Science Inquiry Skills

| Knowledge | Application |
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| Scientific methods enable systematic investigation to obtain measurable evidence. | Deconstruct the parts of a problem to determine the most appropriate method for investigation.  Design investigations, including:   * a hypothesis or inquiry question * types of variables * dependent * independent * factors held constant (how and why they are controlled) * factors that may not be able to be controlled (and why not) * materials required * the procedure to be followed * the type and amount of data to be collected * identification of ethical and safety considerations. |
| Obtaining meaningful data depends on conducting investigations using appropriate procedures and safe, ethical working practices. | Conduct investigations, including:   * selection and safe use of appropriate materials, apparatus, and equipment * collection of appropriate primary and/or secondary data (numerical, visual, descriptive) * individual and collaborative work. |
| Results of investigations are represented in a well-organised way to allow them to be interpreted. | Represent results of investigations in appropriate ways, including:   * use of appropriate SI units, symbols * construction of appropriately labelled tables * drawing of graphs: linear, non-linear, lines of best fit * use of significant figures. |
| Scientific information can be presented using different types of symbols and representations. | Select, use, and interpret appropriate representations, including:   * mathematical relationships, such as ratios * diagrams * writing equations   to explain concepts, solve problems, and make predictions. |
| The analysis of the results of investigations allows them to be interpreted in a meaningful way. | Analyse data, including:   * identification and discussion of trends, patterns, and relationships * interpolation or extrapolation where appropriate * selection and use of evidence and scientific understanding to make and justify conclusions. |
| Critical evaluation of procedures and outcomes can determine the meaningfulness of conclusions. | Evaluate the procedures and results to identify sources of uncertainty, including:   * random and systematic errors * replication * sample size * accuracy * reliability * precision * validity * effective control of variables.   Discuss the impact that sources of uncertainty have on experimental results.  Recognise the limitations of conclusions. |
| Effective scientific communication is clear and concise. | Communicate to specific audiences and for specific purposes using:   * appropriate language * terminology * conventions. |

Topic 1: Materials and Their Atoms

| Knowledge | Application |
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Subtopic 1.1: Properties and Uses of Materials

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| The uses of materials are related to their properties, including solubility, thermal and electrical conductivities, melting point, and boiling point.  Nanomaterials are substances that contain particles in the size range 1–100 nm. | Suggest uses of materials, including nanomaterials, given their properties and vice versa |
| Differences in the properties of substances in a mixture can be used to separate them. | Identify how the components of a mixture can be separated by methods including filtration, distillation, and evaporation. |

Subtopic 1.2: Atomic Structure

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| All materials consist of atoms.  Atoms are commonly modelled as consisting of electrons orbiting a nucleus containing protons and neutrons.  Emission and absorption spectra of elements provide evidence that electrons are arranged in distinct energy levels and can be used to identify some elements in matter. |  |
| Atomic number and mass number provide information about the numbers of subatomic particles in an atom.  Many elements consist of a number of different isotopes, which have different physical properties but the same chemical properties. | Represent isotopes of an element using appropriate notation. |
| The arrangement of electrons in atoms and monatomic ions can be described in terms of shells and subshells. | Write the electron configuration using subshell notation of an atom of any of the first 38 elements in the periodic table |

Subtopic 1.3: Quantities of Atoms

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| The quantities of different substances can be conveniently compared using the mole unit.  The relative atomic mass of an element is determined from all the isotopes of that element.  The number of moles of atoms in a sample can be determined from the number of atoms present or from the mass of the atoms. | Undertake calculations using the relationship    and its rearrangements. |

Subtopic 1.4: The Periodic Table

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| In the modern periodic table, elements are arranged in order of increasing atomic number, and display periodic trends in their properties. | Identify trends in atomic radii, valencies, and electronegativities, across periods and down groups of the periodic table. |
| The position of an element in the periodic table is related to its metallic or non-metallic character. | Identify the position of an atom in the periodic table given its electron configuration.  Identify the s, p, d, and f blocks of the periodic table. |

Topic 2: Combining Atoms

| Knowledge | Application |
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Subtopic 2.1: Types of Materials

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| Materials can be classified according to their structure and bonding into four types of substances.  Melting points can be used to classify materials into molecular and non-molecular lattices. Electrical conductivity of non-molecular materials provides evidence for three types of primary bonding: metallic, ionic, and covalent. | Classify materials as molecular, metallic, ionic, and covalent network, given relevant conductivity and melting point data. |

Subtopic 2.2: Bonding Between Atoms

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| The formation of bonds between atoms results in stable valence-shell configurations.  Energy is released when bonds are formed. Energy is required to break bonds.  Metallic, ionic, and covalent bonds are the strong forces of attraction (primary bonds) between particles. |  |
| Metallic Bonding  Metallic bonding is the force of attraction between metal cations and their delocalised valence electrons.  The physical properties of metallic elements can be explained using the model for metallic bonding. | Explain the melting and boiling points, and electrical conductivities of metallic elements. |
| Ionic Bonding  Valence electrons are transferred from a metallic atom to a non-metallic atom to form ions. Ionic bonding is the force of attraction between the oppositely charged ions.  Ionic compounds are continuous and are represented by empirical formulae.  The properties of ionic compounds can be explained using the model for ionic bonding.  Explain the melting and boiling points, and electrical conductivities of ionic compounds. | Predict the charge on the monatomic ion formed by an element, using its position in the periodic table.  Write the electron configuration, using subshell notation of the monatomic ion of any of the first 38 elements of the periodic table.  Write formulae for ionic compounds given the charges on the ions. |
| Covalent Bonding  Non-metallic atoms share electrons to form covalent bonds.  A covalent bond may be polar or non-polar.  Covalent bonding is found in molecular and non-molecular (continuous) substances.  A molecule can be represented by a molecular formula.  A continuous covalent substance is represented by an empirical formula.  The physical properties of continuous covalent substances can be explained using the model for covalent bonding. | Use electron-dot diagrams and structural formulae to show covalent bonds between non-metallic atoms.  Use electronegativity values, or the position of atoms in the periodic table, to predict and explain the polarity of a covalent bond.  Indicate the polarity of a covalent bond, using the appropriate convention.  Explain the melting point, hardness, and electrical conductivity of continuous covalent substances. |

Subtopic 2.3: Quantities of Molecules and Ions

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| The percentage composition of elements in compounds can be determined from the molar masses of the atoms. | Undertake calculations of percentage composition, by mass, of elements in compounds. |
| The number of moles of particles (molecules, ions) in a sample can be determined from the mass of the sample and the molar masses of the particles. | Undertake calculations using the relationship    and its rearrangements for molecules, and for ions and their compounds. |

Topic 3: Molecules

| Knowledge | Application |
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Subtopic 3.1: Molecule Polarity

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| The shapes of molecules can be explained and predicted using three-dimensional representations of electrons as charge clouds, and using valence-shell electron‑pair repulsion (VSEPR) theory. | Draw and annotate diagrams showing covalent bonds, non-bonding pairs, and shapes of molecules and ions in which there is only one central atom and up to eight valence electrons. |
| The polarity of a molecule results from the polar character of the bonds and their spatial arrangement. | Predict and explain whether or not a molecule is polar, given its spatial arrangement |

Subtopic 3.2: Interactions Between Molecules

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| The physical properties of molecular substances can be explained by considering the nature and strength of the forces of attraction between the molecules.  Secondary interactions between molecules are much weaker than primary metallic, ionic, and covalent bonds.  The shape, polarity, and size of molecules can be used to explain and predict the nature and strength of secondary interactions.  Dispersion forces exist between all molecules. Their strength depends on the size and shape of the molecules. | Predict the relative strengths of interactions between molecules, given relevant information. |
| Dipole–dipole interactions exist between polar molecules and their strength depends on the polarity and size of the molecules.  Hydrogen bonding is a particularly strong form of dipole–dipole interaction that exists between molecules. | Draw diagrams showing partial charges and hydrogen bonding between HF, H2O, and NH3 molecules.  Explain the boiling points of HF, H2O, and NH3 in terms of hydrogen bonding between the molecules. |

Subtopic 3.3: Hydrocarbons

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| Carbon forms hydrocarbon compounds, including alkanes and alkenes. The physical properties of hydrocarbons depend on the size of the molecules. | Compare the melting and boiling points of hydrocarbons, given relevant information. |
| Hydrocarbons are used as fuels and as feedstock for the chemical industry. | Write equations for the complete combustion of hydrocarbons. |
| The chemical reactions of hydrocarbons are determined by the functional groups present. | Predict the product of an addition reaction of an alkene. |
| Hydrocarbons can be represented by empirical formulae, molecular formulae, and structural formulae, including extended, condensed, and skeletal representations.  Hydrocarbons can exist as different structural isomers.  Hydrocarbons are named systematically to provide unambiguous identification.  The structural formula of a hydrocarbon can be deduced from its systematic name.  Organic molecules have a hydrocarbon skeleton and can contain functional groups. | Identify, name systematically, and draw structural formulae of hydrocarbons containing:   * up to eight carbon atoms in the main chain, with side chains limited to a maximum of two carbon atoms * one or more alkene groups. |

Subtopic 3.4 on next page.

Subtopic 3.4: Polymers

| Knowledge | Application |
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| Polymers or macromolecules are very large molecules composed of small repeating structural units. | Identify the repeating unit of a polymer, given the structural formula of a section of a chain. |
| Addition polymerisation occurs when monomer molecules link without the loss of atoms.  Addition polymers can be synthesised from alkene monomers.  Organic polymers have diverse properties and uses.  The properties of organic polymers depend on the interactions between the polymer chains. | Draw the structural formula of an addition polymer that could be produced from monomers containing one carbon–carbon double bond, given the structural formula(e) of the monomer(s) or vice versa. |

Topic 4: Mixtures and Solutions

| Knowledge | Application |
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Subtopic 4.1: Miscibility and Solutions

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| Solvents can be considered as polar (e.g. water, methanol) or non-polar (e.g. hexane, turpentine, petrol).  Polar and non-polar solvents do not readily mix. | Identify water as a polar solvent and hydrocarbons as non-polar solvents.  Identify a solvent as polar or non-polar, based on its miscibility with water and hydrocarbons. |
| Highly polar molecular substances are more soluble in water than non-polar molecules of a similar size.  Molecular substances with small molecules are more soluble in water than larger molecules of similar polarity.  Compounds with non-polar and polar or ionic components facilitate the mixing of polar and non-polar substances. | Predict, given the structural formulae, which of two compounds would be more soluble in polar and non-polar solvents. |

Subtopic 4.2: Solutions of Ionic Substances

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| Many ionic substances are soluble in water. This is particularly so for ammonium and alkali metal salts.  Equations can be written to represent the dissociation and hydration of ions that occurs when ionic substances dissolve in water. | Describe the formation of ion-dipole interactions when ionic substances dissolve in water.  Write equations for the dissolving of ionic substances in water. |
| Some ionic substances are not very soluble in water; such substances form as precipitates when solutions containing the relevant ions are mixed. | Write ionic equations for precipitation reactions.  Explain why soap forms a scum in water containing calcium ions. |

Subtopic 4.3: Quantities in Reactions

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| Chemical equations can be written to describe a chemical change. | Write chemical equations when given the reactants and products of a reaction. |
| The concentration of a solution can be described in terms of mass concentration (mass of solute per unit volume, ) or as molar concentration (moles of solute per unit volume, c). | Undertake calculations using the relationship    and its rearrangements.  Undertake calculations using the relationship    and its rearrangements.  Undertake conversions between mass concentrations and molar concentrations. |
| Chemicals react in definite proportions. | Undertake stoichiometric calculations for precipitation reactions. |

Subtopic 4.4 on next page.

Subtopic 4.4: Energy in Reactions

| Knowledge | Application |
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| All chemical reactions involve the formation of a new substance and are accompanied by the gain of energy (endothermic reactions) or the loss of energy (exothermic reactions).  The energy changes in endothermic and exothermic reactions can be explained in terms of the Law of Conservation of Energy and the breaking and forming of bonds. | Identify a reaction as exothermic or endothermic, given relevant information. |
| When ionic substances dissolve in water, the dissociation of the ions requires energy and the hydration of the ions releases energy. | Explain the endothermic or exothermic nature of dissolving ionic substances in terms of the Law of Conservation of Energy, the energy required for dissociation of ions, and the energy released by hydration of the ions.  Write thermochemical equations for the dissolving of ionic substances in water. |
| Enthalpy changes for solution reactions can be determined experimentally. | Explain the following relationships and undertake calculations involving their rearrangements:      Experimentally determine enthalpies of solution.  Identify a reaction as exothermic or endothermic, given a thermochemical equation or the value of its enthalpy change. |

Topic 5: Acids and Bases

| Knowledge | Application |
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Subtopic 5.1: Acid–Base Concepts

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| Acids are compounds or ions that donate protons, whereas bases are compounds or ions that accept protons, which are H+ ions.  The reactions between acids and bases can be represented using chemical equations that illustrate the transfer of protons. | Write equations showing proton transfer between an acid and a base.  Identify the conjugate acid–base pairs given the equation for a proton-transfer reaction. |
| Acid–base indicators are weak acids or bases where the acidic form is of a different colour from the basic form.  Acids can be classified as monoprotic or polyprotic, depending on the number of protons available for donation. | * Given the structural formula of an acid, classify it as monoprotic, diprotic, or triprotic. |

Subtopic 5.2: Reactions of Acids and Bases

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| The oxides of non-metals are commonly acidic and generate oxyacids when dissolved in water.  Metal oxides are commonly basic. | Draw structural formulae for CO2, SO2 and SO3, H2SO3, H2SO4, and H3PO4.  Write equations for the reactions with water of CO2, SO2, SO3, and P4O10.  Write equations for the reactions with water of Na2O, K2O, and CaO. |
| Similarities in the reactions of different acids with bases (metal oxides, hydroxides, and carbonates) allow products to be predicted from known reactants.  Neutralisation is an exothermic reaction.  The strength of acids is explained by the degree of ionisation in aqueous solution. | Identify the products obtained and write full and ionic equations for reactions between a given acid and a nominated metal oxide, hydroxide, carbonate, or hydrogencarbonate.  Undertake stoichiometric calculations for reactions between acids and bases. |

Subtopic 5.3: The pH Scale

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| The pH scale is a logarithmic scale that describes the concentration of hydrogen ions in aqueous solutions.  Solutions with pH < 7 are acidic, solutions with pH > 7 are basic, and solutions with pH = 7 are neutral.  CO2 dissolves in rainwater to form carbonic acid, which is a weak acid, giving rainwater a pH of about 5.6.  Oxides of sulfur and nitrogen in the atmosphere can produce rain with a pH below 5.6. | Undertake calculations using the relationship  pH = – log [H+]  and its rearrangements.  Write equations for the reaction of CO2 with water to produce hydrogen ions.  Write equations for the reactions of oxides of sulfur and nitrogen with water that lead to acid rain.  Examine the human activities that can cause acid rain to form and the strategies used to prevent this from happening. |

Topic 6: Redox Reactions

| Knowledge | Application |
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Subtopic 6.1: Concepts of Oxidation and Reduction

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| A range of reactions, including reactions of metals, combustion, and electrochemical processes, can be considered as redox reactions.  Oxidation and reduction can be defined in terms of combination with oxygen, transfer of electrons, or change in oxidation number. | Identify oxidation and reduction in given equations.  Write oxidation and reduction half-equations, in neutral and acidic conditions, given reactant and product species.  Combine half-equations to write a chemical equation.  Determine the oxidation states of atoms in elements and monatomic ions, and in compounds and polyatomic ions. |

Subtopic 6.2: Metal Reactivity

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| Metals differ in their tendency to lose electrons; more reactive metals lose electrons more easily.  A more reactive metal is able to donate electrons to the ion of a less active metal in a displacement reaction.  Differences in metal reactivity can be represented as a metal activity series.  The reactivity of a metal affects its ability to react with other chemicals. | Write equations and half-equations for reactions between a metal and the ion of a less active metal.  Determine whether a reaction will occur between a metal and a solution containing the ions of another metal, given a metal activity series containing both metals.  Investigate the reactions of various metals with water and acidic solutions.  Compare the vigour of reactions of different metals with their position on the metal activity series.  Write equations and half-equations for reactions between a given acid and a nominated active metal. |

Subtopic 6.3: Electrochemistry

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| Electrochemical reactions involve a flow of electrons during a chemical reaction.  Galvanic cells produce electrical energy from spontaneous redox reactions.  Galvanic cells are commonly used as portable sources of electric current. | Identify the anode and cathode and their charges, and the direction of ion and electron flow, in a galvanic cell, given sufficient information.  Draw a diagram of a galvanic cell, given sufficient information.  Write electrode half-equations for a galvanic cell, given sufficient information.  Compare the operation of different types of batteries. |