TOPIC 1

1.1 Basic ideas about atoms

Learning outcomes **Topic 1.1**

Candidates should be able to:

(a) describe electrons, protons and neutrons in terms of their relative charges and masses, and the distribution of charges and mass within atoms;

(b) understand the terms *atomic number*, *mass number*, *isotope*, and the connection between atomic numbers and mass numbers;

(c) deduce, given atomic and mass numbers, the numbers of protons, neutrons and electrons in specified isotopes;

(d) explain the formation of ions from atoms by the loss or gain of electrons;

(e) describe the nature of α - and β - particles and of γ - radiation and recall their behaviour in electric fields and their relative penetrating powers;

(f) describe and explain the changes in mass number and atomic number resulting from α - and β - particle emission;

(g) describe the adverse consequences for living cells of exposure to γ - radiation and to α - and β - emitters;

(h) explain what is meant by the half-life of a radioactive isotope; perform simple calculations involving integral numbers of half-lives;

(i) apply their knowledge of radioactive decay and half-life ((e) - (h)) to contexts in health, medicine, radio-dating and analysis;

(j) understand and explain the significance of standard molar ionisation energies of gaseous atoms and their variation from one element to another;

(k) describe and explain how information about the electronic structure of atoms may be deduced from values of successive ionisation energies;

(l) describe the shapes of *s* and *p* orbitals;

(m) recall the appropriate *s, p* and *d* orbital occupations for elements 1 - 36 (using 'arrows in boxes' or otherwise) and relate these to position in the Periodic Table.

(n) explain the origin of emission and absorption spectra in terms of electron transitions between atomic energy levels;

(o) describe and interpret the visible atomic spectrum of the hydrogen atom (first 4 lines in the Balmer Series only);

(p) recall the direct proportionality between energy and frequency, as implied by $E = hf$, and the inverse relationship between frequency and wavelength;
(*No calculations will be set.*)

(q) show understanding of the relationship between the frequency of the convergence limit of the Lyman Series and the ionisation energy of the hydrogen atom.

1.2 Chemical calculations

Learning outcomes **Topic 1.2**

Candidates should be able to:

(a) understand the terms *relative atomic mass*, *relative isotopic mass*, *relative molecular mass* and *molar mass*, based on the $^{12}_{6}C$ scale, and of the Avogadro constant, and define the mole in terms of the $^{12}_{6}C$ isotope;

(b) explain the principles of the mass spectrometer and understand its uses, including the determination of the relative abundance of isotopes, relative isotopic and relative atomic masses, and describe and explain the mass spectrum of the chlorine molecule;

(c) derive *empirical* and *molecular* formulae from given data;

(d) carry out the interconversion of grams to moles (and vice-versa) for any given species;

(e) understand and use concentration data, expressed in terms of either mass or moles, per unit volume;

(f) calculate the mass of one reagent reacting with a given mass of another or forming a given mass of product(s), given the stoichiometry of the process;

(g) use the molar volume to calculate the number of moles in a given volume of a gas, at a given temperature and pressure or the volume of gas from a given number of moles;

(h) calculate the atom economy and percentage yield of a reaction using supplied data.

N.B. The use of the skills listed in outcomes 1.2 (c) to (h) will be expected in **all** units of the AS and A2 specification.

TOPIC 2

2.1 Chemical equilibrium and acid-base reactions

Learning outcomes **Topic 2.1**

Candidates should be able to:

(a) understand the terms reversible reaction and dynamic equilibrium;

(b) recall and understand Le Chatelier's principle and apply it qualitatively to deduce the effects of changes in temperature and in pressure or concentration, on a system at equilibrium;

(c) understand the nature of acids as donors of $H^+(aq)$ and bases as acceptors of $H^+(aq)$ and apply this to their behaviour in aqueous solution;

(d) appreciate the usefulness of the pH scale in describing the degree of acidity to the general public;

(e) use the concept of the mole in calculations involving acid - base titration data;

(f) recall outline details of experimental procedures in acid-base titrations, including apparatus and methods used;

(g) recall that carbon dioxide is an acidic gas and its interaction with water including its effect on the carbonate/hydrogen carbonate equilibrium in sea-water.

2.2 Energetics

Learning outcomes **Topic 2.2**

Candidates should be able to:

(a) appreciate the principle of conservation of energy and construct simple energy cycles;

(b) understand that chemical reactions are accompanied by energy changes, frequently in the form of heat, and that these may be either exothermic or endothermic and depend partly on the physical states of reactants and products;

(c) define standard conditions;

(d) understand the term enthalpy change of reaction and the specific terms enthalpy change of combustion and standard molar enthalpy change of formation, ΔH_f° (formal definitions are not required);

(e) recall details of experimental procedures for determining enthalpy changes in aqueous solution, and calculate such enthalpy changes from experimental data using

$$\Delta H = -\frac{mc\Delta T}{n}$$

where m and c are the mass and specific heat capacity of, for example, the water used, ΔT is the incremental change in temperature, and n is the number of moles;

(f) state Hess's Law and use it to calculate enthalpy changes from energy cycles;

(g) understand the concept of average bond enthalpy (energy) and use Hess's Law to carry out simple calculations involving such quantities.

2.3 Kinetics

Learning outcomes **Topic 2.3**

Candidates should be able to:

(a) name the factors affecting reaction rates, including light in some cases;

(b) outline a method of measuring the rate of a given reaction, explaining the principles involved;

(c) calculate initial rates from graphs of concentration against time and understand how the results can give the relationship between rate and reactant concentrations;

(d) describe simple collision theory and qualitatively explain the effects of changes in concentration (or pressure) and temperature on rate by means of this theory;

(e) define activation energy, describe the concept of energy profiles and recall that $\Delta H = E_f - E_b$;

(f) explain the rapid increase in rate with temperature in terms of changes in the energy distribution curve;

(g) recall the function of a catalyst and understand that at any temperature the presence of a catalyst:

- (i) provides an alternative faster reaction pathway and thus increases the rate of both the forward and back reactions, normally by lowering the activation energy (lower energy profile);
- (ii) does not affect the position of equilibrium;
- (iii) does affect the time taken to reach equilibrium;

(h) recall that catalysts may be homogeneous or heterogeneous and be able to give one example of each type;

(i) appreciate the importance of finding new and better catalysts, including the use of enzymes, in achieving some of the goals of green chemistry, e.g., allowing the possibility of lower temperatures (less energy consumption), lower pressures, etc.;

(j) appreciate the distinction between what may be deduced from **equilibrium** data and what may be deduced from **kinetic** data.

TOPIC 3 Application of the principles studied in unit 1 to problems encountered in the production of chemicals and of energy.

Learning outcomes **Topic 3**

When supplied with relevant data, candidates should be able to:

(a) apply principles from Topics 1 and 2 to a wide range of processes;

(b) evaluate the social, economic and environmental impact of chemical synthesis and the production of energy;

(c) appreciate the role of Green Chemistry in helping to achieve sustainability.