GCSE

WJEC GCSE in

APPLIED SCIENCE (DOUBLE AWARD)

APPROVED BY QUALIFICATIONS WALES

SPECIFICATION

Teaching from 2016
For award from 2018

Version 2 March 2019

SUMMARY OF AMENDMENTS

Version	Description	Page number
2	'Making entries' section has been amended to clarify resit rules, carry forward of Practical Assessment (NEA) marks and the terminal rule.	63

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For teaching from 2016
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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.

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GCSE APPLIED 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 Applied 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) ENERGY, RESOURCES and the ENVIRONMENT Written Examination: 1 hour 30 minutes 22.5% of qualification	75 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) SPACE, HEALTH and LIFE Written Examination: 1 hour 30 minutes 22.5% of qualification	75 marks
Examination with a pre-release paper. Two sections to the examination. One section will have questions based upon the pre-release and related aspects of the specification. The second section will be based on aspects of the specification not tested in the pre-release section. There will be 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) FOOD, MATERIALS and PROCESSES Written Examination: 1 hour 30 minutes 25% of qualification	75 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) TASK BASED ASSESSMENT 20% of qualification	60 marks
A task based assessment which will be externally assessed by WJEC. It will take place in the second half of the autumn term (November – December). It is recommended that this should be in the final year of study. A tiered assessment.	
Unit 5: (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: 601/8237/4

Qualifications Wales Approval Number listed on QiW: C00/0780/2

GCSE APPLED SCIENCE (Double Award)

1 INTRODUCTION

1.1 Aims and objectives

The WJEC GCSE Applied Science (Double Award) specification utlises a context led approach to science learning and assessment. It provides learners with a broad, coherent, practical, satisfying and worthwhile course of study.

Studying the GCSE Applied Science (Double Award) provides insight into, and experience of how science works whilst stimulating learners' curiosity and encouraging them to develop an understanding of science, its applications and its relationship to the individual and society. It should also prepare candidates to make informed decisions about further study and training opportunities in applied science. This WJEC GCSE Applied Science (Double Award) specification will enable learners to develop:

- essential knowledge and understanding of different areas of science and how they relate to each other
- knowledge and understanding of science and its applications
- interest in, and enthusiasm for science, including developing an interest in further study and careers associated with science
- competence and confidence in a variety of practical, mathematical and problem solving skills
- understanding of the scientific process
- practical, problem-solving, enquiry and scientific modelling skills and understanding in laboratory, and work-related contexts
- understanding of the relationships between data, evidence and explanations and their ability to evaluate scientific methods, evidence and conclusions
- understanding of how society makes decisions about scientific issues
- communication, mathematical and technological skills in scientific contexts.

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 set in meaningful contexts enabling 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 vocational/applied sciences at level 3 e.g. WJEC level 3 Extended Diploma / Diploma in Environmental Science and WJEC Diploma / Certificate in Medical Science. In addition, the specification provides a coherent, satisfying and worthwhile course of study for learners who do not wish to 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 Applied Science (Double Award).

GCSE Applied Science (Double Award) provides a context led framework for developing learner's knowledge, understanding and skills. These contexts are intended to enable learners to make meaningful connections between what they learn and how science is used to solve 'real world' problems. Learners should therefore be prepared to apply the knowledge, understanding and skills specified in a range of contexts which include Health Science, sport, food production, our environment, the generation/use of electricity, industrial processes, etc. In order to facilitate meaningful context led assessment, Unit 2 will be assessed through an examination which will contain a section based on a pre-release article. This gives the opportunity to assess learners' ability to understand scientific knowledge and understanding set in an extended context.

Unit 1 section 1.1.1 to 1.3.2(f) contains content which is common to both the GCSE Science (Double Award) and GCSE Biology, Chemistry and Physics qualifications. This will enable learners, if necessary, to transfer between the different qualifications.

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.

This section also includes specified practical work that must be undertaken by learners in order that they are suitably prepared for the written examinations. 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 written examination paper. 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 related to the material, physical and living world
- understand the nature of science and its application to the environment, industry, the individual and society
- 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
- apply their communication and mathematical skills in scientific contexts
- evaluate claims based on science through critical analysis of the methodology, evidence and conclusions, both qualitatively and quantitatively
- appreciate the inter-disciplinary approach to science needed to solve problems.

2.1 Unit 1

(Double Award) ENERGY, RESOURCES and the ENVIRONMENT

Written examination: 1 hour 30 minutes
22.5% of qualification

This unit includes the following topics:

1.1 Energy and life

1.1.1 The cell and respiration
1.1.2 Obtaining the materials for respiration

1.2 Modern living and energy

1.2.1 Underpinning energy concepts
1.2.2 Generating electricity
1.2.3 Making use of energy
1.2.4 Building electric circuits

1.3 Obtaining resources from our planet

1.3.1 Obtaining clean water
1.3.2 Our planet
1.3.3 Producing useful compounds in the laboratory

1.1 ENERGY AND LIFE

1.1.1 THE CELL AND RESPIRATION

Overview

All living things are made of cells. Why do we have different types of cells? How do our cells group together to perform a particular function? How do substances move into and out of cells, to be used by living things or to be removed as waste? How does respiration occur? Why is aerobic respiration more efficient than anaerobic respiration? Learners can apply their knowledge in a number of fields including sport and medicine.

Working Scientifically

The study of cells enables learners to understand how scientific methods and theories develop over time. The specified practical work developed in this topic enable learners to use scientific theories and explanations to develop hypotheses; apply a knowledge 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; make and record observations; evaluate methods and suggest possible improvements and further investigations.

Mathematical skills

There are a number of opportunities for the development of mathematical skills especially within the specified practical work in this topic. These include recognising and using expressions in decimal form, using ratios, fractions and percentages, finding arithmetic means, plotting two variables from experimental data. Microscope work to examine cells allows opportunities for making order of magnitude calculations. Movement of substances into and out of cells allows learners to translate information between graphical and numeric form, plot two variables from experimental or other data, and interpret the slope or intercept of a linear graph.

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

(a) structure of animal and plant cells, and specialisation that results from being multicellular; function of the following parts: cell membrane, cytoplasm, nucleus, cell wall, vacuole, chloroplast

(b) levels of organisation: aggregation of cells into tissues, and tissues into organs

(c) 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

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

(e) **active transport which is an active process whereby substances can enter cells against a concentration gradient**

(f) 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; the word equation to describe aerobic respiration

(g) anaerobic respiration as a process that occurs in the absence of oxygen; anaerobic respiration as a less efficient process than aerobic respiration, where lactate is formed; oxygen debt as a result of anaerobic respiration

SPECIFIED PRACTICAL WORK

- Investigation of the factors that affect the rate of respiration

1.1.2 OBTAINING THE MATERIALS FOR RESPIRATION

Overview

We need to take in oxygen and food as the raw materials for respiration. How do we take in oxygen and remove carbon dioxide? How do we take in the food that we need and how do we digest it into useful components? What is the role of enzymes and how can we use enzymes in everyday life? Learners can apply their knowledge in a number of fields including dietetics, sport and medicine.

Working Scientifically

The study of enzymes in the digestive system enables learners to use models to solve problems, make predictions and to develop scientific explanations and understanding of familiar and unfamiliar facts. In experimental activities they can use theories and explanations to develop hypotheses; make and record observations and measurements using a range of apparatus and methods; evaluate methods and suggest possible improvements and further investigations. Practical work also enables learners to evaluate risk, carry out experiments appropriately having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations. They will also interpret observations, present reasoned explanations relative to data, hypotheses and use scientific vocabulary, terminology and definitions.

Mathematical skills

This topic allows learners to recognise and use expressions in decimal and standard form**,** use ratios, fractions and percentages, and find arithmetic means. Practical work on enzymes enables the **use of an appropriate number of significant figures**, make order of magnitude calculations, translate information between graphical and numeric form, plot two variables from experimental data, **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 purpose of the respiratory system in providing oxygen and removing carbon dioxide

(b) the structure of the respiratory system to include the nasal cavity, trachea, bronchi, bronchioles, alveoli, lungs, diaphragm, ribs and intercostal muscles (knowledge of pleural membranes is not required)

(c) how air is breathed in and out (contraction/relaxation of the intercostal muscles and movement of the diaphragm causing pressure and volume changes, so air is sucked in or forced out of the lungs), and the changes that take place in the composition of the air

(d) digestion as a process whereby large molecules are broken down into smaller molecules so they can be absorbed for use by body cells

(e) enzymes as proteins made by living cells that speed up/catalyse the rate of chemical reactions within the cells; specific enzymes being used for each reaction; optimum temperature and pH of enzymes; boiling destroying/denaturing enzymes

(f) enzyme activity in terms of molecular collisions; the simple 'lock and key' model of enzyme action and formation of the enzyme - substrate complex at the active site

(g) absorption of soluble substances through the wall of the small intestine and eventually into the bloodstream; the limitations of the model gut

(h) fats, made up of fatty acids and glycerol, proteins, made up of amino acids, and starch, made up of a chain of glucose molecules, that are insoluble; breakdown of fats, proteins and carbohydrates during digestion into soluble substances so that they can be absorbed

(i) the structure of the human digestive system, to include mouth, oesophagus/gullet, stomach, liver, gall bladder, bile duct, pancreas, small intestine, large intestine, anus

(j) the role of the following organs in digestion: mouth, stomach, pancreas, small intestine, large intestine

(k) peristalsis as a process whereby food is moved along the digestive tract; the function of bile which is secreted by the liver and stored in the gall bladder, in the breakdown of fats

(l) the fate of products of digestion: fatty acids and glycerol from fats and glucose from carbohydrate provide energy whilst amino acids from digested proteins are needed to build proteins in the body

(m) tests for the presence of starch using iodine solution, glucose using Benedict's reagent and protein using biuret solution

SPECIFIED PRACTICAL WORK

- Investigation into factors affecting enzyme action

1.2 MODERN LIVING AND ENERGY

1.2.1 UNDERPINNING ENERGY CONCEPTS

Overview

Electricity is essential to modern-day living. How can we use energy efficiently either when we generate electricity or when we use it in our homes? It is important to understand energy transfer if we are to efficiently generate electricity or use energy in the home. Learners can apply their knowledge in a number of fields including electricity generation and sustainable development.

This topic introduces some key scientific and mathematical concepts that will need to be applied to both the generation of electricity (1.2.2) and our use of energy (1.2.3).

Working Scientifically

This topic enables learners to explain every day applications of science; evaluate associated personal, social, economic and environmental implications; make decisions based on evaluation of evidence; plan experiments to make observations and test hypotheses; interpret observations and other data, including identifying patters and trends, making inferences and drawing conclusions. Learners will also learn to use scientific vocabulary, understand scientific quantities and interconvert units.

Mathematical skills

This topic gives opportunities for learners to use ratios, fractions and percentages; find arithmetic means; **change the subject of an equation**, substitute numerical values into algebraic equations and solve them using appropriate units for physical quantities.

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

(a) how temperature differences lead to the transfer of energy

(b) 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, transmission and use of energy

(c) mathematical equations to find useful information relating to both the generation and use of electricity:

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

- power = voltage × current
  e.g. in relation to the power output of wind turbines, water turbines and solar panels and power consumption of household appliances

- energy transfer = power × time

(d) how to investigate energy transfer and the efficiency of energy transfer in a range of contexts; the interpretation, analysis and evaluation of data and methods used in investigations. Investigations to include:

- the energy output from a renewable source (e.g. energy output and the construction / location of a wind turbine)
- the efficiency of an electric kettle

(e) the terms ‘sustainable’ and ‘carbon footprint’ when applied to generation of electricity or the use of electricity and energy (e.g. natural gas)

(f) the measurement of the carbon footprint in terms of mass equivalent of carbon dioxide (kgCO2eq) and global warming potential of a gas; the use of the relationship:

kgCO2eq = (mass of a gas) $\times$ (global warming potential of the gas)

SPECIFIED PRACTICAL WORK

- Investigation of the efficiency of energy transfer in electrical contexts

1.2.2 GENERATING ELECTRICITY

Overview

The methods of electricity generation are widely debated. How can we generate electricity? How do different methods compare with respect to their costs, effectiveness and potential impacts on the environment? How do we get electricity to our homes from where it is produced? This topic explores different ways of generating electricity and compares them for cost efficiency, reliability and environmental impact. Learners will also explore how electricity can be transferred from power stations to where it is used. Learners can apply their knowledge in a number of fields including electricity generation and sustainable development.

This topic also requires learners to apply concepts learnt in 1.2.1 to producing electricity.

Working Scientifically

Consideration of methods of energy generation allows learners to explain every day and technological applications of science; evaluate personal, social, economic and environmental implications; and make decisions based on the evaluation of evidence and arguments. This topic also enables learners to appreciate the power and limitations of science and consider any ethical issues which may arise. The specified practical activities enable learners to use scientific theories and explanations to develop hypotheses, plan experiments to make observations, evaluate methods and suggest possible improvements and further investigations. They will also interpret information, observations and other data, including identifying patterns and trends, making inferences and drawing conclusions, and communicate their findings.

Mathematical skills

This topic allows learners to recognise and use expressions in decimal and standard form, use ratios, fractions and percentages, **use the appropriate number of significant figures**, find arithmetic means, construct and interpret tables and diagrams, translate between graphical and numeric form, and plot two variables from scientific data.

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) as a means of generating electricity on a national scale using secondary information

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

(c) sustainability, carbon footprint, cost, reliability, environmental impact to compare different methods of power generation e.g. use data to assess their impact on the environment by considering atmospheric effects (acid rain and carbon dioxide emission), pollution including visual and noise pollution

(d) the lifetime and the useful power produced by renewable energy devices and power stations e.g. solar cell, fuel cell, wind turbines and water turbines

(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

(g) the use of transformers 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

SPECIFIED PRACTICAL WORK

- Investigation of the factors affecting the output from a solar panel

1.2.3 MAKING USE OF ENERGY

Overview

As energy is an expensive commodity, it is important that it is not wasted in industry and every day life. How can we keep our homes warm and yet keep heating bills down? How can we improve the energy efficiency of cars? How can our carbon footprint be reduced? How can we reduce the impact on the environment while using energy? Learners can apply their knowledge in a number of fields including electricity generation and sustainable development.

This topic also requires learners to apply concepts learnt in 1.2.1 to making use of energy.

Working Scientifically

The consideration of useful energy and energy loss enables learners to 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. They will be able to explain every day and technological applications of science; evaluate associated personal, social, economic and environmental implications; and make decisions based on evaluation of evidence and arguments. The specified practical work enables learners to plan experiments or devise procedures to make observations, test hypotheses 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; make and record observations and measurements; evaluate methods and suggest possible improvements and further investigations.

Mathematical skills

This topic enables learners to recognise and use expressions in decimal form, use ratios, fractions and percentages, find arithmetic means, construct and interpret tables and diagrams, **change the subject of an equation** and substitute numerical values into algebraic equations and solve them using appropriate units for physical quantities.

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

(a) processes by which energy can be transferred (conduction, convection or radiation)

(b) 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

(c) how energy loss from houses can be restricted e.g. loft insulation and double glazing; how data can be used to compare the economics of domestic insulation techniques

(d) the cost effectiveness and efficiency of different methods of reducing energy loss from the home, including loft insulation, cavity wall insulation, double-glazing and draught excluders to compare their effectiveness; the economic and environmental issues surrounding controlling energy loss

(e) the efficiency of different vehicle engines (electric > diesel > petrol); how energy efficiency of vehicles can be improved (e.g. reduce aerodynamic losses/air resistance and rolling resistance, reduce idling losses, inertia losses)

(f) energy saving methods with respect to their impact on the carbon footprint

(g) mathematical equations to find the number of units and cost of electricity used:

units used = power (kW) × time (h)

total cost = cost of one unit × units used

SPECIFIED PRACTICAL WORK

- Investigation of the methods of heat transfer

1.2.4 BUILDING ELECTRIC CIRCUITS

Overview

A large number of electrical devices are now used in our homes, at work, or for leisure. Electricity is used in every walk of life. What is an electric circuit? Does it matter how components are arranged in an electric circuit? How is a circuit constructed to switch on/off during changes in light levels or changes in temperature? What size fuse should be used in a circuit? In this topic learners will explore simple electric circuits and understand how the construction of a circuit affects the current and voltage across components. They will also be introduced to key concepts and relationships that need to be considered when building a circuit. Learners can apply their knowledge in a number of fields including electrical engineering, electronics and communications.

Working Scientifically

The study of electrical circuits enables learners to use scientific vocabulary, terminology and definitions; recognise the importance of scientific quantities and understand how they are determined; use a variety of models to solve problems, make predictions and develop scientific explanations. The specified practical work allows learners to plan experiments to make observations; apply a knowledge of a range of techniques, instruments and apparatus to select those appropriate to the experiment; carry out experiments appropriately with due regard to the correct manipulation of apparatus; make and record measurements; carry out mathematical analysis; interpreting observations and other data, including identifying patterns and trends, making inferences and drawing conclusions.

Mathematical skills

This topic enables learners to recognise and use expressions in decimal form; **change the subject of an equation**; substitute numerical values into algebraic equations and solve them using appropriate units for physical quantities; translate information between graphical and numeric forms; plot two variables from experimental or other data.

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) adding components in series or parallel to change the total resistance of a circuit; physical factors that affect the resistance of thermistors and LDRs

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

(e) 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

(f) the significance of, and the relationship between current, voltage and resistance

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

(h) how to calculate total resistance and total current in a series circuit; how to select an appropriate fuse for a circuit; **how to calculate the total resistance and total current in a parallel circuit**

(i) mathematical equations to find useful information:

$$\text{current} = \frac{\text{voltage}}{\text{resistance}} \qquad I = \frac{V}{R}$$

$$\text{power} = \text{voltage} \times \text{current} \qquad P = VI$$

$$\textbf{power = current}^{\mathbf{2}} \times \textbf{resistance} \qquad \boldsymbol{P = I^2R}$$

SPECIFIED PRACTICAL WORK

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

1.3 OBTAINING RESOURCES FROM OUR PLANET

1.3.1 OBTAINING CLEAN WATER

Overview

Water is a fundamental need of every living thing. What is in water? Why does water need to be treated before we can drink it? How can we clean water for household use? How can we reduce the environmental impact of obtaining water? In this topic, learners are introduced to the composition of water and the need to treat water before it can be used by the public. Learners can apply their knowledge in a number of fields including the chemical industry and environmental monitoring.

Working Scientifically

Obtaining clean water allows learners to explain every day and technological applications of science; evaluate associated personal, social, economic and environmental implications; and make decisions based on evaluation of evidence and arguments. Specified practical work enables learners to 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; presenting observations using appropriate methods; interpreting observations and other data, including identifying patterns and trends, making inferences and drawing conclusions; use of SI units and IUPAC chemical nomenclature.

Mathematical skills

This topic will allow learners to recognise and use expressions in decimal form, use ratios, fractions and percentages, make order of magnitude calculations, translate between graphical and numeric form and plot two variables from experimental or other data.

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

(a) elements as substances that cannot be broken down by chemical means and as the building blocks of all substances; the symbols of elements; how to work out the formulae of simple compounds

(b) the terms atomic number, mass number and isotope including their definition; the information obtainable from the atomic number and mass number to include number of protons, neutrons or electrons in a particular atom and the electronic structures of an atom; the difference between an atom and an ion

(c) the differences between elements and compounds in terms of elements being composed of one type of atom while compounds are made of two or more different types of atom that are chemically joined

(d) the composition of water in ‘natural’ water supplies, including dissolved gases, ions including metal ions, carbonates and nitrates, particulate matter, parasitic microorganisms, organic matter and pesticides

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

(f) the treatment of the public water supply using sedimentation, filtration, ozone dosing and chlorination

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

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

(i) solubility curves including the drawing and interpreting of data on changes in solubility with temperature

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

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

(l) the impacts of hard water to include affects upon boilers, water pipes and health

SPECIFIED PRACTICAL WORK

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

1.3.2 OUR PLANET

Overview

Naturally occurring materials such as metals, rocks and minerals can be made into more useful products by physical or chemical change. Where do we get the raw products to make these useful substances from? How did they get there? How do we extract and process them? How long will supplies last? We need a steady supply of essential raw materials (e.g. crude oil) to produce useful substances (e.g. plastics) but what is the impact on the environment and society of obtaining them?

This topic helps learners understand how raw materials such as metal ores, crude oil and gases such as oxygen are obtained from the Earth's crust or atmosphere and processed. They will also consider the benefits and environmental impacts of obtaining these materials. In order to appreciate the extraction and processing of raw materials learners will also consider processes that affect the Earth's crust and the fundamental classification of elements in the periodic table and the idea of chemical change. Learners can apply their knowledge in a number of fields including the chemical industry and engineering.

Working Scientifically

The study of our planet allows learners to understand how scientific methods and theories develop over time; explain every day and technological applications of science; evaluate associated personal, social, economic and environmental implications; make decisions based on evaluation of evidence and arguments; evaluate risks both in practical science and in the wider social context, including the perception of risk in relation to data and consequences. The specified practical work allows learners to plan experiments or devise procedures to make observations, produce or characterise a substance, test hypotheses, check data or explore phenomena; make and record observations and measurements using a range of apparatus and methods; interpret observations and other data, including identifying patterns and trends, making inferences and drawing conclusions.

Mathematical skills

This topic enables learners to recognise and use expressions in decimal form, use ratios, fractions and percentages, make order of magnitude calculations, translate between graphical and numeric form, plot two variables from data, construct and interpret tables and diagrams.

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 process occurring at tectonic plate boundaries where plates slide past one another, move towards one another and move apart

(d) the composition of the original atmosphere to include gases from volcanoes such as carbon dioxide and water vapour

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

(f) the periodic table as a tabular display of elements with elements arranged in periods and groups with elements in the same group having similar properties; the two main classes of elements with metals found to the left and centre of the periodic table and non-metals are to the right of the table; the similarities and trends of elements within a group as illustrated by data from group 1 and 7

(g) chemical reactions that involve transformation of one set of chemical compounds into another; that in a chemical reaction, atoms are re-arranged to make new products and no atoms are lost or gained; word and balanced symbol equations for simple chemical reactions (e.g. magnesium and oxygen, carbon and oxygen to form carbon dioxide, alkali metals and halogens)

(h) methods to obtain raw materials from the Earth's crust or atmosphere, including metal ores via surface and subsurface mining, shale gas via fracking, crude oil via drilling, salt via solution mining or deep-shaft mining, gases such as oxygen or nitrogen from air via fractional distillation, biomass feedstock (e.g. for bioplastic production)

(i) the need to process most raw materials to produce useful materials, including separation of components and / or chemical transformation

(j) crude oil as a complex mixture of hydrocarbons which need separating to produce useful products; fractional distillation which utilises differences in boiling temperatures to separate fractions; each fraction as a less complex mixture which contain hydrocarbons with boiling points in the same range

(k) cracking as a process to make more useful molecules including monomers

(l) polymerisation reactions as processes that produce a polymer by linking monomers together into a repeating pattern

(m) bioplastics as produced from renewable sources such as vegetable oil or corn starch; the advantages and disadvantages of using plastics from renewable biomass sources

(n) ores as rocks that contain metals or compounds of metals

(o) reduction processes used in metal extraction limited to reduction with carbon/carbon monoxide or electrolysis; reduction as a process in which oxygen is removed or electrons added and oxidation as a process in which oxygen is added or electrons removed; a metal's position in the reactivity series determining the reduction processes used; electrolysis reactions that involve an electric current flowing through a molten ionic compound or ionic compound in solution

(p) extraction of iron using a blast furnace and extraction of aluminium using electrolysis including the raw materials and reactions occurring in each process; word and balanced symbol equations for these reactions

(q) the use of electrolysis to electroplate objects; the main reasons for electroplating including reduction of abrasive wear, improve corrosion protection and aesthetics

(r) the main costs of extracting and processing useful raw materials (labour, energy costs, demand)

(s) the fate of discarded products, to include the expected life in the environment, persistence of plastics in the environment, the role of microbes in the breakdown of biodegradable plastics, the corrosion of metals

(t) the environmental, social and economic impacts of obtaining and processing raw materials e.g. the impacts of mining including spoil heaps; drilling for oil including oil spills; fracking; impact of using crops to produce raw materials for fuels/ producing bioplastics on food production; the effect on the world's oceans and marine life of waste plastics in the environment

SPECIFIED PRACTICAL WORK

- Preparation of a biopolymer including the effect of a plasticiser

1.3.3 PRODUCING USEFUL COMPOUNDS IN THE LABORATORY

Overview

The production of chemicals has made a big impact on the way we live. How can we produce chemical compounds in the laboratory? Is there more than one way of producing a compound? If so, which method is the best? This unit introduces the basic chemistry and skills needed to answer questions such as these to allows learners to prepare compounds in the laboratory. Learners will use a variety of methods to prepare salts and will use their understanding of laboratory procedures to evaluate the suitability of a method. Learners can apply their knowledge in a number of fields including the chemical and pharmaceutical industries.

Working Scientifically

The production of useful compounds allows learners to plan experiments or devise procedures to make observations or produce a substance; apply a knowledge of a range of techniques, instruments, apparatus, and materials to select those most 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; evaluate methods and suggest possible improvements and further investigations; use scientific vocabulary, terminology and definitions; recognise the importance of scientific quantities and understand how they are determined; use SI units and IUPAC chemical nomenclature.

Mathematical skills

This topic allows learners to recognise and use expressions in decimal form and use ratios, fractions and percentages.

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

(a) the reactions of acids with metals, metal oxides, hydroxides, carbonates and ammonia; the patterns that exist in these reactions and use these patterns to make predictions about the outcome of reactions

(b) laboratory techniques to make useful salts, including insoluble salts (precipitation reactions e.g. copper carbonate) and soluble salts (e.g. copper sulfate, zinc sulfate, potassium nitrate, ammonium nitrate)

(c) laboratory procedures to evaluate the suitability of different methods of compound preparation, including the hazards in preparation, skills required, time, and success of the preparation

(d) chemical change to write word and symbol equations for simple neutralisation reactions (e.g. the formation of sodium chloride, potassium nitrate)

SPECIFIED PRACTICAL WORK

- Preparation of useful salts (e.g. zinc sulfate)

2.2 Unit 2

(Double Award) SPACE, HEALTH and LIFE

Written examination: 1 hour 30 minutes
22.5% of qualification

This unit includes the following topics:

2.1. Our planet

2.1.1 Our place in the Universe
2.1.2 World of life
2.1.3 Transfer and recycling of nutrients

2.2. Protecting our environment

2.3. Health, fitness and sport

2.3.1 Factors affecting human health
2.3.2 Diagnosis and treatment
2.3.3 Fighting disease
2.3.4 Exercise and fitness in humans

2.1 OUR PLANET

2.1.1 OUR PLACE IN THE UNIVERSE

Overview

Planet Earth is just one body that orbits a star that we know as the Sun. The Sun is just one of a very large number of stars that make up our galaxy. There are estimated to be between 100 and 400 billion stars in our own galaxy. These stars are very far away and can only be examined by powerful telescopes using the electromagnetic radiation emitted from them. Although space probes have landed on the surfaces of planets in our own solar system much of the information comes from examining electromagnetic radiation reflected from the planet's surface.

What is the electromagnetic spectrum and how does it help us learn about objects far from Earth and what they are made of? How can we interpret data to help us understand the Universe? In this section learners will explore the changing Universe. Learners can apply their knowledge in a number of fields including communications and space exploration.

Working Scientifically

The consideration of our place in the Universe allows learners to understand how scientific methods and theories develop over time; use a variety of models such as representational, spatial, descriptive, computational and mathematical to solve problems, make predictions and to develop scientific explanations and understanding of familiar and unfamiliar facts; explain every day and technological applications of science; evaluate associated personal, social, economic and environmental implications; make decisions based on evaluation of evidence and arguments.

Mathematical skills

This topic allows learners to recognise and use expressions in decimal form, recognise expressions in standard form, use ratios, fractions and percentages, make order of magnitude calculations, translate between graphical and numeric form, plot two variables from experimental or other data.

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

(a) the main parts of the electromagnetic spectrum including gamma rays, X-rays, ultraviolet, visible light, infra-red, microwaves and radio waves; the arrangement and scale of the electromagnetic spectrum in terms of frequencies, wavelengths and energies

(b) the relationship between the speed, frequency and wavelength of electromagnetic spectrum waves:

$$\text{wave speed} = \text{frequency} \times \text{wavelength}$$

(c) how theories about the Universe have changed over time to include the Steady State theory and Big Bang; differences in the two theories with reference to expansion of the Universe in the Big Bang theory; the Big Bang in which the Universe is believed to have started about 13.5 thousand million years ago; **how evidence from red shift and Cosmic Microwave Background Radiation (CMBR) is consistent with the Big Bang theory**

(d) how images of the universe are taken by Earth based systems, and space craft and transmitted to Earth; how electromagnetic waves are used to study structures in the universe e.g.

- X-ray images of stars
- ultra violet images of the Sun, galaxies and the planets
- visible light images of the Sun, the planets, moons and galaxies
- infra-red images of the Sun, the planets and the Milky Way
- microwave images of the Sun **and Cosmic Microwave Background Radiation (CMBR)**
- radio wave images of stars
- images of black holes

(e) the relative scale of the Universe, galaxies, and solar systems in terms of light years

(f) absorption spectra to include how they are produced and provide information about stars and galaxies (composition and relative movement)

(g) the structure of our solar system to include the Sun, planets (rocky planets, gas giants, and dwarf planets), main moons, the asteroid belt, comets and the Oort Cloud

(h) the Sun to include the relative size and mass to the Earth; nuclear fusion as the source of solar energy; Sun spots; solar flares and their effect on Earth (e.g. on telecommunications)

(i) data to identify patterns and compare objects in the solar system (e.g. mean surface temperature, period of rotation, length of day, distance from Sun)

2.1.2 WORLD OF LIFE

Overview

Ecology is the study of interactions of organisms and their environment. How can we classify organisms? How are living things suited to their environment? Why do some species survive whereas others do not survive? Where do new species come from? Why do some species become extinct? How have organisms changed over time? Learners should be able to apply the concepts in this section to appreciate the variety of life on Earth, describe how living things depend upon each other and how their evolution is driven by living and non-living factors. Learners can apply their knowledge in a number of fields including the ecology and environmental analysis.

Working Scientifically

The study of evolution allows an understanding of how theories develop over time; appreciate the power and limitations of science and consider any ethical issues which may arise, and make decisions based on evaluation of evidence and arguments. The specified practical work enables learners to plan experiments or devise procedures to make observations, test hypotheses, check data or explore phenomena; apply a knowledge of a range of techniques, instruments, apparatus, and materials to select those most 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. Following data collection they may present observations and data using appropriate methods; carry out and represent mathematical analysis; represent distributions of results and make estimations of uncertainty, and present reasoned explanations including relating data to hypotheses.

Mathematical skills

Analysis of organism distribution allows opportunities to recognise and use expressions in decimal form; recognise expressions in standard form; use ratios, fractions and percentages; construct and interpret tables and diagrams; and make order of magnitude calculations. Fieldwork enables learners to understand the principles of sampling as applied to scientific data.

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

(a) biodiversity as a measure of the health of a biological system over time

(b) how organisms (plants and animals) are adapted to their environment and how this allows them to compete for resources and mates; the use of data (numbers and distribution of organism, characteristics of organism) to investigate the success of an organism in an environment

(c) strategies that organisms use to avoid adverse environmental conditions, such as hibernation and migration

(d) classification of organisms (plants, animals, microorganisms) that have similar features in a logical way

(e) different groups of organisms being distinguished according to characteristic features; genetic sequencing as a tool to confirm and sometimes reclassify species; classifications not necessarily being demonstrated as external features and characteristics

(f) the use of scientific names (binomial system developed by Linnaeus) as opposed to ‘common’ names

(g) natural selection and its importance as a driving force for evolution; variation which occurs naturally; individuals with advantageous traits being more likely to be reproductively successful; genes of these individuals being passed on to future generations

SPECIFIED PRACTICAL WORK

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

2.1.3 TRANSFER AND RECYCLING OF NUTRIENTS

Overview

Transfer and recycling of nutrients is essential to keep ecosystems in balance. How do energy and nutrients pass through food chains? How can we show how energy/biomass pass through a food chain? How are nutrients recycled in nature? Learners will consider how ecosystems are in balance and how living organisms are dependent on their environment and each other for survival. They will also gain an appreciation of the impact that humans have on the Earth and the importance of sustainable developments for future generations. Learners can apply their knowledge in a number of fields including environmental monitoring, energy and biotechnology.

Working Scientifically

Transfer and recycling of nutrients enables learners to use models to solve problems, make predictions and develop scientific explanations and understanding of familiar and unfamiliar facts; evaluate economic and environmental implications, make decisions based on the evaluation of evidence and arguments and evaluate risks in a wider societal context. Consideration of the greenhouse effect allows learners to appreciate the power and limitations of science and consider any ethical issues which may arise, evaluate risks both in practical science and in the wider social context, including the perception of risk in relation to data and consequences.

Mathematical skills

Energy transfer through food chains enables learners to recognise and use expressions in decimal form; use ratios, fractions and percentages; make order of magnitude calculations. Consideration of adaptations allows learners to calculate areas of triangles and rectangles, surface areas and volumes of cubes. The study of biological pyramids enables learners to translate data between graphical and numeric form.

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

(a) food chains and food webs to show the transfer of useful energy between organisms; types of feeding (e.g. herbivore, carnivore); pyramids of numbers and biomass

(b) interdependency of organisms; plants that depend on invertebrates and other animals for pollination, seed dispersal, protection from grazers etc; animals that depend on plants either directly or indirectly for food, shelter etc; predation, disease and competition that cause large numbers of organisms to die; microorganisms that play an important role in the cycling of nutrients

(c) radiation from the Sun being the source of energy for most ecosystems/communities of living organisms; capture of a small percentage of the solar energy by green plants which reaches them in a process known as photosynthesis

(d) loss of energy at each stage in the food chain due to waste materials and as heat during respiration

(e) the carbon cycle (that carbon is recycled via photosynthesis, food chains, respiration and combustion); the role of bacteria and fungi in transferring carbon by feeding on waste materials from organisms and dead plants and animals, respiration and release of carbon dioxide into the atmosphere

(f) the effect of human activity (via burning fossil fuels, clearing forests) upon the levels of carbon dioxide in the atmosphere

(g) the greenhouse effect caused by the Earth absorbing and emitting electromagnetic radiation that is absorbed by some gases (e.g. methane and water vapour) in the atmosphere, so keeping it warmer than it would otherwise be

(h) the greenhouse effect as being important to stabilize conditions for life but an enhanced greenhouse effect may have significant impact on climate, ice sheets and sea levels and agriculture

(i) proposed solutions to global warming to reduce human impact on the climate (e.g. reducing dependence on fossil fuels via reducing energy consumption, using alternative non-carbon sources of energy, carbon capture)

(j) nutrients that are released during decay, e.g. nitrates, and that these nutrients are then taken up by other organisms resulting in nutrient cycles; that the processes which remove materials are balanced by processes which return materials in a stable community

(k) **that nitrogen is also recycled through the activity of soil bacteria and fungi acting as decomposers, converting proteins and urea into ammonia; ammonia is converted to nitrates which are taken up by plant roots and used to make new protein**

2.2 PROTECTING OUR ENVIRONMENT

Overview

The environment and biodiversity is changing due to human impact. How do our unwanted products affect the world around us? How can we live more sustainably? How can we treat our waste products to improve safety? What methods can be used to maintain biodiversity? Learners will consider how the way we live affects the world around us. They will also gain an appreciation of the importance of sustainable development for future generations. Learners can apply their knowledge in a number of fields including environmental monitoring, energy and biotechnology.

Working Scientifically

The issues surrounding pollution of the environment enable learners 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. Learners will also evaluate risks in both practical science and in the wider social context, including perception of risk in relation to data and consequences. In practical work, learners will plan experiments or devise procedures to make observations, 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. When analysing data they will present observations and other data using appropriate methods; carry out and represent mathematical analysis; communicate the scientific rationale for investigations, methods used, findings and reasoned conclusions through paper based and electronic reports and presentations using verbal, graphical, numeric and symbolic forms.

Mathematical skills

This topic enables learners to recognise and use expressions in decimal form; recognise expressions in standard form; use ratios, fractions and percentages; find arithmetic means; make order of magnitude calculations; translate information between graphical and numeric form.

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

(a) how heavy metals from industrial waste and mining enter the food chain; how pesticides can enter the food chain; how heavy metals and pesticides can accumulate in animal bodies and may reach a toxic level and so have harmful effects (bioaccumulation)

(b) the rapid growth of photosynthesisers, plants and algae, in water due to untreated sewage and fertilisers; death of plants and algae, and the microbes which break them down, increase in number and further use up the dissolved oxygen in the water; animals, including fish, which live in the water may suffocate

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

(d) destruction of habitat due to increased land use for building, quarrying, dumping and agriculture, so causing loss of species and a reduction in biodiversity

(e) some of the measures to ensure sustainability such as the impact of reduce, reuse, recycle schemes or the use of biodegradable materials in packaging; problems associated with unsustainable disposal of waste in landfill sites

(f) production of environmentally toxic substances by households (sewage and waste containing toxic substances such as batteries, used low energy light bulbs, old mobile phones); the impact of these waste products on the environment; how science helps manage the disposal of sewage (sewage treatment and the role of microbes in treating sewage)

(g) environmental monitoring using living (e.g. lichens to monitor air pollution, invertebrate animals as water pollution indicators) and non-living indicators (pH and oxygen levels in streams to monitor water pollution)

(h) the need for, and issues surrounding sustainable development; the problem of increased consumption of resources and their continued supply

(i) maintenance of biodiversity using captive breeding programmes, seed banks and protected areas

(j) issues surrounding the creation of nature reserves and the need for corridors between reserves to allow movement and prevent isolation between populations of species

(k) reclamation of land previously used for industry and landfill and its importance for sustainable development

SPECIFIED PRACTICAL WORK

- Investigation into how indicator species and changes in pH and oxygen levels may be used as signs of pollution

2.3 HEALTH, FITNESS AND SPORT

2.3.1 FACTORS AFFECTING HUMAN HEALTH

Overview

Human health is affected by a number of factors. Here you will look at how inheritance, lifestyle and the environment affect human health. What are genes and how do they affect the way that organisms develop? How should genetic information be used? How can we use our knowledge of genes to prevent disease? How do our lifestyle choices affect our health? How does where we live affect our health? How can data backup scientific theory? Learners can apply their knowledge in a number of fields including sport, nutrition and medicine.

Working Scientifically

This section enables learners to appreciate the power and limitations of science and consider any ethical issues which may arise; explain every day applications of science, evaluate associated personal, social, economic and environmental implications, and make decisions based on the evaluation of evidence and arguments; recognise the importance of peer review and results and of communicating results to a range of audiences. The specified practical work allows learners to plan experiments or devise procedures to make observations, 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, recognise when to apply a knowledge of sampling techniques to ensure any samples collected are representative, evaluate methods and suggest possible improvements and further investigations.

Mathematical skills

This section enables learners to recognise and use expressions in decimal form, use ratios, fractions and percentages, find arithmetic means, and translate information between graphical and numeric form. The study of inherited disease allows learners to understand simple probability. The calculation of BMI allows learners to **change the subject of an equation**, substitute numerical values into algebraic equations and solve them using appropriate units for physical quantities.

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

(a) chromosomes that contain DNA molecules which determine inherited characteristics and are found in pairs; genes as sections of DNA molecules that determine inherited characteristics and are found in pairs since chromosomes are normally found in pairs; different forms of genes called alleles that cause variation

(b) the structure of a DNA molecule as two strands coiled to form a double helix, joined by weak bonds between complementary base pairs, A bonds with T, C bonds with G (full names not required)

(c) Punnett squares to explain the outcomes of monohybrid crosses; the terms genotype, phenotype, recessive, dominant and allele; some changes in alleles that cause inherited diseases(e.g. Huntington's and Cystic Fibrosis); the implications of genetic screening and subsequent counselling, and the ethical problems posed by an individual’s prior knowledge of the probability of such a genetic disease

(d) new genes that result from changes (mutations) in existing genes; mutations that may be harmless, beneficial or harmful and may be passed on from parents to offspring

(e) chromosome abnormalities in humans e.g. Down's syndrome

(f) the short term and long term impact of excessive alcohol consumption on the body and society; addiction as a consequence of sustained alcohol consumption

(g) how to calculate daily energy requirements and the body mass index (BMI) using:

$$\text{BMI} = \frac{\text{mass}}{\text{height}^2}$$

(h) the limitations of BMI, particularly for children and athletes; the causes, social and economic impact, and long term harmful effects of anorexia and obesity

(i) the effects of smoking on the body and society

(j) how epidemiological studies inform our knowledge of the impact of lifestyle (e.g. smoking, alcohol consumption, diet) on health; why individual cases do not provide convincing evidence of, for or against, correlation; test design (sample sizes, how well samples match); the use of data to develop an argument that a factor does/does not increase the chance of an outcome

(k) the terms Guideline Daily Amount (GDA) and Recommended Daily Allowance (RDA) and their relevance to a controlled diet; the use of data to assess the energy requirement of individuals; the need for accurate information to be given on food labelling and be able to interpret food labels, including food traffic lights, use by dates, quantities and energy values of nutrients and other components of food, including salt and sugar

(l) the effect of insufficient salt intake (muscle cramps, dizziness, electrolyte disturbance) and the risks with excessive intake (high blood pressure, stroke)

(m) the adverse health risks associated with obesity, especially the effect of obesity on the cardiovascular system and the risks of diabetes; the implications of obesity to society (impact on NHS and resources)

(n) the role of insulin in glucose homeostasis; diabetes as a common disease in which a person has a high blood sugar (glucose) level; type 1 diabetes due to the body not producing enough insulin; type 2 diabetes due to the body cells not properly responding to the insulin that is produced

(o) how type 1 and type 2 diabetes can be controlled; diagnosis of diabetes by the presence of glucose in urine

(p) the effect of pollutants on human health, e.g. atmospheric pollutants linked with asthma, heavy metals)

SPECIFIED PRACTICAL WORK

- Investigation of the energy content of foods

2.3.2 DIAGNOSIS AND TREATMENT

Overview

Medical scientists develop methods to diagnose and treat disease. What techniques are used to image human tissue? How are these techniques used in diagnosis? What other methods are used to treat disease? How do drug companies make sure a new drug is as safe as possible? How can conditions such as cancer be treated? This topic looks at imaging methods to diagnose disease and progresses to study ways to treat disease. Learners can apply their learning in medical and fitness fields.

Working Scientifically

This section will enable learners to understand how scientific methods develop over time; 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; evaluate risks, including perception of risk in relation to data and consequences.

Mathematical skills

This topic allows learners to recognise and use expressions in decimal form; recognise expressions in standard form; use ratios, fractions and percentages; find arithmetic means; translate information between graphical and numeric form; construct and interpret tables and diagrams; make order of magnitude calculations.

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

(a) the role of the electromagnetic spectrum in diagnosis of disease and injury

(b) drug treatments that have positive effects and possible side effects on the patient as exemplified by aspirin as a common treatment of patients suffering cardiovascular disease (positive: reduces the risk of blood clots occurring and so the chances of a heart attack; negative: prolonged treatment with aspirin can cause bleeding in the patient's stomach and stomach ulcers)

(c) the stringent testing that new drugs undergo before they can be released for general use; animal testing and clinical trials; ethical decisions with differences of opinion on what is acceptable

(d) ionising radiation; radioactive emissions from radioisotopes (such as iodine-131) and short wavelength parts of the electromagnetic spectrum (ultraviolet, X-ray and gamma ray)

(e) formation of images by a gamma camera detecting gamma rays, used in diagnosing cancer; delivery of radioisotopes by drugs that carry the radioisotope to target organs in the body

(f) the differences between, alpha, beta and gamma radiation, to include that α and β are particles **(α a helium nucleus and β is a high velocity electron ejected from the nucleus of a decaying atom)** while γ radiation is electromagnetic radiation, their relative penetrating and ionising power

(g) the interaction between ionising radiation and atoms or molecules, damaging the DNA of cells; cancer cells being more susceptible to damage from ionising radiation and die or reproduce more slowly; some healthy cells being affected by the treatment

(h) radiotherapy using ionising radiation in the treatment of cancer; the difference between external radiotherapy which uses an external source of X-rays that are targeted at a tumour and internal radiotherapy which uses a radioisotope, such as iodine-131, taken as a drink or injected into a vein; radioisotopes used in internal radiotherapy that constantly emit ionising radiation but these emissions halve in a short period of time (e.g. the ionising radiation emissions from iodine-131 half every 8 days); the concept of half-life

(i) use of data to select the most suitable radioisotope for a medical purpose

(j) chemotherapy as a type of cancer treatment, in which medicine is used to kill cancer cells by damaging them, so they can't reproduce and spread and is often used in conjunction with radiotherapy

(k) medical imaging as a technique that uses electromagnetic radiation or sound waves to create images of the human body to reveal, diagnose or examine disease

(l) the use of ultrasound in the diagnosis of diseases and safe monitoring during pregnancy; the production of ultrasound images by sound bouncing off a boundary between two different structures of different density

(m) X-rays that are used in both X-ray examinations and CAT scanners; X-ray images as two-dimensional while those taken using a CAT scanner are three-dimensional; CAT scan images formed by processing together a large number of two-dimensional X-ray images taken around an axis; absorption of X-rays by denser objects in the human body (e.g. bones) but not by softer material

(n) MRI scans that use strong magnetic fields to form images of the body

(o) uses of X-rays, CAT scans, ultrasound and MRI

SPECIFIED PRACTICAL WORK

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

2.3.3 FIGHTING DISEASE

Overview

Treatment of infection and disease is extremely important, and as our life expectancy increases, new diseases will arise. Why do we catch some diseases but not others? Why are we encouraged to have vaccinations? Why should we always finish a course of antibiotics? How do our bodies resist infection? Learners can apply their knowledge to the health, medicinal and pharmaceutical industries.

Working Scientifically

In consideration of vaccination and antibiotic resistance, learners will understand how scientific theories develop over time. They can appreciate the power and limitations of science and consider any ethical issues which may arise. In considering whether to vaccinate or not, learners can evaluate risks in a wider social context, recognising the importance of peer review of results and of communicating results to a range of audiences. Practical work enables learners to carry out experiments appropriately with due regard to correct manipulation of apparatus; accuracy of measurement and health and safety considerations; present observations and other data using appropriate methods; be objective, evaluating data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic error; communicate 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.

Mathematical skills

This section allows learners to recognise and use expressions in decimal form; recognise expressions in standard form; use ratios, fractions and percentages; construct and interpret tables and diagrams; make order of magnitude calculations; find arithmetic means.

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

(a) microorganisms, to include some microorganisms that are harmless and perform vital functions, and some microorganisms, called pathogens, that cause diseases; the barrier against microorganisms formed by intact skin; defence of the body by: blood clots to seal wounds; white cells in the blood that ingest microorganisms and produce antibodies and antitoxins; competition of pathogens with the body's natural population of microorganisms

(b) protection of humans from infectious disease by vaccination; factors influencing parents in decisions about whether to have children vaccinated or not, including the need for sound scientific evidence and the effect of the media and public opinion

(c) antigens as molecules that are recognised by the immune system; antigen response by some white blood cells, lymphocytes, which secrete antibodies specific to the antigen; the function of antibodies

(d) vaccines that contain antigens (or parts of antigens) that are derived from disease-causing organisms; protection against infection by vaccines due to stimulating antibody production to protect against bacteria and viruses

(e) **memory cells that are produced following natural infection or vaccination that produce specific antibodies very quickly if the same antigen is encountered a second time**

(f) measles as a condition that most people suffer only once, but flu occurs many times in a lifetime

(g) antibiotics, including penicillin, that were originally medicines produced by living organisms, such as fungi; treatment of bacterial disease by antibiotics that kill the infecting bacteria or prevent their growth

(h) resistance resulting from overuse of antibiotics, such as MRSA; effective control measures for MRSA

SPECIFIED PRACTICAL WORK

- Investigation into the effect of antibiotics on bacterial growth

2.3.4 EXERCISE AND FITNESS IN HUMANS

Overview

It is widely recognised that a heathy lifestyle should involve an appreciable amount of exercise each day. How do our bodies control movement? How do bones and muscles carry out movement and what happens if these are damaged? How does the cardiovascular system allow delivery of substances needed by our body? What factors increase the risk of heart disease? What are the effects of exercise on heart rate and fitness? Learners can apply their learning in medical and fitness fields.

Working Scientifically

The consideration of exercise and fitness in humans allows learners to explain the 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. The specified practical work in this topic allows learners to use scientific theories to develop hypotheses, plan experiments to test hypotheses, check data and 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; evaluate methods and suggest possible improvements and further investigations.

Mathematical skills

This topic allows learners to recognise and use expressions in decimal form; use ratios, fractions and percentages; find arithmetic means; make order of magnitude calculations; translate information between graphical and numeric form; **change the subject of an equation;** substitute numerical values into algebraic equations and solve them using appropriate units for physical quantities; **understand the physical significance of area between a curve and the *x*-axis and measure it by counting squares as appropriate**.

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

(a) the need for energy to do work (muscle contraction)

(b) the role of the nervous system comprised of the central nervous system (the brain and spinal cord) and the peripheral nervous system in muscle contraction; nerve impulses as electrical signals carried by nerve cells, or neurones

(c) action of antagonistic muscles (e.g. biceps and triceps)

(d) a synovial joint and its parts (cartilage, ligaments, synovial fluid and synovial membrane)

(e) disease (limited to osteoarthritis) and injury (e.g. torn ligaments) that can result in limited movement of joints; replacement of badly damaged joints by artificial joints

(f) the different types of fractures of bones: simple, compound and green stick

(g) the locations of a fixed joint (skull), hinge joint (elbow, knee), and ball and socket joint (shoulder, hip)

(h) distance-time and velocity-time graphs to analyse movement (walking, running, cycling)

(i) mathematical equations to find useful information relating to movement:

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

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

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

(k) structure and function of the human cardiovascular system to include the heart, ventricles, valves, atria, veins, arteries, capillaries and double circulatory system (names of valves not required)

(l) how the structure of blood vessels is related to function (arteries have thick, muscular walls, veins have thinner walls and valves to prevent backflow of blood, capillaries are one cell thick to allow exchange of substances); composition of blood and functions of red blood cells (containing haemoglobin), white blood cells, plasma and platelets

(m) measurements to monitor pulse rate, breathing rate and recovery time

(n) physiological effects of exercise on breathing (short term effects: breathing rate increases to provide the oxygen and remove carbon dioxide. Long term effects: the body becomes more efficient at transporting oxygen)

(o) physiological effects of exercise on heart rate and recovery time (short term effects: heart rate increases, cardiac output increases. Long term effects: heart muscle strengthened, heart muscle becomes more efficient)

SPECIFIED PRACTICAL WORK

- Determination of the acceleration of a moving object

2.3 Unit 3

(Double Award) FOOD, MATERIALS and PROCESSES

Written examination: 1 hour 30 minutes
25% of qualification

This unit includes the following topics:

3.1 Materials for a purpose

3.2. Food for the future

3.2.1 Producing food
3.2.2 Food processing and spoilage

3.3 Scientific Detection

3.4 Controlling processes

3.4.1 Controlling chemical reactions
3.4.2 Controlling nuclear reactions

3.1 MATERIALS FOR A PURPOSE

Overview

Choosing the right materials can have a major effect on the success and performance of an object. Which material is best to build the frame for a road bike? What material should we use to build a tennis racket? Does it matter what material is used to make an artificial hip? How do I select a material to construct a safety helmet? This topic helps learners understand why a material is selected for a purpose. Learners should be able to make applications in a range of fields including sports equipment, safety equipment, cars, aircraft, medicine including artificial veins and joints.

This section should be delivered as far as possible in terms of the knowledge, understanding and skills that material scientists use to carry out their work.

Working Scientifically

The consideration of suitability of materials enables learners to explain the 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. The specified practical work in this section allows learners to plan experiments or devise procedures to make observations, produce or characterise a substance, test hypotheses, check data or explore phenomena; make and record observations and measurements using a range of apparatus and methods. Analysis of data allows learners to present observations and other data using appropriate methods; interpret observations and other data, including identifying patterns and trends, making inferences and drawing conclusions; being objective, evaluating data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic errors.

Mathematical skills

This topic allows learners to recognise and use expressions in decimal form; use ratios, fractions and percentages; find arithmetic means; make order of magnitude calculations; translate information between graphical and numeric form; **change the subject of an equation;** substitute numerical values into algebraic equations and solve them using appropriate units for physical quantities; plot two variables from experimental or other data.

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

(a) ionic bonding as strong electrostatic attraction between ions of opposite charge; **how the charge on an ion depends upon the position of an element in the periodic table (restricted to main group elements);** covalent bonding as the sharing of electrons between non-metal atoms to form molecules

(b) the properties of ionic compounds to include high melting points, solubility in water (many, but not all, are soluble in water), electric conduction when molten or in solution

(c) **metallic bonding as the strong attraction between closely packed positive metal ions and a 'sea' of delocalised electrons; how the characteristic properties of metals are related to metallic bonding;** the properties of metals to include awareness that there are important exceptions to the characteristic properties of metals (e.g. lead is a soft metal; mercury is a liquid at room temperature)

(d) the main classes of materials (metals and alloys, polymers, ceramics, composites) and examples of each class of material

(e) alloys, to include the definition of an alloy and differences in malleability, hardness and strength between alloys and pure metals

(f) allotropes of carbon to include the idea of giant molecules, the structure of **diamond**, graphite, graphene, carbon fibres, fullerenes and carbon nanotubes; how the properties of the giant molecules **diamond**, graphite and carbon nanotubes are related to bonding & structure; uses/potential uses of **diamond**, carbon fibre composites, graphite, graphene and carbon nanotubes *(Note: the principles underpinning the semiconducting properties of materials are beyond the scope of a GCSE course)*

(g) characteristic properties of polymers to include awareness that there are important exceptions to these characteristic properties (e.g. Kevlar® is relatively hard and strong); how the properties of polymers are related to bonding and structure to include reference to the extent of cross-linking between chains**,** strong covalent bonding within chains and the weak forces between chains

(h) how carbon fibre can be mixed with polymers to form a material which is an example of a composite material

(i) practical procedures to include planning to test the properties of a material and interpreting the significance of the data obtained. Properties are to include:
- stiffness/flexibility
- toughness/brittleness
- tensile (breaking) strength
- hardness
- density
- durability
- shock absorption
- thermal conductivity
- electrical conductivity

(j) mathematical equations to find useful information about the properties of materials:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

$$\text{stress} = \frac{\text{force}}{\text{cross-sectional area}}$$

Hooke's Law force = constant $\times$ extension

(k) how to assess the suitability of a material for a purpose to include using information on a material's properties (as described by the terms in 3.1(i), resistance to corrosion and biological inertness), cost, environmental impact and sustainability

(l) materials to explain why a combination of properties often makes a material suitable for a particular purpose; developments in materials to explain why materials used in sports equipment, clothing, car/aircraft parts, and surgery have changed over time

SPECIFIED PRACTICAL WORK

- Investigation of the thermal conductivity of metals

3.2 FOOD FOR THE FUTURE

3.2.1 PRODUCING FOOD

Overview

The production and processing of food requires a number of the scientific skills and techniques. How can we produce high quality food for the future? How can we maximise food output? Is there a cost to the environment as a result of changes in agricultural practises? Learners can apply their learning in food science and processing, nutrition and health.

Working Scientifically

The consideration of food production will allow learners to explain every day and technological applications of science; evaluate associated personal, social, economic and environmental implications; make decisions based on evaluation of evidence and arguments. In practical work they will use scientific theories and explanations to develop hypotheses; plan experiments to make observations, test hypotheses or explore phenomena; apply a knowledge of a range of techniques, instruments, apparatus, and materials to select those appropriate to the experiment; make and record observations and measurements using a range of apparatus and methods; evaluate methods and suggest possible improvements and further investigations. When reporting results they will present their observations using appropriate methods; interpret observations and other data, including identifying patterns and trends, making inferences and conclusions; present 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.

Mathematical skills

This topic allows learners to recognise and use expressions in decimal form; use fractions and percentages; find arithmetic means; construct and interpret tables and diagrams; plot two variables from experimental data; make order of magnitude calculations; translate information between graphical and numeric form.

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

(a) the materials required by plants to support life processes

(b) the general structure of a leaf

(c) photosynthesis, whereby green plants use chlorophyll to absorb light energy and convert carbon dioxide and water into glucose, producing oxygen as a by-product; the word equation for photosynthesis (details of the enzymes involved in photosynthesis are not required)

(d) the conditions required for photosynthesis and the factors which affect its rate, including temperature, carbon dioxide and light intensity; **the concept of limiting factors**

(e) the fate of the glucose produced in photosynthesis (glucose may be respired to provide energy, converted to starch or oils for storage or used to make cellulose and proteins which make up the body of plants)

(f) plant nutrient requirements and the effects of deficiencies on plant growth: lack of nitrates results in poor growth, deficiency of potassium results in yellowing of the leaf and deficiency of phosphate results in poor root growth; use of NPK fertilisers

(g) the differences (methods of production, yield, cost of production) between intensive and organic farming; the impact of pesticides and fertilisers on the environment; the differences of opinion on the ethics of these methods of food production

(h) food products being grown in controlled environments to increase productivity; **hydroponics as a method of growing where soil is replaced by a mineral solution pumped around the plant roots**

(i) artificial transfer of genes from one plant species to another to increase crop yield or improve product quality; potential disadvantages and issues involved

(j) selective breeding in plants; potential of plants to be selectively bred in order to produce desirable traits; disadvantages of selective breeding to include a reduction in variation and increased susceptibility to disease

SPECIFIED PRACTICAL WORK

- Investigation of the factors affecting photosynthesis

3.2.2 FOOD PROCESSING AND SPOILAGE

Overview

The food industry requires a number of the scientific skills and techniques. How can we ensure that food is processed so that it is safe and appealing to the consumer? How do we increase the shelf-life of foods? How do we make sure that food is safe without compromising taste? Learners can apply their learning in food science and processing, nutrition and health.

Working Scientifically

The consideration of food processing and spoilage enables learners to understand how scientific methods and theories develop over time; explain the 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

This topic allows learners to recognise and use expressions in decimal form; recognise expressions in standard form; use ratios, fractions and percentages; **use an appropriate number of significant figures**, find arithmetic means; construct and interpret tables and diagrams; make order of magnitude calculations; translate information between graphical and numeric form.

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

(a) bacteria, yeast, and other fungi in food production (bread, wine, beer, yoghurt and cheese)

(b) the different stages in the processing of yoghurt, cheese and beer and interpretation of information regarding these processes

(c) the optimum conditions for growth of bacteria (suitable temperature, moisture, food source) and the significance of this in food production

(d) pasteurisation as a process which slows microbial growth in foods including beer, milk and fruit juice

(e) pasteurisation of milk by heating sufficiently to kill some pathogens, and production of semi-skimmed and skimmed milk

(f) homogenisation of milk by pumping it at high pressure through narrow tubes, affecting the size of fat globules in milk, resulting in an emulsion

(g) food spoilage due to bacterial and fungal action, that may be accelerated by storage conditions

(h) ways in which the growth of bacteria is slowed down or stopped (refrigeration, freezing, heating, drying, salting, smoking, pickling (lowering pH))

(i) how food preparation areas are kept free of bacteria (personal hygiene, disinfectants, detergents, sterilisation, disposal of waste, control of pests e.g. insects, mice and rats)

(j) how cross contamination of food can be prevented

(k) food poisoning which is caused by the growth of microorganisms, usually bacteria, and by the toxins they produce when they grow (*Campylobacter sp., E.coli, Salmonella sp*.); the common symptoms for food poisoning (stomach pains, vomiting, diarrhoea)

(l) data on the growth of microorganisms (colony counts, turbidity)

(m) potential impact of the contamination of food products, with bacteria (e.g. by commercial food preparation outlets)

3.3 SCIENTIFIC DETECTION

Overview

Analytical scientists work in a wide range of different industries and agencies. How clean and free from pollution is the local river? How much flavouring is present in a particular brand of chewing gum? How can athletes be checked for the use of drugs that enhance performance? How is DNA evidence used to connect a suspect to a crime scene? These are all questions that are answered by analytical scientists.

This topic is designed to help learners understand the way in which an analytical scientist works so as to enable them to tackle problems and answer questions. Learners can apply their learning in forensics, water treatment, environmental and pharmaceutical industries.

Working Scientifically

Scientific detection enables learners to understand how scientific methods and theories develop over time; appreciate the power and limitations of science and consider any ethical issues which may arise; explain the 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. The specified practical work allows learners to 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 and carry out experiments appropriately having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.

Mathematical skills

This topic enables learners to recognise and use expressions in decimal form; recognise expressions in standard form; use ratios, fractions and percentages; find arithmetic means; make order of magnitude calculations.

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

(a) how samples are collected which are representative (e.g. water samples from streams/rivers, landfill sites or household water supplies)

(b) analytical techniques to classify a method as qualitative, semi-quantitative or quantitative

(c) **the mole to include the use of the mole to count particles, how to use relative atomic masses to calculate relative molecular mass, how to calculate the number of moles from mass and relative molecular mass**

(d) chromatographic methods to include the separation of species in a mixture, the calculation of R_f values, the use of R_f values / retention times (t_R) to identify components in a mixture, the dependence of the R_f/t_R upon the conditions of the analysis (temperature**,** nature of stationary phase and mobile phase**,** flow rate of mobile phase in instrumental analysis) and applications of each method**; the separation of molecules in chromatography in terms of the differences in the relative attraction of different molecules for a mobile and stationary phase** *(Chromatographic methods to include paper chromatography, TLC, HPLC, GLC)*

(e) colorimetry to find concentration of species (e.g. nitrate) using calibration curves (quantitatively) or by comparing to coloured test strips (e.g. nitrate, pH chlorine, lead) (semi-quantitatively) (see Table 3.3)

(f) DNA to include that it is found in the nucleus of all cells; that is unique to individuals (except for identical twins) which allows for 'genetic profiling'; genetic profiling for identification in criminal and paternity cases; DNA profiles to include comparing DNA profiles for matches (see Table 3.3)

(g) qualitative, quantitative and semi-qualitative analytical procedures to include: selecting an appropriate procedure for an analysis, displaying data (table, bar graph, line graph), processing data (by manipulating and rearranging equations, plotting and using calibration curves, interpreting qualitative data) and drawing valid conclusions (Table 3.3 details techniques)

(h) sources of error in terms of both random errors and systematic errors

SPECIFIED PRACTICAL WORK

- Titration of a strong acid against a strong base using an indicator
- Identification of unknown substances using paper chromatography
- Identification of unknown ionic compounds using flame tests and chemical tests for ions

Table 3.3 Analytical Techniques
The analytical techniques and their uses that learners need to be familiar with in this section are limited to those below.

Technique	***Use***	***Examples of Contexts***	***Calculation/ Interpretation***
Flame tests	Determine the presence of sodium, potassium, barium, calcium, copper.	Water analysis, environmental analysis and forensics.	Infer the presence of ions from the colour of a flame.
Test with aqueous sodium hydroxide	Provide information about the presence of Ca^{2+}, Cu^{2+},Fe^{2+}, Fe^{3+} and Pb^{2+}.	Water analysis, environmental analysis and forensics.	Use test results to draw conclusions about the possible ions present in a sample.
Further chemical tests	Test for carbon dioxide using limewater. Test for carbonates. Use of aqueous barium chloride to test for sulfates. Use of nitric acid followed by silver nitrate solution to test for chlorides.	Water analysis (e.g. testing stream water, water from mines and land fill sites) and forensics.	Use test results to draw conclusions about the ions present in a sample.
Acid-base titrations	Measure the concentration of an acid using simple acid-base titration.	Water analysis, food standards (e.g. concentration ethanoic acid in vinegar), quality assurance.	Calculate the mean titre. Substitute data into a given expression to calculate concentration (one step calculation).

Technique	***Use***	***Examples of Contexts***	***Calculation/ Interpretation***
Paper chromatography	Separate and identify components in a mixture (e.g. food dyes/lipstick).	Forensics (e.g. analysis of coloured substances at a crime scene). Food science (e.g. examine food colourings in food).	Identify components in a mixture by comparing the chromatogram to known compounds / comparing R_f values
Thin layer chromatography	Separate and identify components in a mixture	Forensics (e.g. analysis of coloured substances at a crime scene). Food science (e.g. examine food colourings in food) Environmental Science (e.g. the analysis of pollutants in the environment)	Identify components in a mixture by comparing R_f values
Gas chromatography	Separate and measure air pollutants. Drugs in hair samples.	Analysis of air quality. Forensic science. Monitoring of athletes for drug use.	Use a GLC trace from an analysis to identify an unknown substance using retention time. Recognise that it is possible for two different substances to have the same retention time.
High performance liquid chromatography	Drugs in blood/ hair samples.	Forensics. Monitoring athletes for drug use.	Use an HPLC trace from an analysis to identify an unknown substance using retention time. Recognise that it is possible for two different substances to have the same retention time.
Colorimetry (semi-quantitative and quantitative)	Concentrations of species in water / body fluids etc	Medical laboratories (e.g. haemoglobin levels, calcium concentration) Pollutants in water samples (e.g. nitrates)	Use colour strips to make measurement in a semi-quantitative analysis Plot and use a calibration curve from a colorimetric analysis
Genetic profiling	Identifying DNA.	Forensics/paternity cases/medical (inherited diseases).	Compare the information from a simple DNA profile to identify a match.

3.4 CONTROLLING PROCESSES

3.4.1 CONTROLLING CHEMICAL REACTIONS

Overview

The chemical industry provides many of the chemicals that people need for modern life. The chemical industry today is developing new processes for manufacturing these chemicals more efficiently and with less impact on the environment. How can we control a chemical process so that it remains safe and yet produce what we want in a reasonable time (and for a reasonable cost)? Why can some chemical reactions get faster if we do not take precautions to control what is happening? This unit explores how the rate of reaction depends upon the conditions of a chemical reaction. It also explores thermal runaway reactions and how these have contributed to a number of serious accidents. Learners can apply their learning in pharmaceutical and chemical fields.

Working Scientifically

Consideration of how chemical reactions are controlled allows learners to appreciate the power and limitations of science and consider any ethical issues which may arise; explain the 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 in practical science and in the wider societal context, including perception of risk in relation to data and consequences. Specified practical work allows learners to 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 most 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

This topic allows learners to recognise and use expressions in decimal form; recognise expressions in standard form; use ratios, fractions and percentages; find arithmetic means; make order of magnitude calculations; translate information between graphical and numeric form; plot two variables from experimental or other data; **determine the slope of a linear graph**; **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) how the energy stored in a chemical system changes when a reaction occurs resulting in an endothermic reaction (process causing the temperature of the surroundings to decrease) or exothermic reaction (process causing the temperature of surroundings to increase)

(b) how concentration / pressure, temperature, particle size and surface area affect the reaction rate in terms of collisions between molecules and activation energy

(c) how a catalyst changes the rate of a chemical change while remaining chemically unchanged itself in terms of the energy required for a collision to be successful

(d) how to carry out experiments to study how factors affect rate (e.g. using a light sensor and data logger to follow the precipitation of sulfur during the reaction between sodium thiosulfate and hydrochloric acid); data to draw conclusions, and critically evaluate the method of data collection, the quality of the data and to what extent the data supports the conclusion

(e) the economic and environmental importance of developing new and better catalysts, in terms of increasing yields, preserving raw materials, reducing energy costs etc.

(f) the need to control exothermic reactions which accelerate with an increase in temperature; the danger of thermal runaway in chemical reactions including the definition of a thermal runaway reaction and how thermal runaway reactions can occur; how thermal runaway contributed to disasters such as Texas City disaster (1947) and Bhopal disaster (1984)

SPECIFIED PRACTICAL WORK

- Investigation of the factors that affect the rate of a reaction

3.4.2 CONTROLLING NUCLEAR REACTIONS

Overview

Nuclear reactions are used to generate electricity. What happens in a nuclear reaction? How is it different to a chemical reaction? How is a nuclear reaction controlled in a nuclear reactor? Why have nuclear accidents happened? What have been the consequences of nuclear accidents? How does the risk of using nuclear power compare to other forms of power generation? This topic looks at how we can control a nuclear reaction so that we can generate electricity. It also examines why a small number of accidents have happened and compares the relative risk of generating electricity using nuclear power with other forms of electricity generation. Learners can apply their learning in the fields of electricity generation and health and safety.

Working Scientifically

The control of nuclear reactions enables learners to consider how scientific methods and theories develop over time; appreciate the power and limitations of science and consider any ethical issues which may arise; explain the 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.

Mathematical skills

This topic enables learners to recognise and use expressions in decimal form, use ratios, fractions and percentages and make order of magnitude calculations.

How Science Works

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

(a) nuclear fission to include how a uranium nucleus is split by being hit with a neutron releasing energy and neutrons, and the difference of nuclear fusion which occurs in stars and involves two nuclei joining to form a larger nucleus and energy; nuclear symbols of the form $^{A}_{Z}\mathrm{X}$ in the context of nuclear fission and nuclear fusion, and use data to produce and balance nuclear equations

(b) calculations involving the activity and half-life of radioactive materials

(c) how the uncontrolled decay of uranium starts a chain reaction including the idea of an explosion as a chain reaction out of control

(d) how a nuclear reactor is constructed including fuel rods, moderator, control rods, coolant and concrete shields

(e) how nuclear reactors are kept safe to include using control rods placed in the reactor to control the number of available neutrons and the circulation of coolant to prevent the temperature of the reactor becoming too high

(f) how a failure in following safety protocols and control mechanisms has led to a small number of nuclear accidents (e.g. Three Mile Island, Chernobyl, Fukushima)

(g) the consequences of a nuclear accident to the environment and human health; the relative risks of different methods of power generation to health and the environment (e.g. coal, oil, nuclear)

2.4 Unit 4

(Double Award) TASK BASED ASSESSMENT

20% of qualification

This is a tiered, activity-based assessment which will be externally marked by WJEC. It will take place in the second half of the autumn term (i.e. November - December). It is recommended that this should be in the final year of study.

Learners will acquire the skills needed to carry out practical procedures in the laboratory, industry and commercial work place. They will learn how to develop skills that enable them to:

- Devise and carry out scientific investigations
- Analyse scientific data
- Manage Health and Safety

These skills will be developed in the following topics:

- Energy and life
- Modern living and energy
- Obtaining resources from our planet
- Our planet
- Protecting our environment
- Health, fitness and sport
- Materials for a purpose
- Food for the future
- Scientific detection
- Controlling processes

The content of sections 3.2.1 (producing food) and 3.4.2 (controlling nuclear reactions) will not be assessed in this unit.

Each year, WJEC will offer centres a choice of two packs. Each pack will contain three activities. Learners will be required to submit **one complete pack** so centres can select which pack they wish to use with their learners.

The packs will change on an annual basis.

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

The assessment consists of **three** activities:

ACTIVITY 1 - Carrying out a practical investigation in an applied scientific context (35 marks)

Learners will formulate a plan, analyse and evaluate data, under a high level of control. Learners must work individually and no teacher feedback or assistance is allowed. When obtaining results, learners will be permitted to work in groups of no more than three, under a limited level of control (provided their plans are sufficiently similar). Teacher assistance should not normally be required, but may be given if equipment failure occurs. Activity 1 will be completed in three sessions of 60 minutes duration.

When learners carry out an investigation they will develop the skills that enable them to:

- devise methods to solve problems
    - plan a method to solve a problem/ answer a question
    - write standard procedures
- carry out standard procedures
- collect primary data
- process primary and secondary data
- analyse and interpret primary and secondary data
- draw evidence-based conclusions
- assess the validity and quality of evidence
- evaluate methods used to solve practical problems.

ACTIVITY 2 - **Analysis of data in an applied scientific context (15 marks)**

This will be carried out under a high level of control and will be completed in one session of 60 minutes duration. Learners must work invididually and no teacher feedback or assistance is allowed.

Learners will analyse data which will allow them to develop the skills that enable them to:

- use mathematical methods to analyse data
- draw evidence-based conclusions
- assess the quality of evidence given
- evaluate methods
- suggest improvements

ACTIVITY 3 - Risk assessment (10 marks)

This will be carried out under a high level of control and will be completed in one session of 60 minutes duration. Learners must work invididually and no teacher feedback or assistance is allowed.

Learners will assess risks associated with the collection of numerical and other data and manage risks when using practical techniques, carrying out standard procedures and solving practical problems. They will develop the skills to enable them to:

- use chemical 'safety sheets' to identify chemical hazards
- identify the risks that arise from carrying out procedures
- suggest control measures to reduce risk
- carry out risk assessments
- follow health and safety procedures to manage risk.

2.5 Unit 5

(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 Applied Science (Double Award). 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	9%	9%	4.5%
Unit 2	9%	9%	4.5 %
Unit 3	10%	10%	5%
Unit 4	8%	8%	4%
Unit 5	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 - 3;
- the task based assessment (Unit 4).

Writing accurately takes into account the candidate's use of specialist language. It also takes into account the candidate's spelling, punctuation and grammar.

3.2 Arrangements for non-examination assessment

Please see section 2.4.

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 and Unit 2 will be available in 2017 (and each year thereafter). Unit 3, Unit 4 and Unit 5 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 5 (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.

Candidates may resit an individual unit once only. The better uniform mark score from the two attempts will be used in calculating the final overall grade subject to the **terminal rule** being satisfied first i.e. that candidates must complete a minimum amount of the assessment for a qualification in the series in which they are cashing in. The terminal rule is set at 40% of the overall qualification for GCSE Applied Science (Double Award). If the assessment being re-taken contributes to the 40% terminal rule requirement, the mark for the new assessment will count.

If any unit has been attempted twice and a candidate wishes to enter the unit for the third time, the candidate will have to re-enter all units and the appropriate cash-in(s). This is referred to as a 'fresh start'. When retaking a qualification (fresh start), a candidate may have up to two attempts at each unit. However, no results from units taken prior to the fresh start can be used in aggregating the new grade(s).

Marks for Practical Assessment (NEA) may be carried forward for the life of the specification.

If a candidate has been entered for but is absent for a unit, the absence does not count as an attempt. The candidate would, however, qualify as a resit candidate.

The entry codes appear below.

	Title	**Entry codes**	
		English-medium	**Welsh-medium**
Unit 1	Energy, Resources and the Environment (Foundation Tier)	3445U1	3445N1
	Energy, Resources and the Environment (Higher Tier)	3445UA	3445NA
Unit 2	Space, Health and Life (Foundation Tier)	3445U2	3445N2
	Space, Health and Life (Higher Tier)	3445UB	3445NB
Unit 3	Food, Materials and Processes (Foundation Tier)	3445U3	3445N3
	Food, Materials and Processes (Higher Tier)	3445UC	3445NC
Unit 4	Task Based Assessment (Foundation Tier)	3445U4	3445N4
	Task Based Assessment (Higher Tier)	3445UD	3445ND
Unit 5	Practical Assessment	3445U5	3445N5
GCSE Qualification cash-in		3445QD	3445CD

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**
Unit 1	180	162	144	126	108	90	72	54	36
Unit 2	180	162	144	126	108	90	72	54	36
Unit 3	200	180	160	140	120	100	80	60	40
Unit 4	160	144	128	112	96	80	64	48	32
Unit 5	80	72	64	56	48	40	32	24	16

For Units 1 - 4, which are tiered, the maximum uniform mark available on the foundation tier of the assessment will be 1 mark less than the minimum mark needed to achieve a grade B on the unit (e.g. for Unit 1 it will be 125). As Unit 5 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.

	Skill
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
	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*
	Calculate areas of triangles and rectangles, surface areas and volumes of cubes