Chemistry

Year 11 Knowledge Organisers

AQA GCSE Chemistry (Separate Science) Unit 7: Organic Chemistry Knowledge Organiser

Crude Oil

Hydrocarbons are compounds that are made up of the elements **hydrogen** and **carbon** only.

Crude oil is a **non-renewable resource**, **a fossil fuel**. Crude oil is made up of a mixture of compounds, most of which are long- and short-chain hydrocarbons.

Most of the compounds in crude oil are hydrocarbons called **alkanes**. The alkanes form a **homologous series**. This is a family of hydrocarbons that all share the **same general formula** and have **chemical properties** that are **similar**.

Alkanes are held together by **single bonds**.

The general formula for an alkane is C_nH_{2n+2}.

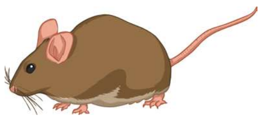
They differ from the neighbouring alkane with the addition of a CH_2.

Alkanes are **saturated hydrocarbons**. This means that all their bonds are taken up and they cannot bond to any more atoms.

Alkanes have **similar chemical properties** but have **different physical properties** due to differences in chain length. The longer the chain, the higher the boiling point of the hydrocarbon.

The first four alkanes are: methane, ethane, propane and butane.

A mnemonic to help you remember the order of the alkanes: **m**ice **e**at **p**aper **b**ags.



Fractional Distillation

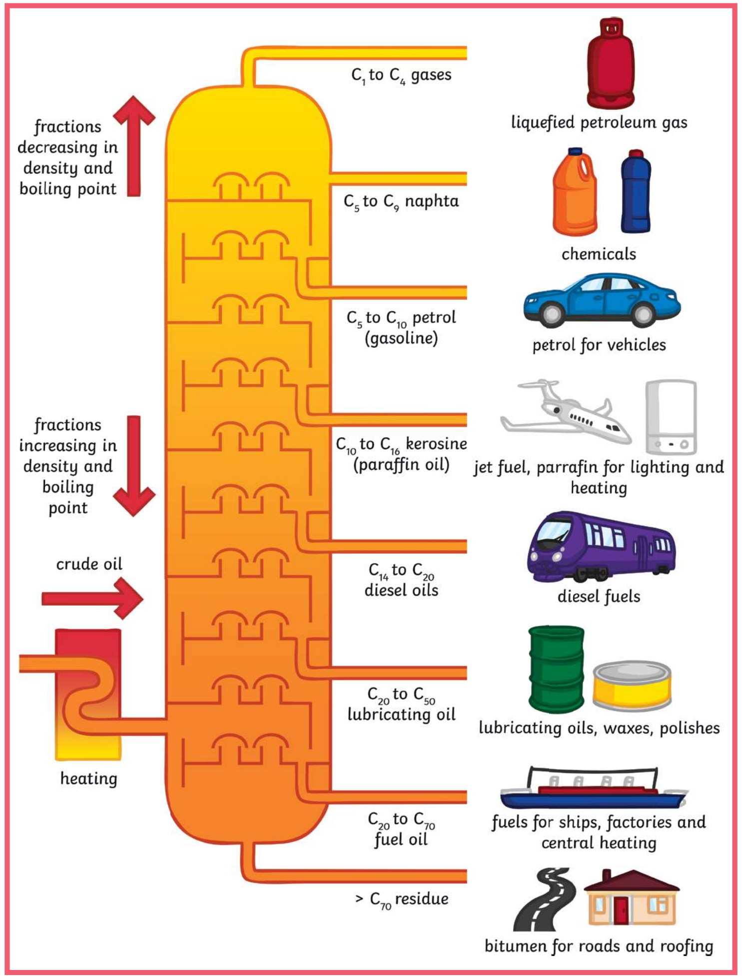
Fractional distillation is used to **separate** a mixture of long-chain hydrocarbons in crude oil into smaller, more useful fractions.

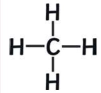
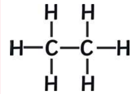
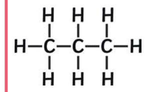
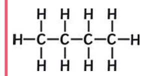
Hydrocarbons have different boiling points depending on their chain length. **Each fraction contains hydrocarbons of a similar chain length**. These fractions will boil at different temperatures due to the difference in sizes of the molecules. The different parts of crude oil are called fractions because they are a small part of the original mixture.

Crude oil is heated and enters at all column called a **fractioning column**. The column is **hot at the bottom** and decreases in temperature toward the top. As the crude oil is heated, it begins to evaporate and its vapours begin to rise up through the column. These vapours condense at the different fractions.

Short-chain hydrocarbons are found at the **top** of the column. This is because shorter chain molecules are held together by **weak intermolecular forces** resulting in low boiling points. These shorter chain hydrocarbons leave the column as gas.

Long-chain hydrocarbons are found at the bottom of the column and are held together by **strong intermolecular forces**, resulting in high boiling points.



Name of Alkane	Structural Formula	Molecular Formula
methane		CH_4
ethane		C_2H_6
propane		C_3H_8
butane		C_4H_{10}

Combustion

Complete combustion occurs when there is **enough oxygen** for a fuel to burn. A hydrocarbon will react with oxygen to produce carbon dioxide and water.

Incomplete combustion occurs when there **isn't enough oxygen** for a fuel to burn. The products in this reaction are water and poisonous **carbon monoxide**.

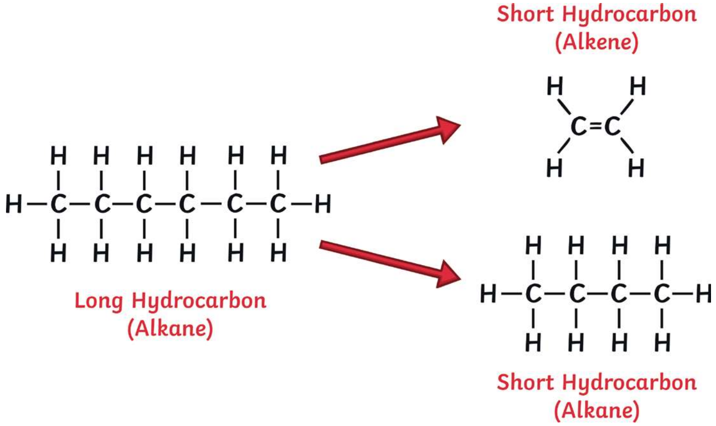
Cracking

Cracking is an example of a **thermal decomposition reaction. Long-chain** hydrocarbons can be **broken** down into **shorter**, more useful hydrocarbon chains.

Cracking can be carried out with a catalyst in **catalytic cracking** or with steam in **steam cracking**.

Catalytic cracking involves heating a hydrocarbon to a high temperature (550˚C) and passing over a hot catalyst.

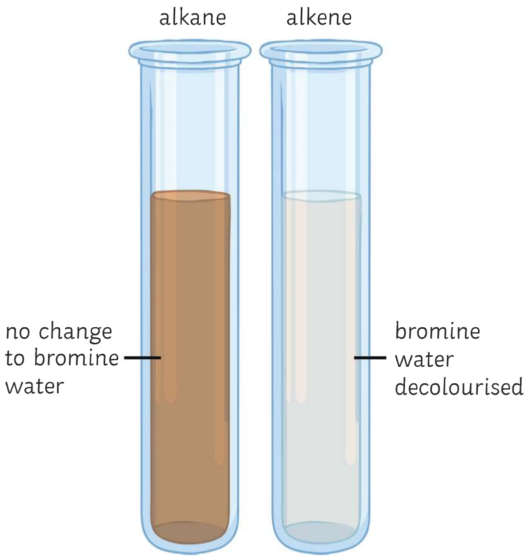
Cracking of a long-chain hydrocarbon **produces** a **short-chain alkane** and an **alkene**.



Test for Alkanes

Bromine, when added to an **alkane**, will **remain brown/orange**. Alkanes are saturated hydrocarbons, they have no double bonds which could be broken to accept the bromine molecule and so remain orange.

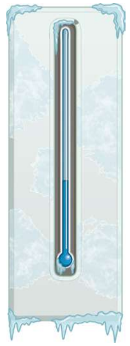
Bromine, when added to an **alkene**, will **change from brown/orange to colourless**. This is because alkenes are unsaturated hydrocarbons. The double bond breaks and the bromine molecule is accepted.



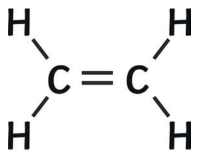
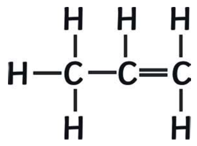
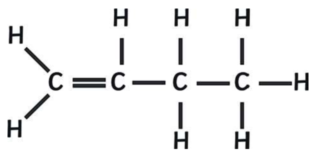
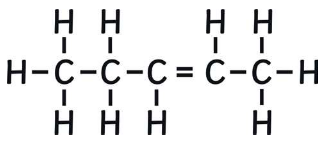
Making Polymers

The fractional distillation of crude oil and cracking produces an array of hydrocarbons that are **key** to our **everyday lives.**

Alkenes are used to produce plastics such as poly(ethene) which is used to make plastic bags, drinks bottles and dustbins. Poly(propene), another polymer, forms very strong, tough plastic.

Short-Chain Molecules	Increasing Chain Length	Long-Chain Molecules
	As chain length increases, the **boiling point** of the hydrocarbon chains also increases.	
thin 	**Viscosity** describes how easily a substance can flow e.g. treacle is very viscous.	thick 
	**Flammability** is a measure of how easily a substance burns.	

Alkenes (Chemistry Only)

Name of Alkene	Structural Formula	Molecular Formula
ethene		C_2H_4
propene		C_3H_6
butene		C_4H_8
pentene		C_5H_{10}

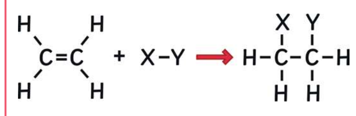
Alkenes are another type of hydrocarbon that is double bonded. The general formula for an alkene is C_nH_{2n}.

Alkenes are **unsaturated hydrocarbons**. In a chemical reaction, the double bond of the alkenes can break. This allows other molecules to bond to it. Note that alkenes all have the suffix '**ene**'.

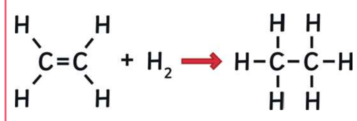
Reactions of Alkenes (Chemistry Only)

Alkenes, just like alkanes, also undergo **combustion** reactions. Alkenes rarely combust completely and tend to undergo **incomplete combustion**. When burning in the air, they produce a smoky flame.

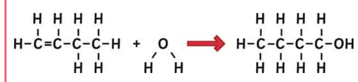
Alkenes have the functional group **C=C**. This double bond between the carbon atoms is able to undergo an addition reaction. This means that the double bond can break and will accept another molecule. **Alkanes** are **unable** to take part in **addition reactions** as their functional group is **C-C**. This means the bond cannot break in order to accept a new molecule.



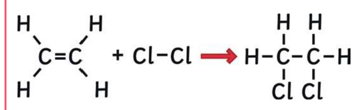
Alkenes are able to **react** with **hydrogen** in an addition reaction called **hydrogenation**. This particular reaction **requires** a **catalyst**.



Alkenes can also **react** with **water** to **produce** an **alcohol**. This is called a **hydration reaction**. The type of compound produced contains a hydroxyl group (-OH), this compound is an alcohol. The reaction **requires** a **high temperature** (300˚C) and a **catalyst**.

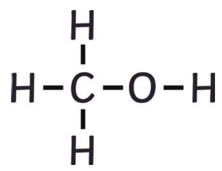
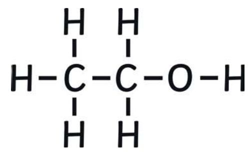
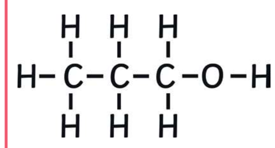
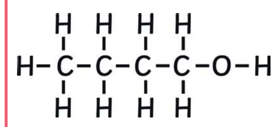


Addition reactions also occur with the **group 7 elements**, the **halogens**. The reaction is called a **halogenation reaction**. When an **alkene reacts** with a **halogen,** an **alkyl halide** is produced.



Alcohols (Chemistry Only)

Alcohols all belong to the **same homologous group**. This is a group of organic compounds that have the same functional group (**-OH, hydroxyl group**) and that have similar chemical properties but different physical properties to each other. Note that alcohols all have the suffix '**ol**'.

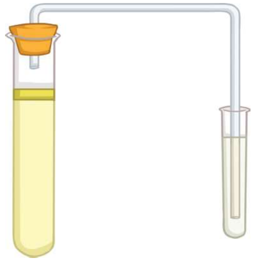
Name of Alcohol	Structural Formula	Molecular Formula	Uses
methanol		CH_3OH	chemical feedstock
ethanol		C_2H_5OH	alcoholic drinks, fuels and solvents
propanol		C_3H_7OH	fuels and solvents
butanol		C_4H_9OH	fuels and solvents

Fermentation

The alcohol that is found in beers, wines and spirits is called ethanol. Ethanol isn't just used in alcoholic drinks, it can also be used as a fuel in vehicles. Ethanol is made through the process of **fermentation**.

Fermentation is an **anaerobic process** and this means that it occurs **without oxygen**.

glucose ⟶ ethanol + carbon dioxide



The fermentation process requires yeast, sugar and water, a warm temperature between 25-35˚C and a reaction vessel that will allow **carbon dioxide** to **escape** but not allow oxygen to get in.

The enzymes needed for fermentation are provided by a single-celled fungus called **yeast**. If the temperature of the reaction mixture is too **cold**, the **fermentation** process will happen very **slowly** or not at all.

If the reaction mixture containing the yeast becomes too **hot**, the **enzymes** may become **denatured** and the process of **fermentation** will **stop**.

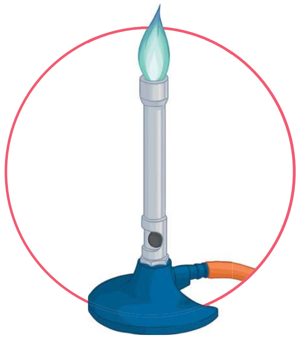
If **oxygen** is allowed to enter the reaction vessel, the **ethanol** will **oxidise** and form ethanoic acid making the drink taste of **vinegar**.

Combustion

Complete combustion occurs when there is **enough oxygen** for a fuel to burn. An alcohol will react with oxygen to produce carbon dioxide and water.

ethanol + oxygen ⟶ carbon dioxide + water

$C_2H_5OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$



Reactions with Sodium Metal

When dropped into **ethanol**, **sodium** produces **sodium ethoxide** and **hydrogen gas**. Methanol, propanol and butanol all undergo a similar reaction with sodium.

The word equation for this reaction is:

sodium + ethanol ⟶ sodium ethoxide + hydrogen

The symbol equation for this reaction is:

$2Na + 2C_2H_5OH \longrightarrow 2C_2H_5ONa + H_2$

Oxidation of Alcohol

Alcohols can be **oxidised** to produce a carboxylic acid. Carboxylic acids are a family of compounds that contain the functional group **–COOH** (carboxyl group). Note that carboxylic acids have the suffix '**oic acid**'. The carboxylic acids have varying physical properties but similar chemical properties.

Oxidation can mean a number of different things: the loss of electrons, the addition of oxygen or the removal of hydrogen. In a chemical equation, the oxidising agent is represented as **[O]**, this symbol means **oxygen from the oxidising agent**.

ethanol + oxidising agent ⟶ ethanoic acid + water

$CH_3CH_2OH + 2[O] \longrightarrow CH_3COOH + H_2O$

The equation can also be written in two stages. The first stage shows the formation of **ethanal** and the second stage shows its oxidation.

Stage 1: $CH_3CH_2OH + [O] \longrightarrow CH_3CHO + H_2O$

Stage 2: $CH_3CHO + [O] \longrightarrow CH_3COOH$

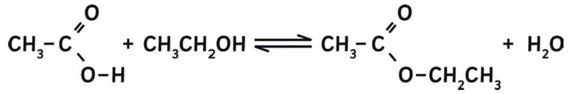
Carboxylic Acids

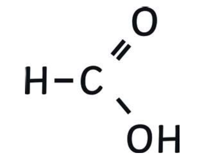
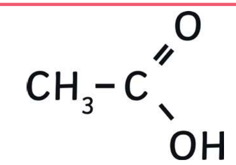
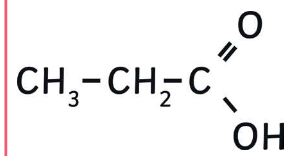
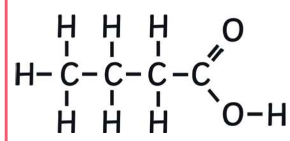
Carboxylic acids are able to react with bases to produce a salt and water. They are also able to react with carbonates to produce a salt, water and carbon dioxide.

When a carboxylic acid is heated with an alcohol in the presence of an acid catalyst (usually concentrated sulfuric acid), an **ester** is formed. Esters typically smell fruity and are used in perfumes. They have the functional group –**COO**-.

For example:

ethanoic acid + ethanol ⇌ ethyl ethanoate + water



Name of Carboxylic Acid	Structural Formula	Molecular Formula
methanoic acid		HCOOH
ethanoic acid		CH_3COOH
propanoic acid		C_2H_5COOH
butanoic acid		C_3H_7COOH

Carboxylic acids are **acidic** due to the hydrogen in the functional group (COOH). When a carboxylic acid forms a salt, the hydrogen is lost and replaced with a metal.

Carboxylic Acids - Higher Tier Only

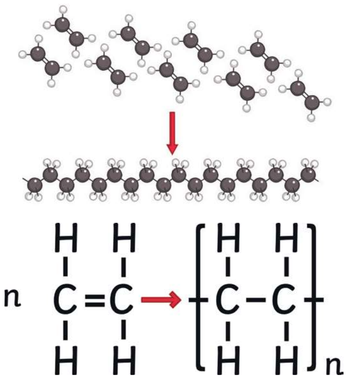
When dissolved in water, carboxylic acids are able to form **acidic solutions**. The pH of the solution is less than 7. They are **weak acids**. Carboxylic acid solutions contain **fewer hydrogen ions** compared with a solution that is the same concentration and contains a strong acid. **Strong acids** are **fully ionised** in solution whereas **weak acids** are only **partially ionised** in solution.

Addition Polymerisation

Addition polymerisation occurs when **two or more monomers** join together to form a **polymer**.
For example, during the polymerisation of ethene, many monomers (single units of ethene) are joined together to make poly(ethene). **Poly** meaning '**many**' (many ethene molecules joined together).

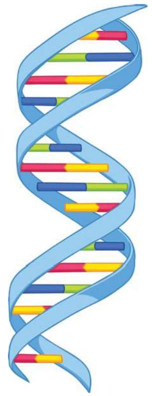
The number of ethene molecules that are joined together could be in the thousands, therefore, when writing the equation the letter 'n' is used to represent the **large number of molecules**.

Notice that the **monomer** of **ethene** has a **double bond**. When it bonds to form **poly(ethene)** the double bond breaks and a **single bond** is formed.



Biological Polymers

DNA (deoxyribonucleic acid) is an example of a **naturally occurring polymer**. DNA is a **double helix** (twisted ladder) and it is made up of two polymer chains that are twisted to form a double helix. The **monomers** of the two polymer chains are called **nucleotides**. The four nucleotides in DNA are called adenine, guanine, cytosine and thyroxine. The nucleotide sequence codes for genes. **Genes** are **sections of DNA** that determine an organisms characteristics.



Proteins are another example of a naturally occurring polymer. Proteins are made from individual **monomer** units called **amino acids**. Proteins have many roles within our bodies; all enzymes are made from proteins.

Plants make the biological polymers **starch** and **cellulose**. They are made up of individual **monomer** units of **sugar** molecules. **Plants** use **starch** as a way to **store energy**. **Cellulose** is used by plants to give the **cell wall strength**.

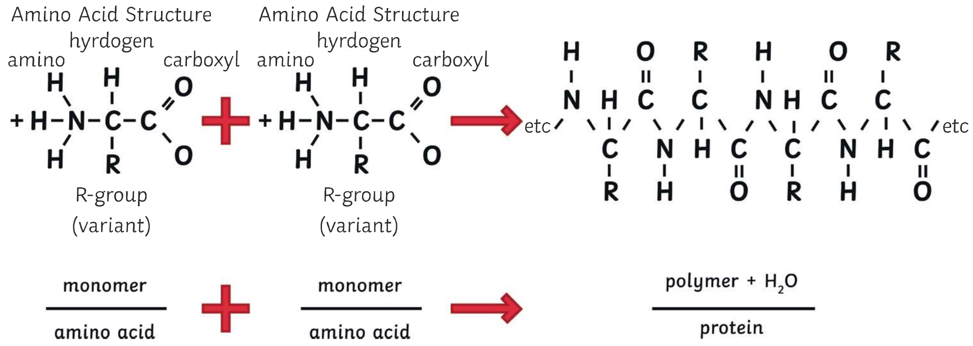
Amino Acids – Higher Tier Only

There are 20 different types of amino acids and when arranged in a particular order, they produce the proteins that are found within our cells.

An amino acid is a molecule that has two functional groups. The amine group (**NH_2**) and the carboxyl group (**COOH**). In between these two functional groups is a single carbon atom with a hydrogen atom bonded to it, along with another group.

Amino acids bond together through the process of a **condensation polymerisation** reaction.

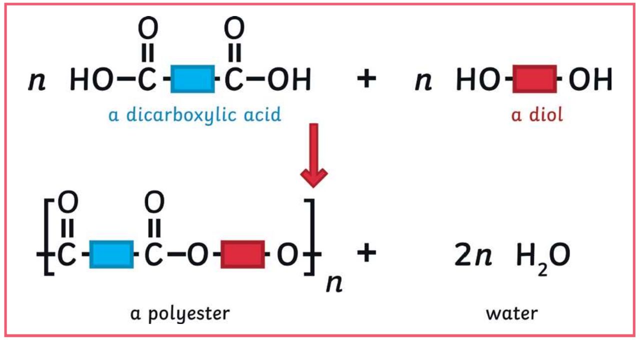
For every **monomer** (amino acid) that is added to the growing chain of the **polymer**, a molecule of **water** is **produced**.



Amino Acids – Higher Tier Only

Addition polymerisation requires the monomers to have a **C=C double bond**. **Condensation polymerisation** does not require a C=C double bond but does need **two functional groups**. When two monomers react, a **water molecule** is usually **produced**.

An example of a condensation polymer is polyester. Polyester is made from one **monomer** that has **two hydroxyl groups** and another monomer which has **two carboxylic acid groups**.

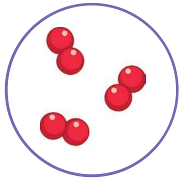


AQA GCSE Chemistry (Separate Science) Unit 8: Chemical Analysis

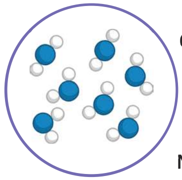
Pure Substances

Pure substances, in chemistry, only contain **one type of element** or **one type of compound**. For example, pure water will just contain water (a compound).

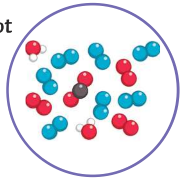
In our everyday language, we use the word 'pure' differently to how it is used in chemistry. Pure can mean a **substance** that has had **nothing else added to it** and is in its natural state. An example of this is pure orange juice. This means that the bottle will just contain orange juice and no other substances.



Elements are made up of **one type of atom**. For example, oxygen is made up of oxygen atoms. Carbon is made up of carbon atoms.



Compounds are **two or more elements** that are **chemically joined** together. For example, NaCl which is sodium chloride.



Mixtures are **two or more elements or compounds** that are **not chemically joined** together. An example of this is a standard cup of coffee. Coffee contains water, milk, coffee and possibly sugar. The components of the cup of coffee are not bonded together.

Pure Substances have a **sharp melting point** compared to **impure** substances which **melt over a range** of temperatures.

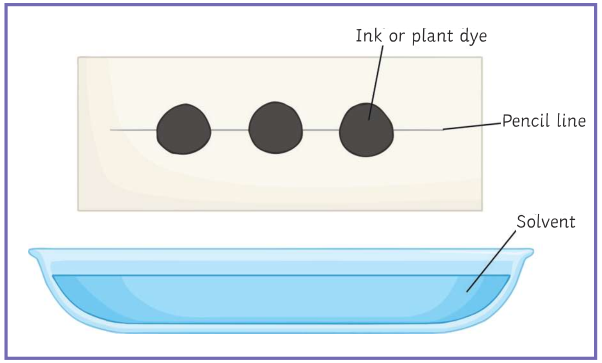
Formulations

Formulations are **mixtures of compounds or substances** that **do not react together**. They do **produce a useful product** with desirable characteristics or properties to suit a particular function.

There are examples of formulations all around us such as medicines, cleaning products, deodorants, hair colouring, cosmetics and sun cream.

Chromatography

Paper chromatography is a separation technique that is used to **separate** mixtures of **soluble substances**. How soluble a substance is determines how far it will travel across the paper.



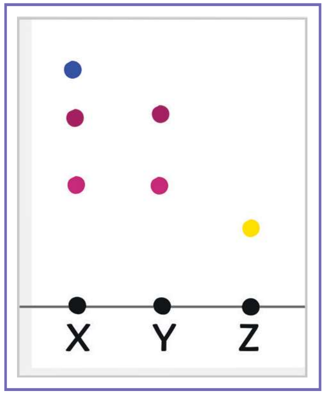
In chromatography, there are **two phases**: the mobile and **stationary** phase.

The **mobile phase moves** through the stationary phase. The **solvent** is the **mobile phase**. It moves through the paper carrying the different substances with it.

The **stationary phase** in paper chromatography is the **absorbent paper**.

Separation of the dissolved substances produces what is called **chromatogram**. In paper chromatography, this can be used to **distinguish** between those substances that are **pure** and those that are **impure**. **Pure substances** have **one spot** on a chromatogram as they are made from a single substance. **Impure substances** produce **two or more spots** as they contain multiple substances.

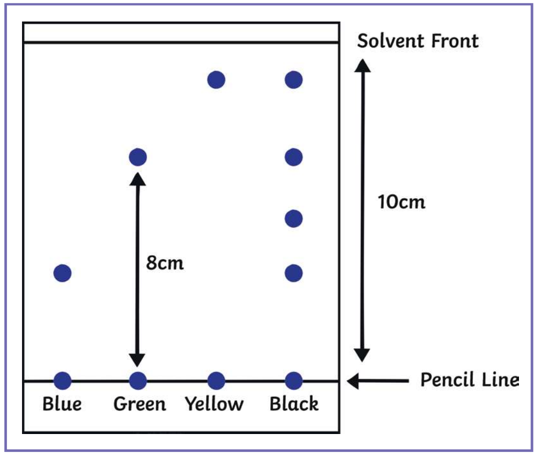
By calculating the **R_f values** for each of the spots, it is possible to identify the unknown substances. Similarly, if an unknown substance produces the **same number** and **colour of spots**, it is possible to match it to a known substance.



R_f Value

$$R_f = \frac{\text{distance travelled by substance}}{\text{distance travelled by solvent}}$$

Different compounds have different R_f values in different solvents. The R_f values of known compounds can be used to help identify unknown compounds.



Required Practical – Paper Chromatography

Investigate how paper chromatography can be used to separate and distinguish between coloured substances.

Step 1 – Using a ruler, measure 1cm from the bottom of the chromatography paper and mark with a small dot using a pencil. Rule a line across the bottom of the chromatography paper with a pencil, going through the dot you have just made.

Step 2 – Using a pipette, drop small spots of each of the inks onto the pencil line. Leave a sufficient gap between each ink spot so that they do not merge.

Step 3 – Get a container and pour a suitable solvent into the bottom. The solvent should just touch the chromatography paper. The solvent line must not go over the ink spots as this will cause the inks to run into each other.

Step 4 – Place the chromatography paper into the container and allow the solvent to move up through the paper.

Step 5 – Just before the solvent line reaches the top of the paper, remove the chromatogram from the container and allow to dry.

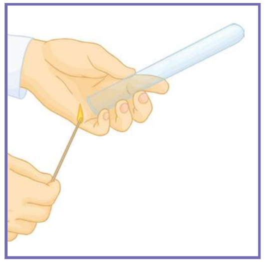
Step 6 – Once the chromatogram has dried, measure the distance travelled by the solvent.

Step 7 – Measure the distance travelled by each ink spot.

Step 8 – Calculate the R_f value. Compare the R_f value for each of the spots of ink.

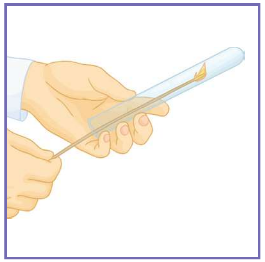
$$R_f = \frac{\text{distance travelled by substance}}{\text{distance travelled by solvent}}$$

Identification of the Common Gases



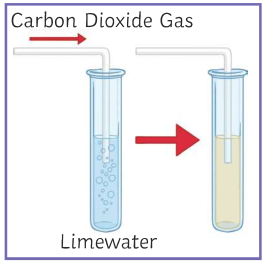
The Test for Hydrogen

Place a burning splint at the opening of a test tube.
If hydrogen gas is present, it will burn rapidly with a **squeaky-pop sound**.



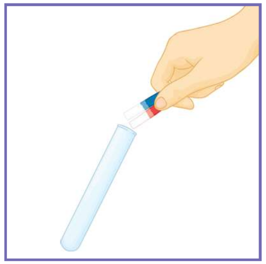
The Test for Oxygen

Place a glowing splint inside a test tube.
The **splint will relight** in the presence of oxygen.



The Test for Carbon Dioxide

Calcium hydroxide (lime water) is used to test for the presence of carbon dioxide. When carbon dioxide is bubbled through or shaken with limewater, the limewater turns **cloudy**.



The Test for Chlorine

Damp litmus paper is used to test for chlorine gas.
The litmus paper becomes **bleached and turns white**.

Flame Tests

Metal ions when heated produce a variety of flame colours. Flame tests are used to **identify** the **metal ion** that is present; each metal ion produces a different coloured flame.

Step 1 – Dip a wire loop into a sample of the solid compound being tested.

Step 2 – Place the loop into the flame of the Bunsen burner. Ensure that the Bunsen burner is set to a roaring blue flame.

Step 3 – Observe the colour of the flame produced and record it in a table.

Mixtures of ions may cause some flame colours to not be as clear.

Ion	Colour of the Flame
Li^+	 crimson
Na^+	 yellow
K^+	 lilac
Ca^{2+}	 orange-red
Cu^{2+}	 green

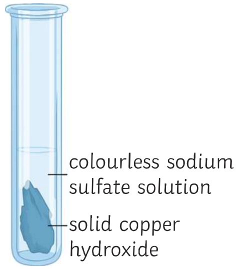
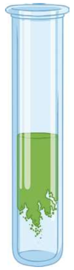
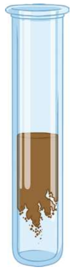
Metal Hydroxides

In order to identify metal ions, **sodium hydroxide solution** is added. Solutions of calcium, magnesium and aluminium all form white precipitates. Only the aluminium hydroxide **precipitate** dissolves in excess sodium hydroxide. Iron (II), iron (III) and copper (II) all form coloured precipitates when sodium hydroxide solution is added.

magnesium sulfate + sodium hydroxide ⟶ magnesium hydroxide + sodium sulfate

$MgSO_4 + 2NaOH \longrightarrow Mg(OH)_2 + Na_2SO_4$

Ion	Colour of the Precipitate Produced
Al^{3+}	white 
Ca^{2+}	white 
Mg^{2+}	white 

Ion	Colour of the Precipitate Produced
Cu^{2+}	blue 
Fe^{2+}	green 
Fe^{3+}	brown 

Ionic Equations

An ionic equation can be used to represent each of the **precipitation** reactions. These equations only show the ions that are involved in the precipitation reaction. The equations do not show the sodium or sulfate ions. This is because these ions are called spectator ions. **Spectator ions** are ions that do not take part in the chemical reaction.

Copper (II)

$Cu^{2+} + 2OH^- \longrightarrow Cu(OH)_2$

Copper has **lost** two **negative charges**, hence why copper is Cu^{2+}. In order to balance out this loss of charges, the copper ion **must gain** two negative charges. These negative charges come in the form of **two OH^- ions**.

Iron (III)

$Fe^{3+} + 3OH^-$ $Fe(OH)_3$

Iron (III) has **lost** three **negative charges**, hence why iron is Fe^{3+}. In order to balance out the loss of charges, the iron ion **must gain** three negative charges. These negative charges come in the form of **three OH^- ions**.

Testing for Carbonate Ions (CO_3^{2-}) Chemistry Only

Place a small volume of limewater into a test tube. In a separate test tube, add a small sample of the **carbonate** and add a few drops of **hydrochloric acid** (acids are a source of H^+ ions) using a pipette. Seal the test tube with a bung connected to a delivery tube; the delivery tube should be placed in the test tube containing the limewater. Bubbles of **carbon dioxide** gas will be produced. The **limewater will turn a milky colour** indicating a positive test for carbon dioxide.

$CO_3^{2-} + 2H^+ \longrightarrow CO_2 + H_2O$

Testing for Sulfate Ions (SO_4^{2-})

Using a pipette, add a few drops of **barium chloride** solution to the sample followed by a few drops of **hydrochloric acid**. A positive result for sulfate ions will produce a white precipitate.

$SO_4^{2-} + Ba^{2+} \longrightarrow BaSO_4$

Testing for Halide Ions (I^-, Br^-, Cl^-)

Using a pipette, add a few drops of dilute **nitric acid** to the sample followed by a few drops of **silver nitrate solution**. Leave it to stand and **observe the colour** of the **precipitate formed**.

Each halide ion produces a different coloured precipitate.

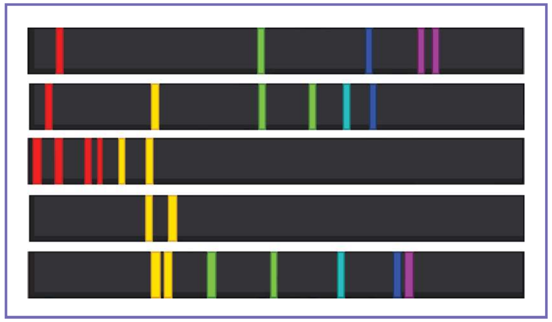
- **Chloride** produces a **white** precipitate.
- **Bromide** ions produce a **cream** precipitate.
- **Iodide** ions produce a **yellow** precipitate.

Flame Emission Spectroscopy

Flame emission spectroscopy is an instrumental method of analysis. The benefits of instrumental methods of analysis are that it is **rapid, accurate and sensitive**. The drawbacks to such methods are that the equipment is often **expensive** and **requires special training** to use.

Flame emission spectroscopy is a technique that is used to **identify** metal ions in solution. The samples that are tested normally include biological fluids and tissues.

How It Works



Step 1 – A sample is heated in a flame.

Step 2 – Electrons in the metal ions are excited by the thermal energy provided from the flame. As a result, the electrons move into a higher energy level.

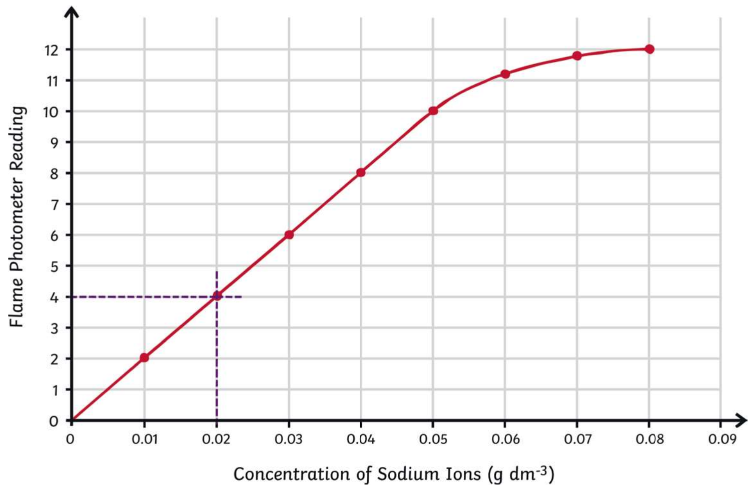
Step 3 – When the electrons fall back into a lower energy level, they release energy in the form of light.

Step 4 – The emitted wavelengths of light are analysed instrumentally.

Step 5 – To identify the metal present, its spectrum is compared with reference spectra from known metal ions.

Above is an example of the spectra produced by flame emission spectroscopy. It looks like a colourful array of lines. **Each metal ion produces a unique emission spectrum**.

Calibration Curve



The readings for different concentrations of metal ions in solutions are taken. These readings are then used to plot a calibration curve.

AQA GCSE Chemistry (Separate Science) Unit 9: Chemistry of the Atmosphere

The Early Atmosphere

Approximately **4.6 billion years ago** the Earth was formed. Scientists have lots of ideas and **theories** about how the atmosphere was produced and the gases within it, but due to the lack of evidence, they cannot be sure.

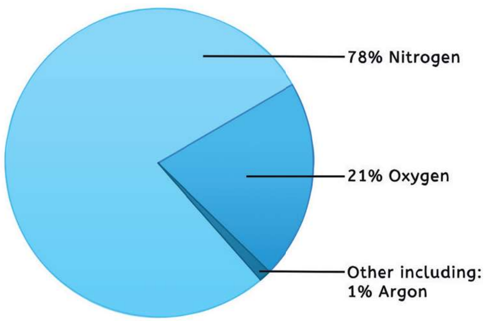
One theory suggested that **intense volcanic activity** released gases that made **Earth's early atmosphere** very similar to that of Mars and Venus. These planet's atmospheres mainly consist of carbon dioxide with little oxygen.

Nitrogen gas would have also been released from volcanoes and would have built up in the atmosphere.

Water vapour in Earth's early atmosphere would have **condensed** to create the **seas and oceans**. Carbon dioxide would have dissolved into the water, decreasing the level in the atmosphere.

Percentage of Gases in the Atmosphere

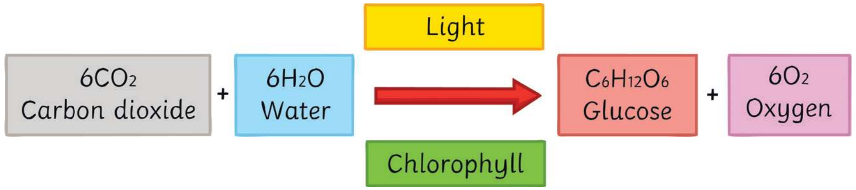
The pie chart below shows the abundance of each gas in our atmosphere.



How Did the Levels of Oxygen Increase?

2.7 billion years ago, algae first produced oxygen. Gradually over time, the levels of oxygen in our atmosphere increased as plants evolved. This was followed by animals as the levels of oxygen increased to a level that would sustain more complex life.

Oxygen is produced by plants in the process of **photosynthesis**.



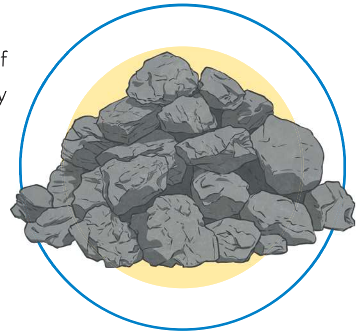
How Did the Levels of Carbon Dioxide Decrease?

Carbon dioxide **dissolves** in water. As water vapour condensed and the oceans and seas formed, the carbon dioxide gas dissolved producing **carbonate compounds**. This process reduced the amount of carbon dioxide in the atmosphere. Carbonate compounds were then **precipitated**: limestone is an example of a sedimentary rock; it has the chemical name calcium carbonate.

Plants in the oceans absorbed **carbon dioxide** gas for **photosynthesis**. The organisms from the food chains that the plants supported were turned into fossil fuels. **Fossil fuels** are **non-renewable** and consist of **coal, crude oil, and gas**, all of which contain carbon.

Crude oil was formed millions of years ago. When aquatic plants and animals died, they fell to the bottom of the sea and got trapped under layers of sand and mud. Over time, the organisms got buried deeper below the surface. The **heat and pressure** rose, turning the remains of the organisms into crude oil or natural gas. Oxidation did not occur due to the lack of oxygen.

Coal is a fossil fuel formed from **giant plants** that lived hundreds of millions of years ago in swamp-like forests. When these plants died, they sank to the bottom of the swamp where dirt and water began to pile on top of them. Over time, pressure and heat increased and the plant remains underwent chemical and physical changes. The oxygen was pushed out and all that remained was coal.



The Human Impact and the Greenhouse Effect

Scientists believe that human activities have resulted in the **increased** amount of greenhouse gases in the atmosphere. Activities such as **farming cattle** and **farming rice** release huge amounts of **methane** into the atmosphere.

Burning **fossil fuels** in cars and power stations releases large amounts of **carbon dioxide**. With large areas of the rainforest being cut down through **deforestation**, the excess carbon dioxide is not being absorbed by photosynthesis.

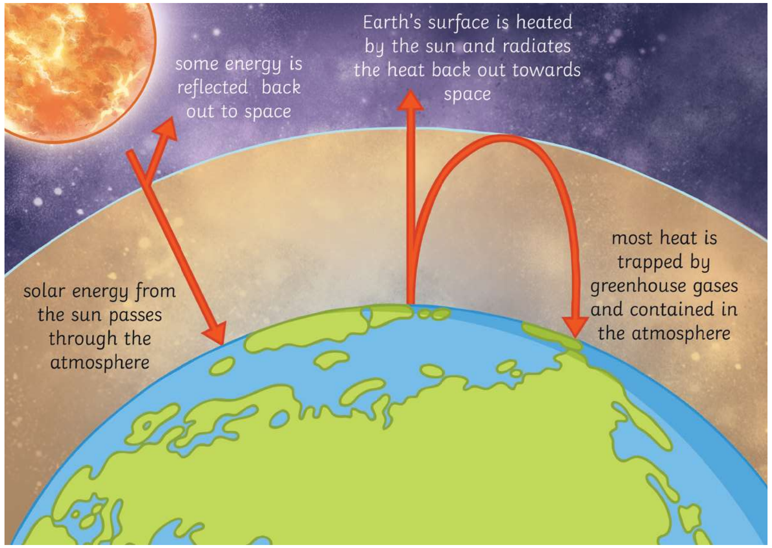
However, not everyone believes that humans are causing the rise in greenhouse gases. Some believe that the rise in global temperatures is associated with cycles of climate change and natural factors.

Climate science is often complicated as there are **difficulties** associated with **predicting future global temperatures**. The media present information that can be biased, inaccurate or lacks substantial evidence.

After reading an article on global warming, consider the trustworthiness of the source by considering these factors:

- Is the research done by an expert in that field and do they have the right skills and qualifications to report on the issue?
- Which organisation is reporting the evidence? If it is a newspaper, some stories are sensationalised in order to sell papers.
- Was the research funded by a legitimate organisation and was it conducted in a non-biased way? Think about the methods that were used to obtain the data and the impact the collection and analysis of this data had on the overall result.

The Greenhouse Effect



A greenhouse is a house made of glass and is commonly used by gardeners to help grow plants and keep them warm. As the sun shines through the greenhouse, the air is heated up and becomes trapped by the glass and is prevented from escaping. During daylight, a greenhouse stays quite warm and this lasts into the night.

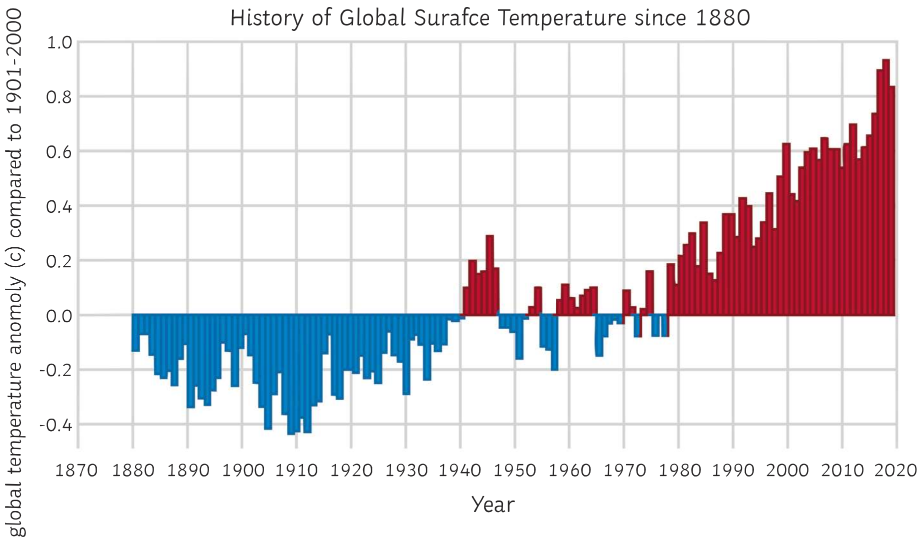
The earth and its atmosphere are very similar to that of a greenhouse. The greenhouse gases in the atmosphere trap the heat and keep the earth warm. The main greenhouse gases are **carbon dioxide**, **water vapour and methane**. During the daylight, the sun warms up the earth's surface. During the night, as the earth begins to cool and release the heat back into the atmosphere, some of the heat is trapped by the greenhouse gases in the atmosphere.

If the **greenhouse effect** becomes too **strong**, the earth will get too warm and melt the Arctic ice. As we burn more fossil fuels, the levels of **carbon dioxide** and the other greenhouse gases **increase** in our atmosphere which makes the greenhouse effect stronger.

What is the Difference Between Climate Change and Global Warming?

Since the Earth was formed over 4.6 billion years ago, its climate has constantly been changing with several ice ages followed by warmer temperatures. Changes in the Sun's energy reaching the Earth and volcanic eruptions were responsible for the changes until about 200 years ago.

Global warming is different to climate change and is used to explain how the earth's climate has warmed up over the past 200 years. Scientists believe that the warming of the climate is due to the activities of humans.

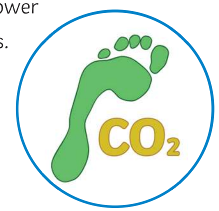


Carbon Footprint

The carbon footprint is the total amount of **carbon dioxide** and other greenhouse gases emitted over the full life cycle of a product, service or event.

An individual's carbon footprint is a calculation of all the activities that that person has taken part in throughout the year.

These activities might involve flying abroad or **travelling** by bus or rail. Each of which might be powered by petrol or diesel. **Heating a home** in winter by using a gas-powered boiler and using electricity to power lights and electronic devices. **Food** also has a **carbon footprint**, for example, beef and rice produces huge amounts of methane when farmed.



Nitrogen

Nitrogen and oxygen react together to make oxides of nitrogen. This occurs inside a **car engine** where there is a high temperature and pressure. Many compounds can be formed when nitrogen reacts with oxygen. The two that are formed inside a car engine are NO and NO_2.

Nitrogen compounds are grouped together with the general formula NO_x. Nitrogen compounds, along with sulfur dioxide, are also responsible for acid rain.

Compounds of nitrogen oxides react in the atmosphere with ultraviolet light from the sun to produce **photochemical smog**. The smog is most noticeable during the morning and afternoon and occurs mainly in densely populated cities.

The presence of smog can have a **major impact on human health**, particularly to those who suffer with **asthma**.

Combustion

Complete combustion occurs when there is **enough oxygen** for a fuel to burn. A hydrocarbon will react with oxygen to produce carbon dioxide and water.

propane + oxygen ⟶ carbon dioxide + water

$C_3H_8 + \mathbf{5}O_2 \longrightarrow \mathbf{3}CO_2 + \mathbf{4}H_2O$

Incomplete combustion occurs when there **isn't enough oxygen** for a fuel to burn. The products in this reaction are water and poisonous **carbon monoxide**. Carbon particles (soot) may also be seen.

ethane + oxygen ⟶ carbon monoxide + water

$\mathbf{2}C_2H_6 + \mathbf{5}O_2 \longrightarrow \mathbf{4}CO + \mathbf{6}H_2O$

Carbon monoxide is a poisonous gas. It is often called the **silent killer** due to it being colourless and odourless. Carbon monoxide works by binding to the **haemoglobin** in your red blood cells. This prevents them from carrying oxygen to the cells around your body. Carbon monoxide detectors are used to detect levels of the gas in the surrounding air and are often placed near gas-powered boilers to detect gas leaks.

Particulate carbon irritates the lining of the lungs making asthma worse and could cause cancer. **Global dimming** is caused by particulates of carbon blocking out the Sun's rays and may reduce rainfall.

Sulfur Dioxide

Sulfur dioxide is an **atmospheric pollutant**. It is a gas that is produced from the burning of **fossil fuels**. Sulfur dioxide is able to dissolve in rainwater and produces **acid rain**. Acid rain causes damage to forests, kills plants and animals that live in aquatic environments, and damages buildings and statues as the acid rain erodes the stone that they are made from.

sulfur + oxygen ⟶ sulfur dioxide

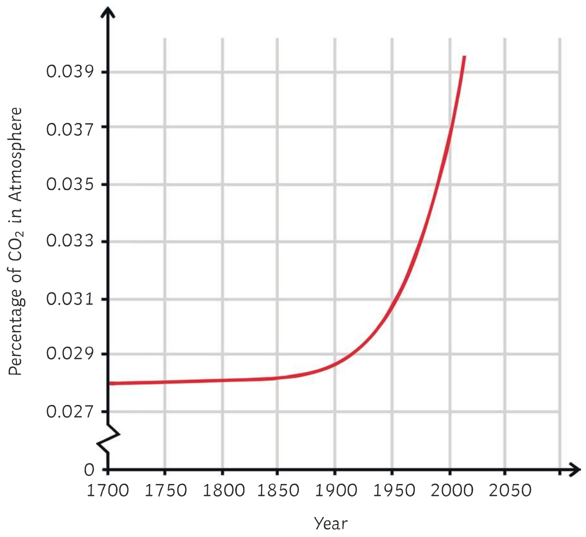
$S + O_2 \longrightarrow SO_2$

Sulfur dioxide can be further oxidised to form sulfur trioxide.

What is the Link Between Carbon Dioxide and Global Warming?

There is a strong correlation between the percentage concentration of carbon dioxide in the atmosphere and increased global temperatures.

The impact of this is that the polar ice caps are melting, sea levels are rising and habitats and rainfall patterns are changing. The impact of which is already being felt around the globe. The consequences of human activity will affect us all.



Sustaining Human Life on Earth

The human **population** is **increasing** rapidly and our use of earth's finite resources has increased. If humans continue to use these resources at the rate at which we are, then we will reach a point where the human population cannot be sustained on earth.

Humans use the **earth's natural resources** for warmth, shelter, food, clothing and transport. Scientists are making **technological advances** in **agricultural** and **industrial processes** to provide food and other products that meet the growing needs of the human population but it is of major importance that this is done in a sustainable way so that our finite resources are not used up.

Earth's Resources

Finite resources are those of which there is a **limited supply**, for example coal, oil and gas. These resources can be used to provide energy but, one day, their supply will run out.

Crude oil is processed through **fractional distillation** and **cracking** to produce many useful materials such as petrol, diesel and kerosene.

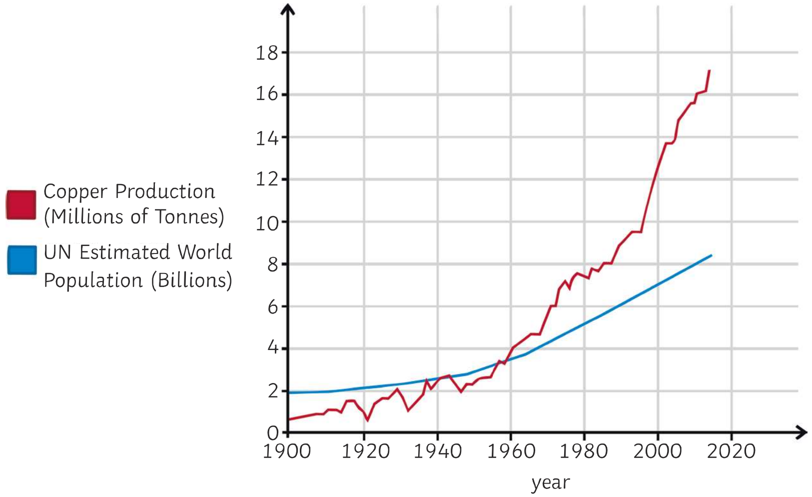
Renewable resources will not run out in the near future because the reserves of these resources are high. Examples of renewable resources include solar energy, wind power, hydropower and geothermal energy.

Haber Process and Copper

Scientists often discover new ways to produce a product; **synthetic methods** of production replace **natural methods**. For example, fertilisers were obtained from manure (a natural resource).

The **Haber process** allowed the synthetic production of **fertilisers** and this enabled **intensive farming** methods to spread across the globe. In turn, this supported the growing human population.

Copper is another resource that has been exploited over time. As the human population has increased since 1900, the demand for copper has also increased. Copper is a finite resource which means that there is a limited supply.



Water

Potable water is water that is **safe to drink**. Potable water is **not pure; dissolved impurities** still **remain** in the water. Pure water is odourless, tasteless and colourless compared to rainfall or water from streams and wells as these **harbour chemicals** such as acid.

Pure – the **definition** of a pure substance is one that contains only a single type of material that has not been contaminated by another substance.

Potable water must contain **low levels** of microbes and salts for it to be deemed safe to consume. This is because **high levels** of microbes and salts can be harmful to human health.

The methods of making water safe vary depending on where you live. Starting with sea water is harder than starting with fresh water. This is because the **energy cost** of removing large amounts of sodium chloride from seawater is greater.

In the UK, our populations' water needs are met through **rainfall**. During the **summer, water levels** in reservoirs **decrease** and local areas are encouraged to reduce their water usage by swapping baths for showers and they are asked to avoid using hosepipes.

In the UK, **insoluble particles** are **removed** from naturally occurring fresh water by passing it through **filter beds**. **Microbes** are **killed** by **sterilising the water**. Several different sterilising agents are used for potable water. These are chlorine, ozone or ultraviolet light. The right amount of chlorine and ozone gas (O_3) must be used as both are harmful to human health.

Desalination of Sea Water

If fresh water supplies are limited, sea water can undergo a process called **desalination**. This process requires **large amounts of energy**, but can be done by distillation or the use of membranes such as **reverse osmosis**.

Distillation involves **heating** the sea water until it reaches **boiling point**. Once the water is boiling, it will begin to **evaporate**. The steam then rises up where it cools and condenses in a condensing tube. The salt is left behind. The **downside** to this process is the **energy cost** of boiling the water and cooling down the steam sufficiently in the condensing tube. Not all of the water evaporates which leaves behind a **salty wastewater** that can be **difficult to sustainably dispose of** without harming aquatic organisms.

Reverse Osmosis of Salt Water

Osmosis, as you will have learnt in biology, is the **movement of particles** from an area of **high** concentration **to** an area of **low** concentration through a **semi-permeable membrane**.

Reverse osmosis involves **forcing water** through a **membrane** at **high pressure**. Each membrane has tiny holes within it that only allow water molecules to pass through. Ions and other molecules are prevented from passing through the membrane as they are too large to fit through the holes.

The **disadvantage** of this method is that it produces **large amounts of wastewater** and requires the use of **expensive membranes**. Due to a large amount of wastewater produced, the efficiency of this method is very small.

Water Treatment

Before the **wastewater** from industry, agriculture and peoples' homes can be released back into the environment, it must be **treated**.

Pollutants such as human waste contain **high levels of harmful bacteria** and **nitrogen compounds** which can be a **danger to aquatic organisms**.

Industrial and agricultural waste may contain **high levels** of **toxic metal compounds** and **fertilisers and pesticides** which may also damage the ecosystem.

Cleaning sewage requires several steps:

Step 1 – The water must be **screened**. This is where material such as branches, twigs and grit is removed.

Step 2 – The water undergoes **sedimentation**; wastewater is placed in a settlement tank. The heavier solids sink to the bottom and form a sludge whilst the lighter effluent floats on the surface above the sludge.

Step 3 - The effluent is then transferred to another tank where the organic matter undergoes **aerobic digestion**. Although not pure, this water can be safely released back into the environment. The sludge is placed in another tank where the organic matter undergoes **anaerobic digestion**. It is broken down to produce fertiliser and methane gas which can be used as an energy resource (fuel).

Required Practical 8 – Analysis and Purification of Water Samples from Different Sources

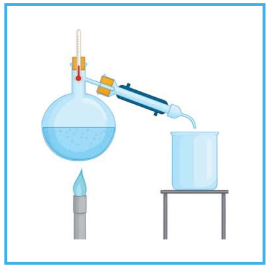
Analysing the pH of Water Samples

Test the pH of each water sample using a pH meter or universal indicator. If using universal indicator, use a pH colour chart so that you are able to identify the pH of the sample against the colour produced by the indicator.

Analysing the Mass of Dissolved Solids

To measure the mass of dissolved solids in a water sample, measure out $50cm^3$ of the sample using a measuring cylinder. Take the mass of an evaporating basin before heating and record the mass in a table. Place the measured amount of water into an evaporating basin and gently heat over a Bunsen burner until all the liquid has evaporated. Once the evaporating basin has cooled, place it on a top pan balance and record its mass. Calculate the mass of the solid left behind.

Distillation of the Water Sample



To distil a water sample, set up your equipment as per the diagram.

Heat the water sample gently using a Bunsen burner. After a short period of time, distilled water should be produced.

Life-Cycle Assessment (LCA)

Life-Cycle Assessments follow the four main stages of the life cycle of a product.

Stage 1 – Extracting the raw materials needed to make the products and then processing them.

At this stage, the energy and environmental costs need to be considered. For example, if the raw material being used is a finite or renewable resource, the energy to extract and transport the raw material should be considered. Environmental factors also play a large part in stage 1 as the extraction of the raw material can leave scars on the landscape and waste products may be produced that could damage local ecosystems.

Life-Cycle Assessment (LCA) (continued)

Stage 2 – Manufacturing and packaging of the product.

The main consideration is how much energy and resources are needed to manufacture the product. Energy may be used in the form of fuel, electricity or chemicals used in the production of the product. In the manufacturing process, there may be pollution and waste products that need to be considered. Transportation of the goods from the factory to the user will have an environmental impact.

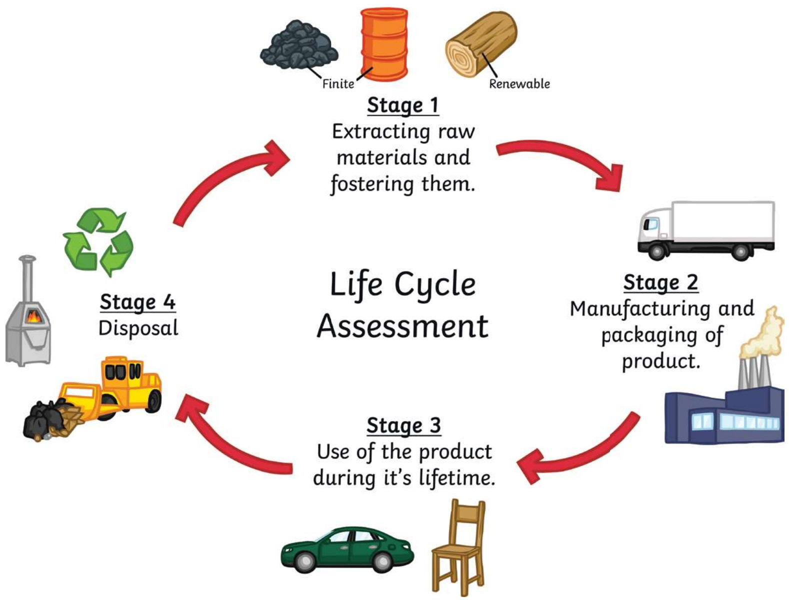
Stage 3 – Use of the product during its lifetime.

The environmental impact of a product during its life depends on the type of product. For example, a car will have a significant impact i.e. it needs to be filled with petrol or diesel, a finite resource, to get to where you are going. A car's engine releases harmful emissions into the atmosphere. On the other hand, a wooden chair may only need minor repairs and is made from a renewable resource.

Stage 4 – Disposal at the end of a product's life.

There are different methods of disposal:

1. Landfill – the product is put in a hole in the ground – high environmental impact.
2. Incineration (organic matter) – burning of the product – low environmental impact.
3. Recycling – for example, batteries contain metal compounds that are not good for the environment. By recycling, it means that no new compounds have to be taken out of the ground.



Comparative LCAs

Comparative LCAs are used to evaluate products and to find which one will have a lower environmental impact.

Stage of Life Cycle	Plastic Bag	Paper Bag
Stage 1 – raw material	Uses a finite resource (crude oil). The processes of fractional distillation, cracking and polymerisation all require energy to make crude oil useful.	Made from trees/recycled paper. Making paper from trees requires more energy than recycled paper because trees have to be chopped down. Still uses less energy than making plastics from crude oil.
Stage 2 – manufacture	Cheap to make.	More expensive to make.
Stage 3 – use	Plastic bags have a low environmental impact as they can be used a number of times. In comparison to paper bags, they are much stronger.	Paper bags can only be reused a limited number of times and so have a short lifetime.
Stage 4 – disposal	The downside to plastic bags is that they do not biodegrade easily in landfill. Recycling options are available. If they are not disposed of correctly, plastic bags can have a detrimental impact on the environment and animal habitats.	Paper bags biodegrade easily in landfill sites.

Disadvantages of Comparative LCAs

The disadvantage of **comparative LCAs** is that some parts of it require certain judgements to be made.

Different people have different opinions and this is dependent on who completes the LCA and whether a certain level of bias is added. For example, if the LCA is completed by a company that is manufacturing a specific product, they may only discuss **some** of the environmental impact of their product in the LCA. Accurate numerical values, for example, show a company how much energy has been used in the **manufacturing process** or how much **carbon dioxide** was produced when the goods were transported.

Recycling

Many materials are made from **natural resources** that have **limited supplies**. Reusing items such as glass bottles that only need washing and sterilising saves energy and reduces the environmental impact. Not all products can be reused, some need to be recycled before reuse.

There are both advantages and disadvantages to recycling materials.

Advantages

- Fewer resources such as **mines** and **quarries** are needed to remove raw, finite materials from the ground. For example, copper.
- Crude oil, the raw material used in the production of plastics, does not need to be extracted. This, in turn, **avoids** high energy cost processes such as fractional distillation and cracking. If more items are recycled, less would end up in landfill sites.
- The amount of greenhouse gases would reduce as the energy cost of recycling is a lot **less** than making a new product.

Disadvantages

- Recycling items require collection and transport of the goods to the organisation. This involves using staff, vehicles and the use of fuel.
- Some materials, such as **metals**, can be **difficult to sort**; the amount of sorting is dependent on the purity of the materials or metals and the level of purity required for the final product. For example, copper used in electrical appliances must have a high purity. To achieve this, the copper needs to be processed and then melted down again to make copper wiring.
- Steel that is used in the construction industry does not require such high purity. Often scrap iron is added to the furnace when steel is made. This reduces the need for as much iron ore and reduces the cost of making steel.

Biological Extraction Methods (Higher Tier Only)

Biological methods of extraction are needed as the resources of **metal ores** on earth are in **short supply**. Large scale **copper mining** leaves **scars on the landscape** and produces significant amounts of waste rock that must be disposed of. Biological methods have a lower impact on the environment and make use of waste containing small amounts of copper. The disadvantages of **biological extraction methods** are that they are **slow**, but they do reduce the need to obtain new ore through mining and conserve limited supplies of high-grade ore.

Phytomining

Phytomining involves the use of **plants**. Plants absorb the metal compounds found in the soil. The plants cannot get rid of the copper ions and it builds up in the leaves. The plants are then **harvested, dried** and then placed in a furnace. The ash that is produced from the burning process contains soluble metal compounds that can be extracted. The ash is dissolved in an acid such as hydrochloric or sulfuric and the copper is then extracted by electrolysis or through a **displacement reaction** with iron.

Bioleaching

Bioleaching uses **bacteria** to produce an acidic solution called **leachate** which contains **copper ions**. The disadvantage of bioleaching is that it produces **toxic substances** that are **harmful to the environment**. To process the copper, the copper undergoes a displacement reaction with iron. Iron is cheaper and a **more cost-effective** way of producing copper from the leachate.

Corrosion

Metals can corrode when **exposed** to **oxygen**; they oxidise and can form metal oxides. Some metals oxidise more quickly than others, like sodium, and some such as gold are very unreactive and do not oxidise at all.

Corrosion occurs when a metal continues to oxidise and the metal becomes weaker over time until it eventually becomes a metal oxide.

Rusting occurs when **iron or steel** reacts with **oxygen** in the **air or water**. Rusting is an example of corrosion.

iron + oxygen + water ⟶ hydrated iron(III) oxide

$4Fe + 3O_2 + 6H_2O \longrightarrow 4Fe(OH)_3$

How Can Rusting Be Prevented?

To prevent rusting, oxygen and water must be kept away from the iron or steel.

Storing the metal in an atmosphere containing unreactive argon prevents it from reacting with oxygen.

A substance such as calcium chloride can be used to absorb water vapour and keep the metal dry.

Barriers to Prevent Rusting

There are several different methods that are used to prevent rusting.

1. painting
2. coating with plastic
3. oiling and greasing

Electroplating

To improve the appearance of metal or to prevent corrosion, a thin layer of a metal can be applied to an object using electrolysis. This process is called **electroplating**.

In electrolysis, there are two electrodes – the **positive anode** (plating metal) and the **negative cathode** (the iron or steel object). The **electrolyte** is the solution that contains the metal ions needed to plate the metal. For example, cutlery made of steel can be electroplated with silver.

Sacrificial Protection

Metals such as iron can be **prevented** from rusting if they are put into contact with **more reactive metals** such as zinc. The reactive metals will react more readily with oxygen whilst iron does not corrode.

We say that the more reactive metal has **'sacrificed'** itself. Once the more reactive metal has corroded away, it can simply be replaced.

Galvanising

Galvanisation is the process of coating iron with zinc. The purpose is to **prevent** oxygen and water reacting with iron and so prevents **rusting**. Zinc acts as a **sacrificial** metal.

Alloys

Name of Alloy	Component Metals	Uses
bronze	copper and tin	bells coins statues
brass	copper and zinc	locks taps instruments door hinges door knobs
gold	Alloyed with other metals such as silver, zinc and copper.	jewellery

Steel Alloys

Steel is an **alloy** made up of **iron** mixed with certain amounts of **carbon**. Different steels have different properties and this determines their use.

- **High-carbon steel** contains a **high proportion of carbon**. This type of steel is **strong and brittle** and is used in the construction industry.
- **Low-carbon steel** contains a **low proportion of carbon** and is softer and more **easily shaped**. This makes it useful for making car body panels.
- **Stainless steel** is made up of **iron** but also the elements **chromium** and **nickel**. It is used for making **cutlery** as it does not rust.

Glass

Glass is made by **melting** a mixture of **sand** (silicon dioxide), **limestone** and **sodium carbonate**. Once it has melted, the molten liquid then cools and solidifies. Glass made with this mixture of ingredients is called soda-lime glass. **Soda-lime glass** is used for window panes, glass jars and bottles.

Glassware that is used in **baking** and in the **laboratory** contains boron trioxide. **Borosilicate glass** has a **higher melting point** than soda-lime glass which makes it better suited to its function where high temperatures are often used.

Ceramics

Ceramics made from **clay** include china, porcelain and brick. Wet clay is shaped and then placed into a furnace where it is heated to a **high temperature**. Crystals form in the clay and join it together.

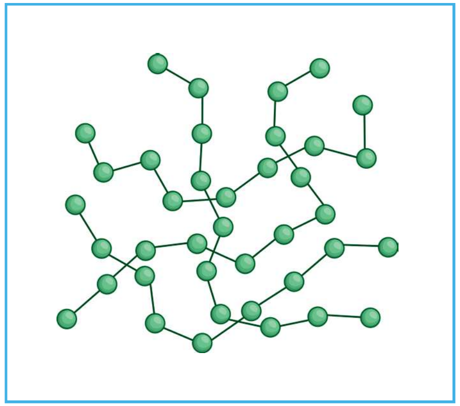
Dinner plates and bowls are made from clay ceramics. Once taken out of the furnace, the ceramics are allowed to cool and are coated with a glaze. This glaze hardens over time and forms a waterproof layer.

Polymers

Polymer properties are dependent upon the **monomer** that it is made from and the conditions in which it was made. For this reason, different polymers have different jobs. For example, **low-density** (LD) and **high-density** (HD) poly(ethene) are made from the monomer ethene using different catalysts and reaction conditions. Low-density poly(ethene) LDPE is flexible and is commonly used in carrier bags and bubble wrap. High-density poly(ethene) HDPE is much stronger, flexible, resists shattering and chemical attack. It is commonly used in plastic bottles, pipes and buckets.

Thermosetting and Thermosoftening Plastics

The polymer chains in **thermosetting plastics** are held together by strong **covalent bonds**. This means that plastics in this group can withstand **higher temperatures** and do not melt when heated – they have **high melting points**. Thermosetting plastics are used to make electrical plugs. Even if there is a fault and the wiring becomes hot, the plastic casing will not melt.



Composite Materials

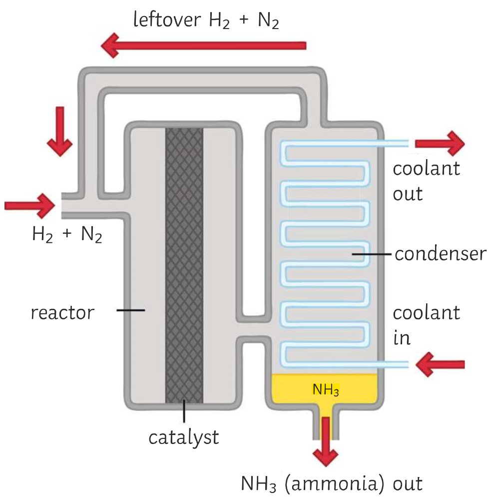
Composites are made up of two materials: a **reinforcement** and a **matrix** which binds the reinforcement together.

Wood is a natural composite. The matrix is **lignin** which is a material that can be found lining the xylem vessels of plants. Wood is reinforced with **cellulose**; in wood, the cellulose fibres are lined up next to each other and this makes the wood stronger in one direction than another. **Chipboard** is a material that can be used for kitchen worktops and doors. Chipboard is made up of **wood chips** (reinforcement) that is randomly arranged and held together by **resin glue** (matrix). This makes it **strong in all directions**.

Fibreglass and carbon fibre reinforced polymer (CFRP) contain fibres that are strong under tension. Fibreglass contains glass fibres and CRFP contains **carbon fibres**, both of the fibre types are used as **reinforcement**. The fibres themselves are flexible but do not easily stretch. The fibres in each of these composite materials are held together by **polymer resin** (matrix) which helps to bind the fibres together making them stiff.

Concrete is such a versatile material and is often used in the construction industry. The strength of concrete can be increased by **reinforcing** it with other materials such as **wire mesh or steel rods**. The compressive strength of **concrete** (matrix) is greater than its tensile strength. This means that it can withstand more force from crushing than it can force under tension. **Steel** (reinforcement), on the other hand, has greater tensile strength. This means that by combining the two materials, one is created that is both strong under tension and strong under compression. This makes reinforced concrete an important material in the construction of large buildings.

Haber Process



The Haber process is used by the chemical industry to synthesise **ammonia**. Ammonia is used in the production of fertilisers, dyes and explosives.

The reaction is a **reversible** one and involves nitrogen reacting with hydrogen to produce ammonia. As the reaction is reversible, some of the ammonia will decompose back into nitrogen and hydrogen.

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

The reaction mixture is cooled, the ammonia liquifies and is then removed. The hydrogen and nitrogen that has not reacted is recycled to increase the efficiency of the process. The reaction reaches **dynamic equilibrium** and this is where the rate of the forward reaction occurs at the same rate as the backward reaction.

In the Haber process, nitrogen and hydrogen are pumped through pipes at a pressure of **200 atmospheres**.

Nitrogen is obtained by extraction from the air and hydrogen is obtained from natural gas. The gases are passed through a tank containing a **catalyst** (iron); catalysts speed up the rate of a chemical reaction without getting used up themselves. The gases are heated to **450˚C** as they pass through the tank.

The reaction mixture is allowed to cool and this allows the ammonia to turn from a gas to a liquid. Once this has happened, the ammonia is removed. Any unreacted nitrogen and hydrogen is then recycled.

Fertilisers

Fertilisers contain lots of **mineral ions** that are key to the growth of healthy crops. Plants absorb these minerals through their root hair cells; these mineral ions need to be replaced and so farmers need to add fertiliser to the soil in order to replace the lost mineral ions.

Farmers often use **NPK fertilisers**. These are fertilisers that contain the elements **nitrogen, phosphorus and potassium**.

- Ammonium nitrate - NH_4NO_3 - and ammonium sulfate - $(NH_4)_2SO_4$ - are examples of fertilisers that contain the essential element nitrogen.
- Ammonium phosphate - $(NH_4)_3PO_4$ - contains the elements nitrogen and phosphorus.
- Potassium nitrate - KNO_3 - contains the elements potassium and nitrogen.

Ammonia

Ammonia has the chemical formula NH_3.

Ammonia produces the ammonium ion NH^{4+} when it is involved in neutralisation reactions. Ammonia is an alkali. Oxidation of ammonia produces nitric acid HNO_3; nitric acid is the source of the nitrate ion NO^{3-}.

alkali + acid ⟶ salt

ammonia + nitric acid ⟶ ammonium nitrate

$NH_3 + HNO_3 \longrightarrow NH_4NO_3$

In aqueous solutions:

ammonium hydroxide + nitric acid ⟶ ammonium nitrate + water

$NH_4OH + HNO_3 \longrightarrow NH_4NO_3 + H_2O$

Mining

The raw materials for fertilisers need to be mined. The minerals needed to make fertilisers are extracted from the **earth's crust**.

Potassium chloride and **potassium sulfate** are a source of potassium ions and are used as fertilisers. **Phosphate rock** is **insoluble** and so cannot be used in fertilisers, but it does contain **phosphorus** which when reacted with acid, will produce **soluble compounds**.

Phosphate rock when reacted with **nitric acid** produces calcium nitrate and phosphoric acid.

Phosphate rock when reacted with **sulfuric acid** produces a mixture of calcium sulfate and calcium phosphate which is called single superphosphate.

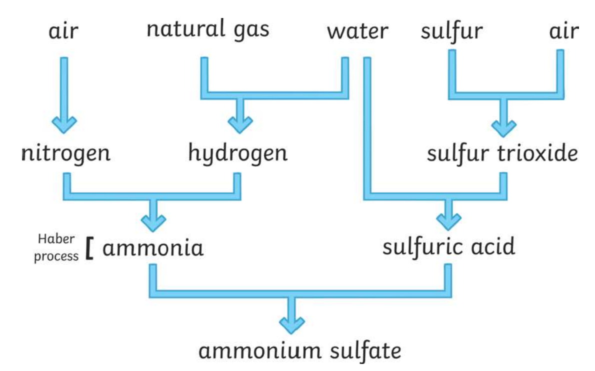
Phosphate rock when reacted with **phosphoric acid** produces calcium dihydrogen phosphate also called triple superphosphate.

Ammonium Sulfate

The salt ammonium sulfate ($(NH_4)_2SO_4$) is used as a fertiliser and is made when ammonia and sulfuric acid react.

ammonia + sulfuric acid ⟶ ammonium sulfate

$2NH_3 + H_2SO_4 \longrightarrow (NH_4)_2SO_4$



Chemical Industry

To make sulfuric acid, sulfur, air and water are needed.

Sulfur first reacts with oxygen to produce sulfur dioxide. The sulfur dioxide further reacts with oxygen at a temperature of 450˚C to produce sulfur trioxide. This in turn reacts with water to produce sulfuric acid.

In the Laboratory

Ammonium sulfate is produced by reacting ammonia solution with sulfuric acid.

Stage 1 – A measured amount of ammonium sulfate solution is poured into a conical flask.

Stage 2 – Two to three drops of the indicator methyl orange is added. The ammonia solution will turn yellow as it is an alkaline.

Stage 3 – The conical flask is placed under a burette containing sulfuric acid. Slowly the sulfuric acid is added to the flask until the indicator turns orange. If the indicator turns red, this means that too much acid has been added.

Stage 4 – Once the solution turns orange, the volume of acid that was added is recorded and the neutral ammonium sulfate solution containing the indicator is discarded.

Stage 5 – The experiment is then repeated with the same volumes of sulfuric acid and ammonia solution, but this time the indicator is not added. The solution is then heated and the water evaporates leaving behind crystals. The crystals left in the evaporating basin are then placed in an oven.

The Advantageous and Disadvantages of Industrial vs Laboratory Method of Fertiliser Production

Industrial Method

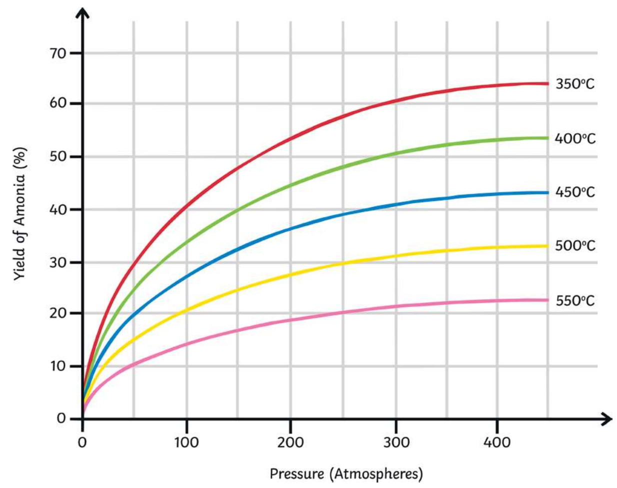
The industrial method of production requires a temperature range between 60-450°C, depending on the stage in the production process. As this is a **continuous method** of production, it requires the use of expensive machinery. The starting materials in this method are acquired from **raw materials** with **large quantities** of fertiliser being made **quickly**. The cost of labour is reduced by using **automated mechanisms** and machines.

Laboratory Method

The laboratory method, on the other hand, is much **slower** and more **labour intensive** and this makes the **running costs high**. The starting materials for this method are purchased directly from a chemical supplier. As this is a batch process, the **equipment** used is **relatively cheap**. A Bunsen burner is used for heating and room temperature is required for the neutralisation stage.

Haber Process – Higher Tier Only

The graph shows that as the temperature increases, the yield of ammonia decreases.



Increasing Temperature

As the temperature increases, the **equilibrium** position moves to the **left** and the **yield** of ammonia **decreases**. Using a low temperature may seem the most sensible option, but if the temperature is too low then the rate of reaction will also be reduced. That is why the temperature that is chosen is a **compromise** between the **yield** and **rate of reaction**.

Increasing Pressure

In a reaction where gas particles are reacting or produced, increasing the pressure will **shift** the **equilibrium** position to the side with the **fewest moles of gas**.

In the Haber process, the right-hand side of the equation has the fewest number of molecules; if the pressure is increased, then the equilibrium position will shift to the right and the yield of ammonia will increase. The disadvantage to using higher pressures are that more expensive equipment is required to cope with the increased pressure and this increases energy costs. The decision here is a **compromise** between **yield** and **cost**.

Catalysts

Catalysts are useful in the Haber process as they **speed** up the rate of reaction in both directions. The time taken for the system to reach **equilibrium** is reduced. A catalyst does not affect the position of the equilibrium or the yield. Using a catalyst allows a low temperature to be used whilst also keeping the yield high.

Reducing Cost

Any unreacted hydrogen and nitrogen are recycled back into the reactor and this reduces the cost of making raw materials. Energy is a large cost. Often, exothermic reactions where energy is released are used to heat up other parts of the process.