AQA Science: Quantitative chemistry

Conservation of mass

Mass is never lost or gained in chemical reactions. We say that mass is always **conserved**. In other words, the total mass of products at the end of the reaction is equal to the total mass of the reactants at the beginning.

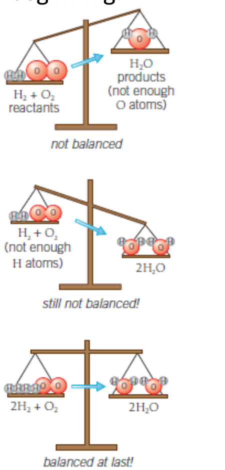


Figure 1 *Balancing an equation*

Balancing equations rules

- Never change the chemical formula
- Total number of reactants must equal total number of products
- Never put a small number yourself
- The big number in front applies to all the atoms in the compound/element
- The small number behind an element applies to that element only
- Use big numbers only and start with 2

Relative formula mass M_r

Mass number = number of protons + number of neutrons
Atomic number = number of protons
Neutron number = mass number – atomic number

The mass of a molecule is called the relative formula mass, M_r. This is calculated by adding up the relative atomic masses of all the atoms in the molecule.

What is the M_r (Relative Formula Mass) of carbon dioxide?

Formula for carbon dioxide	CO_2

Element	Number of atoms in compound		Mass Number (A_r)		Relative atomic mass of atom(s) in compound
C	1	×	12	=	12
O	2	×	16	=	+ 32
Relative Formula Mass (M_r) of carbon dioxide (CO_2) is....					44

Examples of M_r below:

H_2SO_4 → M_r = (1x2=2) + 32 + (16x4=64) = 98

$Ca(OH)_2$ → M_r = 40 + (16 x 2=32) + (1 x 2=2) = 74

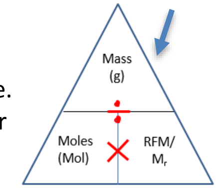
$Mg(HCO_3)_2$ → M_r = 24 + (1x2=2) + (12x2=24) + (16x6=96) = 146

$Al_2(SO_4)_3$ → M_r = (27x2=54) + (32x3=96) + (16x12=192) = 342

Moles and Reacting Masses

One mole of a substance contains the same number of the stated particles, atoms, molecules or ions as one mole of any other substance. The number of atoms, molecules or ions in a mole of a given substance is the Avogadro constant which is 6.02×10^{23} per mole.

Formula to calculate moles



The rules for working out **reacting masses** & example:

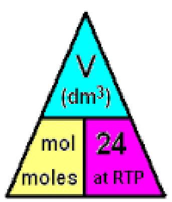
If 28 g of iron reacts with copper sulphate solution, what mass of copper will be made?

- **Step 1.** Write down the balanced symbol equation.
  Fe (28g) + $CuSO_4$ → Cu (?) + $FeSO_4$
- **Step 2.** Write down the relative atomic/formula masses.
  Fe = 56 Cu = 64
- **Step 3.** Write down the ratio of reactants and products.
  Fe : Cu = 1 : 1
- **Step 4.** Convert to ratio of reacting masses.
  Fe : Cu = 1 : 1 = 56 g : 64 g
- **Step 5.** Calculate the scale factor and apply this to the ratio of reacting masses.
  scale factor = 28 g / 56 g = 0.5
  mass of Cu made = 64 g x 0.5 = 32 g

Limiting Reactant (LR)
Is the reactant that gets used up first in a reaction. This is the reactant that is NOT in excess. Therefore, the amounts of product formed in a chemical reaction are determined by the LR

Volume of Gases

One **mole** of any gas has a **volume** of 24 dm^3 or 24,000 cm^3 at rtp (room temperature (20°C) and pressure (1 atmosphere)). This volume is called the molar volume of a gas.



Concentrations

The **concentration** of a solution is usually expressed as the amount of **solute (mol)** dissolved in a given **volume (dm^3)** of solution.

Figure 1 *The orange squash is getting less concentrated going left to right (the darker colour indicates more squash is in the same volume of its solution)*

Figure 2 *Volumetric flasks are used to make up solutions. They have a graduation mark around their narrow necks. Water is added to the solute until the bottom of its meniscus (the curve at the surface of the solution when viewed from the side) is level with the mark*

Concentration continued…

The equations to calculate concentration:

$$\text{concentration (g/dm}^3) = \frac{\text{amount of solute (g)}}{\text{volume of solution (dm}^3)}$$

If you are working in centimetres cubed (cm^3), convert the volume to dm^3 by dividing it by 1000, and use the equation above. Alternatively, substitute your data in cm^3 into the following equation:

$$\text{concentration (g/dm}^3) = \frac{\text{amount of solute (g)}}{\text{volume of solution (cm}^3)} \times 1000$$

* to convert cm^3 → dm^3, divide by 1000 (0.001 dm^3)
* to convert dm^3 → cm^3, multiply by 1000 (1000 cm^3)

You can increase the concentration of an aqueous solution by:

- adding more solute and dissolving it in the same volume of its solution
- evaporating off some of the water from the solution so you have the same mass of solute in a smaller volume of solution.

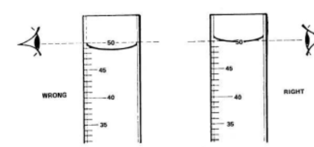
Titrations (TRIPLE ONLY)

Measuring the EXACT volumes of acid and alkali that are needed to react together. **What is this reaction called?** NEUTRALISATION

$$H^+ + OH^- \rightarrow H_2O$$

You can measure the exact volumes of acid and alkali needed to react with each other using a technique called **titration**. The point at which the acid and alkali have reacted completely is called the **end point** of the reaction. You judge when the end point has been reacted using an acid/base indicator, such as **Phenolphthalein Indicator**. It turns colourless in an neutral solution and pink in an alkaline solution.

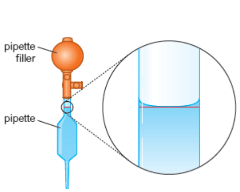
Measuring to the meniscus

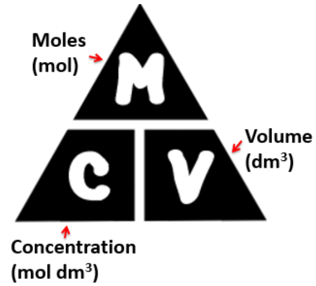


Titrations continued…Carrying out a titration

1. First wash the pipette with distilled water, then with some alkali. Empty alkali into a conical flask.
2. Add a few drops of indicator to the conical flask. Swirl
3. Rinse a **burette** with distilled water and then with some acid. Acid added to burette, starting volume of acid is read accurately.
4. Record the reading on the burette. Open tap to release a bit of acid into flask, swirl.
5. Repeat step 4 until acid in burette has almost run in, then add one drop at a time. Neutralisation occurs. The volume of acid recorded.
6. Repeat 3 times. Discard anomalous results. Repeat the titrations until two results are within of 0.1 cm^3 each other. These precise results are called **concordant**. Calculate a mean.
7. Calculate the concentration of the acid or alkali.

- A volumetric pipette is used to accurately measure a volume of an alkali.
- A pipette filler is used to draw solution into the pipette safely.
- Neutralisation is a change in colour when acid and alkali have been mixed = titration is complete.
- Titre is the volume recorded from a burette





Percentage yield and Atom economy (TRIPLE)

$$\% \text{ yield} = \frac{\text{mass of product obtained}}{\text{maximum theoretical mass of product}} \times 100$$

- The reaction may be reversible – as products form they react to re-form the reactants again. You show reversible reactions using this symbol ⇌ instead of the normal arrow between reactants and products. Chemists can manipulate reversible reactions by the conditions they choose in the reaction vessels in chemical plants.
- Some reactants may react to give unexpected or unwanted products in alternative reactions.
- Some of the product may be lost in handling or left in the apparatus.
- The reactants may not be pure (as in the case of the lime kiln).
- Some of the desired product may be lost during its separation from the reaction mixture.

$$\text{Atom economy} = \frac{\text{mass of wanted product from equation}}{\text{total mass of products from equation}} \times 100$$

Yield Industrial processes –
Industrial processes need as high a percentage yield as possible, because this:
1) Reduces the waste of reactants
2) Reduces the cost of the process

Atom Industrial processes –
Industrial processes need as high an atom economy as possible, because this:
1) Reduces the production of unwanted products
2) Makes the process more *sustainable*
3) Conserve the Earth's resources and minimise pollution