Topic 1: Stoichiometric relationships

13.5 hours

Essential idea: Physical and chemical properties depend on the ways in which different atoms combine.

1.1 Introduction to the particulate nature of matter and chemical change

Nature of science:

Making quantitative measurements with replicates to ensure reliability—definite and multiple proportions. (3.1)

Understandings:

- Atoms of different elements combine in fixed ratios to form compounds, which have different properties from their component elements.
- Mixtures contain more than one element and/or compound that are not chemically bonded together and so retain their individual properties.
- Mixtures are either homogeneous or heterogeneous.

Applications and skills:

- Deduction of chemical equations when reactants and products are specified.
- Application of the state symbols (s), (l), (g) and (aq) in equations.
- Explanation of observable changes in physical properties and temperature during changes of state.

Guidance:

- Balancing of equations should include a variety of types of reactions.
- Names of the changes of state—melting, freezing, vaporization (evaporation and boiling), condensation, sublimation and deposition—should be covered.

International-mindedness:

- Chemical symbols and equations are international, enabling effective communication amongst scientists without need for translation.
- IUPAC (International Union of Pure and Applied Chemistry) is the world authority in developing standardized nomenclature for both organic and inorganic compounds.

Theory of knowledge:

- Chemical equations are the “language” of chemistry. How does the use of universal languages help and hinder the pursuit of knowledge?
- Lavoisier’s discovery of oxygen, which overturned the phlogiston theory of combustion, is an example of a paradigm shift. How does scientific knowledge progress?

Utilization:

- Refrigeration and how it is related to the changes of state.
- Atom economy.
- Freeze-drying of foods.

1.1 Introduction to the particulate nature of matter and chemical change	
• The term “latent heat” is not required. • Names and symbols of elements are in the data booklet in section 5.	Syllabus and cross-curricular links: Topic 4.1—deduction of formulae of ionic compounds Topic 5.1—enthalpy cycle reaction; standard state of an element or compound Topic 6.1—kinetic theory Topic 8.2—neutralization reactions Topic 10.2—combustion reactions Option A.4—liquid crystals **Aims:** • **Aim 8**: The negative environmental impacts of refrigeration and air conditioning systems are significant. The use of CFCs as refrigerants has been a major contributor to ozone depletion.

Essential idea: The mole makes it possible to correlate the number of particles with the mass that can be measured.

1.2 The mole concept

Nature of science:

Concepts—the concept of the mole developed from the related concept of "equivalent mass" in the early 19th century. (2.3)

Understandings:

- The mole is a fixed number of particles and refers to the amount, *n*, of substance.
- Masses of atoms are compared on a scale relative to ^{12}C and are expressed as relative atomic mass (A_r) and relative formula/molecular mass (M_r).
- Molar mass (M) has the units g mol^{-1}.
- The empirical formula and molecular formula of a compound give the simplest ratio and the actual number of atoms present in a molecule respectively.

Applications and skills:

- Calculation of the molar masses of atoms, ions, molecules and formula units.
- Solution of problems involving the relationships between the number of particles, the amount of substance in moles and the mass in grams.
- Interconversion of the percentage composition by mass and the empirical formula.
- Determination of the molecular formula of a compound from its empirical formula and molar mass.
- Obtaining and using experimental data for deriving empirical formulas from reactions involving mass changes.

International-mindedness:

- The SI system (Système International d'Unités) refers to the metric system of measurement, based on seven base units.
- The International Bureau of Weights and Measures (BIPM according to its French initials) is an international standards organization, which aims to ensure uniformity in the application of SI units around the world.

Theory of knowledge:

- The magnitude of Avogadro's constant is beyond the scale of our everyday experience. How does our everyday experience limit our intuition?

Utilization:

- Stoichiometric calculations are fundamental to chemical processes in research and industry, for example in the food, medical, pharmaceutical and manufacturing industries.
- The molar volume for crystalline solids is determined by the technique of X-ray crystallography.

Syllabus and cross-curricular links:
Topic 2.1—the scale of atoms and their component particles
Topics 4.1, 4.3 and 4.5—lattice structure of ionic compounds, molecular structure of covalent compounds and metallic lattice
Topics 5.1 and 15.2—standard enthalpy and entropy changes defined per mole
Topic 19.1—mole ratios of products in electrolysis

1.2 The mole concept	
Guidance: • The value of the Avogadro's constant (*L* or N_A) is given in the data booklet in section 2 and will be given for paper 1 questions. • The generally used unit of molar mass (g mol^{-1}) is a derived SI unit.	**Aims:** • **Aim 6**: Experiments could include percent mass of hydrates, burning of magnesium or calculating Avogadro's number. • **Aim 7**: Data loggers can be used to measure mass changes during reactions.

Essential idea: Mole ratios in chemical equations can be used to calculate reacting ratios by mass and gas volume.

1.3 Reacting masses and volumes

Nature of science:

Making careful observations and obtaining evidence for scientific theories—Avogadro's initial hypothesis. (1.8)

Understandings:

- Reactants can be either limiting or excess.
- The experimental yield can be different from the theoretical yield.
- Avogadro's law enables the mole ratio of reacting gases to be determined from volumes of the gases.
- The molar volume of an ideal gas is a constant at specified temperature and pressure.
- The molar concentration of a solution is determined by the amount of solute and the volume of solution.
- A standard solution is one of known concentration.

Applications and skills:

- Solution of problems relating to reacting quantities, limiting and excess reactants, theoretical, experimental and percentage yields.
- Calculation of reacting volumes of gases using Avogadro's law.
- Solution of problems and analysis of graphs involving the relationship between temperature, pressure and volume for a fixed mass of an ideal gas.
- Solution of problems relating to the ideal gas equation.
- Explanation of the deviation of real gases from ideal behaviour at low

International-mindedness:

- The SI unit of pressure is the Pascal (Pa), N m^{-2}, but many other units remain in common usage in different countries. These include atmosphere (atm), millimetres of mercury (mm Hg), Torr, bar and pounds per square inch (psi). The bar (10^5 Pa) is now widely used as a convenient unit, as it is very close to 1 atm. The SI unit for volume is m^3, although litre is a commonly used unit.

Theory of knowledge:

- Assigning numbers to the masses of the chemical elements has allowed chemistry to develop into a physical science. Why is mathematics so effective in describing the natural world?
- The ideal gas equation can be deduced from a small number of assumptions of ideal behaviour. What is the role of reason, perception, intuition and imagination in the development of scientific models?

Utilization:

- Gas volume changes during chemical reactions are responsible for the inflation of air bags in vehicles and are the basis of many other explosive reactions, such as the decomposition of TNT (trinitrotoluene).
- The concept of percentage yield is vital in monitoring the efficiency of industrial processes.

Syllabus and cross-curricular links:
Topic 4.4—intermolecular forces
Topic 5.1—calculations of molar enthalpy changes

1.3 Reacting masses and volumes	
temperature and high pressure. • Obtaining and using experimental values to calculate the molar mass of a gas from the ideal gas equation. • Solution of problems involving molar concentration, amount of solute and volume of solution. • Use of the experimental method of titration to calculate the concentration of a solution by reference to a standard solution. **Guidance:** • Values for the molar volume of an ideal gas are given in the data booklet in section 2. • The ideal gas equation, $PV = nRT$, and the value of the gas constant (R) are given in the data booklet in sections 1 and 2. • Units of concentration to include: g dm^{-3}, mol dm^{-3} and parts per million (ppm). • The use of square brackets to denote molar concentration is required.	Topic 9.1—redox titrations Topic 17.1—equilibrium calculations Topic 18.2—acid-base titrations Topic 21.1 and A.8—X-ray crystallography Physics topic 3.2—Ideal gas law **Aims:** • **Aim 6**: Experimental design could include excess and limiting reactants. Experiments could include gravimetric determination by precipitation of an insoluble salt. • **Aim 7**: Data loggers can be used to measure temperature, pressure and volume changes in reactions or to determine the value of the gas constant, *R*. • **Aim 8**: The unit parts per million, ppm, is commonly used in measuring small levels of pollutants in fluids. This unit is convenient for communicating very low concentrations, but is not a formal SI unit.