GCSE

eduqas
Part of WJEC

WJEC Eduqas GCSE in

COMBINED SCIENCE

ACCREDITED BY OFQUAL

SPECIFICATION

Teaching from 2016
For award from 2018

wjec cbac

This Ofqual regulated qualification is not available for candidates in maintained schools and colleges in Wales.

WJEC Eduqas GCSE (9-1) in COMBINED SCIENCE

For teaching from 2016
For award from 2018

GCSE COMBINED SCIENCE

SUMMARY OF ASSESSMENT

Component 1: Concepts in Biology
Written examination: 1 hour 45 minutes
25% of qualification

A mix of short answer questions, structured questions, extended writing and data response questions, with some set in a practical context

Component 2: Concepts in Chemistry
Written examination: 1 hour 45 minutes
25% of qualification

A mix of short answer questions, structured questions, extended writing and data response questions, with some set in a practical context

Component 3: Concepts in Physics
Written examination: 1 hour 45 minutes
25% of qualification

A mix of short answer questions, structured questions, extended writing and data response questions, with some set in a practical context

Component 4: Applications in Science
Written examination: 1 hour 45 minutes
25% of qualification

Section A (FT) / Section B (HT):
A mix of short answer questions, structured questions, extended writing and data response questions, all set in a practical context which will contain elements of content from Components 1-3

Section B (FT) / Section A (HT):
A resource booklet containing an unseen article with elements of content from Components 1-3 will provide the basis for a mix of short answer questions, structured questions and data response questions

This linear qualification will be available in May/June each year. It will be awarded for the first time in summer 2018.

Learners entered for this qualification must sit all four components at either foundation or higher tier, in the same examination series.

Qualification Accreditation Number: 601/8765/7

GCSE COMBINED SCIENCE

1 INTRODUCTION

1.1 Aims and objectives

The WJEC Eduqas GCSE in Combined Science provides a broad, coherent, satisfying and worthwhile course of study. It encourages learners to develop confidence in, and a positive attitude towards, science and to recognise its importance in their own lives and to society.

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

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

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

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

1.2 Prior learning and progression

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

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

1.3 Equality and fair access

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

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

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

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

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

2 SUBJECT CONTENT

This section outlines the knowledge, understanding and skills to be developed by learners studying GCSE Combined Science.

Learners should be prepared to apply the knowledge, understanding and skills specified in a range of theoretical, practical, industrial and environmental contexts.

Learners' understanding of the connections between the different elements of the subject and their holistic understanding of the subject is a requirement of all GCSE specifications. In practice, this means that learners will be required to draw together different areas of knowledge, skills and understanding from across the full course of study.

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 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 skills listed in Appendix A. Appendix B lists the practical technique requirements with exemplification in the context of GCSE Combined Science.

Appendix C lists the mathematical skills that will be assessed across the Combined Science GCSE. For the foundation tier, the mathematics will be assessed at levels not lower than expected at KS3. For the higher tier, the mathematics will be assessed at levels not lower than that for foundation tier GCSE Mathematics. Appendix D provides information on the mathematical equations required for use when the Physics sections of the subject content are taught and assessed (i.e. in Components 3 and 4).

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

- develop scientific knowledge and conceptual understanding through the specific disciplines of biology, chemistry and physics
- develop understanding of 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
- develop and learn to apply observational, practical, modelling, enquiry and problem-solving skills, both in the laboratory, in the field and in other learning environments
- develop their ability to evaluate claims based on science through critical analysis of the methodology, evidence and conclusions, both qualitatively and quantitatively.

The specification content is organised in topics. Each topic contains the following:

- An **overview** which sums up the content of each topic.
- **Working scientifically** - this section summarises how ‘working scientifically’ may be developed in the topic. The ‘working scientifically’ section forms part of the assessable content. All of the 'working scientifically' skills listed in Appendix A are referred to at least once in one of these sections.
- **Maths skills** - a summary of mathematical skills that should be developed in each topic. The mathematical statements in this section are part of the assessable content. All of the 'mathematical skills' in Appendix B are referred to at least once in one of these sections.
- **Content statements** - ‘Learner’s should be able to …’ These statements clarify the breadth and depth of the content for each topic. In some cases these statements may be grouped into subtopics.
- **Specified practical work** - this section 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 skills listed in Appendix A. Appendix B lists the practical technique requirements with exemplification in the context of GCSE Combined Science. Practical work forms part of the assessable content.

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

2.1 Component 1

CONCEPTS IN BIOLOGY

Written examination: 1 hour 45 minutes
25% of qualification
90 marks

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

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

TOPICS

1. Cell biology

1.1 Prokaryotic and eukaryotic cells
1.2 Growth and development of cells
1.3 Cell metabolism

2. Transport systems

2.1 Transport in cells
2.2 Transport systems in humans
2.3 Transport systems in plants

3. Health, disease and the development of medicine

3.1 Health and disease
3.2 Communicable disease
3.3 Treating, curing and preventing disease
3.4 Non-communicable diseases in humans

4. Coordination and control

4.1 Nervous coordination and control in humans
4.2 Hormonal coordination and control in humans
4.3 Homeostasis in humans

5. Photosynthesis

6. Ecosystems

6.1 Levels of organisation within an ecosystem
6.2 The principle of material cycling
6.3 Biodiversity

7. Inheritance, variation and evolution

7.1 The genome and gene expression
7.2 Inheritance
7.3 Variation and evolution
7.4 Selective breeding and gene technology

1. CELL BIOLOGY

Overview

The fundamental units of living organisms are cells, which may be part of highly adapted structures including tissues, organs and organ systems, enabling living processes to be performed effectively. Organic compounds are used as fuels in respiration within these cells to allow the other chemical reactions necessary for life. This topic explores the structure and function of cells, how they divide and some metabolic processes that occur within them.

Working scientifically

This topic contains opportunities for learners to understand how scientific methods and theories develop over time by considering the understanding of cell structure in relation to the development of the microscope. It gives learners the opportunity to make and record observations when examining plant and animal cells. It presents the opportunity for learners to carry out experiments appropriately having due regard to the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations when investigating factors affecting enzyme action and in the quantitative identification of biological molecules. Learners should also explain the technological applications of science in the application of stem cell technology and consider the ethical issues which may arise from this.

Mathematical skills

There are a number of opportunities for the development of mathematical skills within this topic. In the microscope work in the content on cell structure, an understanding of number, size and scale and the quantitative relationship between units can be developed. When completing the practical work on enzymes, learners should develop the use of estimations and explain when they should be used. They should also be able to carry out rate calculations for chemical reactions. **Higher tier learners should also be able to calculate with numbers written in standard form.**

1.1 PROKARYOTIC AND EUKARYOTIC CELLS

Learners should be able to:

(a) draw and label animal and plant cells

(b) describe the differences between eukaryotic and prokaryotic cells

(c) explain how the following sub-cellular structures of eukaryotic cells (plants and animals) and prokaryotic cells (bacteria) are related to their functions: nucleus/DNA, plasmids, mitochondria, chloroplasts, cell membranes, cytoplasm, vacuole, cell wall

(d) explain how the development of the microscope (light, electron, laser imaging) increased the understanding of the sub cellular structure of organisms and the proposal that the cell is the basic unit of life

SPECIFIED PRACTICAL WORK

- BSP1.1 Examination of plant and animal cells using a light microscope and production of labelled scientific drawings from observation

1.2 GROWTH AND DEVELOPMENT OF CELLS

Learners should be able to:

(a) describe the process of mitosis in growth, including the cell cycle. Cell division by mitosis enables organisms to grow, replace worm out cells and repair damaged tissues

(b) explain the importance of cell differentiation to produce specialised cells for greater efficiency

(c) describe cancer as the result of changes in cells that lead to uncontrolled growth and division

(d) describe the function of stem cells in embryonic and adult animals and meristems in plants. There are some cells, both plant and animal, that do not lose the ability to differentiate and these are called stem cells

(e) discuss the potential benefits, risks and ethical issues surrounding stem cell technology in medicine including the implications for society e.g. the use of embryonic stem cells

(f) explain the role of meiotic cell division in halving the chromosome number to form gametes; each meiotic division produces four cells that are genetically different because genes separate and are reshuffled during the process of gamete formation

1.3 CELL METABOLISM

Learners should be able to:

(a) explain that chemical reactions in cells are controlled by enzymes. Enzymes are proteins made by living cells. Different proteins are composed of different amino acids linked together to form a chain which is then folded to form a specific shape held by chemical bonds. The specific shape of an enzymes active site enables it to function. This is called the 'lock and key' hypothesis. Enzymes function by the formation of the enzyme-substrate complex at the active site

(b) explain that enzymes speed up/catalyse the rate of chemical reactions. Each enzyme has its own optimum pH and temperature. Interpret enzyme activity in terms of molecular collisions. Boiling denatures most enzymes by altering their shape

(c) describe cellular respiration as an exothermic reaction which is continuously occurring in all living cells, enabling cells to carry out cell processes. Aerobic respiration occurs in cells when oxygen is available. It is a series of chemical reactions within the cell, controlled by enzymes. Glucose and oxygen are used and carbon dioxide, water and energy are produced. The energy released is in the form of ATP. Recall the word equation for aerobic respiration

(d) explain that in the absence of oxygen, anaerobic respiration may occur. This is less efficient than aerobic respiration. In humans energy is released from glucose and lactic acid is produced. An oxygen debt may occur. In yeast, glucose is broken down and ethanol and carbon dioxide are produced. Recall the word equation for anaerobic respiration in human cells and fermentation in yeast. Explain that there is less ATP released per molecule of glucose in anaerobic respiration than in aerobic respiration because of the incomplete breakdown of glucose

(e) compare the processes of aerobic and anaerobic respiration

(f) explain that fats, made up of fatty acids and glycerol, proteins, made up of amino acids, and starch (a carbohydrate), made up of a chain of glucose molecules, in our food are insoluble. They are broken down during digestion into soluble substances so that they can be absorbed

(g) explain the importance of the digested products of fats, carbohydrates and proteins. Fatty acids and glycerol from the breakdown of lipids and glucose from the breakdown of carbohydrate are needed for respiration. Amino acids from digested proteins are needed to synthesise proteins in the body

SPECIFIED PRACTICAL WORK

- BSP1.3A Investigation into factors affecting enzyme action
- BSP1.3B Qualitative identification of starch (iodine), glucose (Benedict's) and protein (biuret)

2. TRANSPORT SYSTEMS

Overview

This topic covers the different mechanisms by which organisms transport substances into and out of cells. This is then developed further into a more detailed consideration of the structure and function of the transport system in humans and plants.

Working scientifically

The use of Visking tubing in this topic provides an opportunity for learners to use a model to develop scientific explanations. The investigation into the effect of solute concentration on osmosis gives learners the opportunity to plan experiments in order to make observations, to interpret observations, identify patterns and trends and draw conclusions. This investigation can develop learners' skills in the evaluation of the method used and can lead to the suggestion of possible improvements and further investigations. This also provides good opportunities to develop learners' analytical skills by evaluating data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic error. The microscope work used in the observation of blood vessels can develop the use of scientific terminology and the idea of order of magnitude.

Mathematical skills

There are a number of opportunities for the development of mathematical skills within this topic. The calculation of surface area:volume ratios in the understanding of the need for a gas exchange surface in multicellular organisms can develop the use of ratios. Learners should be encouraged to carry out rate calculations and use simple compound measures such as rate in the transpiration investigation. The effect of solute concentration on osmosis will enable learners to plot, draw and interpret appropriate graphs and to use percentiles and calculate percentage gain and loss of mass.

2.1 TRANSPORT IN CELLS

Learners should be able to:

(a) explain that diffusion is a passive process and that only certain substances pass through the cell membrane in this way

(b) explain that diffusion is the movement of substances down a concentration gradient including the use of Visking tubing as a model of living material. Explain the role of the cell membrane in diffusion

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

(d) explain that active transport allows substances to enter cells against a concentration gradient and requires energy

(e) explain the need for exchange surfaces and a transport system in multicellular organisms in terms of surface area:volume ratio

(f) describe how oxygen, carbon dioxide, water, dissolved food molecules, mineral ions and urea maybe transported into and out of humans, green plants and single celled organisms

SPECIFIED PRACTICAL WORK

- BSP2.1 Investigation into the effect of solute concentration on osmosis in potato chips

2.2 TRANSPORT SYSTEMS IN HUMANS

Learners should be able to:

(a) describe the human circulatory system as a double circulatory system. The blood passes through the heart twice in every complete circulation. The right side of the heart pumps the blood to the lungs and the left hand side pumps it around the rest of the body

(b) label on a given diagram of the heart: the left and right atria and ventricles, semi-lunar, bicuspid and tricuspid valves, pulmonary artery, pulmonary vein, aorta and vena cava

(c) explain how the structure of the heart is adapted to its function

(d) describe the passage of blood through the heart including explaining the functions of the valves in preventing backflow of blood

(e) describe and be able to compare the structure of arteries and veins

(f) explain how arteries and veins are adapted to their functions

(g) describe that in the organs blood flows through very small blood vessels called capillaries which allow exchange of substances. Explain that the thin walls of the capillaries are an advantage for diffusion and that capillaries form extensive networks so that every cell is near to a capillary carrying blood

(h) describe the functions of the four main parts of the blood: plasma (transport of water, nutrients, hormones, urea, antibodies), red cells (carry oxygen), white cells (defence) and platelets (clotting). Explain how red blood cells, white blood cells, platelets and plasma are adapted to their functions in the blood

SPECIFIED PRACTICAL WORK

- BSP2.2 Examination of artery and vein using a light microscope and production of labelled scientific drawings of these from observation

2.3 TRANSPORT SYSTEMS IN PLANTS

Learners should be able to:

(a) explain that xylem tissue contains tubes of dead cells called xylem vessels and explain how the vessels are adapted to their role in the transport of water and minerals from the roots upwards within plants

(b) explain how phloem is adapted to carry sugar from the photosynthetic areas to other parts of the plant. Sugar is moved to other parts of the plant for use in respiration and converted into starch for storage. This is called translocation

(c) explain the significance of root hairs in increasing the area for absorption, the role of osmosis in the uptake and movement of water through a plant and how mineral salts are taken up by root hairs by active transport

(d) describe the structure of a leaf and be able to label the following structures on a diagram of a T.S. leaf: cuticle, epidermis, stomata, palisade layer, spongy layer, xylem and phloem

(e) describe the structure of stomata to include guard cells and stoma and how stomata can open and close to regulate transpiration

(f) describe the process of transpiration resulting in the movement of water through a plant

(g) explain the environmental factors that can affect transpiration, including light intensity, air movement and temperature and that this can be investigated with the use of a simple potometer

3. HEALTH, DISEASE AND THE DEVELOPMENT OF MEDICINE

Overview

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

Working scientifically

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

Mathematical skills

There are a number of opportunities for the development of mathematical skills from data which is available on the content of this topic. This could include the translation of information between graphical and numerical forms, the construction and interpretation of frequency tables and diagrams, bar charts and histograms, the use of a scatter diagram to identify a correlation between two variables. When considering health data, learners should understand the principles of sampling. In the work on antibiotics learners should be able to calculate the cross-sectional areas of bacterial cultures and clear agar jelly using πr^2.

3.1 HEALTH AND DISEASE

Learners should be able to:

(a) describe the relationship between health and disease

(b) describe diseases as being communicable and non-communicable diseases as exemplified by influenza and cardiovascular disease

(c) describe the interactions between different types of disease, as exemplified by the increased risk of developing skin cancer when HIV positive and the increased risk of cardiovascular disease in diabetes patients

3.2 COMMUNICABLE DISEASE

Learners should be able to:

(a) explain the means by which communicable diseases caused by viruses, bacteria, protists and fungi can be spread in animals and plants. This should include by contact, aerosol, body fluids, water, insects, contaminated food

(b) describe the following diseases, this should include the causative agent, the effect on the infected organism and how they can be prevented from spreading
- HIV/ AIDS
- Chlamydia
- Ash die back
- Malaria

(c) describe the non-specific defence systems of the human body against pathogens, including intact skin forming a barrier against microorganisms and blood clots sealing wounds to seal the skin

(d) explain the role of the immune system of the human body in defence against disease. This should include the roles of lymphocytes in secreting antibodies and antitoxins and phagocytes which ingest and digest micro-organisms. Explain the process by which antigens from micro-organisms trigger lymphocytes to release antigen specific antibodies and that antibodies activate phagocytes

3.3 TREATING, CURING AND PREVENTING DISEASE

Learners should be able to:

(a) explain that a vaccine contains antigens derived from a disease-causing organism. A vaccine will protect against infection by that organism by stimulating the white blood cells to produce antibodies to that antigen. Vaccines may be produced which protect against bacteria and viruses

(b) discuss the 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. Understand that science can only provide a statistically based 'balance of probability' answer to such issues

(c) explain that antibiotics, including penicillin, were originally medicines produced by living organisms, such as fungi. Explain that antibiotics help to cure bacterial disease by killing the infecting bacteria or preventing their growth

(d) explain that antibiotics may kill some bacteria but not viruses. Some resistant bacteria, such as MRSA, can result from the over use of antibiotics. Explain effective control measures for MRSA

(e) explain and understand the safe use of basic aseptic techniques involved in inoculating, plating and incubating microorganisms

(f) describe the process of discovery and development of potential new medicines, including preclinical and clinical testing. New drug treatments may have side effects and extensive, large scale, rigorous testing is required including risk management. Preclinical stages involve testing on human cells grown in the laboratory, then on animals and finally a group of healthy volunteers. The new medicines are then taken for clinical testing using small groups of patients

3.4 NON-COMMUNICABLE DISEASES IN HUMANS

Learners should be able to:

(a) recall that many non-communicable human diseases, including cardiovascular disease, lung cancer, skin cancer, emphysema, type 2 diabetes and cirrhosis can be caused by the interaction of a number of life style factors

(b) explain the effect of the following lifestyle factors on the incidence of non-communicable diseases at local, national and global levels: exercise, diet, alcohol, smoking and exposure to UV radiation

(c) evaluate the advantages and disadvantages of the following treatments for cardiovascular disease

- statins
- angioplasty
- changes to lifestyle diet/exercise

4. COORDINATION AND CONTROL

Overview

This topic comprises coordination and control in humans. Within the content of the nervous system in humans, reflex actions are covered. The hormonal coordination and control in humans section contains an overview of the location of the main glands and a description of the functions of adrenalin and thyroxine. There is also detail of the function and interaction of the reproductive hormones. Homeostasis with regard to blood sugar in humans is also covered.

Working scientifically

The use of hormones in modern reproductive technology will give opportunities for explanations of technological applications of science and an evaluation of the associated personal and social implications. There is also opportunity to evaluate risk. The investigation into reaction time will allow the development of investigative skills in the cycle of collecting, presenting and analysing data.

Mathematical skills

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

4.1 NERVOUS COORDINATION AND CONTROL IN HUMANS

Learners should be able to:

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

(b) describe the structure of the nervous system, including the brain, spinal cord, sensory neurones, motor neurones and sensory receptors and the central nervous system consisting of the brain and spinal cord

(c) explain how the structure of the nervous system (including CNS, sensory and motor neurones and sensory receptors) is adapted to its functions

(d) describe the properties of reflex actions. These reactions are fast and automatic and some are protective, as exemplified by the withdrawal reflex, blinking and pupil size

(e) explain how the structure of a reflex arc is related to its function and be able to label a diagram to show: receptor, sensory neurone, relay neurone in spinal cord, motor neurone, effector and synapses

SPECIFIED PRACTICAL WORK

- BSP4.1 Investigation into factors affecting reaction times

4.2 HORMONAL COORDINATION AND CONTROL IN HUMANS

Learners should be able to:

(a) describe and be able to label the positions of the following glands on a diagram of the human body: pituitary, adrenal, thyroid, pancreas, ovaries and testes

(b) describe hormones as chemical messengers, produced by glands and carried by the blood, which control many body functions

(c) describe the principles of negative feedback mechanisms in maintaining optimum conditions inside the body

(d) explain the role of thyroxine in the body as an example of negative feedback. Description should be limited to effects of TRH and TSH in the release of thyroxine

(e) explain the role of adrenaline in the body. Description should be limited to the effects of adrenaline on the heart, breathing and muscles. Adrenaline is converted into a less active compound by the liver

(f) describe the roles of hormones in human reproduction, including the menstrual cycle

(g) explain the interactions of FSH, LH, oestrogen and progesterone in the control of the menstrual cycle

(h) explain the use of hormones in contraception and evaluate hormonal and non-hormonal methods of contraception

(i) explain the use of hormones in modern reproductive technologies to treat infertility

4.3 HOMEOSTASIS IN HUMANS

Learners should be able to:

(a) explain the importance to animals of maintaining a constant internal environment in response to internal and external change

(b) explain why and how glucose levels need to be kept within a constant range. When the blood glucose level rises, the pancreas releases the hormone insulin, a protein, into the blood. This causes the liver to reduce the glucose level by converting glucose to insoluble glycogen and then storing it

(c) explain how glucagon interacts with insulin to control blood sugar levels in the body

(d) compare type 1 and type 2 diabetes and explain how they can be treated. Diabetes is a common disease in which a person has a high blood sugar (glucose) level. In Type 1 diabetes this is because the body does not produce enough insulin. In Type 2 diabetes the body cells do not properly respond to the insulin that is produced

5. PHOTOSYNTHESIS

Overview

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

Working scientifically

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

Mathematical skills

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

Learners should be able to:

(a) describe the process of photosynthesis and describe photosynthesis as an endothermic reaction, whereby green plants and other photosynthetic organisms use chlorophyll and light to convert carbon dioxide and water into glucose, producing oxygen as a by-product. Recall the word equation for photosynthesis

(b) explain the effect of temperature, light intensity and carbon dioxide concentration on the rate of photosynthesis

(c) explain the interaction of these factors in limiting the rate of photosynthesis

SPECIFIED PRACTICAL WORK

- BSP5 Investigation into factors affecting the rate of photosynthesis

6. ECOSYSTEMS

Overview

Living organisms may form populations of single species, communities of many species and ecosystems, interacting with each other, with the environment and with humans in many different ways. The chemicals within these ecosystems are continually cycling through the natural world. This topic comprises coverage of the levels of organisation within an ecosystem, the principles of material cycling and biodiversity. Opportunities are given to look in detail at the factors affecting communities. The carbon cycle and water cycle are covered in material cycling, along with how human activity affects them. Learners need to acquire an understanding of the importance of biodiversity and how it can be measured.

Working scientifically

The topics discussing the benefits and challenges of maintaining local and global biodiversity will allow learners to develop skills in evaluating social, economic and environmental applications based on the evaluation of evidence and arguments. There are also a number of opportunities to develop skills in analysis and evaluation within the investigation into the abundance and distribution of a species. These would include: presentation of data, translating data from one form to another; carrying out and representing mathematical and statistical analysis; representing distributions of results and making estimations of uncertainty and communicating the methods used, findings and conclusions through written or electronic reports. Learners should also be able to apply sampling techniques within the fieldwork to any ensure any samples collected are representative.

Mathematical skills

There are a number of opportunities for the development of mathematical skills within the investigations in this topic. These would include the calculation of rate changes in the decay of biological material, the calculation of the percentage of mass, the calculation of arithmetic means, being able to use percentages and fractions, plotting and drawing appropriate graphs and selecting appropriate scales for the axes and extracting and interpreting information from charts, graphs and tables.

6.1 LEVELS OF ORGANISATION WITHIN AN ECOSYSTEM

Learners should be able to:

(a) describe different levels of organisation in an ecosystem from individual organisms through populations and communities to the whole ecosystem

(b) explain how some abiotic factors affect communities as exemplified by pH, light, temperature and salinity

(c) explain how some biotic factors affect communities as exemplified by predation, disease and food availability

(d) describe the importance of interdependence and competition in a community

(e) describe photosynthetic organisms as the main producers of food and therefore biomass for life on Earth. Green plants, and other photosynthetic organisms such as algae use the light from the sun to produce organic materials

(f) describe the differences between the trophic levels of organisms within an ecosystem including producers; first, second and third stage consumers; herbivores and carnivores

(g) investigate data about food chains and food webs and explain that they show the transfer of biomass between organisms

6.2 THE PRINCIPLE OF MATERIAL CYCLING

Learners should be able to:

(a) recall that many different materials cycle through the abiotic and biotic components of an ecosystem. Nutrients are released in decay, e.g. nitrates and phosphates and these nutrients are then taken up by other organisms resulting in nutrient cycles. In a stable community the processes which remove materials are balanced by processes which return materials

(b) explain why it is important that carbon is constantly cycled in nature by the carbon cycle via photosynthesis which incorporates it and respiration which releases it

(c) explain that microorganisms, bacteria and fungi, feed on waste materials from organisms and that when plants and animals die their bodies are broken down by microorganisms bringing about decay. These micro-organisms respire and release carbon dioxide into the atmosphere. Burning fossil fuels releases carbon dioxide

(d) explain the importance the water cycle to living organisms

6.3 BIODIVERSITY

Learners should be able to:

(a) describe how to use quadrats to investigate the abundance of species e.g. a comparison of different sides of a hedge or mown and unmown grassland

(b) describe how transects can be used to measure changes in the abundance and distribution of species e.g. seashore

(c) describe the principles of sampling, the need to collect sufficient data and use of appropriate statistical analysis. (Details of statistical tests are not required.) Describe the principles of capture/recapture techniques including simple calculations on estimated population size

(d) explain what is meant by biodiversity, the variety and number of different species in an area, and why it is important. Explain that indicator species are an important set of organisms whose numbers and changing population can tell us a lot about the changing state of ecosystems

(e) describe both positive and negative human interactions within ecosystems and explain their impact on biodiversity

(f) describe the ways in which biodiversity and endangered species can be protected locally and globally, including issues surrounding the use of legislation. Explain the need for and issues associated with the collection of reliable data and ongoing environmental monitoring

(g) explain the use of biological control agents and the introduction of alien species and their effects on local wildlife. Explain the issues surrounding the use of biological control agents and how the approach to using this method of control has changed as requirements for detailed research and scientifically based trials and analysis are now more fully understood

(h) explain some of the benefits and challenges of maintaining local and global biodiversity

SPECIFIED PRACTICAL WORK

- BSP6.3 Investigation into factors affecting the abundance and distribution of a species

7. INHERITANCE, VARIATION AND EVOLUTION

Overview

The characteristics of a living organism are influenced by its genome and its interaction with the environment. Living organisms are interdependent and show adaptations to their environment. These adaptations are a result of evolution. Evolution occurs by a process of natural selection and accounts both for biodiversity and how organisms are all related to varying degrees. Coverage of the genome and gene expression requires that learners understand how DNA controls protein synthesis within the cell and so contributes, along with environmental factors towards the characteristics that an organism shows. The understanding of the genome has vast implications for the medicine of the future. The topic of inheritance covers an understanding of how characteristics are passed on, along with an understanding of how that knowledge has been developed. Learners will acquire an understanding of evolution and how it has resulted in the biodiversity seen on Earth.

Working scientifically

The discussion of the potential for the human genome gives opportunities to explain the technological applications of science and also to evaluate the risks and ethics of such information being more widely available. The study of the work of Charles Darwin and Alfred Wallace allows learners to understand how scientific theories develop over time and also the importance of peer review and communicating results. The study of the development of classification systems also contributes towards this.

Mathematical skills

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

7.1 THE GENOME AND GENE EXPRESSION

Learners should be able to:

(a) describe chromosomes as linear arrangements of genes . Chromosomes that are found in pairs in body cells are strands of DNA

(b) describe DNA as a polymer made up of two strands forming a double helix

(c) describe how an organism's DNA can be analysed by 'genetic profiling' and how this can be used to show the similarity between two DNA samples. The process involves cutting the DNA into short pieces which are then separated into bands. The pattern of the bands produced can be compared to show the similarity between two DNA samples

(d) describe the genome as the entire genetic material of an organism

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

SPECIFIED PRACTICAL WORK

- BSP7.1 Simple extraction of DNA from living material

7.2 INHERITANCE

Learners should be able to:

(a) explain the following terms: gamete, chromosome, gene, allele/variant, dominant, recessive, homozygous, heterozygous, genotype phenotype

(b) describe genes as sections of DNA molecules that determine inherited characteristics and that are in pairs. Genes have different forms, called alleles

(c) explain single gene inheritance and be able to complete Punnett squares to show this

(d) predict the outcomes of monohybrid crosses including ratios

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

(f) describe sex determination in humans. In human body cells, one of the pairs of chromosomes, XX or XY, carries the genes which determine sex. These separate and combine randomly at fertilisation

7.3 VARIATION AND EVOLUTION

Learners should be able to:

(a) describe simply how the genome, and its interaction with the environment, influence the development of the phenotype of an organism. Variation may be due to environmental or genetic causes or a combination of the two

(b) state that there is usually extensive genetic variation within a population of a species

(c) recall that all variants result from changes, mutations, in existing genes and that mutations occur at random. Most mutations have no effect on the phenotype but some influence phenotype and very few determine phenotype. Mutation rates can be increased by ionising radiation

(d) describe evolution as a change in the inherited characteristics of a population over time through a process of natural selection which may result in the formation of new species. Genes which enable better adapted individuals to survive are passed on to the next generation. This may results in new species being formed. The process of natural selection is sometimes too slow for organisms to adapt to new environmental conditions and so organisms may become extinct

(e) explain how individuals with characteristics adapted to their environment are more likely to survive and breed successfully. This results in evolution

(f) describe that evolution is ongoing as shown by the development of resistance to antimicrobial chemicals by bacteria or Warfarin resistance in rats and that evolution can also be evidenced by fossils

(g) describe the impact of developments in biology on classification systems; biological classification systems continue to be modified in the light of ongoing research. Recently, the three Domain system (based on differences in RNA) proposes two Domains of prokaryotes and one further Domain containing four main eukaryote kingdoms – Protists, Fungi, Plants and Animals

7.4 SELECTIVE BREEDING AND GENE TECHNOLOGY

Learners should be able to:

(a) explain the impact of the selective breeding of food plants and domesticated animals

(b) describe genetic engineering as a process which involves modifying the genome of an organism to introduce desirable characteristics

(c) describe the main steps in the process of genetic engineering

(d) explain some of the possible benefits and risks, including practical and ethical considerations, of using gene technology in modern agriculture and medicine

2.2 Component 2

CONCEPTS IN CHEMISTRY

Written examination: 1 hour 45 minutes
25% of qualification
90 marks

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

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

TOPICS

1. **Pure substances and mixtures**

2. **Particles and atomic structure**

3. **Chemical formulae, equations and amount of substance**

4. **The Periodic Table and properties of elements**

5. **Bonding, structure and properties**

6. **Reactivity series and extraction of metals**

7. **Chemistry of acids**

8. **Energy changes in chemistry**

9. **Rate of chemical change and dynamic equilibrium**

10. **Carbon compounds**

11. **Life cycle assessment and recycling**

12. **The Earth and its atmosphere**

1. PURE SUBSTANCES AND MIXTURES

Overview

This topic develops the concepts and terminology used in the classification of substances and explores how characteristic properties of different substances are exploited in laboratory methods used for their separation. The topic content provides opportunities for learners to use knowledge of the properties of substances to describe appropriate methods of separating the components of a mixture and of characterizing them. The usefulness of some commercially important mixtures is explored and exemplified.

Working scientifically

This topic offers opportunities for learners to develop their laboratory skills by selecting and manipulating a range of apparatus, having due regard for health and safety requirements, in order to separate, purify and characterize the substances in a mixture. It offers scope for learners to develop observational skills, of both a qualitative and quantitative nature, to record measurements systematically and to present them graphically. The topic also offers scope for learners to interpret and draw conclusions from the data they obtain.

Mathematical skills

In this topic, learners may use graphical methods (for example, cooling curves) to present and interpret the results of systematic measurements made in the laboratory. Physical properties are quantified and used as a means of identifying substances. For example, R_f values are calculated using the concept of ratio and are used to characterize substances that are separated by chromatography.

Learners should be able to:

(a) explain what is meant by the purity of a substance, distinguishing between the scientific and everyday use of the term 'pure'

(b) use melting point data to distinguish pure from impure substances

(c) explain the differences between elements, compounds and mixtures

(d) explain that many useful materials are formulations of mixtures, e.g. food and drink products, medicines, sunscreens, perfumes and paints

(e) describe, explain and exemplify the processes of filtration, crystallisation, simple distillation and fractional distillation

(f) recall that chromatography involves a stationary and a mobile phase and that separation depends on the distribution between the phases

(g) interpret chromatograms, including measuring R_f values

(h) suggest chromatographic methods for distinguishing pure from impure substances

(i) suggest suitable purification techniques given information about the substances involved

SPECIFIED PRACTICAL WORK

- CSP1.1 Separation of liquids by distillation, e.g. ethanol from water, and by paper chromatography

2. PARTICLES AND ATOMIC STRUCTURE

Overview

The particulate model of matter is developed and used to help learners understand physical phenomena such as change of state. Differences between physical and chemical changes are emphasized. Subatomic structure is introduced in terms of the nuclear atom, contrasting the size of the atom and its nucleus. The properties of the principal subatomic particles are characterized. The differences between atoms of different elements are explored in terms of their subatomic structure and a link is made between electronic structure (in atoms of the first twenty elements) and the arrangement of elements in the Periodic Table. The concept of isotopes is introduced and their relationship to the relative atomic mass of an element is considered, leading to a further look at the criteria used to order the elements in the Periodic Table.

Working scientifically

This topic offers opportunities to show how scientific ideas change over time in response to new knowledge gathered in the laboratory, as exemplified by theories about the structure of the atom and by the attempts of Mendeleev and others to use atomic weights to order the elements in the Periodic Table.

Mathematical skills

Learners will use appropriate units, prefixes and powers of ten to quantify orders of magnitude, for example, when comparing the size of objects in the physical world and the size of particles and also when comparing the size of an atom and its nucleus. Tables of melting and boiling point data will be used to predict the state of a substance under given conditions.

Learners should be able to:

(a) recall and explain the main features of the particle model in terms of the states of matter and changes of state, distinguishing between physical and chemical changes

(b) use data to predict states of substances under given conditions

(c) explain the limitations of the particle model in relation to changes of state when particles are represented by inelastic spheres

(d) describe how the particle model does not explain why atoms of some elements react with one another

(e) recall that experimental observations suggest that atoms are mostly empty space with almost all the mass in a central nucleus

(f) describe the atom as a positively charged nucleus surrounded by negatively charged electrons, with the nuclear radius much smaller than that of the atomic radius

(g) recall that the nucleus includes protons and neutrons (except in the case of ^{1}H)

(h) recall that atoms and small molecules are typically around 10^{-10} m or 0.1 nm in diameter

(i) recall the relative charges and approximate relative masses of protons, neutrons and electrons

(j) explain why atoms as a whole have no electrical charge

(k) calculate numbers of protons, neutrons and electrons in atoms and ions, given atomic number and mass number of isotopes

(l) describe the electronic structure of the first 20 elements

(m) explain how the position of an element in the Periodic Table is related to the arrangement of electrons in its atoms and hence to its atomic number

(n) describe what is meant by isotopes and an element's relative atomic mass

(o) explain that the arrangement proposed by Mendeleev was based on 'atomic weights'; in some cases the order was not quite correct because different isotopes have different masses

3. CHEMICAL FORMULAE, EQUATIONS AND AMOUNT OF SUBSTANCE

Overview

This topic develops the learners' use of symbols in writing the formulae of chemical compounds and balanced symbol equations. A link is made between the formation of simple ions and the positions in the Periodic Table of the elements from which they are derived. Ionic symbols are then used in predicting the formulae of ionic compounds and in writing ionic equations. Quantitative chemistry is introduced using the concept of relative atomic mass and by carrying out simple calculations of relative formula mass. The relation between this and amount of substance is explored and leads to calculations of stoichiometry and of reacting masses.

Working scientifically

Learners should recognise in this topic the importance of quantitative relationships when describing or investigating substances that are involved in chemical change. They should use scientific terminology and definitions accurately, interconvert units as necessary and use an appropriate number of significant figures in calculations.

Mathematical skills

Learners will balance equations, use ratio and carry out percentage and multistep calculations, e.g. when determining empirical formulae and performing calculations involving the mole. They will perform calculations with numbers written in standard form when using the Avogadro constant, change the subject of a formula and provide answers to an appropriate number of significant figures. They will convert units where appropriate, e.g. from mass to number of moles.

Learners should be able to:

(a) use chemical symbols to write the formulae of elements and simple covalent and ionic compounds

(b) deduce the empirical formula of a compound from the relative numbers of atoms present or from a model or a diagram and vice versa

(c) recall and use the law of conservation of mass

(d) use the names and symbols of common elements and compounds and the law of conservation of mass to write formulae and balanced chemical equations **and half equations**

(e) deduce the charge on ions of elements in groups 1, 2, 3, 6 and 7

(f) use the formulae of common ions to deduce the formula of a compound **and write balanced ionic equations**

(g) describe the physical states of products and reactants using state symbols (s, l, g and aq)

(h) calculate relative formula mass of species separately and in balanced chemical equations

(i) use a balanced equation to calculate masses of reactants or products

(j) calculate the empirical formula of a compound from reacting mass data

(k) deduce the stoichiometry of an equation from the masses of reactants and products and explain the effect of a limiting quantity of a reactant

(l) recall and use the definitions of the Avogadro constant (in standard form) and of the mole

(m) explain how the mass of a given substance is related to the amount of that substance in moles and vice versa

4. THE PERIODIC TABLE AND PROPERTIES OF ELEMENTS

Overview

The physical and chemical properties of elements of Groups 0, 1 and 7 of the Periodic Table are investigated in this topic. Reactivity trends within groups 1 and 7 are deduced and are explained in terms of the electronic structures of the elements. The Periodic Table is used throughout to classify elements and their positions within the Table are used to predict properties.

Working scientifically

This topic gives learners scope to make and record qualitative observations from simple chemical reactions, including those used to test for gases. They use their knowledge and understanding of trends within the Periodic Table to predict the properties of unfamiliar elements.

Mathematical skills

Learners will extract and interpret information from charts, graphs and tables, for example in predicting properties of elements from trends within groups.

Learners should be able to:

(a) explain how the reactions of elements are related to the arrangement of electrons in their atoms and hence to their atomic number

(b) recall the trends in melting point/boiling point of elements in Groups 1, 7 and 0

(c) recall the reactions of Group 1 elements with Group 7 elements, with oxygen and with water

(d) recall the reactions of Group 7 elements with Group 1 elements and with iron, and the displacement reactions of halogens

(e) recall that Group 0 elements are completely unreactive

(f) explain the reactivities (or otherwise) of these elements in terms of their electronic structures and the desire to attain/retain a full outer electron shell

(g) explain the trend in reactivities of elements on descending Group 1 and Group 7

(h) predict properties from trends within groups

(i) predict possible reactions and probable reactivity of elements from their positions in the Periodic Table

(j) describe tests to identify hydrogen, oxygen and chlorine gases

(k) describe metals and non-metals and explain the differences between them on the basis of their characteristic physical and chemical properties

(l) explain how the atomic structure of metals and non-metals relates to their position in the Periodic Table

5. BONDING, STRUCTURE AND PROPERTIES

Overview

This topic presents and later refines simple models of bonding in ionic and covalent substances. It introduces structural chemistry by describing examples of both simple and giant structures containing these bond types. Metallic bonding and structure is also introduced, as well as the concept of intermolecular forces. This leads to a consideration of how the properties of a substance are related to both its bonding and its structure. The allotropes of carbon, including fullerenes, are studied, with particular reference to links between their structures, properties and uses.

Working scientifically

This topic develops the terminology that learners need to describe the particulate nature of a wide range of substances. It offers scope for learners to interpret macroscopic properties in terms of models describing bonding and microstructure.

Mathematical skills

There are opportunities in this topic to relate size and scale of atoms to objects in the physical world. Information is translated between diagrammatic and numerical forms and learners are required to visualize three-dimensional shapes presented in two dimensions and vice versa, for example when studying the structures of carbon allotropes.

Learners should be able to:

(a) describe and compare the nature and arrangement of chemical bonds in ionic compounds, simple molecules, giant covalent structures, polymers and metals

(b) explain ionic bonding in terms of electrostatic forces and the transfer of electrons

(c) construct dot and cross diagrams to show ionic bonding in simple ionic substances

(d) explain the physical properties of ionic compounds in terms of their lattice structure

(e) explain covalent bonding in terms of the sharing of electrons

(f) construct dot and cross diagrams to show covalent bonding in simple molecules

(g) explain the physical properties of simple covalent substances in terms of intermolecular bonding

(h) explain metallic bonding in terms of electrostatic forces between the ‘sea’ of electrons/lattice of positive ions

(i) explain the physical properties of metals in terms of the above model

(j) describe the limitations of the different representations and models of bonding, including dot and cross diagrams, ball and stick models and two and three dimensional representations

(k) recall that carbon atoms can form four covalent bonds

(l) explain that the huge number of natural and synthetic organic compounds we use today occur due to the ability of carbon to form families of similar compounds, chains and rings

(m) explain the properties of diamond, graphite, fullerenes and graphene in terms of their structure and bonding

(n) use ideas about energy transfers and the relative strength of chemical bonds and intermolecular forces to explain the different temperatures at which changes of state occur

(o) recognise that individual atoms do not have the same properties as bulk materials as demonstrated by the different properties of diamond, graphite, fullerenes and graphene, which all contain carbon atoms only, and by nano-scale silver particles exhibiting properties not seen in bulk silver

(p) recall the multiplying factors milli- (10^{-3}), micro- (10^{-6}) and nano- (10^{-9})

6. REACTIVITY SERIES AND EXTRACTION OF METALS

Overview

Displacement reactions are used to establish a reactivity series of metals. Such reactions are characterized as redox and appropriate definitions of reduction and oxidation are introduced. The relationship between the position of a metal in the reactivity series and the method used to extract it from its ore is considered, using the industrial production of iron and of aluminium as examples. Further examples of electrolysis involving electrolytes in their molten and aqueous states are used to deepen understanding of the electrode processes involved. The link between the properties and uses of metals is considered.

Working scientifically

This topic offers scope for learners to appreciate the relevance of chemistry to the industrial production of everyday metals and to evaluate the economic and environmental implications of industrial scale chemical processes. The use of symbol equations is extended to include the redox processes that take place at the electrodes during electrolysis.

Mathematical skills

Learners will balance symbol equations (including ionic equations) that represent a range of redox processes.

Learners should be able to:

(a) explain how the reactivity of metals with water or dilute acids is related to the tendency of the metal to form its positive ion

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

(c) deduce an order of reactivity of metals based on experimental results

(d) explain that the method used to extract a metal from its ore is linked to its position within the reactivity series in relation to carbon

(e) explain reduction and oxidation in terms of loss or gain of oxygen, identifying which species are oxidised and which are reduced e.g. during thermit reaction and in the blast furnace

(f) explain reduction and oxidation in terms of gain or loss of electrons, identifying which species are oxidised and which are reduced e.g. during displacement reactions and electrolysis

(g) explain the principles of extraction of iron from iron ore in the blast furnace, including reduction by carbon monoxide and the acid/base reaction that forms slag

(h) describe electrolysis of molten ionic compounds, e.g. lead(II) bromide, in terms of the ions present and reactions at the electrodes

(i) recall that metals (or hydrogen) are formed at the cathode and non-metals are formed at the anode in electrolysis using inert electrodes

(j) predict the products of electrolysis of binary ionic compounds in the molten state

(k) explain why and how electrolysis is used to extract reactive metals from their ores

(l) explain the principles of extraction of aluminium from aluminium ore (bauxite), including the use of cryolite

(m) evaluate the methods of bacterial metal extraction and phytoextraction

(n) describe electrolysis of water in terms of the ions present and reactions at the electrodes

(o) describe competing reactions in the electrolysis of aqueous solutions, e.g. copper(II) chloride, sodium chloride and sulfuric acid, in terms of the different species present

(p) recall the properties of aluminium, copper, iron and titanium

(q) explain how the properties of metals are related to their uses and select appropriate metals given details of the usage required

SPECIFIED PRACTICAL WORK

- CSP6A Determination of relative reactivities of metals through displacement reactions
- CSP6B Investigation into electrolysis of aqueous solutions and electroplating

7. CHEMISTRY OF ACIDS

Overview

This topic offers opportunities for learners to investigate qualitatively the reaction of acids with metals, bases and carbonates and then to use these reactions in the preparation of soluble salts. Acids are defined in terms of their ability to donate hydrogen ions in water and the pH scale is introduced as a quantitative measure of acidity. **Higher tier learners acquire further understanding of pH as a logarithmic scale**. The titration method is introduced when preparing soluble salts from alkalis. The concentration of a solute in a solution is defined and expressed in units of mol/dm^3.

Working scientifically

Preparative and titration work in this topic provides opportunities to select and manipulate a range of apparatus and to handle chemicals, having due regard to health and safety requirements. Learners make and repeat measurements and show awareness of their accuracy. This topic also affords learners the opportunity to plan experiments or devise procedures to make observations, produce or characterise a substance, and check data. There are also opportunities for drawing inferences and making reasoned judgements from the results of chemical testing.

Mathematical skills

Learners will interchange amounts of substance in terms of mass and number of moles in expressing solution concentrations.

Learners should be able to:

(a) recall that acids react with some metals and with bases (including alkalis) and carbonates

(b) write equations predicting products from given reactants

(c) describe a test to identify carbon dioxide gas

(d) describe a test to identify carbonate ions using dilute acid

(e) recall that acids form hydrogen ions when they dissolve in water and solutions of alkalis contain hydroxide ions

(f) recall that acidity and alkalinity are measured by pH and how to measure pH using pH indicator chart and digitally

(g) describe neutralisation as acid reacting with base to form a salt plus water (or with carbonate to form a salt plus water and carbon dioxide

(h) prepare crystals of soluble salts from insoluble bases and carbonates

(i) use a titration method to prepare crystals of soluble salts and to determine relative concentrations of strong acids and strong alkalis

(j) recognise that aqueous neutralisation reactions can be generalised to hydrogen ions reacting with hydroxide ions to form water

$H^+ + OH^- \rightarrow H_2O$

(k) use and explain the terms dilute and concentrated (amount of substance) and weak and strong (degree of ionisation) in relation to acids

(l) describe the observed differences between reactions of strong acids and weak acids

(m) recall that as hydrogen ion concentration increases by a factor of ten the pH value of a solution decreases by one

(n) describe neutrality and relative acidity and alkalinity in terms of the effect of the concentration of hydrogen ions on the numerical value of pH (whole numbers only)

(o) explain how the mass/number of moles of a solute and the volume of the solution is related to the concentration of the solution

SPECIFIED PRACTICAL WORK

- CSP7A Preparation of crystals of a soluble salt from an insoluble base or carbonate

- CSP7B Titration of a strong acid against a strong base using an indicator

8. ENERGY CHANGES IN CHEMISTRY

Overview

By exploring some simple examples of exothermic and endothermic reactions, learners are introduced to the study of the energy changes that accompany chemical reactions. The energy profiles of reactions are presented and the concept of activation energy is developed. Bond energies are introduced and used to calculate the energy change during a chemical reaction.

Working scientifically

This topic gives learners scope to explore the everyday and technological applications of chemistry as evidenced, for example, by the burning of fuels.

Mathematical skills

Learners will carry out the arithmetical operations involved in calculations of energy change of reaction, selecting and using appropriate data. They will represent the energy change of a reaction graphically by means of an energy profile and interpret its main features.

Learners should be able to:

(a) distinguish between endothermic and exothermic reactions on the basis of the temperature change of the surroundings

(b) draw and label a reaction profile for an exothermic and an endothermic reaction, identifying activation energy

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

(d) calculate energy changes in a chemical reaction by considering bond making and bond breaking energies

SPECIFIED PRACTICAL WORK

- CSP8 Determination of the amount of energy released by a fuel

9. RATE OF CHEMICAL CHANGE AND DYNAMIC EQUILIBRIUM

Overview

Learners consider the factors that affect the rate of a chemical reaction and use a range of appropriate laboratory methods to investigate the relationship between reaction rate and the identified key variables. They process the results of their investigations appropriately and explain observed patterns in terms of particle collisions. The effect upon reaction rate of catalysts, including enzymes, is also considered and explained in terms of the lower activation energy of the catalyzed reaction. Examples of reversible chemical reactions are introduced and the main characteristics of a dynamic equilibrium are identified. Learners may also make reasoned predictions of the effect of changing conditions of temperature and pressure upon the equilibrium state.

Working scientifically

Learners have wide scope in this topic to develop experimental skills and strategies. They will plan and investigate the effect upon reaction rate of changing a key variable while holding others constant, select and use necessary apparatus, and make a series of measurements using a range of appropriate methods. They analyse their results, identifying patterns and trends, and present reasoned explanations.

Mathematical skills

Learners will construct a graph to show the relationship between two variables (e.g. reaction time and a key variable) and thus convert numeric data into a graphical form. They will use the gradient of a curve on a graph as a measure of the rate of reaction. They deduce and interpret the relationship, shown graphically or otherwise, between two variables (e.g. reaction rate and a key variable).

Learners should be able to:

(a) suggest practical methods for determining the rate of a given reaction – from gas collection, loss of mass and precipitation (including using data-logging apparatus)

(b) explain any observed changes in mass in non-enclosed systems during a chemical reaction using the particle model

(c) interpret rate of reaction graphs

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

(e) explain the effects on rates of reaction of changes in temperature and concentration (pressure) in terms of frequency and energy of collision between particles

(f) explain the effects on rates of reaction of changes in the size of the pieces of a reacting solid in terms of surface area to volume ratio

(g) describe the characteristics of catalysts and their effect on rates of reaction

(h) identify catalysts in reactions

(i) explain catalytic action in terms of activation energy

(j) recall that enzymes act as catalysts in biological systems

(k) recall that some reactions may be reversed by altering reaction conditions

(l) recall that dynamic equilibrium occurs when the rates of forward and reverse reactions are equal

(m) predict the effect of changing reaction conditions (concentration, temperature and pressure) on equilibrium position and suggest appropriate conditions to produce a particular product

SPECIFIED PRACTICAL WORK

- CSP9A Investigation into the effect of one factor on the rate of a reaction using a gas collection method

- CSP9B Investigation into the effect of one factor on the rate of the reaction between dilute hydrochloric acid and sodium thiosulfate

- CSP9C Investigation into the effect of various catalysts on the decomposition of hydrogen peroxide

10. CARBON COMPOUNDS

Overview

The importance of crude oil as a source of hydrocarbon fuels and its separation by fractional distillation is explained. Cracking reactions are described as a means of obtaining valuable feedstock for the petrochemical industry.

Working scientifically

This topic gives learners scope to explore the everyday and technological applications of chemistry as evidenced in the oil and petrochemical industries. They evaluate the social, economic and environmental implications of the use of fossil fuels as an energy source.

Learners should be able to:

(a) recall that crude oil is a main source of hydrocarbons and is a feedstock for the petrochemical industry

(b) describe and explain the separation of crude oil by fractional distillation

(c) describe the fractions as largely a mixture of compounds of general formula C_nH_{2n+2} which are members of the alkane homologous series

(d) describe the production of materials that are more useful by cracking

(e) explain how modern life is crucially dependent upon hydrocarbons and recognise that crude oil is a finite resource

11. LIFE CYCLE ASSESSMENT AND RECYCLING

Overview

Learners study the impact of manufactured materials on the environment. Life cycle analyses enable them to compare the properties and method of manufacture of a range of materials suitable for a particular use (including their ability to degrade and be recycled) and then to select an appropriate material with due regard for its impact on the environment.

Working scientifically

This topic offers opportunities for learners to evaluate the environmental impact of manufactured products. It gives scope to practise decision making based on the evaluation of technical data and evidence.

Learners should be able to:

(a) describe the basic principles in carrying out a life cycle assessment of a material or product

(b) interpret data from a life-cycle assessment of a material or product

(c) describe a process where a material or product is recycled for a different use, and explain why this is viable

(d) evaluate factors that affect decisions on recycling

12. THE EARTH AND ITS ATMOSPHERE

Overview

The origin of the Earth's atmosphere and changes in its composition over geological time are introduced in this topic. Sources of present day atmospheric pollution are considered, with particular reference to the origins and global effects of greenhouse gases. Evidence for the effects on climate of greenhouse gas emissions is evaluated. Methods of mitigation of these emissions and the likely societal and economic impacts of such measures are also considered. The sources of other gaseous air pollutants and particulates are explained as well as their harmful effects. Learners also study and evaluate methods of increasing the global availability of potable water supplies.

Working scientifically

This topic offers opportunities for learners to understand that scientific evidence and understanding have a key role to play in the mitigation of the social, environmental and economic impacts of air and water pollution. It gives learners further scope to develop decision making skills based on the evaluation of a wide range of scientific and technical evidence relating to the impact of air pollution and climate change. Learners should also recognise the importance of peer review in validating scientific work. This topic also gives the opportunity to communicate results and information to a range of audiences.

Mathematical skills

Learners will extract and interpret information from charts, graph and tables, for example in looking for correlation between carbon dioxide levels and average global temperature over time. They will use orders of magnitude to evaluate the significance of data.

Learners should be able to:

(a) interpret evidence for how it is thought the atmosphere was originally formed

(b) describe how it is thought that the an oxygen-rich atmosphere developed over geological time

(c) recall the approximate composition of the present day atmosphere

(d) describe the greenhouse effect in terms of the interaction of radiation with the Earth's atmosphere

(e) explain global warming in terms of an 'enhanced greenhouse effect'

(f) evaluate the evidence for man-made causes of climate change, including the correlation between change in atmospheric carbon dioxide concentration and the consumption of fossil fuels, and describe the uncertainties in the evidence base

(g) describe the potential effects of increased levels of carbon dioxide and methane on the Earth's climate and how these may be mitigated, including consideration of scale, risk and environmental implications

(h) describe the major sources of carbon monoxide, sulfur dioxide, oxides of nitrogen and particulates in the atmosphere and explain the problems caused by increased amounts of these substances

(i) describe the principal methods for increasing the availability of potable water in terms of the separation techniques used, including ease of treatment of waste water, ground water and salt water

2.3 Component 3

CONCEPTS IN PHYSICS

Written examination: 1 hour 45 minutes
25% of qualification
90 marks

Learners should be helped to understand how, through the ideas of physics, the complex and diverse phenomena of the natural world can be described in terms of a small number of key ideas which are of universal application and which can be illustrated in the separate topics covered in this component. These key ideas (whch are assessable) include:

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

TOPICS

1. Energy

1.1 Energy changes in a system, and in the ways energy is stored before and after such changes
1.2 Conservation, dissipation and national and global energy sources
1.3 Energy transfers

2. Particle model of matter

3. Forces

4. Forces and motion

4.1 Speed and velocity, speed as distance over time; acceleration; distance-time and velocity-time graphs
4.2 Forces, accelerations and Newton's laws of motion
4.3 Safety in public transport

5. Waves in matter

6. Light and electromagnetic waves

6.1 Frequency range of the spectrum
6.2 Interactions of electromagnetic radiation with matter and their applications

7. Electricity

7.1 Current, potential difference and resistance
7.2 Series and parallel circuits
7.3 Domestic uses and safety

8. Magnetism and electromagnetism

8.1 Permanent and induced magnetism, magnetic forces and fields
8.2 Magnetic effects of currents and the motor effect

9. Atomic structure

9.1 Nuclear atom and isotopes
9.2 Absorption and emission of ionising radiations and of electrons and nuclear particles

1. ENERGY

Overview

This topic explores the relationships between work, energy and power. It develops the conservation of energy and the link between work and energy. It investigates energy changes in a system and the different ways in which energy is stored before and after such changes.

Working scientifically

This topic contains opportunities for learners to apply scientific knowledge to practical contexts. It gives learners the opportunity to understand how to use a range of experimental and practical instruments with due consideration for safety. It presents the opportunity for learners to apply the cycle of collecting, presenting and analysing data and presenting observations and other data using appropriate methods. There are opportunities within this topic for learners to carry out experimental activities in a range of topics. Learners can be helped to understand how, through the ideas of physics, physical laws and models are expressed in mathematical form. Learners can apply the conservation of energy to many different situations, including investigating data to be able to compare the efficiency of power stations and explain why transmitting energy from power stations at high voltage is an efficient way of transferring energy.

Mathematical skills

There are a number of opportunities for the development of mathematical skills in this topic. These include performing calculations using compatible units for energy transfers associated with energy changes in a system; recalling or selecting and applying the relevant equations for mechanical, electrical and thermal processes; expressing in quantitative form the overall redistribution of energy within a system e.g. Sankey diagrams; applying the relationship between the change in internal energy of a material and its mass, specific heat capacity and temperature change to calculate the energy change involved; applying the relationship between specific latent heat and mass to calculate the energy change involved in a change of state. These topics afford learners the opportunity to recognise and use expressions in decimal form; to recognise expressions in standard form; to use ratios, fractions and percentages; to change the subject of an equation; to substitute numerical values into algebraic equations using appropriate units for physical quantities and to solve simple algebraic equations.

1.1 ENERGY CHANGES IN A SYSTEM, AND IN THE WAYS ENERGY IS STORED BEFORE AND AFTER SUCH CHANGES

Learners should be able to:

(a) describe all the changes involved in the way energy is stored when a system changes, for common situations: e.g. an object projected upwards or up a slope, a moving object hitting an obstacle, an object being accelerated by a constant force, a vehicle slowing down, bringing water to a boil in an electric kettle, a change of state

(b) describe how heating a system will change the energy stored within the system and raise its temperature or produce changes of state

(c) define the terms specific heat capacity and specific latent heat

(d) calculate the amounts of energy associated with:

- a moving body (kinetic energy = 0.5 × mass × (velocity)^2 [$E_k = \frac{1}{2}mv^2$]
- a stretched spring (energy transferred in stretching = 0.5 × spring constant × (extension)^2 [$E = \frac{1}{2}kx^2$]
- object raised above ground level (potential energy = mass × gravitational field strength × height) [$E_p = mgh$]

(e) calculate the change in energy involved when a system is changed by heating (in terms of temperature change, specific heat capacity [$\Delta Q = mc\Delta\theta$] and specific latent heat [$Q = mL$])

(f) calculate the change in energy involved by work done by forces: work done = force × distance (along the line of action of the force) [$W = Fx$]

(g) calculate the change in energy involved by work done when a current flows:

- energy transferred = power × time
- energy transferred = charge flow × potential difference [$E = QV$]

(h) explain the definition of power as the rate at which energy is transferred e.g. lifting an object, calculate values for power using $\text{power} = \frac{\text{work done}}{\text{time}}$ and describe the relationship between the power ratings for domestic electrical appliances and the changes in stored energy when they are in use e.g. in a kettle how the power is related to the increase in internal energy of the water

SPECIFIED PRACTICAL WORK

- PSP1.1 Determination of the specific heat capacity of a material

1.2 CONSERVATION, DISSIPATION AND NATIONAL AND GLOBAL ENERGY SOURCES

Learners should be able to:

(a) describe how in all system changes, energy is dissipated, so that it is stored in less useful ways

(b) describe where there are energy transfers in a system, that there is no net change to the total energy of a closed system e.g. mass oscillating on a spring

(c) explain ways of reducing unwanted energy transfer e.g. through lubrication, thermal insulation; describe the effects, on the rate of cooling of a building, of thickness and thermal conductivity of its walls (qualitative only)

(d) describe the processes of heat transfer by conduction, convection and radiation including the role of free electrons in thermal conduction in metals

(e) calculate energy efficiency for any energy transfer:

$$\text{efficiency} = \frac{\text{output energy transfer}}{\text{input energy transfer}}$$

and describe ways to increase efficiency

(f) describe the main energy sources available for use on Earth (e.g. fossil fuels, nuclear fuel, bio-fuel, wind, hydro-electricity, the tides and the Sun), compare the ways in which they are used and distinguish between renewable and non-renewable sources

(g) explain patterns and trends in the use of energy resources

1.3 ENERGY TRANSFERS

Learners should be able to:

(a) recall that, in the National Grid, electrical power is transferred at high voltages from power stations, and then transferred at lower voltages in each locality for domestic use, and explain how this system is an efficient way to transfer energy

(b) describe how, in different domestic devices, energy is transferred from batteries and the a.c. mains to the energy of motors or of heating devices

2. PARTICLE MODEL OF MATTER

Overview

This topic studies the differences between the three states of matter in terms of the arrangements of the atoms/molecules. Learners will use this knowledge to explain how gases behave under different conditions of temperature and pressure.

Working scientifically

There are opportunities within this topic for learners to use models, as in the particle model of matter to develop the idea that differences between pressure and temperature are the drivers of change. There are also opportunities for learners to use scientific knowledge and understanding to pose scientific questions and present scientific arguments and ideas. There are opportunities within this topic for learners to use theories, models and ideas to develop scientific explanations. For example, the use of the particle model of matter to explain the different properties and behaviour of solids, liquids and gases. There are also opportunities within this topic for learners to carry out experimental activities, using appropriate risk management.

Mathematical skills

There are a number of opportunities for the development of mathematical skills in this topic. These include applying the relationship between density, mass and volume to changes where mass is conserved. These topics afford learners the opportunity to recognise and use expressions in decimal form; to recognise expressions in standard form; to use ratios, fractions and percentages; to change the subject of an equation and to substitute numerical values into algebraic equations using appropriate units for physical quantities.

Learners should be able to:

(a) define density (i.e. $\text{density} = \frac{\text{mass}}{\text{volume}}$) and explain the differences in density between the three states of matter in terms of the arrangements of the atoms or molecules

(b) describe how, when substances melt, freeze, evaporate, condense or sublimate, mass is conserved, but that these physical changes differ from chemical changes because the substance recovers its original properties if the change is reversed

(c) explain how the motion of the molecules in a gas is related both to its temperature and its pressure: hence explain the relationship between the temperature of a gas and its pressure at constant volume (qualitative only)

SPECIFIED PRACTICAL WORK

- PSP2 Determination of the density of solids and liquids

3. FORCES

Overview

This topic covers the concept of force and free body diagrams. It investigates the way in which pairs of objects interact and how such ways involve forces acting on each object. The topic investigates how forces can be applied to stretch, bend or compress an object and the difference between elastic and inelastic distortions.

Working scientifically

The specified practical work in this topic gives learners the opportunity to know and understand a range of techniques, practical instruments and equipment appropriate to the knowledge and understanding included in the syllabus; to safely and correctly use practical equipment and materials; to make and record observations; to present information and data in a scientific way. There are opportunities within this topic for learners to use theories, models and ideas to develop scientific explanations. Learners can be helped to understand the phenomenon of 'action at a distance' and the related concept of the field, as the key to analysing gravitational, electrical and magnetic effects. Learners can investigate the elastic and inelastic behaviour of a spring by carrying out experimental and investigative activities, including appropriate risk management.

Mathematical skills

There are a number of opportunities for the development of mathematical skills in this topic. These include **using vector diagrams to illustrate the resolution of forces, a net force and equilibrium situations (scale drawings will be required);** calculating relevant values of stored energy and energy transfers. These topics afford learners the opportunity to use ratios, fractions and percentages; to substitute numerical values into algebraic equations using appropriate units for physical quantities; to translate information between graphical and numeric form; to use angular measures in degrees and to visualize and represent 2D and 3D forms, including two dimensional representation of 3D objects.

Learners should be able to:

(a) recall examples of ways in which pairs of objects interact by:

- gravity
- electrostatics
- magnetism and
- contact (including normal contact force and friction)

and describe how such examples involve forces on each object using vector notation

(b) define weight as the gravitational force acting on an object, describe how it is measured and describe the relationship between the weight of that body and the gravitational field strength (weight = mass × gravitational field strength [$W = mg$])

(c) describe examples of the forces acting on an isolated solid object or system; describe, using free body diagrams, examples where several forces lead to a resultant force on an object and the special case of balanced forces when the resultant force is zero: resolve a force into components at right angles

(d) explain that to stretch, bend or compress an object, more than one force has to be applied e.g. a stretched elastic band

(e) describe the difference between elastic and inelastic distortions caused by stretching forces; calculate the work done in stretching; describe the relationship between force and extension for a spring (force = spring constant × extension [$F = kx$]) and other simple systems; describe the difference between linear and non-linear relationships between force and extension, and calculate a spring constant in linear cases

(f) use the relationship between work done, force, and distance moved (along the line of action of the force i.e. work done = force × distance (along the line of action of the force) [$W = Fx$] and describe the energy transfer involved

SPECIFIED PRACTICAL WORK

- PSP3.1 Investigation of the force-extension graph for a spring

4. FORCES AND MOTION

Overview

This topic covers rectilinear motion and also looks at circular motion from a qualitative perspective. Learners study accelerated motion in a straight line, the effects of forces upon objects and the concept of momentum and its conservation.

Working scientifically

The specified practical work in this topic gives learners the opportunity to use apparatus to record a range of measurements; to use stopwatches or light gates for timing; to use analogue apparatus to record a range of measurements. Learners have the opportunity to follow written instructions, to make and record observations, keep appropriate records and present information and data in a scientific way. There are opportunities within this topic for learners to use appropriate methodology, including ICT to answer scientific questions and solve scientific problems. Learners can carry out experimental and investigative activities using stopwatches, light gates and data loggers to measure the acceleration of a moving body, to investigate factors affecting stopping distances and to measure the speed of a moving body. Learners can apply these factors to explain the factors which affect the braking distances of moving vehicles and the attendant safety considerations and to explain the dangers caused by large decelerations.

Mathematical skills

There are a number of opportunities for the development of mathematical skills in this topic. These include making calculations using ratios and proportional reasoning to convert units and compute rates; relating changes and differences in motion to appropriate distance-time and velocity-time graphs and interpreting lines and slopes in such graphs; **interpreting enclosed areas in velocity-time graphs**; applying formulae relating distance, time and speed, for uniform motion, and for motion with uniform acceleration, and calculating mean speed for non-uniform motion; estimating how the distances required for road vehicles to stop in an emergency varies over a range of typical speeds; applying formulae relating force, mass and relevant physical constants, including gravitational field strength, to explore how changes in these are inter-related; applying formulae relating force, mass, velocity and acceleration to explain how the changes involved are inter-related; estimating, for every day road transport, the speed, acceleration and forces. These topics afford learners the opportunity to use expressions in decimal form; use ratios, fractions and percentages; make estimates of the results of simple calculations, without using a calculator; construct and interpret frequency tables and diagrams, bar charts and histograms; make order of magnitude calculations; change the subject of an equation; substitute numerical values into algebraic equations using appropriate units for physical quantities; solve simple algebraic equations; translate information between graphical and numeric form; understand that $y = mx + c$ represents a linear relationship; plot two variables from experimental or other data; determine the slope and intercept of a linear graph; understand the physical significance of area between a curve and the x-axis and measure it by counting squares as appropriate.

4.1 SPEED AND VELOCITY, SPEED AS DISTANCE OVER TIME; ACCELERATION; DISTANCE-TIME AND VELOCITY-TIME GRAPHS

Learners should be able to:

(a) explain the vector-scalar distinction as it applies to displacement / distance and velocity / speed

(b) recall typical speeds encountered in everyday experience for wind and sound, and for walking, running, cycling and other transportation systems; recall the acceleration in free fall on Earth (10 m/s^2) and estimate the magnitudes of everyday accelerations

(c) explain with examples that motion in a circular orbit involves a constant speed but changing velocity (qualitative responses only)

(d) recall and apply the relationships:

- distance travelled = speed × time
- $\text{acceleration} = \dfrac{\text{change in velocity}}{\text{time}} \left[a = \dfrac{\Delta v}{t} \right]$

(e) use motion graphs to describe and determine the speed, acceleration and distance travelled

(f) apply the following equations to situations of uniform acceleration only

- final velocity = initial velocity + acceleration × time [$v = u + at$]
- distance = ½ (initial velocity + final velocity) × time [$x = \frac{1}{2}(u + v)t$]
- (final velocity)^2 = (initial velocity)^2 + 2 × acceleration × distance [$v^2 = u^2 + 2ax$]
- **distance = initial velocity × time + ½ × acceleration × time^2** [$\boldsymbol{x = ut + \frac{1}{2}at^2}$]

4.2 FORCES, ACCELERATIONS AND NEWTON'S LAWS OF MOTION

Learners should be able to:

(a) recall Newton's First Law and apply it to explain the motion of objects moving with uniform velocity and also objects where the speed and/or direction change

(b) recall Newton's Second Law and apply it in calculations relating forces, masses and accelerations: resultant force = mass × acceleration [$F = ma$]

(c) explain that inertial mass is a measure of how difficult it is to change the velocity of an object and that it is defined as the ratio of force over acceleration

(d) recall and apply Newton's Third Law

(e) define momentum (i.e. momentum = mass × velocity $p = mv$]), state the principle of conservation of momentum and apply it to one dimensional interactions

SPECIFIED PRACTICAL WORK

- PSP4.2 Determination of the acceleration of a moving object

4.3 SAFETY IN PUBLIC TRANSPORT

Learners should be able to:

(a) explain methods of measuring human reaction times and its effect on thinking distances and recall values of typical reaction times

(b) explain the factors which affect the braking distance required for road transport vehicles to come to rest in emergencies and the implications for safety

(c) explain the dangers caused by large decelerations **and estimate the forces involved in everyday situations on a road e.g. vehicle braking to a halt**

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

5. WAVES IN MATTER

Overview

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

Working scientifically

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

Mathematical skills

There are a number of opportunities for the development of mathematical skills in this topic. These include applying formulae relating velocity, frequency and wavelength. These topics afford learners the opportunity to use ratios, fractions and percentages; substitute numerical values into algebraic equations using appropriate units for physical quantities.

Learners should be able to:

(a) describe wave motion in terms of amplitude, wavelength, frequency and period i.e. $\text{period} = \dfrac{1}{\text{frequency}}$ $\left[T = \dfrac{1}{f}\right]$; define wavelength and frequency and describe and apply the relationship between these and the wave velocity (wave speed = frequency × wavelength [$v = f\lambda$])

(b) describe the difference between transverse and longitudinal waves

(c) describe how ripples on water surfaces are examples of transverse waves whilst sound waves in air are longitudinal waves; describe evidence that in both cases it is the wave and not the water or air itself that travels

(d) recall that sound requires a medium for transmission

SPECIFIED PRACTICAL WORK

- PSP5.1 Investigation of water waves

6. LIGHT AND ELECTROMAGNETIC WAVES

Overview

This topic covers the properties of electromagnetic waves. Learners study the electromagnetic spectrum and the interactions of electromagnetic radiation with matter.

Working scientifically

Questions set on this topic will assess learners' abilities to explain every day and technological applications of science; to process and analyse data using appropriate mathematical skills; to present data in appropriate ways. There are opportunities within this topic for learners to consider applications and implications of science and evaluate their associated risks. Learners can be given the opportunity to apply the concept of refraction.

Mathematical skills

There are a number of opportunities for the development of mathematical skills in this topic. These include applying the relationships between frequency and wavelength across the electromagnetic spectrum; constructing two-dimensional ray diagrams to illustrate reflection and refraction (qualitatively only). These topics afford learners the opportunity to recognise and use expressions in decimal form; recognise expressions in standard form; use ratios, fractions and percentages; substitute numerical values into algebraic equations using appropriate units for physical quantities; use angular measure in degrees; visualize and represent 2D and 3D forms including two dimensional representations of 3D objects.

6.1 FREQUENCY RANGE OF THE SPECTRUM

Learners should be able to:

(a) recall that light is an electromagnetic wave

(b) recall that electromagnetic waves are transverse, are transmitted through space where all have the same velocity, and explain, with examples, that they transfer energy from a source to an absorber

(c) describe the main groupings of the spectrum – radio, microwave, infra-red, visible (red to violet), ultraviolet, X-rays and gamma rays, that these range from long to short wavelengths and from low to high frequencies, and that our eyes can only detect a limited range

6.2 INTERACTIONS OF ELECTROMAGNETIC RADIATION WITH MATTER AND THEIR APPLICATIONS

Learners should be able to:

(a) recall that radio waves can be produced by or can themselves induce oscillations in electrical circuits

(b) recall that the generation and absorption of radiations over a wide frequency range are associated with changes in atoms and nuclei

(c) give examples of some practical uses of electromagnetic waves in the radio, microwave, infra-red, visible, ultraviolet, X-ray and gamma ray regions and describe how ultraviolet waves, X-rays and gamma rays can have hazardous effects, notably on human bodily tissues

(d) recall that different substances may absorb, transmit, refract, or reflect electromagnetic waves in ways that vary with wavelength; explain how some effects are related to differences in the velocity of the waves in different substances

(e) use ray diagrams to illustrate reflection and refraction at plane surfaces

SPECIFIED PRACTICAL WORK

- PSP6.2 Investigation of refraction in a glass block

7. ELECTRICITY

Overview

This topic covers the basic ideas of electric charge and electric current. It explores the relationship between current and potential difference and develops the idea of resistance. The phenomenon of static electricity is introduced in terms of transfer of electrons between objects.

Working scientifically

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

Mathematical skills

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

7.1 CURRENT, POTENTIAL DIFFERENCE AND RESISTANCE

Learners should be able to:

(a) recall that current is the rate of flow of charge, that for charge to flow, a source of potential difference and a closed circuit are needed and that a current has the same value at any point in a single closed loop

(b) recall and use the relationship between quantity of charge, current and time (charge flow = current × time [$Q = It$])

(c) recall that current (I) depends on both resistance (R) and potential difference (V) and the units in which these are measured

(d) recall and apply the relationship between I, R and V, and know that for some components the value of R remains constant but for lamps it changes as the current changes (potential difference = current × resistance [$V = IR$])

(e) explain how the power transfer in any circuit device is related to the p.d. across it and the current, and to the energy changes over a given time:
- power = potential difference × current = (current)^2 × resistance [$P = IV = I^2R$]
- power $= \dfrac{\text{energy transferred}}{\text{time}}$ and
- energy transferred = charge flow × potential difference [$E = QV$]

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

SPECIFIED PRACTICAL WORK

- PSP7.1 Investigation of the current-voltage (I-V) characteristics of a component

7.2 SERIES AND PARALLEL CIRCUITS

Learners should be able to:

(a) describe the differences between series and parallel circuits, including the properties of currents and potential differences

(b) explain why, if two resistors are in series the net resistance is increased, and calculate the net resistance of two resistors in series

(c) explain why, if two resistors are in parallel the net resistance is decreased.

(d) calculate the currents, potential differences and total resistance in d.c. series circuits, and explain the design and use of such circuits for measurement and testing purposes; represent them with the conventions of positive and negative terminals, and the symbols that represent common circuit elements, including diodes, LDRs and thermistors

SPECIFIED PRACTICAL WORK

- PSP7.2 Investigation of the characteristics of series and parallel circuits

7.3 DOMESTIC USES AND SAFETY

Learners should be able to:

(a) recall that the domestic supply in the UK is a.c. at 50 Hz and 230 V, explain the difference between direct and alternating voltage

(b) recall the differences in function between the live, neutral and earth mains wires, and the potential differences between these wires; hence explain that a live wire may be dangerous even when a switch in a mains circuit is open, and explain the dangers of providing any connection between the live wire and earth

(c) explain the function of a fuse and from calculations select an appropriate rating for a particular appliance

8. MAGNETISM AND ELECTROMAGNETISM

Overview

This topic covers the concept of magnetic fields and investigates the forces on current carrying conductors in magnetic fields.

Working scientifically

The specified practical work in this topic gives learners the opportunity to investigate the magnetic fields of magnets, coils and wires; to make and record observations; to keep appropriate records of experimental activities. There are opportunities within this topic for learners to communicate information and ideas in appropriate ways using appropriate terminology; to consider applications and implications of science and evaluate their associated benefits and risks.

Mathematical skills

There are a number of opportunities for the development of mathematical skills in this topic. Learners are afforded the opportunity to use ratios, fractions and percentages; change the subject of an equation; substitute numeric values into algebraic equations using appropriate units for physical quantities.

8.1 PERMANENT AND INDUCED MAGNETISM, MAGNETIC FORCES AND FIELDS

Learners should be able to:

(a) describe the attraction and repulsion between unlike and like poles for permanent magnets and describe the difference between permanent and induced magnets

(b) describe the characteristics of the magnetic field of a bar magnet, showing how strength and direction change from one point to another

(c) explain how the behaviour of a magnetic compass is related to evidence that the core of the earth must be magnetic

8.2 MAGNETIC EFFECTS OF CURRENTS AND THE MOTOR EFFECT

Learners should be able to:

(a) describe how to show that an electric current can create a magnetic effect and draw the magnetic fields due to currents in a straight conducting wire, a plane coil and a solenoid, including the relationship between the directions of the current and field

(b) recall that the strength of the field depends on the current and the distance from the conductor, and explain how solenoid arrangements can enhance the magnetic effect

(c) describe how a magnet and a current-carrying conductor exert a force on one another and apply Fleming's left-hand rule to the relative orientations of the force, the current in the conductor and the magnetic field

(d) apply the equation that links the force on a conductor to the strength of the field, the current and the length of conductor to calculate the forces involved (force on a conductor (at right angles to a magnetic field) carrying a current = magnetic field strength × current × length [$F = BIl$])

(e) explain how this force is used to cause rotation in electric motors

SPECIFIED PRACTICAL WORK

- PSP8.2 Investigation of the force due to the magnetic field of coils

9. ATOMIC STRUCTURE

Overview

This topic covers the structure of the nuclear atom and its representation using atomic notation. It covers the spontaneous nature of nuclear decay and the nature of alpha, beta and gamma radiation. It introduces the concept of half-life and the random nature of radioactive decay.

Working scientifically

There are opportunities within this topic for learners to plot and interpret graphs; to process and analyse data using mathematical skills. There are opportunities within this topic for learners to use appropriate methodology to answer scientific questions and to solve scientific problems. Learners have the opportunity to evaluate methodology, evidence and data and resolve conflicting evidence to consider ethical issues in the treatment of humans and the environment, to evaluate the ways in which society uses science to inform decision making.

Mathematical skills

There are a number of opportunities for the development of mathematical skills in this topic. These include balancing equations representing alpha, beta or gamma decay in terms of the mass number and atomic number, and charges of the atoms involved; calculating the net decline, expressed as a ratio, in a radioactive emission after a given number of half-lives. These topics afford learners the opportunity to recognise expressions in standard form; use ratios, fractions and percentages; substitute numerical values into algebraic equations using appropriate units for physical quantities; solve simple algebraic equations.

9.1 NUCLEAR ATOM AND ISOTOPES

Learners should be able to:

(a) describe how the model of the atom has changed over time i.e. plum pudding and Bohr models

(b) describe the atom as a positively charged nucleus surrounded by negatively charged electrons, with the nuclear radius much smaller than that of the atom and with almost all of the mass in the nucleus

(c) recall the typical size (order of magnitude) of nuclei, atoms and small molecules

(d) recall that atomic nuclei are composed of both protons and neutrons, that the nucleus of each element has a characteristic positive charge, but that atoms of the same element can differ in nuclear mass by having different numbers of neutrons

(e) use atomic notation (i.e. ${}^{A}_{Z}\mathrm{X}$) to relate differences between isotopes of the same and different elements to their charges and masses

9.2 ABSORPTION AND EMISSION OF IONISING RADIATIONS AND OF ELECTRONS AND NUCLEAR PARTICLES

Learners should be able to:

(a) recall that in each atom its electrons are arranged at different distances from the nucleus, that such arrangements may change with absorption or emission of electromagnetic radiation and that atoms can become ions by loss of outer electrons

(b) recall that some nuclei are unstable and may emit alpha particles, beta particles, or neutrons, and electromagnetic radiation as gamma rays; relate these emissions to possible changes in the mass or the charge of the nucleus, or both

(c) use names and symbols of common nuclei and particles to write balanced equations that represent radioactive decay

(d) explain the concept of half-life and how this is related to the random nature of radioactive decay

(e) calculate the net decline in radioactive emission as a ratio by using the half-life

(f) recall the differences in the penetration properties of alpha particles, beta particles and gamma rays

(g) recall the differences between contamination and irradiation effects and compare the hazards associated with these two effects

2.4 Component 4

APPLICATIONS IN SCIENCE

Written examination: 1 hour 45 minutes
25% of qualification
90 marks

This component will assess the skills of learners in the context of the content of Components 1-3.

The assessment of this component will comprise two sections.

Section A Foundation Tier / Section B Higher Tier (75 marks)
This will contain a mix of short answer questions, structured questions, extended writing and data response questions, all set in a practical context. Some of the questions will be based on specified practical work whilst others will be set in a novel context.

Section B Foundation Tier / Section A Higher Tier (15 marks)
A resource booklet containing an unseen article with elements of content from Components 1-3 will provide the basis for a mix of short answer questions, structured questions and data response questions.

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
- scientific techniques and procedures

AO2
Apply knowledge and understanding of:
- scientific ideas
- scientific enquiry, techniques and procedures

AO3
Analyse information and ideas to:
- interpret and evaluate
- make judgements and draw conclusions
- develop and improve experimental procedures

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

	AO1	**AO2**	**AO3**
Component 1	10%	10%	5%
Component 2	10%	10%	5%
Component 3	10%	10%	5%
Component 4	10%	10%	5%
Overall weighting	**40%**	**40%**	**20%**

For each series:
- The weighting for the assessment of mathematical skills will be a minimum of 20% related to biology, chemistry and physics in a ratio of 1:2:3
- The weighting for the assessment of practical skills will be a minimum of 15%

Learners will be expected to provide extended responses which are of sufficient length to allow them to demonstrate their ability to construct and develop a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.

3.2 Arrangements for practical work

The assessment of practical skills is a compulsory requirement of the course of study for GCSE Combined Science qualifications.

The content 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 skills listed in Appendix A.

In addition, by completing the specified practical work learners will experience each of the practical techniques listed in Appendix B which are a requirement of the qualification. Centres must also ensure that learners keep their own records of the practical work that they undertake.

When completing any practical work safety is of paramount concern. It is the responsibility of each centre to ensure that appropriate safety procedures are followed whenever their learners' complete practical work. Risk assessments are required for all practical work whether it takes place in the laboratory or out in the field.

For each assessment series each centre is required to submit a practical science statement (see Appendix E) to WJEC. The statement is confirmation from a centre that it has taken reasonable steps to ensure that each learner entered for that particular assessment series has completed the practical work listed in the specification. Also the centre has made a record of the specified practical work that each learner has undertaken and the knowledge, skills and understanding that the learner has derived from the completion of the practical work. The practical science statement must be submitted to WJEC for learners in a particular cohort before the awarding of their GCSE. This will be on a date published by WJEC and will fall before the end of May.

If a centre fails to submit a practical science statement to WJEC for an assessment series then it will be treated as a case of malpractice and/or maladministration.

Centres must have systems in place that enable them to ensure that private learners have completed the required specified practical work. It will be the responsibility of the centre entering private learners to validate that these learners have covered the full range of practical requirements described in the specification.

4 TECHNICAL INFORMATION

4.1 Making entries

This is a linear qualification in which all assessments must be taken at the end of the course. Candidates entered for this qualification must sit all four components at either foundation or higher tier, in the same examination series. Assessment opportunities will be available in May/June each year, until the end of the life of this specification. summer 2018 will be the first assessment opportunity.

Where learners wish to re-sit the qualification, all components must be re-taken.

The entry codes appear below.

WJEC Eduqas GCSE Combined Science (Foundation tier):	C430PF
WJEC Eduqas GCSE Combined Science (Higher tier):	C430PH

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

4.2 Grading, awarding and reporting

GCSE Combined Science qualifications are reported on a seventeen point scale from 1-1 to 9-9, where 9-9 is the highest grade. Results not attaining the minimum standard for the award will be reported as U (unclassified).

A candidate who takes higher tier assessments will be awarded a grade within the range of 4-4 to 9-9, or be unclassified. However, if the mark achieved by such a learner is a small number of marks below the lower 4-4 grade boundary that learner may be awarded a grade 4-3.

A candidate who takes foundation tier assessments will be awarded a grade within the range of 1-1 to 5-5, or be unclassified.

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 represent mathematical and statistical 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

Practical requirements and exemplification

All learners are expected to have carried out the **specified practical activities**. These develop skills in the use of the following apparatus and techniques.
The apparatus and techniques listed 1–7 below are common with each of the single sciences i.e. GCSE Biology, GCSE Chemistry and GCSE Physics.

	Biology		Chemistry		Physics
B1	Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, temperature, volume of liquids and gases, and pH	C1	Use of appropriate apparatus to make and record a range of measurements accurately, including mass, time, temperature, and volume of liquids and gases	P1	Use of appropriate apparatus to make and record a range of measurements accurately, including length, area, mass, time, volume and temperature. Use of such measurements to determine densities of solid and liquid objects.
B2	Safe use of appropriate heating devices and techniques including use of a Bunsen burner and a water bath or electric heater	C2	Safe use of appropriate heating devices and techniques including use of a Bunsen burner and a water bath or electric heater	P2	Use of appropriate apparatus to measure and observe the effects of forces including the extension of springs
B3	Use of appropriate apparatus and techniques for the observation and measurement of biological changes and/or processes	C3	Use of appropriate apparatus and techniques for conducting and monitoring chemical reactions, including appropriate reagents and/or techniques for the measurement of pH in different situations	P3	Use of appropriate apparatus and techniques for measuring motion, including determination of speed and rate of change of speed (acceleration/deceleration)
B4	Safe and ethical use of living organisms (plants or animals) to measure physiological functions and responses to the environment	C4	Safe use of a range of equipment to purify and/or separate chemical mixtures including evaporation, filtration, crystallisation, chromatography and distillation	P4	Making observations of waves in fluids and solids to identify the suitability of apparatus to measure speed/frequency/ wavelength. Making observations of the effects of the interaction of electromagnetic waves with matter.
B5	Measurement of rates of reaction by a variety of methods including production of gas, uptake of water and colour change of indicator	C5	Making and recording of appropriate observations during chemical reactions including changes in temperature and the measurement of rates of reaction by a variety of methods such as production of gas and colour change	P5	Safe use of appropriate apparatus in a range of contexts to measure energy changes/transfers and associated values such as work done
B6	Application of appropriate sampling techniques to investigate the distribution and abundance of organisms in an ecosystem via direct use in the field	C6	Safe use and careful handling of gases, liquids and solids, including careful mixing of reagents under controlled conditions, using appropriate apparatus to explore chemical changes and/or products	P6	Use of appropriate apparatus to measure current, potential difference (voltage) and resistance, and to explore the characteristics of a variety of circuit elements
B7	Use of appropriate apparatus, techniques and magnification, including microscopes, to make observations of biological specimens and produce labelled scientific drawings	C7	Use of appropriate apparatus and techniques to draw, set up and use electrochemical cells for separation and production of elements and compounds	P7	Use of circuit diagrams to construct and check series and parallel circuits including a variety of common circuit elements

List of apparatus and techniques

The lists on the following pages cross references the specified practical work against the apparatus and skills listed above. These include opportunities for choice and use of appropriate laboratory apparatus for a variety of experimental problem-solving and/or enquiry based activities.

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

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

COMBINED SCIENCE – BIOLOGY

Specified practical work	Specification topic	Technique code
BSP1.1 Examination of plant and animal cells using a light microscope and production of labelled scientific drawings from observation	1.1	B3, B4, B7
BSP1.3A Investigation into factors affecting enzyme action	1.3	B1, B2, B3, B4, B5
BSP1.3B Qualitative identification of starch (iodine), glucose (Benedict's) and protein (biuret)	1.3	B2, B3
BSP2.1 Investigation into the effect of solute concentration on osmosis in potato chips	2.1	B1, B3, B4, B5
BSP2.2 Examination of artery and vein using a light microscope and production of labelled scientific drawings of these from observation	2.2	B3, B7
BSP4.1 Investigation into factors affecting reaction times	4.1	B1, B3, B4, B5
BSP5 Investigation into factors affecting the rate of photosynthesis	5.1	B1, B2, B3, B4, B5
BSP6.3 Investigation into factors affecting the abundance and distribution of a species	6.3	B1, B3, B4, B6
BSP7.1 Simple extraction of DNA from living material	7.1	B2, B3, B4

COMBINED SCIENCE – CHEMISTRY

Specified practical work	Specification topic	Technique code
CSP1.1 Separation of liquids by distillation, e.g. ethanol from water, and by paper chromatography	1	C2, C4
CSP6A Determination of relative reactivities of metals through displacement reactions	6	C5,
CSP6B Investigation into electrolysis of aqueous solutions and electroplating	6	C3, C5, C6, C7
CSP7A Preparation of crystals of a soluble salt from an insoluble base or carbonate	7	C2, C4
CSP7B Titration of a strong acid against a strong base using an indicator	7	C1, C3, C6
CSP8 Determination of the amount of energy released by a fuel	8	C1, C5, C6
CSP9A Investigation into the effect of one factor on the rate of a reaction using a gas collection method	9	C1, C3, C5, C6
CSP9B Investigation into the effect of one factor on the rate of the reaction between dilute hydrochloric acid and sodium thiosulfate	9	C1, C3, C5, C6
CSP9C Investigation into the effect of various catalysts on the decomposition of hydrogen peroxide	9	C1, C3, C5, C6

COMBINED SCIENCE – PHYSICS

Specified practical work	Specification topic	Technique code
PSP1.1 Determination of the specific heat capacity of a material	1.1	P1, P5
PSP2 Determination of the density of solids and liquids	2	P1
PSP3.1 Investigation of the force-extension graph for a spring	3.1	P1, P2
PSP4.2 Determination of the acceleration of a moving object	4.2	P1, P3
PSP5.1 Investigation of water waves	5.1	P4
PSP6.2 Investigation of refraction in a glass block	6.2	P4
PSP7.1 Investigation of the current-voltage (I-V) characteristics of a component	7.1	P6, P7
PSP7.2 Investigation of the characteristics of series and parallel circuits	7.2	P6, P7
PSP8.2 Investigation of the force due to the magnetic field of coils	8.2	P2

Learners are expected to cover the **full** range of practical techniques using the specified practical work. WJEC will publish teacher/technician guidance sheets and learner worksheets for all the specified practical work which centres may use with their learners. These will ensure that all the techniques referred to in the above table are met. Centres may substitute the exemplar specified practical for another one of comparable standard. In such cases the same techniques cross referenced in the above **must** also be covered by the substituted practical. Learners **must** also be familiar with the same set of skills in this practical as required by the exemplar practical.

Centres should also note that WJEC will:

- review the specified practical work which it has set following any revision by the Secretary of State of the apparatus and/or techniques specified in respect of the qualification
- revise the specified practical work which it has set if appropriate
- promptly publish an amended specification if it makes any revision to the practical activities.

APPENDIX C

Mathematical skills

This table shows the mathematical skills which can be assessed across Combined Science. It also shows the subject content area: Biology (B), Chemistry (C) and Physics (P) in which the skills apply.

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

APPENDIX D

Equations in physics

Equations required for higher tier only are in **bold.**

(a) In solving quantitative problems, learners should be able correctly to recall, and apply the following relationships:

- resultant force = mass × acceleration [$F = ma$]
- kinetic energy = 0.5 × mass × (velocity)^2 [$E_k = \frac{1}{2}mv^2$]
- **momentum = mass × velocity [$p = mv$]**
- work done = force × distance (along the line of action of the force) [$W = Fx$]
- power $= \dfrac{\text{work done}}{\text{time}}$
- efficiency $= \dfrac{\text{output energy transfer}}{\text{input energy transfer}}$
- weight = mass × gravitational field strength [$W = mg$]
- potential energy = mass × gravitational field strength × height [$E_p = mgh$]
- force = spring constant × extension [$F = kx$]
- distance travelled = speed × time
- acceleration $= \dfrac{\text{change in velocity}}{\text{time}}$ $\left[a = \dfrac{\Delta v}{t}\right]$
- period $= \dfrac{1}{\text{frequency}}$ $\left[T = \dfrac{1}{f}\right]$
- wave speed = frequency × wavelength [$v = f\lambda$]
- charge flow = current × time [$Q = It$]
- potential difference = current × resistance [$V = IR$]
- power = potential difference × current = (current)^2 × resistance [$P = IV = I^2R$]

- energy transferred = power × time
- energy transferred = charge flow × potential difference $[E = QV]$
- density $= \frac{\text{mass}}{\text{volume}}$

(b) In addition, learners should be able correctly to select from a list and apply the following relationships:

- final velocity = initial velocity + acceleration × time $[v = u + at]$
- distance = ½ (initial velocity + final velocity) × time $[x = \frac{1}{2}(u + v)t]$
- (final velocity)^2 = (initial velocity)^2 + 2 × acceleration × distance $[v^2 = u^2 + 2ax]$
- **distance = initial velocity × time + ½ × acceleration × time^2 $[x = ut + \frac{1}{2}at^2]$**
- change in thermal energy = mass × specific heat capacity × change in temperature $[\Delta Q = mc\Delta\theta]$
- thermal energy for a change of state = mass × specific latent heat $[Q = mL]$
- energy transferred in stretching = 0.5 × spring constant × (extension)^2 $[E = \frac{1}{2}kx^2]$
- potential difference across primary coil × current in primary coil = potential difference across secondary coil × current in secondary coil $[V_1I_1 = V_2I_2]$
- **force on a conductor (at right angles to a magnetic field) carrying a current = magnetic field strength × current × length $[F = BIl]$**

APPENDIX E

Practical science statement

Practical Science Statement
GCSE Combined Science

Centre Name ....

Centre Number ....

Declaration by head of centre
I confirm that: *1. This centre has taken reasonable steps to ensure that each learner entered for assessment in this summer series has completed the specified practical work listed in the specification and they have kept a record of their work;* *2. This centre has made a record of the specified practical work that each learner has undertaken and the knowledge, skills and understanding that the learner has derived from the completion of the practical work.* ***Head of centre's name**: ....* ***Head of centre's signature**: .... Date ....*

Summer 20....