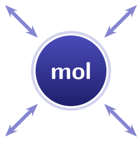
Atoms, Molecules & Stoichiometry

A-Level Chemistry ▪ Topic 2

A-Level Chemistry



What we will cover

1. Relative masses
2. The mole
3. Formulas & equations
4. Reacting masses & yield
5. Gas volumes
6. Titration

mass is the basis

1 Masses and the mole

Relative masses

Masses are compared with $\frac{1}{12}$ of a ^{12}C atom (the unified atomic mass unit, u).

A_r
相对原子质量
average mass of an element's atoms – weighted over its isotopes

M_r
相对分子质量
sum of the A_r values of every atom in the molecule

formula mass
相对式量
the same idea for an ionic compound

Chlorine is 75% ^{35}Cl and 25% ^{37}Cl

$A_r = (75 \times 35 + 25 \times 37)/100 = 35.5$

The mole

$$n = \frac{m}{M}$$

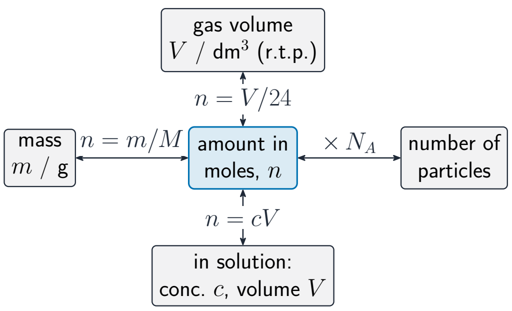
$$N_A = 6.02 \times 10^{23}\,\text{mol}^{-1}$$

Worked example

moles in $8.0\,\text{g}$ of CH_4 ($M = 16$): $n = \dfrac{8.0}{16} = 0.50\,\text{mol}$

One **mole** 摩尔 contains N_A particles (atoms, molecules *or* ions); the **molar mass** 摩尔质量 M in $\text{g}\,\text{mol}^{-1}$ equals A_r or M_r.

The mole map



The mole is the hub of every amount calculation:

- mass: $n = m/M$
- particles: $\times N_A$
- gas: $n = V/24$
- solution: $n = cV$

2 Formulas and reacting masses

Formulas and equations

empirical formula 实验式
simplest ratio – CH_3

molecular formula 分子式
actual atoms – C_2H_6

Equations are **balanced** 配平 with **state symbols** 状态符号 (s, l, g, aq). An **ionic equation** 离子方程式 drops **spectator ions** 旁观离子: $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$.

Reacting masses and yield

Worked example: $2Mg + O_2 \rightarrow 2MgO$

$4.8\,g$ Mg $= 0.20\,mol$; ratio $1:1 \Rightarrow 0.20\,mol$ MgO $= 0.20 \times 40 = 8.0\,g$

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

The numbers in a balanced equation give the mole ratio – the **stoichiometry** 化学计量.

Limiting reagent

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

start with

you get

4 H_2 1 O_2

O_2 runs out first: **limiting reagent**

2 H_2 left over (excess)

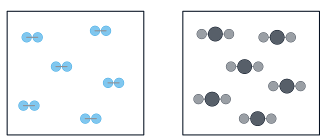
The **limiting reagent** 限量试剂 runs out first and decides how much product forms.

> The leftover reactant is in **excess** 过量试剂. Always base the calculation on the limiting reagent.

3 Gases and solutions

Gas volumes

same volume, same temperature and pressure



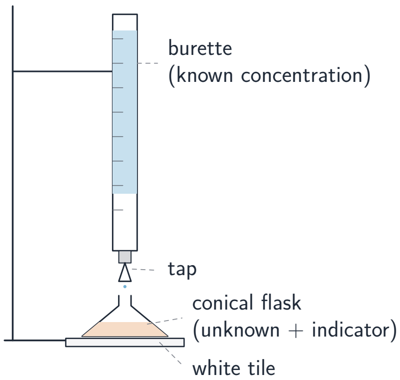
hydrogen, H_2 carbon dioxide, CO_2

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

Equal volumes of any gases (same temperature & pressure) hold equal numbers of molecules.

> At r.t.p., one mole of any gas is $24.0\,\mathrm{dm}^3$, so $n = \dfrac{V}{24.0}$.

Titration



Concentration 浓度: $n = c \times V$ (in $\mathrm{mol\,dm^{-3}}$, V in $\mathrm{dm^3}$).

NaOH neutralised by HCl

$20.0\,\mathrm{cm^3}$ of $0.100\,\mathrm{mol\,dm^{-3}}$ HCl $\Rightarrow$ NaOH $= 0.0800\,\mathrm{mol\,dm^{-3}}$

A **titration** 滴定 finds an unknown concentration.

4 Recap

Topic 2 – key takeaways

1. **The mole**

   $n = m/M$; $N_A = 6.02 \times 10^{23}$

2. **Formulas**

   empirical (ratio) vs molecular (actual)

3. **Reacting masses**

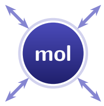
   use the mole ratio; limiting reagent

4. **Gases & solutions**

   $n = V/24$ at r.t.p.; $n = cV$

Check yourself

1. How many moles in 16 g of CH_4?
2. Empirical formula of C_2H_6?
3. What volume does 1 mol of gas occupy at r.t.p.?
4. Which reagent decides how much product forms?



Answers **1.** 1 mol **2.** CH_3 **3.** $24.0\,\mathrm{dm}^3$ **4.** the limiting reagent