Subject matter

Topic 1: Properties and structure of atoms (20 hours)

Science understanding

Atomic structure

- Describe that atoms can be modelled as a nucleus surrounded by electrons in distinct energy levels.
- Discriminate between the terms *atomic number* (Z), *mass number* (A) and *isotopes of an element*.
- Apply the nuclear symbol notation $^{A}_{Z}\mathrm{M}$ to determine the number of protons, neutrons and electrons in atoms, ions and isotopes.
- State the relative energies of the s, p and d orbitals.
- Apply the Aufbau principle, Hund's rule and the Pauli exclusion principle to write electron configurations for atoms and ions up to $Z = 36$.
- Determine full and condensed electron configurations for atoms and ions up to $Z = 36$, e.g. $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$ and $[Ne]3s^2\ 3p^5$.
- Identify the electron configuration of Cr and Cu as exceptions.
- Explain how successive ionisation energy data is related to the electron configuration of an atom.

Isotopes

- Describe that isotopes are atoms of the same element that have different numbers of neutrons.
- State that isotopes can be represented in the form ^{A}X (IUPAC) or X-A.
- Identify that isotopes of an element have the same electron configuration and possess similar chemical properties but have different physical properties.
- Explain that the relative atomic mass of an element is the ratio of the weighted average mass per atom of the naturally occurring form of the element to 1/12 the mass of an atom of carbon-12.

Analytical techniques

- State that mass spectrometry involves the ionisation of substances and the separation and detection of the resulting ions. (The operation of the mass spectrometer is not required.)
- Analyse mass spectrometry spectra, to determine the isotopic composition of elements, the relative atomic mass of an element and percentage abundances of the isotopes of an element.
- Discriminate between absorption and emission line spectra.
- Explain that flame tests and atomic absorption spectroscopy (AAS) rely on electron transfer between atomic energy levels.
- Explain that the emission spectrum of hydrogen provides evidence for the existence of electrons in discrete energy levels (Bohr model), which converge at higher energies.
- Analyse flame tests and atomic absorption spectroscopy (AAS) to identify elements and determine the concentration of metallic ions in solution.

Periodic table and trends

- State that elements are represented by symbols.
- Identify that the structure of the periodic table based on increasing atomic number.
- Identify that the periodic table is arranged into four blocks associated with the four sub-levels — s, p, d and f.
- Describe the relationship between the structure of the periodic table and the electronic configuration of atoms.
- Explain that elements of the periodic table show trends in chemical and physical properties across periods and down groups as exemplified by groups 1, 2, 13–18 and period 3.
- Compare the metallic and non-metallic behaviours of elements, including group trends and the reactivity for the alkali metals (Li–Cs) and the halogens (F–I).
- Identify that oxides change from basic through amphoteric to acidic across period 3.
- Analyse data for atomic radii, valencies, ionic radii, 1st ionisation energy and electronegativities to determine periodic trends, patterns and relationships.

Introduction to bonding

- Explain that the ability of atoms to form chemical bonds, is related to the arrangement of electrons in the atom and the stability of the valence electron shell.
- Identify that the number of electrons lost, gained or shared is determined by the electron configuration of the atom.
- State that transition elements can form more than one ion.
- Explain that ions are atoms or groups of atoms that are electrically charged due to an imbalance in the number of electrons and protons.
- Explain that chemical bonds are caused by electrostatic attractions that arise because of the sharing or transfer of electrons.
- Identify that the valency is a measure of the number of bonds that an atom can form.
- Determine the formula and IUPAC name of ionic and molecular compounds.
- Discriminate between the terms *empirical formula*, *molecular formula* and the *formula unit*.
- Determine Lewis (electron dot) structure of molecules and ions showing all valence electrons for up to four electrons pairs for each atom.
- Identify the numbers of bonding and lone pairs of electrons around each atom in a molecule.

Science as a human endeavour (SHE)

- Appreciate that experiments provided evidence that enabled scientists to develop models of the atom.
- Consider the role Geiger-Marsden's gold foil experiments and Maria Goeppert Mayer's nuclear shell model played in the development of atomic theory.
- Appreciate that radioisotopes require careful evaluation and monitoring because of the potential harmful effects to humans and/or the environment.
- Explore the use of radioisotopes for carbon dating and radiotherapy and Marie Curie's contribution to research on radioactivity.
- Appreciate that analysis of the distribution of elements in living things, Earth and the universe has informed a wide range of scientific understandings.
- Explore the composition of stars and Cecilia Payne-Gaposchkin's contribution to astrophysics.

Science inquiry

Investigate:

- flame tests to identify elements
- mass spectra and isotopes*
- atomic absorption spectroscopy (AAS) and the concentration of aqueous metallic ions.*

***Note:** Simulations may be used.

Topic 2: Properties and structure of materials (5 hours)

Science understanding

Compounds and mixtures

- State that pure substances may be elements or compounds.
- Identify that pure substances have distinct measurable properties (e.g. melting and boiling point, reactivity, strength, density) and mixtures have properties dependent on the identity and relative amounts of the substances that make them up.
- Discriminate between heterogeneous and homogeneous mixtures.
- Analyse data to determine the physical properties of pure substances and mixtures.

Bonding and properties

- Describe the properties of ionic, covalent and metallic compounds, e.g. melting and boiling point, thermal and electrical conductivity, strength and hardness.
- Explain that the type of bonding within ionic, metallic and covalent substances determines their physical properties.
- Explain the properties of ionic compounds by modelling ionic bonding as ions arranged in a crystalline lattice structure with strong electrostatic forces of attraction between oppositely charged ions.
- Discriminate between ionic and metallic bonding.
- Explain the properties of covalent compounds by modelling covalent bonding as the sharing of an electron pair in the region between two nuclei with a strong electrostatic force of attraction between both nuclei.
- Discriminate between covalent molecules, giant covalent networks and allotropes of carbon.
- Explain that hydrocarbons, including alkanes (saturated), alkenes (unsaturated) and benzene, have different chemical properties that are determined by the nature of the bonding within the molecules.
- Analyse data to determine the properties, structure and bonding of ionic, covalent and metallic compounds.

Science as a human endeavour (SHE)

- Appreciate that the development of nanomaterials is important to meet a range of contemporary needs and have specific properties related to the size of the particles (1–100 nm).
- Consider the benefits and potential risks associated with the use of nanomaterials in consumer products, health care, transportation, energy and agriculture.
- Appreciate that impurities can affect the physical and chemical properties of substances, resulting in inefficient or unwanted chemical reactions.
- Explore Ellen Swallow Richard’s contribution to developing water quality standards and the new discipline of home economics.
- Appreciate that carbon has a range of properties that allow a variety of interactions which are pivotal to the formation of biochemical molecules such as carbohydrates, proteins and DNA.
- Consider whether life exists elsewhere in the universe and if it could be carbon-based as it is on Earth.
- Explore Millicent Goldschmidt’s contribution to the development of astrobiology.

Science inquiry

Investigate:

- the separation of mixtures based on physical properties
- the properties of ionic, metallic, and covalent compounds
- tests to distinguish alkanes and alkenes.*

***Note:** Simulations may be used.

Topic 3: Chemical reactions — reactants, products and energy change (20 hours)

Science understanding

Chemical reactions

- Identify that chemical reactions and phase changes involve energy changes, commonly observable as changes in the temperature of the surroundings and/or the emission of light.
- Determine balanced chemical equations, including state symbols (s), (l), (g) and (aq), for a variety of reactions, e.g. single displacement, double-displacement, acid-base, combustion, combination, decomposition and simple redox reactions.

Exothermic and endothermic reactions

- State that heat is a form of energy, and that temperature is a measure of the average kinetic energy of the particles.
- Explain how endothermic and exothermic reactions relate to the law of conservation of energy and the breaking and reforming of bonds.
- Discriminate between exothermic and endothermic reactions.
- Sketch enthalpy level diagrams for exothermic and endothermic reactions.
- Analyse enthalpy level diagrams and thermochemical equations to determine the relative stabilities of reactants and products, and the sign of the enthalpy change (ΔH) for a reaction.
- Explain, in terms of average bond enthalpies, why reactions are exothermic or endothermic.
- Identify the limitations of using average bond enthalpies to calculate enthalpy change.
- Calculate the heat change (Q) for a substance given the mass, specific heat capacity and temperature change. (Formula: $Q = mc\Delta T$)
- Calculate the enthalpy change (ΔH) for a reaction given temperature changes, quantities of reactants and mass of water. (Formula: $\Delta H = H_{(\text{products})} - H_{(\text{reactants})}$)
- Analyse data for heat of combustion, heat of neutralisation and reactions in aqueous solutions to determine heat, mass, specific heat capacity, temperature and enthalpy change.

Mole concept and law of conservation of mass

- State that a mole is a precisely defined quantity of matter equal to Avogadro's number of particles.
- State the law of conservation of mass.
- Explain that the mole concept relates mass, moles and molar mass.
- Apply the mole concept to calculate the mass of reactants and products; amount of substance in moles; number of representative particles; and molar mass of atoms, ions, molecules and formula units. (Formula: $\text{moles}\ (n) = \frac{\text{mass (m)}}{\text{molar mass (M)}}$)
- Determine the percentage composition from relative atomic masses; empirical formula of a compound from the percentage composition by mass; and molecular formula of a compound from its empirical formula and molar mass.
- Determine limiting reactants.
- Discriminate between experimental and theoretical yield.
- Analyse data to determine percentage and theoretical yield.
(Formula: $\text{percentage yield (\%)} = \frac{\text{experimental yield}}{\text{theoretical yield}} \times \frac{100}{1}$)

Science as a human endeavour (SHE)

- Appreciate that chemistry principles can be applied to industrial processes to reduce energy requirements.
- Explore how industries are reducing their energy requirements in order to save money and reduce greenhouse gas emissions.
- Appreciate that bodies rely on the exothermic reaction of respiration to provide us with sufficient energy.
- Explore how cells use food and convert it to energy and Gerty Cori's contribution to the treatment of diabetes.
- Appreciate that biofuels are more efficient and have less environmental impact than fossil fuels.
- Evaluate fuels, including fossil fuels and biofuels, in terms of their energy output, their suitability for purpose, and the nature of products of combustion.

Science inquiry

Investigate:

- types of chemical reactions
- limiting reagent/s and percentage yield
- the empirical formula of a compound from reactions involving mass change
- the enthalpy change of a reaction, e.g. calorimetry or Hess's Law.