Ratio and proportion

We can read ratios from balanced symbol equations. The numbers in front of each formula (the coefficients) tell us the ratio of moles of each substance involved in the reaction.

Using mole ratios is essential in many areas of chemistry:

- **Pharmaceutical companies** use mole ratios to calculate exactly how much of each reactant is needed to produce a batch of medicine, ensuring nothing is wasted and the correct dose is achieved.
- **Industrial chemists** at fertiliser plants, like those running the Haber process, use mole ratios to determine how much nitrogen and hydrogen are needed to produce a target quantity of ammonia.
- **Environmental scientists** use mole ratios when analysing water samples to determine the concentration of dissolved substances and whether they exceed safe limits.
- **Forensic chemists** use mole ratios in titrations to determine unknown concentrations of substances found at crime scenes.

In this worksheet, you will practice reading mole ratios from equations and using them to calculate masses. You can use the key terms list or glossary to look up definitions.

Mole ratios

The mole ratio comes from the coefficients (normal numbers in front of the symbols) in a balanced equation.

For example: $2Mg + O_2 \rightarrow 2MgO$ gives the ratio $Mg : O_2 : MgO = 2:1:2$.

This ratio tells us the number of moles, not the number of grams.

To calculate mass from moles:

Step 1: **write** the balanced equation and identify the mole ratio.

Step 2: **calculate** the moles of the substance you know using: $\text{moles} = \frac{\text{mass}}{M_r}$

Step 3: **use** the mole ratio to **find** the moles of the substance you need.

Step 4: **convert** back to mass using: $\text{mass} = \text{moles} \times M_r$

For solutions: $\text{moles} = \text{concentration (mol/dm}^3) \times \text{volume (dm}^3)$

Remember: to convert cm^3 to dm^3, divide by 1000.

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Worked example

Calculate the mass of sodium chloride ($NaCl$) produced when 4.6 g of sodium reacts with excess chlorine gas.

$$2Na + Cl_2 \rightarrow 2NaCl$$

(Relative atomic masses: $Na = 23$, $Cl = 35.5$)

Step 1: **write** the balanced equation and identify the mole ratio. $Na : NaCl = 2 : 2 = 1 : 1$.

Step 2: **calculate** moles of Na. M_r of $Na = 23$. Moles $= 4.6 \div 23 = 0.2$ mol.

Step 3: **use** the ratio to **find** the moles. $Na : NaCl = 1 : 1$, so, 0.2 mol $Na \rightarrow$ 0.2 mol $NaCl$.

Step 4: **convert** to mass. M_r of $Na = 23 + 35.5 = 58.5$. Mass $= 0.2 \times 58.5 = 11.7$ g.

Questions

1. Write the mole ratio for each balanced equation:

(a) $2H_2 + O_2 \rightarrow 2H_2O$
(b) $CaCO_3 \rightarrow CaO + CO_2$
(c) $2Fe + 3Cl_2 \rightarrow 2FeCl_3$
(d) $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

2. Magnesium reacts with hydrochloric acid to form magnesium chloride and hydrogen gas.

$$Mg + 2HCl \rightarrow MgCl_2 + H_2$$

Calculate the mass of magnesium chloride, $MgCl_2$, produced when 2.4 g of magnesium reacts with excess hydrochloric acid. M_r: $Mg = 24$; $MgCl_2 = 95$

3. Iron reacts with oxygen to form iron(III) oxide.

$$4Fe + 3O_2 \rightarrow 2Fe_2O_3$$

(a) What is the mole ratio of Fe to Fe_2O_3?

(b) Calculate the mass of iron(III) oxide produced when 11.2 g of iron reacts with excess oxygen. M_r: $Fe = 56$; $Fe_2O_3 = 160$

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4. Nitrogen reacts with hydrogen in the Haber process:

$$N_2 + 3H_2 \rightarrow 2NH_3$$

A scientist wants to produce 68 g of ammonia, NH_3. M_r: $N_2 = 28$; $H_2 = 2$

(a) Calculate the mass of nitrogen needed.

(b) Calculate the mass of hydrogen needed.

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