Quantitative Chemistry I

Balanced Equations

In a balanced equation there must be the **same number** of each type of atom on **both sides**. This is because of the law of conservation of mass, which means atoms can't be **created or destroyed** during a reaction.

This is a **multiplier**, which tells you how many H_2O molecules there are. You **can** change this to balance an equation.

$$2H_2O$$

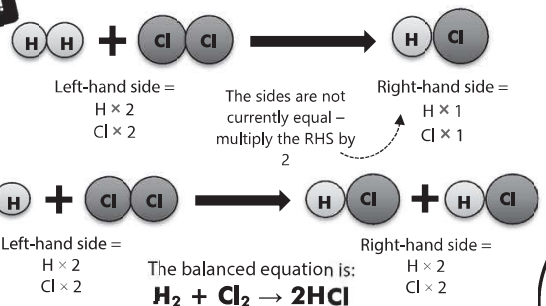
This is a **subscript**, which tells you there are 2 H atoms in each H_2O molecule. You **can't** change this to balance an equation as it will turn it into a different compound!

Hydrogen gas combines with chlorine gas to form hydrogen chloride.

$$H_2 + Cl_2 \rightarrow HCl$$

This equation is not balanced! Count the number of atoms on each side and use multipliers to make the numbers equal.

EXAMPLE!



The balanced equation is:

$$H_2 + Cl_2 \rightarrow 2HCl$$

RELATIVE FORMULA MASS

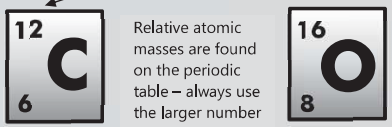
RELATIVE ATOMIC MASS (A_r): the average mass of an atom of an element that accounts for the mass and abundance of different isotopes. It is shown on the periodic table.

RELATIVE FORMULA MASS (M_r): the sum of relative atomic masses of all the atoms in the formula of a compound

EXAMPLE!

The formula for carbon dioxide is CO_2, so it contains 1 C atom and 2 O atoms. The relative formula mass is:

$M_r = 12 + (2 \times 16) = 44$



Relative atomic masses are found on the periodic table – always use the larger number

Conservation of Mass

The law of conservation of mass states:

'the total mass of the products of a reaction must equal the total mass of the reactants'.

- There is **the same number** of each type of atom present **before and after** the reaction, just in **different combinations**.
- There are some types of reaction which appear to break this law, but don't if you look a bit closer:

BURNING METALS IN OXYGEN

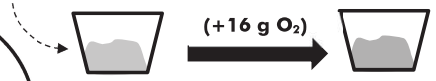
e.g. $2Mg(s) + O_2(g) \rightarrow 2MgO(s)$

The mass of the product is more than that of the starting material. The 'extra' mass comes from oxygen in the air which combines with the metal to form a metal oxide.

THERMAL DECOMPOSITION

e.g. $CaCO_3(s) \rightarrow CaO(s) + O_2(g)$

The mass of the product is less than that of the starting material. The 'missing' mass is another product of the reaction which has been lost as a gas.



24 g Mg → **40 g MgO**

PERCENTAGE YIELD

The amount of product you get in a reaction (yield) isn't always the same as the amount you expect to get from a calculation. Possible reasons include:

- **Reversible reaction** doesn't go to completion
- Some mass is lost in **transferring between containers**
- Reactants form **unwanted by-products**

Percentage yield compares the amount obtained with the amount expected, and shows how efficient a reaction is.

$$\text{Percentage yield} = \frac{\text{mass of product obtained}}{\text{mass of product expected}} \times 100\ \%$$

Exam Tip!

Percentage yield can never be over 100 % – if you calculate it as such, go back and check your work.

EXAMPLE!

A reaction was predicted to form 3.5 g of Product X, but only 2.9 g was made in an experiment. What is the percentage yield of the reaction?

Yield = $\frac{2.9}{3.5}$ × 100 % = 83 %

ATOM ECONOMY

Atom economy measures the fraction of atoms in the reactants that end up in the desired product. It's good to have a high atom economy because this minimises unwanted waste products.

$$\text{Atom economy} = \frac{M_r \text{ of desired product}}{M_r \text{ of all reactants}} \times 100$$

EXAMPLE!

What is the atom economy of producing sodium chloride by the following reaction?
$NaOH + HCl \rightarrow NaCl + H_2O$

Atom economy = $\frac{58.5}{76.5} \times 100$ = 76.5 %

UNCERTAINTIES

Any measurements you make in an experiment will have a degree of **uncertainty –** a range of measurements that the true value lies in. The smaller the uncertainty in a value, the more **accurate** it is.

For a repeated experiment, the uncertainty is **half the range**. The range is the **difference** between the largest value and the smallest value.

In an experiment, a volume in a measuring cylinder was measured in mL. The experiment was repeated four times.

EXAMPLE!

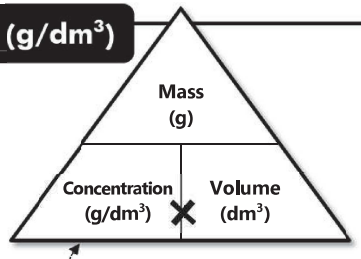
	Repeat 1	Repeat 2	Repeat 3	Repeat 4
Volume (mL)	12.1	12.3	11.9	12.0

Mean volume = $\frac{12.1 + 12.3 + 11.9 + 12.0}{4}$ = 12.1 ± 0.2 mL

All the measurements are within 0.2 mL of the mean, so the uncertainty is quoted as ± 0.2 mL.

Concentration (g/dm³)

The concentration of a solution tells you **how much** of a substance is dissolved in a **given volume** of solution, e.g. in grams per dm^3 **(g/dm^3)**.



An **equation triangle** can help you understand the relationship between mass, volume and concentration – just cover up the quantity you need to find to get the relevant equation.

Exam Tip!

1 dm^3 is 1000 cm^3, or 1 litre.
$dm^3 \rightarrow m^3$ = divide by 1000
$m^3 \rightarrow dm^3$ = multiply by 1000

0.5 g of sodium chloride was dissolved in 250 cm^3 of water. What is the concentration of the solution?

EXAMPLE!

$\frac{250}{1000}$ = 0.25 dm^3

concentration = $\frac{\text{mass}}{\text{volume}} = \frac{0.5}{0.25}$ = 2 g/dm^3