be predicted with reference to the Periodic Table.

Common misconceptions

Learners consider the properties of particles of elements to be the same as the bulk properties of that element. They tend to rely on the continuous matter model rather than the particle model. Learners confuse state changes and dissolving with chemical changes. Also, since the atmosphere is invisible to the eye and learners rely on concrete, visible information, this means learners often avoid the role of oxygen in their explanations for open system reactions. Even if the role of oxygen is appreciated, learners do not realise that solid products of an oxidation reaction have more mass than the starting solid.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
CM4.1i	arithmetic computation and ratio when determining empirical formulae, balancing equations	M1a, M1c

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C4.1a	recall the simple properties of Groups 1, 7 and 0	physical and chemical properties		WS1.2a, WS1.4a WS1.4c	Displacement reactions of halogens with halides.
C4.1b	explain how observed simple properties of Groups 1, 7 and 0 depend on the outer shell of electrons of the atoms and predict properties from given trends down the groups	ease of electron gain or loss; physical and chemical properties			
C4.1c	predict possible reactions and probable reactivity of elements from their positions in the Periodic Table			WS1.1b, WS1.2a, WS1.4a	
C4.1d	explain how the reactivity of metals with water or dilute acids is related to the tendency of the metal to form its positive ion		M1a, M1c	WS1.4a	Reaction of metals with water, dilute hydrochloric acid. PAG C4, PAG C5)
C4.1e	deduce an order of reactivity of metals based on experimental results			WS1.3e, WS2a	Displacement reactions involving metals and metal salts. (PAG C4, PAG C5)

Topic C5: Monitoring and controlling chemical reactions

C5.1 Controlling reactions

Summary
The rate and yield of a chemical reaction can be altered by changing the physical conditions.

Underlying knowledge and understanding
Learners should be familiar with the action of catalysts in terms of rate of reaction. They should know the term surface area and what it means.

Common misconceptions
Learners often misinterpret rate graphs and think that catalysts take part in reactions and run out/get used up.

Tiering
Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
CM5.1i	arithmetic computation, ratio when measuring rates of reaction	M1a, M1c
CM5.1ii	drawing and interpreting appropriate graphs from data to determine rate of reaction	M4b, M4c
CM5.1iii	determining gradients of graphs as a measure of rate of change to determine rate	M4d, M4e
CM5.1iv	proportionality when comparing factors affecting rate of reaction	M1c

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C5.1a	suggest practical methods for determining the rate of a given reaction		M1a, M1c	WS1.2b, WS1.2c, WS1.2d, WS2a, WS2b	Rate of reaction experiments. (PAG C5) Disappearing cross experiment. (PAG C5) Magnesium and acid, marble chips and acid. (PAG C5)
C5.1b	interpret rate of reaction graphs	$1/t$ is proportional to rate and gradients of graphs (not order of reaction)	M4b, M4c	WS1.3a, WS1.3b, WS1.3c, WS1.3d, WS1.3e, WS1.3f, WS1.3g, WS1.3h, WS1.3i, WS2b	Marble chips and acid or magnesium and acid experiments either measuring reaction time or the volume of gas over time. (PAG C4, PAG C5)
C5.1c	describe the effect of changes in temperature, concentration, pressure, and surface area on rate of reaction		M4d, M4e	WS1.4c	Varying surface area with marble chips and hydrochloric acid. (PAG C5)
C5.1d	explain the effects on rates of reaction of changes in temperature, concentration and pressure in terms of frequency and energy of collision between particles			WS1.4c	Reaction of magnesium and acid with different temperatures of acid – measure reaction times. (PAG C5)
C5.1e	explain the effects on rates of reaction of changes in the size of the pieces of a reacting solid in terms of surface area to volume ratio		M1c		

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
C5.1f	describe the characteristics of catalysts and their effect on rates of reaction				
C5.1g	identify catalysts in reactions			WS1.4a	Catalysis of hydrogen peroxide with various black powders including MnO_2. (PAG C5) Catalysis of reaction of zinc with sulfuric acid using copper powder. (PAG C5).
C5.1h	explain catalytic action in terms of activation energy	reaction profiles			
C5.1i	recall that enzymes act as catalysts in biological systems				

C5.2 Equilibria

Summary

In a reaction, when the rate of the forward reaction equals the rate of the backwards reaction, the reaction in a closed system is said to be in equilibrium.

Underlying knowledge and understanding

Learners will be familiar with representing chemical reactions using formulae and using equations.

Common misconceptions

Learners often do not recognise that when a dynamic equilibrium is set up in a reaction the concentration of the reactants and products remain constant. They think that they are equal. Learners also sometimes perceive a dynamic equilibrium as two reactions.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
CM5.2i	arithmetic computation, ratio when measuring rates of reaction	M1a, M1c
CM5.2ii	drawing and interpreting appropriate graphs from data to determine rate of reaction	M4b, M4c
CM5.2iii	determining gradients of graphs as a measure of rate of change to determine rate	M4d, M4e
CM5.2iv	proportionality when comparing factors affecting rate of reaction	M1c

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C5.2a	recall that some reactions may be reversed by altering the reaction conditions		M1a, M4b, M4c		
C5.2b	recall that dynamic equilibrium occurs in a closed system when the rates of forward and reverse reactions are equal		M4b, M4c		
C5.2c	**predict the effect of changing reaction conditions on equilibrium position and suggest appropriate conditions to produce as much of a particular product as possible**	**Le Chatelier's principle concerning concentration, temperature and pressure**	M1a, M4d, M4e, M1c	WS1.2a, WS1.2b, WS1.2c, WS1.4c, WS2a, WS2b	

Topic C6: Global challenges

This topic seeks to integrate learners' knowledge and understanding of chemical systems and processes, with the aim of applying it to global challenges. Applications of chemistry can be used to help humans improve their own lives and strive to create a sustainable world for future generations, and these challenges are considered in this topic. It therefore provides opportunities to draw together the concepts covered in earlier topics, allowing synoptic treatment of the subject of chemistry.

C6.1 Improving processes and products

Summary
Historically, new materials have been developed through trial and error, experience etc. but as our understanding of the structure of materials and chemical processes has improved we are increasing our ability to manipulate and design new materials. Industry is continually looking to make products that have a better performance and are sustainable to produce. This section also explores the extraction of raw materials and their use in making new products.

Underlying knowledge and understanding
Learners should be familiar with the properties of ceramics, polymers and composites. They also will have met the method of using carbon to obtain metals from metal oxides.

Common misconceptions
Learners often think that chemical reactions will continue until all the reactants are exhausted. They also think that equilibrium is a static condition.

Tiering
Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
CM6.1i	arithmetic computation, ratio when measuring rates of reaction	M1a, M1c
CM6.1ii	drawing and interpreting appropriate graphs from data to determine rate of reaction	M4b, M4c

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C6.1a	explain, using the position of carbon in the reactivity series, the principles of industrial processes used to extract metals, including extraction of a non-ferrous metal		M1a, M1c	WS1.4a	Extraction of copper by heating copper oxide with carbon.
C6.1b	explain why and how electrolysis is used to extract some metals from their ores		M4b, M4c	WS1.3a, WS1.3b, WS1.3c, WS1.3d, WS1.3e, WS1.3g, WS1.3h, WS1.3i, WS1.4, WS2b	Electrolysis of aqueous sodium chloride solution. (PAG C1) Electrolysis of aqueous copper sulfate solution. (PAG C1)
C6.1c	**evaluate alternative biological methods of metal extraction**	**bacterial and phytoextraction**		WS1.1a, WS1.1e	
C6.1d	describe the basic principles in carrying out a life-cycle assessment of a material or product				
C6.1e	interpret data from a life-cycle assessment of a material or product				
C6.1f	describe a process where a material or product is recycled for a different use, and explain why this is viable			WS1.1f, WS1.1g	
C6.1g	evaluate factors that affect decisions on recycling			WS1.1f, WS1.1g	
C6.1h	describe the separation of crude oil by fractional distillation	the name of the fractions		WS1.3f, WS1.4a	

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
C6.1i	explain the separation of crude oil by fractional distillation	molecular size and intermolecular forces			
C6.1j	describe the fractions as largely a mixture of compounds of formula C_nH_{2n+2} which are members of the alkane homologous series			WS1.4a	
C6.1k	recall that crude oil is a main source of hydrocarbons and is a feedstock for the petrochemical industry			WS1.4a	
C6.1l	explain how modern life is crucially dependent upon hydrocarbons and recognise that crude oil is a finite resource			WS1.1c, WS1.1f, WS1.1e, WS1.4a	
C6.1m	describe the production of materials that are more useful by cracking	conditions and reasons for cracking and some of the useful materials produced			

C6.2 Interpreting and interacting with earth systems

Summary

As our understanding of the structure of materials and chemical processes has improved we are increasing our ability to interpret and understand chemical and earth systems. Understanding how we interact with them is very important to our survival as a species. This section starts with the history of the atmosphere and moves on to how human activity could be affecting its composition.

Underlying knowledge and understanding

Learners should have some understanding of the composition of the Earth, the structure of the Earth, the rock cycle, the carbon cycle, the composition of the atmosphere and the impact of human activity on the climate.

Common misconceptions

Learners think that the atmosphere is large and that small increases of carbon dioxide or a few degrees of temperature change do not make a difference to the climate. They may consider that global warming is caused by the ozone hole and that human activities alone cause the greenhouse effect.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
CM6.2i	extract and interpret information from charts, graphs and tables	M2c, M4a
CM6.2ii	use orders of magnitude to evaluate the significance of data	M2h

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C6.2a	interpret evidence for how it is thought the atmosphere was originally formed	knowledge of how the composition of the atmosphere has changed over time	M2c, M4a, M2h	WS1.3e	
C6.2b	describe how it is thought an oxygen-rich atmosphere developed over time		M2h	WS1.1a	
C6.2c	describe the greenhouse effect in terms of the interaction of radiation with matter within the atmosphere				
C6.2d	evaluate the evidence for additional anthropogenic (human activity) causes of climate change and describe the uncertainties in the evidence base	the correlation between change in atmospheric carbon dioxide concentration and the consumption of fossil fuels	M2c, M4a, M2h		
C6.2e	describe the potential effects of increased levels of carbon dioxide and methane on the Earth's climate and how these effects may be mitigated	consideration of scale, risk and environmental implications	M2c, M4a, M2h	WS1.1f, WS1.1h	
C6.2f	describe the major sources of carbon monoxide, sulfur dioxide, oxides of nitrogen and particulates in the atmosphere and explain the problems caused by increased amounts of these substances			WS1.4a	
C6.2g	describe the principal methods for increasing the availability of potable water in terms of the separation techniques used	ease of treatment of waste, ground and salt water			

Topic P1: Matter

P1.1 The particle model

Summary

Knowledge and understanding of the particle nature of matter is fundamental to physics. Learners need to have an appreciation of matter in its different forms, they must also be aware of subatomic particles, their relative charges, masses and positions inside the atom. The structure and nature of atoms are essential to the further understanding of physics. The knowledge of subatomic particles is needed to explain many phenomena, for example the transfer of charge, as well as radioactivity. (Much of this content overlaps with that in the GCSE (9–1) in Chemistry A (Gateway).)

Underlying knowledge and understanding

Learners should be aware of the atomic model, and that atoms are examples of particles. They should also know the difference between atoms, molecules and compounds. Learners should understand how density can be affected by the state materials are in.

Common misconceptions

Learners commonly confuse the different types of particles (subatomic particles, atoms and molecules) which can be addressed through the teaching of this topic. They commonly misunderstand the conversions between different units used in the measurement of volume.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers. All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
PM1.1i	recall and apply: density (kg/m^3) = mass (kg)/volume (m^3)	M1a, M1b, M1c, M3b, M3c, M5c

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P1.1a	describe how and why the atomic model has changed over time	the Thomson, Rutherford (alongside Geiger and Marsden) and Bohr models	M5b	WS1.1a, WS1.1c, WS1.1g	Timeline showing the development of atomic theory. Discussion of the different roles played in developing the atomic model and how different scientists worked together.
P1.1b	describe the atom as a positively charged nucleus surrounded by negatively charged electrons, with the nuclear radius much smaller than that of the atom and with almost all of the mass in the nucleus		M5b	WS 1.1b	Model making (including 3D) of atomic structures.
P1.1c	recall the typical size (order of magnitude) of atoms and small molecules	knowledge that it is typically $1x10^{-10}$m	M1b	WS1.1d	
P1.1d	define density			WS1.2b, WS1.2c, WS1.3c, WS1.3d, WS1.4a, WS1.4b, WS1.4e, WS1.4f, WS2a, WS2b, WS2c, WS2d	Measurement of length, volume and mass and using them to calculate density. (PAG P1) Investigation of Archimedes' Principle using eureka cans. (PAG P1)
P1.1e	explain the differences in density between the different states of matter in terms of the arrangements of the atoms and molecules		M5b	WS1.1b	
P1.1f	apply the relationship between density, mass and volume to changes where mass is conserved (M1a, M1b, M1c, M3c)		M1a, M1b, M1c, M3c		

P1.2 Changes of state

Summary

A clear understanding of the foundations of the physical world forms a solid basis for further study of physics. Understanding of the relationship between the states of matter helps to explain different types of everyday physical changes that we see around us.

Underlying knowledge and understanding

Learners should be familiar with the structure of matter and the similarities and differences between solids, liquids and gases. They should have an idea of the particle model and be able to use it to model changes in particle behaviour during changes of state. Learners should be aware of the effect of temperature in the motion and spacing of particles and an understanding that energy can be stored internally by materials.

Common misconceptions

Learners commonly carry misconceptions about matter; assuming atoms are always synonymous with particles. Learners also struggle to explain what is between the particles, instinctively 'filling' the gaps with 'air' or 'vapour'. They often struggle to visualise the 3D arrangement of particles in all states of matter. Learners can find it challenging to understand how kinetic theory applies to heating materials and how to use the term temperature correctly, regularly confusing the terms temperature and heat.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
PM1.2i	apply: change in thermal energy (J) = mass (kg) x specific heat capacity (J/kg°C) x change in temperature (°C)	M1a, M3b, M3c, M3d
PM1.2ii	apply: thermal energy for a change in state (J) = mass (kg) x specific latent heat (J/kg)	M1a, M3b, M3c, M3d

Topic content		Opportunities to cover:		Practical suggestions
Learning outcomes	To include	Maths	Working scientifically	
P1.2a describe how mass is conserved when substances melt, freeze, evaporate, condense or sublimate			WS1.3a, WS1.3e, WS1.4a, WS2a, WS2c	Use of a data logger to record change in state and mass at different temperatures. (PAG P5) Demonstration of distillation to show that mass is conserved during evaporation and condensation. (PAG P5)
P1.2b describe that these physical changes differ from chemical changes because the material recovers its original properties if the change is reversed				
P1.2c describe how heating a system will change the energy stored within the system and raise its temperature or produce changes of state			WS1.3a, WS1.3e, WS1.4a, WS2a, WS2b, WS2c	Observation of the crystallisation of salol in water under a microscope. Use of thermometer with a range of 10 –110°C, to record the temperature changes of ice as it is heated. (PAG P1)
P1.2d define the term specific heat capacity and distinguish between it and the term specific latent heat			WS1.2e, WS1.3b, WS1.3c, WS1.3h, WS1.4a, WS1.4f, WS2a, WS2b	Investigation of the specific heat capacity of different metals or water using electrical heaters and a joulemeter. (PAG P5)

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P1.2e	apply the relationship between change in internal energy of a material and its mass, specific heat capacity and temperature change to calculate the energy change involved (M1a, M3c, M3d)		M1a, M3c, M3d		
P1.2f	apply the relationship between specific latent heat and mass to calculate the energy change involved in a change of state (M1a, M3c, M3d)		M1a, M3c, M3d	WS1.2e, WS1.3b, WS1.3c, WS1.3h, WS1.4a, WS1.4f, WS2a, WS2b	Measurement of the specific latent heat of vaporisation of water. (PAG P5) Measurement of the specific latent heat of stearic acid. (PAG P5)
P1.2g	explain how the motion of the molecules in a gas is related both to its temperature and its pressure	application to closed systems only	M1c, M4a, M5b	WS1.1b, WS1.2a, WS1.2e, WS1.3e, WS1.4a, WS2a	Demonstration of the difference in pressure in an inflated balloon that has been heated and frozen. (PAG P1) Building manometers and using them to show pressure changes in heated/ cooled volumes of gas. (PAG P1)
P1.2h	explain the relationship between the temperature of a gas and its pressure at constant volume (qualitative only)		M1c, M5b	WS1.1b, WS1.2a, WS1.2e, WS1.3e, WS1.4a, WS2a	Demonstration of the exploding can experiment. Building of Alka-Seltzer rockets with film canisters.

Topic P2: Forces

P2.1 Motion

Summary

Having looked at the nature of matter which makes up objects, we move on to consider the effects of forces. The interaction between objects leads to actions which can be seen by the observer, these actions are caused by forces between the objects in question. Some of the interactions involve contact between the objects, others involve no contact. We will also consider the importance of the direction in which forces act to allow understanding of the importance of vector quantities when trying to predict the action.

Underlying knowledge and understanding

From their work in Key Stage 3 Science, learners will have a basic knowledge of the mathematical relationship between speed, distance and time. They should also be able to represent this information in a distance-time graph and have an understanding of the relative motion of objects.

Common misconceptions

Learners can find the concept of action at a distance challenging. They have a tendency to believe that a velocity must have a positive value and have difficulty in associating a reverse in direction with a change in sign. It is therefore important to make sure learners are knowledgeable about the vector/scalar distinction.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
PM2.1i	recall and apply: distance travelled (m) = speed (m/s) x time (s)	M1a, M2b, M3a, M3b, M3c, M3d, M4a, M4b, M4c, M4d, M4e
PM2.1ii	recall and apply: acceleration (m/s^2) = change in velocity (m/s)/time (s)	M1a, M3a, M3b, M3c, M3d
PM2.1iii	apply: (final velocity $(m/s))^2$ – (initial velocity $(m/s))^2$ = 2 x acceleration (m/s^2) x distance (m)	M1a, M3a, M3b, M3c, M3d
PM2.1iv	recall and apply: kinetic energy (J) = 0.5 x mass (kg) x (speed $(m/s))^2$	M1a, M3a, M3b, M3c, M3d

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P2.1a	describe how to measure distance and time in a range of scenarios				
P2.1b	describe how to measure distance and time and use these to calculate speed		M4a, M4b, M4c, M4d, M4f	WS1.2b, WS1.2e, WS1.3a, WS1.3b, WS1.3c, WS1.3g, WS1.3h, WS1.3i, WS2a, WS2b, WS2c, WS2d	Calculations of the speeds of learners when they walk and run a measured distance. Investigation of trolleys on ramps at an angle and whether this affects speed. (PAG P3)
P2.1c	make calculations using ratios and proportional reasoning to convert units and to compute rates (M1c, M3c)	conversion from non-SI to SI units	M1c, M3c		
P2.1d	explain the vector-scalar distinction as it applies to displacement and distance, velocity and speed				
P2.1e	relate changes and differences in motion to appropriate distance-time, and velocity-time graphs; interpret lines and slopes (M4a, M4b, M4c, M4d)		M4a, M4b, M4c, M4d	WS1.3a	Learners to draw displacement–time and velocity–time graphs of their journey to school. (PAG P3)
P2.1f	**Interpret enclosed areas in velocity-time graphs (M4a, M4b, M4c, M4d, M4f)**		M4a, M4b, M4c, M4d, M4f		

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P2.1g	calculate average speed for non-uniform motion (M1a, M1c, M2b, M3c)		M1a, M1c, M2b, M3c		
P2.1h	apply formulae relating distance, time and speed, for uniform motion, and for motion with uniform acceleration (M1a, M1c, M2b, M3c)		M1a, M1c, M2b, M3c	WS1.2b, WS1.2e, WS1.3a, WS1.3b, WS1.3c, WS1.3g, WS1.3h, WS1.3i, WS2a, WS2b, WS2c, WS2d	Investigation of acceleration. (PAG P3)

P2.2 Newton's laws

Summary

Newton's laws of motion essentially define the means by which motion changes and the relationship between these changes in motion with force and mass.

Underlying knowledge and understanding

Learners should have an understanding of contact and non-contact forces influencing the motion of an object. They should be aware of newtons and that this is the measure of force. The three laws themselves will be new to the learners. Learners are expected to be able to use force arrows and have an understanding of balanced and unbalanced forces.

Common misconceptions

Learners commonly have misconceptions about objects needing a net force for them to continue to move steadily and can struggle to understand that stationary objects also have forces acting on them. Difficulties faced by learners when trying to differentiate between scalar and vector quantities is the idea of objects with a changing direction not having a constant vector value, for example, objects moving in a circle. This issue also arises with the concept of momentum and changes in momentum of colliding objects.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
PM2.2i	recall and apply: force (N) = mass (kg) x acceleration (m/s^2)	M1a, M2a, M3a, M3b, M3c, M3d
PM2.2ii	**recall and apply: momentum (kgm/s) = mass (kg) x velocity (m/s)**	**M1a, M2a, M3a, M3b, M3c, M3d**
PM2.2iii	recall and apply: work done (J) = force (N) x distance (m) (along the line of action of the force)	M1a, M2a, M3a, M3b, M3c, M3d
PM2.2iv	recall and apply: power (W) = work done (J)/time (s)	M1a, M2a, M3a, M3b, M3c, M3d

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P2.2a	recall examples of ways in which objects interact	electrostatics, gravity, magnetism and by contact (including normal contact force and friction)			
P2.2b	describe how such examples involve interactions between pairs of objects which produce a force on each object				
P2.2c	represent such forces as vectors	drawing free body force diagrams to demonstrate understanding of forces acting as vectors	M5b	WS1.2a, WS1.2b, WS1.2c, WS1.2e, WS1.3a, WS1.3c, WS1.3e, WS1.3h, WS2a, WS2b, WS2d	Measurement of the velocity of ball bearings in glycerol at different temperatures or of differing sizes. (PAG P3)
P2.2d	apply Newton's First Law to explain the motion of an object moving with uniform velocity and also an object where the speed and/or direction change	looking at forces on one body and resultant forces and their effects (qualitative only)		WS1.3e, WS2a	Demonstration of the behaviour of colliding gliders on a linear air track. (PAG P3) Use of balloon gliders to consider the effect of a force on a body.
P2.2e	**use vector diagrams to illustrate resolution of forces, a net force (resultant force), and equilibrium situations (M4a, M5a, M5b)**	**scale drawings**	M4a, M5a, M5b		

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P2.2f	**describe examples of the forces acting on an isolated solid object or system**	**examples of objects that reach terminal velocity for example skydivers and applying similar ideas to vehicles**		WS1.2a, WS1.2b, WS1.2c, WS1.2e, WS1.3a, WS1.3c, WS1.3e, WS1.3h, WS2a, WS2b, WS2d	Learners to design and build a parachute for a mass, and measure its terminal velocity as it is dropped. (PAG P3)
P2.2g	**describe, using free body diagrams, examples where two or more forces lead to a resultant force on an object**				
P2.2h	**describe using free body force diagrams the special case of balanced forces when the resultant force is zero (qualitative only)**				
P2.2i	apply Newton's Second Law in calculations relating forces, masses and accelerations		M1a, M2a, M3b, M3c, M3d	WS1.2a, WS1.2b, WS1.2c, WS1.2e, WS1.3a, WS1.3c, WS1.3e, WS1.3h, WS2a, WS2b, WS2c, WS2d	Use of light gates, weights and trolleys to investigate the link between force and acceleration. (PAG P2)
P2.2j	**explain that inertia is a measure of how difficult it is to change the velocity of an object and that the mass is defined as the ratio of force over acceleration**				

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P2.2k	**define momentum and describe examples of momentum in collisions**	**an idea of the law of conservation of momentum in elastic collisions**		WS1.2a, WS1.2b, WS1.2c, WS1.2e, WS1.3a, WS1.3c, WS1.3e, WS1.3h, WS2a, WS2b, WS2c, WS2d	Use of light gates, weights and trolleys to measure momentum of colliding trollies. (PAG P3) Use of a water rocket to demonstrate that the explosion propels the water down with the same momentum as the rocket shoots up.
P2.2l	use the relationship between work done, force, and distance moved along the line of action of the force and describe the energy transfer involved		M1a, M2a, M3a, M3b, M3c, M3d	WS1.4a, WS2a, WS2b	Measurement of work done by learners lifting weights or walking up stairs. (PAG P5)
P2.2m	calculate relevant values of stored energy and energy transfers; convert between newton-metres and joules (M1c, M3c)		M1c, M3c	WS1.4e, WS1.4f	
P2.2n	explain, with reference to examples, the definition of power as the rate at which energy is transferred				
P2.2o	recall and apply Newton's Third Law	situations of equilibrium and non-equilibrium			
P2.2p	**explain why an object moving in a circle with a constant speed has a changing velocity (qualitative only)**			WS1.3e	Demonstration of spinning a rubber bung on a string

P2.3 Forces in action

Summary

Forces acting on an object can result in a change of shape or motion. Having looked at the nature of matter, we can now introduce the idea of fields and forces causing changes. This develops the idea that force interactions between objects can take place even if they are not in contact. Learners should be familiar with forces associated with deforming objects, with stretching and compressing (springs).

Underlying knowledge and understanding

Learners should have an understanding of forces acting to deform objects and to restrict motion. They should already be familiar with Hooke's law and the idea that when work is done by a force it results in an energy transfer and leads to energy being stored by an object. Learners are expected to know that there is a force due to gravity and that gravitational field strength differs on other planets and stars.

Common misconceptions

Because of the everyday use of the term 'weighing', learners commonly have difficulty understanding that the weight of an object is not the same as the mass. The concept of force multipliers can also be challenging even though the basic concepts are ones covered at Key Stage 3.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
PM2.3i	recall and apply: force exerted by a spring (N) = extension (m) x spring constant (N/m)	M1a, M2a, M3a, M3b, M3c, M3d
PM2.3ii	apply: energy transferred in stretching (J) = 0.5 x spring constant (N/m) x (extension (m))^2	M1a, M2a, M3a, M3b, M3c, M3d
PM2.3iii	recall and apply: gravity force (N) = mass (kg) x gravitational field strength, g (N/kg)	M1a, M2a, M3a, M3b, M3c, M3d
PM2.3iv	recall and apply: (in a gravity field) potential energy (J) = mass (kg) x height (m) x gravitational field strength, g (N/kg)	M1a, M2a, M3a, M3b, M3c, M3d

<table>
<tr><th colspan="2">Topic content</th><th colspan="2">Opportunities to cover:</th><th rowspan="2">Practical suggestions</th></tr>
<tr><th>Learning outcomes</th><th>To include</th><th>Maths</th><th>Working scientifically</th></tr>
<tr><td>P2.3a explain, that to stretch, bend or compress an object, more than one force has to be applied</td><td>applications to real life situations</td><td></td><td>WS1.1b, WS1.1e, WS1.2a, WS1.2b, WS1.2c, WS1.2e, WS1.3a, WS1.3c, WS1.3e, WS1.3f, WS1.3g, WS2a, WS2b, WS2c</td><td>Use of a liquorice bungee or spring to explore extension and stretching. (PAG P2)</td></tr>
<tr><td>P2.3b describe the difference between elastic and plastic deformation (distortions) caused by stretching forces</td><td></td><td></td><td>WS1.1b, WS1.1e, WS1.2a, WS1.2b, WS1.2c, WS1.2e, WS1.3a, WS1.3c, WS1.3e, WS1.3f, WS1.3g, WS2a, WS2b, WS2c</td><td>Comparisons of behaviour of springs and elastic bands when loading and unloading with weights. (PAG P2)</td></tr>
<tr><td>P2.3c describe the relationship between force and extension for a spring and other simple systems</td><td>graphical representation of the extension of a spring</td><td>M1a, M2a, M4a, M4b, M4c</td><td>WS1.1b, WS1.1e, WS1.2a, WS1.2b, WS1.2c, WS1.2e, WS1.3a, WS1.3c, WS1.3e, WS1.3f, WS1.3g, WS1.4f, WS2a, WS2b, WS2c</td><td>extension of a spring (Hooke's law). Investigation of forces on springs – Hooke's law. (PAG P2)</td></tr>
</table>

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P2.3d	describe the difference between linear and non-linear relationships between force and extension		M1a, M2a, M4a, M4b, M4c	WS1.1b, WS1.1e, WS1.2a, WS1.2b, WS1.2c, WS1.2e, WS1.3a, WS1.3c, WS1.3e, WS1.3f, WS1.3g, WS2a, WS2b, WS2c	Investigation of the elastic limit of springs and other materials. (PAG P2)
P2.3e	calculate a spring constant in linear cases		M1a, M2a, M3a, M3b, M3c, M3d		
P2.3f	calculate the work done in stretching		M1a, M2a, M3a, M3b, M3c, M3d, M4a, M4b, M4c, M4f	WS1.1b, WS1.2a, WS1.2b, WS1.2c, WS1.2e, WS1.3a, WS1.3c, WS1.3e, WS1.3f, WS1.3g, WS1.4f, WS2c	Use of data from stretching an elastic band with weights to plot a graph to calculate the work done. (PAG P2)
P2.3g	describe that all matter has a gravitational field that causes attraction, and the field strength is much greater for massive objects				
P2.3h	define weight, describe how it is measured and describe the relationship between the weight of an object and the gravitational field strength (g)	knowledge that the gravitational field strength is known as g and has a value of 10N/kg at the Earth's surface		WS1.1b	Calculations of weight on different planets.
P2.3i	recall the acceleration in free fall				

Topic P3: Electricity and magnetism

P3.1 Static and charge

Summary

Having established the nature of matter, consideration is now given to the interactions between matter and electrostatic fields. These interactions are derived from the structure of matter which was considered. The movement of charge is considered. Charge is a fundamental property of matter. There are two types of charge which are given the names 'positive' and 'negative'. The effects of these charges are not normally seen as objects generally contain equal amounts of positive and negative charge.

Underlying knowledge and understanding

Learners should be aware of electron transfer leading to objects becoming statically charged and the forces between them. They should also be aware of the existence of an electric field.

Common misconceptions

Learners commonly have difficulty classifying materials as insulators or conductors. They find it difficult to remember that positive charge does not move to make a material positive, rather it is the movement of electrons.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
PM3.1i	recall and apply: charge flow (C) = current (A) x time (s)	M1a, M2a, M3a, M3b, M3c, M3d

Topic content			Opportunities to cover:		
Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P3.1a	describe that charge is a property of all matter and that there are positive and negative charges.	the understanding that in most bodies there are an equal number of positive and negative charges resulting in the body having zero net charge.		WS1.1b, WS1.1e, WS1.2a, WS1.3e, WS2a	Use of charged rods to repel or attract one another. Use of a charged rod to deflect water or pick up paper. Discussion of why charged balloons are attracted to walls.
P3.1b	describe the production of static electricity, and sparking, by rubbing surfaces, and evidence that charged objects exert forces of attraction or repulsion on one another when not in contact	the understanding that static charge only builds up on insulators		WS1.1b, WS1.1e, WS1.2a, WS1.3e	Use of a Van de Graaff generator.
P3.1c	explain how transfer of electrons between objects can explain the phenomena of static electricity			WS1.1b, WS1.3e, WS1.3f, WS2a	Use of the gold leaf electroscope and a charged rod to observe and discuss behaviour.
P3.1d	recall that current is a rate of flow of charge (electrons) and the conditions needed for charge to flow	conditions for charge to flow: source of potential difference in a closed circuit			
P3.1e	recall that current has the same value at any point in a single closed loop				
P3.1f	recall and use the relationship between quantity of charge, current and time		M1a, M2a, M3a, M3b, M3c, M3d		

P3.2 Simple circuits

Summary

Electrical currents depend on the movement of charge and the interaction of electrostatic fields. Electrical current, potential difference and resistance are all discussed in this section. The relationship between them is considered, and learners will investigate the relationship using conventional circuits.

Underlying knowledge and understanding

Learners should have been introduced to the measurement of conventional current and potential difference in circuits. They will have an understanding of how to assemble series and parallel circuits and of how they differ with respect to conventional current and potential difference. Learners are expected to have an awareness of the relationship between potential difference, current and resistance and the units in which they are measured.

Common misconceptions

Learners find the concept of potential difference very difficult to grasp. They find it difficult to understand the behaviour of charge in circuits and through components and how this relates to energy or work done within a circuit.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
PM3.2i	recall and apply: potential difference (V) = current (A) x resistance (Ω)	M1a, M2a, M3a, M3b, M3c, M3d
PM3.2ii	recall and apply: energy transferred (J) = charge (C) x potential difference (V)	M1a, M2a, M3a, M3b, M3c, M3d
PM3.2iii	recall and apply: power (W) = potential difference (V) x current (A) = (current (A))^2 x resistance (Ω)	M1a, M2a, M3a, M3b, M3c, M3d
PM3.2iv	recall and apply: energy transferred (J, kWh) = power (W, kW) x time (s, h)	M1a, M2a, M3a, M3b, M3c, M3d

Topic content			Opportunities to cover:		Practical suggestions
Learning Outcomes		To include	Maths	Working Scientifically	
P3.2a	describe the differences between series and parallel circuits	positioning of measuring instruments in circuits and descriptions of the behaviour of energy, current and potential difference		WS1.1b, WS1.2a, WS1.2b, WS1.2c, WS1.3a, WS1.3b, WS1.3e, WS1.3f, WS1.3h, WS1.4a, WS2a, WS2b, WS2c, WS2d	Building of circuits to measure potential difference and current in both series and parallel circuits. (PAG P6)
P3.2b	represent d.c. circuits with the conventions of positive and negative terminals, and the symbols that represent common circuit elements	diodes, LDRs, NTC thermistors, filament lamps, ammeter, voltmeter and resistors		WS1.1b, WS1.2a, WS1.2b, WS1.2c, WS1.3a, WS1.3b, WS1.3e, WS1.3f, WS1.3h, WS1.4a, WS2a, WS2b, WS2c, WS2d	Building circuits from diagrams. (PAG P6)
P3.2c	recall that current (I) depends on both resistance (R) and potential difference (V) and the units in which these are measured	the definition of potential difference		WS1.1b, WS1.2a, WS1.2b, WS1.2c, WS1.3a, WS1.3b, WS1.3c, WS1.3e, WS1.3f, WS1.3h, WS1.4a, WS2a, WS2b, WS2c, WS2d	Recording of p.d. across and current through different components and calculate resistances. (PAG P6)

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P3.2d	recall and apply the relationship between I, R and V and that for some resistors the value of R remains constant but that in others it can change as the current changes		M1a, M2a, M3a, M3b, M3c, M3d	WS1.1b, WS1.2a, WS1.2b, WS1.2c, WS1.3a, WS1.3b, WS1.3c, WS1.3e, WS1.3f, WS1.3h, WS1.4a, WS2a, WS2b, WS2c, WS2d	Investigation of resistance in a wire. (PAG P6) Investigation of the effect of length on resistance in a wire. (PAG P6)
P3.2e	explain that for some resistors the value of R remains constant but that in others it can change as the current changes				
P3.2f	explain the design and use of circuits to explore such effects	components such as wire of varying resistance, filament lamps, diodes, NTC thermistors and LDRs			Building circuits and measurement of current and potential difference.
P3.2g	use graphs to explore whether circuit elements are linear or non-linear (M4c, M4d)		M4c, M4d	WS1.1b, WS1.2a, WS1.2b, WS1.2c, WS1.3a, WS1.3b, WS1.3c, WS1.3e, WS1.3f, WS1.3h, WS1.4a, WS2a, WS2b, WS2c, WS2d	Investigation of I-V characteristics of circuit elements. (PAG P6)
P3.2h	use graphs and relate the curves produced to the function and properties of circuit elements (M4c, M4d)	components such as wire of varying resistance, filament lamps, diodes, NTC thermistors and LDRs	M4c, M4d	WS1.1b, WS1.2a, WS1.2b, WS1.2c, WS1.3a, WS1.3b, WS1.3c, WS1.3e, WS1.3f, WS1.3h, WS1.4a, WS2a, WS2b, WS2c, WS2d	Use of wires, filament lamps, diodes, in simple circuits. Alter p.d. and keep current same using variable resistor. Record and plot results. (PAG P6)

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P3.2i	explain, why, if two resistors are in series the net resistance is increased, whereas with two in parallel the net resistance is decreased (qualitative explanation only)		M1c	WS1.1b, WS1.2a, WS1.2b, WS1.2c, WS1.3a, WS1.3b, WS1.3e, WS1.3f, WS1.3h, WS1.4a, WS2a, WS2b, WS2c, WS2d	Investigation of the brightness of bulbs in series and parallel. (PAG P6)
P3.2j	calculate the currents, potential differences and resistances in d.c. series and parallel circuits	components such as wire of varying resistance, filament lamps, diodes, NTC thermistors and LDRs	M1a, M2a, M3a, M3b, M3c, M3d	WS1.1b, WS1.2a, WS1.2b, WS1.2c, WS1.3a, WS1.3b, WS1.3c, WS1.3e, WS1.3f, WS1.3h, WS1.4a, WS2a, WS2b, WS2c, WS2d	Investigation of resistance of a thermistor in a beaker of water being heated. (PAG P6) Investigation of resistance of an LDR with exposure to different light intensities. (PAG P6) Investigation of how the power of a photocell depends on its surface area and its distance from the light source. (PAG P6)
P3.2k	explain the design and use of such circuits for measurement and testing purposes				
P3.2l	explain how the power transfer in any circuit device is related to the potential difference across it and the current, and to the energy changes over a given time				

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P3.2m	apply the equations relating potential difference, current, quantity of charge, resistance, power, energy, and time, and solve problems for circuits which include resistors in series, using the concept of equivalent resistance (M1c, M3b, M3c, M3d)		M1c, M3b, M3c, M3d		

P3.3 Magnets and magnetic fields

Summary

Having an understanding of the flow of charge and its effects, we can now consider the links between movement of charge and magnetism. To begin, learners will investigate magnets and magnetic fields around magnets and current-carrying wires.

Underlying knowledge and understanding

Learners should have been introduced to magnets and the idea of attractive and repulsive forces. They should have an idea of the shape of the fields around bar magnets. Learners are expected to have an awareness of the magnetic effect of a current and electromagnets.

Common misconceptions

Learners hold the misconception that larger magnets will always be stronger magnets. They also have difficulty understanding the concept of field line density being an indicator of field strength. Learners often do not know that the geographic and magnetic poles are not located in the same place.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers. All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
PM3.3i	**apply: force on a conductor (at right angles to a magnetic field) carrying a current (N) = magnetic flux density (T) x current (A) x length (m)**	**M1a, M1b, M1d, M2a, M3a, M3b, M3c, M3d**

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P3.3a	describe the attraction and repulsion between unlike and like poles for permanent magnets	diagrams of magnetic field patterns around bar magnets to show attraction and repulsion		WS1.1b, WS1.2a, WS1.2b, WS2a, WS2b	Using suspended magnets to show attraction and repulsion.
P3.3b	describe the difference between permanent and induced magnets				
P3.3c	describe the characteristics of the magnetic field of a magnet, showing how strength and direction, change from one point to another	diagrams to show attraction and repulsion and also depict how the strength of the field varies around them and ways of investigating this	M5b	WS1.1b, WS1.2a, WS1.2b, WS2a, WS2b, WS2c	Plotting of magnetic fields and use of dipping compass.

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P3.3d	explain how the behaviour of a magnetic (dipping) compass is related to evidence that the core of the Earth must be magnetic				
P3.3e	describe how to show that a current can create a magnetic effect and describe the directions of the magnetic field around a conducting wire			WS1.1b, WS1.2a, WS1.2b, WS2a, WS2b, WS2c	Investigation of the magnetic field around a current-carrying wire using plotting compasses.
P3.3f	recall that the strength of the field depends on the current and the distance from the conductor				
P3.3g	explain how solenoid arrangements can enhance the magnetic effect			WS1.1b, WS1.2a, WS1.2b, WS2a, WS2b, WS2c, WS2d	Investigation of the magnetic field around a current-carrying solenoid using plotting compasses. Investigation of factors that can affect the magnetic effect e.g. number of turns and length.
P3.3h	**describe how a magnet and a current-carrying conductor exert a force on one another**			WS1.1b, WS1.1e, WS1.2a, WS1.3e	Demonstration of the jumping wire experiment.
P3.3i	**show that Fleming's left-hand rule represents the relative orientations of the force, the current and the magnetic field**				

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P3.3j	**apply the equation that links the force on a conductor to the magnetic flux density, the current and the length of conductor to calculate the forces involved**		M1a, M1b, M1d, M2a, M3a, M3b, M3c, M3d		
P3.3k	**explain how the force exerted from a magnet and a current-carrying conductor is used to cause rotation in electric motors**	**an understanding of how electric motors work but knowledge of the structure of a motor is not expected**		WS1.1e, WS1.3e, WS2a	Construction of simple motors.

Topic P4: Waves and radioactivity

P4.1 Wave behaviour

Summary

Waves are means of transferring energy and the two main types of wave are introduced in this section: mechanical and electromagnetic. This section considers both what these types of waves are and how they are used. The main terms used to describe waves are defined and exemplified in this topic.

Underlying knowledge and understanding

Learners should have prior knowledge of transverse and longitudinal waves through sound and light. Learners should be aware of how waves behave and how the speed of a wave may change as it passes through different media. They may already have knowledge of how sound is heard and the hearing ranges of different species.

Common misconceptions

Although they will often have heard of the terms ultrasound and sonar, learners find it challenging to explain how images and traces are formed and to apply their understanding to calculations. Learners often misinterpret displacement distance and displacement-time graph presentation of waves.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
PM4.1i	recall and apply: wave speed (m/s) = frequency (Hz) x wavelength (m)	M1a, M1b, M1c, M2a, M3a, M3b, M3c, M3d

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P4.1a	describe wave motion in terms of amplitude, wavelength, frequency and period			WS1.1b, WS1.3b, WS1.3e	Observing sound waves on an oscilloscope.
P4.1b	define wavelength and frequency				
P4.1c	describe and apply the relationship between wavelength, frequency and the wave velocity		M1a, M1b, M1c, M2a, M3a, M3b, M3c, M3d	WS1.1b, WS1.3a, WS1.3b, WS1.3c, WS1.3d, WS1.3e, WS1.3g, WS1.3h, WS2a, WS2b	Investigation of reflection in a ripple tank. (PAG P4)
P4.1d	apply formulae relating velocity, frequency and wavelength (M1c, M3c)		M1c, M3c		
P4.1e	describe differences between transverse and longitudinal waves	direction of travel and direction of vibration		WS1.1b, WS1.3e	Use of a slinky to model waves.
P4.1f	describe how ripples on water surfaces are used to model transverse waves whilst sound waves in air are longitudinal waves, and how the speed of each may be measured			WS1.1b, WS1.3a, WS1.3b, WS1.3c, WS1.3d, WS1.3e, WS1.3g, WS1.3h, WS2a, WS2b	Investigation of refraction in a ripple tank. (PAG P4)
P4.1g	describe evidence that in both cases it is the wave and not the water or air itself that travels				

P4.2 The electromagnetic spectrum

Summary

Having looked at mechanical waves, waves in the electromagnetic spectrum are now considered. This section includes the application of electromagnetic waves with a specific focus on the behaviour of light. Alongside this, it explores the application of other types of electromagnetic radiation for use in medical imaging.

Underlying knowledge and understanding

Learners may be familiar with the uses of some types of radiation but an understanding of all parts of the electromagnetic spectrum is not expected and should be taught as new content.

Common misconceptions

Learners can have misconceptions such as gamma rays, X-rays, ultraviolet light, visible light, infrared light, microwaves and radio waves being independent entities and not being able to view it as a spectrum. They struggle to link the features that waves have in common, alongside the differences and how these relate to their different properties.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P4.2a	recall that electromagnetic waves are transverse and are transmitted through space where they all have the same velocity				
P4.2b	explain that electromagnetic waves transfer energy from source to absorber	examples from a range of electromagnetic waves			
P4.2c	apply the relationships between frequency and wavelength across the electromagnetic spectrum (M1a, M1c, M3c)		M1a, M1c, M3c	WS1.1b, WS1.3b, WS1.3e	Investigation of electromagnetic waves on chocolate or processed cheese in a microwave to measure wavelength. (PAG P4)
P4.2d	describe the main groupings of the electromagnetic spectrum and that these groupings range from long to short wavelengths and from low to high frequencies	radio, microwave, infra-red, visible (red to violet), ultra-violet, X-rays and gamma-rays		WS1.1c, WS1.1d, WS1.1e, WS1.1f, WS1.1h, WS1.1i	Research and design a poster to show the properties, uses and dangers of the different electromagnetic wave groups.
P4.2e	describe that our eyes can only detect a limited range of the electromagnetic spectrum				

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P4.2f	recall that light is an electromagnetic wave				
P4.2g	give examples of some practical uses of electromagnetic waves in the radio, micro-wave, infra-red, visible, ultra-violet, X-ray and gamma-ray regions			WS1.1b, WS1.1d, WS1.1e, WS1.1f, WS1.1h, WS1.1i, WS1.3e, WS1.3f	Demonstration of how microwaves can be used to heat water in a beaker which can in turn be used to light a bulb. This will help to demonstrate that microwaves can heat water and in turn how food is heated. Use a microwave emitter and absorber to demonstrate behaviour of waves. (PAG P4) Use of a phone camera to look at the infra-red emitter on a remote control. (PAG P4)
P4.2h	describe how ultra-violet waves, X-rays and gamma rays can have hazardous effects, notably on human bodily tissues			WS1.1a, WS1.1c, WS1.1d, WS1.1e, WS1.1f, WS1.1h, WS1.1i	Show images of X-rays to discuss how the images are formed; their advantages and disadvantages. Investigation of the balance of risks for staff and patients during radiotherapy.
P4.2i	**recall that radio waves can be produced by, or can themselves induce, oscillations in electrical circuits**				
P4.2j	**recall that different substances may absorb, transmit, refract, or reflect electromagnetic waves in ways that vary with wavelength**				
P4.2k	**explain how some effects are related to differences in the velocity of electromagnetic waves in different substances**				

P4.3 Radioactivity

Summary

Having considered the general characteristics of waves and particles, we now move on to look at radioactive decay which combines these two ideas. The idea of isotopes is introduced, leading into looking at the different types of emissions from atoms.

Underlying knowledge and understanding

Learners should have prior understanding of the atomic model, chemical symbols and formulae. An understanding of radioactivity is not expected and should be taught as new content.

Common misconceptions

Learners tend to struggle with the concept that radioactivity is a random and unpredictable process. The idea of half-life is another area that can lead to confusion. Learners often find it difficult to understand that irradiating objects does not cause them to become radioactive.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P4.3a	recall that atomic nuclei are composed of both protons and neutrons, that the nucleus of each element has a characteristic positive charge		M5b		
P4.3b	recall that atoms of the same elements can differ in nuclear mass by having different numbers of neutrons				
P4.3c	use the conventional representation for nuclei to relate the differences between isotopes	identities, charges and masses			
P4.3d	recall that some nuclei are unstable and may emit alpha particles, beta particles, or neutrons, and electromagnetic radiation as gamma rays			WS1.1a, WS1.1b, WS1.2a, WS1.2d, WS1.3b, WS1.3f	Use of a Geiger-Müller tube and radioactive sources to investigate activity.
P4.3e	relate these emissions to possible changes in the mass or the charge of the nucleus, or both				

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P4.3f	use names and symbols of common nuclei and particles to write balanced equations that represent radioactive decay				
P4.3g	balance equations representing the emission of alpha, beta or gamma radiations in terms of the masses, and charges of the atoms involved (M1b, M1c, M3c)		M1b, M1c, M3c		
P4.3h	recall that in each atom its electrons are arranged at different distances from the nucleus, that such arrangements may change with absorption or emission of electromagnetic radiation and that atoms can become ions by loss of outer electrons	knowledge that inner electrons can be 'excited' when they absorb energy from radiation and rise to a higher energy level. When this energy is lost by the electron it is emitted as radiation. When outer electrons are lost this is called ionisation			
P4.3i	recall that changes in atoms and nuclei can also generate and absorb radiations over a wide frequency range	an understanding that these types of radiation may be from any part of the electromagnetic spectrum which includes gamma rays		WS1.1b, WS1.3e	Demonstration of fluorescence with a black light lamp and tonic water.
P4.3j	explain the concept of half-life and how this is related to the random nature of radioactive decay		M1c, M3d, M4a, M4c	WS1.1b, WS1.3a, WS1.3b, WS1.3c, WS1.3e, WS1.3f, WS1.3h, WS2a	Using dice to model random decay and half-life. Research how half-life can be used in radioactive dating.
P4.3k	**calculate the net decline, expressed as a ratio, during radioactive emission after a given (integral) number of half-lives (M1c, M3d)**	**half-life graphs**	M1c, M3d		

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P4.3l	recall the differences in the penetration properties of alpha-particles, beta-particles and gamma-rays			WS1.1b, WS1.2a, WS1.2b, WS1.2c, WS1.3a, WS1.3f, WS1.3g, WS1.3h	Use of Geiger-Müller tube, sources and aluminium plates of varying thicknesses to investigate change in count rate.
P4.3m	recall the differences between contamination and irradiation effects and compare the hazards associated with these two			WS1.1a, WS1.1b, WS1.2a, WS1.2d, WS1.3b, WS1.3f	Use of spark chamber to demonstrate a different type of activity counter.

Topic P5: Energy

P5.1 Work done

Summary
We now move on to consider how energy can be stored and transferred. This topic acts to consolidate the ideas of energy that have been covered in previous topics as it is a fundamental concept that underpins many of the ways in which matter interacts.

Underlying knowledge and understanding
Learners may have prior knowledge of energy listed as nine types, as this is the teaching approach often taken at Key Stage 2 and Key Stage 3 to increase accessibility to an abstract concept. Learners may find it difficult to move away from this idea but need to be able to approach systems in terms of energy transfers and stores. They will have an understanding that energy can be transferred in processes such as changing motion, burning fuels and in electrical circuits. Learners should also be aware of the idea of conservation of energy and that it has a quantity that can be calculated.

Common misconceptions
Learners may have misconceptions around energy being a fuel-like substance that matter has to 'use up', that resting objects do not have any energy and that all energy is transferred efficiently. There is also often confusion between forces and energy.

Tiering
Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Topic content		Opportunities to cover:		Practical suggestions
Learning outcomes	To include	Maths	Working scientifically	
P5.1a describe for situations where there are energy transfers in a system, that there is no net change to the total energy of a closed system (qualitative only)	the law of conservation of energy			
P5.1b describe all the changes involved in the way energy is stored when a system changes for common situations	an object projected upwards or up a slope, a moving object hitting an obstacle, an object being accelerated by a constant force, a vehicle slowing down, bringing water to a boil in an electric kettle		WS1.2a, WS1.2b, WS1.3c, WS1.3f, WS1.4a, WS1.4e, WS2a, WS2b, WS2c	Exploring energy stores and transfers in different object in a circus based activity. Objects could include a wind-up toy, a weight on a spring, a weight being lifted or dropped, water being heated, electrical appliances.

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P5.1c	describe the changes in energy involved when a system is changed by heating (in terms of temperature change and specific heat capacity), by work done by forces, and by work done when a current flows				
P5.1d	make calculations of the energy changes associated with changes in a system, recalling or selecting the relevant equations for mechanical, electrical, and thermal processes; thereby express in quantitative form and on a common scale the overall redistribution of energy in the system (M1a, M1c, M3c)	work done by forces, current flow, through heating and the use of kWh to measure energy use in electrical appliances in the home	M1a, M1c, M3c	WS1.3a, WS1.3b, WS1.3c, WS1.3e, WS2a, WS2b	Use of a joulemeter to measure the energy used by different electrical appliances. (PAG P5)
P5.1e	calculate the amounts of energy associated with a moving body, a stretched spring and an object raised above ground level		M1a, M1b, M1c, M2a, M3a, M3b, M3c, M3d	WS1.1b, WS1.2a, WS1.2b, WS1.2c, WS1.2e, WS1.3a, WS1.3b, WS1.3c, WS1.3e, WS2a, WS2b	Use of light gates and trolleys to investigate kinetic energy. (PAG P5) Use of a joulemeter and electrical motor to lift a weight to investigate potential energy. (PAG P5) Investigation of energy changes and efficiency of bouncy balls. (PAG P5)

P5.2 Power and efficiency

Summary

This considers the idea of conservation and dissipation of energy in systems and how this leads to the efficiency. Ways of reducing unwanted energy transfers and thereby increasing efficiency will be explored.

Underlying knowledge and understanding

Learners should be aware of the transfer of energy into useful and waste energies. They will have an understanding of power and how domestic appliances can be compared. Learners will have knowledge of insulators and how energy transfer is influenced by temperature. They should have an awareness of ways to reduce heat loss in the home.

Common misconceptions

Learners have the common misconception that energy can be 'used up' or that energy is truly lost in many energy transformations. They also tend to have the belief that energy can be completely changed from one form to another with no energy dissipated.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers. All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
PM5.2i	recall and apply: efficiency = useful output energy transfer (J)/input energy transfer (J)	M1a, M1b, M1d, M2a, M3a, M3b, M3c, M3d

Topic content			Opportunities to cover:		Practical suggestions
Learning Outcomes		To include	Maths	Working scientifically	
P5.2a	describe, with examples, the process by which energy is dissipated, so that it is stored in less useful ways				
P5.2b	describe how, in different domestic devices, energy is transferred from batteries or the a.c. from the mains	how energy may be wasted in the transfer to and within motors and heating devices			

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P5.2c	describe, with examples, the relationship between the power ratings for domestic electrical appliances and how this is linked to the changes in stored energy when they are in use			WS1.3a, WS1.3b, WS1.3c, WS1.3e, WS2a, WS2b	Use of a joulemeter to investigate the power output of different electrical appliances. (PAG P5)
P5.2d	calculate energy efficiency for any energy transfer		M1a, M1b, M1d, M2a, M3a, M3b, M3c, M3d		
P5.2e	**describe ways to increase efficiency**				
P5.2f	explain ways of reducing unwanted energy transfer	through lubrication and thermal insulation		WS1.1b, WS1.1e, WS1.1f, WS1.1g, WS1.1i, WS1.3b	Research, design and building of energy efficient model houses. Examination of thermograms of houses.
P5.2g	describe how the rate of cooling is effected by the thickness and thermal conductivity of its walls (qualitative only)			WS1.2a, WS1.2b, WS1.2c, WS1.3a, WS1.3c, WS1.3d, WS1.3e, WS1.3g, WS1.3h, WS1.3i, WS2a, WS2b, WS2c, WS2d	Investigation of rate of cooling with insulated and non-insulated copper cans. (PAG P5)

Topic P6: Global challenges

This topic seeks to integrate learners' knowledge and understanding of physical systems and processes, with the aim of applying it to global challenges. Applications of physics can be used to help humans improve their own lives and strive to create a sustainable world for future generations, and these challenges are considered in this topic. It therefore provides opportunities to draw together the concepts covered in earlier topics, allowing synoptic treatment of the subject of physics.

P6.1 Physics on the move

Summary
Learners will use their knowledge of forces and motion to develop their ideas about how objects are affected by external factors. They will develop a better understanding of these external factors to be able to understand how the design of objects such as cars may be modified to operate more safely.

Underlying knowledge and understanding
Learners should be familiar with how forces affect motion of objects. They may already have some knowledge of how vehicles are adapted to increase safety.

Common misconceptions
Learners tend to confuse the factors that affect thinking distance and braking distance, thinking that alcohol, drugs and tiredness will affect braking distance rather than thinking distance. It needs to be made clear the distinction between these two terms and that the combination of these gives us the stopping distance.

Tiering
Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P6.1a	recall typical speeds encountered in everyday experience for wind and sound, and for walking, running, cycling and other transportation systems		M1d		
P6.1b	estimate the magnitudes of everyday accelerations		M1d		

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P6.1c	make calculations using ratios and proportional reasoning to convert units and to compute rates (M1c, M3c)	conversion from non-SI to SI units	M1c, M3c		
P6.1d	explain methods of measuring human reaction times and recall typical results		M1a, M2a, M2b	WS1.2b, WS1.2c, WS1.2e, WS1.3a, WS1.3b, WS1.3c, WS1.3e, WS1.3g, WS1.3h, WS2a, WS2b, WS2c, WS2d	Investigation of reaction time using ruler drop experiments. (PAG P3)
P6.1e	explain the factors which affect the distance required for road transport vehicles to come to rest in emergencies and the implications for safety	factors that affect thinking and braking distance and overall stopping distance			
P6.1f	explain the dangers caused by large decelerations			WS1.1e, WS1.1f, WS1.1h, WS1.2a, WS1.2b, WS1.2c, WS1.2e, WS2a, WS2b	Research and building of casing on trolleys for eggs to investigate crumple zones and safety features in cars.

P6.2 Powering Earth

Summary

We are reliant on electricity for everyday life and this topic explores the production of electricity. Consideration will be given to the use of non-renewable and renewable resources and the problems that are faced in the efficient transportation of electricity to homes and businesses. Safe use of electricity in the home is also covered in this topic. It may be an opportunity to revisit power and efficiency.

Underlying knowledge and understanding

Learners should already be familiar with renewable and non-renewable energy resources. Learners are expected to have a basic understanding of how power stations work and the cost of electricity in the home. They may have some idea of electrical safety features in the home.

Common misconceptions

Learners often confuse the idea of energy with terms including the word power such as solar power. There are often difficulties in understanding that higher voltages are applied across power lines and not along them. Another common misconception is that batteries and wall sockets have current inside them ready to escape.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Maths skills
PM6.2i	apply: potential difference across primary coil (V) x current in primary coil (A) = potential difference across secondary coil (V) x current in secondary coil (A)	M1a, M1b, M1c, M1d, M2a, M3a, M3b, M3c, M3d

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
P6.2a	describe the main energy sources available for use on Earth, compare the ways in which they are used and distinguish between renewable and non-renewable sources	fossil fuels, nuclear fuel, bio-fuel, wind, hydro-electricity, tides and the Sun		WS1.1c, WS1.1d, WS1.1e, WS1.1f, WS1.1g, WS1.1h, WS1.1i, WS1.3e	Research of different energy sources. Demonstration of a steam engine and discussion of the transfer of energy taking place.

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
P6.2b	explain patterns and trends in the use of energy resources	the changing use of different resources over time	M2c	WS1.1a, WS1.1b, WS1.1c, WS1.1d, WS1.1e, WS1.1f, WS1.1g, WS1.1h, WS1.1i	Research and present information to convince people to invest in energy saving measures. Research how the use of electricity has changed in the last 150 years.
P6.2c	recall that, in the national grid, electrical power is transferred at high voltages from power stations, and then transferred at lower voltages in each locality for domestic use				
P6.2d	recall that step-up and step-down transformers are used to change the potential difference as power is transferred from power stations			WS1.1b, WS1.1e, WS1.1f, WS1.3e	Use of a model power line to demonstrate the energy losses at lower voltage and higher current.
P6.2e	explain how the national grid is an efficient way to transfer energy				
P6.2f	recall that the domestic supply in the UK is a.c.at 50 Hz and about 230 volts				
P6.2g	explain the difference between direct and alternating voltage			WS1.3b, WS1.3e	Use of a data logger to compare a.c. and d.c. output traces. (PAG P6)
P6.2h	recall the differences in function between the live, neutral and earth mains wires, and the potential differences between these wires			WS2a	Wiring of a plug.
P6.2i	explain that a live wire may be dangerous even when a switch in a mains circuit is open, and explain the dangers of providing any connection between the live wire and earth	the protection offered by insulation of devices			

Topic CS7: Practical skills

Compliance with the requirements for practical work

It is compulsory that learners complete at least *sixteen* practical activities.

OCR has split the requirements from the Department for Education '*Combined science GCSE subject content, July 2015*' – Appendix 4 into sixteen Practical Activity Groups or PAGs: **five** biology, **five** chemistry and **six** physics.

The Practical Activity Groups allow centres flexibility in their choice of activity. Upon completion of at least sixteen practical activities, each learner must have had the opportunity to use all of the apparatus and techniques described in the following tables of this topic.

The tables illustrate the apparatus and techniques required for each PAG and an example practical that may be used to contribute to the PAG. It should be noted that some apparatus and techniques can be used in more than one PAG. It is therefore important that teachers take care to ensure that learners do have the opportunity to use all of the required apparatus and techniques during the course with the activities chosen by the centre.

Within the specification there are a number of practicals that are described in the 'Practical suggestions' column. These can count towards each PAG. We are expecting that centres will provide learners with opportunities to carry out a wide range of practical activities during the course. These can be the ones described in the specification or can be practicals that are devised by the centre. Activities can range from whole investigations to simple starters and plenaries.

It should be noted that the practicals described in the specification need to be covered in preparation for the 15% of questions in the written examinations that will assess practical skills. Learners also need to be prepared to answer questions using their knowledge and understanding of practical techniques and procedures in written papers.

Safety is an overriding requirement for all practical work. Centres are responsible for ensuring appropriate safety procedures are followed whenever their learners complete practical work.

Use and production of appropriate scientific diagrams to set up and record apparatus and procedures used in practical work is common to all science subjects and should be included wherever appropriate.

Revision of the requirements for practical work

OCR will review the practical activities detailed in Topic 7 of this specification following any revision by the Secretary of State of the apparatus or techniques published specified in respect of the GCSE Combined Science A (Gateway Science) qualification.

OCR will revise the practical activities if appropriate.

If any revision to the practical activities is made, OCR will produce an amended specification which will be published on the OCR website. OCR will then use the following methods to communicate the amendment to Centres: Notice to Centres sent to all Examinations Officers, e-alerts to Centres that have registered to teach the qualification and social media.

The following list includes opportunities for choice and use of appropriate laboratory apparatus for a variety of experimental problem-solving and/or enquiry based activities.

Practical Activity Group (PAG)	Apparatus and techniques that the practical must use or cover	Example of a suitable biology activity (a range of practicals are included in the specification and centres can devise their own activity) *
B1 Microscopy	Use of appropriate apparatus, techniques and magnification, including microscopes, to make observations of biological specimens and produce labelled scientific drawings[7]	Investigate different magnification techniques to draw scientific diagrams from a number of biological specimens.
	Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, temperature, volume of liquids and gases, and pH[1]	
B2 Sampling techniques	Application of appropriate sampling techniques to investigate the distribution and abundance of organisms in an ecosystem via direct use in the field (to include: biotic and abiotic factors)	Investigation the differences in habitats using ecological sampling techniques.
	Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, temperature, volume of liquids and gases, and pH[1]	
B3 Rates of enzyme-controlled reactions	Safe use of appropriate heating devices and techniques including use of a Bunsen burner and a water bath or electric heater[2]	Investigate the factors that can affect the rate of enzyme activity.
	Use of appropriate apparatus and techniques for the observation and measurement of biological changes and/or processes[3]	
	Measurement of rates of reaction by a variety of methods including production of gas, uptake of water and colour change of indicator[5]	
	Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, temperature, volume of liquids and gases, and pH[1]	

Practical Activity Group (PAG)	Apparatus and techniques that the practical must use or cover	Example of a suitable biology activity (a range of practicals are included in the specification and centres can devise their own activity) *
B4 Photosynthesis	Use of appropriate apparatus and techniques for the observation and measurement of biological changes and/or processes[3]	Investigate the factors that can affect the rate of photosynthesis on *Cabomba*.
	Safe and ethical use of living organisms (plants or animals) to measure physiological functions and responses to the environment	
	Measurement of rates of reaction by a variety of methods including production of gas, uptake of water and colour change of indicator[5]	
	Safe use of appropriate heating devices and techniques including use of a Bunsen burner and a water bath or electric heater[2]	
	Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, temperature, volume of liquids and gases, and pH[1]	
B5 Microbiological techniques	Use of appropriate apparatus and techniques for the observation and measurement of biological changes and/or processes[3]	Investigate the effectiveness of antimicrobial agents on the growth of a bacterial lawn.
	Use of appropriate apparatus, techniques and magnification, including microscopes, to make observations of biological specimens and produce labelled scientific drawings[7]	
	Safe use of appropriate heating devices and techniques including use of a Bunsen burner and a water bath or electric heater[2]	
	Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, temperature, volume of liquids and gases, and pH[1]	

*** Centres are free to substitute alternative practical activities that also cover the apparatus and techniques from DfE: *Combined science GCSE subject content, July 2015* Appendix 4.**

[1,2,3,5,7] These apparatus and techniques may be covered in any of the groups indicated. Numbers correspond to that used in DfE: *Combined science GCSE subject content, July 2015* Appendix 4.

The following list includes opportunities for choice and use of appropriate laboratory apparatus for a variety of experimental problem-solving and/or enquiry based activities.

Practical Activity Group (PAG)	**Apparatus and techniques that the practical must use or cover**	**Example of a suitable chemistry activity (a range of practicals are included in the specification and centres can devise their own activity) ***
C1 Electrolysis	Use of appropriate apparatus and techniques to draw, set up and use electrochemical cells for separation and production of elements and compounds	Electrolysis of aqueous sodium chloride or aqueous copper sulfate solution testing for the gases produced.
C2 Distillation	Safe use of a range of equipment to purify and/or separate chemical mixtures including evaporation, filtration, crystallisation, chromatography and distillation[4]	Distillation of a mixture, for example, orange juice, cherry cola, hydrocarbons, inks
	Safe use of appropriate heating devices and techniques including use of a Bunsen burner and a water bath or electric heater[2]	
	Use of appropriate apparatus to make and record a range of measurements accurately, including mass, time, temperature, and volume of liquids and gases[1]	
C3 Separation techniques	Safe use of a range of equipment to purify and/or separate chemical mixtures including evaporation, filtration, crystallisation, chromatography and distillation[4]	Use of chromatography to identify the mixtures of dyes in an unknown ink
C4 Production of salts	Safe use of a range of equipment to purify and/or separate chemical mixtures including evaporation, filtration, crystallisation, chromatography and distillation[4]	Production of pure dry sample of a salt
	Use of appropriate apparatus to make and record a range of measurements accurately, including mass, time, temperature, and volume of liquids and gases[1]	
	Use of appropriate apparatus and techniques for conducting and monitoring chemical reactions, including appropriate reagents and/or techniques for the measurement of pH in different situations	
	Safe use and careful handling of gases, liquids and solids, including careful mixing of reagents under controlled conditions, using appropriate apparatus to explore chemical changes and/or products	
	Safe use of appropriate heating devices and techniques including use of a Bunsen burner and a water bath or electric heater[2]	

Practical Activity Group (PAG)	Apparatus and techniques that the practical must use or cover	Example of a suitable chemistry activity (a range of practicals are included in the specification and centres can devise their own activity) *
C5 Measuring rates of reaction	Use of appropriate apparatus to make and record a range of measurements accurately, including mass, time, temperature, and volume of liquids and gases[1]	Investigate the effect of surface area or concentration on the rate of an acid/ carbonate reaction
	Making and recording of appropriate observations during chemical reactions including changes in temperature and the measurement of rates of reaction by a variety of methods such as production of gas and colour change	

*** Centres are free to substitute alternative practical activities that also cover the apparatus and techniques from DfE: *Combined science GCSE subject content, July 2015* Appendix 4.**

[124] These apparatus and techniques may be covered in any of the groups indicated. Numbers correspond to those used in DfE: *Combined science GCSE subject content, July 2015* Appendix 4.

The following list includes opportunities for choice and use of appropriate laboratory apparatus for a variety of experimental problem-solving and/or enquiry based activities.

Practical Activity Group (PAG)	Apparatus and techniques that the practical must use or cover	Example of a suitable physics activity (a range of practicals are included in the specification and centres can devise their own activity) *
P1 Materials	Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature	Determine the densities of a variety of objects, both solid and liquid
	Use of such measurements to determine densities of solid and liquid objects[1]	
P2 Forces	Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature[1]	Investigate the effect of forces on springs
	Use of appropriate apparatus to measure and observe the effects of forces including the extension of springs	
P3 Motion	Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature[1]	Investigate acceleration of a trolley down a ramp
	Use of appropriate apparatus and techniques for measuring motion, including determination of speed and rate of change of speed (acceleration/deceleration)	
P4 Waves	Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature[1]	Use a ripple tank to measure the speed, frequency and wavelength of a wave
	Making observations of waves in fluids and solids to identify the suitability of apparatus to measure speed/frequency/wavelength. Making observations of the effects of the interaction of electromagnetic waves with matter	Investigate the reflection of light off a plane mirror and the refraction of light through prisms
P5 Energy	Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature[1]	Determine the specific heat capacity of a material
	Safe use of appropriate apparatus in a range of contexts to measure energy changes/transfers and associated values such as work done	
P6 Circuits	Use of appropriate apparatus to measure current, potential difference (voltage) and resistance, and to explore the characteristics of a variety of circuit elements	Investigate the I-V characteristics of circuit elements
	Use of circuit diagrams to construct and check series and parallel circuits including a variety of common circuit elements	

*** Centres are free to substitute alternative practical activities that also cover the apparatus and techniques from DfE: *Combined science GCSE subject content, July 2015* Appendix 4.**

[1] These apparatus and techniques may be covered in any of the groups indicated. Number corresponds to that used in DfE: *Combined science GCSE subject content, July 2015* Appendix 4.

Choice of activity

Centres can include additional apparatus and techniques within an activity beyond those listed as the minimum in the above tables. Learners *must* complete a *minimum of sixteen* practicals covering all the apparatus and techniques listed.

The apparatus and techniques can be covered:

(i) by using OCR suggested activities (provided as resources)
(ii) through activities devised by the Centre.

Centres can receive guidance on the suitability of their own practical activities through our free practical activity consultancy service (e-mail: ScienceGCSE@ocr.org.uk).

Where Centres devise their own practical activities to cover the apparatus and techniques listed above, the practical must cover all the requirements and be of a level of demand appropriate for GCSE. Each set of apparatus and techniques described in the middle column can be covered by more than one Centre devised practical activity e.g. "measurement of rates of reaction by a variety of methods including production of gas, uptake of water and colour change of indicator" could be split into two or more activities (rather than one).

2

NEA Centre Declaration Form: Practical Science Statement

Centres must provide a written **practical science statement** confirming that reasonable opportunities have been provided to all learners being submitted for entry within that year's set of assessments to undertake at least **sixteen** practical activities.

The practical science statement is contained within the NEA Centre Declaration Form which can be found on the OCR website at www.ocr.org.uk/formsfinder. By signing the form, the centre is confirming that they have taken reasonable steps to secure that each learner:

a) has completed the practical activities set by OCR as detailed in Topic CS7
b) has made a contemporaneous record of:
   (i) the work which the learner has undertaken during those practical activities, and
   (ii) the knowledge, skills and understanding which that learner has derived from those practical activities.

Centres should retain records confirming points (a) to (b) above as they may be requested as part of the JCQ inspection process. Centres must provide practical science opportunities for their learners. This does not go so far as to oblige centres to ensure that all of their learners take part in all of the practical science opportunities. There is always a risk that an individual learner may miss the arranged practical science work, for example because of illness. It could be costly for the centre to run additional practical science opportunities for the learner.

However, the opportunities to take part in the specified range of practical work must be given to all learners. Learners who do not take up the full range of opportunities may be disadvantaged as there will be questions on practical science in the GCSE (9–1) Combined Science A (Gateway Science) assessment. Please see the JCQ publication *Instructions for conducting non-examination assessments* for further information.

Any failure by a centre to provide a practical science statement to OCR in a timely manner (by means of an NEA Centre Declaration Form) will be treated as malpractice and/or maladministration [under General Condition A8 (*Malpractice and maladministration*)].

3

2d. Prior knowledge, learning and progression

- Learners in England who are beginning a GCSE (9–1) course are likely to have followed a Key Stage 3 programme of study.
- There are no prior qualifications required in order for learners to enter for a GCSE (9–1) in Combined Science A (Gateway Science).
- GCSEs (9–1) are qualifications that enable learners to progress to further qualifications either Vocational or General.

There are a number of science specifications at OCR. Find out more at: www.ocr.org.uk