2c. Content of topics C1 to C6

Topic C1: Particles

C1.1 The particle model

Summary

This short section introduces the particle model and its explanation of different states of matter. A simple particle model can be used to represent the arrangement of particles in the different states of matter and to explain observations during changes in state. It does not, however, explain why different materials have different properties. This explanation is that the particles themselves and how they are held together must be different in some way. Elements are substances that are made up of only one type of atom and atoms of different elements can combine to make compounds.

Underlying knowledge and understanding

Learners should be familiar with the different states of matter and their properties. They should also be familiar with changes of state in terms of the particle model. Learners should have sufficient grounding in the particle model to be able to apply it to unfamiliar materials and contexts.

Common misconceptions

Learners commonly intuitively adhere to the idea that matter is continuous. For example, they believe that the space between gas particles is filled or non-existent, or that particles expand when they are heated. The notion that empty space exists between particles is problematic because this lacks supporting sensory evidence. They also show difficulty understanding the concept of changes in state being reversible; this should be addressed during the teaching of this topic.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
CM1.1i	represent three-dimensional shapes in two dimensions and vice versa when looking at chemical structures, e.g. allotropes of carbon	M5b

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C1.1a	describe the main features of the particle model in terms of states of matter and change of state		M5b	WS1.1a, WS1.1b	
C1.1b	explain in terms of the particle model the distinction between physical changes and chemical changes				
C1.1c	**explain the limitations of the particle model in relation to changes of state when particles are represented by inelastic spheres (e.g. like bowling balls)**	**that it does not take into account the forces of attraction between particles, the size of particles and the space between them**	M5b	WS1.1c	Observations of change of state with comparison to chemical changes.

2

C1.2 Atomic structure

Summary

An atom is the smallest component of an element that gives an element its property. These properties can be explained by models of atomic structure. Current models suggest that atoms are made of smaller sub-atomic particles called protons, neutrons and electrons. They suggest that atoms are composed of a nucleus surrounded by electrons. The nucleus is composed of neutrons and protons. Atoms of each element have the same number of protons as electrons. Atoms of different elements have different numbers of protons. Atoms of the same element will have the same number of protons but may have different numbers of neutrons.

Underlying knowledge and understanding

Learners should be familiar with the simple (Dalton) atomic model.

Common misconceptions

Learners commonly have difficulty understanding the concept of isotopes due to the fact they think that neutral atoms have the same number of protons and neutrons. They also find it difficult to distinguish between the properties of atoms and molecules. Another common misconception is that a positive ion gains protons or a negative ion loses protons i.e. that there is a change in the nucleus of the atom rather than a change in the number of electrons.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
CM1.2i	relate size and scale of atoms to objects in the physical world	M4a
CM1.2ii ☑	estimate size and scale of atoms and nanoparticles	M1c

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C1.2a	describe how and why the atomic model has changed over time	the models of Dalton, Thomson, Rutherford, Bohr, Geiger and Marsden		WS1.1a, WS1.1i, WS1.2b	Timeline of the atomic model.
C1.2b	describe the atom as a positively charged nucleus surrounded by negatively charged electrons, with the nuclear radius much smaller than that of the atom and with most of the mass in the nucleus			WS1.4a	
C1.2c	recall the typical size (order of magnitude) of atoms and small molecules	the concept that typical atomic radii and bond length are in the order of 10^{-10}m	M1c, M4a	WS1.1c, WS1.4b, WS1.4c, WS1.4d, WS1.4e, WS1.4f	
C1.2d	recall relative charges and approximate relative masses of protons, neutrons and electrons			WS1.4a, WS1.4b, WS1.4c	
C1.2e	calculate numbers of protons, neutrons and electrons in atoms and ions, given atomic number and mass number of isotopes	definitions of an ion, atomic number, mass number and an isotope, also the standard notation to represent these		WS1.3c, WS1.4b	

Topic C2: Elements, compounds and mixtures

C2.1 Purity and separating mixtures

Summary

In chemical terms elements and compounds are pure substances and mixtures are impure substances. Chemically pure substances can be identified using melting point. Many useful materials that we use today are mixtures. There are many methods of separating mixtures including filtration, crystallisation, distillation and chromatographic techniques.

Underlying knowledge and understanding

Learners should be familiar with the concept of pure substances. They should have met simple separation techniques of mixtures. The identification of pure substances in terms of melting point, boiling point and chromatography will also have been met before.

Common misconceptions

Learners commonly misuse the word pure and confuse it with natural substances or a substance that has not been tampered with. They think that when a substance dissolves that the solution is pure and not a mixture.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
CM2.1i	arithmetic computation, ratio, percentage and multistep calculations permeates quantitative chemistry	M1a, M1c, M1d
CM2.1ii	provide answers to an appropriate number of significant figures	M2a
CM2.1iii	change the subject of a mathematical equation	M3b, M3c
CM2.1iv	arithmetic computation and ratio when determining empirical formulae, balancing equations	M3b, M3c

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C2.1a	explain what is meant by the purity of a substance, distinguishing between the scientific and everyday use of the term 'pure'			WS1.4a	Purification of compounds. (PAG C4, PAG C7)
C2.1b	use melting point data to distinguish pure from impure substances		M1a, M1c, M1d, M2a		Measurement of melting point.
C2.1c	calculate relative formula masses of species separately and in a balanced chemical equation	the definition of relative atomic mass, relative molecular mass and relative formula mass	M3b, M3c	WS1.3c, WS1.4c	
C2.1d	deduce the empirical formula of a compound from the relative numbers of atoms present or from a model or diagram and vice versa		M3b, M3c	WS1.1b, WS1.4a	
C2.1e	explain that many useful materials are formulations of mixtures	alloys			
C2.1f	describe, explain and exemplify the processes of filtration, crystallisation, simple distillation, and fractional distillation	knowledge of the techniques of filtration, crystallisation, simple distillation and fractional distillation		WS1.2b, WS1.2c, WS2a, WS2b	Separation of mixtures and purification of compounds. (PAG C4, PAG C7) Distillation of mixtures (PAG C4)
C2.1g	describe the techniques of paper and thin layer chromatography			WS1.2b, WS1.2c, WS1.4a, WS2a, WS2b	Thin layer chromatography. (PAG C3)
C2.1h	recall that chromatography involves a stationary and a mobile phase and that separation depends on the distribution between the phases	identification of the mobile and stationary phases		WS1.4a	

2

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
C2.1i	interpret chromatograms, including measuring R_f values	the recall and the use of the formula	M3b, M3c	WS1.3c, WS1.4a	
C2.1j	suggest suitable purification techniques given information about the substances involved				
C2.1k	suggest chromatographic methods for distinguishing pure from impure substances	paper, thin layer (TLC) and gas chromatography		WS1.4a	Using chromatography to identify mixtures of dyes in an unknown ink. (PAG C3)

C2.2 Bonding

Summary

A simple electron energy level model can be used to explain the basic chemical properties of elements. When chemical reactions occur, they can be explained in terms of losing, gaining or sharing of electrons. The ability of an atom to lose, gain or share electrons depends on its atomic structure. Atoms that lose electrons will bond with atoms that gain electrons. Electrons will be transferred between the atoms to form a positive ion and a negative ion. These ions attract one another in what is known as an ionic bond. Atoms that share electrons can bond with other atoms that share electrons to form a molecule. Atoms in these molecules are held together by covalent bonds.

Underlying knowledge and understanding

Learners should be familiar with the simple (Dalton) atomic model.

Common misconceptions

Learners do not always appreciate that the nucleus of an atom does not change when an electron is lost, gained or shared. They also find it difficult to predict the numbers of atoms that must bond in order to achieve a stable outer level of electrons. Learners think that chemical bonds are physical things made of matter. They also think that pairs of ions such as Na^{+} and Cl^{-} are molecules. They do not have an awareness of the 3D nature of bonding and therefore the shape of molecules.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
CM2.2i ☑	estimate size and scale of atoms and nanoparticles	M1c
CM2.2ii	represent three-dimensional shapes in two dimensions and vice versa when looking at chemical structures, e.g. allotropes of carbon	M5b
CM2.2iii	translate information between diagrammatic and numerical forms	M4a

2

Topic content			Opportunities to cover:			
Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
C2.2a	describe metals and non-metals and explain the differences between them on the basis of their characteristic physical and chemical properties	physical properties, formation of ions and common reactions, e.g. with oxygen to form oxides		WS1.3f, WS1.4a	
C2.2b	explain how the atomic structure of metals and non-metals relates to their position in the periodic table				
C2.2c	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	group number and period number	M1c	WS1.4a	
C2.2d	describe and compare the nature and arrangement of chemical bonds in: i. ionic compounds ii. simple molecules iii. giant covalent structures iv. polymers v. metals		M5b, M4a	WS1.4a	Make ball and stick models of molecules.
C2.2e	explain chemical bonding in terms of electrostatic forces and the transfer or sharing of electrons			WS1.4a	
C2.2f	construct dot and cross diagrams for simple covalent and binary ionic substances		M4a	WS1.4a	

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
C2.2g	describe the limitations of particular representations and models to include dot and cross diagrams, ball and stick models and two- and three-dimensional representations		M5b	WS1.1c	
C2.2h	explain how the reactions of elements are related to the arrangement of electrons in their atoms and hence to their atomic number			WS1.1b, WS1.3f, WS1.4a	
C2.2i	explain in terms of atomic number how Mendeleev's arrangement was refined into the modern periodic table			WS1.1a, WS1.4a	

C2.3 Properties of materials

Summary

This section explores the physical properties of elements and compounds and how the nature of their bonding is a factor in their properties.

Underlying knowledge and understanding

Learners will know the difference between an atom, element and compound.

Common misconceptions

Learners commonly have a limited understanding of chemical reactions, for example substances may explode, burn, contract, expand or change state.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
CM2.3i	represent three-dimensional shapes in two dimensions and vice versa when looking at chemical structures, e.g. allotropes of carbon	M5b
CM2.3ii ☑	relate size and scale of atoms to objects in the physical world	M4a
CM2.3iii ☑	estimate size and scale of atoms and nanoparticles	M1d
CM2.3iv ☑	interpret, order and calculate with numbers written in standard form when dealing with nanoparticles	M1b
CM2.3v ☑	use ratios when considering relative sizes and surface area to volume comparisons	M1c
CM2.3vi ☑	calculate surface areas and volumes of cubes	M5c

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C2.3a	recall that carbon can form four covalent bonds			WS1.4a	
C2.3b	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				
C2.3c	explain the properties of diamond, graphite, fullerenes and graphene in terms of their structures and bonding		M5b	WS1.4a	
C2.3d	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			WS1.2a, WS1.3f, WS1.4a, WS1.4c	
C2.3e	use data to predict states of substances under given conditions	data such as temperature and how this may be linked to changes of state			
C2.3f	explain how the bulk properties of materials (ionic compounds; simple molecules; giant covalent structures; polymers and metals) 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	recognition that the atoms themselves do not have the bulk properties of these materials		WS1.4a	

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
C2.3g ☑	compare 'nano' dimensions to typical dimensions of atoms and molecules		M4a, M1d, M1b	WS1.4c, WS1.4d	
C2.3h ☑	describe the surface area to volume relationship for different-sized particles and describe how this affects properties		M1c	WS1.4c	Dissolving tablets. (PAG C8)
C2.3i ☑	describe how the properties of nanoparticulate materials are related to their uses		M5c	WS1.1c, WS1.1e, WS1.3c, WS1.4a	
C2.3j ☑	explain the possible risks associated with some nanoparticulate materials			WS1.1d, WS1.1f, WS1.1h, WS1.1i WS1.4a	

Topic C3: Chemical reactions

C3.1 Introducing chemical reactions

Summary

A chemical equation represents, in symbolic terms, the overall change in a chemical reaction. New materials are formed through chemical reactions but mass will be conserved. This can be explained by a model involving the rearrangement of atoms. Avogadro gave us a system of measuring the amount of a substance in moles.

Underlying knowledge and understanding

Learners should be familiar with chemical symbols and formulae for elements and compounds. They should also be familiar with representing chemical reactions using formulae. Learners will have knowledge of conservation of mass, changes of state and chemical reactions.

Common misconceptions

Although learners may have met the conservation of mass they still tend to refer to chemical reactions as losing mass. They understand that mass is conserved but not the number or species of atoms. They may think that the original substance vanishes 'completely and forever' in a chemical reaction.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
CM3.1i	arithmetic computation and ratio when determining empirical formulae, balancing equations	M1a, M1c
CM3.1ii	**calculations with numbers written in standard form when using the Avogadro constant**	**M1b**
CM3.1iii	provide answers to an appropriate number of significant figures	M2a
CM3.1iv	convert units where appropriate **particularly from mass to moles**	M1c

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C3.1a	use chemical symbols to write the formulae of elements and simple covalent and ionic compounds		M1a, M1c	WS1.4a	
C3.1b	use the names and symbols of common elements and compounds and the principle of conservation of mass to write formulae and balanced chemical equations **and half equations**		M1a, M1c	WS1.4c	
C3.1c	use the names and symbols of common elements from a supplied periodic table to write formulae and balanced chemical equations where appropriate	the first 20 elements, Groups 1, 7, and 0 and other common elements included within the specification			
C3.1d	use the formula of common ions to deduce the formula of a compound		M1a, M1c		
C3.1e	**construct balanced ionic equations**		M1a, M1c		
C3.1f	describe the physical states of products and reactants using state symbols (s, l, g and aq)				
C3.1g	**recall and use the definitions of the Avogadro constant (in standard form) and of the mole**	**the calculation of the mass of one atom/molecule**	M1b, M1c	WS1.4b, WS1.4c, WS1.4d, WS1.4f	
C3.1h	**explain how the mass of a given substance is related to the amount of that substance in moles and vice versa**		M1c, M2a	WS1.4b, WS1.4c	

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
C3.1i	recall and use the law of conservation of mass			WS1.4c	
C3.1j	explain any observed changes in mass in non-enclosed systems during a chemical reaction and explain them using the particle model			WS1.1b, WS1.4c	
C3.1k	**deduce the stoichiometry of an equation from the masses of reactants and products and explain the effect of a limiting quantity of a reactant**		M1c	WS1.3c, WS1.4c, WS1.4d, WS1.4f	
C3.1l	**use a balanced equation to calculate masses of reactants or products**		M1c	WS1.3c, WS1.4c	

C3.2 Energetics

Summary

Chemical reactions are accompanied by an energy change. A simple model involving the breaking and making of chemical bonds can be used to interpret and calculate the energy change.

Underlying knowledge and understanding

Learners should be familiar with exothermic and endothermic chemical reactions.

Common misconceptions

Learners commonly have the idea that energy is lost or used up. They do not grasp the idea that energy is transferred. Learners also wrongly think that energy is released when bonds break and do not link this release of energy with the formation of bonds. They also may think for example that a candle burning is endothermic because heat is needed to initiate the reaction.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
CM3.2i	interpretation of charts and graphs when dealing with reaction profiles	M4a
CM3.2ii	arithmetic computation when calculating energy changes	M1a

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		**To include**	**Maths**	**Working scientifically**	
C3.2a	distinguish between endothermic and exothermic reactions on the basis of the temperature change of the surroundings			WS1.4c	Measuring the temperature change in reactions. (PAG C8)
C3.2b	draw and label a reaction profile for an exothermic and an endothermic reaction	activation energy, energy change, reactants and products	M4a	WS1.3b, WS1.3c, WS1.3d, WS1.3e, WS1.3g, WS1.3h, WS1.4c	
C3.2c	explain activation energy as the energy needed for a reaction to occur			WS1.4c	
C3.2d	**calculate energy changes in a chemical reaction by considering bond making and bond breaking energies**		M1a	WS1.3c, WS1.4c	

C3.3 Types of chemical reactions

Summary
Chemical reactions can be classified according to changes at the atomic and molecular level. Examples of these include reduction, oxidation and neutralisation reactions.

Underlying knowledge and understanding
Learners should be familiar with combustion, thermal decomposition, oxidation and displacement reactions. They will be familiar with defining acids and alkalis in terms of neutralisation reactions. Learners will have met reactions of acids with alkalis to produce a salt and water and reactions of acids with metals to produce a salt and hydrogen.

Common misconceptions
Learners commonly intuitively adhere to the idea that hydrogen ions in an acid are still part of the molecule, not free in the solution. They tend to have little understanding of pH, for example, they tend to think that alkalis are less corrosive than acids. Learners also may think that the strength of acids and bases and concentration mean the same thing.

Tiering
Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
CM3.3i	arithmetic computation, ratio, percentage and multistep calculations permeates quantitative chemistry	M1a, M1c, M1d

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C3.3a	explain reduction and oxidation in terms of loss or gain of oxygen, identifying which species are oxidised and which are reduced	the concept of oxidising agent and reducing agent		WS1.4a	
C3.3b	**explain reduction and oxidation in terms of gain or loss of electrons, identifying which species are oxidised and which are reduced**			WS1.4a	
C3.3c	recall that acids form hydrogen ions when they dissolve in water and solutions of alkalis contain hydroxide ions			WS1.4a	
C3.3d	describe neutralisation as acid reacting with alkali or a base to form a salt plus water			WS1.4a	Production of pure dry sample of salt. (PAG C7)
C3.3e	recognise that aqueous neutralisation reactions can be generalised to hydrogen ions reacting with hydroxide ions to form water			WS1.4a	
C3.3f	recall that carbonates and some metals react with acids and write balanced equations predicting products from given reactants			WS1.4a	
C3.3g	**use and explain the terms dilute and concentrated (amount of substance) and weak and strong (degree of ionisation) in relation to acids**	**ratio of amount of acid to volume of solution**	M1a, M1c, M1d	WS1.4a	
C3.3h	recall that relative acidity and alkalinity are measured by pH			WS1.4a	

2

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
C3.3i	**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)**	**pH of titration curves**		WS1.4a	Neutralisation reactions. (PAG C6)
C3.3j	**recall that as hydrogen ion concentration increases by a factor of ten the pH value of a solution decreases by a factor of one**		M1a, M1c, M1d	WS1.4a	
C3.3k	describe techniques and apparatus used to measure pH				Determining pH of unknown solutions. (PAG C6) Use of pH probes. (PAG C6)

C3.4 Electrolysis

Summary

Decomposition of a liquid during the conduction of electricity is a chemical reaction called electrolysis. This section explores the electrolysis of various molten ionic liquids and aqueous ionic solutions.

Underlying knowledge and understanding

Learners should be familiar with ionic solutions and solids.

Common misconceptions

A common misconception is that ionic solutions conduct because of the movement of electrons. Another common misconception is that ionic solids do not conduct electricity because electrons cannot move.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
CM3.4i	arithmetic computation and ratio when determining empirical formulae, balancing equations	M1a, M1c

2

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C3.4a	recall that metals (or hydrogen) are formed at the cathode and non-metals are formed at the anode in electrolysis using inert electrodes	the terms cations and anions		WS1.4a	
C3.4b	predict the products of electrolysis of binary ionic compounds in the molten state	compounds such as $NaCl$	M1a, M1c	WS1.2a, WS1.2b, WS1.2c, WS1.4a, WS2a, WS2b	
C3.4c	describe competing reactions in the electrolysis of aqueous solutions of ionic compounds in terms of the different species present	the electrolysis of aqueous $NaCl$ and $CuSO_4$ using inert electrodes	M1a, M1c	WS1.4a	Electrolysis of sodium chloride solution. (PAG C2) Electrolysis of copper sulfate solution. (PAG C2)
C3.4d	describe electrolysis in terms of the ions present and reactions at the electrodes		M1a, M1c		
C3.4e	describe the technique of electrolysis using inert and non-inert electrodes				

Topic C4: Predicting and identifying reactions and products

C4.1 Predicting chemical reactions

Summary

Models of how substances react and the different types of chemical reactions that can occur enable us to predict the likelihood and outcome of a chemical reaction. The current periodic table was developed based on observations of the similarities and differences in the properties of elements. The way that the periodic table is arranged into groups and periods reveals the trends and patterns in the behaviour of the elements. The model of atomic structure provides an explanation for trends and patterns in the properties of elements. The arrangement of elements in groups and periods reveals the relationship between observable properties and how electrons are arranged in the atoms of each element.

Underlying knowledge and understanding

Learners should be familiar with the principles underpinning the Mendeleev periodic table; the periodic table: periods and groups; metals and non-metals; the varying physical and chemical properties of different elements; the chemical properties of metals and non-metals; the chemical properties of metal and non-metal oxides with respect to acidity and how patterns in reactions can be predicted with reference to the periodic table.

Common misconceptions

Learners consider the properties of particles of elements to be the same as the bulk properties of that element. They tend to rely on the continuous matter model rather than the particle model. Learners confuse state changes and dissolving with chemical changes. Also, since the atmosphere is invisible to the eye and learners rely on concrete, visible information, this means they therefore often avoid the role of oxygen in their explanations for open system reactions. Even if the role of oxygen is appreciated, learners do not realise that solid products of an oxidation reaction have more mass than the starting solid.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
CM4.1i	arithmetic computation and ratio when determining empirical formulae, balancing equations	M1a, M1c

2

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C4.1a	recall the simple properties of Groups 1, 7 and 0	physical and chemical properties		WS1.2a, WS1.4a WS1.4c	Displacement reactions of halogens with halides. (PAG C1)
C4.1b	explain how observed simple properties of Groups 1, 7 and 0 depend on the outer shell of electrons of the atoms and predict properties from given trends down the groups	ease of electron gain or loss; physical and chemical properties			
C4.1c ☑	recall the general properties of transition metals and their compounds and exemplify these by reference to a small number of transition metals	melting point, density, reactivity, formation of coloured ions with different charges and uses as catalysts		WS1.4a	Investigation of transition metals. (PAG C1, PAG C5, PAG C8)
C4.1d	predict possible reactions and probable reactivity of elements from their positions in the periodic table			WS1.1b, WS1.2a, WS1.4a	
C4.1e	explain how the reactivity of metals with water or dilute acids is related to the tendency of the metal to form its positive ion		M1a, M1c	WS1.4a	Reaction of metals with water, dilute hydrochloric acid. (PAG C1, PAG C7, PAG C8)
C4.1f	deduce an order of reactivity of metals based on experimental results			WS1.3e, WS2a	Displacement reactions involving metals and metal salts. (PAG C1, PAG C7, PAG C8)

C4.2 Identifying the products of chemical reactions

Summary

Types of substances can be classified according to their general physical and chemical properties. This section explores the tests that can be used to identify the products of reactions by looking at their physical and chemical properties.

Underlying knowledge and understanding

Learners should be familiar with cations and anions from their work on electrolysis.

Common misconceptions

Learners confuse mass and density so in reactions involving change of state, learners reason that the products from a precipitation reaction are heavier than the starting materials and that when a gas is produced the reaction has lost mass overall.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
CM4.2i ☑	interpret charts, particularly in spectroscopy	M4a

2

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C4.2a	describe tests to identify selected gases	oxygen, hydrogen, carbon dioxide and chlorine			
C4.2b ☑	describe tests to identify aqueous cations and aqueous anions	calcium, copper, iron (II), iron (III) and zinc using sodium hydroxide; carbonates and sulfates using aqueous barium chloride followed by hydrochloric acid; chloride, bromide and iodide using silver nitrate		WS1.4a	Tests for cations using sodium hydroxide. (PAG C5) Tests for anions using silver nitrate and barium sulfate. (PAG C5)
C4.2c ☑	describe how to perform a flame test			WS1.2b, WS1.2c, WS2a, WS2b	Flame tests. (PAG C5)
C4.2d ☑	identify species from test results				Testing unknown solutions for cations and anions. (PAG C5)
C4.2e ☑	interpret flame tests to identify metal ions	the ions of lithium, sodium, potassium, calcium and copper		WS1.4a	
C4.2f ☑	describe the advantages of instrumental methods of analysis	sensitivity, accuracy and speed		WS1.1e, WS1.2c, WS1.2d, WS1.2e	
C4.2g ☑	interpret an instrumental result given appropriate data in chart or tabular form, when accompanied by a reference set of data in the same form		M4a	WS1.3e	

Topic C5: Monitoring and controlling chemical reactions

C5.1 Monitoring chemical reactions

Summary

This topic tackles the relationship of moles to the concentration of a solution and the volume of a gas. It also tackles the calculation of the mass of a substance in terms of its molarity. The topic then moves on to look at using equations to make predictions about yield by calculations and to calculate atom economy.

Underlying knowledge and understanding

Learners should be familiar with the mole from Topic C3 and know that it measures the amount of something. They should be familiar with representing chemical reactions using formulae and using equations.

Common misconceptions

The most common problem learners' encounter with these calculations is their lack of understanding of ratios. Also most learners think that the mole and mass are the same thing. This is reinforced by use of phrases such as '1 mole is 12 g of carbon, '1 mole is the relative atomic mass in grammes' or '1 mol = 12 g C' in teaching and in textbooks equating amount of substance to mass, portion of substance, number of particles (Avogadro's number) or number of moles. All these phrases reinforce the idea that amount of substance is a measure of mass or a number.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
CM5.1i ☑	**calculations with numbers written in standard form when using the Avogadro constant**	**M1b**
CM5.1ii ☑	provide answers to an appropriate number of significant figures	M2a
CM5.1iii ☑	convert units where appropriate **particularly from mass to moles**	M1c
CM5.1iv ☑	arithmetic computation, ratio, percentage and multistep calculations permeates quantitative chemistry	M1a, M1c, M1d
CM5.1v ☑	arithmetic computation when calculating yields and atom economy	M1a, M1c
CM5.1vi ☑	change the subject of a mathematical equation	M3b, M3c

2

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C5.1a ☑	**explain how the concentration of a solution in mol/dm^3 is related to the mass of the solute and the volume of the solution**		M1b	WS1.3c, WS1.4a, WS1.4c	Making standard solutions.
C5.1b ☑	describe the technique of titration				Acid/alkali titrations. (PAG C6)
C5.1c ☑	**explain the relationship between the volume of a solution of known concentration of a substance and the volume or concentration of another substance that react completely together**	**titration calculations**	M2a, M1c	WS1.3c, WS1.4a, WS1.4b, WS1.4c	
C5.1d ☑	**describe the relationship between molar amounts of gases and their volumes and vice versa**		M1c	WS1.3c, WS1.4a, WS1.4c, WS1.4d, WS1.4f	Measurement of gas volumes and calculating amount in moles. (PAG C8)
C5.1e ☑	**calculate the volumes of gases involved in reactions using the molar gas volume at room temperature and pressure (assumed to be 24dm^3)**		M1b, M1c		
C5.1f	**explain how the mass of a solute and the volume of the solution is related to the concentration of the solution**		M1b, M1c	WS1.3c, WS1.4a, WS1.4c	
C5.1g ☑	calculate the theoretical amount of a product from a given amount of reactant		M1a, M1c, M1d	WS1.3c	

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
C5.1h ☑	calculate the percentage yield of a reaction product from the actual yield of a reaction		M1a, M1c, M1d	WS1.2a, WS1.2b, WS1.2c, WS1.2d, WS1.3c, WS2a, WS2b	
C5.1i ☑	define the atom economy of a reaction				
C5.1j ☑	calculate the atom economy of a reaction to form a desired product from the balanced equation		M1a, M1c	WS1.3c	
C5.1k ☑	**explain why a particular reaction pathway is chosen to produce a specified product given appropriate data**	**data such as atom economy (if not calculated), yield, rate, equilibrium position and usefulness of by- products**	M3b, M3c	WS1.3c, WS1.3f	

2

C5.2 Controlling reactions

Summary
The rate and yield of a chemical reaction can be altered by changing the physical conditions.

Common misconceptions
Learners often misinterpret rate graphs and think that catalysts take part in reactions and run out/get used up.

Underlying knowledge and understanding
Learners should be familiar with the action of catalysts in terms of rate of reaction. They should know the term surface area and what it means.

Tiering
Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
CM5.2i	arithmetic computation, ratio when measuring rates of reaction	M1a, M1c
CM5.2ii	drawing and interpreting appropriate graphs from data to determine rate of reaction	M4b, M4c
CM5.2iii	determining gradients of graphs as a measure of rate of change to determine rate	M4d, M4e
CM5.2iv	proportionality when comparing factors affecting rate of reaction	M1c

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		**To include**	**Maths**	**Working scientifically**	
C5.2a	suggest practical methods for determining the rate of a given reaction		M1a, M1c	WS1.2b, WS1.2c, WS1.2d, WS2a, WS2b	Rate of reaction experiments. (PAG C1, PAG C8) Disappearing cross experiment. (PAG C8) Magnesium and acid, marble chip and acid. (PAG C1, PAG C8)
C5.2b	interpret rate of reaction graphs	1/t is proportional to rate and gradients of graphs (not order of reaction)	M4b, M4c	WS1.3a, WS1.3b, WS1.3c, WS1.3d, WS1.3e, WS1.3f, WS1.3g, WS1.3h, WS1.3i, WS2b	Marble chip and acid or magnesium and acid experiments either measuring reaction time or the volume of gas over time. (PAG C1, PAG C7, PAG C8)
C5.2c	describe the effect of changes in temperature, concentration, pressure, and surface area on rate of reaction		M4d, M4e	WS1.4c	Varying surface area with marble chips and hydrochloric acid. (PAG C1, PAG C8)
C5.2d	explain the effects on rates of reaction of changes in temperature, concentration and pressure in terms of frequency and energy of collision between particles			WS1.4c	Reaction of magnesium and acid with different temperatures of acid – measure reaction times. (PAG C1, PAG C8)
C5.2e	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		M1c		

2

2

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
C5.2f	describe the characteristics of catalysts and their effect on rates of reaction				
C5.2g	identify catalysts in reactions			WS1.4a	Catalysis of hydrogen peroxide with various black powders including MnO_2. (PAG C1, PAG C8) Catalysis of reaction of zinc with sulfuric acid using copper powder. (PAG C1, PAG C8)
C5.2h	explain catalytic action in terms of activation energy	reaction profiles			
C5.2i	recall that enzymes act as catalysts in biological systems				

C5.3 Equilibria

Summary

In a reaction, when the rate of the forward reaction equals the rate of the backwards reaction, the reaction in a closed system is said to be in equilibrium.

Underlying knowledge and understanding

Learners will be familiar with representing chemical reactions using formulae and using equations.

Common misconceptions

Learners often do not recognise that when a dynamic equilibrium is set up in a reaction the concentration of the reactants and products remain constant. They think that they are equal. Learners also sometimes perceive a dynamic equilibrium as two reactions.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers. All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
CM5.3i	arithmetic computation, ratio when measuring rates of reaction	M1a, M1c
CM5.3ii	drawing and interpreting appropriate graphs from data to determine rate of reaction	M4b, M4c
CM5.3iii	determining gradients of graphs as a measure of rate of change to determine rate	M4d, M4e
CM5.3iv	proportionality when comparing factors affecting rate of reaction	M1c

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C5.3a	recall that some reactions may be reversed by altering the reaction conditions		M1a, M4b, M4c		
C5.3b	recall that dynamic equilibrium occurs in a closed system when the rates of forward and reverse reactions are equal		M4b, M4c		
C5.3c	**predict the effect of changing reaction conditions on equilibrium position and suggest appropriate conditions to produce as much of a particular product as possible**	**Le Chatelier's principle concerning concentration, temperature and pressure**	M1a, M4d, M4e, M1c	WS1.2a, WS1.2b, WS1.2c, WS1.4c, WS2a, WS2b	

Topic C6: Global challenges

This topic seeks to integrate learners' knowledge and understanding of chemical systems and processes, with the aim of applying it to global challenges. Applications of chemistry can be used to help humans improve their own lives and strive to create a sustainable world for future generations, and these challenges are considered in this topic. It therefore provides opportunities to draw together the concepts covered in earlier topics, allowing synoptic treatment of the subject of chemistry.

C6.1 Improving processes and products

Summary

Historically, new materials have been developed through trial and error, experience etc. but as our understanding of the structure of materials and chemical processes has improved we are increasing our ability to manipulate and design new materials. Industry is continually looking to make products that have a better performance and are sustainable to produce. This section also explores the extraction of raw materials and their use in making new products.

Underlying knowledge and understanding

Learners should be familiar with the properties of ceramics, polymers and composites. They also will have met the method of using carbon to obtain metals from metal oxides.

Common misconceptions

Learners often think that chemical reactions will continue until all the reactants are exhausted. They also think that equilibrium is a static condition.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
CM6.1i	arithmetic computation, ratio when measuring rates of reaction	M1a, M1c
CM6.1ii	drawing and interpreting appropriate graphs from data to determine rate of reaction	M4b, M4c
CM6.1iii ☑	determining gradients of graphs as a measure of rate of change to determine rate	M4d, M4e
CM6.1iv ☑	proportionality when comparing factors affecting rate of reaction	M1c

2

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C6.1a	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		M1a, M1c	WS1.4a	Extraction of copper by heating copper oxide with carbon. (PAG C1)
C6.1b	explain why and how electrolysis is used to extract some metals from their ores		M4b, M4c	WS1.3a, WS1.3b, WS1.3c, WS1.3d, WS1.3e, WS1.3g, WS1.3h, WS1.3i, WS1.4, WS2b	Electrolysis of aqueous sodium chloride solution. (PAG C2) Electrolysis of aqueous copper sulfate solution. (PAG C2)
C6.1c	**evaluate alternative biological methods of metal extraction**	**bacterial and phytoextraction**		WS1.1a, WS1.1e	
C6.1d ☑	**explain the trade-off between rate of production of a desired product and position of equilibrium in some industrially important processes**	**the Haber process and Contact process**	M4d, M4e	WS1.3f	
C6.1e ☑	**interpret graphs of reaction conditions versus rate**		M1c	WS1.3e	
C6.1f ☑	**explain how the commercially used conditions for an industrial process are related to the availability and cost of raw materials and energy supplies, control of equilibrium position and rate**			WS1.1d	

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
C6.1g ☑	explain the importance of the Haber process in agricultural production			WS1.4a	
C6.1h ☑	compare the industrial production of fertilisers with laboratory syntheses of the same products			WS1.2a, WS1.2b, WS1.2c, WS1.2d, WS1.2e, WS2a, WS2b	Preparation of potassium sulfate or ammonium sulfate using a titration method. (PAG C6)
C6.3i ☑	recall the importance of nitrogen, phosphorus and potassium compounds in agricultural production			WS1.4a	
C6.3j ☑	describe the industrial production of fertilisers as several integrated processes using a variety of raw materials	ammonium nitrate and ammonium sulfate		WS1.2a, WS1.2b, WS1.2c, WS1.2e, WS2a, WS2b	
C6.1k	describe the basic principles in carrying out a life-cycle assessment of a material or product				
C6.1l	interpret data from a life-cycle assessment of a material or product				
C6.1m	describe a process where a material or product is recycled for a different use, and explain why this is viable			WS1.1f, WS1.1g	
C6.1n	evaluate factors that affect decisions on recycling			WS1.1f, WS1.1g	
C6.1o ☑	describe the composition of some important alloys in relation to their properties and uses	steel, brass, bronze, solder, duralumin			
C6.1p ☑	describe the process of corrosion and the conditions which cause corrosion	iron and other metals			

2

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
C6.1q ☑	explain how mitigation of corrosion is achieved by creating a physical barrier to oxygen and water and by sacrificial protection				
C6.1r ☑	compare quantitatively the physical properties of glass and clay ceramics, polymers, composites and metals				
C6.1s ☑	explain how the properties of materials are related to their uses and select appropriate materials given details of the usage required			WS1.1e, WS1.3f	

C6.2 Organic chemistry

Summary

Carbon chemistry is the basis of life on Earth. Organic chemistry is the basis of many of the materials we produce. Organic compounds are covalent in nature and react in a predictable pattern. Crude oil forms the basis of many useful by-products.

Underlying knowledge and understanding

Learners should be familiar with reactions and displayed formula.

Common misconceptions

Learners tend not to bring the concepts from general chemistry in their study of organic chemistry. They have difficulty identifying functional groups and naming and drawing the compounds.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
CM6.2i ☑	represent three-dimensional shapes in two dimensions and vice versa when looking at chemical structures, e.g. allotropes of carbon	M5b

2

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C6.2a ☑	recognise functional groups and identify members of the same homologous series	homologous series, of alkanes, alkenes, alcohols and carboxylic acids			
C6.2b ☑	name and draw the structural formulae, using fully displayed formulae, of the first four members of the straight chain alkanes, alkenes, alcohols and carboxylic acids		M5b	WS1.4a	Use of models.
C6.2c ☑	predict the formulae and structures of products of reactions of the first four and other given members of the homologous series of alkanes, alkenes and alcohols	combustion; addition of bromine and hydrogen across a double bond; oxidation of alcohols to carboxylic acids using potassium manganate(VII)			
C6.2d ☑	recall the basic principles of addition polymerisation by reference to the functional group in the monomer and the repeating units in the polymer				
C6.2e ☑	**explain the basic principles of condensation polymerisation**	**reference to the functional groups of the monomers, the minimum number of functional groups within a monomer, the number of repeating units in the polymer, and simultaneous formation of a small molecule, e.g. a polyester or polyamide, using block diagrams to represent polymers**		WS1.4a	

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
C6.2f ☑	**describe practical techniques to make a polymer by condensation**			WS1.2a, WS1.2b, WS1.2c, WS1.4a, WS2a, WS2b	Making nylon.
C6.2g ☑	deduce the structure of an addition polymer from a simple alkene monomer and vice versa	the following representation of a polymer $[\text{repeat unit}]_n$		WS1.4a	
C6.2h ☑	recall that DNA is a polymer made from four different monomers called nucleotides and that other important naturally-occurring polymers are based on sugars and amino-acids	the names of the nucleotides		WS1.4a	
C6.2i ☑	recall that it is the generality of reactions of functional groups that determine the reactions of organic compounds			WS1.4a	
C6.2j	describe the separation of crude oil by fractional distillation	the names of the fractions		WS1.3f, WS1.4a	
C6.2k	explain the separation of crude oil by fractional distillation	molecular size and intermolecular forces			
C6.2l	describe the fractions as largely a mixture of compounds of formula C_nH_{2n+2} which are members of the alkane homologous series			WS1.4a	
C6.2m	recall that crude oil is a main source of hydrocarbons and is a feedstock for the petrochemical industry			WS1.4a	
C6.2n	explain how modern life is crucially dependent upon hydrocarbons and recognise that crude oil is a finite resource			WS1.1c, WS1.1f, WS1.1e, WS1.4a	

2

Learning outcomes		To include	Maths	Working scientifically	Practical suggestions
C6.2o	describe the production of materials that are more useful by cracking	conditions and reasons for cracking and some of the useful materials produced			
C6.2p ☑	recall that a chemical cell produces a potential difference until the reactants are used up				
C6.2q ☑	evaluate the advantages and disadvantages of hydrogen/oxygen and other fuel cells for given uses	the chemistry of the hydrogen/oxygen fuel cell		WS1.1g, WS1.1i	

C6.3 Interpreting and interacting with earth systems

Summary

As our understanding of the structure of materials and chemical processes has improved we are increasing our ability to interpret and understand chemical and earth systems. Understanding how we interact with them is very important to our survival as a species. This section starts with the history of the atmosphere and moves on to how human activity could be affecting its composition.

Underlying knowledge and understanding

Learners should have some understanding of the composition of the Earth, the structure of the Earth, the rock cycle, the carbon cycle, the composition of the atmosphere and the impact of human activity on the climate.

Common misconceptions

Learners think that the atmosphere is large and that small increases of carbon dioxide or a few degrees of temperature change do not make a difference to the climate. They may consider that global warming is caused by the ozone hole and that human activities alone cause the greenhouse effect.

Tiering

Statements shown in **bold** type will only be tested in the Higher Tier papers.
All other statements will be assessed in both Foundation and Higher Tier papers.

Reference	Mathematical learning outcomes	Mathematical skills
CM6.3i	extract and interpret information from charts, graphs and tables	M2c, M4a
CM6.3ii	use orders of magnitude to evaluate the significance of data	M2h

2

Topic content			Opportunities to cover:		Practical suggestions
Learning outcomes		To include	Maths	Working scientifically	
C6.3a	interpret evidence for how it is thought the atmosphere was originally formed	knowledge of how the composition of the atmosphere has changed over time	M2c, M4a, M2h	WS1.3e	
C6.3b	describe how it is thought an oxygen-rich atmosphere developed over time		M2h	WS1.1a	
C6.3c	describe the greenhouse effect in terms of the interaction of radiation with matter within the atmosphere				
C6.3d	evaluate the evidence for additional anthropogenic (human activity) causes of climate change and describe the uncertainties in the evidence base	the correlation between change in atmospheric carbon dioxide concentration and the consumption of fossil fuels	M2c, M4a, M2h		
C6.3e	describe the potential effects of increased levels of carbon dioxide and methane on the Earth's climate and how these effects may be mitigated	consideration of scale, risk and environmental implications	M2c, M4a, M2h	WS1.1f, WS1.1h	
C6.3f	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			WS1.4a	
C6.3g	describe the principal methods for increasing the availability of potable water in terms of the separation techniques used	ease of treatment of waste, ground and salt water			