IGCSE CHEMISTRY • EXERCISE SHEET

3.3 The mole and the Avogadro constant

Name: ____________ Class: _________ Date: ___________ **Total: 32 marks**

KEY WORDS volume 体积 • concentration 浓度 • solution 溶液 • the mole 摩尔 • titration 滴定

Objective

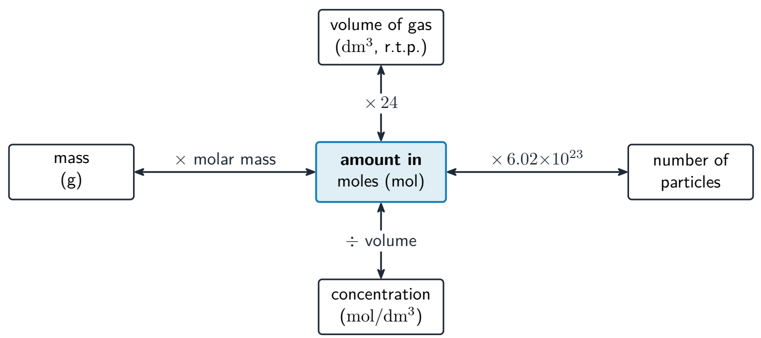
Build the skills to answer exam questions on **the mole** 摩尔 — $n = \frac{\text{mass}}{M_r}$, gas volumes, **concentration** 浓度, reaction calculations, and the **limiting reactant** 限量反应物.

You must be able to:

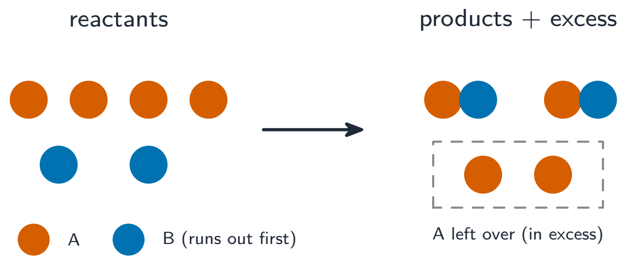
- use $n = \frac{\text{mass}}{M_r}$ and the molar gas volume (24 dm^3)
- use $c = \frac{n}{V}$ and do reacting-mass / titration calculations
- find the limiting reactant and an empirical formula

1 Worked examples

Mole calculations



$$n = \frac{mass}{M_r};\ volume\ of\ gas = n \times 24\ dm^3;\ c = \frac{n}{V}$$



The limiting reactant runs out first and sets how much product forms

36 g **water:** $n = \frac{36}{18} = 2$ mol.

The four calculations, each as a route through the mole

Every quantitative question is the same three steps: **convert what you are given into moles, use the balanced equation to get the moles of what you want,** then **convert those moles into the answer's unit.**

$$n = \frac{m}{M_r} \qquad n = \frac{V(\text{cm}^3)}{24\,000}\ (\text{gas at r.t.p.}) \qquad n = c \times V(\text{dm}^3)$$

Worked example 1 (mass to mass). Calculate the mass of magnesium oxide formed when 4.8 g of magnesium burns completely. (A_r: Mg 24, O 16.)

1. Balanced equation: $2Mg + O_2 \rightarrow 2MgO$.
2. Moles of Mg: $n = \frac{4.8}{24} = 0.20$ mol.
3. The ratio Mg : MgO is 2 : 2, so moles of MgO = 0.20 mol.
4. $M_r(\text{MgO}) = 24 + 16 = 40$, so $m = n \times M_r = 0.20 \times 40 = 8.0$ g.

Worked example 2 (titration, concentration). 25.0 cm^3 of sodium hydroxide needs 20.0 cm^3 of 0.100 mol/dm^3 hydrochloric acid. Find the concentration of the alkali.

1. Moles of HCl $= c \times V = 0.100 \times \frac{20.0}{1000} = 2.00 \times 10^{-3}$ mol.
2. $NaOH + HCl \rightarrow NaCl + H_2O$ is 1 : 1, so moles of NaOH $= 2.00 \times 10^{-3}$ mol.
3. $c = \frac{n}{V} = \frac{2.00 \times 10^{-3}}{0.0250} = 0.0800$ mol/dm^3.

Worked example 3 (limiting reactant, then percentage yield). 6.0 g of carbon reacts with 16.0 g of oxygen. Determine the limiting reactant, the maximum mass of carbon dioxide, and the percentage yield if 19.8 g is collected.

1. $C + O_2 \rightarrow CO_2$; $n(C) = \dfrac{6.0}{12} = 0.50$; $n(O_2) = \dfrac{16.0}{32} = 0.50$.
2. The ratio is 1 : 1 and the moles are equal, so neither is in excess; had one been smaller, that one would be **limiting** because it runs out first and sets how much product forms.
3. Maximum $CO_2 = 0.50 \times 44 = 22.0$ g.
4. percentage yield $= \dfrac{\text{actual}}{\text{theoretical}} \times 100\% = \dfrac{19.8}{22.0} \times 100\% = 90.0\%$.

Percentage composition and empirical formula. Divide each percentage by the element's A_r, then divide every answer by the smallest of them to get the whole-number ratio: 40.0% C, 6.7% H, 53.3% O gives $\frac{40.0}{12} = 3.33$, $\frac{6.7}{1} = 6.7$, $\frac{53.3}{16} = 3.33$, which is 1 : 2 : 1, so CH_2O.

2 Practice

2.1 Find the amount (in mol) in 8.0 g of NaOH ($M_r = 40$). [2]

2.2 Find the volume of 0.50 mol of a gas at r.t.p. [2]

2.3 Calculate the number of moles in 8.8 g of carbon dioxide. ($M_r = 44$.) [2]

2.4 Calculate the volume, at r.t.p., of 0.25 mol of hydrogen gas. [2]

2.5 Determine the empirical formula of a compound containing 52.2% carbon, 13.0% hydrogen and 34.8% oxygen. (A_r: C 12, H 1, O 16.) [3]

3 Exam-style questions

3.1 The number of moles in 22 g of CO_2 ($M_r = 44$) is: [1]

- **A** 0.25
- **B** 0.50
- **C** 1.0
- **D** 2.0

3.2 Magnesium burns: $2Mg + O_2 \rightarrow 2MgO$ (A_r: Mg = 24, O = 16).

(a) Find the moles in 12 g of magnesium. [1]

(b) Find the mass of magnesium oxide formed. [3]

3.3 25.0 cm^3 of sodium hydroxide is neutralised by 20.0 cm^3 of 0.10 mol/dm^3 HCl. $NaOH + HCl \rightarrow NaCl + H_2O$.

(a) Find the moles of HCl. [2]

(b) Find the concentration of the sodium hydroxide. [2]

3.4 Calcium carbonate decomposes when heated: $CaCO_3 \rightarrow CaO + CO_2$. A student heats 25.0 g of calcium carbonate until there is no further change. (A_r: Ca 40, C 12, O 16.)

(a) Calculate the number of moles of calcium carbonate used. [2]

(b) Determine the maximum mass of calcium oxide that can be formed. [3]

(c) The student collects 12.6 g of calcium oxide. Calculate the percentage yield. [2]

(d) Calculate the volume of carbon dioxide, at r.t.p., released in the reaction. [2]

(e) The carbon dioxide is bubbled through 50.0 cm^3 of limewater of concentration 0.0200 mol/dm^3. Calculate the number of moles of calcium hydroxide present, and state whether it is enough to react with all the gas. [3]

Solutions

2.1 $n = \dfrac{8.0}{40} = 0.20$ mol.

2.2 $V = 0.50 \times 24 = 12$ dm^3.

2.3 $n = \dfrac{8.8}{44} = 0.20$ mol.

2.4 $V = 0.25 \times 24 = 6.0$ dm^3, which is 6000 cm^3.

2.5 $\dfrac{52.2}{12} = 4.35$, $\dfrac{13.0}{1} = 13.0$, $\dfrac{34.8}{16} = 2.175$; dividing by the smallest, 2 : 6 : 1; the empirical formula is C_2H_6O.

3.1 **B**. $n = \dfrac{22}{44} = 0.50$ mol.

3.2 (a) $n = \dfrac{12}{24} = 0.50$ mol.
(b) ratio Mg : MgO is 1 : 1, so 0.50 mol MgO; M_r(MgO) = 40; mass = $0.50 \times 40 = 20$ g.

3.3 (a) $n = 0.10 \times \dfrac{20.0}{1000} = 0.0020$ mol.
(b) ratio 1 : 1, so 0.0020 mol NaOH in 25.0 cm^3; $c = \dfrac{0.0020}{25.0/1000} = 0.080$ mol/dm^3.

3.4 (a) $M_r(CaCO_3) = 40 + 12 + 48 = 100$; $n = \dfrac{25.0}{100} = 0.250$ mol.
(b) The ratio $CaCO_3$: CaO is 1 : 1, so n(CaO) = 0.250 mol; M_r(CaO) = 56; $m = 0.250 \times 56 = 14.0$ g.
(c) $\dfrac{12.6}{14.0} \times 100\% = 90.0\%$.
(d) $n(CO_2) = 0.250$ mol; $V = 0.250 \times 24 = 6.0$ dm^3.
(e) $n = c \times V = 0.0200 \times \dfrac{50.0}{1000} = 1.00 \times 10^{-3}$ mol; this is far less than the 0.250 mol of carbon dioxide, so the limewater is not enough to react with all of it.