GCSE

WJEC GCSE in SCIENCE (DOUBLE AWARD)

APPROVED BY QUALIFICATIONS WALES

SPECIFICATION

Teaching from 2016
For award from 2018

This Qualifications Wales regulated qualification is not available to centres in England.

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For teaching from 2016
For award from 2018

This specification meets the GCSE Qualification Principles which set out the requirements for all new or revised GCSE specifications developed to be taught in Wales from September 2016.

GCSE in SCIENCE (Double Award) (Wales)

SUMMARY OF ASSESSMENT

There are two tiers of entry for this qualification:
Higher Tier – Grades A* - D
Foundation Tier – Grades C - G

This GCSE qualification in Science (Double Award) offers assessment at foundation and higher tier. In most cases, we would expect candidates to be assessed within the same tier. Exceptionally, it may be appropriate to enter some candidates for a combination of higher and foundation tier units.

Unit 1: (Double Award) BIOLOGY 1 Written examination: 1 hour 15 minutes 15% of qualification 60 marks
A mix of short answer questions, structured questions, extended writing and data response questions with some set in a practical context. A tiered assessment.
Unit 2: (Double Award) CHEMISTRY 1 Written examination: 1 hour 15 minutes 15% of qualification 60 marks
A mix of short answer questions, structured questions, extended writing and data response questions with some set in a practical context. A tiered assessment.
Unit 3: (Double Award) PHYSICS 1 Written examination: 1 hour 15 minutes 15% of qualification 60 marks
A mix of short answer questions, structured questions, extended writing and data response questions with some set in a practical context. A tiered assessment.
Unit 4: (Double Award) BIOLOGY 2 Written examination: 1 hour 15 minutes 15% of qualification 60 marks
A mix of short answer questions, structured questions, extended writing and data response questions with some set in a practical context. A tiered assessment.

Unit 5: (Double Award) CHEMISTRY 2 Written examination: 1 hour 15 minutes 15% of qualification	60 marks
A mix of short answer questions, structured questions, extended writing and data response questions with some set in a practical context. A tiered assessment.	
Unit 6: (Double Award) PHYSICS 2 Written Examination: 1 hour 15 minutes 15% of qualification	60 marks
A mix of short answer questions, structured questions, extended writing and data response questions with some set in a practical context. A tiered assessment.	
Unit 7: (Double Award) PRACTICAL ASSESSMENT 10% of qualification	60 marks
Practical assessment that will be carried out in centres, but will be externally marked by WJEC. It will take place in the first half of the spring term (January – February). It is recommended that this should be in the final year of study. An untiered assessment.	

This unitised qualification will be available in the summer series each year. It will be awarded for the first time in Summer 2018.

Qualification Number listed on The Register: 601/8236/2

Qualifications Wales Approval Number listed on QiW: C00/0780/3

GCSE SCIENCE (Double Award)

1 INTRODUCTION

1.1 Aims and objectives

This WJEC GCSE Science (Double Award) specification provides a broad, coherent, satisfying and worthwhile course of study. It encourages learners to develop confidence in, and a positive attitude towards, science and to recognise its importance in their own lives and to society.

Studying GCSE Science (Double Award) provides the foundations for understanding the material world. Scientific understanding is changing our lives and is vital to the world's future prosperity, and all learners should be taught essential aspects of the knowledge, methods, processes and uses of science. They should be helped to appreciate how the complex and diverse phenomena of the natural world can be described in terms of a small number of key ideas relating to the sciences which are both inter-linked, and are of universal application. These key ideas include:

- the use of conceptual models and theories to make sense of the observed diversity of natural phenomena
- the assumption that every effect has one or more cause
- that change is driven by differences between different objects and systems when they interact
- that many such interactions occur over a distance without direct contact
- that science progresses through a cycle of hypothesis, practical experimentation, observation, theory development and review
- that quantitative analysis is a central element both of many theories and of scientific methods of inquiry.

These key ideas are relevant in different ways and with different emphases in the three subjects as part of Science (Double Award); examples of their relevance are given for each subject in this specification.

This specification is intended to promote a variety of styles of teaching and learning so that the course is enjoyable for all participants. Learners will be introduced to a wide range of scientific principles which will allow them to enjoy a positive learning experience. Practical work is an intrinsic part of science. It is imperative that practical skills are developed throughout this course and that an investigatory approach is promoted.

1.2 Prior learning and progression

There are no previous learning requirements for this specification. Any requirements set for entry to a course based on this specification are at the school/college's discretion.

This specification builds on subject content which is typically taught at key stage 3 and provides a suitable foundation for the study of Science at either AS or A level. In addition, the specification provides a coherent, satisfying and worthwhile course of study for learners who do not progress to further study in this subject.

1.3 Equality and fair access

This specification may be followed by any learner, irrespective of gender, ethnic, religious or cultural background. It has been designed to avoid, where possible, features that could, without justification, make it more difficult for a learner to achieve because they have a particular protected characteristic.

The protected characteristics under the Equality Act 2010 are age, disability, gender reassignment, pregnancy and maternity, race, religion or belief, sex and sexual orientation.

The specification has been discussed with groups who represent the interests of a diverse range of learners, and the specification will be kept under review.

Reasonable adjustments are made for certain learners in order to enable them to access the assessments (e.g. candidates are allowed access to a Sign Language Interpreter, using British Sign Language). Information on reasonable adjustments is found in the following document from the Joint Council for Qualifications (JCQ): *Access Arrangements and Reasonable Adjustments: General and Vocational Qualifications.*

This document is available on the JCQ website (www.jcq.org.uk). As a consequence of provision for reasonable adjustments, very few learners will have a complete barrier to any part of the assessment.

1.4 Welsh Baccalaureate

In following this specification, learners should be given opportunities, where appropriate, to develop the skills that are being assessed through the Core of the Welsh Baccalaureate:

- Literacy
- Numeracy
- Digital Literacy
- Critical Thinking and Problem Solving
- Planning and Organisation
- Creativity and Innovation
- Personal Effectiveness.

1.5 Welsh perspective

In following this specification, learners must consider a Welsh perspective if the opportunity arises naturally from the subject matter and if its inclusion would enrich learners' understanding of the world around them as citizens of Wales as well as the UK, Europe and the world.

2 SUBJECT CONTENT

This section outlines the knowledge, understanding and skills to be developed by learners studying GCSE Science (Double Award).

Learners should be prepared to apply the knowledge, understanding and skills specified in a range of theoretical, practical, industrial and environmental contexts. Practical work is an intrinsic part of this specification. It is vitally important in developing a conceptual understanding of many topics and it enhances the experience and enjoyment of science. The practical skills developed are also fundamentally important to learners going on to further study in science and related subjects, and are transferable to many careers.

All of the content covered in this specification is also covered in each of the separate science GCSE qualifications (i.e. GCSE Biology, Chemistry and Physics). In addition a significant amount of the content covered in the Biology 1, Chemistry 1 and Physics 1 units of this specification overlaps with the content of Unit 1 of the Applied Science (Double Award) specification. This will allow learners if necessary to transfer between the different qualifications on offer in the GCSE Science suite in the first term of study.

This section includes specified practical work that must be undertaken by learners in order that they are suitably prepared for all assessments. The completion of this practical work will develop the practical skills listed in Appendix A.

Appendix B lists the mathematical requirements. A list of equations will be included at the start of each examination paper for Unit 3 and Unit 6. Foundation tier learners will not be expected to change the subject of an equation, however they may be expected to recognise and use them in other formats.

Some areas of content have been selected for assessment at higher tier only. This content is shown in bold type in the relevant content sections. All content may therefore be examined at higher tier but that in bold will not be examined on foundation tier papers.

All content in the specification should be introduced in such a way that it develops learners' ability to:

- understand scientific concepts through the specific disciplines of biology, chemistry and physics
- understand the nature, processes and methods of science, through different types of scientific enquiries that help them to answer scientific questions about the world around them
- apply observational, practical, modelling, enquiry and problem-solving skills, both in the laboratory, in the field and in other learning environments
- evaluate claims based on science through critical analysis of the methodology, evidence and conclusions, both qualitatively and quantitatively.

2.1 Unit 1

(Double Award) BIOLOGY 1

Written examination: 1 hour 15 minutes
15% of qualification

This unit includes the following topics:

1.1 Cells and movement across membranes

1.2 Respiration and the respiratory system in humans

1.3 Digestion and the digestive system in humans

1.4 Circulatory system in humans

1.5 Plants and photosynthesis

1.6 Ecosystems and human impact on the environment

1.1 CELLS AND MOVEMENT ACROSS CELL MEMBRANES

Overview

The fundamental units of living organisms are cells, which may be part of highly adapted structures including tissues, organs and organ systems, enabling living processes to be performed effectively. This topic explores the structure and function of cells, how they transport materials and some metabolic processes that occur within them.

Working Scientifically

This topic contains opportunities for learners to understand how scientific methods and theories develop over time by considering the understanding of cell structure in relation to the development of the microscope. It gives learners the opportunity to make and record observations when examining plant and animal cells. It presents the opportunity for learners to carry out experiments appropriately having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations when investigating factors affecting enzyme action.

Mathematical skills

There are a number of opportunities for the development of mathematical skills from data which is available on the content of this topic. This could include the translation of information between graphical and numerical forms, the construction and interpretation of frequency tables and diagrams, bar charts and histograms and the use of a scatter diagram to identify a correlation between two variables.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the structure of animal and plant cells, including drawing and labelling diagrams and the function of the following parts: cell membrane, cytoplasm, nucleus, mitochondria, cell wall, chloroplast, vacuole

(b) the use of a light microscope to view animal and plant cells

(c) the differentiation of cells in multicellular organisms to become adapted for specific functions - specialised cells

(d) the levels of organisation within organisms: tissues are groups of similar cells with a similar function and organs may comprise several tissues performing specific functions; organs are organised into organ systems, which work together to form organisms

(e) diffusion as the movement of substances down a concentration gradient; the role of the cell membrane in diffusion; visking tubing as a model of living material; the results of Visking tubing experiments in terms of membrane pore and particle size

(f) diffusion as a passive process, allowing only certain substances to pass through the cell membrane in this way, most importantly oxygen and carbon dioxide

(g) osmosis as the diffusion of water through a selectively permeable membrane from a region of high water (low solute) concentration to a region of low water (high solute) concentration

(h) **active transport as an active process whereby substances can enter cells against a concentration gradient**

(i) enzyme control of chemical reactions in cells; enzymes are proteins made by living cells, which speed up/catalyse the rate of chemical reactions

(j) **how different enzymes are composed of different amino acids linked to form a chain which is then folded into a specific shape**

(k) how the specific shape of the active site of an enzyme enables it to function, a simple understanding of 'lock and key' modelling and be able to interpret enzyme activity in terms of molecular collisions **resulting in the formation of enzyme-substrate complexes**

(l) the effect of temperature and pH on enzyme activity including the effect of boiling which denatures most enzymes

SPECIFIED PRACTICAL WORK

- Examination of animal and plant cells using a light microscope and production of labelled scientific diagrams from observation

- Investigation into factors affecting enzyme action

1.2 RESPIRATION AND THE RESPIRATORY SYSTEM IN HUMANS

Overview

Organic compounds are used as fuels in respiration within cells to allow the chemical reactions necessary for life. This topic examines the processes of aerobic and anaerobic respiration, along with the respiratory system which enables the oxygen required for respiration to be taken to the tissues and the carbon dioxide produced to be removed.

Working Scientifically

This topic contains opportunities for learners to understand how models can be used to develop understanding of inspiration and expiration using the bell jar model. It gives learners the opportunity to discuss the controversy between the sometimes conflicting evidence about the effects of smoking from independent studies and those of vested interest groups and the need for unbiased interpretation of investigations, scientific validation of data and peer review. The evaluation of risks can also be developed in relation to how attitudes to smoking have changed over time as evidence about its effects has been validated by scientists including the conflict between regulation and personal freedom and the cost–benefit considerations. The use of limewater to indicate the presence of carbon dioxide enables learners to carry out experiments appropriately with due regard to health and safety considerations.

Mathematical skills

There are a number of opportunities for the development of mathematical skills from data which is available on the content of this topic. This could include the translation of information between graphical and numerical forms; using data regarding smoking related illnesses, using ratios, fractions and percentages of different gases in inspired and expired air; understand the principles of sampling as related to health data.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) aerobic respiration as a process that occurs in cells when oxygen is available; respiration as a series of enzyme-controlled reactions within the cell, that use glucose and oxygen to release energy and produce carbon dioxide and water; **energy is released in the form of ATP** and be able to state the word equation to describe aerobic respiration

(b) anaerobic respiration as a process that occurs in the absence of oxygen; glucose being broken down to release energy and lactic acid; oxygen debt as a result of anaerobic respiration; **anaerobic respiration as a less efficient process than aerobic respiration because of the incomplete breakdown of glucose; less ATP is produced per molecule of glucose in anaerobic respiration than in aerobic respiration** and be able to state the word equation for anaerobic respiration in human cells

(c) the need for and purpose of the respiratory system and be able to label the following structures on a diagram of a vertical section of the human respiratory system: nasal cavity, trachea, bronchi, bronchioles, alveoli, lungs, diaphragm, ribs and intercostal muscles

(d) the function of mucus and cilia in the respiratory system

(e) the mechanisms of inspiration and expiration, in terms of changes in thoracic volume and pressure brought about by movements of the diaphragm and rib cage; movement of air takes place due to differences in pressure between the lungs and outside the body

(f) the use of a bell jar model to illustrate inspiration and expiration and the limitations of this model

(g) the structure of an alveolus and its blood supply and be able to label the following structures on a diagram: end of bronchiole, wall of alveolus, moist lining of alveolus, wall of capillary, red blood cells and plasma

(h) the percentage composition of inspired and expired air and the reasons for the differences; how gases diffuse between alveolar air and capillaries; the adaptations of alveoli for gas exchange; the use of lime water to indicate the presence of carbon dioxide

(i) the effects of smoking on cilia and mucus in the respiratory system and the consequences for the individual; the link between cigarette smoking and lung cancer and emphysema and the consequences of these conditions

1.3 DIGESTION AND THE DIGESTIVE SYSTEM IN HUMANS

Overview

This topic covers the need for digestion, the structure of the digestive system in humans and the mechanisms by which larger molecules are broken down into smaller soluble molecules which can be absorbed into the blood. There is also consideration of a balanced diet and the effects of excess sugar and fat in the diet.

Working Scientifically

The use of Visking tubing as a model of absorption enables learners to develop scientific explanations regarding digestion and absorption. There are a number of opportunities for practical work in this topic. The carrying out of experiments to test for starch, glucose and protein enables learners to develop skills in recording observations using a range of methods and to show due regard to health and safety considerations. The investigation into the energy content of different foods will allow learners to plan experiments to make observations. It also provides opportunity to carry out mathematical analysis and present reasoned explanation including relating their data to a hypothesis. There will also be opportunities to analyse data from food labelling regarding sugar, fat and salt content in foods.

Mathematical skills

There are a number of opportunities for the development of mathematical skills from data generated within the investigation into the energy content of foods. This would include finding arithmetic means; constructing and interpreting tables; using expressions in decimal form; translating information between graphical and numerical form; plotting data from experimental data.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the need for digestion; the breakdown of large molecules into smaller molecules so they can be absorbed for use by body cells

(b) the digestion of larger insoluble molecules into their soluble products which can then be absorbed: fats made up of fatty acids and glycerol; proteins made up of amino acids; starch (a carbohydrate), made up of a chain of glucose molecules

(c) the tests for the presence of: starch using iodine solution; glucose using Benedict's reagent; protein using biuret solution

(d) the role of the following enzymes in digestion: carbohydrase; protease; lipase

(e) the structure of the human digestive system and associated structures: the mouth, oesophagus, stomach, liver, gall bladder, bile duct, pancreas, small intestine, large intestine, anus and be able to label these on a diagram

(f) the role of the following organs in digestion and absorption: mouth, stomach, pancreas, small intestine, large intestine, liver

(g) how food is moved by peristalsis

(h) the function of bile, secreted by the liver and stored in the gall bladder, in the breakdown of fats

(i) how soluble substances can be absorbed through the wall of the small intestine and eventually into the bloodstream and how Visking tubing can be used as a model gut, including the limitations of the model

(j) the fate of the digested products of fats, carbohydrates and proteins: fatty acids and glycerol from fats provide energy; glucose from carbohydrate provides energy or is stored as glycogen; amino acids from digested proteins are needed to build proteins in the body

(k) the need for a balanced diet, including: protein, carbohydrates and fats, minerals (iron),vitamins (vitamin C), fibre and water

(l) the fact that different foods have different energy contents and that energy from food, when it is in excess, is stored as fat by the body

(m) the implications, particularly for health, of the sugar, fat and salt in foods

SPECIFIED PRACTICAL WORK

- Investigation of the energy content of foods

1.4 CIRCULATORY SYSTEM IN HUMANS

Overview

This topic covers the structure and function of the circulatory system and blood in humans.

Working Scientifically

A heart dissection could be used to develop the use of a range of apparatus and instruments.

Mathematical skills

There are a number of opportunities for the development of mathematical skills using data generated within this topic. This would include the effect of exercise on heart rate. The skills developed could include: interpreting tables and diagrams; translating information between graphical and numerical form; using expressions in decimal form; finding arithmetic means.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the structure of a phagocyte and a red blood cell; be able to draw and label these cells

(b) the functions of the four main parts of the blood: red cells, platelets, plasma, white cells

(c) the fact that the heart is made of muscle which contracts to pump blood around the body

(d) the role of the coronary vessels in supplying the heart muscle with blood

(e) the flow of blood to the organs through arteries and return to the heart through veins

(f) the structure of the heart: the left and right atria and ventricles, tricuspid and bicuspid valves, semi-lunar valves, pulmonary artery, pulmonary vein, aorta and vena cava and be able to label these on a diagram

(g) the passage of blood through the heart including the functions of the valves in preventing backflow of blood

(h) a double circulatory system: involving one system for the lungs - pulmonary and one for the other organs of the body - systemic

(i) the fact that in the organs blood flows through very small blood vessels called capillaries; substances needed by cells pass/diffuse out of the blood to the tissues, and substances produced by the cells pass/diffuse into the blood, through the walls of the capillaries; the thin walls of the capillaries are an advantage for diffusion; capillaries form extensive networks so that every cell is near to a capillary carrying blood

(j) risk factors for cardiovascular disease and the effects of cardiovascular disease

1.5 PLANTS AND PHOTOSYNTHESIS

Overview

Life on Earth is dependent on photosynthesis in which green plants and algae trap light from the Sun to fix carbon dioxide and combine it with hydrogen from water to make organic compounds and oxygen. This topic covers the process of photosynthesis and factors which affect the rate of photosynthesis.

Working Scientifically

The investigation into factors affecting photosynthesis allow many skills to be developed. These include: the use of scientific theories to develop hypotheses; the planning experiments to make observations and test hypotheses; selection of apparatus; carrying out of experiments having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations; making and recording observations and measurements using a range of apparatus and methods; evaluating methods and suggesting possible improvements and further investigations.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills within the investigation. These skills include the understanding and use of simple compound measures such as the rate of a reaction; translating information between graphical and numerical form; plotting and drawing appropriate graphs, selecting appropriate scales for axes; extracting and interpreting information from graphs, charts and tables. **Higher tier learners should be able to understand and use inverse proportion – the inverse square law and light intensity in the context of factors affecting photosynthesis.**

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the importance of photosynthesis whereby green plants and other photosynthetic organisms use chlorophyll to absorb light energy and convert carbon dioxide and water into glucose, producing oxygen as a by-product; and be able to state the word equation for photosynthesis

(b) the conditions needed for photosynthesis to take place and the factors which affect its rate, including temperature, carbon dioxide and light intensity; **these as limiting factors of photosynthesis**

(c) the practical techniques used to investigate photosynthesis: the use of sodium hydroxide to absorb carbon dioxide; how to test a leaf for the presence of starch; how oxygen and carbon dioxide sensors and data loggers could be used

(d) the uses made by plant cells of the glucose produced in photosynthesis: respired to release energy; converted to starch for storage; used to make cellulose, proteins and oils

SPECIFIED PRACTICAL WORK

- Investigation of the factors affecting photosynthesis

1.6 ECOSYSTEMS AND HUMAN IMPACT ON THE ENVIRONMENT

Overview

Living organisms may form populations of single species, communities of many species and ecosystems, interacting with each other, with the environment and with humans in many different ways. This topic comprises coverage of the levels of organisation within an ecosystem and issues surrounding sustainability. Opportunities are given to look in detail at the factors affecting communities and how the numbers of organisms and biomass within each level can be represented.

Working Scientifically

The topics discussing the advantages and disadvantages of intensive farming methods and the need to balance the human requirement for food with the needs of wildlife will allow learners to develop skills in evaluating social, economic and environmental applications based on the evaluation of evidence and arguments. There are also a number of opportunities to develop skills in analysis and evaluation within the data generated from work on food chains and food webs. These would include: presentation of data, translating data from one form to another; carrying out and representing mathematical analysis; representing distributions of results and making estimations of uncertainty.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills within the data in this topic. These would include the calculation of the percentage efficiency in biomass transfer between trophic levels, the calculation of arithmetic means, being able to understand and use percentiles, plotting and drawing appropriate graphs and selecting appropriate scales for the axes and extracting and interpreting information from charts, graphs and tables.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) food chains and food webs showing the transfer of energy between organisms and involving producers; first, second and third stage consumers; herbivores and carnivores; decomposers

(b) the fact that at each stage in the food chain energy is used in repair and in the maintenance and growth of cells whilst energy is lost in waste materials and respiration

(c) pyramids of numbers and biomass

(d) **how to calculate the efficiency of energy transfers between trophic levels and how this affects the number of organisms at each trophic level**

(e) the issues surrounding the need to balance the human requirements for food and economic development with the needs of wildlife

(f) the advantages and disadvantages of intensive farming methods: using fertilisers, pesticides, disease control and battery methods to increase yields

(g) how indicator species and changes in pH and oxygen levels may be used as signs of pollution in a stream and how lichens can be used as indicators of air pollution

(h) the fact that some heavy metals, present in industrial waste and pesticides, enter the food chain, accumulate in animal bodies and may reach a toxic level

(i) the fact that untreated sewage and fertilisers may run into water and cause rapid growth of plants and algae, these then die and are decomposed, the microbes, which break them down, increase in number and use up the dissolved oxygen in the water and animals which live in the water may suffocate

2.2 Unit 2

(Double Award) CHEMISTRY 1

Written examination: 1 hour 15 minutes
15% of qualification

This unit includes the following topics:

2.1 The nature of substances and chemical reactions

2.2 Atomic structure and the Periodic Table

2.3 Water

2.4 The ever-changing Earth

2.5 Rate of chemical change

2.1 THE NATURE OF SUBSTANCES AND CHEMICAL REACTIONS

Overview

This topic brings together the fundamental ideas of Chemistry. It investigates the ideas of elements as pure substances; compounds as substances in which different atoms are chemically joined together and mixtures as substances in which particles are not chemically joined. It explores the ideas of separation of substances. The topic introduces ideas of measuring elements and compounds in terms of atomic and molecular masses, percentage composition and continues onto equations as a means of showing the rearrangement of atoms in reactions, including balancing equations. **For higher tier learners, there is an introduction to moles, the Avogadro constant and related mass calculations.** Conservation of mass is the key to understanding the information given by a chemical equation.

Working Scientifically

In this topic, learners will use scientific vocabulary, terminology and definitions to describe elements, compounds and mixtures. In the investigation of separation methods, they can apply a knowledge of a range of techniques, instruments, apparatus, and materials. Writing chemical equations will enable them to correctly use formulae, symbols and correct nomenclature. In percentage composition, percentage yield and mass calculations, they will learn how to **use appropriate numbers of significant figures.**

Mathematical Skills

Mathematical skills will be used in this topic to balance ionic formulae and chemical equations. Learners will calculate percentage compositions and relative atomic and molecular masses. They can use fractions in the calculations of R_f values. **Higher tier learners will be able to rearrange the subject of equations in mole calculations and combine these principles with the ideas of ratios in reacting mass calculations.**

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) elements as substances that cannot be broken down into simpler substances by chemical means and as the basic building blocks of all substances

(b) elements as substances made up of only one type of atom

(c) compounds as substances made of two or more different types of atom that are chemically joined and having completely different properties to its constituent elements

(d) how to represent elements using chemical symbols and simple molecules using chemical formulae

(e) how to represent simple molecules using a diagram and key

(f) how to write the formulae of ionic compounds given the formulae of the ions they contain

(g) relative atomic mass and relative molecular (formula) mass

(h) the percentage composition of compounds

(i) atoms/molecules in mixtures not being chemically joined and mixtures being easily separated by physical processes such as filtration, evaporation, chromatography and distillation

(j) chromatographic data analysis and R_f values

(k) chemical reactions as a process of re-arrangement of the atoms present in the reactants to form one or more products, which have the same total number of each type of atom as the reactants

(l) colour changes, temperature changes (exothermic/endothermic) and effervescence as evidence that a chemical reaction has taken place

(m) how to represent chemical reactions using word equations

(n) how to represent chemical reactions using balanced chemical equations where the total relative mass of reactants and products is equal

(o) the percentage yield of a chemical reaction

(p) **how to calculate the formula of a compound from reacting mass data**

(q) **how to calculate the masses of reactants or products from a balanced chemical equation**

(r) **the Avogadro constant and the mole and how to convert amount of substance in grams to moles and vice versa**

2.2 ATOMIC STRUCTURE AND THE PERIODIC TABLE

Overview

This topic enables learners to understand the structure of the atom in detail and to link atomic and mass numbers to those of the sub-atomic particles. The arrangement of elements in the Periodic Table allows trends in properties of elements to be investigated. Reactions of Group 1 and Group 7 elements and simple qualitative tests are introduced. Learners should be able to write word and balanced symbol equations for all reactions described in this topic.

Working Scientifically

There are opportunities here for learners to understand how scientific ideas have changed over time. They can identify patterns and trends and use these to make predictions. Writing chemical equations will enable them to correctly use formulae, symbols and correct nomenclature. They can plan and carry out practical work to identify substances in a problem solving context.

Mathematical Skills

Simple order of magnitude calculations should be used in comparing the sizes of atoms with nuclei and with everyday objects. Learners use mathematical skills in this topic to balance ionic formulae and chemical equations. Trends in numerical data are explored and used to predict missing values.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) atoms containing a positively charged nucleus with orbiting negatively charged electrons

(b) atomic nuclei containing protons and neutrons

(c) the relative masses and relative charges of protons, neutrons and electrons

(d) atoms having no overall electrical charge

(e) the terms atomic number, mass number and isotope

(f) how the numbers of protons, neutrons and electrons present in an atom are related to its atomic number and mass number

(g) elements being arranged in order of increasing atomic number and in groups and periods in the modern Periodic Table, with elements having similar properties appearing in the same groups

(h) metals being found to the left and centre of the Periodic Table and non-metals to the right, with elements having intermediate properties appearing between the metals and non-metals in each period

(i) the electronic structures of the first 20 elements

(j) how the electronic structure of any element is related to its position in the Periodic Table

(k) the similarities and trends in physical and chemical properties of elements in the same group as illustrated by Group 1 and Group 7

(l) many reactions, including those of Group 1 elements and many of those of Group 7 elements, involve the loss or gain of electrons and the formation of charged ions

(m) **the trends in reactivity of Group 1 and Group 7 elements in terms of their readiness to lose or gain an electron**

(n) the reactions of the alkali metals with air/oxygen, the halogens and water

(o) the test used to identify hydrogen gas

(p) the reactions of halogens with alkali metals and with iron

(q) **the relative reactivities of chlorine, bromine and iodine as demonstrated by displacement reactions**

(r) the properties and uses of chlorine and iodine

(s) the identification of Li^+, Na^+, K^+, Ca^{2+} and Ba^{2+} ions by flame tests and Cl^-, Br^- and I^- ions by their reactions with silver nitrate solution (including ionic equations)

(t) the unreactive nature of the Group 0 gases and the uses of helium, neon and argon

2.3 WATER

Overview

The first section of this topic deals with the composition and treatment of the water supply, including fluoridation. Different types of water hardness are investigated, with relevant knowledge of the ions involved. **Higher tier learners should be able to write word and balanced symbol equations relating to the removal of hardness.**

Working Scientifically

Learners can consider the ethical issue of water fluoridation in this topic, using this to explain every day and technological applications of science; to evaluate associated personal, social, economic and environmental implications; and to make decisions based on the evaluation of evidence and arguments. They can plan experiments or devise procedures to make observations and test hypotheses.

Mathematical Skills

Work on solubility curves gives learners the opportunity to plot variables and interpret data. They can analyse results of investigations into different types of water hardness and use these to determine hardness levels in unknown samples.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the composition of water in 'natural' water supplies, including dissolved gases, ions, microorganisms and pollutants

(b) the need for a sustainable water supply to include reducing our water consumption, reducing the environmental impacts of abstracting, distributing and treating water

(c) the treatment of the public water supply using sedimentation, filtration and chlorination

(d) the arguments for and against the fluoridation of the water supply in order to prevent tooth decay

(e) desalination of sea water to supply drinking water including the sustainability of this process on a large scale

(f) the separation of water and other miscible liquids by distillation

(g) simple methods to determine solubility and produce solubility curves

(h) the interpretation of solubility curves

(i) the causes of hardness in water and how to distinguish between hard and soft waters by their action with soap

(j) the difference between temporary and permanent hardness

(k) the processes used to soften water to include boiling, adding sodium carbonate and ion exchange; the advantages and disadvantages of different methods of water softening **and the explanation of how these methods work**

(l) the health benefits of hard water and its negative effects, e.g. on boiler elements

SPECIFIED PRACTICAL WORK

- Determination of the amount of hardness in water using soap solution

2.4 THE EVER-CHANGING EARTH

Overview

This topic explores the structure of the Earth and the composition of the atmosphere, looking at changes in both over time. They gain an understanding of how a balance of processes maintains the composition of the atmosphere and the effects upon this of human activity.

Working Scientifically

This topic contributes to an understanding of how scientific methods and theories develop over time. Learners will be able to develop scientific explanations and understanding of familiar and unfamiliar facts.

Mathematical Skills

Standard form can be used to express the age of the Earth in years and the time over which continents have moved and the atmosphere has evolved. Plotting data on graphs and identifying trends can be incorporated.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the large scale structure of the Earth in terms of solid iron core, molten iron outer core, mantle and crust

(b) the theory of plate tectonics and how it developed from Alfred Wegener's earlier theory of continental drift

(c) the processes occurring at conservative, destructive and constructive plate boundaries where plates slide past one another, move towards one another and move apart respectively

(d) the formation of the original atmosphere by gases, including carbon dioxide and water vapour, being expelled from volcanoes

(e) the present composition of the atmosphere and how the composition of the atmosphere has changed over geological time

(f) the roles of respiration, combustion and photosynthesis in the maintenance of the levels of oxygen and carbon dioxide in the atmosphere

(g) the environmental effects and consequences of the emission of carbon dioxide and sulfur dioxide into the atmosphere through the combustion of fossil fuels

(h) the measures used to address the problems of global warming and acid rain

(i) the air as a source of nitrogen, oxygen, neon and argon

(j) the tests used to identify oxygen gas and carbon dioxide gas

2.5 RATE OF CHEMICAL CHANGE

Overview

An understanding of reaction rates is essential in Chemistry. This topic explores the effects of variables on rates and is a chance for a wide range of investigative practical work to be carried out.

Working Scientifically

Learners will be able to use scientific theories and explanations to develop hypotheses, plan experiments or devise procedures to make observations and test hypotheses. They will apply a knowledge of a range of techniques, instruments, apparatus, and materials to select those appropriate to the experiment, carry out experiments appropriately having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

Mathematical Skills

Skills used in this topic include finding arithmetic means and constructing and interpreting tables of data and line graphs. Learners should interpret the slope of a graph to compare rates. **Higher tier learners should be able to draw and use the slope of a tangent to a curve as a measure of rate of change.** Surface areas and volumes of variously-sized cubes should be investigated in explaining the effect of decreasing particle size on reaction rate.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) practical methods used to determine the rate of reaction – gas collection, loss of mass and precipitation (including using data-logging apparatus)

(b) the effect of changes in temperature, concentration (pressure) and surface area on rate of reaction

(c) the particle theory in explaining changes of rate as a result of changes in temperature, concentration (pressure) and surface area

(d) catalysts as substances that increase the rate of a reaction while remaining chemically unchanged **and that they work by lowering the energy required for a collision to be successful (details of energy profiles are not required)**

SPECIFIED PRACTICAL WORK

- Investigation of the factors that affect the rate of a reaction using a gas collection method
- Investigation of the factors that affect the rate of the reaction between dilute hydrochloric acid and sodium thiosulfate

2.3 Unit 3

(Double Award) PHYSICS 1

Written examination: 1 hour 15 minutes
15% of qualification

This unit includes the following topics:

3.1 Electric circuits

3.2 Generating electricity

3.3 Making use of energy

3.4 Domestic electricity

3.5 Features of waves

3.1 ELECTRIC CIRCUITS

Overview

This topic explores the relationship between current and potential difference and develops the idea of resistance. It investigates how potential differences and currents are related in series and parallel circuits and how the total resistance in series and parallel circuits can be calculated. It introduces the concept of power in an electrical circuit as the energy transferred per unit time and introduces the equations which enable the power transferred by an appliance to be calculated.

Working Scientifically

The specified practical work within this topic gives learners the opportunity to plan and devise investigative approaches and methods to practical work; to safely and correctly use a range of practical equipment and materials; to keep appropriate records of experimental observations and measurements; to correctly construct circuits from circuit diagrams using d.c. power supplies, cells and a range of circuit components. There are opportunities within this topic for learners to use theories, models and ideas to develop scientific explanations. Learners can carry out experimental and investigative activities, such as the design and use of circuits to explore the variation of resistance in devices such as lamps, diodes, thermistors and LDRs, selecting techniques, instruments, apparatus and materials appropriate to the experiment. They can then make informed decisions on the use of energy saving devices in their homes. Learners can investigate electrical circuits and use this experience to learn about the risk management issues involved when handling sources of power and the safety aspects involved in the domestic use of electricity.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills in this topic. These include applying the equations relating potential difference, resistance, power, energy and time to solve problems for circuits which include components in series, using the concept of equivalent resistance; using graphs to explore whether circuit elements are linear or non-linear and relate the curves produced to their function and properties. These topics afford learners the opportunity to use ratios, fractions and percentages; **to change the subject of an equation;** to substitute numerical values into algebraic equations using appropriate units for physical quantities; to solve simple algebraic equations; to plot two variables from experimental or other data; to interpret the slope and intercept of a linear graph; **to draw and use the slope of a tangent to a curve as a measure of rate of change**.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the symbols of components (cell, switch, lamp, voltmeter, ammeter, resistor, variable resistor, fuse, LED, thermistor, LDR, diode) used in electrical circuits

(b) series circuits in which the current is the same throughout a circuit and voltages add up to the supply voltage; parallel circuits in which the voltage is the same across each branch and the sum of the currents in each branch is equal to the current in the supply

(c) voltmeters and ammeters to measure the voltage across and current through electrical components in electrical circuits

(d) circuits to investigate how current changes with voltage for a component e.g. for a resistor (or wire) at constant temperature, a filament lamp and a diode

(e) the significance of and the relationship between current, voltage and resistance, $I = \frac{V}{R}$

(f) how adding components in series increases total resistance in a circuit; adding components in parallel decreases total resistance in a circuit

(g) how to calculate total resistance and total current in a series circuit, **a parallel circuit and circuits consisting of combinations of series and parallel connections**;

$R = R_1 + R_2$; $\quad \mathbf{\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}}$

(h) power as energy transferred per unit time: $E = Pt$

(i) the power transferred using:

power = voltage × current $\quad P = VI$

power = current^2 × resistance $\quad \mathbf{P = I^2 R}$

(j) explain the design and use of circuits to explore the variation of resistance – including for lamps, diodes, ntc thermistors and LDRs

SPECIFIED PRACTICAL WORK

- Investigation of the current-voltage (*I*-*V*) characteristics for a component

3.2 GENERATING ELECTRICITY

Overview

This topic begins by looking at the advantages and disadvantages of renewable and non-renewable technologies for the generation of electrical power. It discusses the need for the National Grid as a nationwide electrical distribution system and the use of step-up and step-down transformers in the transmission of electricity from the power station to the home.

Working Scientifically

This unit contains opportunities for learners to explain every day and technological applications of science; to evaluate personal, social economic and environmental implications; and make decisions based on the evaluation of evidence and arguments. Learners can be helped to understand how, through the ideas of physics, physical laws and models are expressed in mathematical form. Learners can apply the conservation of energy to many different situations, including investigating data to be able to compare the efficiency of power stations and explain why transmitting energy from power stations at high voltage is an efficient way of transferring energy.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills in this topic. These include expressing in quantitative form the overall redistribution of energy within a system e.g. Sankey diagrams; applying the relationship between power, voltage and current to calculate the current flowing when electrical power is transmitted at different voltages. These topics afford learners the opportunity to recognise and use expressions in decimal form; to recognise expressions in standard form; to use ratios, fractions and percentages; **to change the subject of an equation;** to substitute numerical values into algebraic equations using appropriate units for physical quantities.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the advantages and disadvantages of renewable energy technologies (e.g. hydroelectric, wind power, wave power, tidal power, waste, crops, solar and wood) for generating electricity on a national scale using secondary information

(b) the advantages and disadvantages of non-renewable energy technologies (fossil fuels and nuclear) for generating electricity

(c) the processes involved in generating electricity in a fuel based power station

(d) Sankey diagrams to show energy transfers; energy efficiency in terms of input energy and energy usefully transferred in a range of contexts including electrical power generation and transmission:

$$\%\ \text{efficiency} = \frac{\text{energy [or power] usefully transferred}}{\text{total energy [or power] supplied}} \times 100$$

(e) the need for the National Grid as an electricity distribution system including monitoring power use and responding to changing demand

(f) advantages and disadvantages of using different voltages of electricity at different points in the National Grid to include transmission of electricity and use in the home, selecting and using the equation:

power = voltage $\times$ current; $P = VI$

(g) the use of step-up and step-down transformers used in the transmission of electricity from the power station to the user in qualitative terms (they should be treated as voltage changers without any reference to how they perform this function)

(h) efficiency, reliability, carbon footprint and output to compare different types of power stations in the UK including those fuelled by fossil fuels, nuclear fuel and renewable sources of energy

3.3 MAKING USE OF ENERGY

Overview

This topic explores the idea that temperature differences can lead to the transfer of thermal energy by conduction, convection and radiation. It uses the molecular model of matter to explain the differences in the mechanism of thermal energy transfer by these three methods. It uses the ideas developed to discuss the efficiency and cost effectiveness of different methods of reducing thermal energy losses in the domestic situation.

Working Scientifically

There are opportunities within this topic for learners to use models, as in the particle model of matter to develop an understanding of the different methods of the transfer of thermal energy. There are also opportunities for learners to use scientific knowledge and understanding to pose scientific questions and present scientific arguments and ideas. There are opportunities within this topic for learners to use theories, models and ideas to develop scientific explanations. For example, the use of the particle model of matter to explain the different properties and behaviour of solids, liquids and gases. There are also opportunities within this topic for learners to carry out experimental activities, using appropriate risk management.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills in this topic. These include applying the relationship between density, mass and volume; calculating the cost effectiveness and efficiency of different methods of reducing energy loss from the home. These topics afford learners the opportunity to recognise and use expressions in decimal form; to recognise expressions in standard form; to use ratios, fractions and percentages; **to change the subject of an equation**; to substitute numerical values into algebraic equations using appropriate units for physical quantities; to calculate areas of rectangles and volumes of cubes.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) how temperature differences lead to the transfer of energy thermally by conduction, convection and radiation

(b) the equation: $\text{density} = \frac{\text{mass}}{\text{volume}}$ and explain the differences in density between the three states of matter in terms of the arrangements of the atoms or molecules

(c) **conduction using a model of molecular motion and account for the better conduction in metals by the presence of mobile electrons**

(d) **convection in liquids and gases in terms of molecular behaviour and variations in volume and density**

(e) how energy loss from houses can be restricted e.g. loft insulation, double glazing, cavity wall insulation and draught excluders

(f) the cost effectiveness and efficiency of different methods of reducing energy loss from the home, to compare their effectiveness; use data to compare the economics of domestic insulation techniques, including calculating the payback time; the economic and environmental issues surrounding controlling energy loss

(g) how data can be obtained and used to investigate the cost of using a variety of energy sources for heating and transport

SPECIFIED PRACTICAL WORK

- Investigation of the methods of heat transfer
- Determination of the density of liquids and solids (regular and irregular)

3.4 DOMESTIC ELECTRICITY

Overview

This topic covers the functions of fuses and other devices which are designed to prevent current flow when faults develop in domestic circuits. It introduces the concept of the ring main circuit and explains the functions of the live, neutral and earth wires. It compares the cost effectiveness of using different renewable energy sources such as solar and wind energy to supplement the user's needs in the domestic situation.

Working Scientifically

Learners can carry out experimental and investigative activities, such as the efficiency of energy transfer of an electric kettle. They will develop the skill of carrying out experiments appropriately, having due regard for the manipulation of apparatus, the accuracy of the measurements and health and safety considerations. They can then make informed decisions on the use of energy saving devices in their homes. Learners can investigate electrical circuits and use this experience to learn about the risk management issues involved when handling sources of power and the safety aspects involved in the domestic use of electricity.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills in this topic. These include applying the equations relating units used, power and time to calculate the cost of electrical energy; determining the efficiency of energy transfer, e.g. whilst using an electric kettle. These topics afford learners the opportunity to use ratios, fractions and percentages; **to change the subject of an equation**; to substitute numerical values into algebraic equations using appropriate units for physical quantities; to solve simple algebraic equations; to construct and interpret tables and diagrams.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the kilowatt (kW) as a convenient unit of power in the domestic context and the kilowatt hour (kWh) as a unit of energy

(b) the cost of electricity using the equations:

$$\text{units used (kWh)} = \text{power (kW)} \times \text{time (h)}$$
$$\text{cost} = \text{units used} \times \text{cost per unit}$$

(c) how data can be obtained either directly or using secondary sources (e.g. through the energy banding (A-G) and the power ratings of domestic electrical appliances) to investigate the cost of using them

(d) the difference between alternating current (a.c.) and direct current (d.c.)

(e) the functions of fuses, miniature circuit breakers (mcb) and residual current circuit breakers (rccb) including calculations of appropriate fuse ratings

(f) the ring main, including the functions of the live, neutral and earth wires

(g) the cost effectiveness of introducing domestic solar and wind energy equipment, including fuel cost savings and payback time by using data

(h) how to investigate energy transfers in a range of contexts including interpreting and analysing data; evaluation of validity of the data and methods, e.g.
- the energy output from a renewable source (e.g. wind turbine: construction and location)
- efficiency of energy transfer (e.g. using an electric kettle)

3.5 FEATURES OF WAVES

Overview

This topic covers the basic properties of transverse and longitudinal waves and the differences between them. It introduces the wave equation and gives learners the fundamental ideas and skills they need to study both electromagnetic and sound waves.

Working Scientifically

Questions set on this topic will assess learners' abilities to apply scientific knowledge to practical contexts; to present data in appropriate ways; to evaluate results and draw conclusions. The specified practical work in this topic gives learners the opportunity to make and record observations; to keep appropriate records of experimental activities; to apply the cycle of collecting, presenting and analysing data. There are opportunities within this topic for learners to carry out experimental and investigative activities, including appropriate risk management, in a range of contexts.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills in this topic. These include applying formulae relating velocity, frequency and wavelength; showing how changes in velocity and wavelength in refraction from one medium to another are inter-related. These topics afford learners the opportunity to use ratios, fractions and percentages; to substitute numerical values into algebraic equations using appropriate units for physical quantities; **to change the subject of an equation**.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the difference between transverse and longitudinal waves

(b) the description of a wave in terms of amplitude, wavelength (λ), frequency (f) and wave speed (v)

(c) the graphical representation of a transverse wave, including labelling the wavelength and amplitude

(d) diagrams showing plane wave fronts being reflected or refracted, e.g. as shown by water waves in a ripple tank

(e) refraction in terms of the speed of waves on either side of a refracting boundary and the effect on the wavelength of the waves

(f) the term "radiation" to both electromagnetic waves and to energy given out by radioactive materials

(g) the characteristics of radioactive emissions and short wavelength parts of the electromagnetic spectrum (ultraviolet, X-ray and gamma ray) as ionising radiation, able to interact with atoms and to damage cells by the energy they carry

(h) the difference between the different regions of the electromagnetic spectrum [radio waves, microwaves, infra-red, visible light, ultraviolet, X-rays and gamma rays] in terms of their wavelength and frequency and know that they all travel at the same speed in a vacuum

(i) the fact that all regions of the electromagnetic spectrum transfer energy and certain regions are commonly used to transmit information

(j) waves in terms of their wavelength, frequency, speed and amplitude

(k) the equations:

wave speed = wavelength $\times$ frequency; $v = \lambda f$ and

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

applied to the motion of waves, including electromagnetic waves

(l) communication using satellites in geosynchronous/geostationary orbit

SPECIFIED PRACTICAL WORK

- Investigation of the speed of water waves

2.4 Unit 4

(Double Award) BIOLOGY 2

Written examination: 1 hour 15 minutes
15% of qualification

This unit includes the following topics:

4.1 Classification and biodiversity

4.2 Cell division and stem cells

4.3 DNA and inheritance

4.4 Variation and evolution

4.5 Response and regulation

4.6 Disease, defence and treatment

4.1 CLASSIFICATION AND BIODIVERSITY

Overview

This topic covers an overview of the need for classification and how different organisms show adaptations which enable them to compete successfully for resources within their habitat. The term biodiversity is also covered, along with factors which affect it and how it can be measured.

Working Scientifically

There are a number of opportunities to develop skills in analysis and evaluation within the investigation into the abundance and distribution of a species. These would include: presentation of data, translating data from one form to another; carrying out and representing mathematical analysis; representing distributions of results and making estimations of uncertainty and communicating the methods used, findings and conclusions through written or electronic reports. Learners should also be able to apply sampling techniques within the fieldwork to any ensure any samples collected are representative. There is also opportunity to evaluate risk when considering the use of biological control agents.

Mathematical skills

There are a number of opportunities for the development of mathematical skills within the investigation in this topic. These include planning experiments to make observations; recognising when to apply knowledge of sampling techniques, to ensure representative samples; evaluating methods; carrying out statistical analysis; interpreting observations and evaluating in terms of accuracy, precision, repeatability and reproducibility.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) living organisms showing a range of sizes, features and complexity; the broad descriptive grouping into plants - non-flowering and flowering; animals - invertebrates and vertebrates

(b) the means by which organisms which have similar features and characteristics are classified into groups; the need for a scientific system for identification and the need for scientific as opposed to 'common' names

(c) the fact that organisms have morphological and behavioural adaptations which enable them to survive in their environment

(d) individual organisms needing resources from their environment e.g. food, water, light and minerals; how the size of a population may be affected by competition for these resources along with predation, disease and pollution

(e) the term biodiversity: the variety of different species and numbers of individuals within those species in an area; why biodiversity is important; the ways in which biodiversity and endangered species can be protected including issues surrounding the use of legislation

(f) how quadrats can be used to investigate the abundance of species

(g) the principles of sampling; the need to collect sufficient data

(h) **the principles of capture/recapture techniques including simple calculations on estimated population size**

(i) the use of biological control agents and possible issues surrounding this; the introduction of alien species and their effects on local wildlife

SPECIFIED PRACTICAL WORK

- Investigation into factors affecting the distribution and abundance of a species

4.2 CELL DIVISION AND STEM CELLS

Overview

Cells need to divide to grow and also to provide cells for sexual reproduction. This topic covers the processes by which these occur. There is also consideration of how uncontrolled mitosis can result in cancer. The use of stem cells in replacing damaged tissue is also discussed.

Working Scientifically

There are opportunities within this topic to explain technological applications of science in the use of stem cells. This can also be used to consider the ethical issues arising from the use of embryos in obtaining stem cells.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) chromosomes as linear arrangements of genes, found in pairs in body cells

(b) the functions of cell division by mitosis and meiosis

(c) the outcomes of mitotic and meiotic divisions and be able to compare these

(d) the fact that if mitosis is uncontrolled, cancer can occur

(e) stem cells: the cells in mature tissues have generally lost the ability to differentiate; some cells, in both plants and animals, do not lose this ability and these are called stem cells

(f) the potential of both adult and embryonic stem cells to replace damaged tissue

4.3 DNA AND INHERITANCE

Overview

This topic covers the structure of DNA and how it acts as a code for the production of proteins and therefore produces the differences seen between different individuals. The application of genetic profiling as an application for looking at differences between individuals is studied. The mechanisms of inheritance are also covered, including the use of Punnett squares.

Working Scientifically

There are opportunities within this topic to discuss the methods by which scientific theories develop over time when teaching the structure of DNA. The discussion of genetic profiling also raises issues with regard to the ethical issues which may arise regarding the ownership of this information and also lead to a discussion regarding evaluating the personal and social implications of this. The topic of transfer of genes can also lead to the development of explanations of the technological applications of science.

Mathematical skills

There are a number of opportunities for the development of mathematical skills within this topic. These include being able to understand and use direct proportions and simple ratios in the study of genetic crosses, understanding and using the concept of probability in predicting the outcome of genetic crosses and extracting and interpreting information from charts, graphs and tables.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the structure of DNA as two long chains of alternating sugar and phosphate molecules connected by bases; the chains are twisted to form a double helix; there are four types of base, A **(adenine)**, T **(thymine)**, C (**cytosine)** and G **(guanine)**; the order of bases forms a code for making proteins; the code determines the order in which different amino acids are linked together to form different proteins

(b) complementary base pairing between A and T, C and G **and the role of the triplet code during protein synthesis**

(c) the process of ‘genetic profiling’ which involves cutting the DNA into short pieces which are then separated into bands

(d) how 'genetic profiling' can be used to show the similarity between two DNA samples, the pattern of the bands produced can be compared to show the similarity between two DNA samples, for instance in criminal cases, paternity cases and in comparisons between species for classification purposes

(e) the benefits of DNA profiling, for example to identify the presence of certain genes which may be associated with a particular disease

(f) genes as sections of DNA molecules that determine inherited characteristics and that genes have different forms, called alleles, which are in pairs

(g) the following terms: gamete, chromosome, gene, allele, dominant, recessive, homozygous, heterozygous, genotype, phenotype, F1, F2, selfing

(h) single gene inheritance; be able to complete Punnett squares to show this; how to predict the outcomes of monohybrid crosses including ratios

(i) the fact that most phenotypic features are the result of multiple genes rather than single gene inheritance

(j) sex determination in humans: in human body cells, one of the pairs of chromosomes, XX or XY, carries the genes which determine sex, these separate and combine randomly at fertilisation

(k) the artificial transfer of genes from one organism to another; the potential advantages, disadvantages and issues involved with this technology

4.4 VARIATION AND EVOLUTION

Overview

The characteristics of a living organism are influenced by its genes and its interaction with the environment. Living organisms are interdependent and show adaptations to their environment. These adaptations are a result of evolution. Evolution occurs by a process of natural selection and accounts both for biodiversity and how organisms are all related to varying degrees. Learners will acquire an understanding of evolution and how it has resulted in the biodiversity seen on Earth.

Working Scientifically

The discussion of the potential for the human genome gives opportunities to explain the technological applications of science and also to evaluate the risks and ethics of such information being more widely available. The study of the work of Charles Darwin and Alfred Wallace allows learners to understand how scientific theories develop over time and also the importance of peer review and communicating results. The investigation into the variation in organisms will allow many practical skills to be developed.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the variation in individuals of the same species having environmental or genetic causes; **variation being continuous or discontinuous**

(b) sexual reproduction leading to offspring being genetically different from the parents, unlike asexual reproduction where genetically identical offspring called clones are produced from a single parent; sexual reproduction therefore giving rise to variation

(c) the facts that new genes result from changes, mutations, in existing genes; mutations occur at random; most mutations have no effect but some can be beneficial or harmful; mutation rates can be increased by ionising radiation

(d) some mutations causing conditions which may be passed on in families, as is shown by the mechanism of inheritance of cystic fibrosis; the development and use of gene therapy in cystic fibrosis sufferers

(e) heritable variation as the basis of evolution

(f) how individuals with characteristics adapted to their environment are more likely to survive and breed successfully; the use and limitations of a model to illustrate the effect of camouflage colouring in predator and prey relationships

(g) how the genes which have enabled these better adapted individuals to survive are then passed on to the next generation; natural selection as proposed by Alfred Russell Wallace and Charles Darwin; how the process of natural selection is sometimes too slow for organisms to adapt to new environmental conditions and so organisms may become extinct

(h) how evolution is ongoing as illustrated by antibiotic resistance in bacteria, pesticide resistance and warfarin resistance in rats

(i) the potential importance for medicine of our increasing understanding of the human genome

SPECIFIED PRACTICAL WORK

- Investigation into variation in organisms

4.5 RESPONSE AND REGULATION

Overview

This topic gives a brief overview of nervous and hormonal control in humans. Regulation is discussed with regard to blood glucose and temperature.

Working Scientifically

The work on the treatment of diabetes allows learners to appreciate the power of science and explain the application of science. The lifestyle choices section allows the discussion of the personal and social implications of alcohol and drug abuse. The investigation into reaction time will allow the development of investigative skills in the cycle of collecting, presenting and analysing data.

Mathematical skills

There are a number of opportunities for the development of mathematical skills from data which is available on the content of this topic. This includes the extraction and interpretation of data from graphs, charts and tables and the translation of information between numerical and graphical forms.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) sense organs as groups of receptor cells which respond to specific stimuli: light, sound, touch, temperature, chemicals and then relay this information as electrical impulses along neurones to the central nervous system

(b) the brain, spinal cord and nerves forming the nervous system; the central nervous system consisting of the brain and spinal cord

(c) the properties of reflex actions: fast, automatic and some are protective, as exemplified by the withdrawal reflex, blinking and pupil size

(d) **the components of a reflex arc: stimulus, receptor, coordinator and effector; be able to label a diagram of a reflex arc to show: receptor, sensory neurone, relay neurone in spinal cord, motor neurone, effector and synapses**

(e) the reasons why animals need to regulate the conditions inside their bodies: to keep them relatively constant and protected from harmful effects - homeostasis

(f) hormones as chemical messengers, carried by the blood, which control many body functions

(g) the need to keep glucose levels within a constant range: so that when the blood glucose level rises, the pancreas releases the hormone insulin, a protein, into the blood, which causes the liver to reduce the glucose level by converting glucose to insoluble glycogen and then storing it

(h) diabetes as a common disease in which a person has a high blood glucose level; type 1 diabetes caused by the body not producing insulin; type 2 diabetes caused by the body cells not properly responding to the insulin that is produced; the causes of both types of diabetes; treatments for diabetes

(i) the structure of a section through the skin: hair, erector muscle, sweat gland, sweat duct, sweat pore, blood vessels; be able to label these structures on a diagram

(j) the role of the structures in the skin in temperature regulation: change in diameter of blood vessels, sweating, erection of hairs; shivering as a means of generating heat

(k) **the principles of negative feedback mechanisms to maintain optimum conditions inside the body as illustrated by the control of blood glucose levels by insulin and glucagon and by the control of body temperature**

(l) the fact that some conditions are affected by lifestyle choices; the effects that alcohol and drug abuse have on the chemical processes in people's bodies; the incidence of diabetes (type 2) and the possible relationship with lifestyle

SPECIFIED PRACTICAL WORK

- Investigation into factors affecting reaction time

4.6 DISEASE, DEFENCE AND TREATMENT

Overview

This topic explores the relationship between health and disease. It includes the different causes of disease, how communicable diseases can be spread and how disease can be prevented. Natural defence mechanisms are covered, along with how diseases can be treated and how new medicines are developed.

Working Scientifically

This topic provides many opportunities to explain every day and technological applications of science; evaluate associated personal, social, economic and environmental implications; and make decisions based on the evaluation of evidence and arguments. There are also a number of topics where learners will appreciate the power and limitations of science and consider any ethical issues which may arise. The understanding of the development of medicines will also develop the learners' skills in evaluating risks in the wider societal context, including perception of risk in relation to data and consequences. The discussion of factors influencing parental decision with regard to vaccination will also develop the skills of recognising the importance of peer review of results and of communicating results to a range of audiences.

Mathematical skills

There are a number of opportunities for the development of mathematical skills from data which is available on the content of this topic. This could include the translation of information between graphical and numerical forms, the construction and interpretation of frequency tables and diagrams, bar charts and histograms, the use of a scatter diagram to identify a correlation between two variables. When considering health data, learners should understand the principles of sampling .

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the harmless nature of most micro-organisms, many performing vital functions; some micro-organisms called pathogens, cause disease

(b) the fact that pathogens include micro-organisms such as bacteria, viruses, protists and fungi; the basic structure of a bacterial cell and virus

(c) the types of organisms which can cause communicable diseases: viruses, bacteria and fungi; the means by which they can be spread: by contact, aerosol, body fluids, water, insects, contaminated food

(d) the means by which the body defends itself from disease: intact skin forming a barrier against micro-organisms; blood clots to seal wounds; phagocytes in the blood ingesting micro-organisms; lymphocytes producing antibodies and antitoxins

(e) an antigen as a molecule that is recognised by the immune system; foreign antigens triggering a response by lymphocytes, which secrete antibodies specific to the antigens; the function of antibodies

(f) how vaccination can be used to protect humans from infectious disease; the factors influencing parents in decisions about whether to have children vaccinated or not

(g) **the fact that a vaccine contains antigens derived from a disease-causing organism; how a vaccine will protect against infection by that organism; how vaccines may be produced which protect against bacteria and viruses**

(h) **how after an antigen has been encountered, memory cells remain in the body and antibodies are produced very quickly if the same antigen is encountered a second time; how this memory provides immunity following a natural infection and after vaccination; the highly specific nature of this response**

(i) the fact that antibiotics, including penicillin, were originally medicines produced by living organisms, such as fungi; how antibiotics help to cure bacterial disease by killing the infecting bacteria or preventing their growth but do not kill viruses

(j) how some resistant bacteria, such as MRSA, can result from the over use of antibiotics; effective control measures for MRSA

(k) how some conditions can be prevented by treatment with drugs or by other therapies

(l) how new drug treatments may have side effects and that extensive, large scale, rigorous testing is required; the associated risks, benefits and ethical issues involved in the development of new drug treatments, including the use of animals for testing drugs and whether this is superceded by new technologies

2.5 Unit 5

(Double Award) CHEMISTRY 2

Written examination: 1 hour 15 minutes
15% of qualification

This unit includes the following topics:

5.1 Bonding, structure and properties

5.2 Acids, bases and salts

5.3 Metals and their extraction

5.4 Chemical reactions and energy

5.5 Crude oil, fuels and carbon compounds

NOTE

All content relating to formulae and equations and calculations based upon them (specified in Unit 2.1) is required for Unit 5.

All chemical tests specified in Unit 2 are required for Unit 5.

5.1 BONDING, STRUCTURE AND PROPERTIES

Overview

This topic explores the changes to atoms and electron structure during bonding, both ionic and covalent and links this to the resulting structures of substances. A good understanding of bonding is fundamental to explaining why chemical reactions happen.

Working Scientifically

Learners will use ideas, theories and models to explain abstract and complex concepts in this topic. They will be able to develop their skill in the clear explanation of ideas and use diagrams to illustrate their explanations. There are opportunities to explain every day and technological applications of science; to evaluate associated personal, social, economic and environmental implications; and to make decisions based on the evaluation of evidence and arguments.

Mathematical Skills

Skills in converting units and using multiplying factors will be used in this topic to understand the sizes involved in nanotechnology. Learners will use prefixes and powers of ten for orders of magnitude (milli-, micro- and nano-). They should use simple order of magnitude calculations in comparing nano-scale particles with individual atoms and with everyday objects.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the properties of metals, ionic compounds, simple molecular covalent substances and giant covalent substances

(b) the 'sea' of electrons/lattice of positive ions structural model for metals in explaining their physical properties

(c) electronic structure in explaining how ionic bonding takes place (and how this is represented using dot and cross diagrams)

(d) the accepted structural model for giant ionic structures in explaining the physical properties of ionic compounds

(e) electronic structure in explaining how covalent bonds are formed (and how this is represented using dot and cross diagrams)

(f) the intermolecular bonding structural model for simple molecular structures in explaining the physical properties of simple molecular substances

(g) the properties of diamond, graphite, fullerenes, carbon nano-tubes and graphene and how these are explained in terms of structure and bonding

(h) individual atoms not having the same properties as bulk materials as demonstrated by diamond, graphite, fullerenes, carbon nano-tubes and graphene having different properties despite all containing only carbon atoms, and by nano-scale silver particles exhibiting properties not seen in bulk silver

(i) the properties and uses of nano-scale particles of silver and titanium dioxide

(j) **the possible risks associated with the use of nano-scale particles of silver and titanium dioxide, and of potential future developments in nanoscience**

(k) the properties and uses of smart materials including thermochromic pigments, photochromic pigments, polymer gels, shape memory alloys and shape memory polymers

5.2 ACIDS, BASES AND SALTS

Overview

In this topic, learners will investigate the reactions of acids in depth. Neutralisation theory and titration concepts are introduced, giving ample opportunity both for practical investigations and for learners to develop their understanding of reaction processes. Learners should be able to write word and balanced symbol equations **(including ionic equations where relevant)** for all reactions described in this topic.

Working Scientifically

In this topic, learners will use scientific vocabulary, terminology and definitions to describe chemical methods and reactions. They can apply a knowledge of a range of techniques, instruments, apparatus, and materials. Writing chemical equations will enable them to correctly use formulae, symbols and correct nomenclature.

Mathematical Skills

Mathematical skills will be used in this topic to balance ionic formulae and chemical equations.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) substances as acidic, alkaline or neutral in terms of the pH scale, including acid/alkali strength

(b) solutions of acids containing hydrogen ions and alkalis containing hydroxide ions

(c) the reactions of dilute acids with metals and how these relate to the metals' position in the reactivity series

(d) the neutralisation of dilute acids with bases (including alkalis) and carbonates

(e) **neutralisation as the reaction of hydrogen ions with hydroxide ions to form water**

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

(f) the acid/carbonate reaction as a test for acidic substances and CO_3^{2-} ions

(g) the preparation of crystals of soluble salts, such as copper(II) sulfate, from insoluble bases and carbonates

(h) the names of the salts formed by hydrochloric acid, nitric acid and sulfuric acid

(i) the test used to identify SO_4^{2-} ions

(j) titration as a method to prepare solutions of soluble salts and to determine relative concentrations of solutions of acids/alkalis

SPECIFIED PRACTICAL WORK

- Preparation of crystals of a soluble salt from an insoluble base or carbonate
- Titration of a strong acid against a strong base using an indicator

5.3 METALS AND THEIR EXTRACTION

Overview

This topic considers the processes involved in extracting metals, based upon initial work with reactivity series and related reactions. It includes an introduction to electrolysis and its use in the extraction of aluminium. Learners should be able to write word and balanced symbol equations for all reactions described in this topic.

Working Scientifically

In this topic, learners will use scientific vocabulary, terminology and definitions to describe extraction processes. They can explain every day and technological applications of science; evaluate associated personal, social, economic and environmental implications; and make decisions based on the evaluation of evidence and arguments.

Mathematical Skills

Mathematical skills will be used in this topic to balance ionic formulae and chemical equations. **Higher tier learners will be able to link these ideas to calculation work and ratios in reacting masses.**

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) ores found in the Earth's crust as the source of most metals and that these metals can be extracted using chemical reactions

(b) some unreactive metals (e.g. gold) being found in their native form and that the difficulty involved in extracting metals increases as their reactivity increases

(c) the relative reactivities of metals as demonstrated by displacement (e.g. iron nail in copper(II) chloride solution) and competition reactions (e.g. thermit reaction)

(d) reduction and oxidation in terms of removal or gain of oxygen

(e) the industrial extraction of iron in the blast furnace, including the combustion, reduction, decomposition and neutralisation reactions

(f) electrolysis of molten ionic compounds e.g. lead(II) bromide (including electrode equations)

(g) reduction and oxidation in terms of gain or loss of electrons

(h) the industrial extraction of aluminium using electrolysis, including the use of cryolite to dissolve alumina

(i) the properties and uses of iron (steel), aluminium, copper and titanium

(j) the general properties of transition metals, including their ability to form ions with different charges

(k) an alloy being a mixture made by mixing molten metals, whose properties can be modified by changing its composition

(l) factors affecting economic viability and sustainability of extraction processes e.g. siting of plants, fuel and energy costs, greenhouse emissions and recycling

SPECIFIED PRACTICAL WORK

- Determination of relative reactivities of metals through displacement reactions

5.4 CHEMICAL REACTIONS AND ENERGY

Overview

This topic looks at the energy changes that happen during chemical reactions. It explains why reactions are exothermic or endothermic in terms of the energy associated with chemical bonds.

Working Scientifically

Learners will use ideas, theories and models to explain abstract and complex concepts in this topic.

Mathematical Skills

Learners will reinforce their understanding of chemical equations in determining the number of bonds of each type present in reactants and products. They will use arithmetical skills to calculate the energy changes associated with reactions.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) exothermic and endothermic reactions in terms of temperature change and energy transfer to or from the surroundings

(b) energy profiles for exothermic and endothermic reactions

(c) the activation energy as the energy needed for a reaction to occur

(d) the use of bond energy data to calculate overall energy change for a reaction and to identify whether it is exothermic or endothermic

5.5 CRUDE OIL, FUELS AND CARBON COMPOUNDS

Overview

This topic provides an introduction to the skills and knowledge, including the representation and naming of organic structures, needed in organic chemistry. The formation and fractional distillation of crude oil, cracking and polymerisation are explored and the products of each process explained. **Higher tier learners will be introduced to the concept of isomerism**. Learners should be able to write word and balanced symbol equations for combustion, cracking and addition reactions and symbol equations representing polymerisation.

Working Scientifically

There are opportunities here for learners to use theories, models and ideas to develop scientific explanations; to communicate information and ideas in appropriate ways using appropriate terminology.

Mathematical Skills

Mathematical skills will be used in this topic to balance organic formulae and chemical equations. Ideas of general formulae and the relationships involved can be investigated.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) crude oil as a complex mixture of hydrocarbons that was formed over millions of years from the remains of simple marine organisms

(b) the fractional distillation of crude oil

(c) fractions as containing mixtures of hydrocarbons (alkanes) with similar boiling points

(d) the trends in properties of fractions with increasing chain length and the effect on their usefulness as fuels

(e) the global economic and political importance and social and environmental impact of the oil industry

(f) the combustion reactions of hydrocarbons and other fuels

(g) how to determine experimentally the energy per gram released by a burning fuel

(h) the combustion reaction of hydrogen and its use as an energy source including its advantages and disadvantages as a fuel

(i) the fire triangle in fire-fighting and fire prevention

(j) the cracking of some fractions to produce smaller and more useful hydrocarbon molecules, including monomers (alkenes) which can be used to make plastics

(k) the general formula C_nH_{2n+2} for alkanes and C_nH_{2n} for alkenes

(l) the names and molecular and structural formulae for simple alkanes and alkenes

(m) **isomerism in more complex alkanes and alkenes**

(n) the addition reactions of alkenes with hydrogen and bromine and the use of bromine water in testing for alkenes

(o) the addition polymerisation of ethene and other monomers to produce polythene, poly(propene), poly(vinylchloride) and poly(tetrafluoroethene)

(p) the general properties of plastics and the uses of polythene, poly(propene), poly(vinylchloride) and poly(tetrafluoroethene)

(q) the environmental issues relating to the disposal of plastics, in terms of their non-biodegradability, increasing pressure on landfill for waste disposal, and how recycling addresses these issues as well as the need to carefully manage the use of finite natural resources such as crude oil

SPECIFIED PRACTICAL WORK

- Determination of the amount of energy released by a fuel

2.6 Unit 6

(Double Award) PHYSICS 2

Written examination: 1 hour 15 minutes
15% of qualification

This unit includes the following topics:

6.1 Distance, speed and acceleration

6.2 Newton's laws

6.3 Work and energy

6.4 Stars and planets

6.5 Types of radiation

6.6 Half-life

6.1 DISTANCE, SPEED AND ACCELERATION

Overview

This topic introduces the ideas of distance, speed, velocity, acceleration and their definitions. Learners will use velocity-time graphs to determine the acceleration of a moving body, and the distance the body travels in a given time. These basic principles will be applied to the safe stopping distances of vehicles and the factors upon which this depends.

Working Scientifically

There are opportunities within this topic for learners to use appropriate methodology, including ICT to answer scientific questions and to solve scientific problems. Learners can carry out experimental and investigative activities using stopwatches, light gates and data loggers to measure the acceleration of a moving body, to investigate factors affecting stopping distances and to measure the speed of a moving body. Learners can apply these factors to explain the factors which affect the braking distances of moving vehicles and the related safety considerations and to explain the dangers caused by large decelerations. Learners can evaluate risks in the wider social context, including perception of risk in relation to given data and discuss traffic control arising from the above.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills in this topic. These include making calculations using ratios and proportional reasoning to convert units and compute rates; relating changes and differences in motion to appropriate distance-time and velocity-time graphs; interpreting enclosed areas of such graphs; applying formulae relating distance, time and speed for uniform motion; estimating how the distances required for road vehicles to stop in an emergency varies over a range of typical speeds. These topics afford learners the opportunity to use expressions in decimal form; to use ratios, fractions and percentages; to make estimates of the results of simple calculations, without using a calculator; **to change the subject of an equation**; to substitute numerical values into algebraic equations using appropriate units for physical quantities; to solve simple algebraic equations; to translate information between graphical and numeric form; **to understand that $y = mx + c$ represents a linear relationship**; to plot two variables from experimental or other data; to interpret the slope of a linear graph; **to understand the physical significance of the area between a curve and the x-axis and to measure it by counting squares as appropriate**.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) motion using speed, velocity and acceleration

(b) speed-time and distance-time graphs

(c) the equations:

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

$$\text{acceleration}\left(\text{or deceleration}\right) = \frac{\text{change in velocity}}{\text{time}}$$

(d) velocity-time graphs to determine acceleration **and distance travelled**

(e) the principles of forces and motion to the safe stopping of vehicles, including knowledge of the terms reaction time, thinking distance, braking distance and overall stopping distance and discuss the factors which affect these distances

(f) the physics of motion together with presented data and opinions to discuss traffic control arising from the above, e.g. the need for speed limits and seat belts

6.2 NEWTON'S LAWS

Overview

This topic introduces the concepts of inertia, mass and weight and the relationship between them. The relationship between force, mass and acceleration is developed. Newton's laws of motion are used to explain the behaviour of objects moving through the air, and the concept of terminal speed.

Working Scientifically

The specified practical work in this topic gives learners the opportunity to know and understand a range of techniques, practical instruments and equipment appropriate to the knowledge and understanding included in the specification; to safely and correctly use practical equipment and materials; to make and record observations; to present information and data in a scientific way.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills in this topic. These include applying the relationship between resultant force, mass and acceleration; calculating the weight of a mass in a given gravitational field. These topics afford learners the opportunity to recognise and use expressions in decimal form; to recognise expressions in standard form; to use ratios, fractions and percentages; **to change the subject of an equation**; to substitute numerical values into algebraic equations using appropriate units for physical quantities.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the concept of inertia, that mass is an expression of the inertia of a body

(b) Newton's first law of motion **and be able to state it**

(c) how unbalanced forces produce a change in a body's motion and that the acceleration of a body is directly proportional to the resultant force and inversely proportional to the body's mass

(d) Newton's second law of motion, **and be able to state it**, in the form:

resultant force = mass $\times$ acceleration; $F = ma$

(e) the distinction between the weight and mass of an object, the approximation that the weight of an object of mass 1 kg is 10 N on the surface of the Earth and use data on gravitational field strength in calculations involving weight ($W = mg$) and gravitational potential energy

weight (N) = mass (kg) $\times$ gravitational field strength (N/kg)

(f) forces and their effects to explain the behaviour of objects moving through the air, including the concept of terminal speed

(g) Newton's third law of motion **and be able to state it**

SPECIFIED PRACTICAL WORK

- Investigation of the terminal speed of a falling object

6.3 WORK AND ENERGY

Overview

This topic explores the relationship between work and energy. The equations for kinetic energy and change in gravitational potential energy are developed. The principles of force, energy and motion are used to analyse such safety features of cars as air bags and crumple zones.

Working Scientifically

This unit contains opportunities for learners to apply scientific knowledge to practical contexts. It gives learners the opportunity to understand how to use a range of experimental and practical instruments with due consideration for safety. It presents the opportunity for learners to apply the cycle of collecting, presenting and analysing data and presenting observations and other data using appropriate methods. There are opportunities within this topic for learners to carry out experimental activities in a range of topics. Learners can be helped to understand how, through the ideas of physics, physical laws and models are expressed in mathematical form. Learners can investigate the elastic and inelastic behaviour of a spring by carrying out experimental and investigative activities, including appropriate risk management.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills in this topic. These include performing calculations using compatible units for energy transfers associated with energy changes in a system; recalling or selecting and applying the relevant equations for work done, kinetic energy and change in gravitational potential energy; calculating the energy stored in a stretched spring. These topics afford learners the opportunity to recognise and use expressions in decimal form; to recognise expressions in standard form; to use ratios, fractions and percentages; **to change the subject of an equation**; to substitute numerical values into algebraic equations using appropriate units for physical quantities; to solve simple algebraic equations; **to understand the physical significance of the area between a curve and the x-axis and to measure it by counting squares as appropriate**.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the fact that, when a force acts on a moving body, energy is transferred although the total amount of energy remains constant

(b) the equation: work = force x distance moved in the direction of the force; $W = Fd$

(c) the fact that work is a measure of the energy transfer, i.e. that work = energy transfer (in the absence of thermal transfer)

(d) the fact that an object can possess energy because of its motion (kinetic energy) and position (gravitational potential energy) and deformation (elastic energy)

(e) **the equations for kinetic energy and changes in gravitational potential energy:**

$$\textbf{kinetic energy} = \frac{\textbf{mass} \times \textbf{velocity}^2}{2};\ \mathbf{KE} = \tfrac{1}{2}mv^2$$

$$\textbf{change in potential energy} = \textbf{mass} \times \textbf{gravitational field strength} \times \textbf{change in height};\ \mathbf{PE} = mgh$$

(f) the relationship between force and extension for a spring and other simple systems;
force = spring constant × extension; $F = kx$

(g) **the work done in stretching by finding the area under the force-extension (F-x) graph**;
$W = \tfrac{1}{2}Fx$ for a linear relationship

(h) how energy efficiency of vehicles can be improved (e.g. by reducing aerodynamic losses/air resistance and rolling resistance, idling losses and inertial losses)

(i) the principles of forces and motion to an analysis of safety features of cars e.g. air bags and crumple zones

SPECIFIED PRACTICAL WORK

- Investigation of the force-extension graph for a spring

6.4 STARS AND PLANETS

Overview

This topic covers the main features of our solar system and the circular orbits of planets, their moons and artificial satellites. It looks at the main observable stages in the life cycle of stars of different masses and discusses the stability of stars and explains the origin of the solar system as being due to the collapse of a cloud of gas and dust.

Working Scientifically

There are opportunities within this topic for learners to understand how scientific methods and theories develop over time. There are opportunities within this topic for learners to use theories, models and ideas to develop scientific questions, define scientific problems, present scientific arguments and ideas; to know that scientific knowledge and understanding develops over time; to communicate information and ideas in appropriate ways using appropriate terminology. Learners can be given the opportunity to understand how scientific knowledge and understanding developed over time and how the theory that the origin of the solar system from the collapse of a cloud of gas and dust was accepted.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the main features of our solar system: their order, size, orbits and composition to include the Sun, terrestrial planets and gaseous giant planets, dwarf planets, comets, moons and asteroids

(b) the features of the observable universe (planets, planetary systems, stars and galaxies) and the use of appropriate units of distance: kilometres, astronomical units (AU) and light years (l-y)

(c) the main observable stages in the life cycle of stars of different masses, using the terms: protostar, main sequence star, red giant, supergiant, white dwarf, supernova, neutron star and black hole

(d) the fact that the stability of stars depends upon a balance between gravitational force and a combination of gas and radiation pressure and that stars generate their energy by the fusion of increasingly heavier elements

(e) the return of material, including heavy elements, into space during the final stages in the life cycle of giant stars

(f) the origin of the solar system from the collapse of a cloud of gas and dust, including elements ejected in supernovae

(g) **the Hertzsprung-Russell (H-R) diagram as a means of displaying the properties of stars, depicting the evolutionary path of a star**

6.5 TYPES OF RADIATION

Overview

This topic covers the structure of the nuclear atom and its representation using atomic notation. It covers the spontaneous nature of nuclear decay and the nature of alpha, beta and gamma radiation. Learners will produce and balance nuclear equations for radioactive decay.

Working Scientifically

There are opportunities within this topic for learners to process and analyse data using mathematical skills. There are opportunities within this topic for learners to use appropriate methodology to answer scientific questions and to solve scientific problems.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills in this topic. These include balancing equations representing alpha, beta or gamma decay in terms of the mass number and atomic number, and charges of the atoms involved. These topics afford learners the opportunity to use ratios, fractions and percentages.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the terms nucleon number (A), proton number (Z) and isotope, and relate them to the number of protons and neutrons in an atomic nucleus

(b) radioactive emissions as arising from unstable atomic nuclei because of an imbalance between the numbers of protons and neutrons

(c) the fact that waste materials from nuclear power stations and nuclear medicine are radioactive and some of them will remain radioactive for thousands of years

(d) background radiation and be able to make an allowance for it in measurements of radiation

(e) the random nature of radioactive decay and that it has consequences when undertaking experimental work, requiring repeat readings to be made or measurements over a lengthy period as appropriate

(f) the differences between alpha, beta and gamma radiation in terms of their penetrating power, relating their penetrating powers to their potential for harm and discussing the consequences for the long term storage of nuclear waste

(g) alpha radiation as a helium nucleus, beta radiation as a high energy electron and gamma radiation as electromagnetic

(h) **producing** and balancing nuclear equations for radioactive decay using the symbols ${}^{4}_{2}\mathrm{He}^{2+}$ or ${}^{4}_{2}\alpha$ for the alpha particle and ${}^{0}_{-1}\mathrm{e}$ and ${}^{0}_{-1}\beta$ for the beta particle respectively

(i) natural and artificial sources of background radiation, respond to information about received dose from different sources (including medical X-rays) and discuss the reasons for the variation in radon levels

6.6 HALF-LIFE

Overview

This topic covers the random nature of radioactive decay and introduces the concept of half-life. Learners will plot decay curves and use them to determine the half-lives of radioactive materials. Different uses of radioactive materials will be studied, the uses being related to their half-lives and their penetrating powers.

Working Scientifically

There are opportunities within this topic for learners to plot and interpret graphs; to process and analyse data using mathematical skills. There are opportunities within this topic for learners to use appropriate methodology to answer scientific questions and to solve scientific problems.

Mathematical Skills

There are a number of opportunities for the development of mathematical skills in this topic. These include calculating how the activity of a radioactive source changes after a given number of half-lives. These topics afford learners the opportunity to recognise expressions in standard form; to use ratios, fractions and percentages; to substitute numerical values into algebraic equations using appropriate units for physical quantities; to solve simple algebraic equations.

Learners should be able to demonstrate and apply their knowledge and understanding of:

(a) the random nature of radioactive decay and to model the decay of a collection of atoms using a constant probability of decay, e.g. using a large collection of dice, coins or a suitably programmed spreadsheet

(b) how to plot or sketch decay curves for radioactive materials, understand that a given radioactive material has a characteristic half-life and determine the half-life of a material from the decay curve

(c) how to perform simple calculations involving the activity and half-life of radioactive materials in a variety of contexts, e.g. carbon dating

(d) the different uses of radioactive materials, relating to the half-life, penetrating power and biological effects of the radiation e.g. radioactive tracers and cancer treatment

SPECIFIED PRACTICAL WORK

- Determination of the half-life of a model radioactive source, e.g. using dice.

2.7 Unit 7

(Double Award) PRACTICAL ASSESSMENT

10% of qualification

This assessment gives learners the opportunity to demonstrate their ability to work scientifically. This will include experimental skills and strategies and skills in analysis and evaluation.

The practical assessment is untiered and will take place in the first half of the spring term (January – February). It is recommended that this should be in the final year of study. Each year, WJEC will provide three tasks based on the content of GCSE Science (Double Award). This will include one task from each of Biology, Chemistry and Physics. Learners are only required to submit **two** tasks so centres can select which two they wish to use with their learners.

The tasks will be externally marked by WJEC and will change on an annual basis.

The details required for the planning and administration of the practical assessment will be provided to centres at appropriate times prior to the assessment.

Each task comprises two sections:

Section A - Obtaining results (6 marks)

Learners will be permitted to work in groups of no more than three, to obtain results from a given experimental method. This will be carried out under a limited level of control i.e. learners may work with others to obtain results but they must provide their own responses to the questions set. Teacher assistance should not normally be required, but may be given if equipment failure occurs. Section A will be completed in one session of 60 minutes duration.

Section B - Analysing and evaluating results (24 marks)

Learners will be assessed on their ability to analyse and evaluate the data obtained in section A. They will require access to their section A assessment in order to complete this. Section B will be carried out under a high level of control i.e. learners must work individually. This section is to be completed with no teacher feedback or assistance allowed and under formal supervision. Section B will be completed in one session of 60 minutes duration.

3 ASSESSMENT

3.1 Assessment objectives and weightings

Below are the assessment objectives for this specification. Learners must:

AO1
Demonstrate knowledge and understanding of scientific ideas, processes, techniques and procedures

AO2
Apply knowledge and understanding of scientific ideas, processes, techniques and procedures

AO3
Analyse, interpret and evaluate scientific information, ideas and evidence, including in relation to issues, to:

- make judgements and reach conclusions
- develop and refine practical design and procedures

The table below shows the weighting of each assessment objective for each unit and for the qualification as a whole.

	AO1	AO2	AO3
Unit 1	6%	6%	3%
Unit 2	6%	6%	3%
Unit 3	6%	6%	3%
Unit 4	6%	6%	3%
Unit 5	6%	6%	3%
Unit 6	6%	6%	3%
Unit 7	4%	4%	2%
Overall weighting	**40 %**	**40 %**	**20 %**

For each series:

- the weighting for the assessment of mathematical skills will be a minimum of 20%
- the weighting for the assessment of practical skills will be a minimum of 15%.

The ability to select, organise and communicate information and ideas coherently using scientific convention and vocabulary will be tested across the assessment objectives.

For each series, writing accurately will be assessed in specified questions that require extended writing (i.e. QER questions) in Units 1 - 6.
Writing accurately takes into account the candidate's use of specialist language. It also takes into account the candidate's spelling, punctuation and grammar.

4 TECHNICAL INFORMATION

4.1 Making entries

This is a unitised qualification which allows for an element of staged assessment.

Assessment opportunities will be available in the summer assessment period each year, until the end of the life of the specification.

Unit 1, Unit 2 and Unit 3 will be available in 2017 (and each year thereafter). Unit 4, Unit 5, Unit 6 and Unit 7 will be available in 2018 (and each year thereafter) and the qualification will be awarded for the first time in Summer 2018.

There are two tiers of entry available for this qualification: Higher Tier (Grades A* - D) and Foundation Tier (Grades C - G). Unit 7 (practical assessment) is untiered. In most cases, we would expect candidates to be assessed within the same tier. Exceptionally, it may be appropriate to enter some candidates for a combination of higher and foundation tier units.

At least 40% of the assessment must be taken at the end of the course to satisfy the requirement for terminal assessment and the results from the terminal assessment must contribute to the subject award.

Candidates may re-sit units ONCE ONLY prior to certification for the qualification, with the better result contributing to the qualification. Individual unit results, prior to the certification of the qualification, have a shelf-life limited only by that of the qualification.

A candidate may retake the whole qualification more than once.

The entry codes appear below.

	Title	Entry codes	
		English-medium	Welsh-medium
Unit 1	Biology 1 (Foundation Tier)	3430U1	3430N1
	Biology 1 (Higher Tier)	3430UA	3430NA
Unit 2	Chemistry 1 (Foundation Tier)	3430U2	3430N2
	Chemistry 1 (Higher Tier)	3430UB	3430NB
Unit 3	Physics 1 (Foundation Tier)	3430U3	3430N3
	Physics 1 (Higher Tier)	3430UC	3430NC
Unit 4	Biology 2 (Foundation Tier)	3430U4	3430N4
	Biology 2 (Higher Tier)	3430UD	3430ND
Unit 5	Chemistry 2 (Foundation Tier)	3430U5	3430N5
	Chemistry 2 (Higher Tier)	3430UE	3430NE
Unit 6	Physics 2 (Foundation Tier)	3430U6	3430N6
	Physics 2 (Higher Tier)	3430UF	3430NF
Unit 7	Practical Assessment	3430U7	3430N7
GCSE Qualification cash-in		3430QD	3430CD

The current edition of our *Entry Procedures and Coding Information* gives up-to-date entry procedures.

4.2 Grading, awarding and reporting

There are two tiers of entry available for this qualification: Higher Tier (Grades A* - D) and Foundation Tier (Grades C - G). In most cases, we would expect candidates to be assessed within the same tier. Exceptionally, it may be appropriate to enter some candidates for a combination of higher and foundation tier units.

The Uniform Mark Scale (UMS) is used in unitised specifications as a device for reporting, recording and aggregating candidates' unit assessment outcomes. The UMS is used so that candidates who achieve the same standard will have the same uniform mark, irrespective of when the unit was taken.

Individual unit results reported on UMS have the following grade equivalences:

Grade	MAX.	A*	A	B	C	D	E	F	G
Units 1 - 6	120	108	96	84	72	60	48	36	24
Unit 7	80	72	64	56	48	40	32	24	16

For Units 1 - 6, which are tiered, the maximum uniform mark available on the foundation tier of the assessment will be 83 (i.e. 1 mark less than the minimum mark needed to achieve a grade B on the unit). As Unit 7 is untiered, the full range of uniform marks is available in the unit.

This GCSE qualification will be reported on a fifteen point scale from A*A*- GG, where A*A* is the highest grade. Results not attaining the minimum standard for the award will be reported as U (unclassified) and learners will not receive a certificate.

The uniform marks obtained for each unit are added up and the subject grade is based on this total. The total results reported on UMS will have the following grade equivalences on the fifteen point scale:

UMS total	Subject Award
720	A*A*
680	A*A
640	AA
600	AB
560	BB
520	BC
480	CC
440	CD
400	DD
360	DE
320	EE
280	EF
240	FF
200	FG
160	GG

APPENDIX A

Working Scientifically

1. Development of scientific thinking

- 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, 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 which may arise
- explain every day 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 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

2. Experimental skills and strategies

- 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 a knowledge of a range of techniques, instruments, apparatus, and materials to select those appropriate to the experiment
- carry out experiments appropriately having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations
- recognise when to apply a knowledge of sampling techniques to ensure any samples collected are representative
- make and record observations and measurements using a range of apparatus and methods
- evaluate methods and suggest possible improvements and further investigations

3. Analysis and evaluation

- apply the cycle of collecting, presenting and analysing data, including:
    - presenting observations and other data using appropriate methods
    - translating data from one form to another
    - carrying out and representing mathematical analysis
    - representing distributions of results and make estimations of uncertainty
    - interpreting observations and other data (presented in verbal, diagrammatic, graphical, symbolic or numerical form), including identifying patterns and trends, making inferences and drawing conclusions
    - presenting reasoned explanations including relating data to hypotheses
    - being objective, evaluating data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic error
    - communicating the scientific rationale for investigations, methods used, findings and reasoned conclusions through paper based and electronic reports and presentations using verbal, diagrammatic, graphical, numerical and symbolic forms

4. Scientific vocabulary, quantities, units, symbols and nomenclature

- use scientific vocabulary, terminology and definitions
- recognise the importance of scientific quantities and understand how they are determined
- use SI units (e.g. kg, g, mg; km, m, mm; kJ, J) and IUPAC chemical nomenclature unless inappropriate
- use prefixes and powers of ten for orders of magnitude (e.g. tera, giga, mega, kilo, centi, milli, micro and nano)
- interconvert units
- **use an appropriate number of significant figures in calculation**

APPENDIX B

Mathematical Skills

This table shows the mathematical skills which can be assessed across the qualification. It also shows the subject content area: Biology (B), Chemistry (C) and Physics (P) in which the skills apply. Skills which will be assessed at higher tier only are shown in bold type.

	Skill	Subject		
		B	C	P
1	*Arithmetic and numerical computation*			
	Recognise and use expressions in decimal form	✓	✓	✓
	Recognise expressions in standard form	✓	✓	✓
	Use ratios, fractions and percentages	✓	✓	✓
2	*Handling data*			
	Use an appropriate number of significant figures	✓	✓	✓
	Find arithmetic means	✓	✓	✓
	Construct and interpret tables and diagrams	✓	✓	✓
	Understand the principles of sampling as applied to scientific data	✓		
	Understand simple probability	✓		✓
	Make order of magnitude calculations	✓	✓	✓
3	*Algebra*			
	Change the subject of an equation		✓	✓
	Substitute numerical values into algebraic equations and solve them using appropriate units for physical quantities	✓	✓	✓
4	*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	✓	✓	✓
	Interpret the slope of a linear graph	✓	✓	✓
	Interpret the 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			✓
5	*Geometry and trigonometry*			
	Use angular measures in degrees			✓
	Calculate areas of triangles and rectangles, surface areas and volumes of cubes	✓	✓	✓