Department for Education

Combined science

GCSE subject content

June 2015

Contents

Subject content

Introduction

These GCSE subject content criteria sets out the assessment objectives, knowledge, understanding and skills, for GCSE specifications in combined science, to ensure progression from key stage 3 national curriculum requirements and the possibility of development into A level. They provide the framework within which awarding organisations create the detail of the subject specifications.

Subject aims and learning outcomes

This document sets out the learning outcomes and content coverage required for GCSE in combined science. In subjects such as the sciences, where topics are taught in progressively greater depth over the course of key stage 3 and key stage 4, GCSE outcomes may reflect or build upon subject content which is typically taught at key stage 3. There is no expectation that teaching of such content should be repeated during the GCSE course where it has already been covered at an earlier stage.

GCSE study 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 students 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 and over time 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 the separate sections below for biology, chemistry and physics components of combined science.

GCSE specifications in combined award science should enable students 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.

Furthermore, the sciences should be studied in ways that help students to develop curiosity about the natural world, insight into how science works, and appreciation of its relevance to their everyday lives. The scope and nature of such study should be broad, coherent, practical and satisfying, and thereby encourage students to be inspired, motivated and challenged by the subject and its achievements.

The two main dimensions of the content

The ways in which GCSE specifications in combined science should enable students to show their understanding of the concepts and methods of science are spelt out below in two main sections.

The first section section explains the main ways in which working scientifically should be developed and assessed. Specifications should encourage the development of knowledge and understanding in science through opportunities for working scientifically. Awarding organisations should identify in their assessment strategy how, over a cycle of assessments, they will ensure that working scientifically is developed and assessed through the subject content.

The second section sets out the key ideas and subject contents for the biology, chemistry and physics components of combined science. In combined science there should be a minimum of 30% of each of biology, chemistry and physics.

These content sections also set out the depth of treatment for both teaching and learning. Awarding organisations' specifications should be designed to set out the level of understanding which pupils are expected to acquire.

The content sections also set out the mathematical skills required for combined science. In order to be able to develop their skills, knowledge and understanding in science, students need to have been taught, and demonstrate competence, to select and apply the appropriate areas of mathematics relevant to the subject as set out under each topic and the mathematical skills listed in appendix 3. The mathematics should be at levels up to, but not beyond, the requirements specified in GCSE mathematics for the appropriate tier.

All mathematics content must be assessed within the lifetime of the specification.

Four **Appendices** provide further details about (1) equations in physics; (2) units in science; (3) mathematical skills; and (4) gives a list of apparatus and techniques.

Working scientifically

This section explains, with both general and subject-specific examples, the main ways in which working scientifically may be developed and assessed.

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 everyday and technological applications of science; evaluate associated personal, social, economic and environmental implications; and make decisions based on the evaluation of evidence and arguments
- evaluate risks both in practical science and 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.

Biology

Biology is the science of living organisms (including animals, plants, fungi and microorganisms) and their interactions with each other and the environment. The study of biology involves collecting and interpreting information about the natural world to identify patterns and relate possible cause and effect. Biological information is used to help humans improve their own lives and strive to create a sustainable world for future generations.

Students 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 set out below. These ideas 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.

This content sets out the full range of content for the biology component of GCSE combined science. Awarding organisations may, however, use flexibility to increase depth, breadth or context within the specified topics or to consolidate teaching of the subject content.

Higher tier GCSE combined science specifications must assess all the content set out below, whether it is underlined or is not underlined. Foundation tier GCSE combined science specifications must assess all the content set out below, except for content which is underlined.

GCSE combined science specifications should require students to:

Cell biology

Prokaryotic and eukaryotic cells

- explain how the main sub-cellular structures of eukaryotic cells (plants and animals) and prokaryotic cells are related to their functions, including the nucleus/genetic material, plasmids, mitochondria, chloroplasts and cell membranes
- explain how electron microscopy has increased our understanding of sub-cellular structures.

Growth and development of cells

- describe the process of mitosis in growth, including the cell cycle
- explain the importance of cell differentiation
- describe cancer as the result of changes in cells that lead to uncontrolled growth and division
- describe the function of stem cells in embryonic and adult animals and meristems in plants
- discuss potential benefits and risks associated with the use of stem cells in medicine
- explain the role of meiotic cell division in halving the chromosome number to form gametes.

Cell metabolism

- explain the mechanism of enzyme action including the active site, enzyme specificity and factors affecting the rate of enzymatic reaction
- describe cellular respiration as an exothermic reaction which is continuously occurring in all living cells
- compare the processes of aerobic and anaerobic respiration
- explain the importance of sugars, amino acids, fatty acids and glycerol in the synthesis and breakdown of carbohydrates, lipids and proteins.

Use of mathematics

- demonstrate an understanding of number, size and scale and the quantitative relationship between units (2a and 2h)
- use estimations and explain when they should be used (1d)
- carry out rate calculations for chemical reactions (1a and 1c)
- calculate with numbers written in standard form (1b).

Transport systems

Transport in cells

- explain how substances are transported into and out of cells through diffusion, osmosis and active transport.

Transport systems in multicellular organisms

- explain the need for exchange surfaces and a transport system in multicellular organisms in terms of surface area:volume ratio
- describe some of the substances transported into and out of a range of organisms in terms of the requirements of those organisms, to include oxygen, carbon dioxide, water, dissolved food molecules, mineral ions and urea.

Human circulatory system

- describe the human circulatory system, including the relationship with the gaseous exchange system, and explain how the structure of the heart and the blood vessels are adapted to their functions
- explain how red blood cells, white blood cells, platelets and plasma are adapted to their functions in the blood.

Transport systems in plants

- explain how the structure of xylem and phloem are adapted to their functions in the plant
- explain how water and mineral ions are taken up by plants, relating the structure of the root hair cells to their function
- describe the processes of transpiration and translocation, including the structure and function of the stomata

- explain the effect of a variety of environmental factors on the rate of water uptake by a plant, to include light intensity, air movement and temperature.

Use of mathematics

- calculate surface area:volume ratios (1c)
- use simple compound measures such as rate (1a, 1c)
- carry out rate calculations (1a and 1c)
- plot, draw and interpret appropriate graphs (4a, 4b, 4c and 4d)
- use percentiles and calculate percentage gain and loss of mass (1c).

Health, disease and the development of medicines

Health and disease

- describe the relationship between health and disease
- describe different types of diseases (including communicable and non-communicable diseases)/
- describe the interactions between different types of disease.

Communicable diseases

- explain how communicable diseases (caused by viruses, bacteria, protists and fungi) are spread in animals and plants
- describe a minimum of one common human infection, one plant disease and sexually transmitted infections in humans, including HIV/AIDS
- describe the non-specific defence systems of the human body against pathogens
- explain the role of the immune system of the human body in defence against disease.

Treating, curing and preventing disease

- explain the use of vaccines and medicines in the prevention and treatment of disease
- describe the process of discovery and development of potential new medicines, including preclinical and clinical testing

- explain how the spread of communicable diseases may be reduced or prevented in animals and plants, to include a minimum of one common human infection, one plant disease and sexually transmitted infections in humans including HIV/AIDS.

Non-communicable diseases in humans

- recall that many non-communicable human diseases are caused by the interaction of a number of factors. To include cardiovascular diseases, many forms of cancer, some lung and liver diseases and diseases influenced by nutrition, including type 2 diabetes

- explain the effect of lifestyle factors, including exercise, diet, alcohol and smoking, on the incidence of non-communicable diseases at local, national and global levels

- evaluate some different treatments for cardiovascular disease.

Use of mathematics

- translate information between graphical and numerical forms (4a)

- construct and interpret frequency tables and diagrams, bar charts and histograms (2c)

- understand the principles of sampling as applied to scientific data (2d)

- use a scatter diagram to identify a correlation between two variables (2g)

- calculate cross-sectional areas of bacterial cultures and clear agar jelly using πr^2 (5c).

Coordination and control

Nervous coordination and control in humans

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

- explain how the structure of a reflex arc is related to its function.

Hormonal coordination and control in humans

- describe the principles of hormonal coordination and control by the human endocrine system

- <u>explain the roles of thyroxine and adrenaline in the body as examples of negative feedback systems</u>

- describe the roles of hormones in human reproduction, including the menstrual cycle
- explain the interactions of FSH, LH, oestrogen and progesterone in the control of the menstrual cycle
- explain the use of hormones in contraception and evaluate hormonal and non-hormonal methods of contraception
- explain the use of hormones in modern reproductive technologies to treat infertility.

Homeostasis in humans

- explain the importance of maintaining a constant internal environment in response to internal and external change
- explain how insulin controls blood sugar levels in the body
- explain how glucagon interacts with insulin to control blood sugar levels in the body
- compare type 1 and type 2 diabetes and explain how they can be treated.

Use of mathematics

- extract and interpret data from graphs, charts and tables (2c)
- translate information between numerical and graphical forms (4a).

Photosynthesis

Importance of photosynthesis

- describe the process of photosynthesis and describe photosynthesis as an endothermic reaction
- describe photosynthetic organisms as the main producers of food and therefore biomass for life on Earth
- explain the effect of temperature, light intensity and carbon dioxide concentration on the rate of photosynthesis
- explain the interaction of these factors in limiting the rate of photosynthesis.

Use of mathematics

- understand and use simple compound measures such as the rate of a reaction (1a and 1c)

- translate information between graphical and numerical form (4a)
- plot and draw appropriate graphs, selecting appropriate scales for axes (4a and 4c)
- extract and interpret information from graphs, charts and tables (2c and 4a)
- <u>understand and use inverse proportion – the inverse square law and light intensity in the context of factors affecting photosynthesis.</u>

Ecosystems

Levels of organisation within an ecosystem

- describe different levels of organisation in an ecosystem from individual organisms to the whole ecosystem
- explain how some abiotic and biotic factors affect communities
- describe the importance of interdependence and competition in a community.

The principle of material cycling

- recall that many different materials cycle through the abiotic and biotic components of an ecosystem
- explain the importance of the carbon cycle and the water cycle to living organisms
- explain the role of microorganisms in the cycling of materials through an ecosystem.

Biodiversity

- describe how to carry out a field investigation into the distribution and abundance of organisms in an ecosystem and explain how to determine their numbers in a given area
- describe both positive and negative human interactions within ecosystems and explain their impact on biodiversity
- explain some of the benefits and challenges of maintaining local and global biodiversity.

Use of mathematics

- calculate the percentage of mass (1c)
- calculate arithmetic means (2b)

- understand and use percentiles (1c)
- plot and draw appropriate graphs selecting appropriate scales for the axes (4a and 4c)
- extract and interpret information from charts, graphs and tables (2c and 4a).

Inheritance, variation and evolution

The genome and gene expression

- describe DNA as a polymer made up of two strands forming a double helix
- describe the genome as the entire genetic material of an organism
- explain the following terms: gamete, chromosome, gene, allele/variant, dominant, recessive, homozygous, heterozygous, genotype and phenotype
- describe simply how the genome, and its interaction with the environment, influence the development of the phenotype of an organism
- discuss the potential importance for medicine of our increasing understanding of the human genome.

Inheritance

- explain single gene inheritance
- predict the results of single gene crosses
- recall that most phenotypic features are the result of multiple genes rather than single gene inheritance
- describe sex determination in humans.

Variation and evolution

- state that there is usually extensive genetic variation within a population of a species
- recall that all variants arise from mutations, and that most have no effect on the phenotype, some influence phenotype and a very few determine phenotype
- 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

- explain how evolution occurs through natural selection of variants that give rise to phenotypes best suited to their environment
- describe the evidence for evolution, including fossils and antibiotic resistance in bacteria
- describe the impact of developments in biology on classification systems.

Selective breeding and gene technology

- explain the impact of the selective breeding of food plants and domesticated animals
- describe genetic engineering as a process which involves modifying the genome of an organism to introduce desirable characteristics
- <u>describe the main steps in the process of genetic engineering</u>
- explain some of the possible benefits and risks, including practical and ethical considerations, of using gene technology in modern agriculture and medicine.

Use of mathematics

- Understand and use direct proportions and simple ratios in genetic crosses (1c)
- Understand and use the concept of probability in predicting the outcome of genetic crosses (2e)
- Extract and interpret information from charts, graphs and tables (2c and 4a).

Chemistry

Chemistry is the science of the composition, structure, properties and reactions of matter, understood in terms of atoms, atomic particles and the way they are arranged and link together. It is concerned with the synthesis, formulation, analysis and characteristic properties of substances and materials of all kinds.

Students 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 set out below. These ideas 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.

This content sets out the full range of content for the chemistry component of GCSE combined science. Awarding organisations may, however, use flexibility to increase depth, breadth or context within the specified topics or to consolidate teaching of the subject content.

Bullet points in bold are common to physics

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GCSE combined science specifications should require students to:

Atomic structure and the Periodic Table

A simple model of the atom, relative atomic mass, electronic charge and isotopes

- **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 most of the mass in the nucleus**
- **recall the typical size (order of magnitude) of atoms and small molecules**
- **describe how and why the atomic model has changed over time**
- recall relative charges and approximate relative masses of protons, neutrons and electrons
- calculate numbers of protons, neutrons and electrons in atoms and ions, given atomic number and mass number of isotopes.

The modern Periodic Table

- 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
- explain in terms of isotopes how this changes the arrangement proposed by Mendeleev
- use the names and symbols of the first 20 elements, Groups 1, 7 and 0 and other common elements from a supplied Periodic Table to write formulae and balanced chemical equations where appropriate
- explain how the reactions of elements are related to the arrangement of electrons in their atoms and hence to their atomic number
- recall the simple properties of Groups 1, 7 and 0
- explain how observed simple properties of Groups 1,7 and 0 depend on the outer shell of electrons of the atoms and predict properties from given trends down the groups
- predict possible reactions and probable reactivity of elements from their positions in the Periodic Table

- describe metals and non-metals and explain the differences between them on the basis of their characteristic physical and chemical properties
- explain how the atomic structure of metals and non-metals relates to their position in the Periodic Table.

Structure, bonding and the properties of matter

States of matter and change of state in terms of particle kinetics, energy transfers and the relative strength of chemical bonds and intermolecular forces

- recall and explain the main features of the particle model in terms of the states of matter and change of state, distinguishing between physical and chemical changes
- explain the limitations of the particle model in relation to changes of state when particles are represented by inelastic spheres
- 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
- use data to predict states of substances under given conditions.

Different kinds of chemical bonds: ionic, covalent and metallic bonding

- describe and compare the nature and arrangement of chemical bonds in ionic compounds, simple molecules, giant covalent structures, polymers and metals
- explain chemical bonding in terms of electrostatic forces and the transfer or sharing of electrons
- construct dot and cross diagrams for simple ionic and covalent substances
- describe the limitations of particular representations and models to include dot and cross diagrams, ball and stick models and two and three dimensional representations
- explain how the bulk properties of materials are related to the different types of bonds they contain, their bond strengths in relation to intermolecular forces and the ways in which their bonds are arranged, recognising that the atoms themselves do not have these properties.

Structure and bonding of carbon

- recall that carbon can form four covalent bonds

- explain that the vast array of natural and synthetic organic compounds occur due to the ability of carbon to form families of similar compounds, chains and rings
- explain the properties of diamond, graphite, fullerenes and graphene in terms of their structures and bonding.

Use of mathematics

- relate size and scale of atoms to objects in the physical world (1d)
- translate information between diagrammatic and numerical forms (4a)
- represent three dimensional shapes in two dimensions and vice versa when looking at chemical structures e.g. allotropes of carbon (5b)
- estimate size and scale of atoms (1d).

Chemical changes

Chemical symbols, formulae and equations

- use chemical symbols to write the formulae of elements and simple covalent and ionic compounds
- deduce the empirical formula of a compound from the relative numbers of atoms present or from a model or diagram and vice versa
- use the names and symbols of common elements and compounds and the principle of conservation of mass to write formulae and balanced chemical equations and half equations
- use the formulae of common ions to deduce the formula of a compound and write balanced ionic equations
- describe the physical states of products and reactants using state symbols (s, l, g and aq).

Identification of common gases

- describe tests to identify selected gases including oxygen, hydrogen, carbon dioxide and chlorine.

Chemistry of acids

- recall that acids react with some metals and with carbonates and write equations predicting products from given reactants
- recall that acids form hydrogen ions when they dissolve in water and solutions of

alkalis contain hydroxide ions

- recall that relative acidity and alkalinity are measured by pH
- describe neutralisation as acid reacting with alkali to form a salt plus water
- recognise that aqueous neutralisation reactions can be generalised to hydrogen ions reacting with hydroxide ions to form water
- use and explain the terms dilute and concentrated (amount of substance) and weak and strong (degree of ionisation) in relation to acids
- recall that as hydrogen ion concentration increases by a factor of ten the pH value of a solution decreases by a factor of one
- 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).

A reactivity series of metals as the tendency of a metal to form its positive ion

- explain how the reactivity of metals with water or dilute acids is related to the tendency of the metal to form its positive ion
- deduce an order of reactivity of metals based on experimental results.

Electrolysis of various molten ionic liquids and aqueous ionic solutions

- describe electrolysis in terms of the ions present and reactions at the electrodes
- recall that metals (or hydrogen) are formed at the cathode and non-metals are formed at the anode in electrolysis using inert electrodes
- predict the products of electrolysis of binary ionic compounds in the molten state
- describe competing reactions in the electrolysis of aqueous solutions of ionic compounds in terms of the different species present.

Redox reactions (reduction and oxidation)

- explain reduction and oxidation in terms of loss or gain of oxygen, identifying which species are oxidised and which are reduced
- explain reduction and oxidation in terms of gain or loss of electrons, identifying which species are oxidised and which are reduced.

Use of mathematics

- arithmetic computation and ratio when determining empirical formulae, balancing equations (1a and 1c).

Energy changes in chemistry

Exothermic and endothermic reactions, including reaction profiles

- distinguish between endothermic and exothermic reactions on the basis of the temperature change of the surroundings
- draw and label a reaction profile for an exothermic and an endothermic reaction, identifying activation energy
- explain activation energy as the energy needed for a reaction to occur
- <u>calculate energy changes in a chemical reaction by considering bond making and bond breaking energies.</u>

Carbon compounds both as fuels and feedstock

- recall that crude oil is a main source of hydrocarbons and is a feedstock for the petrochemical industry
- explain how modern life is crucially dependent upon hydrocarbons and recognise that crude oil is a finite resource.

Uses of mathematics

- arithmetic computation when calculating energy changes (1a)
- interpretation of charts and graphs when dealing with reaction profiles (4a).

The rate and extent of chemical change

Factors that influence the rate of reaction, including catalysts

- suggest practical methods for determining the rate of a given reaction
- interpret rate of reaction graphs
- describe the effect of changes in temperature, concentration, pressure, and surface area on rate of reaction
- explain the effects on rates of reaction of changes in temperature, concentration and pressure in terms of frequency and energy of collision between particles
- 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

- describe the characteristics of catalysts and their effect on rates of reaction
- identify catalysts in reactions
- explain catalytic action in terms of activation energy
- recall that enzymes act as catalysts in biological systems.

Reversible reactions and the concept of dynamic equilibrium

- recall that some reactions may be reversed by altering the reaction conditions
- recall that dynamic equilibrium occurs when the rates of forward and reverse reactions are equal
- predict the effect of changing reaction conditions (concentration, temperature and pressure) on equilibrium position and suggest appropriate conditions to produce a particular product.

Uses of mathematics

- arithmetic computation, ratio when measuring rates of reaction (1a and 1c)
- drawing and interpreting appropriate graphs from data to determine rate of reaction (4b and 4c)
- determining gradients of graphs as a measure of rate of change to determine rate (4d and 4e)
- proportionality when comparing factors affecting rate of reaction (1c).

Chemical analysis

Assessing purity and separating mixtures

- explain what is meant by the purity of a substance, distinguishing between the scientific and everyday use of the term ‘pure’
- explain that many useful materials are formulations of mixtures
- describe, explain and exemplify the processes of filtration, crystallisation, simple distillation, and fractional distillation
- recall that chromatography involves a stationary and a mobile phase and that separation depends on the distribution between the phases
- interpret chromatograms, including measuring Rf values
- suggest suitable purification techniques given information about the substances

involved

- use melting point data to distinguish pure from impure substances
- suggest chromatographic methods for distinguishing pure from impure substances.

Conservation of mass and the quantitative interpretation of balanced equations

- recall and use the law of conservation of mass
- explain any observed changes in mass in non-enclosed systems during a chemical reaction and explain them using the particle model
- calculate relative formula masses of species separately and in a balanced chemical equation.

Use of amount of substance in relation to masses of pure substances

- recall and use the definitions of the Avogadro constant (in standard form) and of the mole
- explain how the mass of a given substance is related to the amount of that substance in moles and vice versa
- deduce the stoichiometry of an equation from the masses of reactants and products and explain the effect of a limiting quantity of a reactant
- use a balanced equation to calculate masses of reactants or products
- explain how the mass of a solute and the volume of the solution is related to the concentration of the solution.

Use of mathematics

- arithmetic computation, ratio, percentage and multistep calculations permeates quantitative chemistry (1a, 1c and 1d)
- calculations with numbers written in standard form when using the Avogadro constant (1b)
- change the subject of a mathematical equation (3b and 3c)
- provide answers to an appropriate number of significant figures (2a)
- convert units where appropriate particularly from mass to moles (1c)
- interpret charts, particularly in spectroscopy (4a).

Chemical and allied industries

Life cycle assessment and recycling

- describe the basic principles in carrying out a life-cycle assessment of a material or product
- interpret data from a life-cycle assessment of a material or product
- describe a process where a material or product is recycled for a different use, and explain why this is viable
- evaluate factors that affect decisions on recycling.

Fractional distillation of crude oil and cracking

- describe and explain the separation of crude oil by fractional distillation
- describe the fractions as largely a mixture of compounds of formula C_nH_{2n+2} which are members of the alkane homologous series
- describe the production of materials that are more useful by cracking.

Different methods of extracting and purifying metals with reference to a reactivity series with oxygen and the position of carbon within it

- explain, using the position of carbon in the reactivity series, the principles of industrial processes used to extract metals, including extraction of a non-ferrous metal
- explain why and how electrolysis is used to extract some metals from their ores
- evaluate alternative biological methods of metal extraction (bacterial and phytoextraction).

Earth and atmospheric science

The composition and evolution of the Earth's atmosphere since its formation

- interpret evidence for how it is thought the atmosphere was originally formed
- describe how it is thought an oxygen-rich atmosphere developed over time.

Carbon dioxide and methane as greenhouse gases

- describe the greenhouse effect in terms of the interaction of radiation with matter
- evaluate the evidence for additional anthropogenic 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

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

Common atmospheric pollutants and their sources

- 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.

The Earth's water resources and obtaining potable water

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

Use of mathematics

- extract and interpret information from charts, graphs and tables (2c and 4a)
- use orders of magnitude to evaluate the significance of data (2h).

Physics

Physics is the science of the fundamental concepts of field, force, radiation and particle structures, which are inter-linked to form unified models of the behaviour of the material universe. From such models, a wide range of ideas, from the broadest issue of the development of the universe over time to the numerous and detailed ways in which new technologies may be invented, have emerged. These have enriched both our basic understanding of, and our many adaptations to, our material environment.

Students 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 set out below. These ideas 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.

This content sets out the full range of content for the physics component of GCSE combined science. Awarding organisations may, however, use flexibility to increase depth, breadth or context within the specified topics or to consolidate teaching of the subject content.

Bullett points in bold are common to chemistry

Higher tier GCSE combined science specifications must assess all the content set out below, whether it is underlined or is not underlined. Foundation tier GCSE combined science specifications must assess all the content set out below, except for content which is underlined.

GCSE combined science specifications should require students to:

Energy

Energy changes in a system, and in the ways energy is stored before and after such changes

- calculate the amounts of energy associated with a moving body, a stretched spring, and an object raised above ground level
- describe and calculate the changes in energy involved when a system is changed by heating (in terms of temperature change and specific heat capacity), by work done by forces and by work done when a current flows
- explain, with reference to examples, the definition of power as the rate at which energy is transferred
- describe all the changes involved in the way energy is stored when a system changes, for common situations: appropriate examples might be 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
- describe, with examples, the relationship between the power ratings for domestic electrical appliances and the changes in stored energy when they are in use.

Conservation, dissipation and national and global energy sources

- describe with examples where there are energy transfers in a system, that there is no net change to the total energy of a closed system (qualitative only)
- describe, with examples, how in all system changes, energy is dissipated, so that it is stored in less useful ways
- 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)
- calculate energy efficiency for any energy transfer, <u>and describe ways to increase efficiency</u>
- describe the main energy sources available for use on Earth (including 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
- explain patterns and trends in the use of energy resources.

Uses of mathematics

- make calculations of the energy changes associated with changes in a system, recalling or selecting the relevant equations for mechanical, electrical, and thermal processes; thereby express in quantitative form and on a common scale the overall redistribution of energy in the system (1a, 1c, 3c).

Forces

Forces and their interactions

- recall examples of ways in which objects interact: by gravity, electrostatics, magnetism and by contact (including normal contact force and friction), and describe how such examples involve interactions between pairs of objects which produce a force on each object; represent such forces as vectors

- define weight, describe how it is measured and describe the relationship between the weight of that body and the gravitational field strength

- <u>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 (qualitative only)</u>

- explain, with examples, that stretch, bend or compress an object, more than one force has to be applied

- 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 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.

Work done as force x distance, energy transfer

- use the relationship between work done, force, and distance moved along the line of action of the force and describe the energy transfer involved.

Uses of mathematics

- <u>use vector diagrams to illustrate resolution of forces, a net force, and equilibrium situations (scale drawings only) (4a, 5a, 5b)</u>

- calculate relevant values of stored energy and energy transfers; convert between newton-metres and joules (1c, 3c).

Forces and motion

Speed and velocity, speed as distance over time; acceleration; distance-time and velocity-time graphs

- explain the vector-scalar distinction as it applies to displacement, distance, velocity and speed
- 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 and estimate the magnitudes of everyday accelerations
- explain with examples that motion in a circular orbit involves constant speed but changing velocity (qualitative only)
- make measurements of distances and times, calculate speeds, and make and use graphs of these to determine the speeds and accelerations involved.

Forces, accelerations and Newton's laws of motion

- apply Newton's First Law to explain the motion of objects moving with uniform velocity and also objects where the speed and/or direction change
- apply Newton's Second Law in calculations relating forces, masses and accelerations
- 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
- recall Newton's Third Law and apply it to examples of equilibrium situations
- define momentum and describe examples of momentum in collisions.

Safety in public transport

- explain methods of measuring human reaction times and recall typical results
- explain the factors which affect the distance required for road transport vehicles to come to rest in emergencies and the implications for safety
- explain the dangers caused by large decelerations and estimate the forces involved in typical situations on a public road.

Uses of mathematics

- make calculations using ratios and proportional reasoning to convert units and to compute rates (1c, 3c)
- relate changes and differences in motion to appropriate distance-time, and

velocity-time graphs, and interpret lines and slopes (4a, 4b, 4c, 4d)

- interpret enclosed areas in distance-time and velocity-time graphs (4a, 4b, 4c, 4d, 4f)
- apply formulae relating distance, time and speed, for uniform motion, and for motion with uniform acceleration, and calculate average speed for non-uniform motion (1a, 1c, 2b, 3c).

Waves in matter

Waves in air, fluids and solids

- describe wave motion in terms of amplitude, wavelength, frequency and period; define wavelength and frequency and describe and apply the relationship between these and the wave velocity
- describe the difference between transverse and longitudinal waves
- describe how ripples on water surfaces are examples of transverse waves whilst sound waves in air are longitudinal waves, and how the speed of each may be measured; describe evidence that in both cases it is the wave and not the water or air itself that travels.

Uses of mathematics

- apply formulae relating velocity, frequency and wavelength (1c, 3c).

Light and electromagnetic waves

Frequency range of the spectrum

- recall that light is an electromagnetic wave
- 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 source to absorber
- describe the main groupings of the spectrum – radio, microwave, infra-red, visible (red to violet), ultra-violet, 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.

Interactions of electromagnetic radiation with matter and their applications

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

- recall that radio waves can be produced by or can themselves induce oscillations in electrical circuits

- recall that changes in atoms and nuclei can also generate and absorb radiations over a wide frequency range

- give examples of some practical uses of electromagnetic waves in the radio, micro-wave, infra-red, visible, ultra-violet, X-ray and gamma-ray regions and describe how ultra-violet waves, X-rays and gamma-rays can have hazardous effects, notably on human bodily tissues.

Uses of mathematics

- apply the relationships between frequency and wavelength across the electromagnetic spectrum: (1a, 1c, 3c).

Electricity

Current, potential difference and resistance

- recall that current is a rate of flow of charge, that for a 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; recall and use the relationship between quantity of charge, current and time

- recall that current (I) depends on both resistance (R) and potential difference (V) and the units in which these are measured; recall and apply the relationship between I, R and V, and explain that for some resistors the value of R remains constant but that in others it can change as the current changes; explain the design and use of circuits to explore such effects – including for lamps, diodes, thermistors and LDRs.

Series and parallel circuits

- describe the difference between series and parallel circuits, explain why, if two resistors are in series the net resistance is increased, whereas with two in parallel the net resistance is decreased (qualitative explanation only)

- calculate the currents, potential differences and resistances 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.

Domestic uses and safety

- recall that the domestic supply in the UK is a.c., at 50Hz and about 230 volts, explain the difference between direct and alternating voltage

- 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.

Energy transfers

- 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
- 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
- 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.

Uses of mathematics

- apply the equations relating p.d., current, quantity of charge, resistance, power, energy, and time, and solve problems for circuits which include resistors in series, using the concept of equivalent resistance (1c, 3b, 3c, 3d)
- use graphs to explore whether circuit elements are linear or non-linear and relate the curves produced to their function and properties (4c, 4d).

Magnetism and electromagnetism

Permanent and induced magnetism, magnetic forces and fields

- describe the attraction and repulsion between unlike and like poles for permanent magnets and describe the difference between permanent and induced magnets
- describe the characteristics of the magnetic field of a magnet, showing how strength and direction change from one point to another
- explain how the behaviour of a magnetic compass is related to evidence that the core of the Earth must be magnetic.

Magnetic effects of currents and the motor effect

- describe how to show that a current can create a magnetic effect and describe the directions of the magnetic field around a conducting wire
- 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

- describe how a magnet and a current-carrying conductor exert a force on one another and show that Fleming's left-hand rule represents the relative orientations of the force, the conductor and the magnetic field

- apply the equation that links the force on a conductor to the magnetic flux density, the current and the length of conductor to calculate the forces involved

- explain how this force is used to cause rotation in electric motors.

Particle model of matter

Changes of state and the particle model

- define density and explain the differences in density between the different states of matter in terms of the arrangements of the atoms or molecules

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

Internal energy, energy transfers and particle motions

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

- define the term specific heat capacity and distinguish between it and and the term specific latent heat

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

Uses of mathematics

- apply the relationship between density mass and volume to changes where mass is conserved (1a, 1b, 1c, 3c)

- apply the relationship between change in internal energy of a material and its mass, specific heat capacity and temperature change to calculate the energy change involved; apply the relationship between specific latent heat and mass to calculate the energy change involved in a change of state (1a, 3c, 3d).

Atomic structure

Nuclear atom and isotopes

- **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**

- **recall the typical size (order of magnitude) of atoms and small molecules**

- **describe how and why the atomic model has changed over time**

- 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 elements can differ in nuclear mass by having different numbers of neutrons

- relate differences between isotopes to differences in conventional representations of their identities, charges and masses.

Absorption and emission of ionizing radiations and of electrons and nuclear particles

- 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

- 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

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

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

- recall the differences in the penetration properties of alpha-particles, beta-particles and gamma-rays

- recall the differences between contamination and irradiation effects and compare the hazards associated with these two.

Uses of mathematics

- balance equations representing alpha-, beta- or gamma-radiations in terms of the masses, and charges of the atoms involved (1b, 1c, 3c)

- <u>calculate the net decline, expressed as a ratio, in a radioactive emission after a given number of half-lives (1c, 3d)</u>.

Appendix 1

Equations in physics

Equations required for higher tier only are underlined

(a) In solving quantitative problems, students should be able correctly to recall, and apply the following relationships, using standard S.I. units:

force = mass x acceleration

kinetic energy = 0.5 x mass x $(\text{acceleration})^2$

<u>momentum = mass x velocity</u>

work done = force x distance (along the line of action of the force)

power = work done ÷ time

efficiency = output energy transfer ÷ input energy transfer

gravity force = mass x gravity constant (g)

In a gravity field: potential energy = mass x height x gravity constant (g)

force exerted by a spring = extension x spring constant

distance travelled = speed x time

acceleration = change in velocity ÷time

wave speed = frequency x wavelength

charge flow = current x time

potential difference = current x resistance

power = potential difference x current = $(\text{current})^2$ x resistance

energy transferred = power x time = charge flow x potential difference

density = mass ÷volume

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

$(\text{final velocity})^2$ - $(\text{initial velocity})^2$ = 2 x acceleration x distance

change in thermal energy = m x specific heat capacity x change in temperature thermal energy for a change of state = m x specific latent heat

energy transferred in stretching = 0.5 x spring constant x $(\text{extension})^2$

potential difference across primary coil x current in primary coil = potential difference across secondary coil x current in secondary coil

force on a conductor (at right angles to a magnetic field) carrying a current: = magnetic flux density x current x length

for gases: pressure x volume = constant (for a given mass of gas and at a constant temperature)

Appendix 2

SI units in science

The International System of Units (Système International d'Unités), which is abbreviated SI, is a coherent system of base units. The six which are relevant for GCSE sciences are listed below. We also list eight of the derived units (which have special names) selected from the SI list of derived units in the same source.

Base units

These units and their associated quantities are dimensionally independent.

metre
Unit symbol: **m**

kilogram
Unit symbol: **kg**

second
Unit symbol: **s**

ampere
Unit symbol: **A**

kelvin
Unit symbol: **K**

mole
Unit symbol: **mol**

Some derived units with special names

Frequency hertz Hz
Force newton N
Energy joule J
Power watt W
Pressure pascal Pa
Electric charge coulomb C
Electric potential difference volt V
Electric resistance ohm Ω
Magnetic flux density tesla B

Appendix 3

Mathematical skills required for biology (B), chemistry (C), physics (P) and combined science (CS)

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

Appendix 4

List of apparatus and techniques

The following list includes 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 students 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.

	BIOLOGY	CHEMISTRY	PHYSICS
1	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	Use of appropriate apparatus to make and record a range of measurements accurately, including mass, time, temperature, and volume of liquids and gases	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.
2	Safe use of appropriate heating devices and techniques including use of a Bunsen burner and a water bath or electric heater	Safe use of appropriate heating devices and techniques including use of a Bunsen burner and a water bath or electric heater	Use of appropriate apparatus to measure and observe the effects of forces including the extension of springs
3	Use of appropriate apparatus and techniques for the observation and measurement of biological changes and/or processes	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	Use of appropriate apparatus and techniques for measuring motion, including determination of speed and rate of change of speed (acceleration/deceleration)
4	Safe and ethical use of living organisms (plants or animals) to measure physiological functions and responses to the environment	Safe use of a range of equipment to purify and/or separate chemical mixtures including evaporation, filtration, crystallisation, chromatography and distillation	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.
5	Measurement of rates of reaction by a variety of methods including production of gas, uptake of water and colour change of indicator	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	Safe use of appropriate apparatus in a range of contexts to measure energy changes/transfers and associated values such as work done
6	Application of appropriate sampling techniques to investigate the distribution and abundance of organisms in an ecosystem via direct use in the field	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	Use of appropriate apparatus to measure current, potential difference (voltage) and resistance, and to explore the characteristics of a variety of circuit elements
7	Use of appropriate apparatus, techniques and magnification, including microscopes, to make observations of biological specimens and produce labelled scientific drawings	Use of appropriate apparatus and techniques to draw, set up and use electrochemical cells for separation and production of elements and compounds	Use of circuit diagrams to construct and check series and parallel circuits including a variety of common circuit elements

	BIOLOGY	CHEMISTRY	PHYSICS
	SINGLE SCIENCES ONLY		
8	Use of appropriate techniques and qualitative reagents to identify biological molecules and processes in more complex and problem-solving contexts including continuous sampling in an investigation.	Use of appropriate qualitative reagents and techniques to analyse and identify unknown samples or products including gas tests, flame tests, precipitation reactions, and the determination of concentrations of strong acids and strong alkalis	Making observations of waves in fluids and solids to identify the suitability of apparatus to measure the effects of the interaction of waves with matter.

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Reference: DFE-00351-2014

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