

2.4 Reacting masses and volumes

Name: _____ Class: _____ Date: _____

Total: 31 marks

KEY WORDS limiting reagent 限量试剂 • titration 滴定 • percentage yield 产率
• stoichiometry 化学计量 • ion 离子

Objective

Build the skills to answer exam questions on **reacting masses and volumes** — **stoichiometry** 化学计量, **percentage yield** 产率, **limiting reagent** 限量试剂, gas volumes, and **titration** 滴定 calculations.

You must be able to:

- calculate reacting masses and percentage yield from a balanced equation
- identify the limiting reagent and calculate gas volumes ($n = V/24$)
- calculate solution concentrations from a titration ($n = cV$)

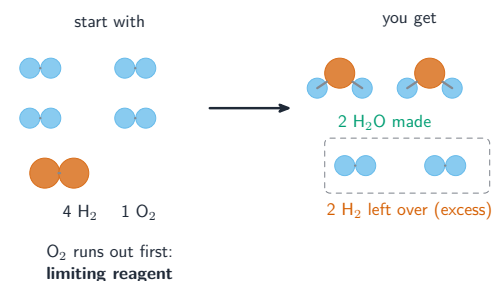
1 Worked examples

■ Reacting masses and percentage yield

Mole ratio comes from the equation. **Example.** Mass of MgO from 4.8 g Mg:
 $2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$. Moles Mg = $4.8/24 = 0.20$; ratio 1:1 $\rightarrow 0.20$ mol MgO; $m = 0.20 \times 40 = 8.0$ g.

$$\text{percentage yield} = \frac{\text{actual product}}{\text{maximum possible}} \times 100\%$$

■ Limiting reagent

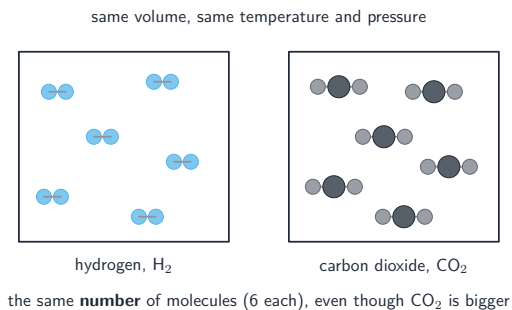


The limiting reagent runs out first and decides the product; the leftover is in excess

Find moles of each reactant, divide by its equation number — the smallest is the **limiting reagent**.

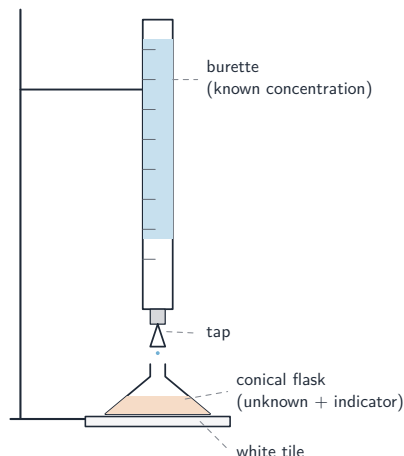
■ Gas volumes

At r.t.p. one mole of any gas = 24.0 dm^3 , so $n = V/24.0$.



Equal gas volumes (same T , p) hold equal numbers of molecules

■ Titration ($n = cV$)



A titration finds an unknown concentration using a solution of known concentration

Example. 20.0 cm^3 of $0.100 \text{ mol dm}^{-3}$ HCl neutralises 25.0 cm^3 NaOH (1:1). Moles HCl = $0.100 \times 0.0200 = 2.00 \times 10^{-3}$; so NaOH conc = $2.00 \times 10^{-3} / 0.0250 = 0.0800 \text{ mol dm}^{-3}$.

■ The three routes through a mole calculation

Every quantitative question is the same shape: **convert to moles** → **use the equation's ratio** → **convert to the answer's unit**.

$$n = \frac{m}{M_r} \quad n = c \times V(\text{dm}^3) \quad n = \frac{V(\text{dm}^3)}{24.0} \text{ (gas at r.t.p.)} \quad pV = nRT$$

Gas volumes shortcut. At the same temperature and pressure, equal volumes contain equal numbers of moles (Avogadro), so for gases the equation's coefficients are **volume ratios directly** — no conversion needed. $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$ burns 24 cm^3 of methane in 48 cm^3 of oxygen and makes 24 cm^3 of carbon dioxide (the water is liquid at r.t.p. and is not counted).

Limiting reactant. Divide each reactant's moles by its coefficient; the **smallest** answer is limiting, and every product amount follows from it. The other reactant is in excess, and the leftover is the difference.

Percentage yield and atom economy are different questions and are often confused:

$$\text{percentage yield} = \frac{\text{actual moles of product}}{\text{theoretical moles}} \times 100 \quad \text{atom economy} = \frac{M_r(\text{desired product})}{\sum M_r(\text{all products})} \times 100$$

Yield is about how well the reaction *ran*; atom economy is a property of the *equation* and is fixed before you start.

Worked example. 0.30 mol of H_2 reacts with 0.20 mol of O_2 : $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$. Find the limiting reactant, the water formed, and the excess left over.

- H_2 : $\frac{0.30}{2} = 0.15$; O_2 : $\frac{0.20}{1} = 0.20$.
- The smaller is hydrogen, so **hydrogen is limiting**.
- Ratio $\text{H}_2 : \text{H}_2\text{O} = 2 : 2$, so 0.30 mol of water forms, which is $0.30 \times 18 = 5.4 \text{ g}$.
- Oxygen used = 0.15 mol , so $0.20 - 0.15 = 0.05 \text{ mol}$ of oxygen remains.

2 Practice

2.1 Calculate the mass of carbon dioxide made when 10 g of calcium carbonate decomposes: $\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$ (M_r : CaCO_3 100, CO_2 44). [2]

2.2 Calculate the volume of 0.50 mol of gas at r.t.p. [1]

2.3 Calculate the volume of oxygen, at r.t.p., needed to burn 50 cm^3 of propane completely. [2]

2.4 State the difference between percentage yield and atom economy. [2]

2.5 0.40 mol of N_2 reacts with 0.90 mol of H_2 to make ammonia. Identify the limiting reactant. [2]

3 Exam-style questions

3.1 24 cm³ of methane is burned completely in oxygen: $\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}$. What volume of CO₂ is made (same conditions)? [1]

- | | |
|---|---|
| A | B |
| C | D |
- A 12 cm³
B 24 cm³
C 48 cm³
D 96 cm³

3.2 0.30 mol of H₂ reacts with 0.20 mol of O₂: $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$. The limiting reagent is: [1]

- | | |
|---|---|
| A | B |
| C | D |
- A hydrogen
B oxygen
C water
D neither — they react exactly

3.3 In a titration, 25.0 cm³ of sulfuric acid is exactly neutralised by 20.0 cm³ of 0.100 mol dm⁻³ NaOH: $\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}$.

(a) Calculate the moles of NaOH used. [1]

(b) Calculate the concentration of the sulfuric acid. [3]

3.4 8.0 g of methanol is made from a reaction whose maximum possible yield is 12.8 g. Calculate the percentage yield. [2]

3.5 Ammonia is manufactured by the Haber process: $\text{N}_2 + 3\text{H}_2 \rightleftharpoons 2\text{NH}_3$. In one run, 2.80 kg of nitrogen is mixed with 0.750 kg of hydrogen. (*A_r*: N 14.0, H 1.0.)

(a) Calculate the amount, in mol, of each reactant. [2]

(b) Determine which reactant is limiting, showing your reasoning. [2]

(c) Calculate the maximum mass of ammonia that could be formed. [3]

(d) The plant actually collects 1.02 kg of ammonia. Calculate the percentage yield. [2]

(e) Calculate the atom economy of this reaction for ammonia, and explain why it takes that value. [3]

(f) Calculate the volume that the unreacted excess reactant would occupy at r.t.p. [2]