GCSE

Rewarding Learning

CCEA GCSE Specification in

Double Award Science

For first teaching from September 2017
For first assessment from February 2018
For first award in Summer 2019
Subject Code: 1370

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1 Introduction

This specification sets out the content and assessment details for our GCSE course in Double Award Science. We have designed this specification to meet the requirements of:

- Northern Ireland GCSE Design Principles; and
- Northern Ireland GCE and GCSE Qualifications Criteria.

First teaching is from September 2017. We will make the first award based on this specification in Summer 2019.

This specification is a unitised course. The guided learning hours for this Double Award qualification are 240 hours.

The specification supports the aim of the Northern Ireland Curriculum to empower young people to achieve their potential and to make informed and responsible decisions throughout their lives, as well as its objectives:

- to develop the young person as an individual;
- to develop the young person as a contributor to society; and
- to develop the young person as a contributor to the economy and environment.

If there are any major changes to this specification, we will notify centres in writing. The online version of the specification will always be the most up to date; to view and download this please go to www.ccea.org.uk

1.1 Aims

This specification aims to encourage students to:

- develop their knowledge and understanding of the material, physical and living worlds;
- develop their understanding of the effects of science on society;
- develop their understanding of the importance of scale in science;
- develop and apply their knowledge and understanding of the nature of science and of the scientific process;
- develop their understanding of the relationships between hypotheses, evidence, theories and explanations;
- develop their awareness of risk and the ability to assess potential risk and potential benefits;
- develop and apply their observational, practical, modelling, enquiry and problem-solving skills and understanding in laboratory, field and other learning environments;
- develop their ability to evaluate claims based on science through critical analysis of the methodology, evidence and conclusions both qualitatively and quantitatively; and
- develop their skills in communication, mathematics and the use of technology in scientific contexts.

1.2 Key features

The following are important features of this specification.

- It offers opportunities to build on the skills and capabilities developed through the delivery of the Northern Ireland Curriculum at Key Stage 3.
- This specification is unitised and includes seven units.
- Units B1, C1 and P1 are available for assessment in the first year of teaching.
- All units are assessed through a written examination, either at Foundation Tier (grades C*–G) or Higher Tier (grades A*–D/E).
- Unit 7 is a practical skills unit that replaces the controlled assessment tasks:
  - Booklet A contains three practicals from the prescribed practicals listed in this specification; and
  - Booklet B is a timetabled written examination, taken at the end of the final year of teaching. It includes questions about planning and carrying out any of the prescribed practical activities and general questions about any practical situation that arises from this specification.
- Students receive two different grades in their Double Award Science qualification, such as AA or AB.
- Students can resit each unit once. Students must take at least 40 percent of the assessment (based on unit weightings) at the end of the course as terminal assessment.
- This specification encourages students to develop transferable skills that will benefit them in vocational training and employment. It also enables them to progress to studying science and related courses at GCE.
- Details of the mathematical skills expected of students are given in Appendix 1.

- The content in this specification is assessed in the context of How Science Works (see Appendix 2).
- There is a range of support available for both teachers and students, including specimen papers, mark schemes and planning frameworks. You can download these from our Science microsite at www.ccea.org.uk

1.3 Prior attainment

Students do not need to have reached a particular level of attainment before beginning to study this specification.

However, the specification builds on the knowledge, skills and understanding developed through the Northern Ireland Curriculum for science at Key Stage 3.

Before studying this specification, we expect students to have a level of skills in science, numeracy, literacy and communication that is commensurate with having studied science to Key Stage 3.

1.4 Classification codes and subject combinations

Every specification has a national classification code that indicates its subject area. The classification code for this qualification is 1370.

Please note that if a student takes two qualifications with the same classification code, schools, colleges and universities that they apply to may take the view that they have achieved only one of the two GCSEs. The same may occur with any two GCSE qualifications that have a significant overlap in content, even if the classification codes are different. Because of this, students who have any doubts about their subject combinations should check with the schools, colleges and universities that they would like to attend before beginning their studies.

2 Specification at a Glance

The table below summarises the structure of this GCSE course.

Content	Assessment	Weightings	Availability
Biology Unit B1: Cells, Living Processes and Biodiversity	External written examination Students answer compulsory structured questions that include short responses, extended writing and calculations. There are two tiers of entry. Foundation and Higher Tiers: 1 hour	11%	November, February and Summer From February 2018
Chemistry Unit C1: Structures, Trends, Chemical Reactions, Quantitative Chemistry and Analysis	External written examination Students answer compulsory structured questions that include short responses, extended writing and calculations. There are two tiers of entry. Foundation and Higher Tiers: 1 hour	11%	November, February and Summer From February 2018
Physics Unit P1: Motion, Force, Moments, Energy, Density, Kinetic Theory, Radioactivity, Nuclear Fission and Fusion	External written examination Students answer compulsory structured questions that include short responses, extended writing and calculations. There are two tiers of entry. Foundation and Higher Tiers: 1 hour	11%	November, February and Summer From February 2018

Content	Assessment	Weightings	Availability
Biology Unit B2: Body Systems, Genetics, Microorganisms and Health	External written examination Students answer compulsory structured questions that include short responses, extended writing and calculations. There are two tiers of entry. Foundation and Higher Tiers: 1 hour 15 mins	14%	Summer from 2019
Chemistry Unit C2: Further Chemical Reactions, Rates and Equilibrium, Calculations and Organic Chemistry	External written examination Students answer compulsory structured questions that include short responses, extended writing and calculations. There are two tiers of entry. Foundation and Higher Tiers: 1 hour 15 mins	14%	Summer from 2019
Physics Unit P2: Waves, Light, Electricity, Magnetism, Electromagnetism and Space Physics	External written examination Students answer compulsory structured questions that include short responses, extended writing and calculations. There are two tiers of entry. Foundation and Higher Tiers: 1 hour 15 mins	14%	Summer from 2019

Content	Assessment	Weightings	Availability
Unit 7: Practical Skills **This comprises Unit 7 Biology, Unit 7 Chemistry and Unit 7 Physics**	**Booklet A** Externally marked Students carry out three pre-release practicals (Biology, Chemistry and Physics) in the final year of study. There are two tiers of entry. Foundation and Higher Tiers: 3 hours	7.5%	Between 1 January and 1 May from 2019
	Booklet B External written examination Students answer compulsory structured questions that include short responses, extended writing and calculations, all set in a practical context for Biology, Chemistry and Physics. There are two tiers of entry. Foundation and Higher Tiers total time: 1 hour 30 mins (Biology 30 mins, Chemistry 30 mins and Physics 30 mins)	17.5% (Unit 7 total: 25%)	Summer from 2019

Students must take at least 40 percent of the assessment (based on unit weightings) at the end of the course as terminal assessment.

3 Subject Content

We have divided this course into seven units. The content of each unit and the respective learning outcomes appear below.

Content for the **Higher Tier only** is in **bold**.
Questions in Higher Tier papers may be set on any content in the specification.

Content for the Foundation Tier is in normal type.
Questions in Foundation Tier papers will only be set on this content.

The 18 prescribed practicals (six in each discipline), which are assessed in Booklets A and B of Unit 7: Practical Skills, are shown in *italics*.

3.1 Biology Unit B1: Cells, Living Processes and Biodiversity

In this unit, students learn about cells, photosynthesis, nutrition and health, enzymes, breathing and respiration, the nervous system and hormones, and ecological relationships. Students begin by investigating the cell and its importance as the fundamental building block of life, and develop their understanding of the key processes that occur in plants and animals. Finally, they carry out fieldwork in a natural ecosystem to observe living specimens and explore how organisms are adapted to their environment.

Cells

In this section, students prepare temporary slides of both plant and animal cells. They develop understanding of the structures and functions of animal and plant cells. Students compare and contrast the structures of animal, plant and bacterial cells. They gain understanding of the stages involved in the changes from a cell to a multicellular organism.

Content	Learning Outcomes
1.1 **Cells** **Microscopy** **Animal cells**	Students should be able to: 1.1.1 carry out practical work to make a temporary slide and use a light microscope to examine and identify the structures of a typical plant and animal cell; and 1.1.2 demonstrate knowledge of the structure and function of animal cells, including nucleus and chromosomes, cytoplasm, **mitochondria as the site of cell respiration**, and cell and nuclear membranes.

Content	Learning Outcomes
Plant cells **Bacterial cells** **Specialisation**	Students should be able to: 1.1.3 demonstrate knowledge that plant cells can have additional structures not found in animal cells: cellulose cell wall, large permanent vacuole and chloroplasts; 1.1.4 compare and contrast the structure of bacterial cells with plant and animal cells: non-cellulose cell wall, absence of nucleus and presence of plasmids; and 1.1.5 demonstrate knowledge and understanding that multicelled organisms' cells can form specialised tissues, organs and organ systems.

Photosynthesis and Plants

In this section, students develop understanding of leaf structure. They investigate and explain photosynthesis as the key process that enables plants to make food, as well as the role of plants in supporting life.

Content	Learning Outcomes
1.2 Photosynthesis and plants	Students should be able to: 1.2.1 demonstrate knowledge and understanding of photosynthesis as an endothermic process that takes place in chloroplasts, where chlorophyll absorbs light energy and produces sugars and starch;
Equation for photosynthesis	1.2.2 recall the word equation for photosynthesis carbon dioxide + water $\xrightarrow[\text{(chlorophyll)}]{\text{light}}$ glucose + oxygen **and the balanced chemical equation** $\mathbf{6CO_2 + 6H_2O \xrightarrow[(chlorophyll)]{light} C_6H_{12}O_6 + 6O_2}$
Investigating photosynthesis	1.2.3 explain investigations into how photosynthesis requires light, carbon dioxide and chlorophyll to show that biology is an evidence-based discipline, including: • how and why a plant is destarched; • testing a leaf for starch by boiling in water, boiling in ethanol, softening in water and testing with iodine solution; • the production of oxygen; • using sodium hydroxide to absorb carbon dioxide; and • using a variegated leaf to illustrate the role of chlorophyll; • *investigate the need for light and chlorophyll in photosynthesis by testing a leaf for starch (Prescribed Practical B1);* and
Limiting factors	1.2.4 explain how temperature, light intensity and carbon dioxide concentration affect the rate of photosynthesis **and interpret data on how the limiting factors affect the rate of photosynthesis**.

Content	Learning Outcomes
Gas exchange	Students should be able to: 1.2.5 **explain how the relationship between photosynthesis and respiration affects the gas exchange between organisms and their environment, including:** • **demonstrating knowledge of the colour changes of hydrogencarbonate indicator (high CO_2 – yellow, normal CO_2 – red and low CO_2 – purple); and** • **demonstrating compensation point;** and
Leaf structure	1.2.6 describe the structure and shape of the mesophytic leaf and identify its adaptations for gas exchange and light absorption, including: • the epidermis, with cell walls as a physical defence that are transparent to allow light through; • the waxy cuticle, which is a physical defence that is transparent to allow light through and waterproof to reduce water loss; • the palisade mesophyll cells, which are tightly packed, end on to the upper surface with many chloroplasts to increase photosynthesis; • the spongy mesophyll cells, with a few chloroplasts and a large surface area for gas exchange; • intercellular spaces, which allow diffusion of gases through the leaf; and • guard cells and stomata, which allow gases to diffuse into and out of the leaf.

Nutrition and Food Tests

In this section, students develop knowledge and understanding of the different food groups and their functions. They investigate food tests and energy content in food.

<table>
<tr><th>Content</th><th>Learning Outcomes</th></tr>
<tr><td>1.3
Nutrition and food tests

Enzymes and Digestion

In this section, students investigate enzymes and their role in digestion. They develop their knowledge and understanding of a range of factors that affect enzyme activity.

Content	Learning Outcomes
1.4 Enzymes and digestion	Students should be able to: 1.4.1 describe the actions of enzymes as proteins that are biological catalysts that speed up the rate of reactions without being used up, including carbohydrase (amylase), lipase and protease, and interpret the results using the lock and key model to illustrate substrate specificity; 1.4.2 interpret how temperature, pH, enzyme concentration **and inhibitors** affect the action of enzymes, including: • low temperature causing reduced rates of collision between substrate and enzyme; • describing the maximum rate of reaction as the optimum; • denaturation occurring increasingly at levels above the optimum, explained as an irreversible change to the shape of the active site that inhibits enzyme action; **and** • **inhibitors as molecules that fit the active site but are not broken down (no further detail required);** • *investigate the effect of temperature on the action of an enzyme (Prescribed Practical B3);* and 1.4.3 demonstrate knowledge and understanding that in food digestion, enzymes are needed to break down (digest) large, insoluble molecules into small, soluble ones that can then be absorbed into the bloodstream and that they have commercial and economic uses, including biological washing powders.

The Respiratory System, Breathing and Respiration

In this section, students explore how respiratory surfaces in plants and animals are adapted to ensure rapid gas exchange. They develop understanding of the effect of exercise on depth and rate of breathing. Students also learn about aerobic respiration and its similarities to and differences from anaerobic respiration.

Content	Learning Outcomes
1.5 The respiratory system, breathing and respiration **Respiratory surfaces**	Students should be able to: 1.5.1 explain the adaptations of respiratory surfaces in plants and animals, including large surface area, thin, moist, permeable, good blood supply and diffusion gradient;
	1.5.2 demonstrate knowledge and understanding of the effect of exercise on the depth and rate of breathing;
Respiration	1.5.3 demonstrate knowledge and understanding that respiration is a reaction **that is exothermic, taking place in mitochondria,** continuously releasing energy in all cells that organisms can use for heat, movement, growth, reproduction **and active uptake/transport**;
Equation for respiration	1.5.4 recall the word equation for aerobic respiration glucose + oxygen → energy + carbon dioxide + water **and the balanced chemical equation** **$C_6H_{12}O_6 + 6O_2 \rightarrow$ energy $+ 6CO_2 + 6H_2O$**
Aerobic and anaerobic respiration	1.5.5 compare and contrast aerobic respiration with anaerobic respiration in mammalian muscle glucose → energy + lactic acid and in yeast glucose → energy + alcohol + carbon dioxide
	1.5.6 carry out practical work to investigate the respiration of yeast.

Nervous System and Hormones

In this section, students develop understanding of how the nervous system and hormones are involved in co-ordination and internal maintenance in the body. They also explore the role of hormones in plants. Students develop knowledge and understanding of the excretory system and the homeostatic role of the kidney.

Content	Learning Outcomes
1.6 Nervous system and hormones	Students should be able to:
	1.6.1 compare and contrast the two communication systems (nervous and hormonal) in the human body, including the speed and nature of the response;
Central nervous system	1.6.2 describe and explain the basic structure and function of the central nervous system: the brain and spinal cord together form the central nervous system that controls and co-ordinates the responses between the receptors and effectors, and muscles;
Voluntary and reflex actions	1.6.3 distinguish between voluntary and reflex actions, referring to conscious control and speed of response;
Reflex arc	1.6.4 **demonstrate knowledge and understanding of the pathway of the spinal reflex arc, including:** • **a receptor that detects stimuli in the environment and produces nerve impulses**; • **a sensory, an association and a motor neurone connected by synapses (gaps between neurones)**; **and** • **an effector (a muscle or gland) that responds to impulses from the motor neurone;** and
Homeostasis	1.6.5 explain the importance of maintaining a constant internal environment for the proper functioning of cells and enzymes in response to internal and external change, limited to controlling blood glucose concentration and osmoregulation.

Content	Learning Outcomes
Hormones	Students should be able to: 1.6.6 demonstrate knowledge and understanding that hormones are chemical messengers produced by glands and released into the blood, which carries them to a target organ where they act, referring to: • the pancreas constantly monitoring blood glucose concentration; • the pancreas producing insulin in response to increasing blood glucose concentration; • insulin acting by causing the liver to absorb more glucose from the blood, so lowering blood glucose concentration; and • liver cells either respiring the absorbed glucose or converting it to glycogen, which they store;
Diabetes	1.6.7 demonstrate knowledge and understanding that: • diabetes is a condition in which the blood glucose control mechanism fails; • Type 1 diabetes usually occurs early in life when the pancreas stops producing insulin, which then has to be taken as medication throughout life; • Type 2 diabetes is a progressive disease linked to lifestyle factors and obesity, when the pancreas gradually produces less insulin, which in early stages means it can be controlled by diet but later may also require insulin injections; • the symptoms of diabetes include high blood glucose, glucose in the urine, lethargy and thirst; • possible long-term effects of diabetes include eye damage, kidney failure, heart disease and strokes; and • the number of people with diabetes in the population is rising and evaluate why; and
Excretory system	1.6.8 describe the gross structure of the excretory system, including the kidney (renal artery, renal vein, cortex, medulla and pelvis only, no detail of the nephron needed), ureters, bladder and urethra.

Content	Learning Outcomes
Osmoregulation	Students should be able to: 1.6.9 demonstrate knowledge and understanding of the kidney's homeostatic role in maintaining water balance in the body (osmoregulation), limited to: • water gained through intake of food and drink and the production of water by respiration; • water lost through evaporation of sweat, evaporation during breathing and the production of urine by the kidney; and • the role of the kidney in filtering the blood and controlling the reabsorption of water; 1.6.10 **explain the role of antidiuretic hormone (ADH) as a hormone that causes the kidney to reabsorb more water and so reduce the volume of urine production (negative feedback not required);**
Plant hormones	1.6.11 explain how plant hormones are important in controlling and co-ordinating plant growth and development, referring to phototropism in stems as a differential growth of cells caused by uneven distribution of the hormone auxin in response to unidirectional light; **and** 1.6.12 **extend their knowledge and understanding of phototropism, including:** • **auxin produced at the tip of the shoot;** • **auxin moving down the shoot;** • **light causing uneven distribution of auxin; and** • **auxin causing cell elongation, which results in bending of the shoot.**

Ecological Relationships and Energy Flow

In this section, students observe living specimens and carry out fieldwork in a natural ecosystem. Any plants or animals they collect should be returned to their habitat as soon as possible. Students explore how organisms are adapted to their environment and to compete for resources. They develop understanding that life on Earth is ultimately reliant on energy from the Sun and that this energy is transferred through the ecosystem by feeding relationships.

Content	Learning Outcomes
1.7 Ecological relationships and energy flow	Students should be able to:
	1.7.1 demonstrate knowledge and understanding of the terms biodiversity, population, habitat, environment, community and ecosystem;
Fieldwork	1.7.2 measure biotic and abiotic factors such as wind speed, water, pH, light, temperature and biodiversity (the number of plant and animal species) and explain how they affect communities;
	1.7.3 describe how to use quadrats to investigate changes in the distribution and population of organisms within a sample area of a habitat, limited to belt transect and random sampling;
	• *use quadrats to investigate the abundance of plants and/or animals in a habitat (Prescribed Practical B4);*
Competition	1.7.4 account for the distribution of plants and animals by describing how the organisms found have adapted to their environment and the competition for resources – water, light, space and minerals in plants and water, food, territory, mates and predators in animals – that can affect population growth and how humans influence the normal balance of ecosystems; and
Role of the Sun as energy source	1.7.5 demonstrate knowledge and understanding that the Sun is the source of energy for most ecosystems on Earth and demonstrate understanding of the role of green plants as producers in capturing this energy and making it available to other organisms.

Content	Learning Outcomes
Food chains and food webs	Students should be able to: 1.7.6 demonstrate knowledge and understanding of food chains and webs by: • identifying producers and consumers; • describing the differences between the trophic levels; and • understanding that arrows represent consumption and the transfer of substances (carbon and nitrogen) and energy through the ecosystem;
Decomposition	1.7.7 demonstrate knowledge and understanding of the decomposing action of saprophytic fungi and bacteria, including: • the secretion of enzymes, extracellular digestion and absorption; • recycling nutrients through the abiotic and biotic components of the ecosystem; and • forming humus; 1.7.8 investigate the key features of the decay process (temperature and water content) and their effect on the rate of decomposition in aerobic and anaerobic environments;
Carbon cycle	1.7.9 demonstrate knowledge and understanding of the significance of photosynthesis, respiration, combustion, fossilisation, feeding, excretion, egestion and decomposition in the carbon cycle, and how substances are constantly removed from and returned to the environment; **and**
Nitrogen cycle	1.7.10 **demonstrate knowledge and understanding of the role that microorganisms have in the nitrogen cycle, including nitrogen fixation, nitrification, denitrification and decomposition (knowledge of the names of specific bacteria is not required) and apply this to aerobic and anaerobic conditions, for example waterlogging.**

Content	Learning Outcomes
Minerals	Students should be able to: 1.7.11 demonstrate knowledge and understanding that plants absorb minerals from the soil through root hair cells **by active uptake/transport**, including: • absorption of nitrates for proteins; • root hair cells as specialised cells that are adapted to absorbing minerals and water from the soil by having an extended shape, providing an increased surface area; **and** • **active uptake/transport is a process that requires energy from respiration to transport the minerals against a concentration gradient;**
Eutrophication	1.7.12 **explain how sewage disposal and fertiliser run-off can cause eutrophication, including:** • **nitrates stimulating growth of aquatic plants and algae;** • **aquatic plants and algae dying due to subsequent nitrate depletion and shading;** • **the role of aerobic microorganisms in the decomposition of plants and algae; and** • **the consequences of oxygen depletion on other aquatic vertebrates and invertebrates.**

3.2 Biology Unit B2: Body Systems, Genetics, Microorganisms and Health

In this unit, students focus on osmosis and plant transport, the circulatory system, reproduction, fertility and contraception, genome, chromosomes, genes and DNA, cell division and genetics, variation and selection, microorganisms, defence mechanisms and cancer. Students develop their understanding of the processes involved in maintaining all life and investigate problems that arise due to genetic or environmental causes. Students also explore the issues associated with non-communicable diseases such as heart attacks, strokes and cancer.

Osmosis and Plant Transport

In this section, students investigate the transport of water between the cells and organs of a plant.

Content	Learning Outcomes
2.1 Osmosis and plant transport	Students should be able to: • *investigate the process of osmosis by measuring the change in length or mass of plant tissue or model cells, using Visking tubing (Prescribed Practical B5);*
Osmosis, plasmolysis and turgidity	2.1.1 identify changes in plant cell structure that occur in plasmolysed and turgid cells due to osmosis (linked to 1.1.3); 2.1.2 explain osmosis as diffusion of water molecules from a dilute solution to a more concentrated solution, through a selectively permeable membrane; 2.1.3 explain how osmosis causes plant cells to become plasmolysed and turgid and demonstrate knowledge and understanding of the role of the cell wall in limiting the entry of water; and
The potometer	• *use a potometer (bubble and weight potometer) to investigate the factors affecting the rate of water uptake by a plant and washing line method to investigate the factors affecting the rate of water loss from leaves (Prescribed Practical B6).*

Content	Learning Outcomes
Transpiration **Uses of water**	Students should be able to: 2.1.4 define transpiration as evaporation from mesophyll cells followed by diffusion through airspaces and stomata (linked to 1.2.6); 2.1.5 explain how surface area, wind, temperature, humidity and light intensity affect transpiration and the rate of water uptake by a plant (linked to 1.2.6); and 2.1.6 demonstrate knowledge and understanding that plants use water for support, transport, transpiration and photosynthesis.

The Circulatory System

In this section, students learn about the role of the circulatory system along with its components and their functions. They also investigate the effects of exercise on the circulatory system.

Content	Learning Outcomes
2.2 The circulatory system **Blood components**	Students should be able to: 2.2.1 use a microscope to examine a blood smear, identify the component parts and demonstrate understanding of their function: • red cells are a specialised cell adapted to oxygen transport – biconcave shape, absence of nucleus and haemoglobin containing iron; • white cells are a defence against disease; • platelets have a role in converting fibrinogen to fibrin, causing blood clotting and scab formation; and • plasma transports cells, food molecules, carbon dioxide, hormones and urea;
Cell lysis	2.2.2 **demonstrate knowledge and understanding of the effect of placing red blood cells in water, causing cell lysis (linked to 1.1.2 and 1.6.9);**
Blood vessels	2.2.3 describe the structure of blood vessels (arteries, veins and capillaries) and relate their structures to their functions, including: • wall thickness; • presence of muscle and elastic fibres; • lumen diameter; and • presence of valves; and 2.2.4 demonstrate knowledge and understanding of the role of the different types of blood vessel, including: • arteries carrying blood under high pressure away from the heart (usually oxygenated blood); • veins carry (usually deoxygenated) blood under low pressure towards the heart with valves that maintain the direction of flow; and • capillaries allowing the exchange of material with tissues through permeable walls.

Content	Learning Outcomes
Blood vessels (cont.)	Students should be able to:
	2.2.5 name and demonstrate knowledge and understanding of the functions of blood vessels entering and leaving the heart, lungs, liver, kidneys and intestine, describing the sequence and direction of flow in double circulation of oxygenated and deoxygenated blood;
Effects of exercise	2.2.6 investigate the effects of exercise on the pulse rate and describe how the circulatory system benefits from regular exercise – strengthened heart muscle and increased cardiac output when at rest; and
The heart	2.2.7 examine the heart and relate its structures to the function of a unidirectional pump, including identifying the four chambers, valves, thickness of muscle wall and coronary blood vessels.

Reproduction, Fertility and Contraception

In this section, students develop their understanding of human reproduction. They also address fertility issues and examine contraception as a mechanism for preventing pregnancy.

Content	Learning Outcomes
2.3 Reproduction, fertility and contraception	Students should be able to: 2.3.1 demonstrate knowledge and understanding of the structure and function of the male reproductive system, including the testes, urethra, scrotum, penis, sperm tube and prostate gland; 2.3.2 demonstrate knowledge and understanding of the structure and function of the female reproductive system, including the ovaries, oviducts, uterus, cervix and vagina;
Sperm formation and pregnancy	2.3.3 demonstrate knowledge and understanding that: • sperm cells are specialised cells (linked to 1.1.5) formed by meiosis and are adapted to their function by having a haploid nucleus**, mitochondria for energy production (linked to 1.1.2)** and a flagellum for swimming; • fertilisation takes place in the oviducts when the haploid sperm and egg nuclei fuse to give a diploid zygote; • the zygote divides by mitosis many times to form a ball of cells as it travels down the oviduct to the uterus; • after implantation in the uterus lining, the embryo then differentiates to produce a variety of tissues and organs; • the placenta is adapted for diffusion by having a large surface area for exchanging dissolved nutrients, oxygen, carbon dioxide and urea **and explain the role of villi in providing these adaptations**; • these substances are carried to or from the foetus in the blood vessels in the umbilical cord; and • the amnion and amniotic fluid cushion the foetus.

Content	Learning Outcomes
Sex hormones	Students should be able to: 2.3.4 demonstrate knowledge and understanding that testosterone, produced by the testes, and oestrogen, produced by the ovaries, are sex hormones (linked to 1.6.6) and recall the secondary sexual characteristics they cause to develop;
Menstrual cycle	2.3.5 describe the events of the menstrual cycle, including menstruation, ovulation, the time when fertilisation is most likely to occur and the roles of oestrogen and progesterone;
Infertility	2.3.6 **explain some of the causes of infertility and the following developments in fertility treatment:** • **the use of hormones to produce multiple ova;** • **in vitro fertilisation; and** • **the transfer of several embryos into the uterus;** and
Contraception	2.3.7 examine how different methods of contraception work and evaluate the advantages and disadvantages of each, including: • mechanical – the condom (male and female) as a barrier to prevent the passage of sperm and also prevent the spread of sexually transmitted infections (such as HIV leading to AIDS) some of which can lead to infertility if left untreated, for example chlamydia; • chemical – the contraceptive pill and implants, which change hormone levels and stop the development of the ovum; • surgical – male and female sterilisation to prevent the passage of sperm and ova respectively; and • an awareness that contraception can raise ethical issues for some people.

Genome, Chromosomes, Genes, DNA and Genetics

In this section, students develop understanding of the structure and function of chromosomes, genes and DNA. Students investigate the processes of cell division and monohybrid genetics. Students develop understanding that mutation can occur in genetic codes and they investigate opportunities and moral issues that are linked to our developing understanding in this area. They also learn about genetic engineering.

Content	Learning Outcomes
2.4 Genome, chromosomes, DNA and genetics	Students should be able to:
	2.4.1 describe the genome as the entire genetic material of an organism;
Chromosomes	2.4.2 identify and describe chromosomes as genetic structures occurring in functional pairs in the nucleus of cells, except gametes and bacteria (linked to 1.1.2 and 1.1.4);
Genes and alleles	2.4.3 identify and describe genes and alleles as sections of chromosomes made up of short lengths of DNA that operate as functional units to control characteristics and demonstrate understanding that alleles are different forms of the same gene;
DNA structure	2.4.4 demonstrate knowledge and understanding of the structure of DNA, including: • a phosphate and sugar (deoxyribose) backbone with interlinking bases to form a double helix; • base pairing rules and the unique nature of an individual's DNA; **and** • **the link between the DNA code and the build-up of amino acids in the correct sequence to form protein: the base triplet hypothesis (transcription and translation not required);** and
Cell division	2.4.5 demonstrate knowledge and understanding of mitosis as part of the cell cycle, limited to cell growth and cell division, which allows organisms to: • grow; • replace worn out cells; and • repair damaged tissue.

Content	Learning Outcomes
Mitosis	Students should be able to: 2.4.6 outline mitosis as the exact duplication of chromosomes producing daughter cells that are genetically identical to parent cells and clones (names of phases and details of DNA replication not required);
Meiosis	2.4.7 demonstrate knowledge and understanding of meiosis as reduction division (one cell producing four genetically different, haploid daughter cells) **and as a process that, through independent assortment, reassorts the chromosomes to provide variation (crossing over and the stages of meiosis are not required)**;
Genetic diagrams and terminology	2.4.8 demonstrate knowledge and understanding of and interpret genetic diagrams consisting of a single characteristic controlled by a single gene with two alleles (monohybrid cross) in plants, animals and humans, including: • dominant and recessive alleles; • genotype, phenotype, gamete and offspring ratios, percentages and probabilities; • homozygous and heterozygous genotypes; • Punnett squares to determine genotype frequencies; • **test (back) crosses to determine an unknown genotype; and** • **pedigree diagrams**;
The X and Y chromosomes	2.4.9 demonstrate knowledge and understanding of how sex is determined in humans; and
Genetic conditions	2.4.10 demonstrate knowledge and understanding of and explain the inheritance of these genetic conditions: • **haemophilia;** • cystic fibrosis; • Huntington's disease; and • Down's syndrome.

Content	Learning Outcomes
Genetic screening	Students should be able to: 2.4.11 explore the increasing understanding of the human genome and evaluate associated ethical issues of genetic screening, including: • who decides who will be tested; • benefits and risks of amniocentesis compared to blood tests; • the dilemma for carriers of genetic conditions after a test that diagnoses abnormalities; and • making genetic information available to wider society, for example insurance companies; and
Genetic engineering	2.4.12 demonstrate knowledge and understanding of genetic engineering as a process that modifies the genome of an organism to introduce desirable characteristics**, including:** • **the basic techniques used to produce human insulin for treatment of diabetes (transfer of a human insulin gene into a plasmid of a bacterial cell to form a genetically modified bacterium that can then be cultured in a fermenter to produce human insulin);** • **using restriction enzymes to produce 'sticky ends';** • **the need for down streaming (extraction, purification and packaging) to produce a pure form of insulin that can be used to treat diabetes; and** • **the advantages of producing human insulin and other products by this method**.

Variation and Natural Selection

In this section, students develop understanding of the nature of variation in living organisms and the relationship between variation and selection.

Content	Learning Outcomes
2.5 Variation and natural selection **Types of Variation**	Students should be able to: 2.5.1 investigate variation in living things and display data using appropriate graphical techniques, including: • height and length as examples of continuous variation (histogram); and • tongue rolling and hand dominance as examples of discontinuous variation (bar chart); 2.5.2 demonstrate knowledge and understanding that variation in living organisms has: • a genetic basis – mutations (random changes in the number of chromosomes or the structure of a gene) and sexual reproduction produce different phenotypes in a population; and • an environmental basis influencing the development of a phenotype (for example height in humans); and
Natural selection	2.5.3 demonstrate knowledge and understanding of how variation and natural selection may lead to evolution or extinction, including: • variation in the phenotypes of a population; • competition for resources often leading to differential survival of the best adapted phenotypes, for example antibiotic resistance; • surviving phenotypes are more likely to reproduce and pass on their genes to the next generation; • **the theory of evolution as a continuing process of natural selection that leads to gradual changes in organisms over time, which may result in the formation of a new species;** and • extinction of a species over time as a consequence of failure to adapt to environmental change.

Content	Learning Outcomes
Selective breeding	Students should be able to: 2.5.4 explain selective breeding in food plants and domesticated animals as a process in which: • humans select individual plants or animals for their desirable genetic characteristics, for example appearance, increased food quantity or quality or disease resistance, and breed them to produce offspring; and • repeated selection and breeding over many generations causes all the offspring to show the desired characteristic.

Health, Disease, Defence Mechanisms and Treatments

In this section, students learn about how diseases are caused by microorganisms and explore the body's defence mechanisms against disease. They explore the role of vaccinations and medicines in our lives and the adverse effects of misusing drugs. They also explore the causes of heart attacks, strokes and cancer along with some of the treatments for these diseases.

Content	Learning Outcomes
2.6 Health, disease, defence mechanisms and treatments	Students should be able to: 2.6.1 define health as being free from communicable and non-communicable disease; 2.6.2 explain the costs to society of communicable and non-communicable diseases, including the economic cost of treatment for the National Health Service;
Communicable diseases	2.6.3 demonstrate knowledge and understanding of the types of communicable diseases caused by microorganisms, how they are spread, prevented and treated, including: • bacteria (chlamydia, salmonella and tuberculosis); • viruses (HIV leading to AIDS, cold and flu and human papilloma virus (HPV)); and • fungi (athlete's foot and potato blight); and
Aseptic techniques	2.6.4 safely use aseptic techniques to grow uncontaminated colonies of bacteria in nutrient broth or on an agar plate, including: • sterilising Petri dishes, culture media, inoculating loops and culture bottles by autoclaving, flaming and alcohol to kill unwanted microorganisms; • needing to keep Petri dishes partially covered and to work near a Bunsen burner during inoculation to reduce the risk of contamination by microorganisms from the air; • incubating sealed Petri dishes at a maximum temperature of 25°C to avoid growth of pathogens; and • cleaning work surfaces and hands and safely disposing of bacterial cultures by autoclaving.

Content	Learning Outcomes
The body's defence mechanisms	Students should be able to: 2.6.5 demonstrate knowledge and understanding of the body's defence mechanisms, including: • the skin, mucous membranes and blood clotting; • the production of antibodies by white blood cells (lymphocytes) in response to antigens; • the role of antibodies in defence – antibody-antigen reaction, clumping, reduced spread of disease microorganisms and symptoms; • the role of phagocytes in engulfing and digesting microorganisms; • the role of memory lymphocytes in a secondary response; and • immunity, in terms of active and passive;
Antibiotics	2.6.6 demonstrate knowledge and understanding that antibiotics, for example penicillin, are chemicals produced by fungi that are used against bacterial diseases to kill bacteria or reduce their growth;
Antibiotic-resistant bacteria	2.6.7 **demonstrate knowledge and understanding of the implications on the health of the population of:** • **overuse of antibiotics leading to bacterial resistance, resulting in the development of superbugs such as MRSA; and** • **procedures to reduce the incidence of superbugs and why they are difficult to eradicate;** and
Vaccinations	2.6.8 demonstrate knowledge and understanding of the role of vaccines, including: • the use of modified disease-causing organisms to produce raised antibody levels and memory lymphocyte levels in the blood; **and** • **the role of booster vaccinations and the interpretation of graphs of blood antibody levels**.

Content	Learning Outcomes
Non-communicable diseases	Students should be able to: 2.6.9 recall that many non-communicable diseases may involve interactions between different types of disease and are caused by the interaction of these factors: • inherited – some people may carry a gene that predisposes them to some cancers; and • lifestyle, including: – poor diet: excess sugar and fat intake; – lack of exercise: energy used in exercise being lower than energy intake is the cause of obesity; – overexposure to the Sun: ultraviolet (UV) radiation causes mutations leading to skin cancer; – misuse of drugs: alcohol: binge drinking can cause liver disease and affect foetal development (foetal alcohol syndrome); tobacco smoke: tar can cause bronchitis (narrowing of bronchi and bronchioles), emphysema (damage to alveoli reducing the surface area for gas exchange) and lung cancer (abnormal cell division); nicotine is addictive and affects heart rate; and carbon monoxide combines with red blood cells to reduce the oxygen-carrying capacity of the blood; and 2.6.10 describe the interactions between different types of disease: obesity causing cardiovascular diseases and Type 2 diabetes.

Content	Learning Outcomes
Heart attacks and strokes	Students should be able to: 2.6.11 demonstrate knowledge and understanding of the cause and effect of a blockage in a blood vessel: • a blockage caused by a build-up of cholesterol deposits leads to clot formation; • restricted blood flow means less oxygen and glucose reaching cells, and the resulting reduced cell respiration leads to cell death; • a blockage in the coronary blood vessels restricts blood flow to the heart muscle and causes death of heart muscle cells (heart attack); and • a blockage in the blood vessels to the brain causes death of brain cells, resulting in reduced brain function (stroke); 2.6.12 explain these treatments for cardiovascular disease: • angioplasty and stents; and • statins and aspirin; 2.6.13 recall that certain lifestyle factors increase or reduce the risk of heart disease and strokes (excess dietary fats, smoking, stress and lack of exercise);
Cancer	2.6.14 recall that uncontrolled cell division produces cancer cells, which can result in two types of tumour: benign (encapsulated and not spreading) and malignant (capable of spreading); and 2.6.15 appreciate how lifestyle choices can affect the risk of developing certain types of cancer, for example cervical (HPV vaccine), lung (smoking) and skin (UV radiation).

3.3 Chemistry Unit C1: Structures, Trends, Chemical Reactions, Quantitative Chemistry and Analysis

In this unit, students cover atomic structure, bonding, structures, nanoparticles, symbols, formulae and equations, the Periodic Table, quantitative chemistry, acids, bases and salts, and chemical analysis. Students begin to develop understanding that all chemical elements are made up of atoms that consist of subatomic particles, and they use the arrangement of the electrons to explain what happens when elements react. They explain ionic, covalent and metallic bonding and describe the properties of the structures that form. They use this knowledge and understanding to write formulae and balanced symbol equations, and to explain the reactions of acids and alkalis.

Atomic Structure

In this section, students learn about atomic structures. They begin to develop understanding that all chemical elements are made up of atoms that consist of nuclei and electrons. They use data to deduce the number and arrangement of the subatomic particles in atoms, ions and isotopes.

Content	Learning Outcomes
1.1 Atomic structure	Students should be able to: 1.1.1 describe the structure of an atom as a central positively charged nucleus containing protons and neutrons (most of the mass) surrounded by orbiting electrons in shells; 1.1.2 state the relative charges and approximate relative masses of protons, neutrons and electrons; 1.1.3 define atomic number as the number of protons in an atom; 1.1.4 define mass number as the total number of protons and neutrons in an atom; 1.1.5 demonstrate knowledge and understanding that an atom as a whole has no electrical charge because the number of protons is equal to the number of electrons; and 1.1.6 calculate the number of protons, neutrons and electrons in an atom or an ion and deduce the charge on an ion or determine the number of subatomic particles given the charge.

Content	Learning Outcomes
1.1 Atomic structure (cont.)	Students should be able to: 1.1.7 write and draw the electronic configuration (structure) of atoms and ions with atomic number 1–20; 1.1.8 define isotopes as atoms of an element with the same atomic number but a different mass number, indicating a different number of neutrons; 1.1.9 interpret data on the number of protons, neutrons and electrons to identify isotopes of an element; 1.1.10 **calculate the relative atomic mass of elements from the mass number and abundances of its isotopes**; and 1.1.11 recall that a compound is two or more elements chemically combined.

Bonding

In this section, students use the arrangement of electrons in atoms to explain what happens when elements react. They examine ionic, covalent and metallic bonding.

Content	Learning Outcomes
1.2 Bonding **Ionic bonding**	Students should be able to: 1.2.1 demonstrate knowledge and understanding that an ion is a charged particle formed when an atom gains or loses electrons and a molecular ion is a charged particle containing more than one atom; 1.2.2 **define the terms cation and anion;** 1.2.3 explain, using dot and cross diagrams, how ions are formed and how ionic bonding takes place in simple ionic compounds, limited to elements in Groups 1 (I) and 2 (II) with elements in Groups 6 (VI) and 7 (VII), the ions of which have a noble gas electronic configuration; 1.2.4 demonstrate knowledge and understanding that: • ionic bonding involves attraction between oppositely charged ions; • ionic bonds are strong; and • substantial energy is required to break ionic bonds; 1.2.5 recognise that ionic bonding is typical of metal compounds;
Covalent bonding	1.2.6 describe a single covalent bond as a shared pair of electrons; 1.2.7 explain, using dot and cross diagrams, how covalent bonding occurs in H_2, Cl_2, HCl, **H_2O, NH_3, CH_4** and similar molecules and label lone pairs of electrons; 1.2.8 **draw dot and cross diagrams and indicate the presence of multiple bonds in O_2, N_2 and CO_2 ;** and 1.2.9 recognise covalent bonding as typical of non-metallic elements and compounds.

Content	Learning Outcomes
Covalent bonding (cont.)	Students should be able to: 1.2.10 demonstrate knowledge and understanding that a molecule is two or more atoms covalently bonded and that diatomic means there are two atoms covalently bonded in a molecule; 1.2.11 demonstrate knowledge and understanding that covalent bonds are strong and substantial energy is required to break covalent bonds; 1.2.12 demonstrate knowledge and understanding that a covalent bond may be represented by a line; **and**
Metallic bonding	1.2.13 **demonstrate knowledge and understanding that metallic bonding results from the attraction between the positive ions in a regular lattice and the delocalised electrons.**

Structures

In this section, students examine the structural models of ionic lattices and molecular covalent, giant covalent and metallic structures. They use these accepted models to explain the properties and uses of the different structures.

Content	Learning Outcomes
1.3 Structures **Ionic structures**	Students should be able to: 1.3.1 use the accepted structural model for giant ionic lattices to explain the physical properties of ionic substances such as sodium chloride, including melting point, boiling point and electrical conductivity (diagram of giant ionic lattice is not expected); 1.3.2 recall that most ionic compounds are soluble in water;
Molecular covalent structures	1.3.3 use the accepted structural model for molecular covalent structures to explain the physical properties of molecular covalent structures such as iodine and carbon dioxide, including melting point, boiling point and electrical conductivity; 1.3.4 demonstrate knowledge and understanding that the intermolecular forces between covalent molecules are weak forces called van der Waals' forces; 1.3.5 recall that many covalent molecular substances are insoluble in water;
Giant covalent structures	1.3.6 demonstrate knowledge and understanding of the giant covalent structure of carbon (diamond) and carbon (graphite), and predict and explain their physical properties, including: • electrical conductivity; • hardness; • melting point and boiling point; and • their uses in cutting tools (diamond), lubricants and pencils (graphite); **and**
Metallic structures	1.3.7 **use the accepted structural model for metals to predict and explain their structure and physical properties including melting point, malleability, ductility and electrical conductivity.**

Content	Learning Outcomes
Metallic structures (cont.)	Students should be able to: 1.3.8 demonstrate knowledge and understanding that an alloy is a mixture of two or more elements, at least one of which is a metal, and the resulting mixture has metallic properties;
Structure and bonding of carbon	1.3.9 demonstrate knowledge and understanding that carbon can form four covalent bonds; 1.3.10 demonstrate knowledge and understanding of the structure of graphene (a single atom thick layer of graphite), explain its physical properties, including strength and electrical conductivity, and recall its uses such as those in batteries and solar cells; 1.3.11 demonstrate knowledge and understanding of the meaning of the term allotrope as applied to carbon (diamond), carbon (graphite) and graphene; and
Classification of structures	1.3.12 **use given information to classify the structure of substances as giant ionic lattice, molecular covalent, giant covalent or metallic.**

Nanoparticles

In this section, students gain appreciation of this emerging area of science. They study applications of nanoparticles in medicine and other fields.

Content	Learning Outcomes
1.4 Nanoparticles	Students should be able to: 1.4.1 demonstrate knowledge and understanding that nanoparticles are structures that are 1–100 nm in size and contain a few hundred atoms; and 1.4.2 evaluate the benefits of nanoparticles in sun creams, including better skin coverage and more effective protection from the Sun's ultraviolet rays, and the risks, such as potential cell damage in the body and harmful effects on the environment.

Symbols, Formulae and Equations

In this section, students develop skills of writing formulae and writing and balancing symbol equations. This section may be tested throughout the specification, in both Units C1 and C2.

Content	Learning Outcomes
1.5 Symbols, formulae and equations	Students should be able to: 1.5.1 recognise symbols and names for common elements and recall the diatomic elements; 1.5.2 interpret chemical formulae by naming the elements and stating the number of each type of atom present; 1.5.3 write chemical formulae of compounds; 1.5.4 demonstrate understanding that chemical reactions use up reactants and produce new substances called products; 1.5.5 construct word equations to describe the range of reactions covered in this specification; 1.5.6 recognise that in a chemical reaction no atoms are lost or made but they are rearranged, and as a result we can write balanced symbol equations showing the atoms involved; 1.5.7 write balanced symbol equations for all reactions covered in this specification and for unfamiliar chemical reactions when the names of the reactants and products are specified; 1.5.8 **write balanced ionic equations for reactions, including reactions covered in this specification;** 1.5.9 **write half equations for reactions covered in this specification where appropriate;** and 1.5.10 demonstrate knowledge and understanding that in chemical equations the three states of matter are shown as (s), (l) and (g), with (aq) for aqueous solutions, and include appropriate state symbols in equations for the reactions in this specification.

The Periodic Table

In this section, students investigate how attempts to classify elements in a systematic way, including that of Mendeleev, have led, through the growth of chemical knowledge, to the modern Periodic Table. Students also examine important features of the Periodic Table and trends in Groups 1 (I) and 7 (VII).

Content	Learning Outcomes
1.6 **The Periodic Table** **Basic structure of the Periodic Table**	Students should be able to: 1.6.1 describe how Mendeleev arranged the elements in the Periodic Table and left gaps for elements that had not been discovered at that time, and how this enabled him to predict properties of undiscovered elements; 1.6.2 demonstrate knowledge and understanding of how scientific ideas have changed over time in terms of the differences and similarities between Mendeleev's Periodic Table and the modern Periodic Table; 1.6.3 describe an element as a substance that consists of only one type of atom and demonstrate understanding that elements cannot be broken down into simpler substances by chemical means; 1.6.4 demonstrate knowledge and understanding that a group is a vertical column in the Periodic Table and a period is a horizontal row; 1.6.5 identify and recall the position of metals and non-metals in the Periodic Table and distinguish between them according to their properties, including conduction of heat and electricity, ductility, malleability, melting point and sonority; 1.6.6 identify elements as solids, liquids and gases (at room temperature and pressure) in the Periodic Table; and 1.6.7 demonstrate knowledge and understanding that elements in the same group in the Periodic Table have the same number of electrons in their outer shell and this gives them similar chemical properties.

Content	Learning Outcomes
Basic structure of the Periodic Table (cont.)	Students should be able to: 1.6.8 recall that elements with similar properties appear in the same group (for example Group 1 (I) and Group 2 (II) are groups of reactive metals, Group 7 (VII) is a group of reactive non-metals and Group 0 is a group of non-reactive non-metals), locate these groups in the Periodic Table and recall the names of the groups;
Group 1 (I)	1.6.9 demonstrate knowledge and understanding that the alkali metals have low density and the first three are less dense than water; 1.6.10 assess and manage risks associated with the storage and use of alkali metals and recall that alkali metals are easily cut, are shiny when freshly cut and tarnish rapidly in air; 1.6.11 demonstrate knowledge and understanding that Group 1 (I) metals react with water to produce hydrogen and a metal hydroxide, and give observations for the reactions; 1.6.12 **demonstrate knowledge and understanding that alkali metals have similar chemical properties because when they react an atom loses an electron to form a positive ion with a stable electronic configuration;** 1.6.13 **write half equations for the formation of a Group 1 (I) ion from its atom;** 1.6.14 demonstrate knowledge and understanding of how the trend in reactivity down the group depends on the outer shell of electrons of the atoms; 1.6.15 demonstrate knowledge and understanding that most Group 1 (I) compounds are white and dissolve in water to give colourless solutions; and
Group 7 (VII)	1.6.16 recall data about the colour, physical state at room temperature and pressure, diatomicity and toxicity of the elements in Group 7 (VII), **interpret given data to establish trends within the group and make predictions based on these trends.**

Content	Learning Outcomes
Group 7 (VII) (cont.)	Students should be able to: 1.6.17 recall the observations when solid iodine sublimes on heating and demonstrate understanding of the term sublimation; 1.6.18 describe how to test for chlorine gas (damp universal indicator paper changes to red and then bleaches white); 1.6.19 **investigate the displacement reactions of Group 7 (VII) elements with solutions of other halides to establish the trend in reactivity within the group and make predictions based on this trend;** 1.6.20 demonstrate knowledge and understanding of how the reactivity down the group depends on the outer shell electrons of the atoms; 1.6.21 **demonstrate knowledge and understanding that the halogens have similar chemical properties because when they react an atom gains an electron to form a negative ion with a stable electronic configuration;** 1.6.22 **write half equations for the formation of a halide ion from a halogen molecule or atom;**
Group 0	1.6.23 use the concept of electronic configuration to explain the lack of reactivity and the stability of the noble gases; 1.6.24 recall that the noble gases are colourless gases; 1.6.25 **demonstrate knowledge and understanding of the trend in boiling points of the noble gases going down the group;** and
Transition metals	1.6.26 demonstrate knowledge that transition elements form ions with different charges (for example iron(II) and iron(III)) and form coloured compounds: • copper(II) oxide is black; • copper(II) carbonate is green; • hydrated copper(II) sulfate is blue; and • copper(II) salts are usually blue in solution.

Quantitative Chemistry

In this section, students examine calculations involving solid substances. They deduce relative molecular masses and use moles to determine reacting masses. They also appreciate that not all chemical reactions produce the expected amount of product and calculate the percentage yield.

Content	Learning Outcomes
1.7 Quantitative chemistry **Formula mass**	Students should be able to: 1.7.1 recall that the relative atomic mass (A_r) of an atom is the mass of the atom compared with that of the carbon-12 isotope, which has a mass of exactly 12, and demonstrate knowledge and understanding that A_r is a weighted mean of the mass numbers (linked to 1.1.10); 1.7.2 calculate the relative formula mass (M_r) (relative molecular mass) of a compound and the percentage of an element, by mass, in a compound;
The mole	1.7.3 demonstrate knowledge and understanding that chemical amounts are measured in moles and that the mass of one mole of a substance in grams is numerically equal to the relative formula mass; 1.7.4 convert the given mass of a substance to the amount of the substance in moles (and vice versa) by using the relative atomic or formula mass; 1.7.5 **calculate the reacting masses of reactants or products, given a balanced symbol equation and using moles and simple ratio, including examples where there is a limiting reactant;**
Percentage yield	1.7.6 **calculate the theoretical yield and the percentage yield of a chemical reaction given the actual yield; and** 1.7.7 **recognise possible reasons why the percentage yield of a product is less than 100%, including loss of product in separation from the reaction mixture, as a result of side reactions or because the reaction is reversible and may not go to completion.**

Acids, Bases and Salts

This section focuses on the classification of substances as acids and alkalis and how acids react with bases, carbonates and metals. Students develop understanding of what a salt is and learn about the colour of different salts.

Content	Learning Outcomes
1.8 Acids, bases and salts **Indicators and pH**	Students should be able to: 1.8.1 describe the effects of acidic, alkaline and neutral solutions on indicator papers (red and blue litmus papers and universal indicator paper) and the use of a pH meter to give pH data to at least one decimal place; 1.8.2 interpret given data about universal indicator (colour or pH) to classify solutions as acidic, alkaline or neutral and to indicate the relative strengths of acidic and alkaline solutions according to the following classification: • pH 0–2 strong acid; • pH 3–6 weak acid; • pH 7 neutral; • pH 8–11 weak alkali; and • pH 12–14 strong alkali; 1.8.3 demonstrate knowledge and understanding that acids dissolve in water to produce hydrogen (H^+ (aq)) ions; 1.8.4 **recall that the higher the concentration of hydrogen ions in an acidic solution, the lower the pH;** 1.8.5 demonstrate knowledge and understanding that alkalis dissolve in water to produce hydroxide (OH^- (aq)) ions; and 1.8.6 **demonstrate knowledge and understanding that strong acids and strong alkalis are completely ionised in water,** recall examples of strong acids (including hydrochloric acid, sulfuric acid and nitric acid) and recall examples of strong alkalis (including sodium hydroxide and potassium hydroxide).

Content	Learning Outcomes
Indicators and pH (cont.)	Students should be able to: 1.8.7 **demonstrate knowledge and understanding that weak acids and weak alkalis are partially ionised in water,** recall examples of weak acids (including ethanoic acid and carbonic acid) and recall examples of weak alkalis (including ammonia); 1.8.8 **explain dilute and concentrated in terms of the amount of substances in solution;**
Reactions of acids	1.8.9 describe neutralisation as the reaction between the hydrogen ions in an acid and the hydroxide ions in an alkali to produce water **and recall the ionic equation as:** $H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$ 1.8.10 investigate the temperature change during neutralisation and demonstrate understanding that neutralisation reactions are exothermic (heat is given out); 1.8.11 recall that a base is a metal oxide or hydroxide that neutralises an acid to produce a salt and water and that an alkali is a soluble base; 1.8.12 demonstrate knowledge and understanding of and write observations on and equations for the general reactions of hydrochloric, sulfuric and nitric acids with: • metals; • bases; • carbonates; and • hydrogencarbonates; 1.8.13 describe how to test for hydrogen gas: apply a lighted splint and a popping sound results; and 1.8.14 describe how to test for carbon dioxide: limewater (calcium hydroxide solution) will change from colourless to milky if the test is positive.

Content	Learning Outcomes
Salts	Students should be able to: 1.8.15 demonstrate knowledge and understanding that a salt is a compound formed when some or all of the hydrogen ions in an acid are replaced by metal ions or ammonium ions; 1.8.16 demonstrate knowledge and understanding that most Group 1 (I), Group 2 (II), aluminium and zinc salts are white and if they dissolve in water they give colourless solutions, and that transition metal salts are generally coloured; 1.8.17 develop awareness of the importance of safety in the laboratory to assess potential risks, including the hazards associated with chemicals labelled with the GHS/CLP international chemical hazard labelling (including toxic, corrosive, flammable, explosive and caution); and • *investigate the reactions of acids, including temperature changes that occur (Prescribed Practical C1)*.

Chemical Analysis

In this section, students examine what the term 'pure' means in a scientific context. They also investigate practical ways to separate mixtures and perform diagnostic tests for ions and other pure substances.

Content	Learning Outcomes
1.9 Chemical analysis **Assessing purity and separating mixtures**	Students should be able to: 1.9.1 demonstrate knowledge and understanding that a pure substance is a single element or compound not mixed with any other substance; 1.9.2 demonstrate knowledge and understanding that pure elements and compounds melt and boil at specific temperatures and melting point and boiling point can be used to distinguish pure substances from mixtures; 1.9.3 demonstrate knowledge and understanding that a formulation is a mixture that has been designed as a useful product and is formed by mixing together several different substances in carefully measured quantities to ensure the product has the required properties, for example alloys, medicines and fertilisers; 1.9.4 demonstrate knowledge and understanding of the terms soluble, insoluble, solute, solvent, solution, residue, filtrate, distillate, miscible, immiscible, evaporation and condensation; 1.9.5 investigate practically how mixtures can be separated using filtration, crystallisation, paper chromatography, simple distillation or fractional distillation (including using fractional distillation in the laboratory to separate miscible liquids, for example ethanol and water); 1.9.6 describe paper chromatography as the separation of mixtures of soluble substances by running a solvent (mobile phase) through the mixture on the paper (stationary phase), which causes the substances to move at different rates over the paper; and 1.9.7 interpret a paper chromatogram **including calculating R_f values**.

Content	Learning Outcomes
Assessing purity and separating mixtures (cont.) **Tests for ions**	Students should be able to: 1.9.8 analyse given data on mixtures to make judgements on the most effective methods of separation and plan experiments to carry out this separation; 1.9.9 use anhydrous copper(II) sulfate to test for water; 1.9.10 describe how to carry out a flame test using nichrome wire and concentrated hydrochloric acid to identify metal ions; 1.9.11 demonstrate knowledge of the flame colours of different metal ions: • lithium (crimson); • sodium (yellow/orange); • potassium (lilac); • calcium (brick red); and • copper(II) (blue–green/green–blue); and • *identify the ions in an ionic compound using flame tests (Prescribed Practical C2).*

3.4 Chemistry Unit C2: Further Chemical Reactions, Rates and Equilibrium, Calculations and Organic Chemistry

In this unit, students cover the reactivity series of metals, redox reactions, rates of reaction, equilibrium, organic chemistry, quantitative chemistry, electrochemistry, energy changes and gas chemistry. Students investigate experimentally the reactions of metals and use this to predict chemical properties of other metals. This knowledge is further applied to explain different types of reactions and their rate. Students investigate the chemistry of carbon and the importance of hydrocarbons. Throughout this unit, students are required to carry out mathematical calculations relevant to numerous reactions and processes.

Metals and the Reactivity Series

In this section, students investigate experimentally the reactions of metals with water, air (oxygen) and solutions containing other metal ions, to construct a reactivity series. Knowledge of the reactivity series is useful in predicting chemical properties of other metals and understanding how metals are extracted from their ores.

Content	Learning Outcomes
2.1 Metals and the reactivity series	Students should be able to: 2.1.1 recall the reactivity series of metals, including K, Na, Ca, Mg, Al, Zn, Fe and Cu; 2.1.2 describe the reactions, if any, of the above metals with the following and describe how to collect the gas produced, where appropriate: • air; • water; and • steam; 2.1.3 explain how the reactivity of metals is related to the tendency of a metal to form its positive ion; 2.1.4 explain and describe the displacement reactions of metals with other metal ions in solution; and 2.1.5 collect and/or analyse experimental data to predict where an unfamiliar element should be placed in the reactivity series or make predictions about how it will react.

Content	Learning Outcomes
2.1 Metals and the reactivity series (cont.)	Students should be able to: 2.1.6 examine the relationship between the extraction of a metal from its ore and its position in the reactivity series, for example: • aluminium, a reactive metal, is extracted by electrolysis; and • iron, a less reactive metal, is extracted by chemical reduction; and • *investigate the reactivity of metals (Prescribed Practical C3)*.

Redox, Rusting and Iron

In this section, students learn about oxidation and reduction. They study the extraction and uses of iron and investigate the cause and prevention of rusting.

Content	Learning Outcomes
2.2 Redox, rusting and iron	Students should be able to: 2.2.1 recognise oxidation and reduction in terms of loss or gain of oxygen or hydrogen and identify in a reaction or symbol equation which species is oxidised and which is reduced **(link to suitable industrial processes covered in this specification)**; 2.2.2 **recognise oxidation and reduction in terms of loss or gain of electrons and identify in a symbol equation, ionic equation or half equation which species is oxidised and which is reduced (link to suitable industrial processes covered in this specification);** 2.2.3 investigate experimentally rusting as a reaction of iron with water and air producing hydrated iron(III) oxide (other practical activity); 2.2.4 demonstrate knowledge and understanding of the methods used to prevent iron from rusting, including barrier methods such as painting, oiling, plastic coating and suitable metal coating or plating (galvanising)**, and explain sacrificial protection of iron related to the reactivity series**; 2.2.5 describe the extraction of iron from haematite including: • **the production of the reducing agent;** • the reduction of haematite; **and** • **the removal of acidic impurities;** and 2.2.6 demonstrate knowledge and understanding that iron is used in bridges and structures due to its strength.

Rates of Reaction

In this section, students explore the effects of changing concentration, temperature and particle size on the rate of different chemical reactions. They also learn about catalysts and activation energy.

Content	Learning Outcomes
2.3 Rates of reaction	Students should be able to: 2.3.1 demonstrate knowledge and understanding that the rate of a reaction may be determined by measuring the loss of a reactant or gain of a product over time and use the equation: $\text{rate} = \frac{1}{\text{time}}$ 2.3.2 suggest appropriate practical methods to measure the rate of a reaction and collect reliable data (methods limited to measuring a change in mass, gas volume or formation of a precipitate against time) for the reaction of: • metals with dilute acid; • calcium carbonate/marble chips with dilute hydrochloric acid; • catalytic decomposition of hydrogen peroxide; and • sodium thiosulfate with acid (equation not required); 2.3.3 interpret experimental data quantitatively, for example drawing and interpreting appropriate graphs to determine the rate of reaction; 2.3.4 **describe and explain the effects on rates of reaction when there are changes in:** • **temperature;** • **concentration;** • **frequency and energy of collisions between particles; and** • **changes in particle size in terms of surface area to volume ratio (other practical activity);** and 2.3.5 demonstrate knowledge and understanding that a catalyst is a substance which increases the rate of a reaction without being used up and recall that transition metals and their compounds are often used as catalysts.

Content	Learning Outcomes
2.3 **Rates of reaction (cont.)**	Students should be able to: 2.3.6 **explain catalytic action in terms of providing an alternative reaction pathway of lower activation energy;** and • *investigate how changing a variable changes the rate of reaction (Prescribed Practical C4)*.

Equilibrium

In this section, students learn about the concepts of reversible reactions and dynamic equilibrium.

Content	Learning Outcomes
2.4 Equilibrium	Students should be able to: 2.4.1 demonstrate knowledge and understanding that many chemical reactions are reversible and the direction of a reversible reaction can be changed by altering the reaction conditions; **and** 2.4.2 **demonstrate knowledge and understanding that dynamic equilibrium occurs in a closed system when the rates of forward and reverse reactions are equal and the amounts of reactants and products remain constant.**

Organic Chemistry

In this section, students examine the importance of oil to the chemical industry. They investigate the reactions of some simple carbon compounds. Students also study the importance of hydrocarbons and ethanol as fuels and the production of polymers from alkenes, as well as their uses.

Content	Learning Outcomes
2.5 Organic chemistry	Students should be able to: 2.5.1 demonstrate knowledge and understanding that carbon can form four covalent bonds and there is a large number of carbon compounds, the study of which is simplified by grouping the compounds into homologous series; 2.5.2 define a homologous series as a family of organic molecules that have the same general formula, show similar chemical properties, show a gradation in their physical properties and differ by a CH_2 group; 2.5.3 recall that a hydrocarbon is a compound/molecule consisting of hydrogen and carbon only; 2.5.4 recall the general formula of the alkanes and the molecular formula, structural formula and state at room temperature and pressure of methane, ethane, propane and butane; 2.5.5 recall that crude oil is a finite resource and is the main source of hydrocarbons and a feedstock for the petrochemical industry; and 2.5.6 describe and explain the separation of crude oil by fractional distillation.

Content	Learning Outcomes
2.5 Organic chemistry (cont.)	Students should be able to: 2.5.7 describe the fractions as largely a mixture of compounds of formula C_nH_{2n+2}, which are members of the alkane homologous series, and recall the names and uses of the following fractions: • refinery gases used for bottled gases; • petrol used as a fuel for cars; • naphtha used to manufacture chemicals and plastics; • kerosene as a fuel for aircraft; • diesel as a fuel for cars and trains; • fuel oils used as fuel for ships; and • bitumen used to surface roads and roofs; 2.5.8 explain that cracking involves the breakdown of larger saturated hydrocarbons (alkanes) into smaller more useful ones, some of which are unsaturated (alkenes); 2.5.9 describe the complete combustion of alkanes to produce carbon dioxide and water, including observations and tests to identify the products; 2.5.10 describe the incomplete combustion of alkanes to produce carbon monoxide and water and sometimes carbon (soot – equations for the production of soot are not required); 2.5.11 demonstrate knowledge and understanding that carbon monoxide is a toxic gas that combines with haemoglobin in the blood, reducing its capacity to carry oxygen; 2.5.12 recall the general formula of the alkenes and the molecular formula, structural formula and state at room temperature and pressure of ethene, propene, but-1-ene and but-2-ene; **and** 2.5.13 **describe the complete and incomplete combustion of alkenes.**

Content	Learning Outcomes
2.5 Organic chemistry (cont.)	Students should be able to: 2.5.14 demonstrate knowledge and understanding that a functional group is a reactive group in a molecule, recognise the functional groups of alkenes, **alcohols and carboxylic acids**, and recognise that alkanes do not have a functional group and so are less reactive; 2.5.15 **recall and describe the addition reaction across a C=C double covalent bond, including the reaction of ethene with bromine, hydrogen and steam (name of the bromo product is not required);** 2.5.16 determine the presence of a C=C using bromine water; 2.5.17 describe how monomers, for example ethene or chloroethene (vinyl chloride), can join together to form very long chain molecules called polymers and recall that the process is known as addition polymerisation; 2.5.18 **write equations for the polymerisation of ethene and chloroethene;** 2.5.19 **deduce the structure of an addition polymer from a simple alkene monomer and vice versa;** 2.5.20 **recall the general formula of the alcohols and the molecular formula, structural formula and state at room temperature and pressure of methanol, ethanol, propan-1-ol and propan-2-ol;** 2.5.21 **describe the complete and incomplete combustion of alcohols;** 2.5.22 describe the preparation of ethanol from sugars by fermentation (equation for fermentation of sugars is not required), including the conditions required; **and** 2.5.23 **recall the molecular formula, structural formula, state at room temperature and pressure of the carboxylic acids: methanoic acid, ethanoic acid, propanoic acid and butanoic acid.**

Content	Learning Outcomes
2.5 Organic chemistry (cont.)	Students should be able to: 2.5.24 demonstrate knowledge that carboxylic acids are weak acids **as they are only partially ionised in solution**; 2.5.25 investigate experimentally the reactions of carboxylic acids with carbonates, hydroxides and metals, test any gases produced **and write balanced symbol equations for these reactions**; and 2.5.26 demonstrate knowledge that the combustion of fuels is a major source of atmospheric pollution due to: • combustion of hydrocarbons producing carbon dioxide, which leads to the greenhouse effect causing sea level rises, flooding and climate change; • incomplete combustion producing carbon monoxide (toxic) and soot (carbon particles), which cause lung damage; and • presence of sulfur impurities in fuels, which leads to acid rain damaging buildings, destroying vegetation and killing fish.

Quantitative Chemistry

This section involves a quantitative study of the mole in terms of solids and solutions. Students carry out calculations that are important in industry. **For this section, students need to know the content of section 1.7.**

Content	Learning Outcomes
2.6 Quantitative chemistry	Students should be able to: 2.6.1 demonstrate knowledge and understanding of the terms **empirical formula, molecular formula,** hydrated, anhydrous and water of crystallisation; 2.6.2 demonstrate knowledge and understanding that water of crystallisation can be removed by heating to constant mass and any thermal decomposition may be carried out to completion by heating to constant mass; 2.6.3 calculate the relative formula mass of compounds containing water of crystallisation; 2.6.4 **determine the empirical formulae of simple compounds and determine the moles of water of crystallisation present in a hydrated salt from percentage composition, mass composition or experimental data;** 2.6.5 **calculate the concentration of a solution in mol/dm^3 given the mass of solute and volume of solution;** 2.6.6 **calculate the number of moles or mass of solute in a given volume of solution of known concentration;** 2.6.7 **calculate the atom economy of a reaction to form a desired product from the balanced equation:** $\frac{\text{mass of desired product}}{\text{total mass of products}} \times 100$ 2.6.8 **demonstrate knowledge and understanding that a high atom economy is important for sustainable development and economic reasons;** and • *determine the mass of water present in hydrated crystals (Prescribed Practical C5).*

Electrochemistry

In this section, students learn to use the key terms associated with electrolysis and study electrolysis of molten ionic compounds. **For this section, students need to know the content of sections 1.2 and 1.3.**

Content	Learning Outcomes
2.7 Electrochemistry	Students should be able to: 2.7.1 explain the meaning of the terms electrolysis, inert electrode, anode, cathode and electrolyte and explain conduction in an electrolyte in terms of ions moving and carrying charge; 2.7.2 predict the products of electrolysis of molten salts including lithium chloride and lead(II) bromide using graphite electrodes and state appropriate observations at the electrodes; 2.7.3 **interpret and write half equations for the reactions occurring at the anode and cathode for the electrolysis processes listed in 2.7.2, for other molten halides and in the extraction of aluminium;** 2.7.4 describe the industrial extraction of aluminium from alumina, demonstrate knowledge and understanding that the alumina has been purified from the ore bauxite and demonstrate knowledge and understanding of the need to replace the anodes periodically; and 2.7.5 demonstrate knowledge and understanding that recycling aluminium uses only a fraction of the energy needed to extract it from bauxite and saves waste.

Energy Changes in Chemistry

This section looks at energy changes that take place in chemical reactions, qualitatively and quantitively.

Content	Learning Outcomes
2.8 Energy changes in chemistry	Students should be able to: 2.8.1 demonstrate knowledge and understanding that chemical reactions in which heat is given out are exothermic and that reactions in which heat is taken in are endothermic; 2.8.2 **draw and interpret reaction profile diagrams for exothermic and endothermic reactions identifying activation energy;** 2.8.3 **explain activation energy as the minimum energy needed for a reaction to occur;** 2.8.4 **recall that bond breaking takes in energy and bond making releases energy, and demonstrate understanding that the overall energy change in a reaction is a balance of the energy taken in when bonds break in the reactants and the energy released when bonds form in the products; and** 2.8.5 **calculate energy changes in a chemical reaction from bond energies by considering bond making and bond breaking energies.**

Gas Chemistry

In this section, students prepare a range of gases and carry out simple tests for their identification. Students also learn about the uses of some important gases.

Content	Learning Outcomes
2.9 **Gas chemistry**	Students should be able to: 2.9.1 recall the composition of the gases in the atmosphere: • about 78% nitrogen; • about 21% oxygen; • about 0.03–0.04% carbon dioxide; • about 1% argon; • small proportions of other noble gases; and • varying proportions of water vapour; 2.9.2 recall the physical properties of nitrogen and describe its lack of reactivity due to its triple covalent bond; 2.9.3 demonstrate knowledge and understanding of using nitrogen as a coolant and in food packaging; 2.9.4 **demonstrate knowledge and understanding of the test for ammonia, using a glass rod dipped in concentrated hydrochloric acid, and recall the use of ammonia in the manufacture of fertilisers by its reaction with acids;** 2.9.5 describe the laboratory preparation and collection of hydrogen using zinc (or other suitable metal) and hydrochloric acid, and recall the physical properties of hydrogen and its uses, including weather balloons and hardening oils, and its potential as a clean fuel; 2.9.6 describe the laboratory preparation and collection of oxygen by the catalytic decomposition of hydrogen peroxide, and recall the physical properties of oxygen and its uses in medicine and welding; 2.9.7 describe the reaction of carbon, sulfur, magnesium, iron and copper with oxygen and classify the products as acidic or basic; and 2.9.8 describe the laboratory preparation and collection of carbon dioxide gas using calcium carbonate and hydrochloric acid, and recall the uses of carbon dioxide in fizzy drinks and fire extinguishers.

Content	Learning Outcomes
2.9 **Gas chemistry (cont.)**	Students should be able to: 2.9.9 investigate the chemical reactions of carbon dioxide with water producing carbonic acid and with calcium hydroxide (limewater) until carbon dioxide is in excess; and • *investigate the preparation, properties, tests and reactions of the gases hydrogen, oxygen and carbon dioxide (Prescribed Practical C6).*

3.5 Physics Unit P1: Motion, Force, Moments, Energy, Density, Kinetic Theory, Radioactivity, Nuclear Fission and Fusion

In this unit, students investigate motion, including its graphical treatment, forces and applications such as moments and pressure. Students explore energy, power and heat transfer, along with density and kinetic theory to explain density. They investigate atomic and nuclear physics, including radioactivity, fission and fusion.

Motion

In this section, students investigate motion. They establish the relationship between distance, average speed, time and rate of change of speed through practical work. They are introduced to graphical methods of describing motion. At Higher Tier, students are introduced to the concept of vectors and scalars and they learn about the terms displacement, velocity and acceleration.

Content	Learning Outcomes
1.1 Motion	Students should be able to: 1.1.1 investigate and use the quantitative relationships between initial speed, final speed, average speed, distance moved, rate of change of speed and time, to: • calculate the average speed from linear distance–time graphs; • define that distance is measured in metres (m), speed in metres per second (m/s) and rate of change of speed in metres per second squared (m/s^2); and • recall and use the equations: $\text{average speed} = \frac{\text{distance moved}}{\text{time taken}}$ $\text{average speed} = \frac{\text{initial speed} + \text{final speed}}{2}$ $\text{rate of change of speed} = \frac{\text{final speed} - \text{initial speed}}{\text{time taken}}$

Content	Learning Outcomes
1.1 Motion (cont.)	Students should be able to: • *use simple apparatus, including trolleys, ball-bearings, metre rules, stopclocks and ramps to investigate experimentally how the average speed of an object moving down a runway depends on the slope of the runway measured as the height of one end of the runway (ICT resources could be used to process the measurements and analyse the data) (Prescribed Practical P1);*
Vectors and scalars	1.1.2 **demonstrate understanding that:** • **a vector is a quantity that depends on direction and scalar is a quantity that does not;** • **displacement is a vector and that distance is a scalar but both are measured in metres (m);** • **velocity is a vector and speed is scalar but both are measured in metres per second (m/s); and** • **acceleration is a vector and rate of change of speed is a scalar but both are measured in metres per second squared (m/s^2);**
Motion, displacement, velocity and acceleration	1.1.3 **recall and use the quantitative relationships between:** • **displacement, time and average velocity:** $\text{average velocity} = \frac{\text{displacement}}{\text{time}} \quad v = \frac{d}{t}$ • **initial velocity, final velocity, acceleration and time:** $\text{average velocity} = \frac{\text{initial velocity + final velocity}}{2}$ • **initial velocity, final velocity and average velocity (problems will only be set on motion in one direction):** $\text{acceleration} = \frac{\text{final velocity – initial velocity}}{\text{time taken}}$ $\text{acceleration} = \frac{v - u}{t}$ 1.1.4 **explain that negative acceleration is called retardation.**

Content	Learning Outcomes
Distance–time graphs and speed–time graphs	Students should be able to: 1.1.5 use graphical methods to determine speed, distance and rate of change of speed, applying knowledge that: • the slope of a distance–time graph is the speed; • the slope of a speed–time graph is the rate of change of speed; and • the area under a speed–time graph is the distance moved; **and**
Displacement–time graphs and velocity–time graphs	1.1.6 **use graphical methods to determine velocity, acceleration and displacement, applying knowledge that:** • **the slope of a displacement–time graph is the velocity;** • **the slope of a velocity–time graph is the acceleration; and** • **the area under a velocity–time graph is the displacement.**

Force

In this section, students are introduced to the idea of forces between objects existing as pairs. They learn about the unit of force and the concept of a resultant force. Students investigate Newton's first and second laws through practical investigation or computer simulation. They carry out calculations based on the second law and establish the difference between mass and weight. Experimental investigation of Hooke's law introduces students to the idea of proportionality and teaches them that experimental laws are only valid provided certain conditions are met. They are introduced to the idea of pressure along with applications that are dependent on the concept. Students find out how to calculate the moment of a force and how to establish the Principle of Moments through practical investigation. They are introduced to the meaning of centre of gravity and learn how it affects the stability of an object.

Content	Learning Outcomes
1.2 Force **Newton's laws**	Students should be able to: 1.2.1 demonstrate understanding that forces arise between objects, that the forces on these objects are equal and opposite, and that friction is a force that always opposes motion; 1.2.2 demonstrate understanding that: • force is measured in newtons (N); and • a force acting in one direction can be given a positive value and one acting in the opposite direction can be given a negative value; 1.2.3 calculate the resultant of two one-dimensional forces using the rule stated in 1.2.2; 1.2.4 recall that Newton's first law states that in the absence of unbalanced forces an object will continue to move in a straight line at constant speed; and 1.2.5 investigate experimentally Newton's first and second laws, for example using an air track and data logger, or a computer simulation, to study the effect of balanced and unbalanced forces on an object, and through mathematical modelling derive the relationship between resultant force, mass and acceleration.

Content	Learning Outcomes
Mass and weight	Students should be able to: 1.2.6 explain that Newton's second law states that a resultant force will cause an object to accelerate and that the acceleration is proportional to the size of the resultant force; 1.2.7 recall and use the equation: resultant force = mass × acceleration or F = m × a 1.2.8 demonstrate understanding that: • mass is defined as the amount of matter in an object and is measured in kilograms (kg); • weight is a force due to the pull of gravity on the object; and • on the Earth the pull of gravity is 10 N on a mass of 1 kg; 1.2.9 use the equation W = mg to calculate the weight W of an object in newtons when given the mass m in kilograms and the value of g in N/kg; 1.2.10 explain that: • all objects in the absence of air resistance (friction) fall at the same rate regardless of their mass; and • due to gravity the speed of an object dropped from rest from a height will increase at the rate of 10 m/s every second that it falls; 1.2.11 **recall that due to gravity an object allowed to fall freely from rest will accelerate at the rate of 10 m/s^2 and this is known as the acceleration of free fall, 'g';** and
Hooke's law	• *investigate experimentally the extension of a spring and how it is related to the applied force, and recall that the extension of a spring is directly proportional to the force applied, provided that the limit of proportionality is not exceeded (Prescribed Practical P2).*

Content	Learning Outcomes
Hooke's law (cont.)	Students should be able to: 1.2.12 recall and use the equation F = ke, where F is the applied force, e is the extension of the spring and k is called the spring constant; 1.2.13 demonstrate understanding that the gradient of the graph of force (y-axis) and extension (x-axis) is numerically equal to the spring constant;
Pressure	1.2.14 demonstrate understanding that pressure is the force exerted per m^2 and that the unit of pressure is the pascal (Pa), where 1 Pa = 1 N/m^2; 1.2.15 recall and use the equation $P = \frac{F}{A}$ to calculate pressure, force or area (questions may be set in which cm^2 and mm^2 are used but students will not be expected to convert mm^2 or cm^2 to m^2); 1.2.16 interpret the importance of pressure in a range of everyday situations, for example: • when using a sharp knife, the small area of the blade creates a large pressure, making cutting easier; and • having caterpillar tracks on vehicles means their weight acts over a large area, so reducing the pressure they exert on the ground;
Moment of a force	1.2.17 define the moment of a force and recall and use the equation moment = force × perpendicular distance from the pivot or moment = F × d (problems will only be set in which the force and distance are perpendicular to each other); and
Principle of Moments	• *plan and carry out experiments to verify the Principle of Moments using a suspended metre rule and attached weights or a pivoted beam and square weights (Prescribed Practical P3).*

Content	Learning Outcomes
Principle of Moments (cont.)	Students should be able to: 1.2.18 use the Principle of Moments to carry out a practical task to find the weight of an object; 1.2.19 use the Principle of Moments to calculate the size of a force, or its distance from the pivot, when an object is balanced under the turning effects of no more than two forces, one of which could be the object's weight;
Centre of gravity	1.2.20 investigate that the centre of gravity of an object is the point where all of the weight of the object can be considered as acting; 1.2.21 identify the position of the centre of gravity for a disc, a ring and a rectangle; 1.2.22 explain how the position of the centre of gravity and the width of an object's base affects the stability of the object; and 1.2.23 demonstrate understanding of when the weight of an object will have a turning effect.

Density and Kinetic Theory

In this section, students investigate the relationship between the volume of a material and its mass, leading to the concept of density. They are introduced to simple kinetic theory and this is used to explain the differences between the densities of solids, liquids and gases.

Content	Learning Outcomes
1.3 Density and kinetic theory	Students should be able to: 1.3.1 carry out practical work to investigate experimentally the relationship between the mass and volume of liquids and regular solids; 1.3.2 analyse and interpret the data gathered in 1.3.1 to derive the relationship between mass and volume; 1.3.3 measure the density of an irregular solid (that sinks in water), and use the displacement method to measure the volume using either a measuring cylinder or eureka can; 1.3.4 recall and use the equation $\text{density} = \frac{\text{mass}}{\text{volume}}$ or $D = \frac{m}{v}$ to solve simple problems, and recall and use the units of density as g/cm^3 and kg/m^3; and 1.3.5 use kinetic theory to explain qualitatively that the difference between the densities of solids, liquids and gases is due to the distance between the particles in each state of matter.

Energy

In this section, students examine the various forms of energy and apply the Principle of Conservation of Energy to a range of situations. They study the difference between renewable and non-renewable energy resources, along with their impact on the environment. Students also study the concepts of work, power, kinetic and gravitational potential energy.

Content	Learning Outcomes
1.4 Energy **Forms of energy**	Students should be able to: 1.4.1 recall that energy can exist in many forms such as chemical, heat, electrical, sound, light, magnetic, strain energy, kinetic and gravitational potential;
Principle of Conservation of Energy	1.4.2 recall that the Principle of Conservation of Energy states that energy can be changed from one form to another but the total amount of energy does not change; 1.4.3 demonstrate understanding that energy is measured in joules (J) and that 1 J is approximately the energy needed to lift an apple vertically 1 m; 1.4.4 draw energy transfer diagrams for the energy conversions that occur in a range of common devices found in everyday life and interpret them using the Principle of Conservation of Energy;
Renewable energy resources	1.4.5 explain that renewable energy is defined as energy that is collected from resources that will never run out or which are naturally replenished within a human lifetime; 1.4.6 evaluate examples of renewable energy such as sunlight, wind, hydroelectricity, tidal, waves, wood and geothermal heat; and 1.4.7 demonstrate knowledge of how using renewable energy resources can affect the environment, for example causing habitat destruction or visual pollution.

Content	Learning Outcomes
Non-renewable energy resources	Students should be able to: 1.4.8 explain that: • a non-renewable energy resource is one that has a finite supply and it will run out some time; and • fossil fuels such as oil, natural gas and coal are considered non-renewable because they cannot be replaced within a human lifetime; 1.4.9 demonstrate knowledge that nuclear energy based on fission is also non-renewable since supplies of uranium ore will not last forever; 1.4.10 demonstrate understanding of how using non-renewable energy resources can affect the environment, for example causing acid rain or global warming;
Efficiency	1.4.11 demonstrate understanding that: • not all of the energy used in a particular process or device is useful; and • the efficiency is a measure of how much of the input energy to a process or device appears as useful output energy; 1.4.12 recall, demonstrate understanding of and use the equation $\text{efficiency} = \frac{\text{useful output energy}}{\text{total input energy}}$ quoting the efficiency as a decimal or a percentage;
Work	1.4.13 demonstrate understanding that work is said to be done when energy changes from one form to another and that the amount of work can be calculated by the equation: work = force × distance or W = F × d 1.4.14 recall that work is measured in joules (J), the force in newtons (N) and the distance in metres (m).

Content	Learning Outcomes
Power	Students should be able to: 1.4.15 demonstrate understanding that: • power is the amount of energy transferred in one second or the amount of work done in one second; and • power is measured in watts (W) so 1 W = 1 joule per second (1 W = 1 J/s); 1.4.16 recall and use the equations $\text{power} = \frac{\text{energy transferred}}{\text{time taken}}$ or $P = \frac{E}{t}$ $\text{power} = \frac{\text{work done}}{\text{time taken}}$ or $P = \frac{W}{t}$ to calculate power, work done, time taken or energy transferred; • *plan and carry out experiments to measure personal power, either by measuring the time taken to climb a staircase or perform a number of step-ups to a platform (Prescribed Practical P4)*; and
Kinetic energy, E_k	1.4.17 explain that kinetic energy E_k is the energy possessed by a moving object and recall and use the equation $E_k = \frac{1}{2} mv^2$ to calculate kinetic energy in joules, where m is the mass of the object in kg and v is the speed of the object in m/s.

Content	Learning Outcomes
Gravitational potential Energy, E_p	Students should be able to: 1.4.18 demonstrate understanding that an object has gravitational potential energy E_p because of its position above the ground; and 1.4.19 recall and use the equation $E_p = mgh$ to calculate the potential energy in joules, where m is the mass in kilograms, h is the vertical height in metres and g is 10 N/kg.

Atomic and Nuclear Physics

In this section, students explore the particle structure of both the atom and the nucleus. They examine radioactivity as a consequence of unstable nuclei and study the properties of alpha, beta and gamma radiation. They are introduced to the terms background and half-life and discuss the damaging effect that nuclear radiations have on our bodies. They also learn about fusion and fission as sources of energy.

Content	Learning Outcomes
1.5 Atomic and nuclear physics **Structure of the atom** **Structure of the nucleus** **Radioactive decay**	Students should be able to: 1.5.1 describe the structure of atoms in terms of protons, neutrons and electrons; 1.5.2 recall the relative charge and relative mass of protons, neutrons and electrons; 1.5.3 describe a nucleus in terms of atomic number Z and mass number A, using the notation $^{A}_{Z}X$; 1.5.4 explain what an isotope is; 1.5.5 recall that some nuclei are unstable and disintegrate, emitting alpha, beta or gamma radiation randomly and spontaneously, and that such nuclei are described as radioactive; 1.5.6 explain that alpha particles are helium nuclei consisting of two protons and two neutrons, beta particles are fast electrons, and gamma radiation is an electromagnetic wave of high energy; and 1.5.7 **describe nuclear disintegrations in terms of equations involving mass numbers and atomic numbers, and complete the equations by balancing the mass numbers and atomic numbers:** **alpha decay** $^{A}_{Z}X \rightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}He$ (or $^{4}_{2}\alpha$) **beta decay** $^{A}_{Z}X \rightarrow {}^{A}_{Z+1}Y + {}^{0}_{-1}e$ (or $^{0}_{-1}\beta$) **gamma decay** $^{A}_{Z}X \rightarrow {}^{A}_{Z}X + \gamma$

Content	Learning Outcomes
Radioactive decay (cont.)	Students should be able to: 1.5.8 recall: • through demonstrations or computer simulations, the range of alpha, beta and gamma radiations; • that alpha radiation is stopped by a few centimetres of air or a thin sheet of paper; • that beta radiation is stopped by several metres of air or a thin sheet of aluminium; and • that gamma radiation easily passes through all of these but can be blocked by lead; 1.5.9 recall that: • background activity is detected when no radioactive sources are present; and • the measured activity from a radioactive source has to be corrected by subtracting the background activity; 1.5.10 demonstrate understanding that: • most radioactive background activity comes from natural sources such as cosmic rays from space, rocks and soil, some of which contain radioactive elements such as radon; • gas, living things and plants absorb radioactive materials from the soil, which are then passed along the food chain; • there is little we can do about natural background radiation, although people who live in areas with a high background due to radon gas require homes to be well ventilated to remove the gas; and • human behaviour also adds to the background activity that we are exposed to through medical X-rays, radioactive waste from nuclear power plants and the radioactive fallout from nuclear weapons testing; and
Dangers of radioactivity	1.5.11 recall that radioactive emissions cause dangerous ionisations by removing electrons from atoms and when this happens with molecules in living cells, the genetic material of a cell is damaged and the cell may become cancerous.

Content	Learning Outcomes
Dangers of radioactivity (cont.)	Students should be able to: 1.5.12 recall that: • alpha radiation is not as dangerous if the radioactive source is outside the body, because it cannot pass through the skin and is unlikely to reach cells inside the body; • beta and gamma radiation can penetrate the skin and cause damage to cells; and • alpha radiation will damage cells if the radioactive source has been breathed in or swallowed; 1.5.13 explain that steps should be taken when handling radioactive sources to minimise the risk to those using them, such as: • wearing protective clothing; • keeping the source as far away as possible by using tongs; • being exposed to the source for as short a time as possible; and • keeping radioactive materials in lead-lined containers; and
Half-life	1.5.14 explain the meaning of the term half-life, carry out simple calculations involving half-life and determine half-life from appropriate graphs.

Content	Learning Outcomes
Uses of radioactivity	Students should be able to: 1.5.15 describe some uses of radioactivity in industry, medicine and agriculture, and recall that: • radioactive isotopes are used as tracers to find out what is happening inside an object without the need to break into the object; • radioactive isotopes are used in industry to find the route of underground pipes using a gamma ray emitter, or to control the thickness of metal as it is rolled into thin sheets; • gamma rays are used in medicine to sterilise plastic objects such as syringes, and different radioactive isotopes are used to monitor the function of organs by injecting a small amount into the bloodstream and detecting the emitted radiation; and • alpha radiation is used in smoke alarms; 1.5.16 demonstrate understanding that the half-life of the radioactive material used in all applications needs to be considered to ensure that the application works but minimal harm is done to the environment or to people;
Nuclear fission	1.5.17 describe nuclear fission in simple terms and be aware that it is a form of energy used to generate electricity (fission equations are not required); and 1.5.18 demonstrate knowledge that: • for fission to occur, the uranium nucleus must first absorb a neutron and then split into two smaller nuclei, releasing energy and several neutrons; and • these fission neutrons go on to cause further fissions, creating a chain reaction.

Content	Learning Outcomes
Nuclear fission (cont.)	Students should be able to: 1.5.19 discuss and debate some of the political, social, environmental and ethical issues relating to using nuclear energy to generate electricity, demonstrating understanding that: • although using nuclear power produces employment opportunities for many people, many are still concerned about living close to nuclear power plants and the storage facilities used for radioactive waste; • incidents at nuclear power plants in Ukraine and Japan have caused huge economic, health and environmental damage to the area surrounding the power plant; and • although nuclear fission does not release carbon dioxide, the mining, transport and purification of the uranium ore releases significant amounts of greenhouse gases into the atmosphere;
Nuclear fusion	1.5.20 describe nuclear fusion in simple terms and be aware that it is the source of a star's energy; 1.5.21 demonstrate understanding: • of the potential of nuclear fusion to solve the world's energy needs, provided the technological difficulties of fusion reactors can be overcome; • that the isotopes of hydrogen, deuterium and tritium are widely available as the constituents of seawater and so are nearly inexhaustible; and • that fusion does not emit carbon dioxide or other greenhouse gases into the atmosphere as its major by-product is helium, an inert, non-toxic gas; and 1.5.22 recall that: • fusing nuclei together in a controlled way releases four million times more energy per kg than a chemical reaction such as burning coal, oil or gas; and • fusing nuclei together in a controlled way releases four times as much energy as nuclear fission reactions per kg.

Content	Learning Outcomes
Nuclear fusion (cont.)	Students should be able to: 1.5.23 explain that: • there are many difficulties to overcome before nuclear fusion provides electricity on a commercial scale and it may be another 50 years before that happens; and • nuclear fusion reactors will be expensive to build and the system used to contain them will be equally expensive because of the very high temperatures needed for the nuclei to fuse.

3.6 Physics Unit P2: Waves, Light, Electricity, Magnetism, Electromagnetism and Space Physics

In this unit, students explore waves and reflection and refraction of light, including lenses. They investigate current and domestic electricity, which is then extended to magnetism and electromagnetism. Students investigate the Earth, the Solar System and the Universe and also the life cycle of stars. At the end of this unit, students learn about the Big Bang and evidence for this theory.

Waves

In this section, students are introduced to the two main categories of waves, as well as the terms used to describe their various properties. They study echoes and their applications. They explore the electromagnetic spectrum and examine the use of the various types of electromagnetic wave.

Content	Learning Outcomes
2.1 Waves	Students should be able to:
	2.1.1 recall that waves transfer energy from one point to another through vibrations;
Transverse and longitudinal waves	2.1.2 distinguish between transverse and longitudinal waves in terms of the motion of the particles of the medium, recalling: • sound and ultrasound as examples of longitudinal waves; and • water waves and electromagnetic waves as examples of transverse waves;
Frequency, wavelength and amplitude	2.1.3 explain the meaning of frequency, wavelength and amplitude of a wave, and extract details of these quantities from graphs of displacement of the particles against time and displacement of the particles against distance; and
	2.1.4 recall and use the equation $v = f\lambda$ to calculate the velocity of the wave in m/s, frequency of the wave in hertz (Hz) and the wavelength of the wave in metres (m).

Content	Learning Outcomes
Echoes, sonar and radar	Students should be able to: 2.1.5 describe some applications of echoes and carry out calculations on the echo principle; 2.1.6 recall that ultrasound is the name given to sound waves that have frequencies greater than 20 000 Hz, and is used in medicine to measure foetal head diameter and in industry to detect defects in metals; 2.1.7 demonstrate knowledge that sonar uses sound pulses to detect objects under water and electromagnetic waves are used in radar to detect aircraft and ships;
Electromagnetic waves	2.1.8 distinguish between the different regions of the electromagnetic spectrum (radio waves, microwaves, infrared, visible light, ultraviolet, X-rays and gamma rays) in terms of their wavelength and frequency, arrange them in order of wavelength and recall that they all travel at the same speed in a vacuum; and 2.1.9 recall that overexposure to certain types of electromagnetic radiation can be harmful and that the higher the frequency of the radiation, the more damage it is likely to cause to the body, for example: • microwaves cause internal heating of body tissues; • infrared radiation is felt as heat and causes skin burns; • certain wavelengths of ultraviolet can damage skin cells and lead to skin cancer; • intense visible light can damage eyes; and • X-rays and gamma rays damage cells, which may lead to cancer.

Light

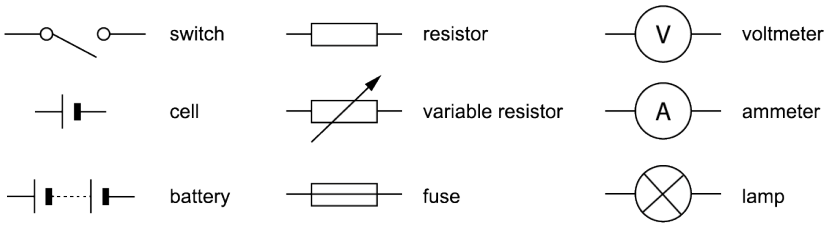
In this section, students investigate the reflection and refraction of light. They relate refraction to a change of speed as light moves from one medium to another. They also study how a prism disperses white light.

Content	Learning Outcomes
2.2 **Light** **Reflection of light**	Students should be able to: 2.2.1 investigate how light is reflected by a plane mirror, and recall that: • angles of incidence and reflection are measured from a line at right angles to the mirror known as the normal; and • the angle of incidence equals the angle of reflection, and apply this rule in practical situations; 2.2.2 investigate the properties of an image seen in a plane mirror through ray tracing and use the properties to solve simple problems;
Refraction of light	2.2.3 observe the refraction of light as it passes from air into glass and air into water and vice versa; • *use ray tracing to measure the angles of incidence and refraction when light is refracted by a glass block, demonstrate knowledge that the angles of incidence and refraction are measured from a line at right angles to the normal and use the measurements taken to plot a graph of angle of incidence against angle of refraction to show that they are related but not proportional (Prescribed Practical P5)*; 2.2.4 recall and demonstrate understanding that when light slows it bends towards the normal and the converse; and 2.2.5 relate the amount of refraction to the change of speed, so the greater the refraction, the larger the change of speed of the light (a knowledge of Snell's law is not expected).

Content	Learning Outcomes
Dispersion of white light	Students should be able to: 2.2.6 investigate how prisms disperse white light and recall that: • a spectrum can be produced because different colours of light travel at different speeds in the glass; • the greater the amount of refraction, the greater the change of speed; and • since red is refracted the least, it is slowed the least, and violet is refracted the most because it has been slowed the most;
Lenses	2.2.7 distinguish between the action of converging and diverging lenses (qualitative treatment only) through practical investigation, and define the focal length of a converging lens; 2.2.8 carry out and describe an experiment that uses a distant object to measure the focal length of a converging lens; 2.2.9 draw ray diagrams to show how converging lenses form real images; 2.2.10 use ray diagrams to explain the principle of the simple camera and the projector (details of the construction of these are not required); **and** 2.2.11 **draw a ray diagram to show how a converging lens is used as a magnifying glass, forming a virtual image.**

Electricity

In this section, students investigate electrical circuits and draw circuit diagrams using the correct symbols. They examine series and parallel circuits and investigate the rule for currents and voltages in each type of circuit. They also study the transfer of electrical energy and electricity in the home.

Content	Learning Outcomes
2.3 Electricity **Conductors and insulators**	Students should be able to: 2.3.1 demonstrate understanding of the difference between conductors and insulators in terms of free electrons;
	2.3.2 recall that an electric current in a metal is a flow of electrons and that the electrons move in the opposite direction to that of a conventional current;
Simple circuits	2.3.3 demonstrate understanding of the role of conductors, insulators and switches in simple series and parallel circuits;
Standard symbols	2.3.4 interpret and draw circuit diagrams using the standard symbols illustrated below: 
	2.3.5 explain the meaning of cell polarity and relate it to the symbol for a cell;
Electric charge flow	2.3.6 recall and use the quantitative relationship between current, charge and time charge = current × time $Q = I \times t$ and recall that charge is measured in coulombs; and
	2.3.7 demonstrate understanding that the voltage provided by cells connected in series is the sum of the voltages of each cell, having regard to their polarity.

Content	Learning Outcomes
Ohm's law	Students should be able to: • *use a voltmeter to measure the voltage across a metal wire and an ammeter to measure the current passing through the wire, and:* – *demonstrate understanding that the temperature of the wire is kept constant using a switch and small currents;* – *demonstrate understanding of the need to obtain sufficient values of voltage and current so that a voltage–current characteristic graph (V-I graph) can be plotted, with voltage on the y-axis and current on the x-axis;* – *recall that the V-I graph is a straight line that passes through the origin; and* – *recall that this shows that the current and voltage are proportional for a metal wire at constant temperature, and that this is known as Ohm's law (Prescribed Practical P6)*;
Resistance	2.3.8 recall and use the equation voltage = current × resistance V = I × R where voltage is measured in volts, current in amperes and resistance in ohms;
Filament lamp	2.3.9 **describe and carry out an experiment to obtain the voltage–current characteristic graph (V-I graph) for a filament lamp with voltage on the y-axis and current on the x-axis, and show that the resistance of a filament lamp increases as the current through the filament increases by taking the ratio of the voltage to the current at different values of the current;** and
Series and parallel circuits	2.3.10 recall that for components connected in series: • the current through each component is the same; and • the voltage of the supply is equal to the sum of the voltages across the separate components.

Content	Learning Outcomes
Series and parallel circuits (cont.)	Students should be able to: 2.3.11 recall that for components connected in parallel: • the voltage across each component is the same as that of the supply; and • the total current taken from the supply is the sum of the currents through the separate components;
Calculating resistance	2.3.12 calculate the total resistance of resistors in series; 2.3.13 calculate the resistance of two equal resistors in parallel; 2.3.14 **calculate the combined resistance of any two resistors in parallel;** 2.3.15 **calculate the combined resistance of circuits with series and parallel sections;**
Factors affecting resistance	2.3.16 carry out practical work to investigate experimentally how the resistance of a metallic conductor at constant temperature depends on length and obtain sufficient values to plot a graph of resistance (y-axis) and length (x-axis), recalling that: • the graph is a straight line that passes through the origin; and • for a metal wire at constant temperature the resistance and length of wire are proportional;
Electrical energy and power	2.3.17 demonstrate understanding of why an electrical current flowing through a metal wire generates heat in terms of free electron–atom collisions; and 2.3.18 recall and use the quantitative relationships energy = power × time $E = P \times t$ power = current × voltage $P = I \times V$ to calculate energy in joules (J), power in watts (W), current in amps (A), voltage in volts (V) and the time in seconds (s).

Content	Learning Outcomes
Electricity in the home	Students should be able to: 2.3.19 describe the difference between a.c. and d.c. and identify sources for each, and recognise the waveforms of a.c. and d.c. supplies from diagrams of cathode ray oscilloscope (CRO) traces; 2.3.20 recall that the unit used in the cost of electricity to the consumer is the kilowatt-hour, and demonstrate understanding of the meaning of the kilowatt-hour and use of the power rating of electrical appliances to calculate their cost; 2.3.21 demonstrate understanding that in one-way switching the switch basically operates as a make or break switch, because: • when it is turned on, the two terminals are connected, and when it is turned off, the contact between the two is broken; and • the switch is always placed on the positive or live side of a circuit; 2.3.22 recall the wiring inside a fused three-pin plug and demonstrate understanding of the function of the live, neutral and earth wires; 2.3.23 recall that appliances with metal cases are usually earthed and demonstrate understanding of how the earth wire and fuse together protect the user from electric shock and the apparatus from potential damage; 2.3.24 demonstrate understanding of how double insulation protects the user; and 2.3.25 recall the equation power = current × voltage $P = I \times V$ and use this in calculations to select the appropriate rating of a fuse.

Magnetism and Electromagnetism

In this section, students plot the magnetic field around a bar magnet and a current-carrying coil. They investigate the factors that affect the strength of the magnetic field.

Content	Learning Outcomes
2.4 Magnetism and electromagnetism **Magnetic field of a bar magnet**	Students should be able to: 2.4.1 use plotting compasses to investigate, describe and recall the shape and direction of the magnetic field around a bar magnet;
Magnetic field of a current-carrying coil	2.4.2 use plotting compasses to investigate, describe and recall the shape and direction of the magnetic field produced by the current in a coil of wire, and relate the polarity to the direction of the current in the coil; and
Factors affecting the strength of an electromagnet	2.4.3 carry out practical work to investigate, describe and recall how the strength of the magnetic field depends on the current in the coil, the number of turns in the coil and the material used as the core of the coil.

Space Physics

In this section, students are introduced to the objects that make up our Solar System. They develop understanding of how the objects move and the force that keeps them in orbit. Students are introduced to the life cycle of stars and how the mass of a star determines its final outcome, leading to the idea of a black hole. They also study the Big Bang and supporting evidence.

Content	Learning Outcomes
2.5 Space physics **The Earth and Solar System**	Students should be able to: 2.5.1 describe the main features of the Solar System, including the Sun, the rocky and gas planets, moons, asteroids and comets; 2.5.2 recall the order of the eight planets from the Sun outwards; 2.5.3 recall that gravity provides the force needed for the orbital motion of planets, comets, moons and artificial satellites; 2.5.4 recall the use of artificial satellites in the observation of the Earth, weather monitoring, astronomy and communications;
Stars	2.5.5 recall that: • stars form when enough dust and gas from space is pulled together by gravitational attraction; and • smaller masses may also form and be attracted by a larger mass to become planets; 2.5.6 recall that studies of light from stars, including our Sun, show they are composed mainly of hydrogen and helium and that their energy is supplied by the fusion of hydrogen into helium; 2.5.7 **recall that all the naturally occurring elements apart from hydrogen are formed by nuclear fusion in stars; and**
Life cycle of stars	2.5.8 **recall the life cycle of a star with the mass of our Sun from protostar to main sequence to red giant to white dwarf to black dwarf.**

Content	Learning Outcomes
Life cycle of stars (cont.)	Students should be able to: 2.5.9 **recall that a star is stable during the 'main sequence' period of its life cycle because the outward force of thermal expansion is balanced by the inward force of gravity**;
Supernovae	2.5.10 **recall that:** • **more massive stars have a very different life cycle after the main sequence period;** • **they become red supergiants followed by an explosion in which the outer layers of the star are ejected;** • **this is called a supernova and the star will shine for a relatively short time with the brightness of 10 billion suns; and** • **after the supernova the remaining core of the star may collapse more, and some become neutron stars while very massive ones form black holes;**
Black holes	2.5.11 **demonstrate knowledge that there is such a strong gravitational field in a black hole that nothing can escape from it, including electromagnetic radiation such as light;**
The Universe	2.5.12 demonstrate knowledge that the Universe began as a Big Bang which, according to current measurements, occurred 14 billion years ago;
Big Bang model	2.5.13 **describe the Big Bang model for the formation and evolution of the Universe, including:** • **the rapid expansion and cooling of the Universe;** • **the eventual formation of neutrons and protons;** • **how further expansion and cooling allowed nuclei to form; and** • **how eventually, after further expansion and cooling, the temperature had dropped sufficiently for electrons to combine with neutrons and protons to form atoms of hydrogen;** and
Red shift	2.5.14 describe and explain that evidence for the Big Bang includes that light from other galaxies is shifted to the red end of the spectrum, and that this can be explained by space expanding.

Content	Learning Outcomes
CMBR	Students should be able to: 2.5.15 **explain that the existence of cosmic microwave background radiation (CMBR) is further evidence of the Big Bang, and that the Big Bang is currently the only model that explains CMBR.**

3.7 Unit 7: Practical Skills

Units 1 and 2 in each discipline include a number of practical tasks that students carry out during the course; 18 of these are prescribed practicals. This unit comprises Unit 7 Biology, Unit 7 Chemistry and Unit 7 Physics. Each of these has two parts: Booklet A and Booklet B. We set and mark both booklets.

Booklet A is a practical skills assessment. It assesses students' ability to carry out **three** practical tasks based on but not identical to the 18 prescribed practicals listed in this specification.

Booklet B is a written, externally assessed examination taken during the final year of study. It assesses students' knowledge and understanding of practical science. It consists of questions about planning and carrying out any of the prescribed practical tasks, together with more general questions about any practical situation that arises in Units B1, B2, C1, C2, P1 and P2 in this specification.

Content	Learning Outcomes
Planning an investigation	Students should be able to: • identify the dependent, independent and controlled variables in an investigation (if appropriate); • suggest a hypothesis for investigation in the context of How Science Works; • plan a method to allow a hypothesis to be tested or to allow an analysis to be carried out; • carry out a risk assessment on all planned practical activities; • select equipment or apparatus that is suitable and will contribute to obtaining accurate results; • produce a results table with appropriate headings (and units if appropriate) for recording a wide range of appropriate raw data including observations and deductions; • draw a diagram of the apparatus used in an experiment; and • demonstrate knowledge and understanding of the steps that must be taken to ensure the validity of the practical process and the reliability of data collected (if appropriate).

Content	Learning Outcomes
Carrying out an experiment	Students should be able to: • demonstrate the practical skills necessary to use the following apparatus correctly, skilfully and safely: – Bunsen burner and associated apparatus such as heatproof mat, tripod, gauze, pipeclay triangle, crucible and evaporating basin/dish; – general glassware such as beakers, conical flasks, test tubes, boiling tubes, glass rod, pipettes (disposable plastic pipettes may be used), filter funnels, watch glass and combustion tubes; – gas preparation apparatus including gas jar and lid, thistle funnel, delivery tubes, beehive shelf and trough (or basin); – graduated glassware (volume) such as measuring cylinders of varying sizes; – quadrat, measuring tape and line transect (string or rope may be used); – potometer; – Visking tubing; – gas syringe; – electronic balance (mass); – ruler (length); – stopclock or stopwatch (time); – thermometer or sensor (temperature); – ammeter (electric current); – voltmeter (potential difference); – ohmmeter (resistance); – angle (protractor); and – any other appropriate apparatus.

Content	Learning Outcomes
Analysing experimental data **Drawing conclusions from an experiment**	Students should be able to: • record detailed observations or numerical data (where appropriate) during chemical reactions, including discrete or continuous variables; • demonstrate knowledge and understanding of the differences between accuracy (practical techniques or apparatus that helps to ensure accuracy), reliability (reproducibility of results) and validity (whether the experiment is suitable for the task); • demonstrate knowledge and understanding of the mathematical techniques that can be used to identify the relationships between variables; • use appropriate scales and axes labels when plotting a graph of experimental data; • demonstrate knowledge and understanding of what is meant by an anomalous result in a set of experimental data and how it should be treated; • plot data points accurately and draw the appropriate straight line or curve; • make reasoned judgements and draw evidence-based conclusions; • analyse, interpret and critically evaluate a broad range of experimental data; • make deductions from given observations; • use reliable numerical data to carry out appropriate calculations of moles, mass, percentage by mass, gas volume, concentration, solution volume, degree of hydration and any other appropriate quantity; and • demonstrate understanding that for a graph of y against x, a straight line through (0,0) is an indicator of direct proportion.

Content	Learning Outcomes
Drawing conclusions from an experiment (cont.)	Students should be able to: • demonstrate understanding that for a graph of y against 1/x, a straight line through (0,0) is an indicator of inverse (indirect) proportion; • discuss in detail the areas of an investigation that could affect the reliability of the data or evidence collected; • develop and defend a hypothesis with appropriate and detailed scientific reasoning; and • develop arguments and explanations, taking account of the limitations of the available evidence.

Content	Learning Outcomes
Prescribed practicals	Below is a list of prescribed practicals that may be assessed in Unit 7. Students should be able to:
Biology Unit B1	• investigate the need for light and chlorophyll in photosynthesis by testing a leaf for starch (Prescribed Practical B1); • investigate the energy content of food by burning food samples (Prescribed Practical B2); • investigate the effect of temperature on the action of an enzyme (Prescribed Practical B3); • use quadrats to investigate the abundance of plants and/or animals in a habitat (Prescribed Practical B4);
Biology Unit B2	• investigate the process of osmosis by measuring the change in length or mass of plant tissue or model cells, using Visking tubing (Prescribed Practical B5); • use a potometer (bubble and weight potometer) to investigate the factors affecting the rate of water uptake by a plant and washing line method to investigate the factors affecting the rate of water loss from leaves (Prescribed Practical B6);
Chemistry Unit C1	• investigate the reactions of acids, including temperature changes that occur (Prescribed Practical C1); • identify the ions in an ionic compound using flame tests (Prescribed Practical C2);
Chemistry Unit C2	• investigate the reactivity of metals (Prescribed Practical C3); • investigate how changing a variable changes the rate of reaction (Prescribed Practical C4); • determine the mass of water present in hydrated crystals (Prescribed Practical C5); and • investigate the preparation, properties, tests and reactions of the gases hydrogen, oxygen and carbon dioxide (Prescribed Practical C6).

Content	Learning Outcomes
Prescribed practicals (cont.) **Physics Unit P1**	Students should be able to: • use simple apparatus, including trolleys, ball-bearings, metre rules, stopclocks and ramps to investigate experimentally how the average speed of an object moving down a runway depends on the slope of the runway measured as the height of one end of the runway (ICT resources could be used to process the measurements and analyse the data) (Prescribed Practical P1); • investigate experimentally the extension of a spring and how it is related to the applied force, and recall that the extension of a spring is directly proportional to the force applied, provided that the limit of proportionality is not exceeded (Prescribed Practical P2); • plan and carry out experiments to verify the Principle of Moments using a suspended metre rule and attached weights or a pivoted beam and square weights (Prescribed Practical P3); • plan and carry out experiments to measure personal power, either by measuring the time taken to climb a staircase or perform a number of step-ups to a platform (Prescribed Practical P4); and
Physics Unit P2	• use ray tracing to measure the angles of incidence and refraction when light is refracted by a glass block, demonstrate knowledge that the angles of incidence and refraction are measured from a line at right angles to the normal and use the measurements taken to plot a graph of angle of incidence against angle of refraction to show that they are related but not proportional (Prescribed Practical P5).

Content	Learning Outcomes
Prescribed practicals (cont.) **Physics Unit P2 (cont.)**	Students should be able to: • use a voltmeter to measure the voltage across a metal wire and an ammeter to measure the current passing through the wire, and: – demonstrate understanding that the temperature of the wire is kept constant using a switch and small currents; – demonstrate understanding of the need to obtain sufficient values of voltage and current so that a voltage–current characteristic graph (V-I graph) can be plotted, with voltage on the y-axis and current on the x-axis; – recall that the V-I graph is a straight line that passes through the origin; and – recall that this shows that the current and voltage are proportional for a metal wire at constant temperature, and that this is known as Ohm's law (Prescribed Practical P6).

4 Scheme of Assessment

4.1 Assessment opportunities

For the availability of examinations and assessment, see Section 2.

This is a unitised specification; candidates must complete at least 40 percent of the overall assessment requirements at the end of the course, in the examination series in which they request a final subject grade. This is the terminal rule.

Candidates may resit individual assessment units once before cash-in. The better of the two results will count towards their final GCSE grade unless a unit is required to meet the 40 percent terminal rule. If it is, the more recent mark will count (whether or not it is the better result). Results for individual assessment units remain available to count towards a GCSE qualification until we withdraw the specification.

4.2 Assessment objectives

There are three assessment objectives (AO1, AO2 and AO3) for this specification. Candidates must:

AO1 demonstrate knowledge and understanding of:
- scientific ideas; and
- scientific techniques and procedures;

AO2 apply knowledge and understanding of and develop skills in:
- scientific ideas; and
- scientific enquiry, techniques and procedures; and

AO3 analyse scientific information and ideas to:
- interpret and evaluate;
- make judgements and draw conclusions; and
- develop and improve experimental procedures.

4.3 Assessment objective weightings

The table below sets out the approximate assessment objective weightings for each assessment component and the overall GCSE qualification.

Assessment Objective	Unit Weighting (%)							Overall Weighting (%)
	Unit 1			Unit 2			Unit 7	
	Biology	Chemistry	Physics	Biology	Chemistry	Physics		
AO1	5	5	5	5.33	5.33	5.33	9	40
AO2	5	5	5	5.67	5.67	5.67	8	40
AO3	1	1	1	3	3	3	8	20
Total Weighting	11	11	11	14	14	14	25	100

4.4 Quality of written communication

In GCSE Double Award Science, candidates must demonstrate their quality of written communication. They need to:

- ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
- select and use a form and style of writing that suit their purpose and complex subject matter; and
- organise information clearly and coherently, using specialist vocabulary where appropriate.

Quality of written communication is assessed in responses to questions and tasks that require extended writing.

Units 1 and 2 of the three disciplines and Booklet B of Unit 7 each have **one** question that has 6 marks allocated to a candidate's quality of written communication. These questions are marked using a three tier banded mark scheme that stipulates the minimum number of marks required for each band. Quality of written communication is then assessed within each individual band.

4.5 Reporting and grading

We report the results of individual assessment units on a uniform mark scale that reflects the assessment weighting of each unit. Candidates entering for Foundation Tier can achieve notional grades C* to G. For Higher Tier units, candidates can achieve notional grades A* to D (with allowable E). Candidates may choose to enter individual units at different tiers.

We determine the overall qualification grades awarded by aggregating the uniform marks that candidates obtain on individual assessment units. We award Double Award GCSE qualifications on a grade scale from A*A* to GG, with A*A* being the highest. If candidates fail to attain grade GG or above, we report their result as unclassified (U).

5 Grade Descriptions

Grade descriptions are provided to give a general indication of the standards of achievement likely to have been shown by candidates awarded particular grades. The descriptions must be interpreted in relation to the content in the specification; they are not designed to define that content. The grade awarded depends in practice upon the extent to which the candidate has met the assessment objectives overall. Shortcomings in some aspects of candidates' performance in the assessment may be balanced by better performances in others.

Grade	Description
A	Candidates recall, select and communicate precise knowledge and detailed understanding of science. They demonstrate a comprehensive understanding of the nature of science, its laws, its principles and applications and the influences of society on science and science on society. They understand the relationships between scientific advances, their ethical implications and the benefits and risks associated with them. They use scientific and technical knowledge, terminology and conventions appropriately and consistently, showing a detailed understanding of scale in terms of time, size and space. They apply appropriate skills, including communication, mathematical, technical and observational skills, knowledge and understanding effectively in a wide range of practical and other contexts. They show a comprehensive understanding of the relationships between hypotheses, evidence, theories and explanations and make effective use of models to explain phenomena, events and processes. They use a wide range of appropriate methods, sources of information and data consistently, applying relevant skills to address scientific questions, solve problems and test hypotheses. Candidates analyse, interpret and critically evaluate a broad range of quantitative and qualitative data and information. They evaluate information systematically to develop arguments and explanations, taking account of the limitations of the available evidence. They make reasoned judgements consistently and draw detailed, evidence-based conclusions.

Grade	Description
C	Candidates recall, select and communicate secure knowledge and understanding of science. They demonstrate understanding of the nature of science, its laws, its principles and applications and the influences of society on science and science on society. They understand how scientific advances may have ethical implications, benefits and risks. They use scientific and technical knowledge, terminology and conventions appropriately, showing understanding of scale in terms of time, size and space. They apply appropriate skills, including communication, mathematical, technical and observational skills, knowledge and understanding in a range of practical and other contexts. They recognise, understand and use straightforward links between hypotheses, evidence, theories and explanations. They use models to explain phenomena, events and processes. Using appropriate methods, sources of information and data, they apply their skills to answer scientific questions, solve problems and test hypotheses. Candidates analyse, interpret and evaluate a range of quantitative and qualitative data and information. They understand the limitations of evidence and develop arguments with supporting explanations. They draw conclusions consistent with the available evidence.

Grade	Description
F	Candidates recall, select and communicate limited knowledge and understanding of science. They recognise simple interrelationships between science and society. They show a limited understanding that scientific advances may have ethical implications, benefits and risks. They use limited scientific and technical knowledge, terminology and conventions, showing some understanding of scale in terms of time, size and space. They apply skills, including limited communication, mathematical, technical and observational skills, knowledge and understanding in practical and some other contexts. They show limited understanding of the nature of science and its applications. They can explain straightforward models of phenomena, events and processes. Using a limited range of skills and techniques, they answer scientific questions, solve straightforward problems and test ideas. Candidates interpret and evaluate limited qualitative and quantitative data and information from a narrow range of sources. They can draw elementary conclusions having collected limited evidence.

6 Guidance on Practical Skills Assessment

6.1 Overview

Unit 7 assesses practical skills. It has two parts: Booklet A is a practical skills assessment and Booklet B is an examination.

All of the 18 prescribed practicals should be taught throughout the course. We will provide three Booklet As, one each for Biology, Chemistry and Physics. Each will contain one pre-release practical assessment task based on but not identical to those on the list of 18 prescribed practicals. We change the three assessed practicals every year to ensure that they continue to set an appropriate challenge and remain valid, reliable and stimulating.

For each Booklet A, candidates carry out the practical task in the laboratory. Each Booklet A is a practical skills assessment and should be carried out under a high level of control, with teacher and invigilator supervision to comply with health and safety regulations.

We will send centres a list of the materials required for Booklet A in the December before the Summer submission. We will send Booklet As to centres in January of the final year of study.

Candidates collect qualitative or quantitative results depending on the demands of the practical skills assessment. We will publish a timetabled period for this practical skills assessment on the examinations timetable. Centres must send Booklet As to us for marking.

Booklet B is a timetabled, externally assessed examination taken at the end of the final year of study. It consists of questions about planning and carrying out any of the prescribed practical tasks. It also has more general questions about any practical situation that arises from this specification.

6.2 Skills assessed by Unit 7

The following skills are assessed:

- planning an investigation;
- carrying out an experiment;
- analysing experimental data; and
- drawing conclusions from an experiment.

6.3 Task taking in Booklet A

Booklet A is a practical skills assessment and must be carried out under a high level of control.

An appropriate teacher should be present with an invigilator to ensure compliance with health and safety regulations.

Teachers and invigilators should **not** offer direction or guidance to candidates where this would assist them in completing Booklet A.

Candidates may work collaboratively in groups of up to three when carrying out the practical tasks, but they must work individually and independently to complete Booklet A.

Candidates have **1 hour** to complete each of the following:

- Booklet A (Biology);
- Booklet A (Chemistry); and
- Booklet A (Physics).

If the experimental process of the Biology practical assessment takes longer than 1 hour, we will provide candidates with a separate practical instruction sheet specific to the practical. This sheet will detail the set-up of the practical and any recording that candidates may have to carry out. The initial recording is not worth any marks. The time required for setting up the practical is not part of the 1 hour allowed for completing Booklet A (Biology), as this extra time is only for set-up or preparation purposes. This practical can only be set up a maximum of three days before candidates complete Booklet A (Biology). If candidates have recorded data on the practical instruction sheet, they will have access to this when completing Booklet A (Biology).

Foundation and Higher Tier candidates may carry out the practical skills assessment in the same room but can only work with others taking the same tier.

The examinations officer must keep all Booklet A papers (completed and unused) securely at all times.

Centres must return Booklet A papers to us for marking after 1 May.

We will provide additional information relating to Booklet A as a support document.

For Booklet A, the level of control for task taking is **high**. The table below exemplifies high levels of control for this practical skills assessment.

Areas of Control	Detail of Control
Authenticity	• Booklet A is an externally set and externally marked practical skills assessment. • Teachers must ensure that all candidates are in direct sight of the supervisor at all times. • Interaction between candidates is tightly prescribed during the practical tasks. • They should not communicate with each other when completing their response in Booklet A. • We will publish a timetabled period for this practical skills assessment on the examinations timetable. • Candidates must carry out the practical tasks and complete each Booklet A in 1 hour. • We send an apparatus and materials list to examinations officers in December of the final year of study. They should distribute this list to the relevant head of department.
Feedback	• Teachers should not provide guidance or feedback during the practical skills assessment except to intervene on the grounds of health and safety.
Page Limit	• We set Booklet A. It has no prescribed page limit.
Collaboration	• Candidates for the same tier of entry may work collaboratively to carry out the practical tasks, but they must provide an individual response in Booklet A.
Resources	• The only allowed additional resource is the GCSE Data Leaflet that appears in Appendix 3, if required.

For up-to-date advice on plagiarism, or any kind of candidate malpractice, see *Suspected Malpractice in Examinations and Assessments: Policies and Procedures* on the Joint Council for Qualifications website at www.jcq.org.uk

6.4 Task marking

Our examiners mark the tasks.

7 Curriculum Objectives

This specification builds on the learning experiences from Key Stage 3 as required for the statutory Northern Ireland Curriculum. It also offers opportunities for students to contribute to the aim and objectives of the Curriculum at Key Stage 4, and to continue to develop the Cross-Curricular Skills and the Thinking Skills and Personal Capabilities. The extent of the development of these skills and capabilities will be dependent on the teaching and learning methodology used.

7.1 Cross-Curricular Skills at Key Stage 4

Communication
Students should be able to: • communicate meaning, feelings and viewpoints in a logical and coherent manner, *for example outline ways in which modern life is dependent on hydrocarbons and crude oil;* • make oral and written summaries, reports and presentations, taking account of audience and purpose, *for example produce a presentation about lifestyle factors that can lead to disease;* • participate in discussions, debates and interviews, *for example research and prepare points for a class discussion about the consequences of an unhealthy diet, researching background information by interviewing a health professional or analysing points from a newspaper article or TV programme;* • interpret, analyse and present information in oral, written and ICT formats, *for example prepare a PowerPoint presentation or a poster on the different formats in which chemists present information about organic compounds from different homologous series, such as molecular formulae, structural formulae and perhaps extending the homologous series;* and • explore and respond, both imaginatively and critically, to a variety of texts, *for example review several newspaper articles about an unhealthy diet and the consequences to individuals and society.*

Using Mathematics

Students should be able to:

- use mathematical language and notation with confidence, *for example use appropriate units, measurements and calculations in experiments such as enzyme experiments, osmosis experiments and transpiration experiments*;
- use mental computation to calculate, estimate and make predictions in a range of simulated and real-life contexts, *for example during fieldwork to work out average percentage cover of a species or average number of a species*;
- select and apply mathematical concepts and problem-solving strategies in a range of simulated and real-life contexts, *for example understand and describe probability associated with genetic conditions*;
- interpret and analyse a wide range of mathematical data, *for example compare pH values to identify substances as being strong or weak acids or alkalis*;
- assess probability and risk in a range of simulated and real-life contexts, *for example describe the probability associated with genetic inheritance and genetic conditions*; and
- present mathematical data in a variety of formats which take account of audience and purpose, *for example plot a graph of extension against force in a Hooke's law experiment*.

Using ICT

Students should be able to make effective use of information and communications technology in a wide range of contexts to access, manage, select and present information, including mathematical information, *for example:*

- *in Biology, use data loggers to record experimental data about an abiotic factor during fieldwork and use an appropriate format for presenting experimental results and conclusions (such as a presentation, word processing, spreadsheet or graphical package);*
- *in Chemistry, prepare a PowerPoint presentation on the properties of Group 7 elements, making comparisons and highlighting trends within the group;* and
- *in Physics, use a spreadsheet to calculate the resistance of wires from data relating to voltage and currents and plot a graph of resistance against length.*

7.2 Thinking Skills and Personal Capabilities at Key Stage 4

Self-Management
Students should be able to: • plan work; • set personal learning goals and targets to meet deadlines; • monitor, review and evaluate their progress and improve their learning; and • effectively manage their time, *for example carry out an individual project or assignment that pulls together data on reactions of metals with air and water, along with displacement reactions carried out in class, to develop a reactivity series.*
Working with Others
Students should be able to: • learn with and from others through co-operation; • participate in effective teams and accept responsibility for achieving collective goals; and • listen actively to others and influence group thinking and decision-making, taking account of others' opinions, *for example plan and carry out experiments in groups to verify the Principle of Moments and use it to calculate the size of a force, or its distance from the pivot, when an object is balanced under the turning effects of no more than two forces, one of which could be the object's weight*.

Problem Solving
Students should be able to: • identify and analyse relationships and patterns, *for example interpret data to identify and state trends such as the reactivity of the Group 1 metals*; • propose justified explanations, *for example explain trends in reactivity for Group 1 and Group 7 elements in terms of electronic structure*; • reason, form opinions and justify their views, *for example interpret the effects of exercise on the pulse rate and describe how the circulatory system benefits from regular exercise*; • analyse critically and assess evidence to understand how information or evidence can be used to serve different purposes or agendas, *for example describe a range of renewable and non-renewable energy resources, and evaluate different views about the effect on the environment of using renewable and non-renewable energy resources*; • analyse and evaluate multiple perspectives, *for example describe nuclear fission in simple terms and be aware that it is a form of energy used in the generation of electricity*; • weigh up options and justify decisions, *for example outline advantages and disadvantages of recycling aluminium when compared to extracting it from aluminium ore*; and • apply and evaluate a range of approaches to solve problems in familiar and novel contexts, *for example investigate the energy content in food by burning food samples, calculate results and compare their data with data from food labels, evaluating the methods of data collection and their reliability and validity*.

Although not referred to separately as a statutory requirement at Key Stage 4 in the Northern Ireland Curriculum, **Managing Information** and **Being Creative** may also remain relevant to learning.

8 Links and Support

8.1 Support

The following resources are available to support this specification:

- our Science microsite at www.ccea.org.uk and
- specimen assessment materials.

We also intend to provide:

- past papers;
- mark schemes;
- Chief Examiner's reports;
- Principal Moderator's reports;
- guidance on progression from Key Stage 3;
- planning frameworks;
- centre support visits;
- support days for teachers;
- practical skills guidance for teachers;
- practical skills guidance for candidates;
- a resource list; and
- exemplification of examination performance.

8.2 Examination entries

Entry codes for this subject and details on how to make entries are available on our Qualifications Administration Handbook microsite, which you can access at www.ccea.org.uk

Alternatively, you can telephone our Examination Entries, Results and Certification team using the contact details provided.

8.3 Equality and inclusion

We have considered the requirements of equality legislation in developing this specification and designed it to be as free as possible from ethnic, sexual orientation, gender, religious, political and other forms of bias.

GCSE qualifications often require the assessment of a broad range of competences. This is because they are general qualifications that prepare students for a wide range of occupations and higher level courses.

During the development process, an external equality panel reviewed the specification to identify any potential barriers to equality and inclusion. Where appropriate, we have considered measures to support access and mitigate barriers.

We can make reasonable adjustments for students with disabilities to reduce barriers to accessing assessments. For this reason, very few students will have a complete barrier to any part of the assessment.

Students with a physical impairment may instruct a practical assistant to set up equipment but may have difficulty in making observations and in manipulating the equipment to carry out the experiment.

Students with a visual impairment may find elements of the assessment difficult, but technology may help visually impaired students to take readings and make observations. Therefore, the assessments should not pose a difficulty for these students.

It is important to note that where access arrangements are permitted, they must not be used in any way that undermines the integrity of the assessment. You can find information on reasonable adjustments in the Joint Council for Qualifications document *Access Arrangements and Reasonable Adjustments*, available at www.jcq.org.uk

8.4 Contact details

If you have any queries about this specification, please contact the relevant CCEA staff member or department:

- Specification Support Officer: Louise Millar
  (email: lmillar@ccea.org.uk)

- Education Manager: Dr Alan McMurray
  (email: amcmurray@ccea.org.uk)

- For a full list of contacts within CCEA visit our website at
  www.ccea.org.uk/examiner-centre-support/examinations-support/key-contacts

Appendix 1

Mathematical Content

The mathematics that must form part of GCSE Double Award Science should be at levels up to, but not beyond, the requirements specified in GCSE Mathematics for the appropriate tier.

This specification ensures that the number of marks used to credit the relevant mathematical skills is no less than 20 percent of the total marks for the qualification. Those marks are allocated to questions and tasks related to Biology, Chemistry and Physics in a ratio of 1:2:3.

Students need to be familiar with and competent in the following areas of mathematics to develop their skills, knowledge and understanding in Double Award Science content.

Mathematical Skills
Arithmetic and numerical computation
Recognise and use expressions in decimal form
Recognise and use expressions in standard form
Use ratios, fractions and percentages
Make estimates of the results of simple calculations
Handling data
Use an appropriate number of significant figures
Find arithmetic means
Construct and interpret frequency tables and diagrams, bar charts and histograms
Understand the principles of sampling as applied to scientific data
Understand simple probability
Understand the terms mean, mode and median
Use a scatter diagram to identify a correlation between two variables
Make order of magnitude calculations
Algebra
Understand and use the symbols =, <, <<, >>, >, ∝, ~
Change the subject of an equation
Substitute numerical values into algebraic equations using appropriate units for physical quantities
Solve simple algebraic equations
Graphs
Translate information between graphical and numeric form
Understand that y = mx + c represents a linear relationship
Plot two variables from experimental or other data
Determine the slope and intercept of a linear graph
Draw and use the slope of a tangent to a curve as a measure of rate of change
Understand the physical significance of area between a curve and the x-axis and measure it by counting squares as appropriate
Geometry and trigonometry
Use angular measures in degrees
Visualise and represent two dimensional (2D) and three dimensional (3D) forms, including 2D representations of 3D objects
Calculate areas of triangles and rectangles, and surface areas and volumes of cubes

Physical quantities, units and unit abbreviations

The table below gives the physical quantities, units and abbreviations commonly used for GCSE Double Award Science.

Students should also understand the prefixes nano (n), milli (m), centi (c), deci (d) and kilo (k) where appropriate.

Physical Quantity	Unit	Abbreviation for Unit
Amount	mole	mol
Concentration	mole per cubic decimetre gram per cubic decimetre	mol/dm^3 g/dm^3
Current	ampere/amp	A
Energy	Joule kilojoule	J kJ
Length	metre centimetre millimetre nanometre kilometre	m cm mm nm km
Mass	gram kilogram tonne	g kg t
Potential difference/voltage	volt	V
Power	watt	W
Pressure	atmosphere newtons per square metre pascal	atm N/m^2 Pa
Resistance	ohm	Ω
Temperature	degree Celsius	°C
Time	second minute hour	s min h
Volume	cubic decimetre cubic centimetre cubic metre	dm^3 cm^3 m^3

Appendix 2

How Science Works

We assess students' practical skills through written examinations and practical assessments. This specification emphasises the importance of practical work. The content in this specification is assessed in the context of How Science Works and assesses students' abilities in the following skills.

Students should be able to:

- understand how scientific methods and theories develop over time;
- use a variety of models such as representational, spatial, descriptive, computational and mathematical to solve problems, to make predictions and to develop scientific explanations and understanding of familiar and unfamiliar facts;
- appreciate the power and limitations of science and consider any ethical issues that may arise;
- explain everyday and technological applications of science, evaluate associated personal, social, economic and environmental implications and make decisions based on the evaluation of evidence and arguments;
- evaluate risks both in practical science and in the wider societal context, including perception of risk in relation to data and consequences;
- recognise the importance of peer review of results and of communicating results to a range of audiences;
- use scientific theories and explanations to develop hypotheses;
- plan experiments or devise procedures to make observations, produce or characterise a substance, test hypotheses, check data or explore phenomena;
- apply knowledge of a range of techniques, instruments, apparatus and materials to select those appropriate to the experiment;
- carry out experiments with the appropriate manipulation of apparatus, taking accurate measurements and considering health and safety;
- recognise when to apply knowledge of sampling techniques to ensure any samples collected are representative; and
- make and record observations and measurements using a range of apparatus and methods.

Students should be able to:

- evaluate methods and suggest possible improvements and further investigations;
- present observations and other data using appropriate methods;
- translate data from one form to another;
- carry out and represent mathematical and statistical analysis;
- represent the distribution of results and make estimations of uncertainty;
- interpret observations and other data (presented in verbal, diagrammatic, graphical, symbolic or numerical form), including identifying patterns and trends, making inferences and drawing conclusions;
- present reasoned explanations including relating data to hypotheses;
- be objective, evaluate data in terms of accuracy, precision, repeatability and reproducibility and identify potential sources of random and systematic error;
- communicate the scientific rationale for investigations, methods used, findings and reasoned conclusions through written and electronic reports and presentations using verbal, diagrammatic, graphical, numerical and symbolic forms;
- use scientific vocabulary, terminology and definitions;
- recognise the importance of scientific quantities and understand how they are determined;
- use SI units (for example kg, g, mg; km, m, mm; kJ, J) and IUPAC chemical nomenclature if appropriate;
- use prefixes and powers of 10 for orders of magnitude (for example tera, giga, mega, kilo, centi, milli, micro and nano);
- interconvert units; and
- use an appropriate number of significant figures in calculations.

Appendix 3

Data Leaflet including the Periodic Table of the Elements to be used with Units C1, C2 and 7

This data leaflet is for use with the specimen assessment materials. The same information will be provided with live Chemistry (C1, C2 and Booklet A and B of Unit 7) examination papers and may be subject to updates as required.

SYMBOLS OF SELECTED IONS

Positive ions

Name	Symbol
Ammonium	NH_4^+
Chromium(III)	Cr^{3+}
Copper(II)	Cu^{2+}
Iron(II)	Fe^{2+}
Iron(III)	Fe^{3+}
Lead(II)	Pb^{2+}
Silver	Ag^+
Zinc	Zn^{2+}

Negative ions

Name	Symbol
Butanoate	$C_3H_7COO^-$
Carbonate	CO_3^{2-}
Dichromate	$Cr_2O_7^{2-}$
Ethanoate	CH_3COO^-
Hydrogencarbonate	HCO_3^-
Hydroxide	OH^-
Methanoate	$HCOO^-$
Nitrate	NO_3^-
Propanoate	$C_2H_5COO^-$
Sulfate	SO_4^{2-}
Sulfite	SO_3^{2-}

SOLUBILITY IN COLD WATER OF COMMON SALTS, HYDROXIDES AND OXIDES

Soluble
All sodium, potassium and ammonium salts
All nitrates
Most chlorides, bromides and iodides EXCEPT silver and lead chlorides, bromides and iodides
Most sulfates EXCEPT lead and barium sulfates Calcium sulfate is slightly soluble

Insoluble
Most carbonates EXCEPT sodium, potassium and ammonium carbonates
Most hydroxides EXCEPT sodium, potassium and ammonium hydroxides
Most oxides EXCEPT sodium, potassium and calcium oxides which react with water

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Rewarding Learning

GCSE

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DATA LEAFLET
CHEMISTRY

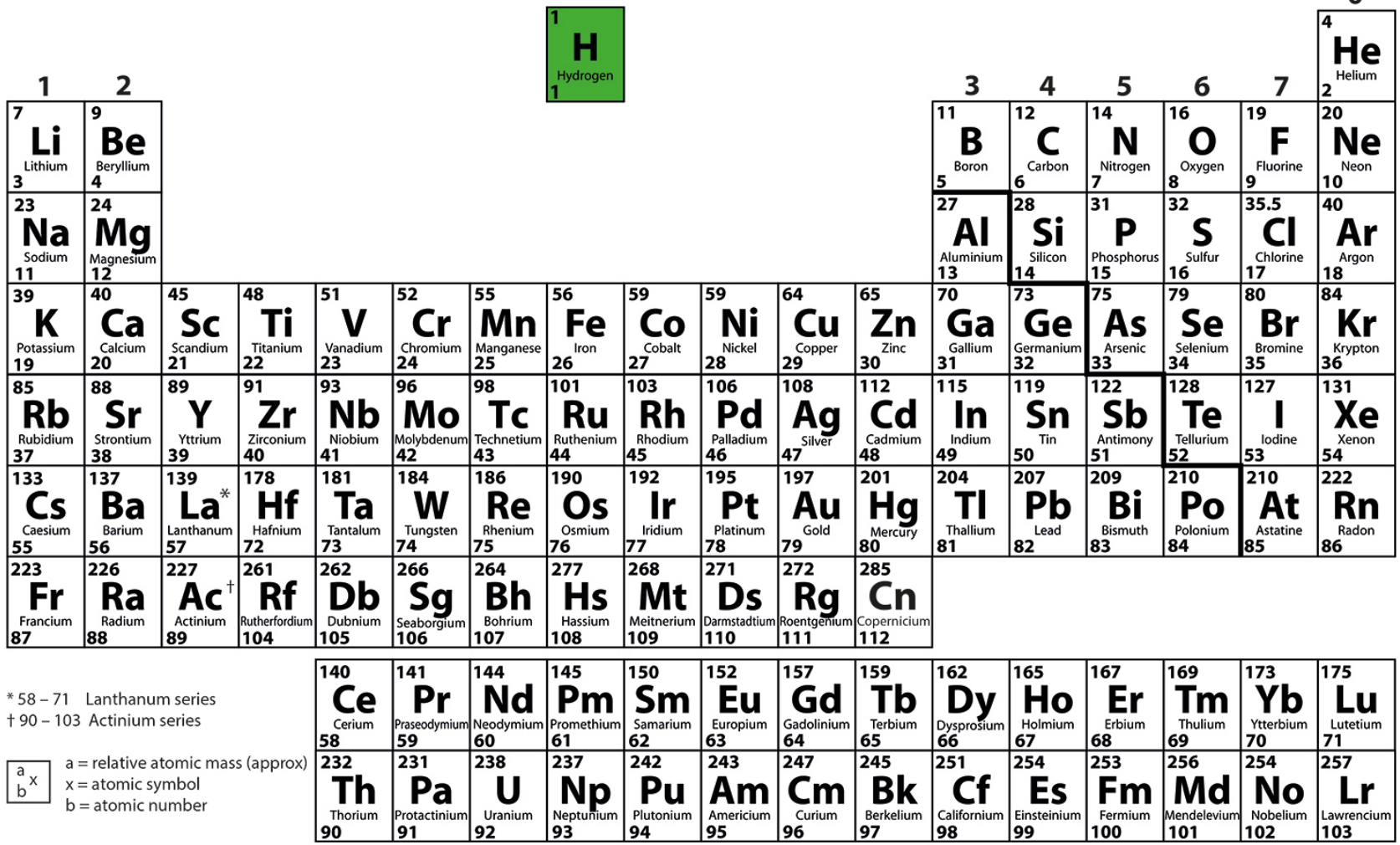
Including the Periodic Table of the Elements

For the use of candidates taking
Science: Chemistry,
Science: Double Award
or Science: Single Award

Copies must be free from notes or additions of any kind. No other type of data booklet or information sheet is authorised for use in the examinations.

THE PERIODIC TABLE OF ELEMENTS

Group



* 58 – 71 Lanthanum series
† 90 – 103 Actinium series

a = relative atomic mass (approx)
x = atomic symbol
b = atomic number

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