

AQA Combined Science: **Trilogy**

Year 11

Knowledge organiser booklet

Paper 2

CHEMISTRY

C6 Rates

C7 Organic chemistry

C8 Chemical analysis

C9 Earth & Atmosphere

C10 Using resources

Name:

C6 – Rate and extent of chemical change

Rate of reaction.

Measuring the rate of anything always involves a **measurement of time**

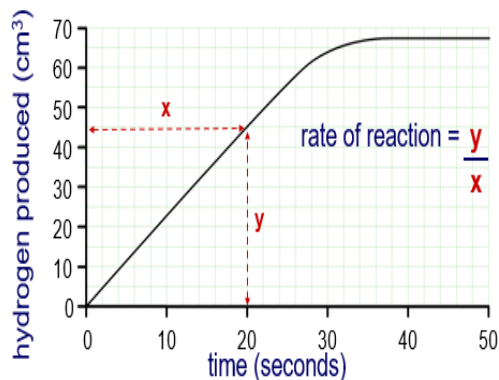
The rate of a chemical reaction can be found using:

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

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

Quantities for reactants or products are measured in **mass in g** or by **volume in cm³**

Rate calculations can be done from tables of data or graphs:



Volume of hydrogen produced = 45cm³

Time taken = 20 seconds

Rate = $\frac{45}{20}$ cm³

20 s

rate = 2.25 cm³/s

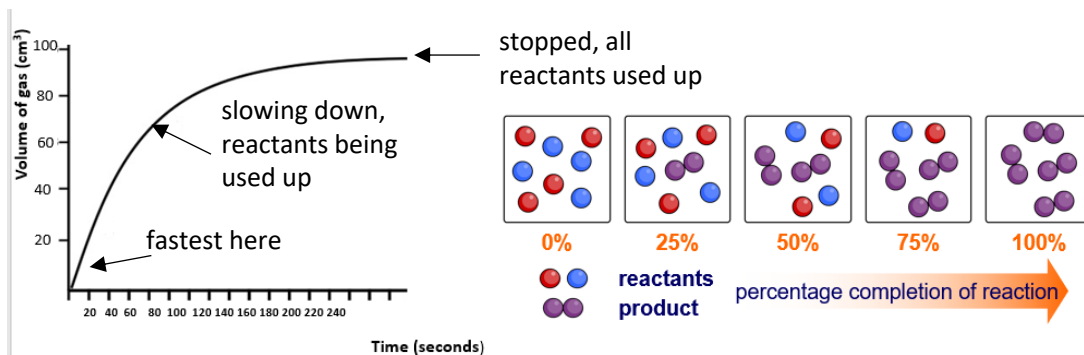
The progression of a chemical reaction

For a reaction to take place, reactant particles have to collide.

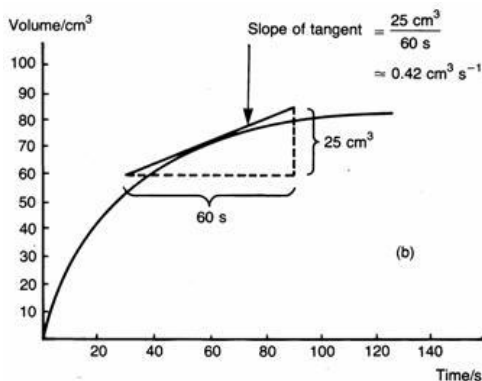
The rate of a reaction depends on the **frequency of collisions** and the **energy with which the particles collide**.

The minimum amount of energy needed to start a reaction is called the **activation energy**.

A reaction is always **fastest at the beginning** and slows down over time as the reactants get used up and the frequency of collisions decreases.



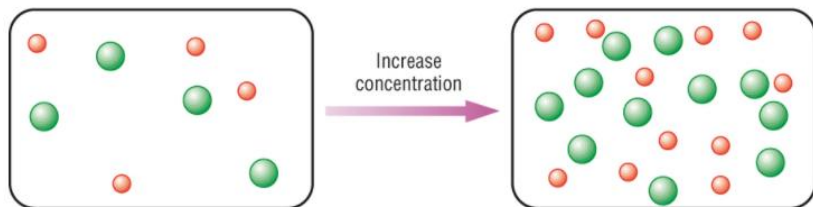
Using a tangent to calculate rate (HT)



- Draw a line along the point you're interested in. The line should touch the curve at the point given.
- Make a triangle. Try to make the angles either side of the line equal.
- Measure the change in volume and change in time
- Calculate the gradient
- Use units from the axes to determine the units for rate

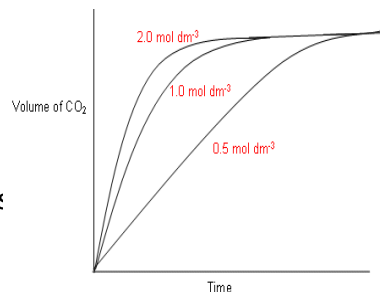
C6 – Rate and extent of chemical change

The effect of concentration

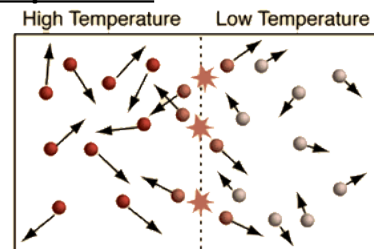


Concentration means number of particles per cm^3
Increasing the concentration of any of the reactants increases the rate of the reaction

This is because there are more particles per cm^3 so there are **more frequent collisions**, increasing the rate.

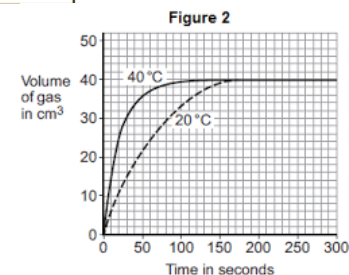


The effect of temperature



Increasing the temperature of the reactants increases the rate of the reaction.

This is because the particles have more kinetic energy and therefore move faster, so there are **more frequent collisions**, increasing the rate.

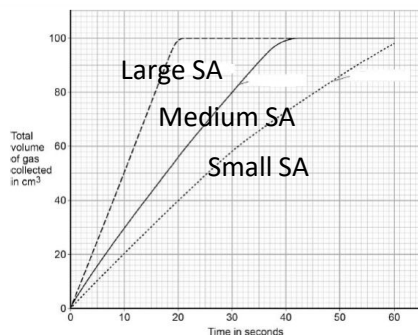


The effect of surface area

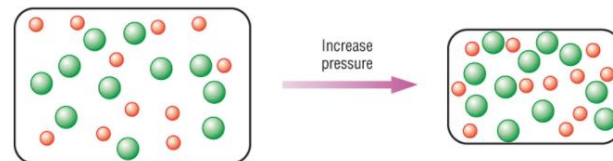


The smaller the pieces of a solid, the higher the surface area
Increasing the surface area of solid reactants increases the rate of reaction.

This is because there is a greater area available for collisions to occur so there are **more frequent collisions**, increasing the rate.

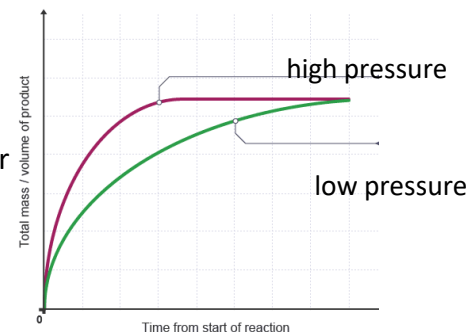


The effect of pressure



Increasing the pressure of gaseous reactions increases the rate of the reaction.

This is because the same number of particles are now in a smaller volume, so there are **more frequent collisions**, increasing the rate.

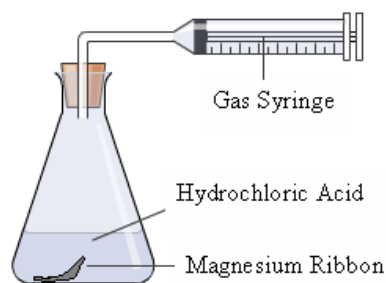


In all cases, the overall amount of product is the SAME, the end point of the reaction is just reached faster

C6 – Required practical – the effect of concentration on rate of reaction

Experiment 1

Using volume of gas collected over time as a measure of the rate



Independent variable: concentration of HCl

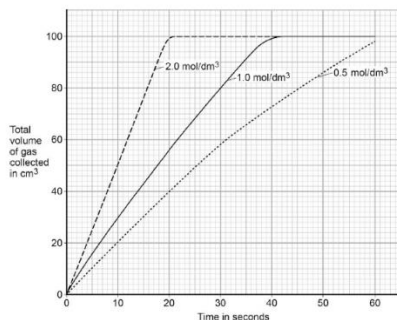
Dependent variable: Volume of gas produced / min

Control variables: volume of HCl, mass of Mg, temperature of acid

Method

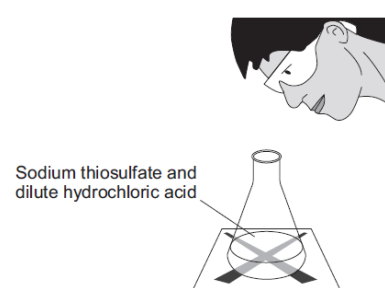
1. Measure 20cm³ 0.5M HCl into a conical flask.
2. Insert 2 x 2cm pieces of Mg and attach a gas syringe
3. Start a stopwatch and measure the volume of gas collected every 20 seconds until the reaction is over.
4. Repeat using different concentrations of HCl.

An increase in the concentration leads to an increase in the rate of the reaction, but the same volume of product overall



Experiment 2

Investigating the effect of changing the concentration of HCl on the rate of reaction



The sulphur being made is insoluble and is what makes the liquid go cloudy

Independent variable: concentration of HCl

Dependent variable: Time taken for the cross to disappear

Control variables: volume of HCl, volume of sodium thiosulphate, temperature of both solutions, concentration of sodium thiosulphate

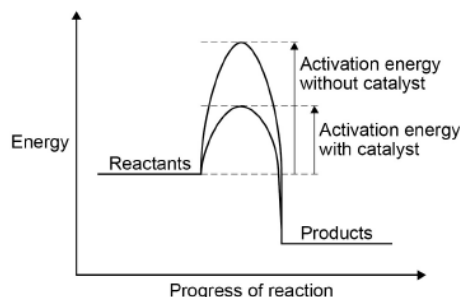
Method

1. Use a measuring cylinder to put 10 cm³ sodium thiosulfate solution into the conical flask.
2. Put the conical flask on the black cross.
3. Put 10 cm³ of 0.5M hydrochloric acid into the 10 cm³ measuring cylinder.
4. Put this acid into the flask. At the same time swirl the flask gently and start the stopwatch.
5. Look down through the top of the flask. Stop the stopwatch when you can no longer see the cross. Record the time.
6. Repeat steps 1-5 using different concentrations of HCl – 1M, 1.5M, 2M and 2.5M

C6 – Rate and extent of chemical change

Catalysts

- Catalysts are substances that speed up chemical reactions without themselves being used up.
- They provide a different pathway for the reaction with a lower activation energy.
- Different reactions require different catalysts.



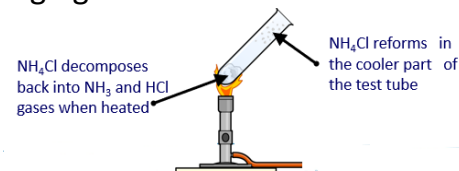
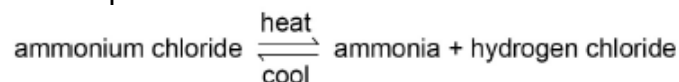
Reversible reactions

These are reactions in which the products can react to produce the original reactants

They are represented by the symbol $\rightleftharpoons$

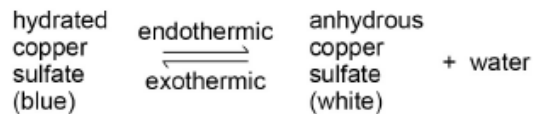
The direction of the reaction can be changed by changing the conditions

For example:



If a reaction is exothermic in one direction, it is endothermic in the opposite direction.

The same amount of energy is transferred in each case.



When a reversible reaction takes place in sealed apparatus, then a point occurs when the forward and backward reactions occur at the same rate. This is **equilibrium**

The effect of changing conditions on equilibrium (HT)

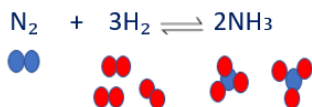
If a system is at equilibrium and a change is made to the conditions, then the system responds to counteract the change.

E.g. – if the temperature is increased, then the system will respond by increasing the rate of the endothermic reaction, to bring the temperature back down

If the concentration of the reactants is increased, then equilibrium will shift right and more products will be made.

In gaseous reactions, a change in pressure will result in equilibrium shifting to the side that restores the pressure.

E.g. :



In this reaction, there are 4 moles of gas on the reactants side and only 2 on the product side

If the pressure is increased, equilibrium will shift right as there are fewer moles on the products side, and this will decrease the pressure.

C7 – Organic Chemistry

Crude oil

Crude oil = a mixture of **hydrocarbons**.

- It is a **non-renewable resource (fossil fuel)**
- Made from remains of dead sea creatures **compressed** over millions of years

Hydrocarbons - molecules containing **hydrogen** and **carbon only**.

Two types of hydrocarbons are **alkanes** and **alkenes**.
The hydrocarbons in crude oil are mostly alkanes.

Alkanes

- Alkanes = **saturated** hydrocarbons.
- Held together by **single covalent bonds**.
- General formula = C_nH_{2n+2}
- Have different boiling points – longer the chain, higher the boiling point

You need to remember the names, and formulas of the first 4 alkanes.

Name of Alkane	Structural Formula	Molecular Formula
methane	$\begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{H} \\ \\ \text{H} \end{array}$	CH_4
ethane	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array}$	C_2H_6
propane	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \end{array}$	C_3H_8
butane	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{H} \\ \quad \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \end{array}$	C_4H_{10}

Fractional Distillation

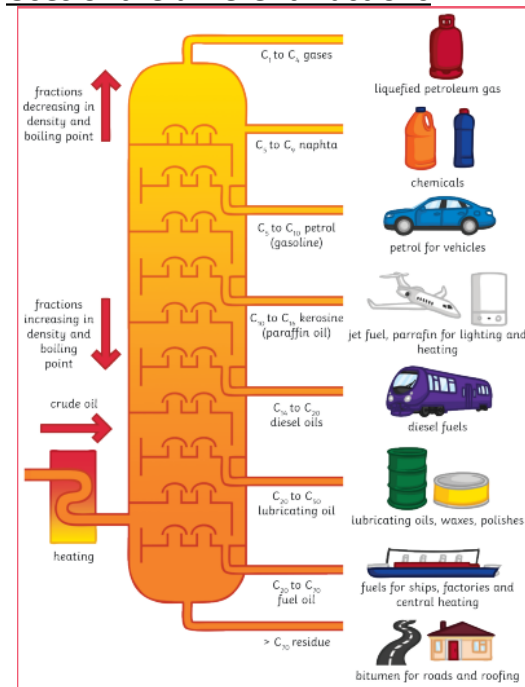
- Used to **separate** the mixtures of hydrocarbons in **crude oil**.

Steps in Fractional Distillation

1. Crude oil enters **fractioning column** and is heated to boiling point so the hydrocarbons evaporate.
2. It is **cooler** at the **top** of the fractionating column and **hotter** at the **bottom**.
3. Vapours rise up the column and, as they rise, they cool
4. The different hydrocarbons condense at different **boiling points**
5. The different 'fractions' have different **properties**

Short-Chain Molecules	Increasing Chain Length	Long-Chain Molecules
		
thin	As chain length increases, the boiling point of the hydrocarbon chains also increases.	thick
		
	Flammability is a measure of how easily a substance burns.	

Uses of the different fractions



Supply and demand

Product	Supply in tonnes	Demand in tonnes
petrol	100	300
diesel	200	100
heating oil	250	50

After fractional distillation, we find:

- we have more of the long chain hydrocarbons than we need
- There are not enough short chain hydrocarbons.
- Short chain are more useful as they are more flammable so can be used as fuels.

C7 – Organic Chemistry

Cracking

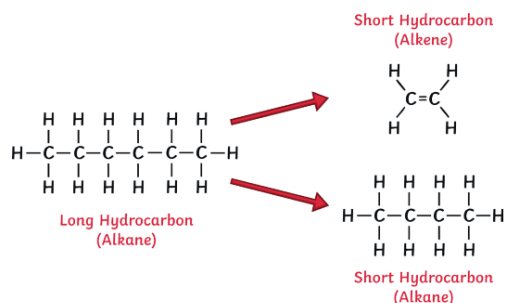
- This is done to solve the problem of having too many long chain hydrocarbons and not enough short ones
- Long hydrocarbons are **broken down** into smaller, more useful hydrocarbons.
- Short chain hydrocarbons are more useful as they are more flammable

Two types of cracking: catalytic and steam cracking.

Catalytic cracking – needs a **high temperature** and a **catalyst**.

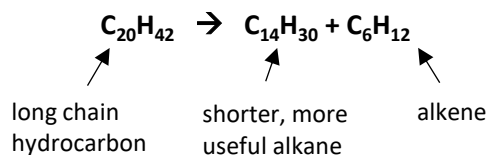
Steam cracking – **high temperature** and **steam**

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



Cracking equations

Same number of carbon and hydrogen atoms on both sides of the equation:



Alkenes

- Alkenes are **unsaturated** hydrocarbons.
- Contain carbon-carbon **double bonds**.

Test for Alkenes

Use bromine water to test for alkenes.

If an alkene is present, the bromine water turns from orange/brown to colourless.

Alkanes do not react with bromine water.

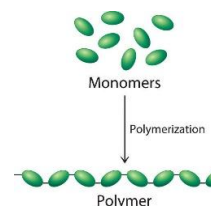


Uses for alkenes:

- Can be used as fuels
- Can be used as a starting material for other chemicals
- Can be used to make polymers (e.g. plastic)

Polymers

- Polymers are large molecules made of many repeating units (monomers)
- Alkenes (small molecules) are joined together to make polymers



Poly(ethene) – plastic bags/drinks bottles

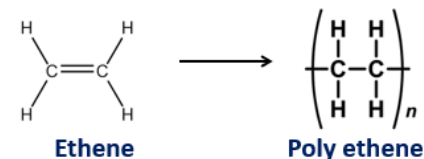
Poly(propene) – strong tough plastics

Drawing and naming polymers

1. Redraw the **monomer given**, but without the double bond. Make sure to copy all other elements exactly.
2. Put brackets around the monomer and extend joining bonds out through the brackets on both sides
3. Add an 'n' at the bottom right of the bracket
4. To name the polymer, you put **poly** in front of the monomer name

E.g.:

Draw and name the polymer made from the monomer ethene:



Combustion of Hydrocarbons

Combustion means burning.

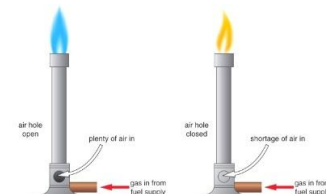
Complete combustion - when there is a good supply of **oxygen** for a fuel to burn.

Fuel + oxygen → carbon dioxide + water

Incomplete combustion - **not enough oxygen**

Products are **carbon monoxide** and water.

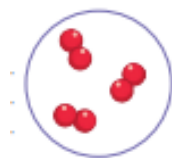
Carbon monoxide = poisonous gas



C8 – Chemical Analysis

Pure substances

Pure = single element or compound – not mixed with any other substance.



Testing to see if a substance is pure:

- Pure substances have specific melting and boiling points

- Compare your data to a library of known values.

E.g. Water has a boiling point of 100°C, if it is above or below this, it is not pure.

Formulations

Formulation = a mixture that is designed as a useful product.

- Components mixed carefully to get the required **properties**.

Examples of formulations:

- Fuels
- Cleaning agents
- Paints
- Medicines
- Alloys
- Fertilisers
- Food



Chromatography

- Technique used to separate mixtures of **soluble substances**.
- How soluble a substance is determines how far it travels across paper.

More soluble = travels further (higher up paper)

Mobile phase

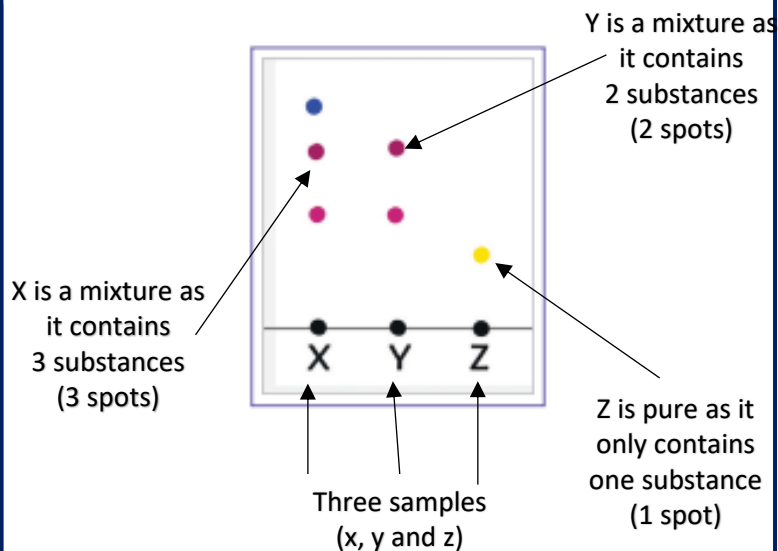
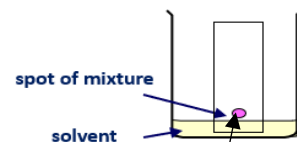
- **Solvent** is the mobile phase
- The substances dissolve in the solvent
- The solvent then moves through the stationary phase.

Stationary phase

- Does not move. The paper is the stationary phase.

Important – start line on paper must be drawn in **pencil** as pencil is **insoluble** and **will not run**

The spot and start line must be **above the solvent line** so the colours won't just wash into the solvent in the beaker.

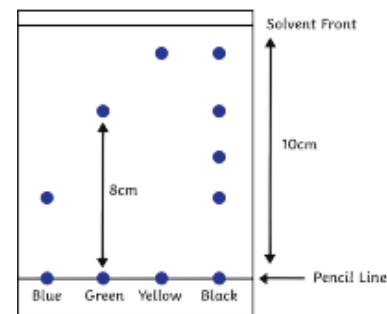


Rf Values

This is the ratio of the distance moved by a substance to the distance moved by the compound

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

- Should always be between 0 and 1.
- Each substance has a unique Rf value.
- Can compare Rf values to a library of known substances
- Can identify unknown substances.



Rf value of green:

$$8\text{cm} / 10\text{cm} = 0.8$$

C8 – Chemical Analysis

Required Practical – Paper Chromatography

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

Method

- 1) Using a ruler, measure 1cm from bottom of chromatography paper and draw a line across the paper with a **pencil**.
- 2) Using a pipette, drop small spots of each ink onto pencil line (leave a gap so do not merge).
- 3) Pour solvent into a beaker, do not fill solvent above the pencil line on the paper.
- 4) Place chromatograph paper into beaker and allow solvent to move up the paper.
- 5) Remove paper just before solvent reaches top of the paper and leave to dry.
- 6) Calculate R_f values of all the spots using the equation below:

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

Common questions

Q1) Why is a pencil used instead of a pen?

A1) Ink in the pen would move up the paper with the substances.

Q2) Why do you not fill the solvent above the line?

A2) Substances would wash off into the solvent instead of rising up the paper

Q3) Why might water not work as a solvent?

A3) Some substances are **insoluble** in water.

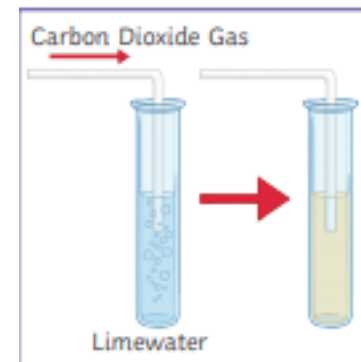
Identification of the Common Gases

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



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

Test for Carbon Dioxide – Bubble the gas through the lime water – if the gas is carbon dioxide, the limewater turns **cloudy**.

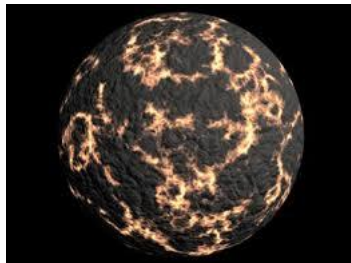


Test for Chlorine – Damp litmus paper is held over the of gas. If the tube contains chlorine, the litmus paper becomes **bleached** and **turns white**.

C9 – Earth & Atmosphere

Early Atmosphere vs modern atmosphere:

Gas	Levels in earth's early atmosphere	Percentage in air today
Nitrogen	None	78
Oxygen	None	21
Others – CO ₂ and argon	Very High	1
Water vapour	Very high	Varies – but usually only around 1%
Ammonia	High	None



4.6
billion
years



We think that the atmosphere on Earth was once like that of Mars or Venus is today

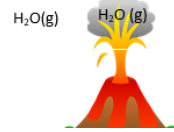
When Earth was formed it was so hot it was molten on the surface, and the atmosphere was full of toxic gases like methane and ammonia.

We cannot be sure about exactly what the Earth's early atmosphere as we have no evidence from so long ago

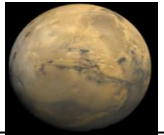
How did the atmosphere change?

N₂ CO₂ H₂O (g)

1. Volcanoes released nitrogen, carbon dioxide and water vapour



2. The earth cooled and solidified

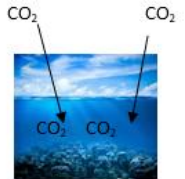


3. Water vapour in the atmosphere condensed and fell as rain



4. Oceans, lakes and rivers formed

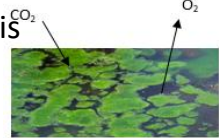
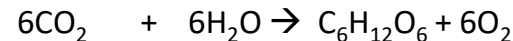
5. Carbon dioxide from the air dissolved in the oceans



6. Some of this reacted to form sedimentary rocks like limestone

7. Algae and then plants evolved, removing carbon dioxide from the air and produced oxygen by photosynthesis

Carbon dioxide + water → glucose + oxygen



8. Many early plants and marine organisms were buried and decayed underground, locking up carbon in fossil fuels like coal (plants) and oil (animals)



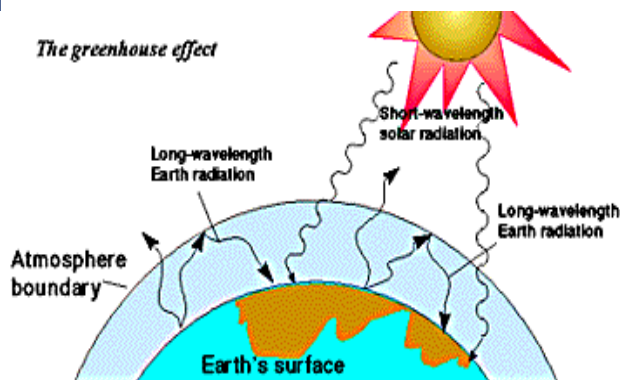
C9 – Earth & Atmosphere

The greenhouse effect

The greenhouse layer is a layer of gases in the atmosphere made of:

- carbon dioxide
- methane
- water vapour

The greenhouse effect



1. Short wavelength infrared radiation from the sun reaches Earth
2. Some energy is absorbed by the Earth
3. Longer wavelength IR is reflected by the Earth
4. Longer wavelength IR cannot get through the greenhouse layer as easily so some is trapped, warming the Earth

The thicker the layer of gases, the more heat is trapped

Global warming

The greenhouse layer is getting thicker, because:

- CO₂ released from fossil fuels to generate electricity
- CO₂ released from fossil fuels in vehicles
- Methane released from cattle
- Methane released from rotting landfill sites

Many scientists believe that human activities are causing the warming of the Earth.

Potential consequences:

- Melting ice caps
- Loss of habitats for animals and plants
- Damage to coral reefs caused by warmer oceans
- Changes to animal migration patterns
- Extreme weather patterns – more hurricanes, heat waves, droughts, snow and ice
- Difficulty growing crops so reduced food supply

Carbon footprint



The total amount of CO₂, CH₄ and water vapour released by of a product or service. E.g for a concert:

- electricity in performance
- Fossil fuels used by people travelling there
- Plastics used and disposed of in refreshments etc

Carbon footprints can be reduced by recycling, reducing energy use or eating vegetarian diets but this is hard to get people to do.

Pollutants :

Pollutant	Source	Effects
Carbon dioxide	Combustion	Global warming
Carbon monoxide	Incomplete combustion of fuels	Toxic gas, can be fatal
Sulfur dioxide	Traces of sulfur in coal react with oxygen when burned	Acid rain
Nitrogen oxides	Hot engines provide the energy for N ₂ to react with O ₂	Acid rain
particulates	Incomplete combustion	Global dimming, breathing problems

C10 – Using Resources

Earth's Resources

We use Earth's resources to provide **warmth, shelter, food and transport**.

E.g.:

- metals from the Earth's crust to build buildings and cars
- Timber and oil to burn for warmth
- Crop plants for food
- Products from crude oil to serve as fuels in cars, trains and planes

Finite resources – ones that will run out as they are being used much faster than they can be replaced, e.g. oil

Renewable resources – resources that will not run out, e.g. wood, wind etc.

Chemistry plays an important part in finding improvements or alternatives to **current resources**.

Natural	Improved or replaced by....
Wood for furniture	Plastic/polymers
Food crops	Fertilisers/artificially grown foods such as Quorn
Oil for fuel	Ethanol/hydrogen fuel cells
Rubber for tyres	Polymers

Life-Cycle Assessments (LCA)

- These assess the environmental impact of a product in these stages:

Stage 1 – extracting raw materials needed to make products.

- Energy cost and effect on habitats of extraction
- Are the raw materials finite/renewable?

Stage 2 – Manufacturing and packaging product

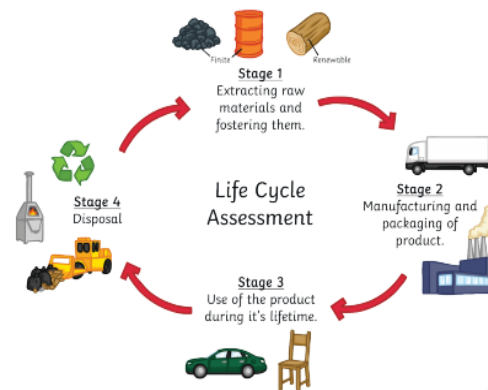
- How much energy and resources are needed?
- What waste products/pollution are released?
- Transportation of goods from factories to user need considering.

Stage 3 – Use of product during its lifetime

- E.g. a car has a significant impact as needs filled up with petrol which is a finite resource.

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

- 1) Landfill – high environmental impact
- 2) Incineration – burning of product
- 3) Recycling – e.g. batteries contain metals that are harmful to environment – recycling means no new compounds need to be taken out of the ground.



Example LCA for plastic vs paper bags:

Stage of Life Cycle Assessment	Plastic Bag	Paper Bag
Stage 1 – raw material	Uses finite resource. Process of fractional distillation, cracking and polymerisation all require energy.	Made from trees/recycled paper. Making paper from trees required more energy than recycled paper. Less energy than plastic bags.
Stage 2 – Manufacture	Cheap to make	More expensive to make
Stage 3 – Use	Low environmental impact as can be re-used many times. Much stronger product.	Only be reused a limited number of times – short lifetime.
Stage 4 - disposal	Do not biodegrade easily in landfill.	Paper bags degrade easily in landfill sites.

- Different people have different opinions and so depends on who completes the LCA. Bias may be added.
- Some companies may only discuss some of environmental impacts of their product.
- Accurate numerical values should be used where possible – for example to show how much energy has been used.

C10 – Using Resources

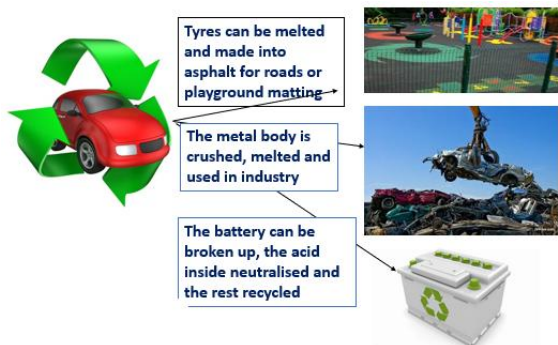
Reducing the use of resources

Metals, glass, ceramics, building materials and most plastics are produced from limited resources. The energy for the processes involved in making/extracting raw materials also comes from limited resources – e.g. oil. We can reduce the use of limited resources by reducing use, reusing materials and recycling materials at the end of their life.

Reduce, reuse, recycle.

E.g.

- Glass bottles can be reused.
- Metals can be melted down and recast and so recycled.
- Scrap steel can be added to extracted iron to reduce the amount of iron that has to be extracted in the blast furnace.



Evaluating methods to reduce, reuse, recycle

Advantages	Disadvantages
Fewer resources such as mines and quarries are needed to extract finite materials	Requires collection and transport of items – involving staff, vehicles and use of fuel
Crude oil does not need to be extracted – avoids high energy costs for fractional distillation etc.	Materials, such as metals, very often have to be separated from other materials first
Less greenhouse gases produced.	Some metals need melting before being reused – energy costs.
Less items in landfill	

Biological extraction techniques (HT only)

- Earth's supply of metal ores is limited.
- There are fewer sites that give lots of copper (high grade ore sites)
- New ways of extracting from low grade ore sites are:

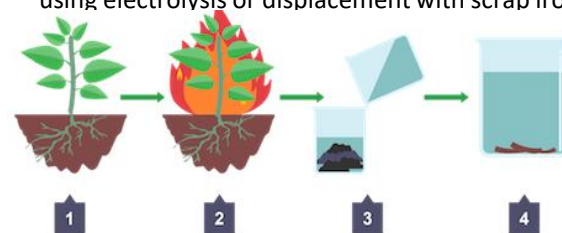
- Phytomining
- Bioleaching

Disadvantage = **slow processes**

Advantage = reduce need for the traditional mining methods of digging, moving and disposing of large amounts of rock.

Phytomining (HT only)

- 1) Plants are grown on a low-grade ore
- 2) The plants absorb metal ions through their roots
- 3) The plants are harvested and burnt
- 4) Ash left behind contains metal compounds
- 5) Ash is dissolved in acid and copper is extracted using electrolysis or displacement with scrap iron.



Bioleaching (HT only)

- Uses **bacteria** to produce a solution called **leachate** – contains copper ions.
- The copper can be extracted by using iron to **displace** the copper from the leachate.
- Does not need high temperatures
- Produces **toxic substances** which can damage the environment.
- Iron is cheaper than copper – use of scrap iron is a cost-effective way to produce copper from leachate.
- Can also undergo **electrolysis** to produce copper.

C10 – Using Resources

Water

Potable Water

- Water is **essential** for life.
- **Potable water** is water that is safe to drink.
- Potable water is not pure as it contains some dissolved substances.

In the UK – rain water provides water with low levels of dissolved substances that collects in the ground and in lakes and rivers. This is fresh water.

Most potable water is produced by:

- 1) Choosing an appropriate source of fresh water
- 2) Passing the water through filter beds
- 3) Sterilising to kill bacteria

Sterilising agents used for potable water include:

- Chlorine
- Ozone
- Ultraviolet light



Desalination of Sea Water

- **Potable** water can be made from sea water through desalination.
- Required a lot of **energy** to **remove salt** in sea water.

Can be done by:

Distillation

- Sea water heated until it boils
- Steam is **condensed** to make potable water
- Requires a lot of **energy**

Reverse Osmosis

- Water put under **high pressure** and passed through **membrane** with tiny holes in.
- Holes allow water through but not salt/ions
- Very **expensive**
- Produces **large volumes** of waste water.

Waste Water Treatment

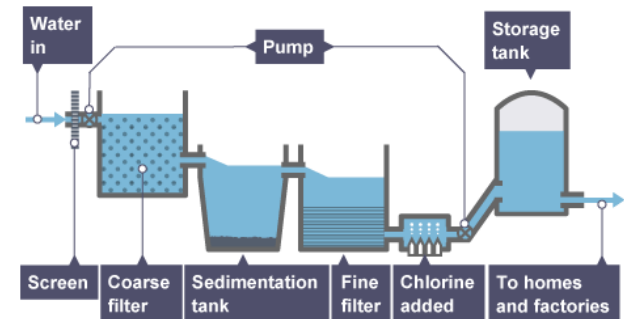
- Waste water needs to be treated before being released back into environment

Pollutants can be present in waste water including:

- Human waste contains harmful **bacteria** and nitrogen – can harm aquatic ecosystems.
- Industrial waste can contain **toxic** substances
- Agricultural waste water can contain **fertilisers** or **pesticides** – disrupt ecosystems.

Sewage treatment involves:

- 1) Screening and grit removal to remove large particles
- 2) Sedimentation – allows tiny particles to settle – produces sewage sludge and effluent (liquid that remains on the top)
- 3) Sewage sludge is digested anaerobically by specific bacteria
- 4) Effluent is treated with aerobic bacteria to reduce volume of solid waste.



C10 – Using Resources – Required Practical – Analysis and purification of water

Analysing the pH of Water Samples

- Test pH of each water sample using pH probe or universal indicator.
- Compare to pH chart if using universal indicator

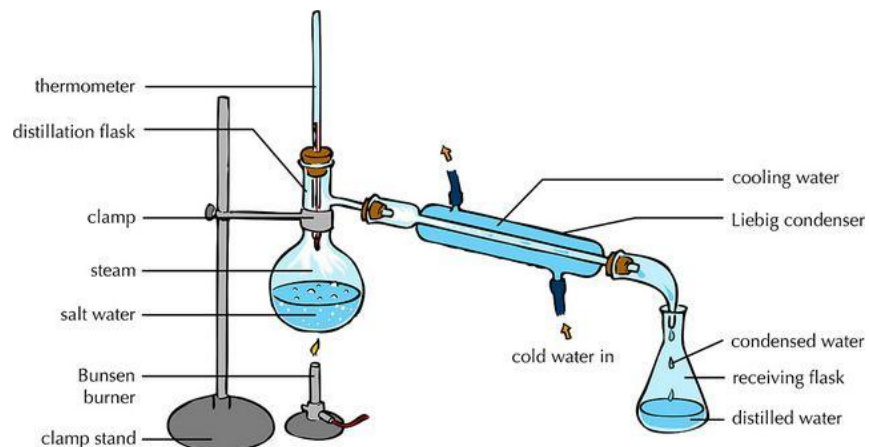
Analysis the Mass of Dissolved Solids

- 1) Measure out 50 cm³ of water sample using measuring cylinder.
- 2) Take the mass of evaporating basin using top pan balance.
- 3) Heat the sample in the evaporating basin gently until all liquid evaporates.
- 4) Let the evaporating basin cool
- 5) Re-take the mass of the evaporating basin.



- 6) Calculate the mass of the solid left behind by doing: final mass – initial mass.
- 7) Repeat with different water samples (e.g. rainwater, salt water, spring water)

Distillation of water Sample



- 1) Set up apparatus as shown in picture with the sample of water in the round bottom flask.
- 2) Heat water sample until it boils gently.
- 3) Water vapour enters the tube at the side (condenser)
- 4) There is cold water surrounding the tube
- 5) The water vapour cools and condenses and collects in the flask.
- 6) The water collected should be **pure**.