Triple Science - Chemistry

SC 14-16 Knowledge organiser

SC14-16: Quantitative analysis

Sequence

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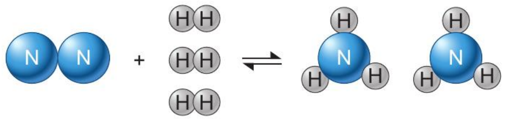
1. Yields	
Theoretical yield	The maximum calculated amount of a product that could be formed from a given amount of reactants.
Actual yield	The amount of product obtained from a chemical reaction.
Percentage yield	The actual yield divided by the theoretical yield, as a percentage. $\frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100 = \text{Percentage yield}$
Incomplete reaction	When a reaction has not been fully completed, meaning that not all of the reactants have been converted into products and thus reducing the percentage yield.
Side reactions	When an unwanted reaction takes place during a targeted reaction, resulting in unwanted products being formed and reducing the percentage yield.

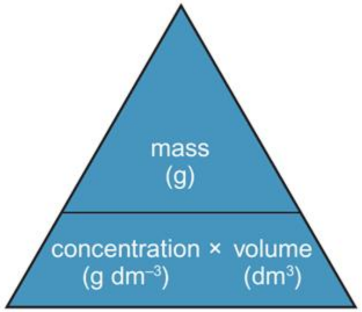
B When you bake a cake, some of the ingredients may get left behind on the scales, in the mixing bowl or in the cake tin. In a chemical reaction, some of the reactants and products may get left behind on the apparatus.

2. Atom economy	
Atom economy	The percentage, by mass, of reactants that are converted into useful products. $\frac{\text{Useful product}}{\text{All products}} \times 100 = \text{Atom economy}$
By-product	Substances produced in chemical reactions in addition to the desired product.
Reaction pathways	A series of reactions needed to make a particular product.
Useful products	The desired product from a chemical reaction that can be used to synthesise other useful products or can be used for a function on its own.
Waste products	The undesired product of a chemical reaction that has no functional uses and so does not generate a profit. They often cost money to dispose of.

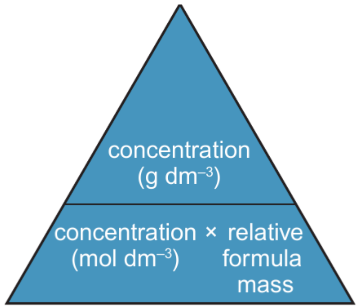


A The atom economy for making ammonia is 100%.

3. Concentrations	
Concentration in g/dm^{-3}	The mass of a solute dissolved in a solvent to form a solution. $\frac{\text{Mass of solute (g)}}{\text{Volume of solvent (dm}^3\text{)}} = \text{Concentration (g/dm}^{-3}\text{)}$
Concentration in mol/dm^{-3}	The moles of a solute dissolved in a solvent to form a solution. $\frac{\text{Moles of solute (mol)}}{\text{Volume of solvent (dm}^3\text{)}} = \text{Concentration (mol/dm}^{-3}\text{)}$
Decimetre (dm^3)	A decimetre is a unit of volume equal to 1 litre or 1000cm^3. To convert from cm^3 to dm^3 divide the volume by 1000.



C equation triangle for working out concentration



E equation triangle for converting concentrations

A A volumetric flask is used for making an accurate solution.

B Fill the flask so the bottom of the meniscus is on the graduation mark.

4. Titrations and calculations

Burette	A piece of apparatus used to accurately measure the volume of solution that has been added during a titration.
Graduated pipette	A piece of apparatus used to accurately measure a set volume of solution during a titration.
Titration	A technique in volumetric analysis that is used to find the exact volumes of solutions which react with each other.
Rough titration	A quick titration that allows you identify the rough end point, allowing you to then carry out accurate titrations accurately and relatively quickly.
Rough end point	The approximate volume of a solution required to react fully with another solution. The rough end point allows you to identify when you should slow the flow of the solution and add it drop wise to ensure the exact volume is added.
Concordant	Results that are in agreement to 0.1 cm^3 of each other.

Reagent	Ratio	Concentration (mol/dm^{-3})	Volume (dm^3)	Moles
NaOH				
HNO_3				

Titration calculations

Calculations carried out using the exact volumes of reacting solutions and the concentration of one of the solutions to calculate the unknown concentration of the other solution.

$$Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O$$

15.0 cm^3 of calcium hydroxide was neutralised by 9.1cm^3 of 2.000 mol/dm^{-3} hydrochloric acid. Calculate the concentration of the calcium hydroxide.

Step 1: Identify the stoichiometric ratio between the reactants e.g.

$Ca(OH)_2 + 2HCl = 1:2$

Step 2: Convert the volumes of each reactant from cm^3 to dm^3 by dividing them by 1000 e.g.

$Ca(OH)_2 = 15/1000 = 0.015\ dm^3$
$HCl = 9.1/1000 = 0.0091\ dm^3$

Step 3: Calculate the number of moles of the reactant with the known concentration and volume e.g.

Moles of HCl = 2.00 x 0.0091 = 0.0182

Step 4: Use the stoichiometric ratio identified in step 1 to work out the number of moles of the reactant with the unknown concentration e.g.

$Ca(OH)_2 + 2HCl = 1:2$
Moles of HCl/2 = Moles of $Ca(OH)_2$
0.0182/2 = 0.0091 moles

Step 5: Calculate the unknown reactants concentration by dividing the number of moles by its volume e.g.

0.0091/0.015 = 0.61 mol/dm^{-3}

$$2KOH + H_2SO_4 \rightarrow K_2SO_4 + 2H_2O$$

25.0 cm^3 of Sulphuric acid was neutralised by 78.0cm^3 of 1.500 mol/dm^{-3} potassium hydroxide. Calculate the concentration of the sulphuric acid.

Reagent	Ratio	Concentration (mol/dm^{-3})	Volume (dm^3)	Moles
KOH				
H_2SO_4				

5. Core practical – Acid-alkali titration

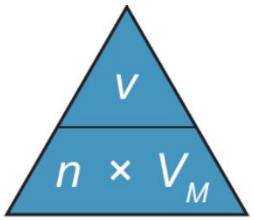
Aim	Carry out an accurate acid-alkali titration, using a burette, a pipette and a suitable indicator.
Task	You will carry out a titration to find the exact volume of hydrochloric acid needed to neutralise 25.0 cm^3 of a solution of sodium hydroxide.
Method	1. Rinse a burette with hydrochloric acid, then fill the burette with acid, making sure the jet below the tap is full. 2. Record the initial volume of acid in the burette, 3. Rinse the pipette with sodium hydroxide solution, then fill the pipette to the 25.0cm^3 mark and empty the solution into a conical flask, 4. Add a few drops of phenolphthalein to the flask and place it on a white tile under the burette. 5. Add the acid to the sodium hydroxide solution while swirling the flask. 6. When the indicator starts to change colour add the acid drop by drop until the end point is reached, 7. Record the final volume of acid in the burette, 8. Repeat the experiment, apart from the initial rinsing of the burette and pipette, until concordant results are obtained.
Results	When considering the results, you should discard the initial rough titration, then use the two concordant results to calculate the average volume of acid used. This will provide you with the volume of acid required to neutralise the alkali, which you can use to calculate the concentration of the alkali. Alternatively you can use this volume to neutralise the alkali without the indicator to form a pure sample of the salt using crystallisation.

A a titration experiment

B The initial volume of solution in the burette is 0.20 cm^3 and the final burette reading is 22.20 cm^3.

6. Molar volume of gases

Avogadro's law	This is the number of particles in one mole of a substance ($6.02x10^{23}$ mol^{-1})
Molar gas volume	The volume occupied by one mole of molecules of any gas. It is 24 dm^3 or 24000 cm^3 at room temperature and pressure.



B n = amount in mol, v = volume of gas, V_m = molar volume

6. Molar volume of gases

At normal room temperature and pressure the molar volume is 24 dm^3.

1. What would the volume of 4 moles of oxygen be?

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2. What would the volume of 0.5 moles of carbon dioxide be?

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3. What would the volume of 48 moles of helium be?

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1. How many moles of argon would a 100cm^3 light bulb hold?

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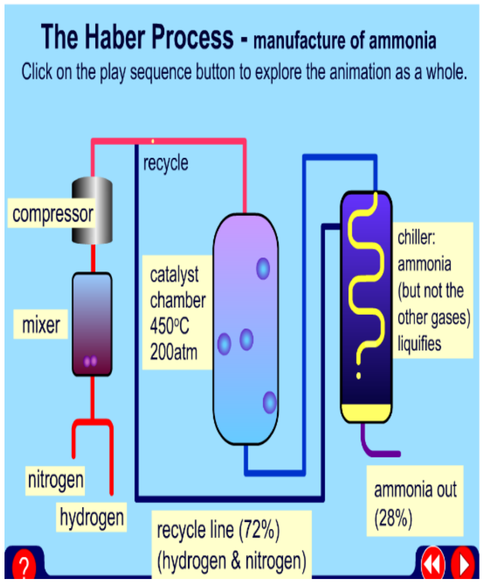
7. Fertilisers and the Haber process

Fertilisers	Soluble compounds added to the soil to replace minerals used up by plants.
Reversible reactions	A reaction that can work in both directions.
Forward reaction	The reaction of reactants reacting to form the products in a reversible reaction, or the reaction moving from left to right.
Backward reaction	The reaction of products breaking back down to form the reactants again in a reversible reaction, or the reaction moving from right to left.
Haber process	The industrial process used to form ammonia, named after the German Chemist Fritz Haber.
Ammonia	An alkaline gas that can be used to create fertilisers, cleaning products and explosives.
Dynamic equilibrium	When the forwards and backwards reactions in a reversible chemical reaction are happening at the same rate, and time, so that there is no increase or decrease in the amount of reactants or products.



8. Factors affecting equilibrium

Closed system	When substances cannot enter or leave an observed environment e.g. a stoppered test tube.
High pressure	A pressure that is significantly above that of atmospheric pressure, which is 1 atmosphere. High pressures are used to increase the concentrations of gas in reactions by squeezing them into a smaller volume. For example a pressure of 200 atmospheres is used in the Haber process as it favours the forward reaction forming a higher yield of ammonia.
High temperature	A temperature that is significantly above that of room temperature, which is 20°C. High temperatures are used to increase the rate of all chemical reactions. For example a temperature of 350°C is used in the Haber process even though it favours the endothermic backward reaction, forming a lower yield of ammonia, as the forward reaction would be too slow at a lower temperature.
Catalyst	A substance that speeds up chemical reactions, without being used up. For example a powdered iron catalyst is used in the Haber process as it lowers the activation energy and increases the rate of the reaction forming ammonia at a faster rate, but it does not affect the yield of ammonia formed.

Change in conditions	Position of equilibrium	Time taken to reach equilibrium
temperature increased	moves in the direction of the endothermic reaction	decreases
pressure increased in a reaction involving gases	moves towards the side of the balanced equation with the fewer molecules of reacting gas	decreases
concentration of a reacting substance increased	moves away from the reacting substance in the balanced equation	decreases
catalyst added	no change	decreases

9. Chemical cells and fuel cells

Chemical cells	A device that produces a voltage due to reactions between reactants stored inside it, until one of the reactants is used up.
Fuel cells	A device that produces a voltage due to reactions between a fuel and oxygen, for as long as the reactants are supplied.
Hydrogen-oxygen fuel cells	Hydrogen- oxygen fuel cells react hydrogen and oxygen to create a voltage, producing only water as a waste product. They do not directly produce carbon dioxide. Although hydrogen is produced by electrolysis, which requires electricity that is often formed by burning fossil fuels, which creates large amounts of carbon dioxide.