# Raedwald Trust KS4 Science Programme of Study - Combined Science

These GCSE subject content criteria set 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. The full AQA Combined Science: Synergy GCSE content taught at The Raedwald Trust, is listed below.

## Working Scientifically

***All of the below skills are taught throughout this Programme of Study, within the separate units. The lists below are for reference only and should only be taught explicitly if a significant difficulty with certain aspects are identified, to help a student to close any gaps in learning.***

| Previous Learning at Key Stage 3 | Foundation AQA Synergy GCSE | Higher AQA Synergy GCSE – Extra content on top of Foundation content |
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| **1. Scientific attitudes**<br>• Pay attention to objectivity and concern for accuracy, precision, repeatability and reproducibility<br>• Understand that scientific methods and theories develop as earlier explanations are modified to take account of new evidence and ideas, together with the importance of publishing results and peer review evaluate risks<br><br>**2. Experimental skills and investigations**<br>• Ask questions and develop a line of enquiry based on observations of the real world, alongside prior knowledge and experience<br>• Make predictions using scientific knowledge and understanding<br>• Select, plan and carry out the most appropriate types of scientific enquiries to test predictions, including identifying independent, dependent and control variables<br>• Use appropriate techniques, apparatus, and materials during fieldwork and laboratory work, paying attention to health and safety<br>• Make and record observations and measurements using a range of methods for different investigations; and evaluate the reliability of methods and suggest possible improvements<br>• Apply sampling techniques | **1 Development of Scientific Thinking**<br>WS 1.1 Understand how scientific methods and theories develop over time.<br>WS 1.2 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.<br>WS 1.3 Appreciate the power and limitations of science and consider any ethical issues which may arise.<br>WS 1.4 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.<br>WS 1.5 Evaluate risks both in practical science and the wider societal context, including perception of risk in relation to data and consequences.<br>WS 1.6 Recognise the importance of peer review of results and of communicating results to a range of audiences.<br><br>**2 Experimental Skills and Strategies**<br>WS 2.1 Use scientific theories and explanations to develop hypotheses.<br>WS 2.2 Plan experiments or devise procedures to make observations, produce or characterise a substance, test hypotheses, check data or explore phenomena.<br>WS 2.3 Apply a knowledge of a range of techniques, instruments, apparatus, and materials to select those appropriate to the experiment. | All aspects of working scientifically are in both the Foundation and Higher Assessments. |

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| **3. Analysis and evaluation**<br>• Apply mathematical concepts and calculate results<br>• Present observations and data using appropriate methods, including tables and graphs<br>• Interpret observations and data, including identifying patterns and using observations, measurements and data to draw conclusions<br>• Present reasoned explanations, including explaining data in relation to predictions and hypotheses<br>• Evaluate data, showing awareness of potential sources of random and systematic error<br>• Identify further questions arising from their results<br><br>**4. Measurement**<br>• Understand and use SI units and IUPAC (International Union of Pure and Applied Chemistry) chemical nomenclature<br>• Use and derive simple equations and carry out appropriate calculations<br>• Undertake basic data analysis including simple statistical techniques | WS 2.4 Carry out experiments appropriately having due regard for the correct manipulation of apparatus, the accuracy of measurements and health and safety considerations.<br>WS 2.5 Recognise when to apply a knowledge of sampling techniques to ensure any samples collected are representative.<br>WS 2.6 Make and record observations and measurements using a range of apparatus and methods<br>WS 2.7 Evaluate methods and suggest possible improvements and further investigations.<br><br>**3 Analysis and Evaluation**<br>WS 3.1 Presenting observations and other data using appropriate methods.<br>WS 3.2 Translating data from one form to another.<br>WS 3.3 Carrying out and represent mathematical and statistical analysis.<br>WS 3.4 Representing distributions of results and make estimations of uncertainty.<br>WS 3.5 Interpreting observations and other data (presented in verbal, diagrammatic, graphical, symbolic or numerical form), including identifying patterns and trends, making inferences and drawing conclusions.<br>WS 3.6 Presenting reasoned explanations including relating data to hypotheses.<br>WS 3.7 Being objective, evaluating data in terms of accuracy, precision, repeatability and reproducibility and identifying potential sources of random and systematic error<br>WS 3.8 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. | |

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| | 4 **Scientific Vocabulary, quantities, units, symbols and nomenclature.**<br><br>WS 4.1 Use scientific vocabulary, terminology and definitions.<br>WS 4.2 Recognise the importance of scientific quantities and understand how they are determined.<br>WS 4.3 Use SI units (eg kg, g, mg; km, m, mm; kJ, J) and IUPAC chemical nomenclature unless inappropriate.<br>WS 4.4 Use prefixes and powers of ten for orders of magnitude (eg tera, giga, mega, kilo, centi, milli, micro and nano).<br>WS 4.5 Interconvert units.<br>WS 4.6 Use an appropriate number of significant figures in calculation. | |

## UNIT 1: Building Blocks (NC Atomic structure and the Periodic Table)

| Previous Learning at Key Stage 3 | Foundation AQA Synergy GCSE | Higher AQA Synergy GCSE – Extra content on top of Foundation content |
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| **The particulate nature of matter**<br>• the properties of the different states of matter (solid, liquid and gas) in terms of the particle model, including gas pressure<br>• changes of state in terms of the particle model | **Chemistry**<br>***4.1 Building blocks***<br>**4.1.1 States of matter**<br>4.1.1.1 A particle model<br>• 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.<br><br>Scientific, practical and mathematical skills<br>• WS 1.2 Recognise/draw simple diagrams to model the difference between substances in the solid, liquid and gas states. | • Explain the limitations of the particle model in relation to changes of state when particles are represented by inelastic spheres |

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| **Pure and impure substances**<br>• the concept of a pure substance<br>• mixtures, including dissolving<br>• diffusion in terms of the particle model<br>• simple techniques for separating mixtures: filtration, evaporation, distillation and chromatography<br>• the identification of pure substances | • WS 3.5 Predict the states of substances at different temperatures given appropriate data.<br>• MS 1d Relate the size and scale of atoms to objects in the physical world.<br><br>4.1.1.2 Density<br>• Define density and explain the differences in density between the different states of matter in terms of the arrangements of the atoms or molecules.<br><br>Scientific, practical and mathematical skills<br>• MS 1a, 1b, 1c, 3c Recall and apply this equation to changes where mass is conserved.<br>• WS 3.3 Carry out and represent mathematical and statistical analysis.<br>• WS 4.3, 4.5 Use and interconvert SI units in calculations.<br><br>4.1.1.3 Gas pressure<br>• 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).<br><br>4.1.1.4 Heating and changes of state<br>• Describe how heating a system will change the energy stored within the system and raise its temperature or produce changes of state.<br>• 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.<br>• Define the term specific heat capacity and distinguish between it and the term specific latent heat. | |

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| | • Describe and calculate the changes in energy involved when a system is changed by heating (in terms of temperature change and specific heat capacity).<br><br>Scientific, practical and mathematical skills<br>• WS 3.3 Carry out and represent mathematical and statistical analysis.<br>• WS 3.5, MS 4a Interpret heating and cooling graphs that include changes of state.<br>• WS 4.3, 4.5, MS 1a, 3c, 3d Apply this equation, which is given on the Physics equations sheet, to calculate energy changes when a material is heated or cooled.<br><br>4.1.1.5 Meanings of purity<br>• Explain what is meant by the purity of a substance, distinguishing between the scientific and everyday use of the term 'pure'<br><br>Scientific, practical and mathematical skills<br>• WS 3.5 Use melting point data to distinguish pure from impure substances.<br><br>**4.1.2 Atomic structure**<br>4.1.2.1 Scientific models of the atom<br>• Describe how and why the atomic model has changed over time.<br>Scientific, practical and mathematical skills<br>• WS 1.1 Explain, with examples, why new data from experiments or observations led to changes in atomic models.<br>• Decide whether or not given data supports a particular theory.<br><br>4.1.2.2 The size of atoms<br>• Recall the typical size (order of magnitude) of atoms and small molecules. | |
| **Atoms, elements and compounds**<br>• a simple (Dalton) atomic model<br>• differences between atoms, elements and compounds<br>• chemical symbols and formulae for elements and compounds<br>• conservation of mass changes of state and chemical reactions | | |

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| | Scientific, practical and mathematical skills<br>• MS 1b Interpret expressions in standard form.<br>• WS 4.4 Use SI units and the prefix nano.<br>• MS 1d Estimate the size of atoms based on scale diagrams.<br><br>4.1.2.3 Sub-atomic particles<br>• 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.<br>• Recall that atomic nuclei are composed of both protons and neutrons, that the nucleus of each element has a characteristic positive charge, but that elements can differ in nuclear mass by having different numbers of neutrons.<br>• Recall relative charges and approximate relative masses of protons, neutrons and electrons.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Interpret and draw diagrams to represent atoms.<br><br>4.1.2.4 Isotopes<br>• Relate differences between isotopes to differences in conventional representations of their identities, charges and masses.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Work out numbers of protons, neutrons and electrons in atoms and ions, given atomic number and mass number of isotopes.<br><br>4.1.2.5 Electrons in atoms<br>• Recall that in each atom its electrons are arranged at different distances from the nucleus. | *Students should be able to describe ways to increase the efficiency of an intended energy transfer. |

# UNIT 1: Building Blocks NC Cell Biology)

| Previous Learning at Key Stage 3 | Foundation AQA Synergy GCSE | Higher AQA Synergy GCSE – Extra content on top of Foundation content |
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| **Cells and organisation**<br>• Cells as the fundamental unit of living organisms, including how to observe, interpret and record cell structure using a light microscope<br>• The functions of the cell wall, cell membrane, cytoplasm, nucleus, vacuole, mitochondria and chloroplasts<br>• The similarities and differences between plant and animal cells<br>• The role of diffusion in the movement of materials in and between cells<br>• The structural adaptations of some unicellular organisms<br>• The hierarchical organisation of multicellular organisms: from cells to tissues to organs to systems to organisms | **Biology**<br>**4.1.3 Cells in animals and plants**<br>4.1.3.1 Electron microscopy<br>• Explain how electron microscopy has increased our understanding of subcellular structures.<br>Scientific, practical and mathematical skills<br>• MS 2a, 2h Demonstrate understanding of number, size and scale and the quantitative relationship between units.<br>• WS 4.5 Interconvert units.<br>• MS 1a,1b, 1c, 2h Carry out calculations involving magnification, real size and image size including numbers written in standard form.<br>• WS 3.3 Carry out and represent mathematical and statistical analysis.<br>• WS 4.6 Use an appropriate number of significant figures. WS4.4 Use prefixes centi, milli, micro and nano.<br>• MS 1d, 2h Make order of magnitude calculations.<br>• MS 1d Use estimations and explain when they should be used.<br><br>4.1.3.2 Cell structures<br>• 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.<br><br>4.1.3.3 Transport into and out of cells | |

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| | • Explain how substances are transported into and out of cells through diffusion, osmosis and active transport.<br>Scientific, practical and mathematical skills<br>• MS 4a, 4b, 4c, 4d Plot, draw and interpret appropriate graphs.<br>• WS 3.4 Represent the distribution of results and make estimations of uncertainty.<br>• MS 1c Calculate percentage gain and loss of mass.<br>• WS 3.3 Carry out and represent mathematical and statistical analysis.<br><br>4.1.3.4 Mitosis and the cell cycle<br>• Describe the process of mitosis in growth, including the cell cycle.<br><br>4.1.3.5 Meiosis<br>• Explain the role of meiotic cell division in halving the chromosome number to form gametes.<br><br>4.1.3.6 Cell differentiation<br>• Describe the function of stem cells in embryonic and adult animals. Explain the importance of cell differentiation. | |

# UNIT 1: Building Blocks (NC Light and electromagnetic waves)

| Previous Learning at Key Stage 3 | Foundation AQA Synergy GCSE | Higher AQA Synergy GCSE – Extra content on top of Foundation content |
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| **Observed waves**<br>• Waves on water as undulations which travel through water with transverse motion; these waves can be reflected, and add or cancel – superposition<br><br>**Sound waves**<br>• Frequencies of sound waves, measured in hertz (Hz); echoes, reflection and absorption of sound<br>• Sound needs a medium to travel, the speed of sound in air, in water, in solids<br>• Sound produced by vibrations of objects, in loudspeakers, detected by their effects on microphone diaphragm and the ear drum; sound waves are longitudinal<br>• The auditory range of humans and animals<br><br>**Energy and waves**<br>• Pressure waves transferring energy; use for cleaning and physiotherapy by ultrasound; waves transferring information for conversion to electrical signals by microphone | **Physics**<br>**4.1.4 Waves**<br><br>4.1.4.1 Transverse and longitudinal waves<br>• Describe the difference between transverse and longitudinal waves.<br>• 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.<br>• Describe evidence that in both cases it is the wave and not the water or air itself that travels.<br>Scientific, practical and mathematical skills<br>• WS 2.3 Describe one method to measure the speed of sound waves in air.<br>• WS 2.2, 2.3 Describe one method to measure the speed of ripples on a water surface.<br>• WS 3.5 Interpret given data from experiments to measure the speed of sound or water waves.<br><br>4.1.4.2 A wave equation<br>• 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.<br>Scientific, practical and mathematical skills<br>• WS 4.6, MS 1b, 2a Calculate with numbers written in standard form and give answers to an appropriate number of significant figures.<br>• MS 1c, 3b, 3c Recall and apply the wave equation. | |

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| **Light waves**<br>• The similarities and differences between light waves and waves in matter<br>• Light waves travelling through a vacuum; speed of light the transmission of light through materials: absorption, diffuse scattering and specular reflection at a surface<br>• Use of ray model to explain imaging in mirrors, the pinhole camera, the refraction of light and action of convex lens in focusing (qualitative); the human eye<br>• Light transferring energy from source to absorber, leading to chemical and electrical effects; photosensitive material in the retina and in cameras<br>• Colours and the different frequencies of light, white light and prisms (qualitative only); differential colour effects in absorption and diffuse reflection | • MS1a, 1c, 3b, 3c Apply the equation for relationship between period and frequency, which is given on the Physics equations sheet.<br>• WS 3.3 Carry out and represent mathematical and statistical analysis.<br><br>4.1.4.3 Electromagnetic waves<br>• 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.<br>• Recall that light is an electromagnetic wave.<br>• Describe the main groupings of the spectrum – radio, microwave, infrared, 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.<br>• Give examples of some practical uses of electromagnetic waves in the radio, microwave, infrared, visible, ultraviolet, Xray and gamma ray regions.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Show that the uses of electromagnetic waves illustrate the transfer of energy from source to absorber.<br>• MS 1a, 1c, 3c Recall and apply the relationship between frequency and wavelength across the electromagnetic spectrum. | 4.1.4.4 Radio waves<br>• Recall that radio waves can be produced by, or can themselves induce, oscillations in electrical circuits.<br><br>4.1.4.5 Reflection and refraction of electromagnetic waves<br>• Recall that different substances may refract, or reflect these waves; explain how some effects are related to differences in the velocity of the waves in different substances<br>Scientific, practical and mathematical skills<br>• WS 1.2 Construct ray diagrams to illustrate the refraction of a wave at the boundary between two different media. Use wavefront diagrams to explain refraction in terms of the change of wave speed. |

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## UNIT 2: Transport over larger distances NC Biology: Transport Systems)

| Previous Learning at Key Stage 3 | Foundation AQA Synergy GCSE | Higher AQA Synergy GCSE – Extra content on top of Foundation content |
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| **The skeletal and muscular systems**<br>• The structure and functions of the human skeleton, to include support, protection, movement and making blood cells<br>• Biomechanics – the interaction between skeleton and muscles, including the measurement of force exerted by different muscles<br>• The function of muscles and examples of antagonistic muscles | **Biology**<br>**4.2 Transport over larger distances**<br>**4.2.1 Systems in the human body**<br>4.2.1.1 Respiration<br>• Describe cellular respiration as an exothermic reaction which is continuously occurring in all living cells.<br>• Compare the processes of aerobic and anaerobic respiration.<br><br>4.2.1.2 Exchange surfaces<br>• Explain the need for exchange surfaces and a transport system in multicellular organisms in terms of surface area:volume ratio<br>Scientific, practical and mathematical skills<br>• MS 1c Calculate and compare surface area:volume ratios.<br><br>4.2.1.3 The human circulatory system<br>• 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.<br>• 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 and dissolved food molecules.<br>Scientific, practical and mathematical skills | 4.2.1.1 Respiration<br>Scientific, practical and mathematical skills<br>• WS 1.2 Write a balanced symbol equation for respiration, given the formula of glucose. |

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| | • MS 1a, 1c Use simple compound measures such as rate.<br>• MS 1a, 1c Carry out rate calculations.<br><br>4.2.1.4 Blood cells<br>• Explain how red blood cells, white blood cells, platelets and plasma are adapted to their functions in the blood.<br>Scientific, practical and mathematical skills<br>• WS 3.5 Identify different types of blood cells in a photograph or diagram.<br><br>4.2.1.5 The human digestive system<br>• Explain the importance of sugars, amino acids, fatty acids and glycerol in the synthesis and breakdown of carbohydrates, lipids and proteins.<br>• Describe some of the substances transported into and out of a range of organisms in terms of the requirements of those organisms, to include dissolved food molecules and urea.<br><br>4.2.1.6 The human nervous system<br>• Explain how the structure of the nervous system (including the central nervous system, sensory and motor neurones and sensory receptors) is adapted to its functions.<br>• Explain how the structure of a reflex arc is related to its function.<br>• Explain methods of measuring human reaction times and recall typical results.<br><br>4.2.1.7 The human endocrine system<br>• Describe the principles of hormonal coordination and control by the human endocrine system. | 4.2.1.7 The human endocrine system<br>• Explain the roles of thyroxine and adrenaline in the body including thyroxine as an example of a negative feedback system.<br>Scientific, practical and mathematical skills<br>• WS1.2, MS 2c (HT only) Interpret and explain simple diagrams of negative feedback control. |

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| **Photosynthesis**<br>• The reactants in, and products of, photosynthesis, and a word summary for photosynthesis<br>• The dependence of almost all life on Earth on the ability of photosynthetic organisms, such as plants and algae, to use sunlight in photosynthesis to build organic molecules that are an essential energy store and to maintain levels of oxygen and carbon dioxide in the atmosphere<br>• The adaptations of leaves for photosynthesis | **4.2.2 Plants and photosynthesis**<br>4.2.2.1 Meristem tissue<br>• Describe the function of meristems in plants<br>Scientific, practical and mathematical skills<br>• WS 1.4 Describe and explain the use of stem cells from meristems to produce clones of plants quickly and economically.<br><br>4.2.2.2 Plant structures<br>• 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 and mineral ions.<br><br>4.2.2.3 Transpiration<br>• Explain the need for exchange surfaces and a transport system in multicellular organisms.<br>• Explain how water and mineral ions are taken up by plants, relating the structure of the root hair cells to their function.<br>• Explain how the structure of xylem is adapted to its functions in the plant.<br>• Describe the process of transpiration including the structure and function of the stomata.<br>• 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.<br>Scientific, practical and mathematical skills<br>• MS 1a, 1c Understand and use simple compound measures such as the rate of a reaction.<br>• MS 4a Translate information between graphical and numerical form. | |

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| | • MS 4a, 4c Plot and draw appropriate graphs, selecting appropriate scales for axes.<br>• WS 3.3 Carry out and represent mathematical and statistical analysis.<br>• MS 2c, 4a Extract and interpret information from graphs, charts and tables.<br><br>4.2.2.4 Chlorophyll and other plant pigments<br>• Recall that chromatography involves a stationary and a mobile phase and that separation depends on the distribution between the phases.<br>• Interpret chromatograms, including measuring Rf values.<br>• Suggest chromatographic methods for distinguishing pure from impure substances.<br>Scientific, practical and mathematical skills<br>• MS 1a Recognise and use expressions in decimal form.<br>• MS 1c Use ratios and percentages.<br>• WS 3.3 Carry out and represent mathematical and statistical analysis.<br>• MS 1d Make estimates of the results of simple calculations.<br>• WS 4.6, MS 2a Use an appropriate number of significant figures.<br>• MS 4a Extract and interpret information from charts and tables. Translate information between graphical and numeric form when calculating Rf values.<br><br>4.2.2.5 Photosynthesis<br>• Describe the process of photosynthesis and describe photosynthesis as an endothermic reaction.<br><br>4.2.2.6 Factors affecting the rate of photosynthesis<br>• Explain the effect of temperature, light intensity and carbon dioxide concentration on the rate of photosynthesis. | 4.2.2.5 Photosynthesis<br>Scientific, practical and mathematical skills<br>• WS 1.2 Write a balanced symbol equation for photosynthesis given the formula of glucose<br><br>4.2.2.6 Factors affecting the rate of photosynthesis<br>• Explain the interaction of these factors in limiting the rate of photosynthesis. |

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| | Scientific, practical and mathematical skills<br>• MS 1a, 1c Carry out rate calculations for photosynthesis.<br><br>4.2.2.7 Translocation<br>• Describe the process of translocation.<br>• Explain how the structure of phloem is adapted to its functions in the plant.<br><br>4.2.2.8 Plant diseases<br>• Explain how communicable diseases are spread in plants.<br>• Explain how the spread of communicable diseases may be reduced or prevented in plants, to include a minimum of one plant disease.<br>Scientific, practical and mathematical skills<br>• WS 1.4 Explain applications of science to prevent the spread of plant diseases. | Scientific, practical and mathematical skills<br>• WS 1.4 Use data to relate limiting factors to the cost effectiveness of adding heat, light or carbon dioxide to greenhouses.<br>• MS 1a, 1c, 2c, 4a, 4c Translate information between numerical and graphical forms and extract and interpret information from graphs, charts and tables.<br>• WS 3.5 Understand and use inverse proportion – the inverse square law – and light intensity in the context of factors affecting photosynthesis. |

## UNIT 3: Interactions with the environment (NC Health, disease and the development of medicines)

| Previous Learning at Key Stage 3 | Foundation AQA Synergy GCSE | Higher AQA Synergy GCSE – Extra content on top of Foundation content |
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| **Nutrition and digestion**<br>• The content of a healthy human diet: carbohydrates, lipids (fats and oils), proteins, vitamins, minerals, dietary fibre and water, and why each is needed<br>• Calculations of energy requirements in a healthy daily diet<br>• The consequences of imbalances in the diet, including obesity, starvation and deficiency diseases<br>• The tissues and organs of the human digestive system, including adaptations to function and how the digestive system digests food (enzymes simply as biological catalysts)<br>• The importance of bacteria in the human digestive system<br>• Plants making carbohydrates in their leaves by photosynthesis and gaining mineral nutrients and water from the soil via their roots<br><br>**Health**<br>• The effects of recreational drugs (including substance misuse) on behaviour, health and life processes | ***4.3 Interactions with the environment***<br><br>***Biology***<br>**4.3.1 Lifestyle and health**<br>4.3.1.1 Health and disease<br>• Describe the relationship between health and disease.<br>• Describe different types of diseases (including communicable and non-communicable diseases).<br><br>4.3.1.2 Risk factors for non-communicable diseases<br>• Recall that many noncommunicable 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.<br>• Explain the effect of lifestyle factors, including exercise, diet, alcohol and smoking, on the incidence of noncommunicable diseases at local, national and global levels.<br>Scientific, practical and mathematical skills<br>• WS 1.5 Interpret data about risk factors, or about differences in the incidence of noncommunicable diseases in different parts of the world.<br>• WS 1.4 Discuss the human and financial cost of these non-communicable diseases to an individual, a local community, a nation or globally.<br>• MS 4a Translate information between graphical and numerical forms.<br>• MS 2c, 4a Extract and interpret information from charts, graphs and tables.<br>• MS 2d Understand the principles of sampling as applied to scientific data in terms of risk factors.<br>• MS 2c Construct and interpret frequency tables and diagrams, bar charts and histograms. | |

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| **Reproduction**<br>• Reproduction in humans (as an example of a mammal), including the structure and function of the male and female reproductive systems, menstrual cycle (without details of hormones), gametes, fertilisation, gestation and birth, to include the effect of maternal lifestyle on the foetus through the placenta<br>• Reproduction in plants, including flower structure, wind and insect | • MS 2g Use a scatter diagram to identify a correlation between two variables.<br><br>4.3.1.3 Treatments for cardiovascular disease<br>• Evaluate some different treatments for cardiovascular disease.<br>Scientific, practical and mathematical skills<br>• WS 1.4 Evaluate given information about the advantages and disadvantages of treating cardiovascular diseases by drugs, mechanical devices or transplant.<br>• WS 1.3 Evaluate methods of treatment bearing in mind the benefits and risks associated with the treatment.<br><br>4.3.1.4 Homeostasis<br>• Explain the importance of maintaining a constant internal environment in response to internal and external change.<br><br>4.3.1.5 Insulin and diabetes<br>• Explain how insulin controls blood sugar levels in the body<br>• Compare Type 1 and Type 2 diabetes and explain how they can be treated.<br>Scientific, practical and mathematical skills<br>• MS 1a, 1c, 2c, 4a, 4c Translate information between numerical and graphical forms and extract and interpret information from graphs, charts and tables.<br><br>4.3.1.6 Human reproductive hormones<br>• Describe the roles of hormones in human reproduction, including the menstrual cycle. | 4.3.1.5 Insulin and diabetes<br>• Explain how glucagon interacts with insulin to control blood sugar levels in the body.<br><br>4.3.1.6 Human reproductive hormones<br>• Explain the interactions of FSH, LH, oestrogen and progesterone in the control of the menstrual cycle.<br>Scientific, practical and mathematical skills<br>• MS 2c, 4a (HT only) Extract and interpret data from graphs showing hormone levels during the menstrual cycle. |

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| pollination, fertilisation, seed and fruit formation and dispersal, including quantitative investigation of some dispersal mechanisms | 4.3.1.7 Contraception<br>• Explain the use of hormones in contraception and evaluate hormonal and non-hormonal methods of contraception.<br>Scientific, practical and mathematical skills<br>• WS 1.4 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.<br><br>4.3.2.7 Cancer<br>Describe cancer as the result of changes in cells that lead to uncontrolled growth and division.<br><br>**4.3.3 Preventing, treating and curing diseases**<br>4.3.3.1 Spread of communicable diseases<br>• Explain how communicable diseases (caused by viruses, bacteria, protists and fungi) are spread in animals.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Apply the ideas in this section to the transmission of the common cold, flu, cholera, athlete's foot and malaria. | 4.3.1.8 Treatments for infertility<br>• Explain the use of hormones in modern reproductive technologies to treat infertility.<br>Scientific, practical and mathematical skills<br>• WS 1.4 Evaluate, from the perspective of patients and doctors, the methods of treating fertility bearing in mind that although fertility treatment gives couples the chance to have a baby of their own it is very emotionally and physically stressful; the success rates are not high and it can lead to multiple births which are a risk to both the babies and the mother. |

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| | 4.3.3.2 Human communicable diseases<br>• Describe a minimum of one common human infection, and sexually transmitted infections in humans, including HIV/AIDS.<br>• Explain how the spread of communicable diseases may be reduced or prevented in animals. This should include a minimum of one common human infection, and sexually transmitted infections in humans including HIV/AIDS.<br>Scientific, practical and mathematical skills<br>• WS 1.4 Explain applications of science to prevent the spread of diseases.<br><br>4.3.3.3 Defences against pathogens<br>• Describe the nonspecific defence systems of the human body against pathogens.<br><br>4.3.3.4 The human immune system<br>• Explain the role of the immune system of the human body in defence against disease.<br><br>4.3.3.5 Vaccination<br>• Explain the use of vaccines in the prevention and treatment of disease<br><br>4.3.3.6 Medicines<br>• Explain the use of medicines in the prevention and treatment of disease.<br>• Explain that many useful materials are formulations of mixtures.<br><br>4.3.3.7 Testing new drugs<br>• Describe the process of discovery and development of potential new medicines, including preclinical and clinical testing.<br>Scientific, practical and mathematical skills | |

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| | • WS 1.6 Explain that the results of testing and trials, like the findings of all scientific research, are published only after evaluation by peer review.<br><br>4.3.3.8 Genetic modification<br>• Explain some of the possible benefits and risks, including practical and ethical considerations, of using gene technology in modern medicine.<br>Scientific, practical and mathematical skills<br>• WS 1.3 Evaluate gene technologies, taking into account benefits, risks, and the ethical issues raised by the use of animals in medical research.<br><br>4.3.3.9 Stem cells<br>• Discuss potential benefits and risks associated with the use of stem cells in medicine.<br>Scientific, practical and mathematical skills<br>• WS 1.3 Give a simple ethical argument about the rights and wrongs of the uses of stem cells.<br>• Evaluate possible uses of stem cells taking into account benefits, risks and the ethical issues raised by sources of the cells.<br><br>4.3.3.10 Interactions between different types of disease<br>• Describe the interactions between different types of disease. | |

## UNIT 3: Interactions with the environment (Atomic structure NC)

| Previous Learning at Key Stage 3 | Foundation AQA Synergy GCSE | Higher AQA Synergy GCSE – Extra content on top of Foundation content |
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| | **4.3.2 Radiation and risk** | |

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| | 4.3.2.1 Absorption and emission of radiation<br>• Recall that the arrangements of electrons in atoms may change with absorption or emission of electromagnetic radiation.<br>Scientific, practical and mathematical skills<br>WS 1.2 Use of the energy level model of the atom.<br><br>4.3.2.2 Radioactive decay<br>• 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.<br>• Use names and symbols of common nuclei and particles to write balanced equations that represent radioactive decay.<br>Scientific, practical and mathematical skills<br>• WS 1.2, MS 1b, 1c, 3c Refer to a copy of the periodic table and use the names and symbols of common nuclei and particles to write balanced equations that show single alpha (α) and beta (β) decay. This includes balancing atomic numbers and mass numbers.<br><br>4.3.2.3 Half-life<br>• Explain the concept of half-life and how this is related to the random nature of radioactive decay.<br>Scientific, practical and mathematical skills<br>• WS 3.3 Carry out and represent mathematical and statistical analysis.<br>• MS 4a Determine the half-life of a radioactive isotope from given information.<br><br>4.3.2.4 Penetration properties of radiations<br>• Recall the differences in the penetration properties of alpha particles, beta particles and gamma rays. | 4.3.2.3 Half-life<br>Scientific, practical and mathematical skills<br>• MS 1c, 3d Calculate the net decline, expressed as a ratio, in a radioactive emission after a given number of half-lives. |

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| | 4.3.2.5 Contamination and irradiation<br>• Recall the differences between contamination and irradiation effects and compare the hazards associated with these two.<br><br>4.3.2.6 Ionising radiations<br>• Recall that changes in atoms and nuclei can also generate and absorb radiations over a wide frequency range.<br>• Describe how ultraviolet waves, Xrays and gamma rays can have hazardous effects, notably on human bodily tissues.<br>• Recall that atoms can become ions by loss of outer electrons.<br>Scientific, practical and mathematical skills<br>• WS 1.5 Interpret simple measures of risk showing the probability of harm from different types of radiation.<br>• Describe precautions that can be taken to reduce the risks from ionising radiation.<br>• Give examples to show that the perceived risk can be very different from the measured risk, especially if the cause of the risk is unfamiliar or invisible. | |

## UNIT 4: Explaining Change (Earth and atmospheric science NC)

| Previous Learning at Key Stage 3 | Foundation AQA Synergy GCSE | Higher AQA Synergy GCSE – Extra content on top of Foundation content |
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| | ***Chemistry***<br>***4.4 Explaining change***<br>**4.4.1 The Earth's atmosphere**<br>4.4.1.1 Development of the Earth's atmosphere<br>• Describe how it is thought an oxygen-rich atmosphere developed over time.<br>Scientific, practical and mathematical skills | |

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| **Earth and atmosphere**<br>• The composition of the Earth<br>• The structure of the Earth<br>• The rock cycle and the formation of igneous, sedimentary and metamorphic rocks | • WS 1.1 Given appropriate information, interpret evidence and evaluate different theories about the Earth's early atmosphere.<br>• WS 1.3 Explain why evidence is uncertain or incomplete in a complex context.<br>• MS 1c Use ratios, fractions and percentages.<br><br>4.4.1.2 The carbon cycle<br>• Recall that many different materials cycle through the abiotic and biotic components of an ecosystem.<br>• Explain the importance of the carbon cycle to living organisms.<br>• Describe photosynthetic organisms as the main producers of food and therefore biomass for life on Earth.<br>• Explain the role of microorganisms in the cycling of materials through an ecosystem.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Draw and interpret diagrams to represent the main stores of carbon and the flows of carbon between them in the cycle.<br><br>4.4.1.3 The greenhouse effect<br>• Describe the greenhouse effect in terms of the interaction of radiation with matter.<br>Scientific, practical and mathematical skills<br>WS 1.2 Interpret and draw diagrams to describe the greenhouse effect.<br><br>4.4.1.4 Human impacts on the climate<br>• 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.<br>Scientific, practical and mathematical skills | 4.4.1.3 The greenhouse effect<br>• Recall that different substances may absorb, transmit or reflect these waves in ways that vary with wavelength. |

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| • Earth as a source of limited resources and the efficacy of recycling<br>• The composition of the atmosphere<br>• The production of carbon dioxide by human activity and the impact on climate | • WS 1.6 Explain the importance of scientists publishing their findings and theories so that they can be evaluated critically by other scientists. Understand that the scientific consensus about global warming and climate change is based on systematic reviews of thousands of peer reviewed publications.<br>• WS 1.3 Explain why evidence is uncertain or incomplete in a complex context.<br>• MS 2c, 4a Extract and interpret information from charts, graphs and tables.<br>• MS 2h Use orders of magnitude to evaluate the significance of data.<br><br>4.4.1.5 Climate change: impacts and mitigation<br>• 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<br>Scientific, practical and mathematical skills<br>• WS 1.4 In the context of climate change, evaluate associated economic and environmental implications; and make decisions based on the evaluation of evidence and arguments.<br><br>4.4.1.6 Pollutants that affect air quality<br>• 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<br>Scientific, practical and mathematical skills<br>• WS 1.4 Describe, explain or evaluate ways in which human activities affect the environment.<br><br>4.4.1.7 The water cycle | |

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| | • Explain the importance of the water cycle to living organisms.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Draw and interpret diagrams to represent the main stores of water and the flows of water between them in the cycle<br><br>4.4.1.8 Sources of potable water<br>• 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.<br>• Describe, explain and exemplify the processes of simple distillation.<br>Scientific, practical and mathematical skills<br>• WS 1.4 Explain everyday and technological applications of science; evaluate associated personal, social, economic and environmental implications with reference to the sources of potable water and treatment of waste water. | |

## UNIT 4: Explaining Change (Ecosystems NC)

| Previous Learning at Key Stage 3 | Foundation AQA Synergy GCSE | Higher AQA Synergy GCSE – Extra content on top of Foundation content |
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| **Interactions and interdependencies**<br>**Relationships in an ecosystem**<br>• The interdependence of organisms in an ecosystem, including food webs and insect pollinated crops<br>• The importance of plant reproduction through insect pollination in human food security<br>• How organisms affect, and are affected by, their environment, including the accumulation of toxic materials | ***Biology***<br>***4.4 Explaining Change***<br>**4.4.2 Ecosystems and biodiversity**<br>4.4.2.1 Levels of organisation in an ecosystem<br>• Describe different levels of organisation in an ecosystem from individual organisms to the whole ecosystem.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Interpret graphs used to model predator–prey cycles.<br><br>4.4.2.2 Interdependence and competition<br>• Describe the importance of interdependence and competition in a community.<br><br>4.4.2.3 Factors that affect communities<br>• Explain how some abiotic and biotic factors affect communities.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Predict how a change in an abiotic, or biotic, factor would affect a given community given appropriate data or context.<br>• MS 1c Calculate the percentage of mass.<br>• MS 2c, 4a Extract and interpret information from charts, graphs and tables.<br><br>4.4.2.4 Field investigations<br>• 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<br>Scientific, practical and mathematical skills<br>• MS 2b Calculate arithmetic means.<br>• WS 3.3 Carry out and represent mathematical and statistical analysis. | |

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| **Genetics and evolution**<br>**Inheritance, chromosomes, DNA and genes**<br>• Heredity as the process by which genetic information is transmitted from one generation to the next<br>• A simple model of chromosomes, genes and DNA in heredity, including the part played by Watson, Crick, Wilkins and | • MS 4a, 4c Plot and draw appropriate graphs, selecting appropriate scales for the axes.<br>• MS 2d Understand the principles of sampling as applied to scientific data.<br><br>4.4.2.5 Biodiversity<br>• Explain some of the benefits and challenges of maintaining local and global biodiversity.<br><br>4.4.2.6 Negative human impacts on ecosystems<br>• Describe negative human interactions within ecosystems and explain their impact on biodiversity.<br>Scientific, practical and mathematical skills<br>• WS 1.4 Evaluate given information about ways in which human activities affect the environment.<br><br>4.4.2.7 Positive human impacts on ecosystems<br>• Describe positive human interactions within ecosystems and explain their impact on biodiversity.<br>Scientific, practical and mathematical skills<br>• WS 1.4 Evaluate given information about methods that can be used to tackle problems caused by human impacts on the environment.<br><br>**4.4.3 Inheritance**<br>4.4.3.1 Chromosomes and genes<br>• Explain the following terms: gamete, chromosome and gene.<br>• Describe DNA as a polymer made up of two strands forming a double helix.<br>• Describe the genome as the entire genetic material of an organism.<br><br>4.4.3.2 Sex determination in humans<br>• Describe sex determination in humans. | |

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| Franklin in the development of the DNA model<br>• Differences between species<br>• The variation between individuals within a species being continuous or discontinuous, to include measurement and graphical representation of variation<br>• The variation between species and between individuals of the same species meaning some organisms compete more successfully, which can drive natural selection<br>• Changes in the environment which may leave individuals within a species, and some entire species, less well adapted to compete successfully and reproduce, which in turn may lead to extinction<br>• The importance of maintaining biodiversity and the use of gene banks to preserve hereditary material | 4.4.3.3 Single gene inheritance<br>• Explain single gene inheritance.<br>• Predict the results of single gene crosses.<br>• Explain the terms allele/variant, dominant, recessive, homozygous, heterozygous.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Complete a Punnett square diagram or interpret the results of a genetic cross diagram for a single gene, and understand family trees.<br>• MS 2e (HT only) Construct a Punnett square diagram to make predictions based on simple probability.<br>• MS 1c Use direct proportion and simple ratios in genetic crosses.<br><br>4.4.3.4 Genotype and phenotype<br>• Describe simply how the genome, and its interaction with the environment, influences the development of the phenotype of an organism.<br>• Explain the terms genotype and phenotype.<br>• Recall that most phenotypic features are the result of multiple genes rather than single gene inheritance.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Explain why studies involving identical twins help to separate the contribution of genes and the environment to the development of their phenotypes.<br>• WS 1.1 Given a context and related information, discuss the potential importance for medicine of our increasing understanding of the human genome.<br><br>**4.4.4 Variation and evolution**<br>4.4.4.1 Mutations<br>• State that there is usually extensive genetic variation within a population of a species.<br>• Recall that all variants arise from mutations, and that most have no effect on the phenotype, some influence | 4.4.4.6 Genetic engineering<br>• Describe the main steps in the process of genetic engineering. |

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| | the phenotype and a very few determine the phenotype.<br><br>4.4.4.2 Evolution through natural selection<br>• 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.<br>• Explain how evolution occurs through natural selection of variants that give rise to phenotypes best suited to their environment.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Use the theory of evolution by natural selection in an explanation.<br><br>4.4.4.3 Evidence for evolution<br>• Describe the evidence for evolution, including fossils and antibiotic resistance in bacteria.<br>Scientific, practical and mathematical skills<br>• MS 2c, 4a Extract and interpret information from charts, graphs and tables.<br><br>4.4.4.4 Identification and classification of living things<br>• Describe the impact of developments in biology on classification systems.<br>Scientific, practical and mathematical skills<br>• WS 1.1 Show how new methods of investigation and new discoveries led to new scientific ideas.<br><br>4.4.4.5 Selective breeding<br>• Explain the impact of the selective breeding of food plants and domesticated animals.<br>Scientific, practical and mathematical skills<br>• WS 1.3, 1.4 Evaluate the benefits and risks of selective breeding given appropriate information and consider related ethical issues. | • Explain some of the possible benefits and risks, including practical and ethical considerations, of using gene technology in modern agriculture |

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| | 4.4.4.6 Genetic engineering<br>• Describe genetic engineering as a process which involves modifying the genome of an organism to introduce desirable characteristics.<br>Scientific, practical and mathematical skills<br>• WS 1.4 Evaluate the advantages and disadvantages of GM technologies based on data or other information.<br>• WS 1.3 Give a simple ethical argument about the rights and wrongs of a GM technology.<br>• Recognise, in given information, the difference between a practical and an ethical argument. | |

## UNIT 5: Bulding blocks for understanding (Atomic structure and the Periodic Table NC)

| Previous Learning at Key Stage 3 | Foundation AQA Synergy GCSE | Higher AQA Synergy GCSE – Extra content on top of Foundation content |
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| **The periodic table**<br>• The varying physical and chemical properties of different elements<br>• The principles underpinning the Mendeleev periodic table<br>• The periodic table: periods and groups; metals and non-metals<br>• How patterns in reactions can be predicted with reference to the periodic table<br>• The properties of metals and non-metals<br>• The chemical properties of metal and non-metal oxides with respect to acidity | ***Chemistry***<br>***4.5 Building blocks for understanding***<br>**4.5.1 The periodic table**<br>4.5.1.1 Atomic number and the periodic table<br>• 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.<br>• Explain in terms of isotopes how this changes the arrangement proposed by Mendeleev.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Represent the electronic structure of the first 20 elements of the periodic table (diagram).<br>• Predict possible reactions and probable reactivity of elements from their positions in the periodic table.<br>• WS 1.1 Show how scientific methods and theories have changed over time. | |

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| | 4.5.1.2 Metals and non-metals<br>• Explain how the atomic structure of metals and non-metals relates to their position in the periodic table.<br>• Explain how the reactions of elements are related to the arrangement of electrons in their atoms and hence to their atomic number<br>Scientific, practical and mathematical skills<br>• WS 1.2 Describe metals and non-metals and explain the differences between them in terms of their characteristic physical and chemical properties<br><br>4.5.1.3 Group 0<br>• Recall the simple properties of Group 0.<br>• Explain how the observed simple properties of Group 0 depend on the outer shell of electrons of the atoms and predict properties from given trends down the group.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Predict properties from given trends down Group 0.<br><br>4.5.1.4 Group 1<br>• Recall the simple properties of Group 1.<br>• Explain how the observed simple properties of Group 1 depend on the outer shell of electrons of the atoms and predict properties from given trends down the group.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Predict properties from given trends down Group 1.<br><br>4.5.1.5 Group 7<br>• Recall the simple properties of Group 7.<br>• Explain how the observed simple properties of Group 7 depend on the outer shell of electrons of the atoms | |

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| | and predict properties from given trends down the group.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Predict properties from given trends down Group 7.<br><br>**4.5.2 Chemical quantities**<br>4.5.2.1 Chemical equations<br>• Use the names and symbols of common elements and compounds and the principle of conservation of mass to write formulae and balanced chemical equations.<br>Scientific, practical and mathematical skills<br>• WS 4.1 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.<br>• Name compounds of these elements from given formulae or symbol equations.<br>• Write word equations for the reactions in this specification.<br>• Write formulae and balanced chemical equations for the reactions in this specification.<br><br>4.5.2.2 Conservation of mass<br>• Recall and use the law of conservation of mass.<br>• Explain any observed changes in mass in non-enclosed systems during a chemical reaction and explain them using the particle model.<br>Scientific, practical and mathematical skills<br>• MS 1a Use arithmetic computation and ratio when writing and balancing equations.<br>• WS 1.2 Explain any observed changes in mass in nonenclosed systems during a chemical reaction given the balanced symbol equation for the reaction. | 4.5.2.1 Chemical equations<br>• (HT only) and half equations. Use chemical symbols to write the formulae of elements and simple covalent and ionic compounds. Describe the physical states of products and reactants using state symbols (s, l, g and aq).<br><br>4.5.2.4 Amounts in moles<br>• Explain how the mass of a given substance is related to the amount of that substance in moles and vice versa.<br>• Recall and use the definitions of the Avogadro constant (in standard form) and of the mole.<br>Scientific, practical and mathematical skills<br>• MS 1a, 1b, 1c, 2a Recognise and use expressions in decimal form when using the relative formula mass of a substance to calculate the amount in moles in a given mass of that substance and vice versa, giving the answer in the appropriate units.<br>• MS 3b, 3c Change the subject of a mathematical equation.<br>• WS 4.6, MS 2a Provide answers to an appropriate number of significant figures.<br>• MS 1b Calculate with numbers written in standard form when using the Avogadro constant.<br>• MS 3a Understand and use the symbols: =, <>, >, ∝ , ~ |

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| | 4.5.2.3 Relative formula masses<br>• Calculate relative formula masses of species separately and in a balanced chemical equation.<br>• Students should be able to calculate the percentage by mass in a compound given the relative formula mass and the relative atomic masses.<br>Scientific, practical and mathematical skills<br>• MS 1a, 3a Calculate the relative formula mass (Mr ) of a compound from its formula, given the relative atomic masses.<br>• WS 3.3 Carry out and represent mathematical and statistical analysis. | 4.5.2.5 Calculations based on equations<br>• Deduce the stoichiometry of an equation from the masses of reactants and products and explain the effect of a limiting quantity of a reactant.<br>• Use a balanced equation to calculate masses of reactants or products.<br>Scientific, practical and mathematical skills<br>• MS 3c, 3d Balance an equation given the masses of reactants and products.<br>• Explain the effect of a limiting quantity of a reactant on the amount of products it is possible to obtain in terms of amounts in moles or masses in grams.<br>• MS 1a, 1c, 3c, 3d Calculate the masses of reactants and products from the balanced symbol equation and the mass of a given reactant or product.<br>• WS 4.6, MS 2a Provide answers to an appropriate number of significant figures.<br><br>4.5.2.6 Concentrations of solutions<br>• Explain how the mass of a solute and the volume of the solution is related to the concentration of the solution.<br>Scientific, practical and mathematical skills<br>• MS 1c, 3c Calculate the mass of solute in a given volume of solution of known concentration in terms of mass per given volume of solution. |

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## UNIT 6: Interactions over small and large distances (Forces NC)

| Previous Learning at Key Stage 3 | Foundation AQA Synergy GCSE | Higher AQA Synergy GCSE – Extra content on top of Foundation content |
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| **Forces**<br>• Forces as pushes or pulls, arising from the interaction between 2 objects<br>• Using force arrows in diagrams, adding forces in 1 dimension, balanced and unbalanced forces<br>• Moment as the turning effect of a force<br>• Forces: associated with deforming objects; stretching and squashing – springs; with rubbing and friction between surfaces, with pushing things out of the way; resistance to motion of air and water | ***Physics***<br>***4.6 Interactions over small and large distances***<br>**4.6.1 Forces and energy changes**<br><br>4.6.1.1 Forces as vectors<br>• 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, representing such forces as vectors. | 4.6.1.2 Resolving forces<br>• 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).<br>Scientific, practical and mathematical skills |

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| • Forces measured in newtons, measurements of stretch or compression as force is changed<br>• Force-extension linear relation; Hooke's Law as a special case<br>• Work done and energy changes on deformation<br>• Non-contact forces: gravity forces acting at a distance on Earth and in space, forces between magnets, and forces due to static electricity | 4.6.1.3 Work<br>• Describe and calculate the changes in energy involved when a system is changed by the work done by forces acting upon it.<br>• Use the relationship between work done, force and distance moved along the line of action of the force, describing the energy transfer involved.<br>Scientific, practical and mathematical skills<br>• WS 1.2, MS 3b, 3c Recall and apply this equation to calculate energy transfers.<br>• WS 4.5, MS 1c, 3c Convert between newton-metres and joules.<br><br>4.6.1.4 Mass and weight<br>• Define weight, describe how it is measured and describe the relationship between the weight of that body and the gravitational field strength.<br>Scientific, practical and mathematical skills<br>• WS 1.2, MS 3b, 3c Recall and apply this equation. In any calculation the value of the gravitational field strength (g) will be given.<br>• MS 3a Understand and use the symbol for proportionality, $\propto$<br><br>4.6.1.5 Gravitational potential energy<br>• Calculate the amounts of energy associated with an object raised above ground level.<br>Scientific, practical and mathematical skills | • WS 1.2, MS 4a, 5a, 5b Use vector diagrams to illustrate resolution of forces and equilibrium situations and determine the resultant of two forces, to include both magnitude and direction (scale drawings only) |

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| | • WS 1.2, MS 3c Recall and apply this equation to calculate changes in stored energy.<br>• In any calculation the value of the gravitational field strength (g) will be given<br><br>4.6.1.6 Elastic deformation<br>• Explain, with examples, that to stretch, bend or compress an object, more than one force has to be applied.<br>• Describe the difference between elastic and inelastic distortions caused by stretching forces; 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.<br>Scientific, practical and mathematical skills<br>• WS 1.2, MS 3c, 4a, 4b, 4c Recall and apply this equation<br><br>4.6.1.7 Energy stored in a stretched spring<br>• Calculate the amounts of energy associated with a stretched spring.<br>Scientific, practical and mathematical skills<br>• WS 1.2, MS 1c, 3c Calculate the work done in stretching.<br>• MS 3b, 3c Apply this equation, which is given on the Physics equations sheet. | |

## UNIT 6: Interactions over small and large distances Structure, bonding and the properties of matter NC)

| Previous Learning at Key Stage 3 | Foundation AQA Synergy GCSE | Higher AQA Synergy GCSE – Extra content on top of Foundation content |
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| | ***Chemistry*** | |

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| | ***4.6.2 Structure and bonding***<br><br>4.6.2.1 Types of chemical bonding<br>• Describe and compare the nature and arrangement of chemical bonds in ionic compounds, simple molecules, giant covalent structures, and polymers and metals.<br><br>4.6.2.2 Ionic bonding<br>• Explain chemical bonding in terms of electrostatic forces and the transfer of electrons.<br>• Construct dot and cross diagrams for simple ionic substances.<br>• Deduce the empirical formula of a compound from the relative numbers of atoms present or from a model or diagram and vice versa.<br>• Use the formulae of common ions to deduce the formula of a compound.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Draw dot and cross diagrams for ionic compounds formed by metals in groups 1 and 2 with non-metals in groups 6 and 7.<br>• Work out the charge on the ions of metals and non-metals from the group number of the element, limited to the metals in groups 1 and 2, and non-metals in groups 6 and 7.<br>• Describe the limitations of particular representations and models to include dot and cross diagrams, ball and stick models and two- and threedimensional representations.<br>• MS 4a Translate data between diagrammatic and numeric forms.<br>• MS 5b Draw or complete diagrams to represent 2D and 3D forms including twodimensional representations of 3D structures.<br>• MS 1a Use arithmetic computation and ratio when determining empirical formulae. | |

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| | 4.6.2.3 Properties of ionic compounds<br>• Explain how the bulk properties of materials are related to the different types of bonds they contain, their bond strengths and the ways in which their bonds are arranged, recognising that the atoms themselves do not have these properties.<br>Scientific, practical and mathematical skills<br>• WS 1.2 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.<br>• Use data to predict states of substances under given conditions<br><br>4.6.2.4 Covalent bonding<br>• Explain chemical bonding in terms of electrostatic forces and the sharing of electrons.<br>• Construct dot and cross diagrams for simple covalent substances.<br>• Deduce the empirical formula of a compound from the relative numbers of atoms present or from a model or diagram and vice versa.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Recognise substances as small molecules, polymers or giant structures from diagrams showing their bonding.<br>• Draw dot and cross diagrams for the molecules of hydrogen, chlorine, oxygen, nitrogen, hydrogen chloride, water, ammonia and methane.<br>• Represent the covalent bonds in small molecules, in the repeating units of polymers and in part of giant covalent structures, using a line to represent a single bond.<br>• Describe the limitations of particular representations and models to include dot and cross diagrams, ball and | |

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| | stick models and two- and three dimensional representations.<br>• MS 5b Draw or complete diagrams to represent 2D and 3D forms including two dimensional representations of 3D molecules.<br>• MS 1a Use arithmetic computation and ratio when determining empirical formulae.<br><br>4.6.2.5 Properties of substances with covalent bonding<br>• 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.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Use the idea that intermolecular forces are weak compared with covalent bonds to explain the bulk properties of molecular substances.<br>• 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.<br>• Recognise polymers from diagrams showing their bonding.<br>• Recognise giant covalent structures from diagrams showing their bonding.<br>• Use data to predict states of substances under given conditions.<br><br>4.6.2.6 Metallic bonding<br>• Explain chemical bonding in terms of electrostatic forces and the sharing of electrons.<br>Scientific, practical and mathematical skills | |

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| | • MS 5b Draw or complete diagrams to represent 2D and 3D forms including two dimensional representations of 3D structures.<br><br>4.6.2.7 Properties of metals<br>• Explain how the bulk properties of materials are related to the different types of bonds they contain, their bond strengths and the ways in which their bonds are arranged, recognising that the atoms themselves do not have these properties.<br>Scientific, practical and mathematical skills<br>• WS 1.2 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.<br>• Use data to predict states of substances under given conditions. | |

## UNIT 6: Interactions over large and small distances Magnetism and electromagnetism NC)

| Previous Learning at Key Stage 3 | Foundation AQA Synergy GCSE | Higher AQA Synergy GCSE – Extra content on top of Foundation content |
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| **Magnetism**<br>• Magnetic poles, attraction and repulsion<br>• Magnetic fields by plotting with compass, representation by field lines<br>• Earth's magnetism, compass and navigation<br>• The magnetic effect of a current, electromagnets, DC motors (principles only) | ***Physics***<br>***4.6.3 Magnetism and electromagnetism***<br><br>*4.6.3.1 Magnets*<br>• Describe the attraction and repulsion between unlike and like poles for permanent magnets and describe the difference between permanent and induced magnets.<br><br>4.6.3.2 Magnetic fields | |

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| | • Describe the characteristics of the magnetic field of a magnet, showing how strength and direction change from one point to another.<br>Scientific, practical and mathematical skills<br>• WS 2.2 Draw the magnetic field pattern of a bar magnet and describe how to plot the magnetic field pattern using a compass.<br><br>4.6.3.3 The Earth's magnetism<br>• Explain how the behaviour of a magnetic compass is related to evidence that the core of the Earth must be magnetic.<br>Scientific, practical and mathematical skills<br>• WS 1.3 Explain why the data needed to answer a scientific question, in a given context, may not be available because of matters of scale and complexity.<br><br>4.6.3.4 The magnetic effect of an electric current<br>• Describe how to show that a current can create a magnetic effect and describe the directions of the magnetic field around a conducting wire.<br>• 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.<br>Scientific, practical and mathematical skills<br>• WS 1.2, 3.1 Draw the magnetic field pattern for a straight wire carrying a current (showing the direction of the field).<br>• WS 1.2 Use the 'right-hand grip rule' to predict the direction of the field.<br>• WS 3.1 Draw the magnetic field pattern for a solenoid carrying a current (showing the direction of the field).<br>• WS 1.4 Compare the advantages and disadvantages of permanent and electromagnets for particular uses. | 4.6.3.5 The motor effect<br>• Describe how a magnet and a currentcarrying 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.<br>• 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.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Use Fleming's left hand rule to predict the direction of the force on a conductor.<br>• MS 3c Apply this equation, which is given on the Physics equations sheet.<br>• WS 3.3 Carry out and represent mathematical and statistical analysis<br><br>4.6.3.6 Electric motors<br>• Explain how this force is used to cause rotation in electric motors. |

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| | | Scientific, practical and mathematical skills<br>• WS 1.2 Apply Fleming's lefthand rule to a simple electric motor.<br>• WS 1.4 Explain everyday and technological applications of science. |

## UNIT 7: Movement and interactions Forces and motion NC)

| Previous Learning at Key Stage 3 | Foundation AQA Synergy GCSE | Higher AQA Synergy GCSE – Extra content on top of Foundation content |
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| Describing motion<br>• Speed and the quantitative relationship between average speed, distance and time (speed = distance ÷ time)<br>• The representation of a journey on a distance-time graph<br>• Relative motion: trains and cars passing one another | ***Physics***<br>***4.7 Movement and interactions***<br>**4.7.1 Forces and motion**<br>4.7.1.1 Speed and velocity<br>• Explain the vector– scalar distinction as it applies to displacement, distance, velocity and speed.<br>• Recall typical speeds encountered in everyday experience for wind and sound, and for walking, running, cycling and other transportation systems.<br><br>4.7.1.2 Distance, speed and time<br>• Make measurements of distances and times, calculate speeds, and make and use graphs of these to determine the speeds and accelerations involved.<br>Scientific, practical and mathematical skills<br>• MS 3b, 3c Recall and apply this equation.<br>• WS 4.5, MS 1c, 3b, 3c Use ratios and proportional reasoning to convert units and to compute rates.<br>• WS 1.2, 3.5, MS 4a, 4b, 4c, 4d, 4f Relate changes and differences in motion to appropriate distance– time, and velocity–time graphs, and interpret lines, slopes and enclosed areas in such graphs. | 4.7.1.3 Circular motion |

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| | • MS 1a, 1c, 2f, 3c Calculate average speed for non-uniform motion.<br><br>4.7.1.4 Free fall<br>• Recall the acceleration in free fall and estimate the magnitudes of everyday accelerations.<br>Scientific, practical and mathematical skills<br>• WS 1.2, 3.3, MS 3b, 3c Recall and apply this equation.<br>• WS 1.2, 3.5, MS 4a, 4b, 4c, 4d, 4f, 5c Relate changes and differences in motion to appropriate velocity–time graphs, and interpret lines and slopes to determine acceleration<br><br>4.7.1.5 Newton's First Law<br>• 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.<br><br>4.7.1.6 Newton's Second Law<br>• Apply Newton's Second Law in calculations relating forces, masses and accelerations.<br>Scientific, practical and mathematical skills<br>• MS 3a Recognise and be able to use the symbol: • for proportionality, α • that indicates an approximate value or answer,~<br>• WS 1.2, 3.3, MS 3c Recall and apply this equation.<br><br>4.7.1.7 Newton's Third Law<br>• Recall Newton's Third Law and apply it to examples of equilibrium situations. | • Explain with examples that motion in a circular orbit involves constant speed but changing velocity (qualitative only).<br>4.7.1.4 Free fall<br>Scientific, practical and mathematical skills<br>• Interpret enclosed areas in such graphs to determine distance travelled (or displacement).<br>• Measure, when appropriate, the area under a velocity– time graph by counting squares.<br>• WS 1.2, 3.3, MS 3c: Apply this equation, which is given on the Physics equation sheet.<br><br>4.7.1.6 Newton's Second Law<br>• 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.<br><br>4.7.1.8 Momentum<br>• Define momentum and describe examples of momentum in collisions.<br>Scientific, practical and mathematical skills<br>• WS 1.2, 3.3, MS 3c Recall and apply this equation.<br>• WS 1.2 Use the concept of momentum as a model to analyse an event such as a collision. |

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| **Current electricity**<br>• Electric current, measured in amperes, in circuits, series and parallel circuits, currents add where branches meet and current as flow of charge | 4.7.1.9 Kinetic energy<br>• Calculate the amounts of energy associated with a moving body.<br>• Describe all the changes involved in the way energy is stored when a system changes for common situations: a moving object hitting an obstacle, or an object being accelerated by a constant force.<br>Scientific, practical and mathematical skills<br>• WS 1.2, 3.3, MS 3c Recall and apply this equation.<br><br>4.7.1.10 Stopping distances<br>• Explain the factors which affect the distance required for road transport vehicles to come to rest in emergencies and the implications for safety<br>• Explain the dangers caused by large decelerations. Describe all the changes involved in the way energy is stored when a system changes, for common situations, like a vehicle slowing down<br>Scientific, practical and mathematical skills<br>• WS 3.6 Analyse a given situation to explain why braking could be affected.<br>• WS 1.5 Discuss the implications for safety.<br>• WS 3.5, MS 4a Interpret graphs relating speed to stopping distance for different types of vehicles.<br>• WS 1.5, 2.2, MS 1a, 1c Evaluate the effect of various factors on thinking distance based on given data.<br><br>**4.7.2 Electricity**<br>4.7.2.1 Electric current<br>• 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.<br>• Recall and use the relationship between quantity of charge, current and time.<br>Scientific, practical and mathematical skills | 4.7.1.10 Stopping distances<br>Scientific, practical and mathematical skills<br>• WS 1.5, MS 1d (HT only) Estimate the forces involved in typical situations on a public road. |

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| • Potential difference, measured in volts, battery and bulb ratings; resistance, measured in ohms, as the ratio of potential difference (p.d.) to current<br>• Differences in resistance between conducting and insulating components (quantitative)<br><br>**Static electricity**<br>• Separation of positive or negative charges when objects are rubbed together: transfer of electrons, forces between charged objects<br>• The idea of electric field, forces acting across the space between objects not in contact | • WS 3.3, MS 3b, 3c Recall and apply this equation.<br><br>4.7.2.2 Current, resistance and potential difference<br>• 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.<br>• Explain that in other types of resistor the value of R can change as the current changes; explain the design and use of circuits to explore such effects – including lamps, diodes, thermistors and light-dependent resistors (LDRs).<br>Scientific, practical and mathematical skills<br>• WS 3.3, MS 3c Recall and apply this equation.<br>• WS 1.2, 3.5, MS 4c, 4d, 4e Use graphs to determine whether circuit components are linear or non-linear and relate the curves produced to the function and properties of the component.<br><br>4.7.2.3 Series and parallel circuits<br>• 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).<br>• Calculate the currents, potential differences and resistances in direct current (dc) series circuits, and explain the design and use of such circuits for measurement and testing purposes.<br>Scientific, practical and mathematical skills<br>• WS 3.3, MS 1c, 3b, 3c, 3d Solve problems for circuits which include resistors in series using the concept of equivalent resistance. | |

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| | • WS 3.3, MS 1c, 3b, 3c, 3d Calculate the currents, potential differences and resistances in dc series circuits.<br>• Calculating the total resistance of two resistors joined in parallel is not required.<br><br>4.7.2.4 Circuit elements<br>• Represent in dc series circuits with the conventions of positive and negative terminals, the symbols that represent common circuit elements, including diodes, LDRs and thermistors.<br><br>4.7.2.5 Direct and alternating currents<br>• Recall that the domestic supply in the UK is ac, at 50Hz and about 230 volts; explain the difference between direct and alternating voltage.<br><br>4.7.2.6 Mains cables<br>• 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.<br>Scientific, practical and mathematical skills<br>• WS 1.5 Identify an electrical hazard in a given context.<br><br>4.7.2.7 Power<br>• Explain, with reference to examples, the definition of power as the rate at which energy is transferred.<br>• Explain how the power transfer in any circuit device is related to the potential difference across it and the current, and to the energy changes over a given time.<br>Scientific, practical and mathematical skills | |

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| | • WS 1.2, 3.3,MS 3b, 3c Recall and apply both of these equations.<br>• WS 1.2, 3.3, MS 3b, 3c Recall and apply both of these equations.<br><br>4.7.2.8 Power and domestic electric appliances<br>• Describe how, in different domestic devices, energy is transferred from batteries and the ac mains to the energy of motors or of heating devices.<br>• Describe all the changes involved in the way energy is stored when a system changes, for common situations: bringing water to a boil in an electric kettle.<br>• Describe, with examples, the relationship between the power ratings for domestic electrical appliances and the changes in stored energy when they are in use.<br>• Describe and calculate the changes in energy involved when a system is changed by work done when a current flows<br>Scientific, practical and mathematical skills<br>• WS 1.4 Explain everyday and technological applications of science.<br>• WS 1.2, 3.3, MS 3c Recall and apply both of these equations.<br><br>4.7.2.9 The National Grid<br>• 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.<br>Scientific, practical and mathematical skills<br>• WS 1.4 Explain everyday and technological applications of science. Detailed knowledge of the structure of a transformer is not required. | |

## UNIT 7: Movement and interactions (Chemical changes NC)

| Previous Learning at Key Stage 3 | Foundation AQA Synergy GCSE | Higher AQA Synergy GCSE – Extra content on top of Foundation content |
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| **Chemical reactions**<br>• Chemical reactions as the rearrangement of atoms<br>• Representing chemical reactions using formulae and using equations<br>• Combustion, thermal decomposition, oxidation and displacement reactions<br>• Defining acids and alkalis in terms of neutralisation reactions<br>• The pH scale for measuring acidity/alkalinity; and indicators<br>• Reactions of acids with metals to produce a salt plus hydrogen<br>• Reactions of acids with alkalis to produce a salt plus water<br>• What catalysts do<br><br>**Energetics**<br>• Energy changes on changes of state (qualitative)<br>• Exothermic and endothermic chemical reactions (qualitative) | ***Chemistry***<br>***4.7.3 Acids and alkalis***<br>4.7.3.1 Reactions of acids<br>• Recall that acids react with some metals and with carbonates, and write equations predicting products from given reactants.<br>• Describe tests to identify selected gases including hydrogen and carbon dioxide.<br><br>4.7.3.2 Making salts<br>• Describe neutralisation as acid reacting with alkali to form a salt plus water.<br>• Describe, explain and exemplify the processes of filtration and crystallisation.<br>• Suggest suitable purification techniques given information about the substances involved.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Predict products from given reactants.<br>• Use the formulae of common ions to deduce the formulae of salts.<br><br>4.7.3.3 Energy changes and reactions<br>• Distinguish between endothermic and exothermic reactions on the basis of the temperature change of the surroundings.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Identify examples of exothermic and endothermic reactions based on the temperature change of the reaction mixture. | 4.7.3.1 Reactions of acids<br>Scientific, practical and mathematical skills<br>WS 1.2 (HT only) Explain, in terms of gain or loss of electrons, that the reactions of metals with acids are redox reactions (see Atoms into ions and ions into atoms (page 134)).<br>WS 4.1 (HT only) Identify which species are oxidised and which are reduced in given chemical reactions. |

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| | 4.7.3.4 The pH scale and neutralisation<br>• Recall that acids form hydrogen ions when they dissolve in water and solutions of alkalis contain hydroxide ions.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Write an ionic equation to represent neutralisation.<br>• WS 2.3 Describe the use of universal indicator or a wide range indicator to measure the approximate pH of a solution.<br>• WS 3.2 Use the pH scale to identify acidic or alkaline solutions.<br><br>**4.7.4 The rate and extent of chemical change**<br>4.7.4.1 Factors that affect reaction rates<br>• Describe the effect of changes in temperature, concentration, pressure, and surface area on rate of reaction.<br>• Suggest practical methods for determining the rate of a given reaction.<br>Scientific, practical and mathematical skills | 4.7.3.4 The pH scale and neutralisation<br>• Use the formulae of common ions to write balanced ionic equations.<br>• Recall that relative acidity and alkalinity are measured by pH.<br>• Recognise that aqueous neutralisation reactions can be generalised to hydrogen ions reacting with hydroxide ions to form water<br><br>4.7.3.5 Strong and weak acids<br>• Use and explain the terms dilute and concentrated (amount of substance) and weak and strong (degree of ionisation) in relation to acids.<br>• Recall that as hydrogen ion concentration increases by a factor of ten the pH value of a solution decreases by a factor of one.<br>• 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).<br><br>4.7.4.1 Factors that affect reaction rates<br>Scientific, practical and mathematical skills<br>• Calculate the gradient of a tangent to the curve on these graphs as a measure of rate of reaction at a specific time. |

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| | • WS 3.3, MS 1a, 1c Calculate the mean rate of a reaction from given information about the quantity of a reactant used or the quantity of a product formed and the time taken.<br>• WS 3.5, MS 4a, 4b, 4c Draw, and interpret, graphs showing the quantity of product formed or quantity of reactant used up against time to compare or determine rates of reaction.<br>• WS 3.3, MS 4e Draw tangents to the curves on these graphs and use the gradient of the tangent as a measure of the rate of reaction. WS 3.3, MS 4d, 4e<br><br>4.7.4.2 The effect of surface area on rates of reaction<br>• 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.<br>Scientific, practical and mathematical skills<br>• MS 1c Use proportionality when comparing factors affecting rate of reaction.<br>• MS 5c Calculate surface areas and volumes of cubes.<br><br>4.7.4.3 The effect of temperature, concentration and pressure on rates of reaction<br>• Explain the effects on rates of reaction of changes in temperature, concentration and pressure in terms of the frequency and energy of collision between particles.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Predict and explain the effects of changing conditions on the rate of a reaction<br><br>4.7.4.4 Activation energy<br>• Explain activation energy as the energy needed for a reaction to occur. | |

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| | • Draw and label a reaction profile for an exothermic and an endothermic reaction, identifying activation energy.<br>Scientific, practical and mathematical skills<br>• WS 3.2, 3.5, MS 4a Interpret reaction profiles, including using them to identify reactions as exothermic or endothermic. | 4.7.4.5 Bond breaking and bond forming<br>• Calculate energy changes in a chemical reaction by considering bond making and bond breaking energies.<br>Scientific, practical and mathematical skills<br>• WS 3.3, MS 1a Use arithmetic computation when calculating energy changes.<br>• WS 1.2, 3.3, MS 1a, 4a Calculate the energy transferred in chemical reactions between simple molecules in the gas state using bond energies supplied. |
| | 4.7.4.6 Catalysts<br>• Describe the characteristics of catalysts and their effect on rates of reaction.<br>• Identify catalysts in reactions.<br>• Explain catalytic action in terms of activation energy.<br>Scientific, practical and mathematical skills<br>• WS 3.5 Identify catalysts in reactions from their effect on the rate of reaction and because they are not included in the chemical equation for the reaction.<br>• WS 1.2 Use reaction profiles to explain catalytic action.<br><br>4.7.4.7 Enzymes<br>• Recall that enzymes act as catalysts in biological systems.<br>• Explain the mechanism of enzyme action including the active site, enzyme specificity and factors affecting the rate of enzymatic reaction.<br>Scientific, practical and mathematical skills | 4.7.4.10 Factors affecting the position of equilibrium<br>• Predict the effect of changing reaction conditions on equilibrium position<br>• Predict the effect of changing concentration on equilibrium position and suggest appropriate conditions to produce a particular product.<br>• Predict the effect of changing temperature on equilibrium position and suggest appropriate conditions to produce a particular product.<br>• Predict the effect of changing pressure on equilibrium position and suggest appropriate conditions to produce a particular product.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Apply Le Châtelier's principle to make qualitative predictions about the effect of changes on systems at equilibrium when given appropriate information.<br>• WS 3.5 Interpret appropriate given data to predict the effect of a change in concentration |

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| | • WS 3.3, 3.5, MS 1a, 1c, 1d Carry out rate calculations for chemical reactions and make estimates of simple calculations without using a calculator.<br><br>4.7.4.8 Reversible reactions<br>• Recall that some reactions may be reversed by altering the reaction conditions.<br><br>4.7.4.9 Dynamic equilibrium<br>• Recall that dynamic equilibrium occurs when the rates of forward and reverse reactions are equal.<br><br>**4.7.5 Atoms into ions and ions into atoms**<br>4.7.5.1 A reactivity series for metals<br>• Explain how the reactivity of metals with water or dilute acids is related to the tendency of the metal to form its positive ion.<br>Scientific, practical and mathematical skills | of a reactant or product on given reactions at equilibrium.<br>• WS 1.2 Apply the idea that if a reversible reaction is exothermic in one direction, it is endothermic in the opposite direction.<br><br>4.7.5.1 A reactivity series for metals<br>Scientific, practical and mathematical skills<br>• WS 1.2 Write ionic equations for displacement reactions<br><br>4.7.5.2 Electrolysis<br>Scientific, practical and mathematical skills<br>• Write half equations for the reactions occurring at the electrodes during electrolysis. Students may be required to complete and balance supplied half equations.<br><br>4.7.5.3 Electrolysis of aqueous solutions<br>Scientific, practical and mathematical skills<br>• WS 1.2 (HT only) Write half equations for the reactions occurring at the electrodes during electrolysis. Students may be required to complete and balance supplied half equations. |

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| | • WS 3.8 Recall and describe the reactions, if any, of potassium, sodium, lithium, calcium, magnesium, zinc, iron and copper with water or dilute acids.<br>• WS 3.5 Deduce an order of reactivity of metals based on experimental results<br><br>4.7.5.2 Electrolysis<br>• Describe electrolysis in terms of the ions present and reactions at the electrodes.<br>• Recall that metals (or hydrogen) are formed at the cathode and non-metals are formed at the anode in electrolysis using inert electrodes.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Predict the products of electrolysis of binary ionic compounds in the molten state.<br><br>4.7.5.3 Electrolysis of aqueous solutions<br>• Describe competing reactions in the electrolysis of aqueous solutions of ionic compounds in terms of the different species present.<br><br>4.7.5.4 Tests for gases<br>• Describe tests to identify selected gases including oxygen, hydrogen and chlorine.<br>Scientific, practical and mathematical skills<br>• WS 3.5 Interpret the observations from gas tests. | 4.7.5.5 Electron transfer reactions<br>• Explain reduction and oxidation in terms of gain or loss of electrons, identifying which species are oxidised and which are reduced.<br>Scientific, practical and mathematical skills<br>• WS 4.1 Identify, in a given reaction, symbol equation or half equation, which species are oxidised and which are reduced. |

## UNIT 8: Guiding Spaceship Earth towards a sustainable future (Energy changes in chemistry NC)

| Previous Learning at Key Stage 3 | Foundation AQA Synergy GCSE | Higher AQA Synergy GCSE – Extra content on top of Foundation content |
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| **Materials**<br>• The order of metals and carbon in the reactivity series<br>• The use of carbon in obtaining metals from metal oxides<br>• Properties of ceramics, polymers and composites (qualitative) | ***Chemistry***<br>***4.8 Guiding Spaceship Earth towards a sustainable future***<br>**4.8.1 Carbon chemistry**<br>4.8.1.1 Bonding and structure in forms of carbon<br>• Explain the properties of diamond, graphite, fullerenes and graphene in terms of their structures and bonding.<br>Scientific, practical and mathematical skills<br>• MS 5b Visualise and represent 2D and 3D forms including twodimensional representations of 3D objects.<br>• WS 1.4 Give examples of the uses of diamond, graphite and fullerenes, including carbon nanotubes.<br><br>4.8.1.2 Hydrocarbons in crude oil<br>• Recall that crude oil is a main source of hydrocarbons and is a feedstock for the petrochemical industry.<br>• Recognise that crude oil is a finite resource.<br>• Recall that carbon can form four covalent bonds.<br>• 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.<br>• Describe the fractions as largely a mixture of compounds of formula CnH2n+2 which are members of the alkane homologous series.<br>Scientific, practical and mathematical skills<br>• WS 1.2, MS 5b Recognise substances as alkanes given their formulae.<br><br>4.8.1.3 Fractional distillation of crude oil<br>• Describe and explain the separation of crude oil by fractional distillation.<br>• Describe, explain and exemplify the processes of fractional distillation. | |

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| | • Explain how modern life is crucially dependent upon hydrocarbons.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Write balanced equations for the complete combustion of hydrocarbons with a given formula. Relate trends in the hydrocarbons to molecular size using ideas in Covalent bonding<br><br>4.8.1.4 Cracking hydrocarbons<br>• Describe the production of materials that are more useful by cracking.<br>• WS 1.2 Balance chemical equations as examples of cracking given the formulae of the reactants and products.<br><br>**4.8.2 Resources of materials and energy**<br>4.8.2.1 Metal extraction by reduction of oxides<br>• Explain reduction and oxidation in terms of loss or gain of oxygen, identifying which species are oxidised and which are reduced.<br>• 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.<br>Scientific, practical and mathematical skills<br>• WS 1.2 Identify the substances which are oxidised or reduced in terms of gain or loss of oxygen.<br>• WS 1.4 Explain in terms of the reactivity series why some metals are extracted with carbon and others by electrolysis.<br>• Interpret or evaluate specific metal extraction processes when given appropriate information.<br><br>4.8.2.2 Metal extraction by electrolysis<br>• Explain why and how electrolysis is used to extract some metals from their ores. | |

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| | Scientific, practical and mathematical skills<br>• WS 1.4 Explain technological applications of science, including the use of cryolite for the extraction of aluminium and the need to replace the anodes.<br><br>4.8.2.4 Energy resources<br>• Describe the main energy resources available for use on Earth (including fossil fuels, nuclear fuel, biofuel, wind, hydroelectricity, the tides and the Sun); compare the ways in which they are used and distinguish between renewable and non-renewable resources<br>Scientific, practical and mathematical skills<br>• WS 1.4 Explain technological applications of science. Explain patterns and trends in given data about the use of energy resources. Evaluate the use of different energy resources, taking into account reliability, cost and impact on the environment.<br>• WS 4.4, MS 1c, 2c, 4a Interpret data with energy quantities given, using the prefixes kilo, mega, giga and tera.<br><br>4.8.2.5 Energy conservation and dissipation<br>• Describe, with examples, where there are energy transfers in a system and where there is no net change to the total energy of a closed system (qualitative only).<br>• Describe, with examples, how in all system changes, energy is dissipated so that it is stored in less useful ways.<br>Scientific, practical and mathematical skills | 4.8.2.3 Metal extraction by biological methods<br>• Evaluate alternative biological methods of metal extraction (bacterial and phytoextraction).<br>Scientific, practical and mathematical skills<br>• WS 1.4 Evaluate environmental implications of the applications of science.<br><br>4.8.2.7 Energy efficiency<br>• Calculate energy efficiency for any energy transfer, (HT only) and describe ways to increase efficiency. |

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| | • WS 3.3, MS 1a, 1c, 3c 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.<br><br>4.8.2.6 Preventing unwanted energy transfers<br>• Explain ways of reducing unwanted energy transfer, eg through lubrication and thermal insulation; describe the effects, on the rate of cooling of a building, of the thickness and thermal conductivity of its walls (qualitative only).<br>Scientific, practical and mathematical skills<br>• WS 1.4 Explain technological applications of science.<br><br>4.8.2.7 Energy efficiency<br>• Calculate energy efficiency for any energy transfer<br>Scientific, practical and mathematical skills<br>• WS 3.3, MS 3c Recall and apply this equation.<br>• MS 1a, 1c, 3c Calculate or use efficiency values as a decimal or as a percentage.<br><br>4.8.2.8 Life cycle assessment<br>• Describe the basic principles in carrying out a life cycle assessment of a material or product.<br>• Interpret data from a life cycle assessment of a material or product.<br>Scientific, practical and mathematical skills<br>• WS 1.3, 1.4, 3.3, 3.5 Interpret data from LCAs of materials or products given appropriate information.<br>• MS 1a Recognise and use expressions in decimal form.<br>• MS 1d Make estimates of the results of simple calculations.<br>• WS 4.6, MS 2a Use an appropriate number of significant figures. | |

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| | • WS 3.5, MS 4a Translate information between graphical and numeric form.<br><br>4.8.2.9 Recycling<br>• Describe a process where a material or product is recycled for a different use, and explain why this is viable.<br>Scientific, practical and mathematical skills<br>• WS 1.4 Evaluate factors that affect decisions on recycling, given appropriate information. | |
| | **4.9 Key ideas in Biology:**<br>• life processes depend on molecules whose structure is related to their function<br>• 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<br>• 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<br>• living organisms are interdependent and show adaptations to their environment<br>• 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<br>• organic compounds are used as fuels in cellular respiration to allow the other chemical reactions necessary for life<br>• the chemicals in ecosystems are continually cycling through the natural world<br>• the characteristics of a living organism are influenced by its genome and its interaction with the environment<br>• evolution occurs by a process of natural selection and accounts both for biodiversity and how organisms are all related to varying degrees. | |
| | **4.9 Key ideas in Chemistry:**<br>Key ideas in chemistry:<br>• matter is composed of tiny particles called atoms and there are about 100 different naturally occurring types of atoms called elements<br>• elements show periodic relationships in their chemical and physical properties<br>• these periodic properties can be explained in terms of the atomic structure of the elements<br>• atoms bond by either transferring electrons from one atom to another or by sharing electrons<br>• 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<br>• there are barriers to reaction so reactions occur at different rates | |

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| | • chemical reactions take place in only three different ways: proton transfer; electron transfer; electron sharing<br>• energy is conserved in chemical reactions so can therefore be neither created or destroyed. |
| | **4.9 Key ideas in Physics:**<br>• the use of models, as in the particle model of matter or the wave models of light and of sound<br>• 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<br>• the phenomena of 'action at a distance' and the related concept of the field as the key to analysing electrical, magnetic and gravitational effects<br>• that differences, for example between pressures or temperatures or electrical potentials, are the drivers of change<br>• 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<br>• that physical laws and models are expressed in mathematical form. |