Topic 11 – The Mole, Molar Mass, Empirical and Molecular Formula

Learning outcome:

(a)	calculate empirical and molecular formulae from relevant data
(b)	calculate stoichiometric reacting masses and volumes of gases (one mole of gas occupies 24 dm^3 at room temperature and pressure); calculations involving the idea of limiting reactants may be set (Knowledge of the gas laws and the calculations of gaseous volumes at different temperatures and pressures are not required.)

11.1 Mole

Mole: unit of measurement for a group of atoms / molecules / ions

One mole of any substance contains 6×10^{23} particles

Unit: **mol**

Avogadro's constant: $\mathbf{6 \times 10^{23}}$

Number of moles:

$$\text{Number of moles} = \frac{\text{number of particles of atoms or molecules}}{6 \times 10^{23}}$$

11.2 Molar Mass

Molar mass

Mass of one mole of a substance

Unit: **g/mol**

- For atoms: same as A_r with g/mol as its units
- For molecules: same as M_r with g/mol as its units

Molar mass:

$$\text{Number of atoms or molecules} = \frac{\text{mass of element / compound (g)}}{\text{molar mass of element / compound (g/mol)}}$$

11.3 Molar Volume of Gases

Avogadro's Law

Equal volume of all gases, under same conditions of temperature & pressure, contain same number of particles

Molar volume

One mole of gas always has the same volume of 24 dm^3 at r.t.p. (temperature 25℃, pressure 1 atm)

Number of moles of gas:

$$\text{Number of moles of gas} = \frac{\text{volume of gas } (dm^3)}{24\ dm^3}$$

Note:

- Same volume = same no. of particles (24 dm^3 = 1 mole)
- Same mass ≠ same no. of particles (different molar mass)

11.4 Empirical Formula and Molecular Formula

Empirical formula: simplest formula of a compound (simplest mole ratio of atoms)
Molecular formula: actual formula of a compound (exact number of atoms)

Molecular formula of compound

To find the molecular formula, we need to know:

1. **Empirical formula**
2. **Relative molecular mass**

If empirical formula = A_xB_y,
then molecular formula = $(A_xB_y)_n$ where $n \in \mathbb{Z}^+$

$$n = \frac{M_r \text{ of substance}}{M_r \text{ of empirical formula}}$$

Calculation questions

Type 1: Mass

A compound contains 0.4 g carbon and 0.1 g hydrogen. It has relative molecular mass of 30. Calculate the empirical formula and hence deduce the molecular formula of this compound.

Solution:

	C	H
No. of moles / mol	$\frac{0.4\text{ g}}{12\text{ g/mol}} = 0.033$	$\frac{0.1\text{ g}}{1\text{ g/mol}} = 0.1$
Mole ratio	1	3

Empirical formula = CH_3

Let molecular formula be $(CH_3)_n$

M_r of $(CH_3)_n = 30$

$[12+3(1)]n = 30$

$n = 2$

Hence, molecular formula = **C_2H_6**

Type 2: Percentage

Calculate the empirical formula of a compound containing 40% carbon, 53.33% oxygen and 6.67% hydrogen. If the relative molecular mass of the compound is 180, what is its molecular formula?

Solution:

Let the mass of the compound be 100 g

	C	O	H
No. of moles / mol	$\frac{40\text{ g}}{12\text{ g/mol}} = 3.33$	$\frac{53.33\text{ g}}{16\text{ g/mol}} = 3.33$	$\frac{6.67\text{ g}}{1\text{ g/mol}} = 6.67$
Mole ratio	1	1	2

Empirical formula = COH_2

Let molecular formula be $(COH2)_n$

M_r of $(COH2)_n = 180$

$[12+16+2(1)]n = 180$

$n = 6$

Hence, molecular formula = $C_6H_{12}O_6$