# Stoichiometry

IGCSE Chemistry ▪ Topic 3

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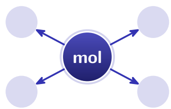
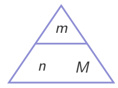





## What we will cover






$n = m/M$

*the mole and molar mass*

# 1 Formulae and equations



## Chemical formulae


gives $Al_2O_3$

the charge numbers cross over to become the subscripts (then simplify if they share a factor)

- The **molecular formula** 分子式 is the actual number of each atom in one **molecule** 分子. For glucose it is $C_6H_{12}O_6$.
- The **empirical formula** 实验式 is the simplest whole-number **ratio** 比例 of the atoms or **ions** 离子 in a **compound** 化合物. For glucose it is $CH_2O$.



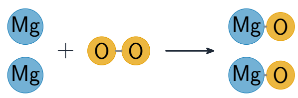
## Formulae, equations and state symbols

| | |
|---|---|
| **an ionic compound 离子化合物** | work the formula out from the charges: total positive must balance total negative |
| **the common ions** | +: $Na^+$, $K^+$, $Ca^{2+}$, $Mg^{2+}$, $Al^{3+}$, $NH_4^+$. −: $Cl^-$, $OH^-$, $NO_3^-$, $SO_4^{2-}$, $CO_3^{2-}$, $O^{2-}$ |
| **a word equation 文字方程式** | uses names: *magnesium + oxygen → magnesium oxide* |
| **a symbol equation** | uses formulae, and must be balanced |
| **state symbols 状态符号** | (*s*) solid, (*l*) liquid, (*g*) gas, (*aq*) **aqueous** 水溶液 – dissolved in water |
| **an ionic equation 离子方程式** | shows only the ions that actually change; spectator ions are left out |

Balance by changing the numbers in front, never the formulae themselves. Changing a subscript makes it a different substance.



## Writing and balancing equations




$$2Mg + O_2 \rightarrow 2MgO$$

2 Mg and 2 O on each side: balanced

A **balanced** 配平 symbol equation has the same number of each atom on both sides.

$$2Mg + O_2 \rightarrow 2MgO$$

**State symbols** 状态符号: (*s*) (*l*) (*g*) (*aq*).

## The words an equation uses

| | |
|---|---|
| **Reactants** | The **reactants** 反应物 are on the left – what you start with. |
| **Products** | The **products** 生成物 are on the right – what you finish with. |
| **Balancing** | Change the *numbers in front*, never the formulas. Atoms are conserved, so each element must appear the same number of times on both sides. |
| **In solution** | A **solute** 溶质 dissolves in a solvent to give a solution; concentration is moles of solute per $dm^3$. |

> A balanced equation is a recipe in *moles*, which is why every reacting-mass calculation begins by writing one.

# 2 The mole



## The mole and molar mass

One **mole** 摩尔 $= 6.02 \times 10^{23}$ particles (the **Avogadro constant** 阿伏伽德罗常数).

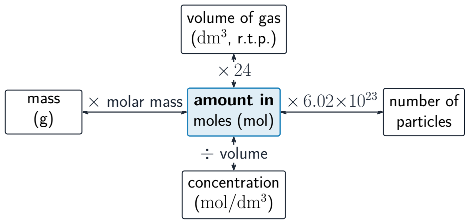
$$n = \frac{\text{mass}}{\text{molar mass}}$$

**Example**

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



## The mole and molar mass, in detail




> One **mole** 摩尔 $= 6.02\times10^{23}$ particles (the **Avogadro constant** 阿伏伽德罗常数).



## Gas volumes and concentration

> At r.t.p. one mole of any gas fills 24 $dm^3$.
> $V = n \times 24$

**Example**

0.25 mol $CO_2$: $V = 0.25 \times 24 = 6$ $dm^3$.

$$\text{conc } (mol/dm^3) = \frac{n}{V(dm^3)}$$

Convert volume first: $1$ $dm^3$ $= 1000$ $cm^3$.



## Reaction calculations

Three steps:

1. known mass → moles
2. use the equation ratio
3. moles → mass / volume

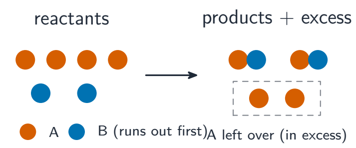
**12 g Mg burns: mass of MgO?**

$2Mg + O_2 \rightarrow 2MgO$
moles Mg $= 12/24 = 0.5$
ratio $1{:}1 \Rightarrow 0.5$ mol MgO
mass $= 0.5 \times 40 = \mathbf{20}$ g

# 3 Applications



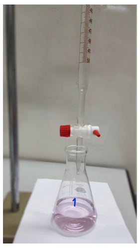
## Limiting reactant




The **limiting reactant** 限量反应物 runs out first and decides how much product forms. The other reactant is left over **in excess** 过量.



## Titration



**$25.0$ cm$^3$ NaOH neutralised by $20.0$ cm$^3$ of $0.10$ HCl**

moles HCl $= 0.10 \times \dfrac{20.0}{1000} = 0.0020$

ratio $1{:}1 \Rightarrow 0.0020$ mol NaOH

conc $= \dfrac{0.0020}{25.0/1000} = \mathbf{0.08}$ mol/dm$^3$

A titration measures exactly how much acid reacts with a base.



## Empirical formula and percentages

**40% Ca, 12% C, 48% O**

$\div A_r$: $1,\ 1,\ 3$

ratio $1{:}1{:}3 \Rightarrow \mathbf{CaCO_3}$

$$\% \text{ by mass} = \frac{\text{mass of element}}{M_r} \times 100$$

**% N in $NH_4NO_3$**

$\dfrac{28}{80} \times 100 = \mathbf{35}\%$



## Relative masses

A laboratory balance measures mass – the basis of mole calculations.



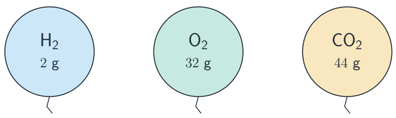
## The masses, and the amount of substance

| | |
|---|---|
| Relative atomic mass | $A_r$: the average mass of an atom of an element, against $\frac{1}{12}$ of a carbon-12 atom. |
| Relative molecular mass | **Relative molecular mass** 相对分子质量 $M_r$: the $A_r$ values of every atom in the molecule, added. |
| Relative formula mass | **Relative formula mass** 相对式量: the same sum for something with no molecules – an ionic compound such as NaCl. |
| Amount of substance | The **amount of substance** 物质的量 is measured in *moles*: $n = m/M_r$, and one mole is $6.02 \times 10^{23}$ particles. |
| Molar gas volume | The **molar gas volume** 摩尔气体体积: one mole of any gas occupies $24$ dm$^3$ at room temperature and pressure. |

**Percentage composition by mass** 质量百分组成 is $\dfrac{\text{mass of that element}}{M_r} \times 100$ – the same arithmetic, read the other way.

## Volumes of gases

**one mole of any gas at r.t.p.**




different masses, the **same volume**: $24$ dm$^3$ each

volume (dm$^3$) = moles $\times$ 24

> One mole of any gas fills 24 cubic decimetres at room temperature and pressure



## Titration calculation

**known acid**: 20.0 cm$^3$ of 0.10 mol/dm$^3$ HCl → $n = c \times \frac{V}{1000}$ → **moles of HCl**: $0.10 \times \frac{20.0}{1000} = 0.0020$ mol → ratio 1 : 1 from the equation → **moles of NaOH**: $= 0.0020$ mol → $c = \frac{n}{V}$ → **concentration**: $\frac{0.0020}{0.0250} = 0.08$ mol/dm$^3$

it is in $25.0$ cm$^3$ of the NaOH solution, so divide by $0.0250$ dm$^3$

> The titration calculation: known solution to moles, ratio, then the unknown concentration



## Exam tips

- Always turn masses, gas volumes and concentrations into **moles** first, use the balanced equation's ratio, then convert back. Never compare masses directly across an equation.
- Key formulas: $n = \frac{\text{mass}}{M_r}$, gas volume $= n \times 24$ dm$^3$ at r.t.p., and concentration $= \frac{n}{\text{volume in dm}^3}$. Change cm³ to dm³ by dividing by 1000.
- To balance a symbol equation you may only change the big numbers *in front* of a formula, never the small subscripts inside it.
- The **limiting reactant** is the one that runs out (fewest moles once you allow for the ratio); it sets how much product forms. The other reactant is in excess.
- **Percentage yield** = actual ÷ theoretical × 100; **percentage purity** = mass of pure substance ÷ mass of sample × 100. Both are always 100% or less.

# 4 Recap



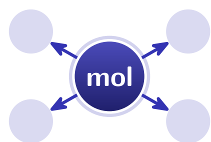
## Topic 3 – key takeaways

1. **Mole** — $n$ = mass / molar mass; $6.02 \times 10^{23}$
2. **Gas & conc** — $24$ dm$^3$ per mole; conc = $n/V$
3. **Calculations** — to moles, use the ratio, back again
4. **Limiting** — the reactant that runs out sets the yield



## Check yourself

1. How many moles are in 18 g of water?
2. What volume does 1 mol of gas fill at r.t.p.?
3. What is a spectator ion?
4. How do you find an empirical formula from masses?




> **Answers** **1.** 1 mol **2.** $24$ dm$^3$ **3.** an ion unchanged on both sides **4.** divide each mass by $A_r$, then by the smallest