CHEMISTRY

PAPER 2 TOPICS

REVISION ORGANISER

Chapter 8: Rates and equilibrium 1

Knowledge organiser

Rates of reaction

The **rate of a reaction** is how quickly the reactants turn into the products.

To calculate the rate of a reaction, you can measure:

- how quickly a reactant is used up

$$\text{mean rate of reaction} = \frac{\text{quantity of reactant used}}{\text{time taken}}$$

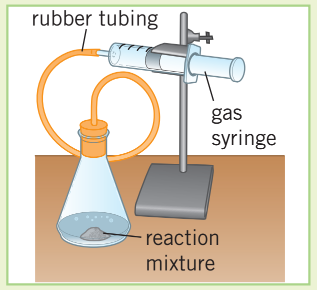
- how quickly a product is produced.

$$\text{mean rate of reaction} = \frac{\text{quantity of product formed}}{\text{time taken}}$$

For reactions that involve a gas, this can be done by measuring how the mass of the reaction changes or the volume of gas given off by the reaction.

Volume of gas produced

The reaction mixture is connected to a gas syringe or an upside down measuring cylinder. As the reaction proceeds the gas is collected.



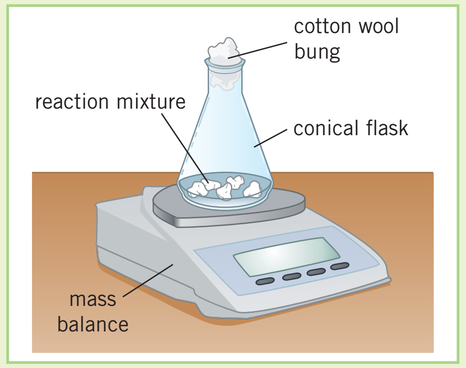
The rate for the reaction is then:

$$\text{rate} = \frac{\text{volume of gas produced}}{\text{time taken}}$$

Volume is measured in cm^3 and time in seconds, so the unit for rate is cm^3/s.

Change in mass

The reaction mixture is placed on a mass balance. As the reaction proceeds and the gaseous product is given off, the mass of the flask will decrease.



The rate for the reaction is then:

$$\text{rate} = \frac{\text{change in the mass}}{\text{time taken}}$$

The mass is measured in grams and time is measured in seconds. Therefore, the unit of rate is g/s.

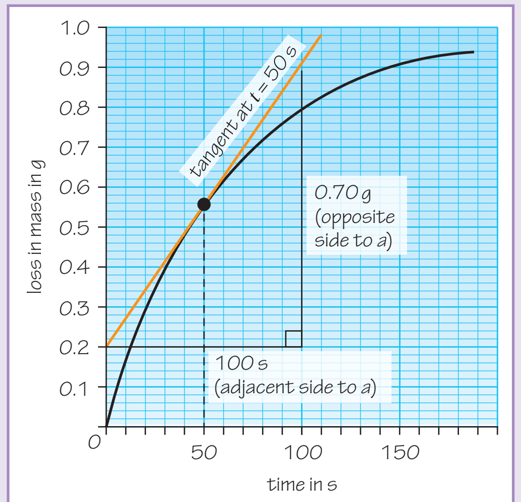
Calculating rate from graphs (HT only)

The results from an experiment can be plotted on a graph.

- A steep gradient means a high rate of reaction – the reaction happens quickly.
- A shallow gradient means a low rate of reaction – the reaction happens slowly.

Mean rate at specific time

To obtain the rate at a specific time draw a **tangent** to the graph and calculate its **gradient**.

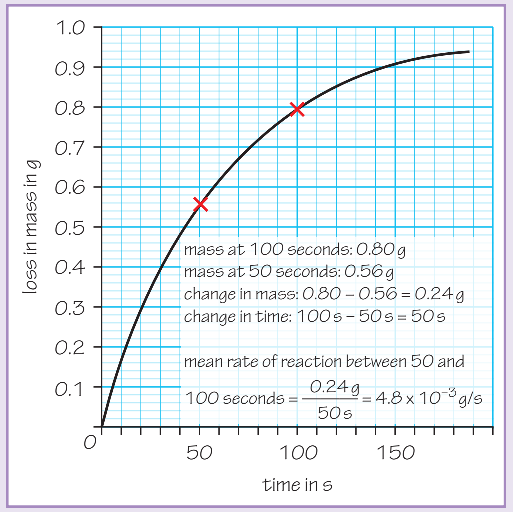


$$\text{Rate at 50 s} = \frac{0.70\text{ g}}{100\text{ s}} = 0.007\text{ g/s}$$

The gradient is the change in y divided by the change in x for a right-angled triangle drawn from the tangent.

Mean rate between two points in time

To get the mean rate of reaction between two points in time:



Collision theory

For a reaction to occur, the reactant particles need to collide. When the particles collide, they need to have enough energy to react or they will just bounce apart. This amount of energy is called the **activation energy**.

You can increase the rate of a reaction by:

- increasing the **frequency of collisions**
- increasing the energy of the particles when they collide.

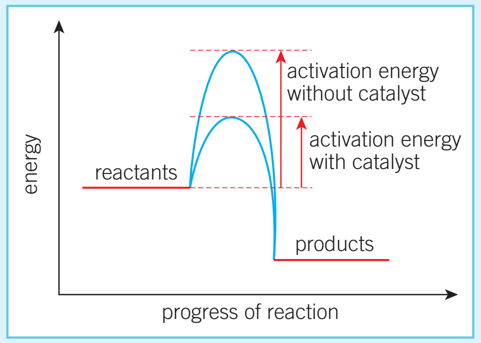
Factors affecting rate of reaction

Condition that increases rate	How is this condition caused?	Why it has that effect
increasing the temperature	Heat the container in which the reaction is taking place.	1 particles move faster, leading to more frequent collisions 2 particles have more energy, so more collisions result in a reaction note that these are two *separate* effects
increasing the concentration of solutions	Use a solution with more solute in the same volume of solvent.	there are more reactant particles in the reaction mixture, so collisions become more frequent
increasing the pressure of gases	Increase the number of gas particles you have in the container or make the container smaller.	less space between particles means more frequent collisions
increasing the surface area of solids	Cut the solid into smaller pieces, or grind it to create a powder, increasing the surface area. Larger pieces decrease the surface area.	only reactant particles on the surface of a solid are able to collide and react; the greater the surface area the more reactant particles are exposed, leading to more frequent collisions

Catalysts

Some reactions have specific substances called **catalysts** that can be added to increase the rate. These substances are not used up in the reaction.

A catalyst provides a different reaction pathway that has a lower activation energy. As such, more particles will collide with enough energy to react, so more collisions result in a reaction.



Chapter 8: Rates and equilibrium 2

Knowledge organiser

Reaction conditions

The conditions of a reaction refer to the external environment of the reaction. When the reaction occurs in a closed system, you can change the conditions by:

- changing the concentration of one of the substances
- changing the temperature of the entire reaction vessel
- changing the pressure inside the vessel.

Le Châtelier's principle (HT only)

At equilibrium, the amount of reactants and products is constant. In order to change the amounts of reactant and product at equilibrium the *conditions* of the reaction must be changed. The closed system will then counteract the change by favouring either the forward reaction or the reverse reaction. This is known as **Le Châtelier's principle**.

For example, lowering the concentration of the product in the system causes the forward reaction to be **favoured** to increase the concentration of the product.

Changing concentrations (HT only)

Change	Effect	Explanation
decrease concentration of product	favours the forward reaction	opposes the change by making *less* reactant and *more* product
increase concentration of product	favours the reverse reaction	opposes the change by making *more* reactant and *less* product
decrease concentration of reactant	favours the reverse reaction	opposes the change by making *more* reactant and *less* product
increase concentration of reactant	favours the forward reaction	opposes the change by making *less* reactant and *more* product

Changing temperature (HT only)

Change	Effect	Explanation
increase temperature of surroundings	favours the endothermic reaction	opposes the change by decreasing the temperature of the surroundings
decrease temperature of surroundings	favours the exothermic reaction	opposes the change by increasing the temperature of the surroundings

Changing pressure (HT only)

Change	Effect	Explanation
increase the pressure	favours the reaction that results in fewer molecules	decreasing the number of molecules within the vessel opposes the change because it decrease pressure
decrease the pressure	favours the direction that results in more molecules	increasing the number of molecules within the vessel opposes the change because it increase pressure

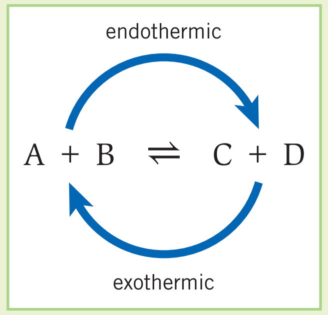
Key terms

Make sure you can write a definition for these key terms.

activation energy *catalyst* *collision* *collision theory* *closed system*
conditions *dynamic equilibrium* *frequency of collision* *gradient*
Le Châtelier's principle *rate of reaction* *reversible reaction* *tangent*

Reversible reactions

In some reactions, the products can react to produce the original reactants. This is called a **reversible reaction**. When writing chemical equations for reversible reactions, use the $\rightleftharpoons$ symbol.



In this reaction:

- A and B can react to form C and D – the forward reaction
- C and D can react to form A and B – the reverse reaction.

The different directions of the reaction have opposite energy changes.

If the forward reaction is *endothermic*, the reverse reaction will be *exothermic*.

The same amount of energy is transferred in each direction.

Equilibrium

In a **closed system** no reactants or products can escape. If a reversible reaction is carried out in a closed system, it will eventually reach **dynamic equilibrium** – a point in time when the forward and reverse reactions have the same rate.

At dynamic equilibrium:

- the reactants are still turning into the products
- the products are still turning back into the reactants
- *the rates of* these two processes are *equal*, so overall the amount of reactants and products are constant.

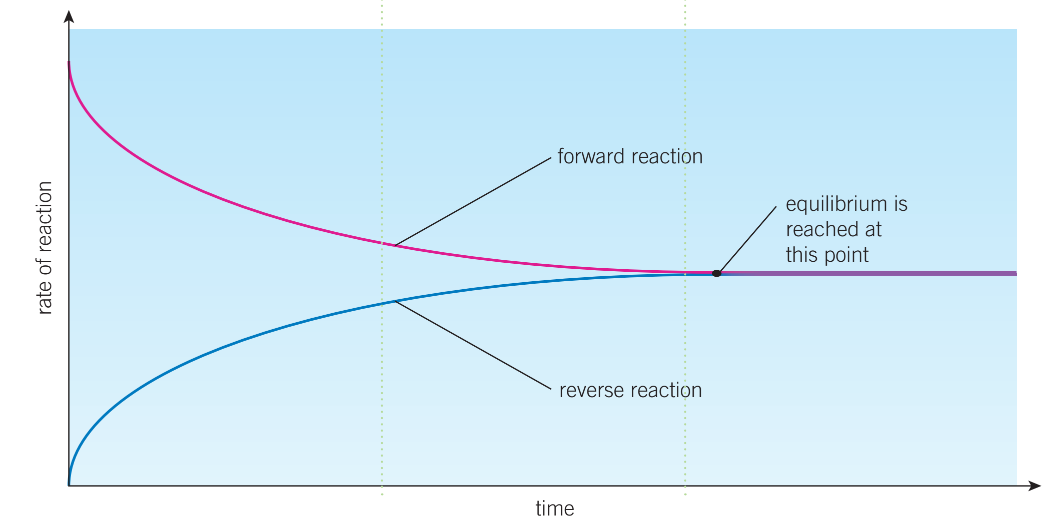
Dynamic equilibrium

At dynamic equilibrium the amount of reactant and product are constant, but not necessarily equal.

You could have a mixture of reactants and products in a 50:50 ratio, in a 75:25 ratio, or in any ratio at all. The **conditions** of the reaction are what change that ratio.

How dynamic equilibrium is reached

Progress of reaction	start of reaction	middle of reaction	at dynamic equilibrium
Amount of A + B	high	decreasing	constant
Frequency of collisions A + B	high	decreasing	constant
Rate of forward reaction	high	decreasing	same as rate of reverse reaction



Progress of reaction	start of reaction	middle of reaction	at dynamic equilibrium
Amount of C + D	zero	increasing	constant
Frequency of collisions C + D	no collisions	increasing	constant
Rate of reverse reaction	zero	increasing	same as rate of forward reaction

Chapter 9: Crude oils and fuels

Knowledge organiser

Crude oil

Crude oil is incredibly important to our society and economy. It is formed from the remains of ancient biomass – living organisms (mostly plankton) that died many millions of years ago.

Raw crude oil is a thick black liquid made of a large number of different compounds mixed together. Most of the compounds are **hydrocarbons** of various sizes. Hydrocarbons are molecules made of carbon and hydrogen only.

Combustion

Hydrocarbons are used as **fuels**. This is because when they react with oxygen they release a lot of energy. This reaction is called **combustion**. Complete combustion is a type of combustion where the only products are carbon dioxide and water.

Properties

Whether or not a particular hydrocarbon is useful as a fuel depends on its properties:

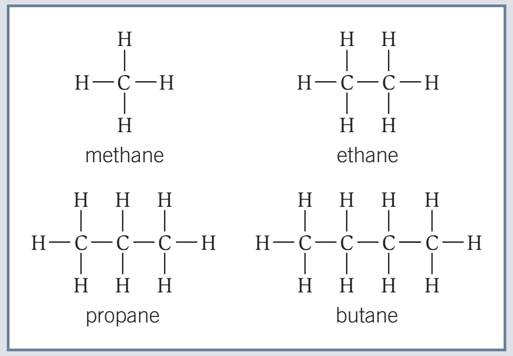
- **flammability** – how easily it burns
- **boiling point** – the temperature at which it boils
- **viscosity** – how thick it is

Its properties in turn depend on the length of the molecule.

Chain length	Flammability	Boiling point	Viscosity
long chain	low	high	high (very thick)
short chain	high	low	low (very runny)

Alkanes

One family of hydrocarbon molecules are called **alkanes**. Alkane molecules only have single bonds in them. The first four alkanes are:



The different alkanes have different numbers of carbon atoms and hydrogen atoms. You can always work the molecular formula of an alkane by using C_nH_{2n+2}.

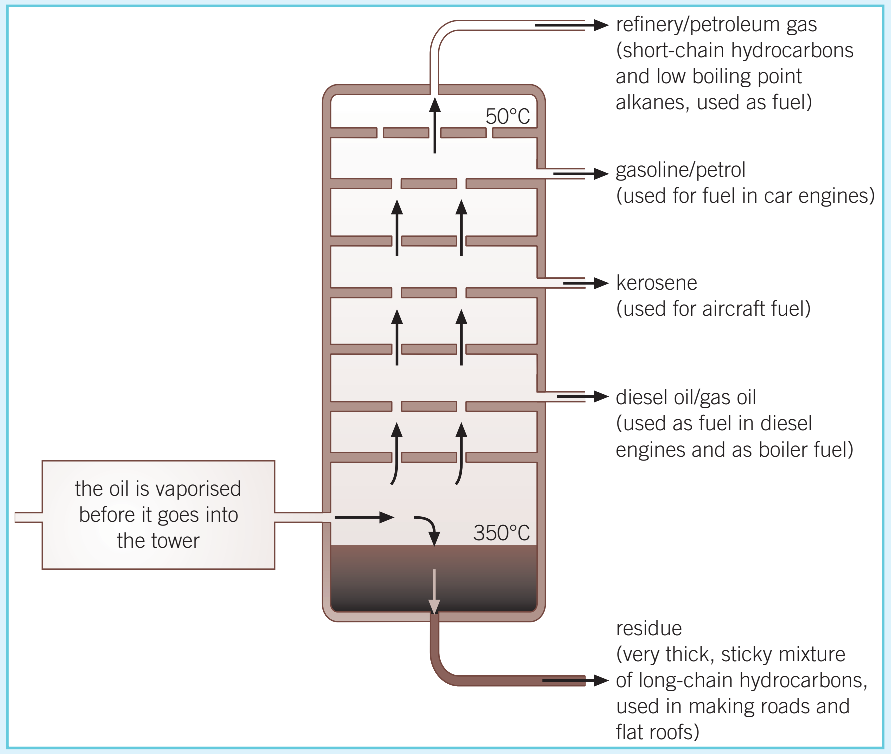
Fractional distillation

The different hydrocarbons in crude oil are separated into fractions based on their boiling points in a process called **fractional distillation**. All the molecules in a fraction have a similar number of carbon atoms, and so a similar boiling point.

The process takes place in a fractionating column, which is hot at the bottom and cooler at the top.

The process works like this:

1. crude oil is vapourised (turned into a gas by heating)
2. the hydrocarbon gases enter the column
3. the hydrocarbon gases rise up the column
4. as hydrocarbon gases rise up the column they cool down
5. when the different hydrocarbons reach their boiling point in the column they condense
6. the hydrocarbon fraction is collected.



Products from fractional distillation

Many useful products come from the separation of crude oil by fractional distillation.

Fuels	Feedstock	Useful materials produced
petrol, diesel oil, kerosene, heavy fuel oil, and liquefied petroleum gases	fractions form the raw material for other processes and the production of other substances	solvents, lubricants, polymers, and detergents

Cracking

Not all hydrocarbons are as useful as each other. Longer molecules tend to be less useful than shorter ones. As such, there is a higher demand for shorter-chain hydrocarbons than longer-chain hydrocarbons.

A process called **cracking** is used to break up longer hydrocarbons and turn them into shorter ones.

Cracking produces shorter alkanes and **alkenes**.

Two methods of cracking are:

- catalytic cracking – vaporise the hydrocarbons, then pass them over a hot catalyst
- steam cracking – mix the hydrocarbons with steam at a very high temperature

Alkenes

Alkenes are a family of hydrocarbons that contain double bonds between carbon atoms.

Alkenes are also used as fuels, and to produce polymers and many other materials.

They are much more reactive than alkanes. When mixed with bromine water, the bromine water turns from orange to colourless. This can be used to tell the difference between alkanes and alkenes.

Key terms

Make sure you can write a definition for these key terms.

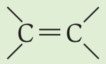
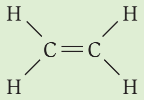
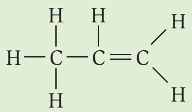
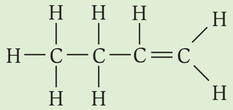
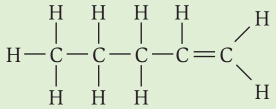
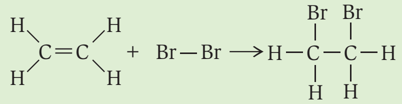
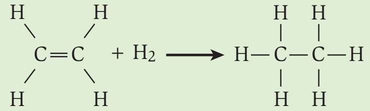
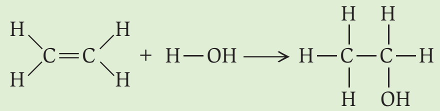
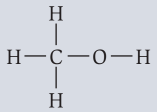
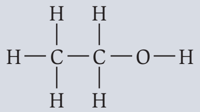
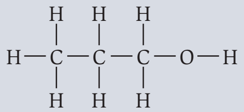
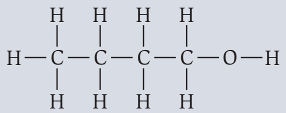
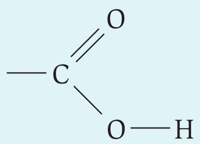
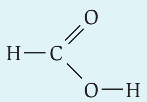
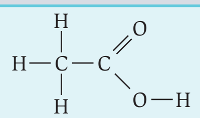
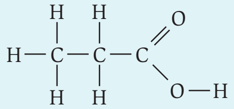
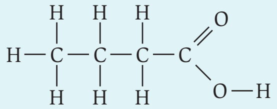
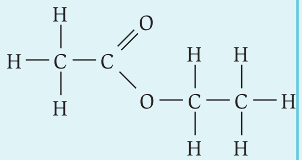
alkanes, alkenes, boiling point, combustion, cracking, crude oil, feedstock, flammability, fractional distillation, fuel, hydrocarbon, viscosity

Chapter 10: Organic reactions

Knowledge organiser

Organic chemistry

There are lots of different 'families' of carbon-containing compounds, for example, alkanes and **alkenes**. These families are called a **homologous series**. Each compound within a homologous series has similar properties and reactions. They all contain specific atoms in specific orders, called the **functional group**.

Homologous series	Functional group	First four of homologous series	Formation	Uses	Combustion reaction	Other reactions	Other information
alkenes		 ethene, C_2H_4  propene, C_3H_6  butene, C_4H_8  pentene, C_5H_{10}	cracking	• formation of polymers • a chemical feedstock	• complete combustion produces carbon dioxide and water • incomplete combustion more likely, resulting in a smoky yellow flame • both types of alkene combustion release less energy per mole than alkanes	**Addition with halogens** The two atoms from the halogen molecule are *added* across the carbon – carbon double bond. $C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$  **Addition with hydrogen** The two atoms from the hydrogen molecule are *added* across the carbon – carbon double bond to form an alkane. $C_2H_4 + H_2 \rightarrow C_2H_6$  **Addition with steam** React with steam at high temperature and pressure in the presence of a catalyst to form alcohols. $C_2H_4 + H_2O \rightarrow C_2H_5OH$ 	Alkenes are called **unsaturated** because they have double bonds. As such, atoms can be added to the molecule by breaking the double bond. This contrasts with alkanes which are called **saturated** as there is no space to add more atoms. Alkenes have a general formula C_nH_{2n}.
alcohols	–OH	 methanol  ethanol  propanol  butanol	Ethanol can be formed from the **fermentation** of sugar – warm a sealed mixture of yeast and a sugar solution. glucose → ethanol + carbon dioxide $C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$	• *ethanol* is used in alcoholic drinks • first four alcohols mix easily with water, so are used as solvents for substances that don't dissolve in water • common in perfumes, aftershaves and mouthwashes	• short alcohols are very effective fuels and combust easily, burning with a blue flame and producing carbon dioxide and water $2CH_3OH + 3O_2 \rightarrow 2CO_2 + 4H_2O$	**Reaction with sodium** Alcohols react with sodium to release hydrogen. The product from this reaction is called an **alkoxide**, which if added to water forms a strongly alkaline solution. **Oxidation** Alcohols can react with **oxidising agents**, like potassium dichromate, to form carboxylic acids.	Alcohols are highly flammable and must not be handled near naked flames.
carboxylic acids		 methanoic acid  ethanoic acid  propanoic acid  butanoic acid	oxidation of alcohols	• ethanoic acid is used in vinegar	• carboxylic acids can undergo combustion, but we do not generally do this or use them as a fuel	Carboxylic acids react in the same way as other acids. **Reaction with sodium carbonate** Carboxylic acids react with bases to form salts. For example, carboxylic acids react with a metal carbonate to produce a salt, carbon dioxide, and water. **Reaction with alcohols** Carboxylic acids react with alcohols to make water and **esters**. The reaction requires sulfuric acid as a catalyst.  Esters have distinctive smells and are used in perfumes and flavourings. The product of ethanol and ethanoic acid is ethyl ethanoate.	(HT only) When added to water, carboxylic acids are partially ionised to form weakly acidic solutions. They are weak acids.

Key terms Make sure you can write a definition for these key terms.

addition reaction | alcohols | alkene | alkoxide | carboxylic acid | ester | fermentation | cracking | functional group | homologous series | oxidation | oxidising agent | saturated | unsaturated

Chapter 11: Polymers

Knowledge organiser

Polymers

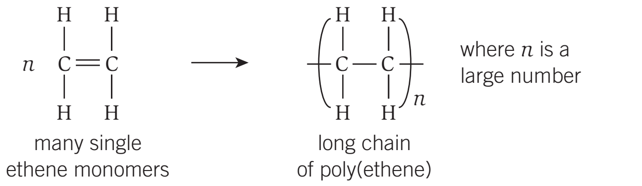
Polymers are very long molecules made up of lots of smaller molecules joined together in a repeating pattern. The smaller molecules are called **monomers**. The process of turning many monomers into a polymer is called polymerisation.

There are two main types of polymerisation.

Type of polymerisation	Monomers	Products of polymerisation
addition polymerisation	molecules with C=C bonds, such as alkenes	just the polymer
condensation polymerisation	diols, dicarboxylic acids, or diamines	polymer and water

Addition polymerisation

Addition polymerisation starts with molecules with a C=C bond (e.g., alkenes) as the monomer. The carbon-carbon double bond breaks in each molecule, and the carbon atoms then link together.



The *n* refers to a large number of molecules. The rounded brackets and the bonds sticking out of them represent where the next molecule in the chain goes.

The inside of the brackets is known as the **repeating unit** – the section that repeats over and over again many thousands of times in the polymer.

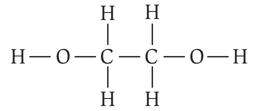
Addition polymers are named after the monomer used to create them.

- An addition polymer made of ethene is called poly(ethene).
- An addition polymer made of propene is called poly(propene).

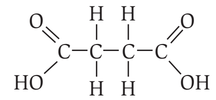
Condensation polymerisation (HT only)

Condensation polymerisation can involve two different monomers, each has *two* functional groups.

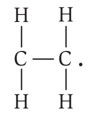
Molecule **A** is a diol. It has two –OH groups: one at either end.



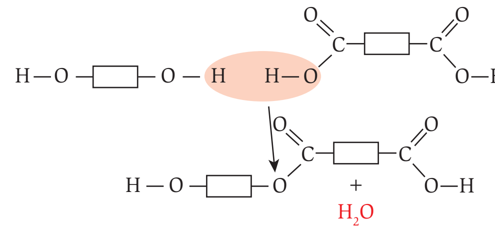
Molecule **B** is a **dicarboxylic acid**. It has a carboxylic acid group at either end.



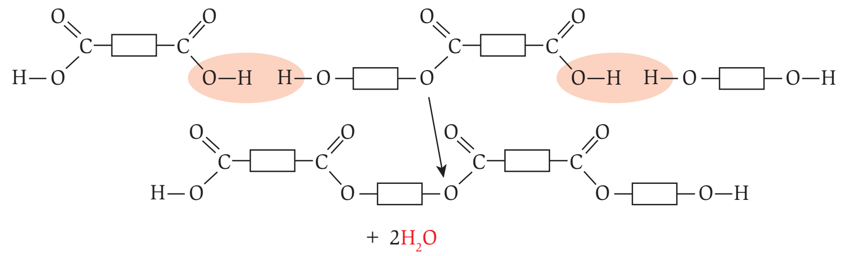
To simplify the diagrams, a rectangle is used to represent



When molecule **A** and molecule **B** react together, the –OH group from the carboxylic acid and a hydrogen atom from the –OH group on the alcohol join together to form water.



Another molecule **B** and another molecule **A** can now react with either side of the molecule that has been formed.



You could keep adding more molecules in the pattern ABABABABA. Every time a molecule is added, a water molecule is produced. This type of reaction is called a **condensation reaction**.

If you keep adding molecules, a condensation polymer is produced. This is represented by:

When diols (compounds with two –OH groups) and dicarboxylic acids react together, they form polyesters.

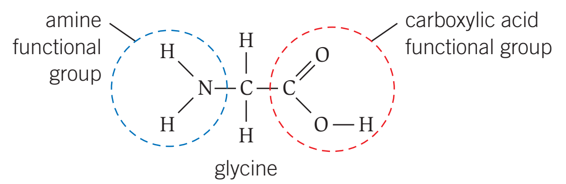
Natural polymers

Amino acids and proteins (HT only)

Condensation reactions can also happen with just one monomer molecule, so long as the molecule has two different functional groups.

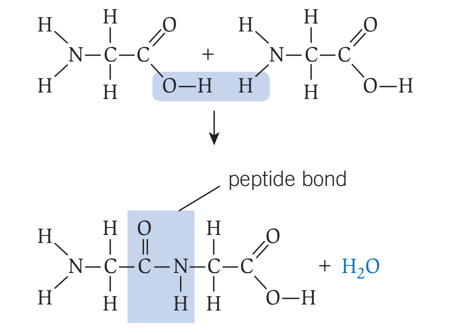
Amino acids have an **amine** functional group and a carboxylic acid functional group. The amine functional group has a nitrogen bonded to a carbon and two hydrogens.

Glycine is the simplest amino acid.



When many molecules of glycine react together they form a **polypeptide**.

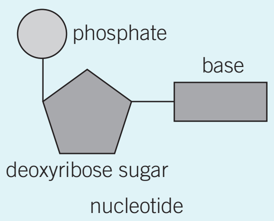
There are many different types of amino acids. They can react together to form many different polypeptides. When lots of polypeptides come together they form something called a **protein**.



DNA

All genetic information is stored in **DNA**. Genetic information contains the instructions for the functioning and development of living organisms.

DNA is made of two long polymers that wind around each other in a double helix. The polymers are made of four different monomers called **nucleotides**.



Starch and cellulose

Starch and cellulose are another two **natural polymers**. Both of these are made from glucose molecules joined together. Whether the resulting polymer is starch or cellulose depends on how the glucose molecules form chains with each other.

Key terms

Make sure you can write a definition for these key terms.

addition polymerisation · amine · amino acid · condensation polymerisation · DNA · monomer · natural polymer · nucleotide · polymer · polypeptide · protein · repeating unit

Chapter 12: Chemical analysis

Knowledge organiser

Pure and impure

In chemistry, a **pure** substance contains a single element or compound that is not mixed with any other substance.

Pure substances melt and boil at specific temperatures.

An **impure** substance contains more than one type of element of compound in a **mixture**.

Impure substances melt and boil at a range of temperatures.

Formulations

Formulations are examples of mixtures. They have many different components (substances that make them up) in very specific proportions (amounts compared to each other).

Scientists spend a lot of time trying to get the right components in the right proportions to make the most useful product.

Formulations include fuels, cleaning agents, paints, alloys, fertilisers, and foods.

Chromatography

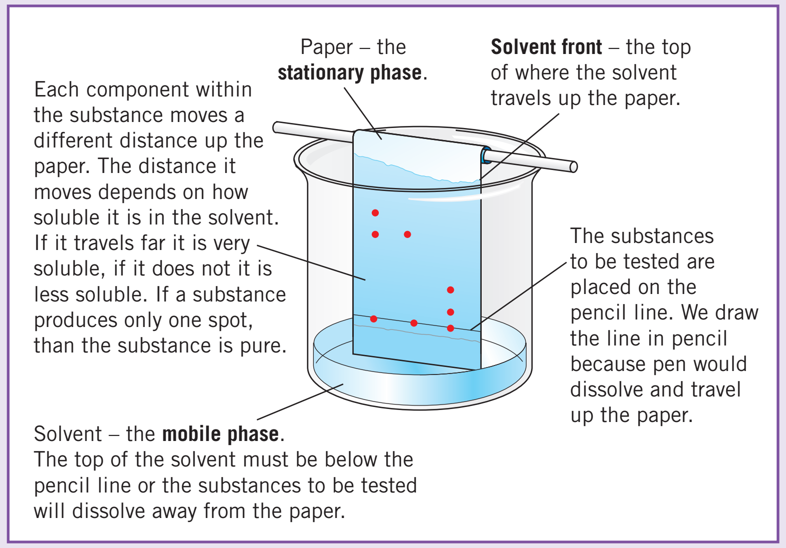
Chromatography is a method to separate different components in a mixture. It is set up as shown here, with a piece of paper in a beaker containing a small amount of solvent.

The R_f **value** is a ratio of how far up the paper a certain spot moves compared to how far the **solvent** has travelled.

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

It will always be a number between 0 and 1.

The R_f value depends on the solvent and the temperature, and different substances will have different R_f values. The R_f values for particular solvents can be used to identify a substance.



Testing gases

Common gases can be identified using the follow tests:

Gas	What you do	What you observe if gas is present
hydrogen	hold a lighted splint near the gas	hear a squeaky pop
oxygen	hold a glowing splint near the gas	splint re-lights
carbon dioxide	bubble the gas through limewater	the limewater turns milky (cloudy white)
chlorine	hold a piece of damp litmus near the gas	bleaches the litmus white

Flame tests

Substances containing metals can produce a coloured light in a flame. This can be used to identify the metal. However, if there is more than one metal in the substance then this method will not work, as the colours mix and intense colours mask more subtle colours.

Metal	Flame colour
lithium	crimson
sodium	yellow
potassium	lilac
calcium	orange-red
copper	green

Instrumental methods

Instrumental analysis involves using complex scientific equipment to test substances.

Instrumental methods are rapid and accurate. They are also sensitive, which means they can give results even with very small amounts of substance.

Flame emission spectroscopy

Flame emission spectroscopy is a type of instrumental analysis similar to a **flame test**.

The sample solution is put into a flame and the light given off is passed through a spectroscope. Instead of a human observing a colour, the instrument tells you exactly which wavelength of light is being given off as a line spectrum. You can then compare the spectrum to a reference to establish the identity of your sample. You can also measure the concentration of the substance in your sample solution.

Testing for cations

Metal ions always have a positive charge (i.e., they are cations). Sodium hydroxide solution can be used to identify some metal ions.

Cation	Positive result
aluminium ions, Al^{3+}	on slow addition of excess sodium hydroxide solution, white **precipitate** forms that eventually dissolves again with excess sodium hydroxide
calcium ions, Ca^{2+}	on addition of excess sodium hydroxide solution, white precipitate that does not dissolve
magnesium ions, Mg^{2+}	on addition of excess sodium hydroxide solution, white precipitate that does not dissolve
copper(II) ions, Cu^{2+}	forms a blue precipitate
iron(II) ions, Fe^{2+}	forms a green precipitate
iron(III) ions, Fe^{3+}	forms a brown precipitate

Testing for anions

Anion	Test	Positive result
carbonate, CO_3^{2-}	add dilute acid	carbon dioxide gas formed which can be test for with limewater
chloride, Cl^-	add silver nitrate solution in the presence of nitric acid	white precipitate formed
bromide, Br^-	add silver nitrate solution in the presence of nitric acid	cream precipitate formed
iodide, I^-	add silver nitrate solution in the presence of nitric acid	yellow precipitate formed
sulfate, SO_4^{2-}	add barium chloride solution in the presence of hydrochloric acid	white precipitate formed

Key terms

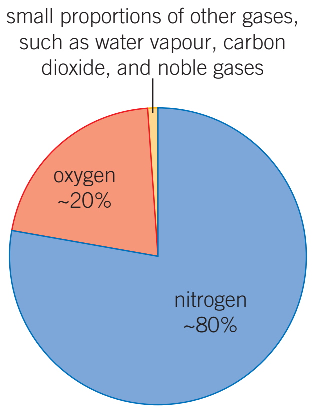
Make sure you can write a definition for these key terms.

chromatography flame emission spectroscopy flame test formulation impure instrumental analysis mobile phase precipitate pure R_f value solvent solvent front stationary phase

Chapter 13: The Earth's atmosphere

Knowledge organiser

The Earth's changing atmosphere

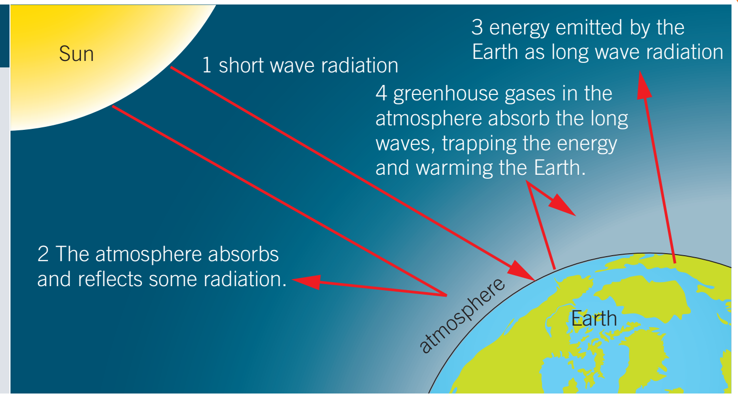
Period	Proportions of gases	Evidence
about 4.6 billion years to about 2.7 billion years ago	• **carbon dioxide, CO_2** Released by volcanoes. Biggest component of the **atmosphere**. • **oxygen, O_2** Very little oxygen present. • **nitrogen, N_2** Released by volcanoes. • **water vapour, H_2O** Released by volcanoes. Existed as vapour as Earth was too hot for it to condense. • **other gases** Ammonia, NH_3, and methane, CH_4, may also have been present.	Because it was billions of years ago there is very little evidence to draw upon.
about 2.7 billion years ago to about 200 million years ago	• **carbon dioxide, CO_2** Amount in atmosphere begins to reduce because: ◦ water condenses to form the oceans, in which CO_2 then dissolves ◦ algae (and later plants) start to photosynthesise carbon dioxide + water $\xrightarrow{\text{light}}$ glucose + oxygen $6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$ ◦ CO_2 precipitates in the oceans as solid carbonates (sediments) that form rocks ◦ CO_2 taken in by plants and animals. When they die, the carbon in them is locked up as fossil fuels • **oxygen, O_2** Starts to increase as a product of photosynthesis. • **nitrogen, N_2** Continues to increase. Nitrogen is a very stable molecule so any process that produces it causes the overall amount to build up over time. • **water vapour, H_2O** Starts to decrease. As the Earth cools, the vapour condenses and forms the oceans.	Still limited as billions of years ago, but can look at processes that happen today (like photosynthesis) and make theories about the past.
about 200 million years ago until the present	• **carbon dioxide, CO_2** about 0.04% • **oxygen, O_2** about 20% • **nitrogen, N_2** about 80% • **water vapour, H_2O** Very little overall. Collects in large clouds as part of the water cycle. • **other gases** Small proportions of other gases such as the noble gases.  	Ice core evidence for millions of years ago and lots of global measurements taken recently.

Greenhouse gases

Greenhouse gases, such as carbon dioxide, methane, and water vapour, absorb radiation and maintain temperatures on the Earth to support life.

However, in the last 150 years, more greenhouse gases have been released due to human activities.

- carbon dioxide – combustion of fossil fuels, deforestation
- methane – planting rice fields, cattle farming



Global warming

Scientists have gathered peer-reviewed evidence to demonstrate that increasing the amount of greenhouse gases in the atmosphere will increase the overall average temperature of the Earth. This is called **global warming**.

However, it is difficult to make predictions about the atmosphere as it is so big and complex. This leads some people to doubt what scientists say.

Global climate change

Global warming leads to another process called **global climate change** – how the overall weather patterns over many years and across the entire planet will change.

There are many different effects of climate change, including:

- sea levels rising
- extreme weather events
- changes in the amount and time of rainfall
- changes to ecosystems and habitats
- polar ice caps melting.

Carbon footprints

Increasing the amount of greenhouse gases in the atmosphere increases the global average temperature of the Earth, which results in global climate change.

As such, it is important to reduce the release of greenhouse gases into the atmosphere. The amount of carbon dioxide and methane that is released into the atmosphere by a product, person, or process is called its **carbon footprint**.

Other pollutants released in combustion of fuels

Pollutant	Origin	Effect
carbon monoxide	incomplete combustion of fuels	colourless and odourless toxic gas
particulates (soot and unburnt hydrocarbons)	incomplete combustion of fuels especially in diesel engines	**global dimming**, respiratory problems, potential to cause cancer
sulfur dioxide	sulfur impurities in the fuel reacting with oxygen from the air	**acid rain** and respiratory problems
oxides of nitrogen	nitrogen from the air being heated near an engine and reacting with oxygen	acid rain and respiratory problems

Key terms Make sure you can write a definition for these key terms.

acid rain *atmosphere* *carbon footprint* *global climate change* *carbon monoxide* *global dimming* *global warming* *greenhouse gas* *particulate* *pollutant*

Chapter 14: The Earth's resources 1

Knowledge organiser

Natural and synthetic resources

We use the Earth's resources to provide us with warmth, fuel, shelter, food, and transport.

- Natural resources are used for food, timber, clothing, and fuels.
- Synthetic resources are made by scientists. They can replace or supplement natural resources.

When choosing and synthesising resources, it is important to consider **sustainable development**. This is development that meets the needs of current generations without compromising the ability of future generations to meet their own needs.

Finite and renewable resources

Some resources are **finite**. This means that they will eventually run out.

Fossil fuels are an example of a finite resource. They take so long to form that we use them faster than they are naturally formed.

Resources that will not run out are called **renewable** resources.

Wood is an example of a renewable resource. Trees can be grown to replace any that are cut down for wood.

Potable water

Water is a vital resource for life. **Potable** water is water that is safe to drink. However, most water on Earth is not potable.

Type of water	What it has in it
pure water	just water molecules and nothing else
potable water	water molecules, low levels of salts, safe levels of harmful microbes
salty water (sea water)	water molecules, dangerously high levels of salt, can have high levels of harmful microbes
fresh water (from rivers, lakes, or underground)	water molecules, low levels of salt, often has harmful microbes at high levels

Fresh water

In the UK, potable water is produced from rain water that collects in lakes and rivers. To produce potable water:

1. Choose an appropriate source of fresh water.
2. Pass the water through filters to remove large objects.
3. **Sterilise** the water to kill any microbes using ozone, chlorine, or UV light.

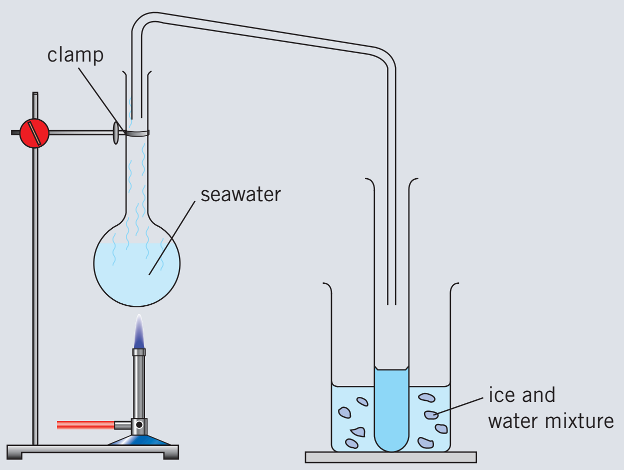
Salty water

Some countries do not have lots of fresh water available. **Desalination** is the process to turn saltwater into potable water. This requires a lot of energy and can be done by:

- distillation
- **reverse osmosis**

Reverse osmosis involves using membranes to separate the salts dissolved in the water. The water needs to be pressurised and the salty water corrodes the pumps. As such, it is an expensive process.

Distillation



Waste water

Human activities produce lots of waste water as sewage, agricultural waste, and industrial waste.

- **Sewage** and agricultural waste contain organic matter and harmful microbes.
- Industrial waste contains organic matter and harmful chemicals.

These need to be removed before the water can be put back into the environment.

Treating sewage water

screening and grit removal
The sewage passes through a metal grid that filters out large objects.

sedimentation
The sewage is left so that solid sediments settle out of the water. The sediments sink to the bottom of the tank. The liquid sits above the sediment.

Treating sludge

sewage sludge
This sediment is called **sludge**. Sludge contains organic matter, water, dissolved compounds, and small solid particles.

anaerobic treatment
Bacteria are added to digest the organic matter. These bacteria break down the matter anaerobically – with a limited supply of oxygen.

biogas
The anaerobic digestion of sludge produces biogas. Biogas is a mixture of methane, carbon dioxide and hydrogen sulfide. It can be used as fuel.

remaining sludge used as fuel
The remaining sludge can be dried out and can also be burnt as a fuel.

Treating effluent

effluent
The remaining liquid is called **effluent**. This effluent has no solid matter visible, but still contains some matter and harmful microorganisms.

aerobic treatment
Bacteria are added to the effluent. These bacteria feed on organic matter and the harmful microorganisms in the effluent. The bacteria break down the matter by aerobic respiration – oxygen needs to be present.

bacteria removed
The bacteria are allowed to settle out of the water.

discharged back to rivers
The water is now safe enough to be released back into the environment.

Chapter 14: The Earth's resources 2

Knowledge organiser

Metal extraction (HT only)

Metals are used for many different things. Some metals can be extracted from their ores by reduction or electrolysis.

However, metal ores are a finite resource and these processes require lots of energy.

Scientists are looking for new ways to extract metals that are more sustainable.

Phytomining and **bioleaching** are two alternative processes used to extract copper from low grade ores (ores with only a little copper in them).

Phytomining

1. Grow plants near the metal ore.
2. Harvest and burn the plants.
3. The ash contains the metal compound.
4. Process the ash by electrolysis or displacement with scrap metal.

Bioleaching

1. Grow bacteria near the metal ore.
2. Bacteria produce leachate solutions that contain metal compound.
3. Process the leachate by electrolysis or displacement with scrap metal.

Both of these methods avoid the digging, moving, and disposing of large amounts of rock associated with traditional mining techniques.

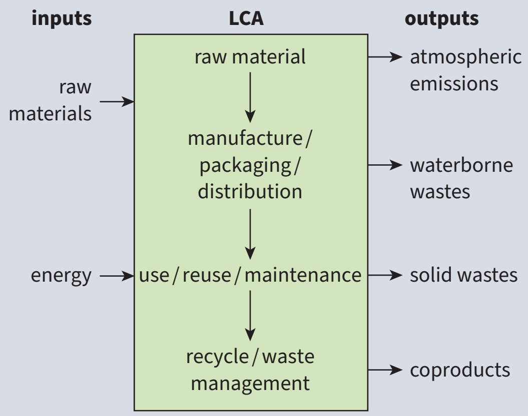
Life cycle assessment

A **life cycle assessment (LCA)** is a way of looking at the whole life of a product and assessing its impact on the environment and sustainability. It is broken down into four categories:

- extracting and processing raw materials
- manufacturing and packaging
- use and operation during its lifetime
- disposal at the end of its useful life, including transport and distribution at each stage

Some parts of an LCA are objective, such as the amount of water used or waste produced in the production of a product.

However, other parts of an LCA require judgements, such as the polluting effect, and so LCAs are not a completely objective process.



Key terms

Make sure you can write a definition for these key terms.

aerobic *anaerobic* *biodegrade* *bioleaching* *distillation* *effluent* *finite resources* *life cycle assessment* *phytomining* *potable water* *recycling* *renewable resources* *reverse osmosis* *screening* *sedimentation* *sewage* *sludge* *sterilisation* *sustainable development*

Disposal of products

When someone finishes with a product, it can be

- added to a landfill
  This can cause habitat loss and other problems in the local ecosystem. Some items persist in landfills as they do not **biodegrade** and could be there for hundreds of years.
- incinerated
  Some products can be incinerated to produce useful energy. However, the combustion can often be incomplete and result in harmful pollutants being released to the atmosphere.
- reused
  This is when an item is used again for a similar purpose.
- **recycled**
  Recycling requires energy, but conserves the limited resources and often requires less energy than needed to make brand new materials.

The table shows information about the extraction, processing, and disposal of some common materials. This information is used when making a LCA.

Material	Extraction/processing	Disposal
metal	• quarrying and mining cause habitat loss • machinery involved in mining release greenhouse gases • extraction from metal ores require lots of energy	• metals can normally be recycled by melting them down and then casting them into new shapes • metals in landfill can persist for a long time
plastic	normally come from fossil fuels that are non-renewable	• many plastic products can be reused and recycled • plastics often end up in landfills where they persist as they are not biodegradable • incinerating plastics releases lots of harmful pollutants like carbon monoxide and particulates
paper	produced from trees that require land and lots of water to grow lots of water also used in the production process	• many paper products can be recycled • paper products can also be incinerated or they can decay naturally in a landfill • incineration and decay release greenhouse gases
glass	produced by heating sand, which requires a lot of energy	• many glass products can be reused, or crushed and recycled • if glass is added to landfills it persists as it is not biodegradable
ceramics	• come from clay and rocks • generally require quarrying, which requires energy, releases pollutants from heavy machinery, and causes habitat loss	• most ceramics are not commonly recycled in the UK, and once broken cannot be reused • ceramics tend to persist in landfills

Chapter 15: Making our resources 1

Knowledge organiser

Corrosion

Corrosion is when a material reacts with substances in the environment and eventually wears away. Corrosion can be prevented in in two ways:

- physical barriers
- sacrificial protection

Rusting is an example of corrosion. It is caused by iron reacting with oxygen *and* water from the environment.

Physical barriers

The material is covered with a physical barrier like grease, paint, or a thin layer of another metal by a process called electroplating.

Aluminium reacts with oxygen to make a very thin layer of aluminium oxide around the metal that acts as a physical barrier. This layer then protects the rest of the metal from corrosion.

Sacrificial protection

A more reactive substance is placed on the material. The more reactive substance will react with the environment, and not the main material.

For example, iron is **galvanised** with zinc. The zinc then reacts with the oxygen and water in place of the iron.

Alloys

Alloys allow us to tailor the properties of metals to specific uses.

Alloy	Composition	Properties	Use
bronze	copper and tin	resistant to corrosion	statues, decorative items, ship propellers
brass	copper and zinc	very hard but workable	door fittings, taps, musical instruments
gold alloys	mostly gold with copper, silver and zinc added	attractive, corrosion resistant, hardness depends on carat	jewellery the proportion of gold is measured in carats. 24 carat gold contains 100% gold, 18 carat gold contains 75% gold
high carbon steel	iron with 1–2% carbon	strong but brittle	cutting tools, metal presses
low carbon steel	iron with <1% carbon	soft, easy to shape	extensive use in manufacture of cars, machinery, ships, containers, structural steel
stainless steel	iron with chromium and nickel	resistant to corrosion, hard	cutlery, plumbing
aluminium alloys	over 300 alloys available	low density, properties depend on composition	aircraft, military uses

Ceramics

Ceramics are materials with versatile properties that can have many different uses.

Ceramic	Manufacture	Properties	Uses
soda-lime glass	heat a mixture of sand, sodium carbonate, limestone	transparent, brittle	everyday glass objects
borosilicate glass	heat sand and boron trioxide	higher melting point than soda-lime glass	oven glassware, laboratory glassware
clay ceramics (pottery + bricks)	shape wet clay then heat in a furnace	hard, brittle, easy to shape before manufacture, resistant to corrosion	crockery, construction, plumbing fixtures

Polymers

The properties of polymers depend on

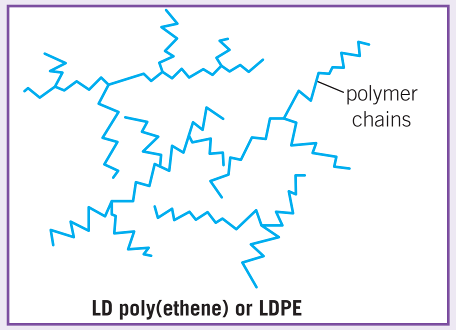
- the monomers that make them up
- the conditions under which they are made.

For example, **low density poly(ethene)** and **high density poly(ethene)** are both made from ethene monomers but have very different properties due to the way that the polymer chains line up in the material.

Low density poly(ethene)

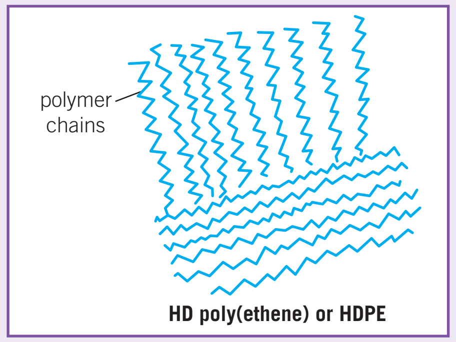
LDPE is formed when the addition polymerisation reaction of ethene is carried out under high pressure and in the presence of a small amount of oxygen.

The branched polymer chains cannot pack together, so causing the low density of the polymer.



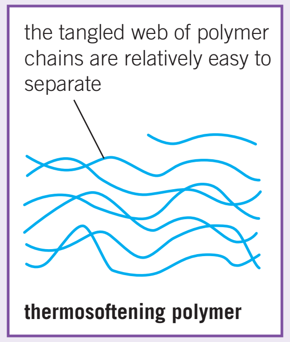
High density poly(ethene)

HDPE is formed when the addition polymerisation reaction of ethene is carried out using a catalyst at 50 °C. The polymer chains are straight and can pack tightly together, so causing the high density of the polymer.



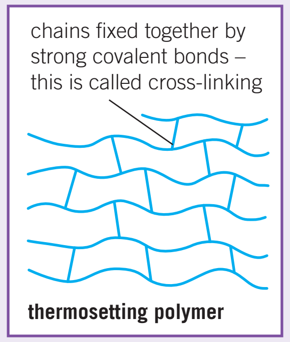
Thermosoftening polymers

Thermosoftening polymers do not have links between the different chains, and soften when they are heated.



Thermosetting polymers

Thermosetting polymers have strong links between the different chains, and do not melt when they are heated.



Composites

Composites are made from a main material (called a **matrix**) with fragments or fibres of other materials (called **reinforcements**) added into them. This means the material's properties can be made more useful.

Plywood and reinforced concrete are examples of composites.

Chapter 15: Making our resources 2

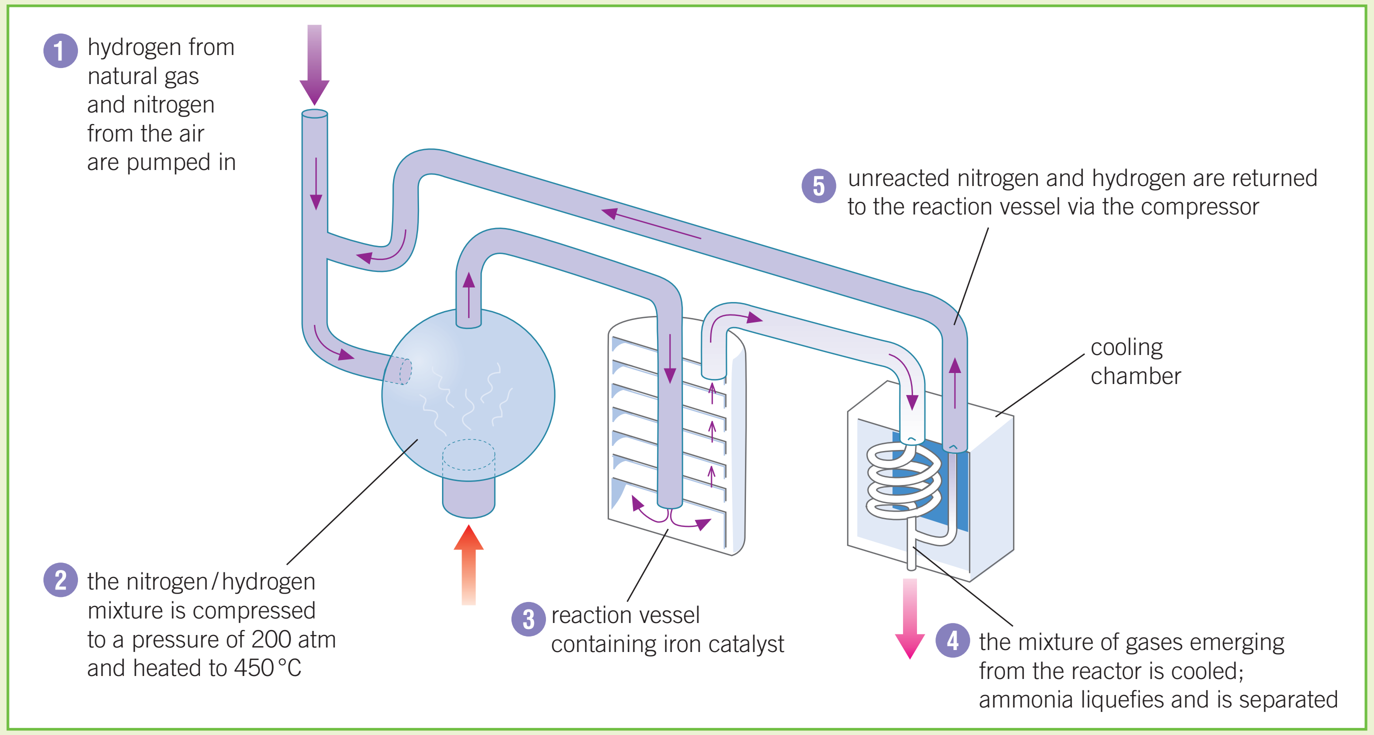
Knowledge organiser

The Haber process

Fertilisers are important chemicals used to improve the growth of crop plants. Ammonia is a vital component of many fertilisers. It is produced in the **Haber process**:

- nitrogen + hydrogen ⇌ ammonia
- $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

It is a reversible reaction, so the conditions affect the yield.



Conditions

Compromise

The conditions used for the Haber process are a *compromise* to balance yield, cost, and rate.

- an iron catalyst
- temperatures of about 450 °C
- pressure of about 200 atmospheres

Temperature

The forward reaction is exothermic. Therefore, lowering the temperature would increase the yield of ammonia, but would also decrease the rate of reaction.

Pressure

There are fewer gas molecules on the product side, so increasing the pressure would increase the yield and the rate of reaction. However, it is very expensive to increase the pressure.

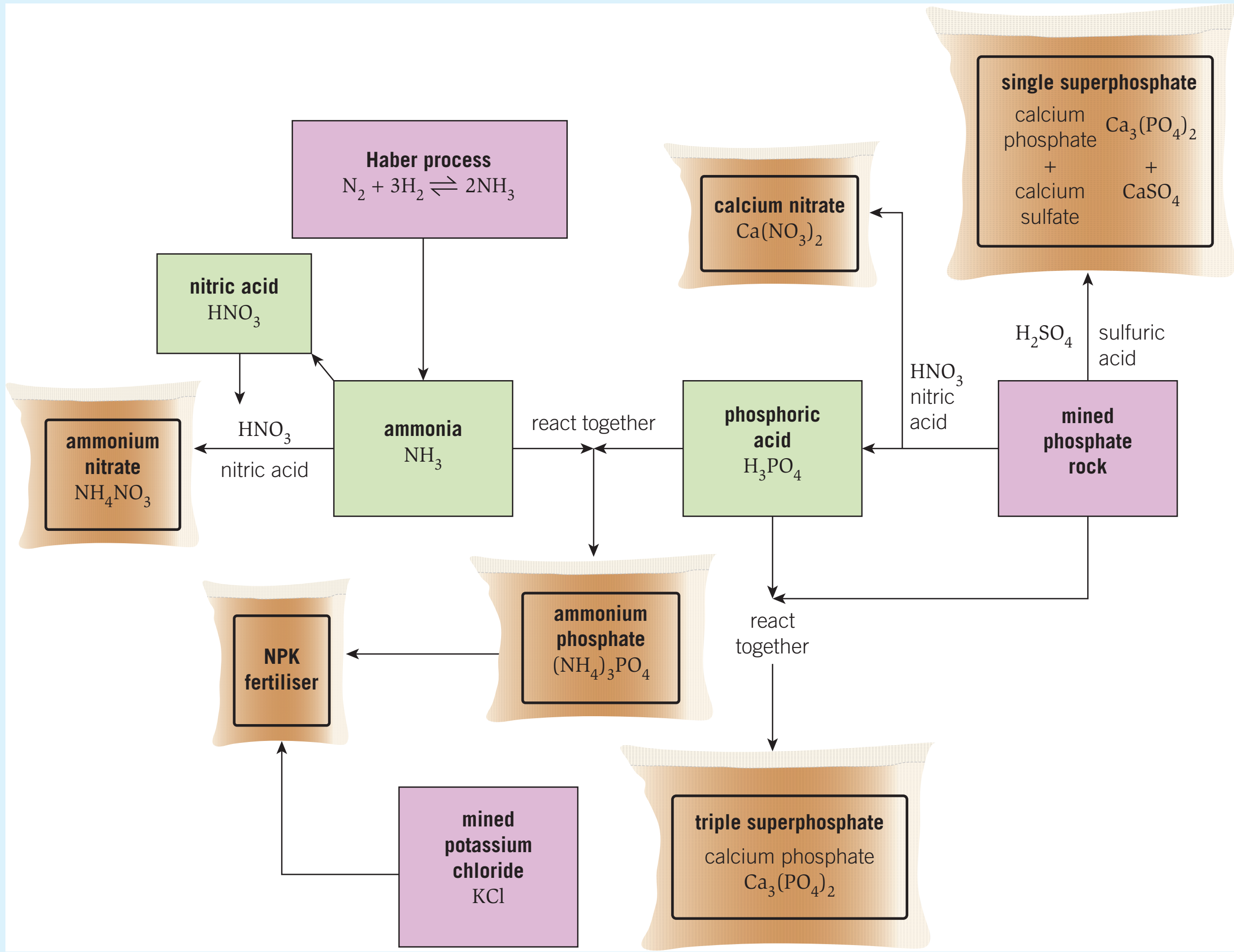
Catalyst

Iron is an effective catalyst for the Haber process. It does not increase the yield, but does increase the rate.

Fertilisers

Fertilisers are produced industrially to increase the amount of food obtained from crops. Compounds containing nitrogen, phosphorous, and potassium are used, and fertilisers with all three in them are called **NPK fertilisers**.

NPK fertilisers are formulations. Some of the substances that go into NPK fertilisers can be mined straight from the ground (like potassium chloride or potassium sulfate). Others, like phosphate rock, need to be processed first. Phosphate rock can react with different acids to make different products, which can either be used as fertilisers on their own or added to an NPK fertiliser.



Laboratory vs. industry

The compounds found in fertilisers can be produced in the laboratory as well as industrially:

	laboratory	industrial
Quantities produced	small	large
Process	batch (do it once)	continuous (can keep doing it)
Apparatus	glass	stainless steel
Speed	slow	fast

Key terms

Make sure you can write a definition for these key terms.

alloy, ceramic, composite, corrosion, galvanise, Haber process, matrix, NPK fertiliser, reinforce, rusting, thermosetting, thermosoftening