Exercise walk-through

Reacting masses and volumes (of solutions and gases) ▪ 2.4

eXercise

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 ($n = cV$)

Method — Reacting masses and percentage yield

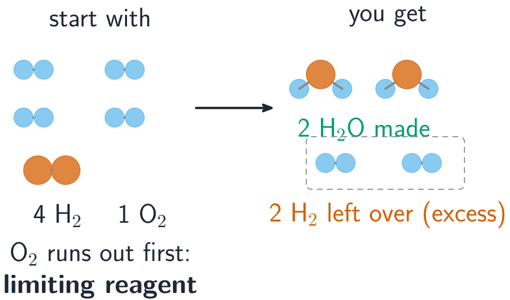
Mole ratio comes from the equation. **Example.** Mass of MgO from 4.8 g Mg: $2\mathrm{Mg} + \mathrm{O_2} \rightarrow 2\mathrm{MgO}$. Moles Mg $= 4.8/24 = 0.20$; ratio 1:1 → 0.20 mol MgO; $m = 0.20 \times 40 = 8.0$ g.

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

Method — Limiting reagent

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

$$2\mathbf{H}_2 + \mathbf{O}_2 \rightarrow 2\mathbf{H}_2\mathbf{O}$$

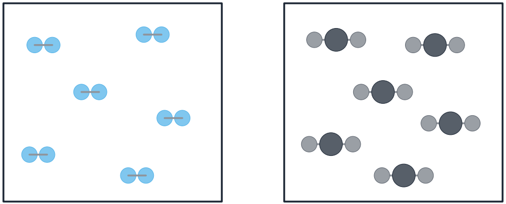


Burning 4 hydrogen molecules with 1 oxygen makes 2 water and leaves 2 hydrogen unreacted

Method — Gas volumes

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

same volume, same temperature and pressure



hydrogen, H_2 carbon dioxide, CO_2

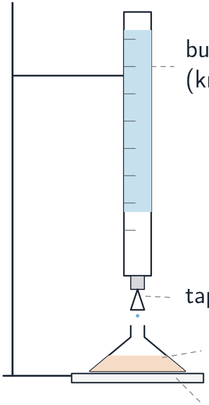
the same **number** of molecules (6 each), even though CO_2 is bigger

Equal-sized boxes of hydrogen and carbon dioxide each holding six molecules

Method — Titration ($n = cV$)

Example. 20.0 cm^3 of 0.100 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 $= 2.00 \times 10^{-3}/0.0250 = 0.0800$ mol dm^{-3}.

Method — Titration ($n = cV$)



A burette above a conical flask on a white tile

Practice 2.1 ▪ 2 marks

Calculate the mass of carbon dioxide made when 10 g of calcium carbonate decomposes: $CaCO_3 \rightarrow CaO + CO_2$ (M_r: CaCO 100, CO 44).

Solution 2.1

Worked steps

moles CaCO $= 10/100 = 0.10$; ratio 1:1 $\rightarrow$ 0.10 mol CO **M1**; $m = 0.10 \times 44 = 4.4$ g **A1**.

Practice 2.2 ▪ 1 mark

Calculate the volume of 0.50 mol of gas at r.t.p.

Solution 2.2

Worked steps

$V = 0.50 \times 24.0 = 12\ \mathrm{dm}^3$ **B1**.

Exam-style 3.1 ▪ 1 mark

24 cm^3 of methane is burned completely in oxygen: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$. What volume of CO is made (same conditions)?

A 12 cm^3

B 24 cm^3

C 48 cm^3

D 96 cm^3

Solution 3.1

A 12 cm^3

B 24 cm^3 ✓

C 48 cm^3

D 96 cm^3

Worked steps

B. Ratio CH : CO is 1:1, so 24 cm^3 of CO .

Exam-style 3.2 ▪ 1 mark

0.30 mol of H_2 reacts with 0.20 mol of O_2: $2H_2 + O_2 \rightarrow 2H_2O$. The limiting reagent is:

A hydrogen

B oxygen

C water

D neither — they react exactly

Solution 3.2

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

Worked steps

A. $0.30/2 = 0.15$ for H vs $0.20/1 = 0.20$ for O ; H gives the smaller value, so hydrogen is limiting.

Exam-style 3.3 ▪ 1 mark

In a titration, 25.0 cm^3 of sulfuric acid is exactly neutralised by 20.0 cm^3 of 0.100 mol dm^{-3} NaOH: $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$.

(a) Calculate the moles of NaOH used.

(b) Calculate the concentration of the sulfuric acid.

Solution 3.3

Method: Titration ($n = cV$)

Worked steps

(a) $n = 0.100 \times 0.0200 = 2.00 \times 10^{-3}$ mol **B1**.
(b) ratio H SO : NaOH is 1:2, so moles H SO $= 1.00 \times 10^{-3}$ **M1**; $c = n/V = 1.00 \times 10^{-3}/0.0250$ **M1** $= 0.0400$ mol dm^{-3} **A1**.

Exam-style 3.4 ▪ 2 marks

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

Solution 3.4

Method: Reacting masses and percentage yield

Worked steps

$$\frac{8.0}{12.8} \times 100 = 62.5\%$$ **M1** **A1**.