

1.1 Formulae, equations and amount of substance

Name: _____ Class: _____ Date: _____

Total: 20 marks

KEY WORDS mole • atom economy • percentage yield
• empirical formula • molar volume

Objective

Practise Topic 1: mole arithmetic, reacting masses, gas volumes, solution amounts, empirical formulae, yield and atom economy – the skills every WCH11 question leans on.

1 Key knowledge and worked examples

■ The three doors to n

$$n = \frac{m}{M} \quad n = \frac{V}{24 \text{ dm}^3} \quad (\text{RTP}) \quad n = cV$$

Here M is molar mass and ν is the balanced product coefficient. For gases not at RTP, $pV = nRT$ with $R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$ and Pascals throughout.

■ Worked example: a full combustion chain

A 7.6 g hydrocarbon forms 26.4 g CO_2 and 3.6 g H_2O on complete combustion. The carbon in the sample becomes CO_2 , and pairs of H atoms become H_2O .

$$n(\text{C}) = n(\text{CO}_2) = \frac{m(\text{CO}_2)}{M(\text{CO}_2)} = \frac{26.4 \text{ g}}{44.0 \text{ g mol}^{-1}} = 0.600 \text{ mol}$$

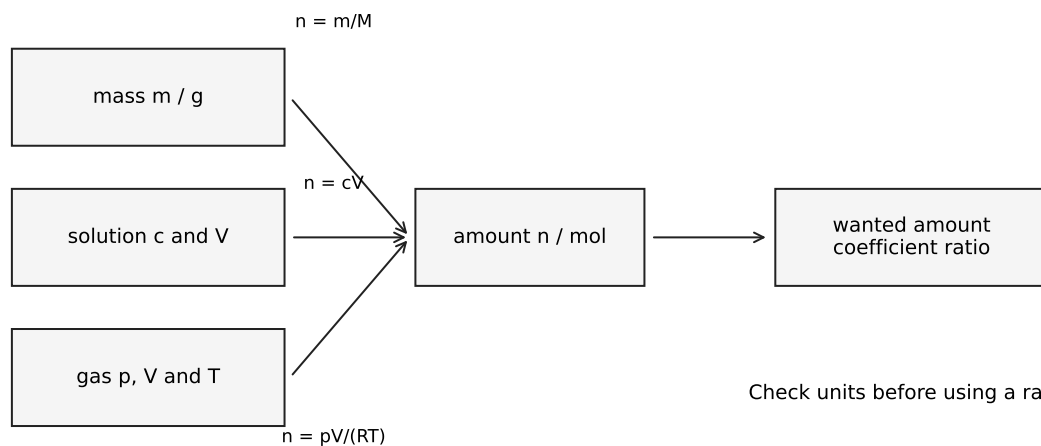
$$n(\text{H}) = 2n(\text{H}_2\text{O}) = \frac{2m(\text{H}_2\text{O})}{M(\text{H}_2\text{O})} = \frac{2 \times 3.6 \text{ g}}{18.0 \text{ g mol}^{-1}} = 0.400 \text{ mol}$$

Ratio $\text{C}:\text{H} = 0.600:0.400 = 3:2$, so the empirical formula is C_3H_2 . Check element masses: $m(\text{C}) = nM = 0.600 \times 12.0 = 7.20 \text{ g}$ and $m(\text{H}) = nM = 0.400 \times 1.00 = 0.400 \text{ g}$, adding to 7.60 g. A molecular formula also needs measured M_r .

Yield and atom economy

$$\% \text{ yield} = \frac{\text{actual}}{\text{theoretical}} \times 100$$

$$\text{atom economy} = \frac{\nu_{\text{wanted}} M_r(\text{wanted})}{\sum \nu_i M_r(\text{product } i)} \times 100$$



2 Practice

2.1 Calculate the number of atoms in 10 g of methane, CH_4 . (A_r : H = 1.0, C = 12.0; $L = 6.02 \times 10^{23}$) [2]

2.2 What volume of oxygen, measured at RTP, is needed for the complete combustion of 0.25 mol of butane? [2]

2.3 State what is meant by the term atom economy. [2]

3 Exam-style questions

3.1 A 2.50 g fertiliser sample contains ammonium sulfate, $(\text{NH}_4)_2\text{SO}_4$ ($M_r = 132$), and inert sand. Excess sodium hydroxide releases all the ammonia from the salt. The ammonia reacts exactly with 48.0 cm^3 of $0.250 \text{ mol dm}^{-3}$ sulfuric acid. No ammonia escapes. Use $(\text{NH}_4)_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{NH}_3 + 2\text{H}_2\text{O}$ and $\text{H}_2\text{SO}_4 + 2\text{NH}_3 \rightarrow (\text{NH}_4)_2\text{SO}_4$ to calculate the percentage by mass of ammonium sulfate. [5]

3.2 Copper(II) nitrate, $\text{Cu}(\text{NO}_3)_2$ ($M_r = 188$), can be made by reacting copper(II) oxide with nitric acid. Calculate the maximum mass of copper(II) nitrate that can be produced from 4.0 g of copper(II) oxide with excess nitric acid ($M_r = 80$), and the atom economy of the reaction if water is the only other product. [5]

3.3 A 0.050 cm^3 drop of water is analysed. Calculate the number of molecules in the drop and the number of oxygen atoms. (density of water = 1.0 g cm^{-3}) [4]
