# 1.2 Formulae equations and moles

Name: _____ Class: _____ Date: _____ **Total: 30 marks**

## Objective

Build the skills to answer exam questions on **chemical formulae, equations and calculations** 、 : balanced equations with state symbols, relative formula mass, moles, reacting masses, percentage yield, empirical formulae and solution concentration.

**You must be able to:**

- balance equations and add state symbols
- calculate $M_r$, moles and reacting masses
- calculate empirical formulae and percentage yield
- calculate the concentration of a solution

## 1 Key knowledge and worked examples

### Mole calculations

| idea | formula |
|---|---|
| moles | mass (g) $\div M_r$ |
| mass | moles $\times M_r$ |
| concentration (mol/dm$^3$) | moles $\div$ volume (dm$^3$); 1000 cm$^3$ = 1 dm$^3$ |
| percentage yield | actual mass $\div$ theoretical mass $\times 100$ |
| empirical formula | moles of each element (mass $\div A_r$), then the simplest whole-number ratio |

**Worked example 1: moles.** Find the moles in 8.0 g of sodium hydroxide, NaOH ($M_r = 40$).

1. Known: 8.0 g; $M_r = 40$.
2. Rule: mass $\div M_r$.
3. Numbers: $8.0 \div 40$.
4. Result: 0.20 **mol**.

**Worked example 2: empirical formula.** A compound contains 2.4 g of carbon and 0.6 g of hydrogen. Find its empirical formula.

1. Known: C 2.4 g ($A_r$ 12); H 0.6 g ($A_r$ 1).
2. Rule: moles of each, then simplest ratio.
3. Numbers: C 0.2; H 0.6; ratio 1 : 3.
4. Result: $\mathbf{CH_3}$.

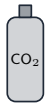
**Answer shapes:** write the equation first, then use the mole ratio from it.

## 2 Practice

**2.1** Calculate the relative formula mass of calcium carbonate, $CaCO_3$ ($A_r$: Ca 40, C 12, O 16). [2]




**2.2** Calculate the number of moles in 4.4 g of carbon dioxide, $CO_2$ ($M_r = 44$). [2]




**2.3** Balance the equation and add state symbols: $Mg + O_2 \rightarrow MgO$. [2]

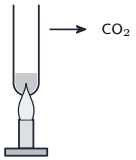


**2.4** 0.25 mol of a salt is dissolved to make 500 cm$^3$ of solution. Calculate the concentration in mol/dm$^3$. [2]



## 3 Exam-style questions

**3.1** Calcium carbonate decomposes: $CaCO_3 \rightarrow CaO + CO_2$. Calculate the mass of calcium oxide ($M_r = 56$) made from 25 g of calcium carbonate ($M_r = 100$). [3]




**3.2** A compound contains 1.4 g of nitrogen and 3.2 g of oxygen. Calculate its empirical formula ($A_r$: N 14, O 16). [3]




**3.3** A student heats magnesium ribbon in a crucible to make magnesium oxide. The results are shown in the table. ($A_r$: Mg 24, O 16)

(a) Calculate the mass of magnesium used and the mass of oxygen that reacted. [3]

| | mass / g |
|---|---|
| empty crucible and lid | 20.00 |
| crucible, lid and magnesium | 20.48 |
| crucible, lid and product | 20.80 |

(b) Use your answers to show that the empirical formula of magnesium oxide is MgO. [4]

(c) Another student starts with 0.48 g of magnesium but collects only 0.68 g of magnesium oxide ($M_r = 40$). Calculate the percentage yield. [3]

(d) Explain why the second student's yield is less than 100%, and describe how the method could be improved. [6]

## Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

**2.1**

- $40 + 12 + 3 \times 16$
- **100**

**2.2**

- $4.4 \div 44$
- **0.10** mol

**2.3**

- $2Mg + O_2 \rightarrow 2MgO$
- (s), (g), (s)

**2.4**

- $0.25 \div 0.500$
- **0.50** mol/dm$^3$

**3.1**

- moles $CaCO_3 = 25 \div 100 = 0.25$
- moles CaO $= 0.25$ (1 : 1)
- mass $0.25 \times 56 =$ **14** g

**3.2**

- N $1.4 \div 14 = 0.1$; O $3.2 \div 16 = 0.2$
- ratio 1 : 2
- **$NO_2$**

**3.3**

(a) Mg $20.48 - 20.00 =$ **0.48** g; oxygen $20.80 - 20.48 =$ **0.32** g

(b) moles Mg $0.48 \div 24 = 0.02$; moles O $0.32 \div 16 = 0.02$; ratio 1 : 1; so MgO

(c) theoretical: 0.02 mol MgO $\times 40 = 0.80$ g; $0.68 \div 0.80 \times 100 =$ **85**%

(d) points to include:

- some magnesium did not react, e.g. it was not heated for long enough (An)
- some magnesium oxide smoke escaped when the lid was lifted (An)
- some magnesium may have reacted with nitrogen in the air (K)
- improvement: heat strongly until there is no further change, lifting the lid only a little (App)
- heat, cool and weigh again until the mass stays the same (heating to constant mass) (App)
- clean the ribbon with sandpaper first, so the oxide layer does not affect the mass (App)

Levels: **5–6** a full, logical answer with correct chemistry and correct terms; **3–4** several correct points, partly linked; **1–2** one or two relevant points.