Chapter 1: Stoichiometric relationships – fast facts

1.1 Introduction to the particulate nature of matter and chemical change

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

- Elements are single substances, composed of atoms of the same type.
- Compounds contain a fixed ratio of atoms of different elements and have different properties from their component elements.
- Mixtures contain more than one element or compound that are not chemically combined.
- Kinetic-molecular theory describes the differences in the properties of solids, liquids, and gases on the basis of the different kinetic energies of the particles.
- Every substance changes state by melting/freezing and boiling/condensing at a defined temperature at constant pressure.
- Chemical equations summarize the change when reactants are converted to products.
- State symbols indicate the state of a substance: (s) solid, (l) liquid, (g) gas and (aq) aqueous solution (dissolved in water).
- The coefficients in a chemical equation describe the relative amounts of reactants and products.

1.2 The mole concept

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

- The amount of substance (n) is measured in moles (mol). The mole concept applies to all species: atoms, molecules, ions, electrons, formula units.
- 1 mol contains the same number of chemical species as there are atoms in exactly 12 g of the isotope carbon-12, $^{12}_{6}\mathrm{C}$.
- 1 mol of any substance contains 6.02×10^{23} species.
- $6.02 \times 10^{23}\ \mathrm{mol^{-1}}$ is called Avogadro's constant (L). It has units as it is the number of particles per mole.
- The relative atomic mass (A_r) of an element is the average mass of an atom according to relative abundances of its isotopes, on a scale where the mass of one atom of $^{12}_{6}\mathrm{C}$ is 12 exactly. It has no units.
- The relative molecular mass (M_r) is the sum of the relative atomic masses of the atoms in the molecular formula.
- The relative formula mass of an ionic compound is the sum of the relative atomic masses of the ions in the formula.
- The molar mass (M) is the relative mass expressed in g and has units of $\mathrm{g\ mol^{-1}}$.
- The empirical formula gives the ratio of the atoms of different elements in a compound. It is the molecular formula expressed as its simplest ratio.
- The molecular formula is a whole-number multiple of the empirical formula.

- The empirical formula of a compound containing the elements X, Y and Z can be determined by completing the following table:

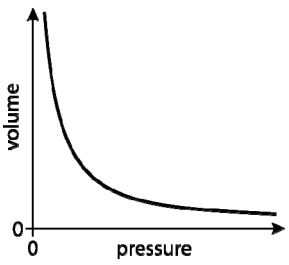
	Mass/g or % of X	Mass/g or % of Y	Mass/g or % of Z
Mass / g	m_X	m_Y	m_Z
n / mol	$= m_X/M_X$	$= m_Y/M_Y$	$= m_Z/M_Z$
Simplest ratio (divide by smallest amount in previous row)			

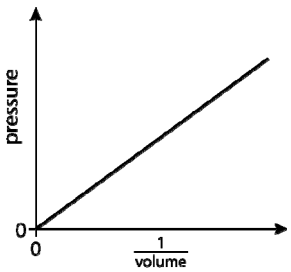
- The molecular formula shows the number of atoms of each element present in a molecule.
- Number of mol = mass/molar mass: $n = m/M$
- Number of particles = number of mol × Avogadro's constant: $N = nL$

1.3 Reacting masses and volumes

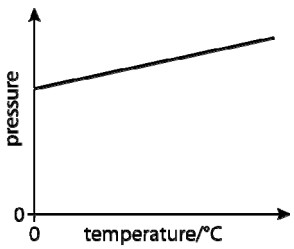
Mole ratios in chemical equations can be used to calculate reacting ratios by mass and gas volume.

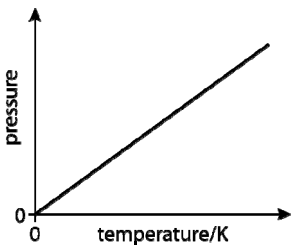
- The limiting reactant determines the theoretical yield of product. The other reactants are in excess.
- The theoretical yield is the mass or amount of product produced according to the chemical equation, assuming 100% reaction of the limiting reagent.
- Percentage yield = (experimental yield/theoretical yield) × 100%
- The kelvin is the SI unit of temperature: T (K) = T (°C) + 273
- Units of volume: 1 $dm^3 = 1 \times 10^{-3}$ $m^3 = 1 \times 10^3$ cm^3
- For a fixed mass of an ideal gas at constant T: $P = k_1/V$ (k_1 constant)





- For a fixed mass of an ideal gas at constant V: $P = k_2T$





- The combined gas law: for a fixed mass of gas: $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$
- The ideal gas equation: $PV = nRT$
- R = 8.31 J K^{-1} mol^{-1}, T must be in K.
- Temperature (in K) is a measure of the average kinetic energy of the particles. Particles have minimum kinetic energy at absolute zero (0 K).
- As kinetic energy = $\frac{1}{2}mv^2$ and all gases have the same kinetic energy at the same temperature, particles with smaller mass move faster.
- Avogadro's law states that equal volumes of different gases contain equal numbers of particles at the same temperature and pressure.
- Number of mol = volume/molar volume = V/V_{mol}
- Molar volume, V_m, of any gas at STP = 2.27×10^{-2} m^3 mol^{-1}.
- STP for gases is standard temperature (0 °C or 273 K) and pressure (100 kPa).
- Density = mass/volume; $\rho = m/V$
- A solution is a homogeneous mixture of a liquid (the solvent) with another substance (the solute). The solute can be solid, liquid, or gas but the solvent is generally a liquid.
- Concentration is the amount of solute in a known volume of solution. It can be expressed either in g dm^{-3} or mol dm^{-3}. Concentration in mol dm^{-3} is often represented by square brackets around the substance:

  [solute] (mol dm^{-3}) = n_{solute} (mol)/$V_{solution}$ (dm^3)

  n_{solute} = [solute] $\times$ $V_{solution}$ (dm^3)

  n_{solute} = [solute] $\times$ $V_{solution}$ (cm^3)/1000
- Titration is a chemical technique in which one solution is used to analyse another solution to find its concentration or amount.