GCSE

Rewarding Learning

CCEA GCSE Specification in

Single Award Science

Version 3: 7 November 2017

For first teaching from September 2017
For first assessment from February 2018
For first award in Summer 2019
Subject Code: 1310

Contents

Subject Code 1310
QAN 603/1246/4

This specification is available online at www.ccea.org.uk

Version 3: 7 November 2017

1 Introduction

This specification sets out the content and assessment details for our GCSE course in Single 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, as for all our GCSEs, are 120 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 nature of science and its applications and the interrelationships between science and society;
- develop their understanding of the relationships between hypotheses, evidence, theories and explanations;
- develop and apply their observational, practical, 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; 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.
- It allows students the opportunity to develop and demonstrate their practical skills.
- All units are externally assessed; teachers do not mark any of the components.
- It provides a meaningful, relevant programme of study to equip students for vocational studies in science or entry into the world of work.
- Students can resit each unit once. (See Section 4 for details.)
- Details of the mathematical skills expected of students are given in Appendix 1.

1.3 Prior attainment

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

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 1310.

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
Unit 1: Biology	External written examination Foundation and Higher Tiers: 1 hour Students answer compulsory structured questions that include short responses, extended writing and calculations.	25%	February and November only in 2018 February, Summer and November from 2019
Unit 2: Chemistry	External written examination Foundation and Higher Tiers: 1 hour Students answer compulsory structured questions that include short responses, extended writing and calculations.	25%	February and November only in 2018 February, Summer and November from 2019
Unit 3: Physics	External written examination Foundation and Higher Tiers: 1 hour Students answer compulsory structured questions that include short responses, extended writing and calculations.	25%	February and November only in 2018 February, Summer and November from 2019

Content	Assessment	Weightings	Availability
Unit 4: Practical Skills	**Booklet A** Practical skills assessment Foundation and Higher Tiers: 2 hours Students carry out two pre-release practical tasks (from two of Biology, Chemistry and Physics) in the final year of study.	7.5%	Between 1 January and 1 May from 2019
	Booklet B External written examination Foundation Tier: 1 hour Higher Tier: 1 hour 15 mins Students answer compulsory structured questions that include short responses, extended writing and calculations all set in a practical context for Biology, Chemistry and Physics.	17.5%	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 four 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 nine prescribed practicals (three in each discipline) are shown in *italics*. These are assessed in Booklets A and B of Unit 4: Practical Skills.

3.1 Unit 1: Biology

This unit provides students with a broad introduction to key biological concepts and allows them to investigate a range of practical applications of biology.

Content	Learning Outcomes
1.1 Cells **Microscopy** **Animal cells** **Plant cells** **Stem cells**	Students should be able to: 1.1.1 *make a temporary slide and use a light microscope to examine and identify the structures of a typical plant and animal cell (Prescribed Practical B1)*; 1.1.2 demonstrate knowledge of the structure and function of animal cells, including nucleus and chromosomes, cytoplasm and cell membranes; 1.1.3 demonstrate knowledge that plant cells have additional structures not found in animal cells: cellulose cell wall, large permanent vacuole and chloroplasts; 1.1.4 demonstrate understanding that a stem cell is a simple cell in animals and plants which has the ability to divide to form cells of the same type; **and** 1.1.5 **demonstrate understanding that the use of stem cells in medicine has:** • **potential benefits, including bone marrow transplants in the treatment of leukaemia; and** • **risks, with ethical implications, including pre-treatment using radiotherapy or chemotherapy, transfer of viruses or diseases from other animals, formation of tumours or development of unwanted cell types.**

<table>
<tr><th>Content</th><th>Learning Outcomes</th></tr>
<tr><td>Specialisation</td><td>Students should be able to:
1.1.6 demonstrate understanding that the cells of multi-celled organisms are organised to form specialised tissues, organs and organ systems;</td></tr>
<tr><td>1.2
Food and diet
Food and energy</td><td>1.2.1 describe food as a source of chemical energy in humans;
1.2.2 investigate the energy content of food by burning food samples (Prescribed Practical B2);
1.2.3 explore and evaluate how the energy required by individuals is different depending on age, gender and activity;</td></tr>
<tr><td>Biological molecules</td><td>1.2.4 explain the functions and sources of biological molecules, limited to:
• carbohydrates as sources of energy;
• fats as sources of energy and insulation;
• proteins for growth and repair;
• water as a solvent and for transport;
• fibre to prevent constipation;
• sources and functions of the vitamins C and D; and
• sources and functions of the minerals calcium and iron; and</td></tr>
<tr><td>Nutrition and food tests</td><td>1.2.5 recall the following reagents and their colour changes:
<table>
<tr><td>Reagent</td><td>Initial colour</td><td>End colour for positive result</td></tr>
<tr><td>Benedict’s</td><td>Blue</td><td>Brick red precipitate</td></tr>
<tr><td>Iodine</td><td>Yellow–brown</td><td>Blue–black</td></tr>
<tr><td>Biuret</td><td>Blue</td><td>Lilac/Purple</td></tr>
<tr><td>Ethanol</td><td>Clear</td><td>White emulsion</td></tr>
</table></td></tr>
</table>

Content	Learning Outcomes
Nutrition and food tests (cont.)	Students should be able to: 1.2.6 carry out practical work to investigate food samples using food tests, including: • reducing sugar (Benedict's); • starch (iodine solution); • amino acid/protein (Biuret); and • fats (ethanol);
Food and health	1.2.7 examine and evaluate the relationship between diet and health, obesity, heart disease and strokes, and recognise why many people in society are slow to accept these links or fail to adapt their lifestyle; 1.2.8 research the ways in which the risk of heart disease or strokes may be reduced, including: • lifestyle – increasing exercise, reducing stress and stopping smoking; and • diet – choosing low salt, low saturated fats and low cholesterol;
Cost to society	1.2.9 evaluate the costs to society of circulatory diseases (medical and wider costs, such as the effect on families);
Effects of exercise	1.2.10 investigate the effects of exercise on the pulse rate; 1.2.11 **describe how the circulatory system benefits from regular exercise, resulting in a strengthened heart muscle and increased cardiac output when at rest;**
Respiration	1.2.12 demonstrate understanding that respiration is an exothermic reaction which releases energy; and 1.2.13 recall the word **and balanced symbol** equation for aerobic respiration: *glucose + oxygen → carbon dioxide + water + energy* $\boldsymbol{C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + energy}$

Content	Learning Outcomes
1.3 Chromosomes and genes **Genome**	Students should be able to: 1.3.1 describe the genome as the entire genetic material of an organism;
Chromosomes	1.3.2 identify and describe chromosomes as genetic structures occurring in functional pairs in the nucleus of cells;
Genes	1.3.3 identify and describe genes as sections of chromosomes made up of short lengths of deoxyribonucleic acid (DNA) that operate as functional units to control characteristics;
DNA	1.3.4 recognise DNA as the core component of genes and chromosomes; 1.3.5 recognise the double helix structure of DNA;
Genetic diagrams and terminology	1.3.6 **demonstrate 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; and** • **pedigree diagrams;**
Cancer	1.3.7 demonstrate understanding that cancer cells are produced by uncontrolled cell division;
Mutations	1.3.8 explain that variation in living organisms can be due to mutations – random changes in the structure or number of chromosomes or genes which can be triggered by environmental factors (such as ultraviolet (UV) light causing skin cancer); and
Genetic conditions	1.3.9 recall that cystic fibrosis and Down's syndrome are examples of genetic conditions (symptoms and causes are not required).

Content	Learning Outcomes
Genetic screening	Students should be able to: 1.3.10 evaluate ethical issues linked to genetic screening, including: • who decides who will be tested; • benefits and risks of amniocentesis **compared to blood tests**; • the dilemma for potential parents carrying a foetus with a genetic condition following diagnosis of abnormalities by a test; and • making genetic information available to wider society, for example insurance companies;
Genetic engineering	1.3.11 **demonstrate understanding of genetic engineering as a process which modifies the genome of an organism, and demonstrate understanding that genetic engineering has:** • **advantages – producing human insulin and other products by this method; and** • **disadvantages – unforeseen outcomes, moral issues, and the spread of genes to the wild;**
1.4 Co-ordination and control **Central nervous system**	1.4.1 describe the basic structure and function of the central nervous system, explaining how the brain and spinal cord together form the central nervous system that controls and co-ordinates the responses between the receptors and effector muscles;
Voluntary and reflex actions	1.4.2 distinguish between voluntary and reflex actions in terms of conscious control and speed of response; **and**
Reflex arc	1.4.3 **demonstrate understanding of the pathway of the spinal reflex arc in terms of:** • **a receptor that detects stimuli in the environment and produces nerve impulses;** • **a sensory, an association and a motor neuron connected by synapses; and** • **an effector (a muscle or gland) that responds to impulses from the motor neuron.**

Content	Learning Outcomes
Plant hormones	Students should be able to: 1.4.4 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;**
Hormones	1.4.5 demonstrate understanding that hormones are chemical messengers produced by glands and released into the blood, which carries them to a target organ, where they act;
Insulin	1.4.6 demonstrate understanding that: • insulin is produced by the pancreas in response to increasing blood glucose levels and acts in the liver; and • insulin lowers blood glucose levels by converting glucose to glycogen or causes glucose to move from the blood into cells where it is used for respiration; and
Diabetes	1.4.7 demonstrate 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, where the pancreas gradually produces less insulin; • Type 2 diabetes can be controlled by diet but later requires medication or insulin injections; • the symptoms of diabetes include high blood glucose, the presence of 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.

Content	Learning Outcomes
1.5 Reproductive system **Male and female reproductive system**	Students should be able to: 1.5.1 demonstrate knowledge of the structure and function of the male reproductive system, including the testes, urethra, scrotum, penis, sperm tube and prostate gland; 1.5.2 demonstrate knowledge of the structure and function of the female reproductive system, including the ovaries, oviducts, uterus, cervix and vagina;
Menstrual cycle	1.5.3 **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;** and
Pregnancy	1.5.4 demonstrate knowledge that: • fertilisation takes place in the oviducts when the sperm and egg **(ovum)** nuclei fuse to give a zygote; • **sperm and ova contain half the normal number of chromosomes so that when they combine the normal (full) number of chromosomes is restored in the zygote;** • **cells (for example gametes such as sperm and ovum) that contain half the number of chromosomes are described as being haploid;** • **cells that contain the full number of chromosomes are described as diploid;** • the zygote divides many times to form a ball of cells as it travels down the oviduct to the uterus; • this then implants in the uterus lining, where it develops over 40 weeks; • the placenta is where exchange of dissolved nutrients, oxygen, carbon dioxide and urea occurs; • these substances are carried to or from the foetus in the blood vessels in the umbilical cord; • the amnion and amniotic fluid cushion the foetus; and • scientific evidence shows that consuming alcohol while pregnant can cause harm to the foetus**.**

Content	Learning Outcomes
Contraception	Students should be able to: 1.5.5 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 to 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 egg **(ovum)**; • surgical – male and female sterilisation to prevent the passage of sperm and eggs respectively; and • an awareness that contraception can raise ethical and moral issues for some people;
1.6 Variation and adaptation **Types of variation**	1.6.1 demonstrate understanding that variation can be observed in living things, for example: • height and length as examples of continuous variation (as displayed in a histogram); and • tongue rolling and hand dominance as examples of discontinuous variation (as displayed in a bar chart); and 1.6.2 demonstrate understanding that variation can be genetic and/or environmental.

Content	Learning Outcomes
Natural selection	Students should be able to: 1.6.3 **demonstrate understanding of how variation and natural selection may lead to evolution or extinction, including:** • **variation within the phenotypes of a population;** • **competition for resources often leading to differential survival of the best adapted phenotypes, for example antibiotic resistance;** • **recognition that surviving phenotypes are more likely to reproduce and pass on their genes to the next generation;** • **Darwin's theory of evolution as a continuing process of natural selection, which leads to gradual changes in organisms over time and which may result in the formation of a new species;** • **a description of the role of fossils in providing evidence for evolution; and** • **extinction of a species over time as a consequence of failure to adapt to environmental change;**
1.7 Disease and body defences **Types of microorganisms**	1.7.1 demonstrate knowledge of the types of communicable diseases caused by microorganisms and 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
The body's defence mechanisms	1.7.2 demonstrate 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.

Content	Learning Outcomes
Antibiotics	Students should be able to: 1.7.3 demonstrate understanding that antibiotics, for example penicillin, are chemicals produced by fungi which are used against bacterial diseases to kill bacteria or reduce their growth;
Antibiotic-resistant bacteria	1.7.4 **demonstrate understanding of the implications of the following on the health of the population:** • **overuse of antibiotics leading to bacterial resistance, resulting in the development of superbugs such as MRSA; and** • **procedures used to reduce the incidence of superbugs and why they are difficult to eradicate;**
Development of medicines	1.7.5 demonstrate understanding of how medicines are developed, including the discovery of penicillin by Fleming and its later development for medical applications by Florey and Chain; 1.7.6 evaluate issues involved in developing treatments, including: • in vitro testing; • animal testing; • species difference and side effects; and • clinical trials and licensing; and
Alcohol and tobacco	1.7.7 demonstrate understanding of how the misuse of drugs can affect health, including: • alcohol – binge drinking can cause liver disease and affect the development of the foetus; and • tobacco smoke, which contains tar – a cause of bronchitis, emphysema and lung cancer; nicotine – which is addictive and affects heart rate; and carbon monoxide – which combines with red blood cells to reduce the oxygen-carrying capacity of the blood.

Content	Learning Outcomes
1.8 Ecological relationships **Photosynthesis**	Students should be able to: 1.8.1 demonstrate knowledge and understanding of photosynthesis as an endothermic process that takes place in chloroplasts, where chlorophyll absorbs light energy, producing sugars and starch; 1.8.2 recall the word **and balanced symbol** equation for photosynthesis: *carbon dioxide + water → glucose + oxygen* $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$ 1.8.3 explain investigations of how light is needed for photosynthesis, 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; and • the production of oxygen; 1.8.4 *investigate the need for light and chlorophyll in photosynthesis by testing a leaf for starch (Prescribed Practical B3)*;
Role of the Sun as an energy source	1.8.5 demonstrate understanding that the Sun is the source of energy for most ecosystems on Earth, and of the role of green plants as producers in capturing this energy and making it available to other organisms; and
Food chains and food webs	1.8.6 demonstrate understanding of food chains and webs by: • identifying producers and consumers; and • demonstrating understanding that arrows represent consumption and the transfer of energy through the ecosystem.

Content	Learning Outcomes
Monitoring environmental changes	Students should be able to: 1.8.7 demonstrate understanding that biotic and abiotic factors can be used to monitor changes in the environment as follows: • abiotic factors, including CO_2 levels, pH, temperature, water levels and decreasing ice fields; and • biotic factors, including lichens as pollution monitors;
Competition	1.8.8 demonstrate understanding that organisms compete for resources (water, light, space and minerals for plants, and water, food, territory and mates for animals), which can affect population growth, including: • practically investigating the effect of planting density on seedling growth; and • the effects of introducing competitive invasive species; and
Human activity on Earth	1.8.9 demonstrate understanding that human activity can have positive effects on biodiversity, including the role of: • agriculture (replanting hedgerows, managing field margins for wildlife, and using fertilisers efficiently); • land use and management (reclaiming industrial sites, using brown-field building sites and planting sustainable woodlands); • seas (protecting fish stocks by quotas, fishing bans and restrictions on net size); • nature reserves (protecting habitats and rare species); and • international treaties to combat global pollution.

3.2 Unit 2: Chemistry

This unit provides students with a broad introduction to key chemistry concepts and allows them to investigate a range of practical applications of chemistry.

Content	Learning Outcomes
2.1 Acids, bases and salts	Students should be able to:
Hazard symbols	2.1.1 develop an awareness of the importance of safety in the laboratory to assess potential risk, including the hazards associated with chemicals, and demonstrate knowledge of the following hazard symbols: toxic, corrosive, flammable, explosive and caution;
Indicators	2.1.2 recall the effect of acid and alkali on indicator papers (red and blue litmus papers and universal indicator paper);
	2.1.3 investigate how indicators can be obtained from natural dyes that can be extracted from plants, such as red cabbage or beetroot;
pH scale	2.1.4 interpret given data about universal indicator (colour/pH) to classify solutions as acidic, alkaline or neutral;
	2.1.5 indicate the relative strengths of acidic and alkaline solutions, classifying them as: • pH 0–2 strong acid; • pH 3–6 weak acid; • pH 7 neutral; • pH 8–11 weak alkali; and • pH 12–14 strong alkali;
	2.1.6 demonstrate understanding of the usefulness of a pH meter;
	2.1.7 recall examples of: • strong acids (including hydrochloric acid and sulfuric acid); and • strong alkalis (including sodium hydroxide and potassium hydroxide); and
	2.1.8 recall examples of: • weak acids (including ethanoic acid); and • weak alkalis (including ammonia).

Content	Learning Outcomes
Neutralisation	Students should be able to: 2.1.9 explore neutralisation in everyday contexts, for example treating indigestion and using toothpaste; 2.1.10 demonstrate knowledge and understanding of the general reactions of acids (hydrochloric and sulfuric acid) with metals, bases, metal carbonates and hydrogencarbonates, and write observations and equations; 2.1.11 *follow a neutralisation reaction by monitoring pH (Prescribed Practical C1)*;
2.2 Elements, compounds and mixtures **Solids, liquids and gases**	2.2.1 **classify substances as solids, liquids or gases given melting point and boiling point data;** 2.2.2 draw particle diagrams to represent solids, liquids and gases; 2.2.3 describe changes of state as a physical reaction, including melting, evaporating/boiling, freezing, condensing and subliming;
Different types of substances	2.2.4 define the terms element, compound and mixture; 2.2.5 recall that a pure substance is a single element or compound not mixed with any other substance; 2.2.6 demonstrate knowledge and understanding of the terms soluble, insoluble, solute, solvent, solution, residue, filtrate, distillate **and miscible**;
Separation	2.2.7 investigate how mixtures can be separated using filtration, crystallisation, paper chromatography and simple distillation; and 2.2.8 describe paper chromatography as the separation of mixtures of soluble substances by running a solvent **(known as the mobile phase)** through the mixture on the paper **(known as the stationary phase)**, which causes the substances to move at different rates over the paper.

Content	Learning Outcomes
Separation (cont.)	Students should be able to: 2.2.9 interpret a paper chromatogram **including measuring R_f value using the solvent front and leading edge of the spot;** 2.2.10 analyse given data on mixtures to make judgements on the most effective methods of separation, and plan experiments to carry out this separation;
2.3 Atomic structure and Periodic Table **Atomic structure**	2.3.1 describe the structure of an atom; 2.3.2 **state the relative charges and approximate relative masses of protons, neutrons and electrons;** 2.3.3 define atomic number as the number of protons in an atom and the mass number as the total number of protons and neutrons in an atom; 2.3.4 **demonstrate understanding that an atom as a whole has no electrical charge because the number of protons is equal to the number of electrons;** 2.3.5 calculate the number of protons, neutrons and electrons in an atom using data from the Periodic Table; 2.3.6 write and draw the electronic configuration (structure) of atoms with atomic number 1–20;
Periodic Table	2.3.7 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; 2.3.8 **demonstrate 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;** and 2.3.9 demonstrate understanding that a group is a vertical column in the Periodic Table and a period is a horizontal row.

Content	Learning Outcomes
Periodic Table (cont.)	Students should be able to: 2.3.10 identify and recall the position of metals and non-metals in the Periodic Table; 2.3.11 demonstrate understanding that elements in the same group in the Periodic Table have the same number of electrons in their outer shell, and that this gives them similar chemical properties; 2.3.12 demonstrate understanding that elements in the same period in the Periodic Table have the same number of electron shells; 2.3.13 recall that elements with similar properties appear in the same group and locate these groups in the Periodic Table, for example: • Group 1 is a group of reactive metals, the alkali metals; • Group 2 is a group of alkaline earth metals; • Group 7 is a group of reactive non-metals, the halogens; and • Group 0 is a group of non-reactive non-metals, the noble gases;
Group 1	2.3.14 demonstrate knowledge that Group 1 metals react with water to produce hydrogen and a metal hydroxide, and record observations for the reactions of sodium and potassium with water; 2.3.15 demonstrate understanding of the relationship between the rate at which alkali metals react and their position in the group;
Group 0	2.3.16 use the concept of electronic configuration to explain the lack of reactivity and the stability of the noble gases; and 2.3.17 recall that the noble gases are colourless gases.

Content	Learning Outcomes
2.4 **Bonding** **Ionic bonding**	Students should be able to: 2.4.1 explain how, when elements react, their atoms join other atoms to form compounds, and in doing so achieve a full outer shell of electrons or have an electronic structure like the noble gases; 2.4.2 demonstrate understanding that an ion is a charged particle formed when an atom gains or loses electrons; 2.4.3 **explain, using dot and cross diagrams, how:** • **ions are formed; and** • **ionic bonding takes place in simple ionic compounds, limited to elements in Group 1 with Group 7 and Group 2 with Group 6;** 2.4.4 **demonstrate understanding that ionic bonding involves attraction between oppositely charged ions, that ionic bonds are strong, and that substantial energy is required to break ionic bonds;** 2.4.5 recognise that ionic bonding is typical of a metal reacting with a non-metal;
Covalent bonding	2.4.6 describe a single covalent bond as a shared pair of electrons; 2.4.7 **explain, using dot and cross diagrams, how covalent bonding occurs in H_2, HCl, H_2O and CH_4, and label lone pairs of electrons;** 2.4.8 recognise covalent bonding as typical of non-metallic elements reacting and that a covalent bond can be represented as a single line; **and** 2.4.9 **demonstrate understanding that covalent bonds are strong and substantial energy is required to break covalent bonds.**

Content	Learning Outcomes
2.5 Materials **Physical properties**	Students should be able to: 2.5.1 examine how materials differ with respect to their physical properties, such as melting point, boiling point, strength, conductivity, density and hardness, and use such data to assess the suitability of a material for a particular purpose;
	2.5.2 describe and give examples of natural and synthetic materials;
Smart materials	2.5.3 describe a smart material as one whose properties change depending on a change in the surroundings, limited to thermochromic and photochromic materials;
Nanomaterials	2.5.4 describe a nanomaterial **as one that contains a few hundred atoms which are nanoparticles (1–100 nm in size) and recall that 1 nm is 1×10^{-9} m;**
	2.5.5 evaluate: • the benefits of nanoparticles in sun creams, including better skin coverage and more effective protection from the Sun's ultraviolet rays; and • the possible risks, including potential cell damage in the body and harmful effects on the environment;
	2.5.6 **demonstrate understanding of the structure of graphene (a one-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; and**
Emergent materials	2.5.7 **describe the ongoing emergence of new carbon-based materials, including fullerene, and discuss their possible uses in modern society.**

Content	Learning Outcomes
Using materials to fight crime **Forensic evidence**	Students should be able to: 2.5.8 explore the variety of evidence that can be collected at a crime scene, including biological evidence, fingerprint evidence, footprints or tyre tracks, trace evidence, digital evidence, and drug or explosive evidence; 2.5.9 describe the usefulness of collecting trace evidence – hair, fibres, paint or glass fragments – at a crime scene, and how these may be analysed for comparison;
Fingerprints	2.5.10 recognise the variety of types of fingerprints: arch, loop, whorl and composite; 2.5.11 demonstrate understanding that fingerprints are unique and so can be used for identification purposes; 2.5.12 examine the process by which forensic scientists collect fingerprint evidence from different surfaces at a crime scene and preserve the print, including the use of: • powders such as carbon black and aluminium dust; • alternative light sources; and • chemical developers to visualise prints; 2.5.13 explore how forensic scientists compare a photograph or scan of a fingerprint to a database of fingerprints to help identify the individual; and 2.5.14 explore the use of fingerprint recognition as a security measure, for example to access a mobile phone or tablet.

Content	Learning Outcomes
2.6 Symbols, formulae and equations **Symbols** **Formulae**	Students should be able to: 2.6.1 recognise names and symbols for common elements; 2.6.2 interpret chemical formulae by naming the elements and stating the number of each type of atom present; 2.6.3 write chemical formulae of compounds; 2.6.4 demonstrate understanding that chemical reactions use up reactants and produce new substances called products;
Equations	2.6.5 construct word equations to describe the range of reactions covered in this unit; 2.6.6 **write balanced symbol equations for all reactions covered in this unit and for unfamiliar chemical reactions when the names of the reactants and products are specified;** 2.6.7 **demonstrate 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 balanced symbol equations for the reactions in this specification;**
2.7 Qualitative analysis	2.7.1 describe how to test for hydrogen gas: apply a lighted splint and a popping sound results **(equation for reaction required)**; 2.7.2 describe how to test for carbon dioxide: limewater (calcium hydroxide solution) will change from colourless to milky if the test is positive; 2.7.3 describe how to test for oxygen gas: apply a glowing splint and it relights in the presence of oxygen; and 2.7.4 investigate how a flame test can be carried out with a nichrome wire and concentrated acid using metal chlorides to identify metal ions.

Content	Learning Outcomes
2.7 Qualitative analysis (cont.)	Students should be able to: 2.7.5 recall the flame colours of some metal ions: lithium (crimson), sodium (yellow–orange), potassium (lilac), calcium (brick red), and copper (blue–green);
2.8 Metals and the reactivity series	2.8.1 recall the reactivity series of metals, including K, Na, Ca, Mg, Al, Zn, Fe and Cu; 2.8.2 demonstrate knowledge that this series is based on the differing reactivity of metals with water and acid; 2.8.3 collect and/or analyse experimental data to predict where an unfamiliar element should be placed in the reactivity series or to make predictions about how it will react; 2.8.4 *investigate the reactivity of metals (Prescribed Practical C2)*;
Energetics	2.8.5 demonstrate understanding that chemical reactions in which heat is given out are exothermic and that reactions in which heat is taken in are endothermic; 2.8.6 investigate the temperature change during a reaction; 2.8.7 *investigate the temperature changes which occur during a reaction (Prescribed Practical C3)*;
Aluminium extraction	2.8.8 **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;** 2.8.9 **describe the industrial extraction of aluminium from alumina, demonstrate understanding that the alumina has been purified from the ore bauxite, and demonstrate understanding of the need to replace the anodes periodically; and** 2.8.10 **interpret and write half equations for the reactions occurring at the anode and cathode for the electrolysis of aluminium oxide.**

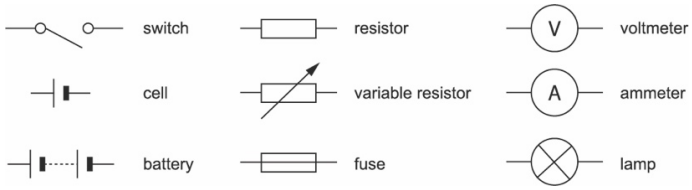
Content	Learning Outcomes
Aluminium extraction (cont.) **2.9 Rates of reaction**	Students should be able to: 2.8.11 **demonstrate knowledge that recycling aluminium uses only a fraction of the energy needed to extract it from bauxite and saves waste;** 2.9.1 describe the rate of a reaction in terms of the change in the amount of reactants or products with time; 2.9.2 demonstrate understanding that the rate of a reaction may be determined by measuring the loss of a reactant or gain of a product over time; 2.9.3 suggest appropriate practical methods to measure the rate of a reaction and collect reliable data (methods limited to measuring a change in mass or gas volume against time) for the reaction of: • metals with dilute acid; and • metal carbonates with dilute acid; 2.9.4 interpret simple experimental data quantitatively, for example drawing and interpreting appropriate graphs to determine the rate of reaction; 2.9.5 describe the effects of changes in temperature and concentration on rates of reaction, **and explain these in terms of frequency and energy of collisions between particles;** 2.9.6 **demonstrate understanding that a catalyst is a substance which increases the rate of a reaction without being used up;** and 2.9.7 carry out practical work to investigate how changing a variable changes the rate of reaction.

Content	Learning Outcomes
2.10 Organic chemistry **Hydrocarbons**	Students should be able to: 2.10.1 demonstrate understanding that there is a large number of carbon compounds, the study of which is simplified by splitting the compounds into 'families' or homologous series (limited to alkanes and alkenes); 2.10.2 recall: • that a hydrocarbon is a molecule consisting of hydrogen and carbon only; • that alkanes are one of the homologous series of hydrocarbons; • the general formula of the alkanes; and • the molecular formula, structural formula, state at room temperature and pressure of methane, ethane, propane and butane;
Crude oil	2.10.3 recall that crude oil is a finite resource that has been formed over millions of years from dead plants and animals and that it is the main source of hydrocarbons;
Fractional distillation	2.10.4 describe and explain the separation of crude oil by fractional distillation, describe the fractions as largely a mixture of alkanes, and recall the names and uses of the following fractions: • petrol used as a fuel for cars; • kerosene as a fuel for aircraft; • diesel as a fuel for cars, lorries and trains; and • bitumen used to surface roads and roofs;
Combustion of alkanes	2.10.5 describe the combustion of alkanes (limited to complete combustion) to produce carbon dioxide and water, including word **and symbol** equations;
Alkenes	2.10.6 **recall the general formula of the alkenes, along with the molecular formula, structural formula, state at room temperature and pressure of ethene, propene and butene; and**
Combustion of alkenes	2.10.7 **describe the combustion of alkenes (limited to complete combustion) to produce carbon dioxide and water, including word and symbol equations.**

Content	Learning Outcomes
Atmospheric pollution	Students should be able to: 2.10.8 recall that the combustion of fuels is a major source of atmospheric pollution due to the combustion of hydrocarbons producing carbon dioxide, which leads to the greenhouse effect, causing sea level rises, flooding and climate change;
Polymers	2.10.9 **describe how monomers, for example ethene or chloroethene (vinyl chloride), can join together to form very long chain molecules called polymers and the process is known as addition polymerisation;** 2.10.10 **write equations for the polymerisation of ethene and chloroethene;** and 2.10.11 demonstrate understanding that addition polymers (plastics) are non-biodegradable and evaluate the advantages and disadvantages of their disposal by landfill and incineration.

3.3 Unit 3: Physics

This unit provides students with a broad introduction to key physics concepts and allows them to investigate a range of practical applications of physics.

Content	Learning Outcomes
3.1 Electrical circuits **Conductors and insulators**	Students should be able to: 3.1.1 demonstrate understanding of the difference between conductors and insulators, **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	3.1.2 demonstrate understanding of the role of conductors, insulators and switches in simple series and parallel circuits;
Standard symbols	3.1.3 interpret and draw circuit diagrams using the standard symbols illustrated below: 
	3.1.4 recall the meaning of cell polarity and relate it to the symbol for a cell;
Series and parallel circuits	3.1.5 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; 3.1.6 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; and 3.1.7 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.

Content	Learning Outcomes
Ohm's law	Students should be able to: 3.1.8 *carry out practical work to*: • *describe and carry out an experiment using a voltmeter to measure the voltage across a metal wire and an ammeter to measure the current passing through the wire*; • *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 P1)*;
Resistance	3.1.9 recognise and use the equation *voltage = current × resistance* where voltage is measured in volts, current in amperes and resistance in ohms;
Factors affecting resistance	3.1.10 *carry out practical work to:* • *investigate experimentally how the resistance of a metallic conductor at constant temperature depends on length*; • *obtain sufficient values to plot a graph of resistance (y-axis) and length (x-axis)*; • *recall that the graph is a straight line that passes through the origin*; *and* • *recall that this shows that when a metal wire is at constant temperature, the resistance and length of wire are proportional (Prescribed Practical P2)*; 3.1.11 solve simple problems using the knowledge that the resistance of a metal wire at constant temperature is proportional to its length; **and** 3.1.12 **investigate experimentally how the resistance of a metallic conductor at constant temperature depends on the area of cross section and the material it is made from.**

Content	Learning Outcomes
Factors affecting resistance (cont.)	Students should be able to: 3.1.13 **recall how the resistance of a metallic conductor at constant temperature depends on the area of cross section and the material it is made from, and solve simple problems using this knowledge (knowledge of resistivity is not required);** 3.1.14 **examine how variable resistors control current in a circuit and where they are used;**
3.2 Household electricity **Power**	3.2.1 recognise the equation *power = voltage × current* and use this in calculations to select the appropriate rating of a fuse;
Fuses	3.2.2 evaluate the consequences of incorrect fuses in common electrical appliances;
Kilowatt-hour	3.2.3 **recall that the unit used in the cost of electricity to the consumer is the kilowatt-hour (kWh);** 3.2.4 **demonstrate understanding of the meaning of the kilowatt-hour and use of the power rating of electrical appliances to calculate their cost;** 3.2.5 **recognise and use the formula** ***energy (kWh) = power (kW) × time (hr)*** **to calculate the cost of using appliances for varying amounts of time;** 3.2.6 use meter readings to calculate the cost of household electricity and investigate the factors that affect these bills;
Protection from electrical shock	3.2.7 recall the wiring inside a fused three-pin plug and demonstrate understanding of the function of the live, neutral and earth wires; and 3.2.8 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.

Content	Learning Outcomes
Protection from electrical shock (cont.)	Students should be able to: 3.2.9 demonstrate understanding of how double insulation protects the user;
3.3 Energy **Forms of energy**	3.3.1 recall that energy can exist in many forms such as chemical, heat, electrical, sound, light, magnetic, strain energy, kinetic and gravitational potential;
Conservation of energy	3.3.2 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; 3.3.3 recall that energy is measured in joules (J);
Energy transfers	3.3.4 draw and interpret energy transfer diagrams for the energy conversions that occur in a range of common devices found in everyday life, and interpret these diagrams using the Principle of Conservation of Energy (Sankey diagrams are not required); 3.3.5 **recall that kinetic energy E_k is the energy possessed by a moving object, and recognise and use the equation** $E_k = \frac{1}{2} mv^2$ **to calculate kinetic energy in joules (J), the mass of an object in kilograms (kg) and the velocity of an object in metres per second (m/s); and** 3.3.6 **recall that an object has gravitational potential energy E_p because of its position above the ground, and recognise and use the equation** $E_p = mgh$ **to calculate the potential energy in joules, the mass in kilograms and the vertical height in metres, using g as 10 N/kg**.

Content	Learning Outcomes
Renewable sources **Non-renewable sources** **Efficiency**	Students should be able to: 3.3.7 demonstrate knowledge that renewable energy is defined as energy which is collected from resources that will never run out or that are naturally replenished within a human lifetime; 3.3.8 recall examples of renewable energy such as sunlight, wind, rain, tidal, waves, wood and geothermal heat, and demonstrate understanding that biomass is renewable if the plant material used is regrown; 3.3.9 explain why the emphasis on developing alternative renewable fuels has increased in recent years due to the finite nature of fossil fuels; 3.3.10 demonstrate knowledge that: • a non-renewable energy source is one that has a finite supply (it will run out some time); • fossil fuels such as oil, natural gas and coal are considered non-renewable because their formation takes millions of years; • nuclear energy based on fission is also non-renewable since supplies of uranium ore will not last forever; and • biomass is non-renewable if it uses plants that are not regrown; 3.3.11 recall that not all of the energy used in a particular process or device is useful and that the efficiency is a measure of how much of the input energy to a process or device appears as useful output energy; and 3.3.12 recognise, understand and use the equation $efficiency = \frac{useful\ output\ energy}{total\ input\ energy}$ quoting the efficiency as a decimal or a percentage.

Content	Learning Outcomes
3.4 Electricity generation **Power stations**	Students should be able to: 3.4.1 examine the principle of electricity generation (limited to a magnet moving near or inside conducting coils); 3.4.2 interpret, using a block diagram, the component parts of power stations and their functions, and apply knowledge of energy transfers to those that take place within power stations;
Transformers	3.4.3 **describe the distribution of electricity across the grid, including the use of step-up and step-down transformers and the reasons for their use;** 3.4.4 deduce that electricity is the most useful energy type (as it is easily transferred into heat, movement, sound and light), and name devices in the home that use these energy transfers;
3.5 Heat transfer	3.5.1 *compare the heat conductivity of different materials by measuring the time it takes heat to travel through a variety of conductors and at least one insulator (Prescribed Practical P3)*; 3.5.2 recall experiments or demonstrations to show that heat can be transferred from place to place by conduction and that metals are the best conductors of heat; 3.5.3 recall experiments or demonstrations that show convection in liquids and gases; and 3.5.4 recall experiments or demonstrations that show that dark matt surfaces are better at absorbing and radiating heat energy than light shiny surfaces.

Content	Learning Outcomes
3.5 Heat transfer (cont.)	Students should be able to: 3.5.5 **demonstrate knowledge that the transfer of energy by conduction and convection involves particles, and of how this transfer takes place;** 3.5.6 **demonstrate understanding, in simple terms, of how the arrangement and movement of particles determine whether a material is a conductor or an insulator, and demonstrate understanding of the role of free electrons in the conduction of heat through a metal;** 3.5.7 describe everyday applications of heat transfer and the role each transfer method plays; 3.5.8 recall that heat energy can be lost from homes mainly through conduction and convection and recall ways of reducing these heat losses;
3.6 Waves **Properties of waves**	3.6.1 recall that waves transfer energy from one point to another through vibrations; 3.6.2 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	3.6.3 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
Speed of sound	3.6.4 recognise and use the equation $v = f\lambda$ to calculate the velocity of the wave in metres per second (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 **Ultrasound** **Electromagnetic spectrum** **Effects of electromagnetic radiation** **Microwaves** **Mobile phones**	Students should be able to: 3.6.5 examine how to measure the speed of sound using both the echo method **and the flash-bang method**; 3.6.6 explain how sound can be reflected, recall that this is known as an echo and recall what steps are taken in auditoria to counteract this problem; 3.6.7 describe some applications of echoes and carry out calculations on the echo principle, including radar and sonar, and describe some contemporary applications of ultrasound in industry and medicine; 3.6.8 demonstrate knowledge and understanding that a human's audible range is from 20 Hz to 20 kHz and that ultrasound has a frequency greater than 20 kHz; 3.6.9 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; 3.6.10 research and recall the uses and dangers of electromagnetic waves; 3.6.11 **explain the microwave heating effect in terms of energy absorption and molecular behaviour; and** 3.6.12 examine how mobile phones work by passing microwaves from one cell to another, demonstrate understanding that this requires phone masts to act as repeater stations, and consider possible health risks of mobile phone use.

Content	Learning Outcomes
3.7 Road transport and safety – reducing reliance on fossil fuels	Students should be able to: 3.7.1 examine data on the use of fossil fuels in transport and evaluate the attempts being made to minimise reliance on fossil fuels **by using substitutes (such as biodiesel) and extenders (such as alcohol)**; 3.7.2 **examine strategies that car manufacturers are currently developing to reduce reliance on fossil fuels (such as regenerative braking and hybrid systems);**
Thinking, braking and stopping distances	3.7.3 apply the terms thinking distance, braking distance and stopping distance in relation to drivers of road vehicles; 3.7.4 explain the meaning of reaction time and describe a simple experiment to measure it; 3.7.5 carry out practical work to measure reaction time by using a metre stick in pairs, measuring distance dropped and relating the measurement to reaction times; 3.7.6 investigate how thinking distance changes with speed and appreciate that it may increase when the driver has taken alcohol, prescribed medicines or illegal drugs; 3.7.7 describe how braking distance increases with speed and investigate factors that affect braking distance, such as: • the state of a road's surface; • the weather; and • the condition of the tyres and brakes; and
Friction	3.7.8 explain that friction is the name given to the force which opposes motion, demonstrate understanding of the role it plays when a vehicle brakes, and examine factors that can affect frictional force on a moving object.

Content	Learning Outcomes
Safety in cars	Students should be able to:
	3.7.9 evaluate how the use of seatbelts, airbags, crumple zones and a rigid passenger cell reduce the risk of serious injury to people **and examine how vehicles are designed to absorb energy in collisions to reduce injury to passengers**;
Road safety	3.7.10 assess how speed restrictions, speed bumps and traffic cameras contribute to road safety;
Speed calculations	3.7.11 recognise and use the equation $average\ speed = \frac{distance\ travelled}{time\ taken}$ to calculate average speed;
	3.7.12 produce and interpret straight line graphs of distance against time;
Balanced forces	3.7.13 **explain that when forces on an object are balanced, the object will move at a steady speed in a straight line or remain at rest;**
Resultant force	3.7.14 **explain the meaning of resultant force and appreciate that a resultant force will cause an acceleration;**
	3.7.15 **recognise and use the equation:** ***resultant force = mass × acceleration***
3.8 Radioactivity	3.8.1 recognise that some combinations of neutrons and protons are unstable and disintegrate, and that such nuclei are described as radioactive;
Alpha, beta and gamma radiation	3.8.2 explain that radioactive nuclei emit alpha, beta and gamma radiation; and
	3.8.3 recall that: • alpha radiation is stopped by a few centimetres of air or a thin sheet of paper; • beta radiation is stopped by several metres of air or a thin sheet of aluminium; and • gamma radiation easily passes through all of these but can be blocked by lead.

Content	Learning Outcomes
Background radioactivity	Students should be able to: 3.8.4 demonstrate knowledge of what background activity is, its source **and how it is taken into account when measuring activity;**
Half-life	3.8.5 **explain the meaning of the term half-life, carry out simple calculations involving half-life, and link the concepts of half-life and background activity to the time taken for a radioactive source to become safe;**
Ionising radiation	3.8.6 **demonstrate knowledge of what ionisation is, recall that radioactive emissions cause dangerous ionisations, and recall the steps taken to minimise the risk to those who use ionising radiations;** 3.8.7 describe some uses of radioactivity in industry, medicine and agriculture;
3.9 Earth in space **The Solar System**	3.9.1 describe the main features of the Solar System, including the Sun, the rocky and gas planets, moons, asteroids and comets; 3.9.2 recall the order of the eight planets from the Sun outwards;
Gravitational force	3.9.3 recall that gravity provides the force needed for the orbital motion of planets, comets, moons and artificial satellites; 3.9.4 recall the use of artificial satellites in the observation of the Earth, weather monitoring, astronomy and communications; 3.9.5 investigate how gravitational force varies on different planets and how this can affect weight; and 3.9.6 distinguish between the weight and mass of an object, knowing that an object of mass 1 kg has a weight of 10 N, and calculate the weight of an object when given the mass in kilograms using the equation: *weight = mass x gravity*

Content	Learning Outcomes
Asteroid strikes	Students should be able to: 3.9.7 deduce that there is the possibility of the Earth being struck by an asteroid, that such events have taken place in the past and that evidence for this exists;
Stars	3.9.8 **explain:** • **that stars are formed from clouds of hydrogen gas;** • **the processes that bring about star formation; and** • **that nuclear fusion is the energy source of a star;**
Galaxies	3.9.9 **explain that galaxies are huge collections of stars and that:** • **our galaxy is called the Milky Way;** • **the distances between the stars and the galaxies are enormous;** • **a light year is the distance that light travels in a year;** • **galaxies are moving away from each other and the further away the galaxies are, the faster they are moving apart;** • **space is expanding; and** • **there is a red shift in light observed from most distant galaxies and the further away the galaxies are, the bigger the red shift; and**
Expanding Universe	3.9.10 **evaluate data that suggests that the expanding Universe began with a Big Bang some 14 billion years ago, and be aware that other theories may exist or co-exist (for example the Steady State theory).**

3.4 Unit 4: Practical Skills

Units 1, 2 and 3 include a number of practical tasks that students carry out during the course. Nine of these are prescribed practicals. This unit 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 plan and carry out two practical tasks based on but not identical to the nine 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 1, 2 and 3 in this specification.

Content	Learning Outcomes
Planning an investigation	Students should be able to: • identify the dependent, independent and controlled variables in an investigation; • suggest a hypothesis/prediction for investigation and explain their reasoning for this hypothesis/prediction; • plan a method to allow their hypothesis/prediction to be tested; • carry out a risk assessment on all planned practical activities; • select suitable equipment/apparatus that will allow them to obtain appropriate and accurate results; • produce a results table with appropriate headings and units for recording a suitable extent and range of data; • draw a diagram of the apparatus used in an investigation; and • demonstrate understanding of the steps that must be taken to ensure the reliability of data collected.

Content	Learning Outcomes
Carrying out an experiment	Students should be able to: • demonstrate the practical skills necessary to use appropriate apparatus correctly, skilfully and safely for the following practical tasks that are identified in the specification: – making temporary slides of plant and animal cells (see learning outcome 1.1.1); – investigating the energy content of food by burning food samples (1.1.2); – investigating food samples using food tests, including the tests for sugar, starch, amino acid/protein and fat (1.2.6); – investigating the need for light and chlorophyll in photosynthesis (1.8.4); – following a neutralisation reaction by monitoring pH (2.1.11); – investigating the reactivity of metals (2.8.4); – investigating the temperature changes that occur during a reaction (2.8.7); – investigating how changing a variable changes the rate of a reaction (2.9.7); – using electrical circuits to measure the voltage and current passing through a wire (3.1.8); – using electrical circuits to demonstrate Ohm's law (3.1.10); – investigating the heat conductivity of different materials (3.5.1); and – investigating reaction times (3.7.5).

Content	Learning Outcomes
Analysing experimental data and drawing conclusions from an experiment	Students should be able to: • obtain and record accurately sufficient experimental evidence to test a hypothesis/prediction; • demonstrate understanding of the mathematical techniques which can be used to identify the relationships between variables; • use appropriate scales and axes labels when plotting a graph of experimental data; • demonstrate understanding of what is meant by an anomalous result in a set of experimental data and how it should be treated; • make reasoned judgements and draw evidence-based conclusions; • analyse, interpret and critically evaluate a broad range of experimental data; • use, where appropriate, the mathematical formulae and skills identified in Appendix 1; • discuss in detail the areas of an investigation that could affect the reliability of the data or evidence collected; and • develop arguments and explanations, taking account of the limitations of the available evidence.

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 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;

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 (%)
	External Assessment				
	Unit 1	Unit 2	Unit 3	Unit 4	
AO1	10.3	10.3	10.4	9	40
AO2	10.7	10.7	10.6	8	40
AO3	4	4	4	8	20
Total Weighting	25	25	25	25	100

4.4 Quality of written communication

In GCSE Single 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.

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. We determine the grades awarded by aggregating the uniform marks that candidates obtain in individual assessment units.

We award GCSE qualifications on a grade scale from A* to G, with A* being the highest. The nine grades available are as follows:

Grade	A*	A	B	C*	C	D	E	F	G

If candidates fail to attain a grade G 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 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 and technological 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 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 and technological 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.
F	Candidates recall, select and communicate their limited knowledge and understanding of science. They recognise simple interrelationships between science and society. They have a limited understanding that advances in science 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 and technological 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 some qualitative and quantitative data and information from a limited range of sources. They can draw elementary conclusions having collected limited evidence.

6 Guidance on Practical Skills Assessment

6.1 Overview

Unit 4 assesses practical skills. It has two parts: Booklet A and Booklet B.

All of the nine prescribed practicals should be taught throughout the course. Booklet A consists of two pre-release practical tasks based on but not identical to those on the list of nine prescribed practicals. We change the two assessed practicals every year to ensure that they continue to set an appropriate challenge and remain valid, reliable and stimulating.

For Booklet A, candidates carry out two practical tasks in the laboratory. Booklet A is a practical assessment and should be carried out under examination conditions, with teacher and invigilator supervision to comply with health and safety regulations.

We send centres a list of the materials required for Booklet A in the December before the Summer submission. We send Booklet A 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 A 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 4

The following skills are assessed:

- planning an investigation;
- carrying out an experiment; and
- 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. Both practical components must be completed within the same session on the same day.

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.

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

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

Candidates have 2 hours to complete this assessment.

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	Details 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 Booklet A in 2 hours. • We send an apparatus and materials list to examinations officers in December of the last 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 2, 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 in those parts of the course suitable for group or class discussion, such as the ethics involved in using genetic screening*;
- make oral and written summaries, reports and presentations, taking account of audience and purpose, *for example when discussing the results of a prescribed practical or summarising the structure of the Periodic Table*;
- participate in discussions, debates and interviews, *for example when reviewing theories such as the Big Bang and the formation of the Universe or reviewing the effects of climate change as a consequence of global warming*; and
- interpret, analyse and present information in oral, written and ICT formats, *for example when analysing and evaluating data produced when carrying out the prescribed practicals and other practical activities*.

Using Mathematics

Students should be able to:

- use mathematical language and notation with confidence, *for example when completing calculations or dealing with very large or very small numbers using standard form*;
- use mental computation to calculate, estimate and make predictions in a range of simulated and real-life contexts, *for example when working out probability in genetic crosses*;
- select and apply mathematical concepts and problem-solving strategies in a range of simulated and real-life contexts, *for example when analysing data about the Solar System, such as planet masses, orbit times and distances from the Sun, or calculating half-lives*;
- interpret and analyse a wide range of mathematical data, *for example when interpreting tables and graphs*;
- assess probability and risk in a range of simulated and real-life contexts, *for example when investigating the inheritance of disease using genetic crosses*; and
- present mathematical data in a variety of formats which take account of audience and purpose, *for example when producing tables and drawing graphs to present results in a prescribed practical, such as investigating Ohm's law*.

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 when analysing, evaluating and drawing conclusions and writing up prescribed practical tasks*.

7.2 Thinking Skills and Personal Capabilities at Key Stage 4

Self-Management
Students should be able to: • plan work, *for example planning with others how they might carry out one of the prescribed practical tasks*; • set personal learning goals, *for example learning how to use a scientific calculator to solve the mathematical problems encountered throughout the course*; • monitor, review and evaluate their progress and improve their learning, *for example when comparing performance in class tests over time*; and • effectively manage their time, *for example completing and writing up prescribed practicals in the allocated time*.
Working with Others
Students should be able to: • learn with and from others through co-operation, *for example plan and carry out with others an experiment to measure the average speed of a trolley moving down a ramp*; • participate in effective teams and accept responsibility for achieving collective goals, *for example when carrying out prescribed practicals and ensuring that each group member is fully involved in the process*; and • listen actively to others and influence group thinking and decision-making, taking account of others' opinions, *for example research the uses and dangers of electromagnetic waves and record their findings*.

Problem Solving
Students should be able to: • identify and analyse relationships and patterns, *for example explore the relationship between the rate at which the alkali metals react and their position in the Periodic Table*; • propose justified explanations, *for example the explanation for cosmic red shift is the expansion of the Universe*; • reason, form opinions and justify their views, *for example the section on electromagnetic waves and potential dangers could be used to discuss issues such as the safety of wi-fi or mobile phones*; • analyse critically and assess evidence to understand how information or evidence can be used to serve different purposes or agendas, *for example the section on energy resources requires students to describe a range of renewable and non-renewable energy resources, and recall their effect on the environment*; • analyse and evaluate multiple perspectives, *for example explain why the emphasis on developing alternative renewable fuels has increased in recent years*; and • explore unfamiliar views without prejudice, *for example explore Darwin's theory of evolution and differing viewpoints on it*.

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;
- 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, 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: Nuala Tierney
  (telephone: (028) 9026 1200, extension 2292, email: ntierney@ccea.org.uk)

- Subject Officer: Gavin Gray
  (telephone: (028) 9026 1200, extension 2270, email: ggray@ccea.org.uk)

- Examination Entries, Results and Certification
  (telephone: (028) 9026 1262, email: entriesandresults@ccea.org.uk)

- Examiner Recruitment
  (telephone: (028) 9026 1243, email: appointments@ccea.org.uk)

- Distribution
  (telephone: (028) 9026 1242, email: cceadistribution@ccea.org.uk)

- Support Events Administration
  (telephone: (028) 9026 1401, email: events@ccea.org.uk)

- Moderation
  (telephone: (028) 9026 1200, extension 2236, email: moderationteam@ccea.org.uk)

- Business Assurance (Complaints and Appeals)
  (telephone: (028) 9026 1244, email: complaints@ccea.org.uk or appealsmanager@ccea.org.uk).

Appendix 1

Mathematical Content and Skills

Students need to be familiar with and competent in the following areas of mathematics in order to develop their skills, knowledge and understanding in Single Award Science. Material in **bold** will only be required in Higher Tier papers.

Arithmetic and numerical computation

- Recognise and use expressions in decimal form.
- **Recognise and use expressions in standard form.**
- Use ratios, fractions and percentages and positive whole number powers.

Handling data

- Use an appropriate number of significant figures.
- Express a number to one or two decimal places.
- Find arithmetic means.
- Construct and interpret diagrams, tables, pie charts, line graphs, histograms and bar charts.
- Make estimates based on trends and/or patterns deduced from information given in text, tables or graphs.
- Understand simple probability.

Algebra

- Understand and use the symbols +, −, ×, /, ÷, =, <, > and ∝.
- **Change the subject of an equation.**
- Substitute numerical values into algebraic equations to calculate a physical quantity (including squared and square root values).
- Deduce appropriate units for physical quantities.
- Solve simple algebraic equations.
- Understand the meaning of direct **and inverse (indirect)** proportion.

Graphs

- Translate information between graphical and numeric form.
- Understand that $y = mx$ represents a linear relationship, where m is the gradient, and that the graph of y against x is a straight line through the origin.
- Plot two variables from experimental or other data.
- Determine the slope and intercept of a linear graph.

The mathematics content above will be assessed within the lifetime of the specification.

Appendix 2

Data Leaflet including the Periodic Table of the Elements

This data leaflet is for use with the specimen assessment materials. The same information will be provided with live 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

1	2											3	4	5	6	7	0
							1 H Hydrogen 1										4 He Helium 2
7 Li Lithium 3	9 Be Beryllium 4											11 B Boron 5	12 C Carbon 6	14 N Nitrogen 7	16 O Oxygen 8	19 F Fluorine 9	20 Ne Neon 10
23 Na Sodium 11	24 Mg Magnesium 12											27 Al Aluminium 13	28 Si Silicon 14	31 P Phosphorus 15	32 S Sulfur 16	35.5 Cl Chlorine 17	40 Ar Argon 18
39 K Potassium 19	40 Ca Calcium 20	45 Sc Scandium 21	48 Ti Titanium 22	51 V Vanadium 23	52 Cr Chromium 24	55 Mn Manganese 25	56 Fe Iron 26	59 Co Cobalt 27	59 Ni Nickel 28	64 Cu Copper 29	65 Zn Zinc 30	70 Ga Gallium 31	73 Ge Germanium 32	75 As Arsenic 33	79 Se Selenium 34	80 Br Bromine 35	84 Kr Krypton 36
85 Rb Rubidium 37	88 Sr Strontium 38	89 Y Yttrium 39	91 Zr Zirconium 40	93 Nb Niobium 41	96 Mo Molybdenum 42	98 Tc Technetium 43	101 Ru Ruthenium 44	103 Rh Rhodium 45	106 Pd Palladium 46	108 Ag Silver 47	112 Cd Cadmium 48	115 In Indium 49	119 Sn Tin 50	122 Sb Antimony 51	128 Te Tellurium 52	127 I Iodine 53	131 Xe Xenon 54
133 Cs Caesium 55	137 Ba Barium 56	139 La* Lanthanum 57	178 Hf Hafnium 72	181 Ta Tantalum 73	184 W Tungsten 74	186 Re Rhenium 75	190 Os Osmium 76	192 Ir Iridium 77	195 Pt Platinum 78	197 Au Gold 79	201 Hg Mercury 80	204 Tl Thallium 81	207 Pb Lead 82	209 Bi Bismuth 83	210 Po Polonium 84	210 At Astatine 85	222 Rn Radon 86
223 Fr Francium 87	226 Ra Radius 88	227 Ac† Actinium 89	261 Rf Rutherfordium 104	262 Db Dubnium 105	266 Sg Seaborgium 106	264 Bh Bohrium 107	277 Hs Hassium 108	268 Mt Meitnerium 109	271 Ds Darmstadtium 110	272 Rg Roentgenium 111	285 Cn Copernicium 112						

140 Ce Cerium 58	141 Pr Praseodymium 59	144 Nd Neodymium 60	145 Pm Promethium 61	150 Sm Samarium 62	152 Eu Europium 63	157 Gd Gadolinium 64	159 Tb Terbium 65	162 Dy Dysprosium 66	165 Ho Holmium 67	167 Er Erbium 68	169 Tm Thulium 69	173 Yb Ytterbium 70	175 Lu Lutetium 71
232 Th Thorium 90	231 Pa Protactinium 91	238 U Uranium 92	237 Np Neptunium 93	242 Pu Plutonium 94	243 Am Americium 95	247 Cm Curium 96	245 Bk Berkelium 97	251 Cf Californium 98	254 Es Einsteinium 99	253 Fm Fermium 100	256 Md Mendelevium 101	254 No Nobelium 102	257 Lr Lawrencium 103

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

a
b x

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

Summary of Changes since First Issue

(Most recent changes are indicated in red on the latest version)

Revision History Number	Date of Change	Page Number	Change Made
Version 1	N/A	N/A	First issue
Version 2	25 May 2017	5	'May' changed to 'Summer'
Version 3	7 November 2017	35	Bullet point removed from 3.3.10

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