Contents

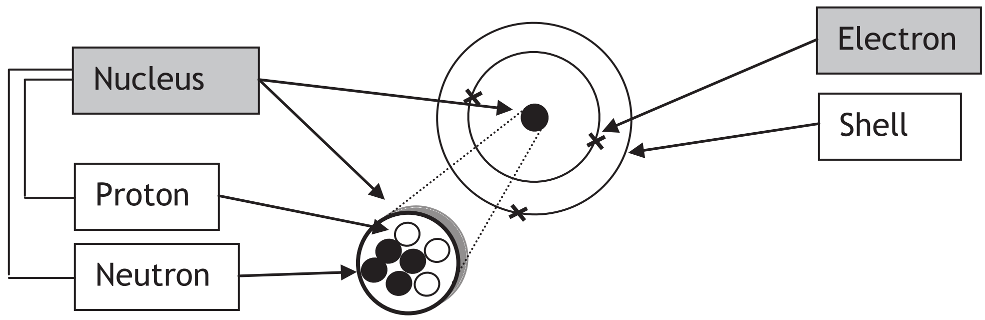
Atomic Structure

Atoms contain a **nucleus** and **electrons**

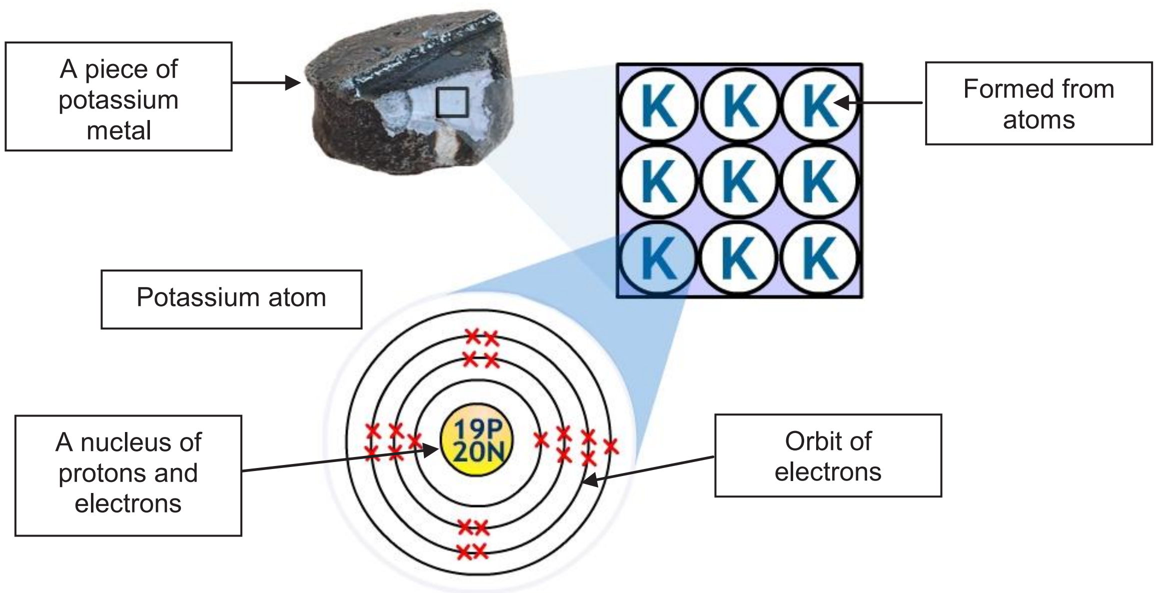
The small central nucleus is made from **protons** and **neutrons**.

Around these are **orbits** (shells) of **electrons**.

Here is a diagram showing an atom of **Lithium**



This diagram shows that a piece of **Potassium** is made up of millions of the same atom.



Atoms of **different** elements are different.

The number of **protons** is always different with different elements.

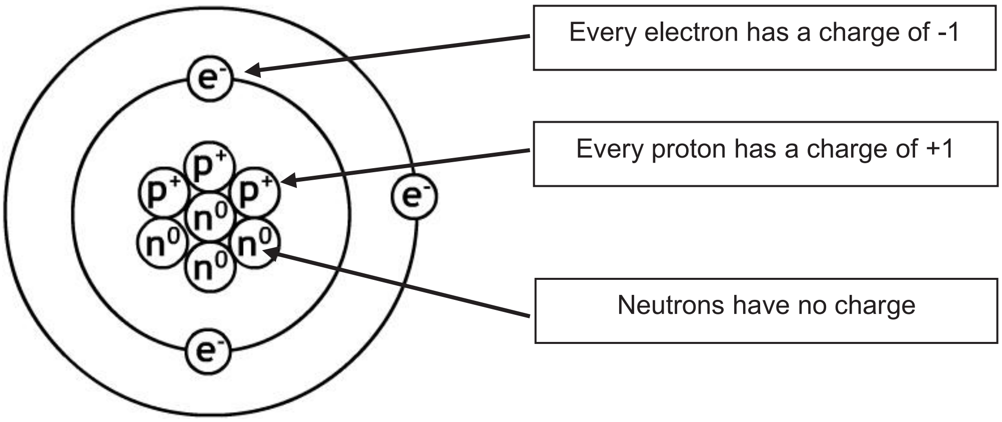
Element	*Lithium*	*Potassium*
Protons	**3**	**19**
Neutrons	4	20
Electrons	3	19

Neutron number for some elements are the same.
Electron number can be the same when the atoms have bonded.

Atoms have no charge.

The number of protons (in the nucleus) is always **the same** as the number of electrons (in shells)

Protons are positively charged. (**+**)
Electrons are negatively charged (**-**)
Neutrons do not have a charge (**0**)



Therefore an atom of **lithium** has no charge :- +3p + -3e = **0** **no charge**

Ion has **uneven** number of **protons and electrons**

This happens when an **electron is lost**

Or when an **electron is gained**

The proton number does not change**.**

Mass and **Charge** of atoms

Here are the relative mass of each particle and their electric charge.

	mass	charge
proton	1	+1
electron	0	-1
neutron	1	0

Protons and **neutrons** have similar mass.
Electrons have no mass, or extremely little amount.

Atomic Number

$^{7}_{3}Li$

Number on the **bottom** which means the number of protons or electrons

The number increases across the periodic table

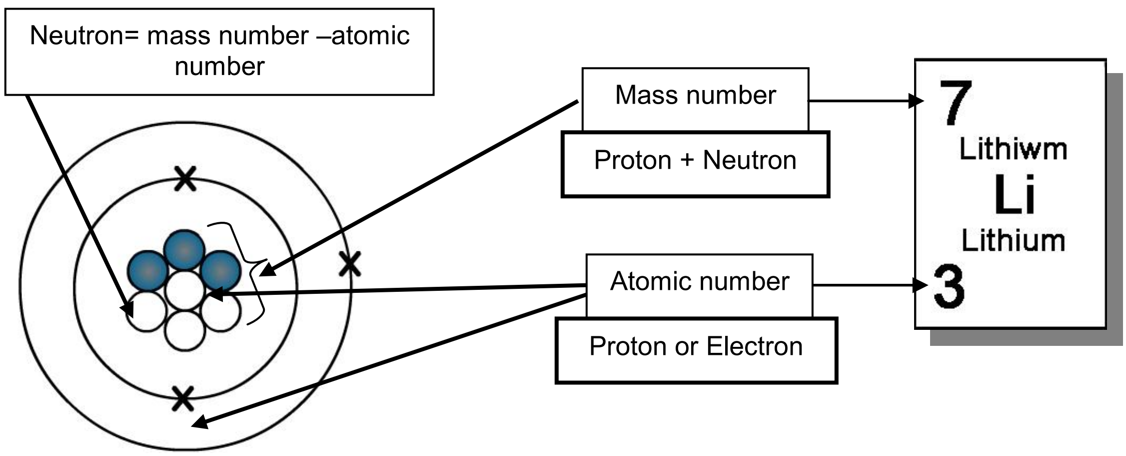
Mass Number

$^{7}_{3}Li$

Number on the **top** which means the number of protons and neutrons in the nucleus.

Neutron Number

The number of neutrons in an atom is worked out by subtracting the number of protons (Atomic number) from the Mass number.

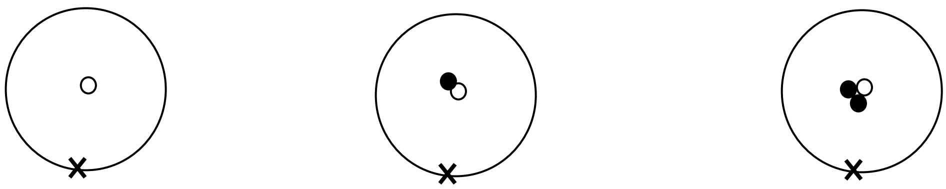


Isotopes

The same element (as it has the same number of protons) but with different number of neutrons (making the mass number different). Hydrogen

Proton = ○
Electron = ✕
Neutron = ●

$^{1}_{1}H$ $^{2}_{1}H$ $^{3}_{1}H$

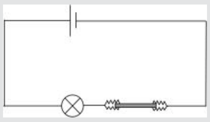


$^{1}_{1}H$	$^{2}_{1}H$	$^{3}_{1}H$
Proton number = 1	Proton number = 1	Proton number = 1
Neutron number = 0	Neutron number = 1	Neutron number = 2

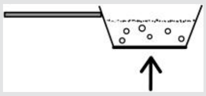
Metals

Physical Properties

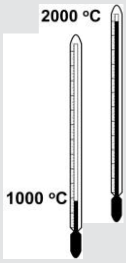
Non-Metals



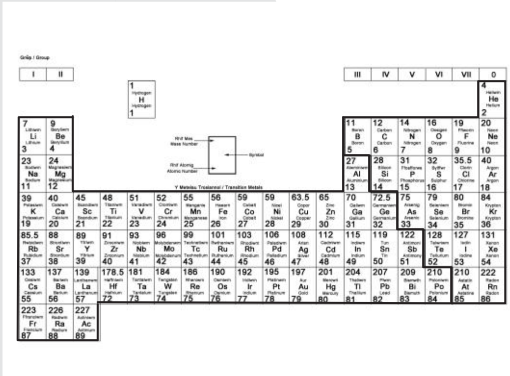
Conduct Electricity



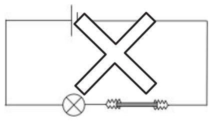
Conduct Heat



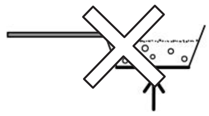
High Melting point Boiling point



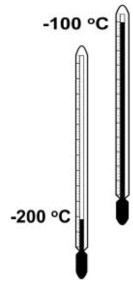
Does not conduct Electricity

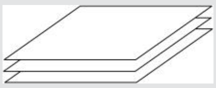


Does not conduct heat



Low Melting point Boiling point

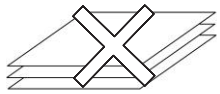


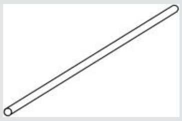


Malleable

Can be hammered into sheets

Not malleable

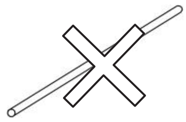




Ductile

Can be pulled into wires

Not ductile



Group 1

Alkali Metals

1 electron on the outer shell

Physical Properties

7 Lithiwm **Li** Lithium 3
23 Sodiwm **Na** Sodium 11
39 Potasiwm **K** Potassium 19
85.5 Rwbidiwm **Rb** Rubidium 37
133 Cesiwm **Cs** Caesium 55
223 Ffranciwm **Fr** Francium 87

All metals look dull on the outside.

Over a short period of time a layer of oxide makes the metal look dull.

The inside of every metal is shiny

It is possible to cut every metal with a knife

They are kept in **oil** to prevent them from reacting with oxygen and moisture in the air.

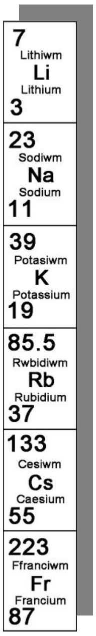
Their **density** is low therefore most float

The boiling point and melting point are lower than many other metals

Group 1 | Alkali Metals

Chemical Properties

They react with **oxygen** and water.



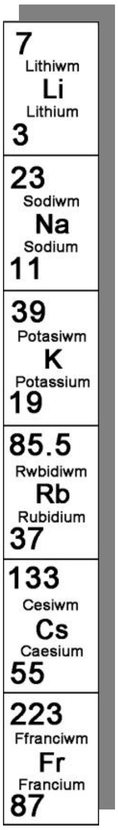
Alkali metals with **oxygen** and **water**

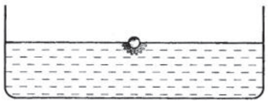
Oxygen causes the surface of the metal to turn dull by forming a layer of oxide

eg. potassium + oxygen ⟶ potassium oxide

$$4K(s) + O_2\,(g) \longrightarrow 2K_2O(s)$$

The oxide layer forms quicker as we go down the group





Alkali metals with **water**

The metal creates alkali as it reacts water (purple with universal indicator)

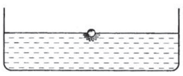
The metal with water creates hydrogen

The metal **floats, moves** and **fizzes.**

eg. lithium + water ⟶ lithium hydroxide + hydrogen

$$2Li(s) + 2H_2O\,(l) \longrightarrow 2LiOH\,(aq) + H_2\,(g)$$

Sodium



In addition this **moves quicker** and has a **ball shape.**

Potassium

In addition it **moves quickly** and has a **lilac flame.**

Safety Precautions

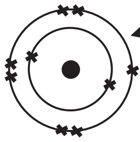
Use safety goggles
Use a small piece of metal in the water
Use tongs to hold the metal

Group 7 — Halogens

Physical Properties

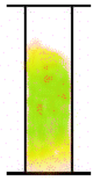
They react with **group 1 metals and salts**

19 Fflworin **F** Fluorine 9
35.5 Clorin **Cl** Chlorine 17
80 Bromin **Br** Bromine 35
127 Iodin **I** Iodine 53
210 Astatin **At** Astatine 85



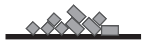
7 electrons on the outer shell

Chlorine — Yellow Green Gas



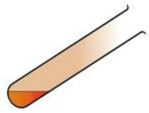
Bromine — Orange Red Liquid

Iodine — Shiny Grey Solid



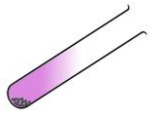
State and appearance

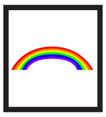
Poisonous Vapours



Bromine
Orange gas

Iodine
Purple gas





Vapours With colour

Halogen with **group 1 metals**

7 Lithiwm **Li** Lithium 3
23 Sodiwm **Na** Sodium 11
39 Potasiwm **K** Potassium 19
85.5 Rwbidiwm **Rb** Rubidium 37
133 Cesiwm **Cs** Caesium 55
223 Ffranciwm **Fr** Francium 87

Least reactive

They create white solids.

The halogens become less reactive down the group

eg. potassium + chlorine ⟶ potassium chloride

$$2K(s) + Cl_2(g) \longrightarrow 2KCl\ (s)$$

Most reactive

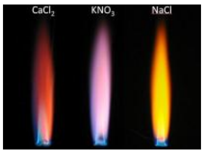
19 Fflworin **F** Fluorine 9
35.5 Clorin **Cl** Chlorine 17
80 Bromin **Br** Bromine 35
127 Iodin **I** Iodine 53
210 Astatin **At** Astatine 85

Safety Precautions

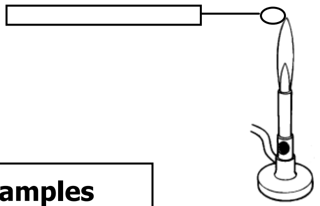
Use safety goggles
Use a fume cupboard
Use plastic gloves

Group 7 | The Halogens | **Identifying compounds**

Metal	**Flame test**
Lithium	Red
Sodium	Yellow-orange
Potassium	Lilac



Non-metal	**Silver Nitrate test**
Chloride	white
Bromide	cream
Iodide	yellow



Flame Test
(to identify the metal)

Silver Nitrate Test
(to identify non metal ions)

Examples
Lithium Chloride
Sodium Iodide
Potassium Bromide

Red
due to lithiwm

Yellow-orange
due to sodium

Lilac
due to potassium

White precipitate
due to chloride ions

Yellow precipitate
due to iodide ions

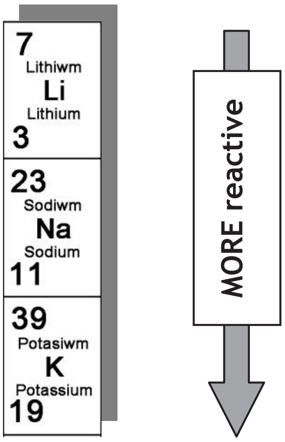
Cream precipitate
Due to bromide ions

Higher Tier: Silver Nitrate ionic equation:
e.e. Ag^+ (aq) + Cl^- (aq) $\Rightarrow$ AgCl (s)

Atomic Spectroscopy (Higher Tier): This method is used to identify and show the amount (concentration) of specific atoms/ions present in the sample.

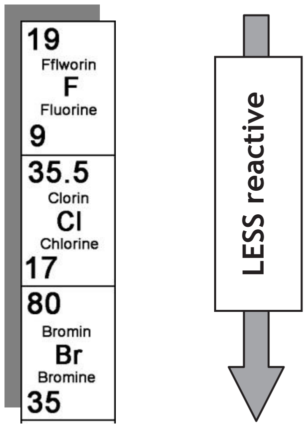
Higher Tier

Alkali Metals	Group 1 metals become more reactive down the group.

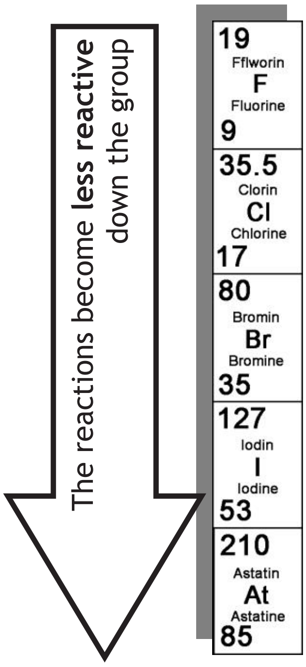


- **Group 1 metals react by <u>losing</u> 1 electron**
- There are more orbits as you go down the group.
- The outer electron becomes further from the nucleus.
- Due to less attraction it is easier to lose an electron.

The Halogens	Group 7 non-metals become less reactive down the group.



- **Group 7 non-metals react by <u>gaining</u> 1 electron**
- As you go down the group there are more orbits, because of this it is harder to attract an electron, they become less reactive



Displacement reactions

This reaction shows the trend in reactivity down the group

Chlorine → Sodium Bromide ⇨ Sodium Chloride + **Bromine**

Bromine → Sodium Iodide ⇨ Sodium Bromide + **Iodine**

$$Cl_2(g) + 2NaBr(aq) \longrightarrow 2NaCl\ (aq) + Br_2(aq)$$

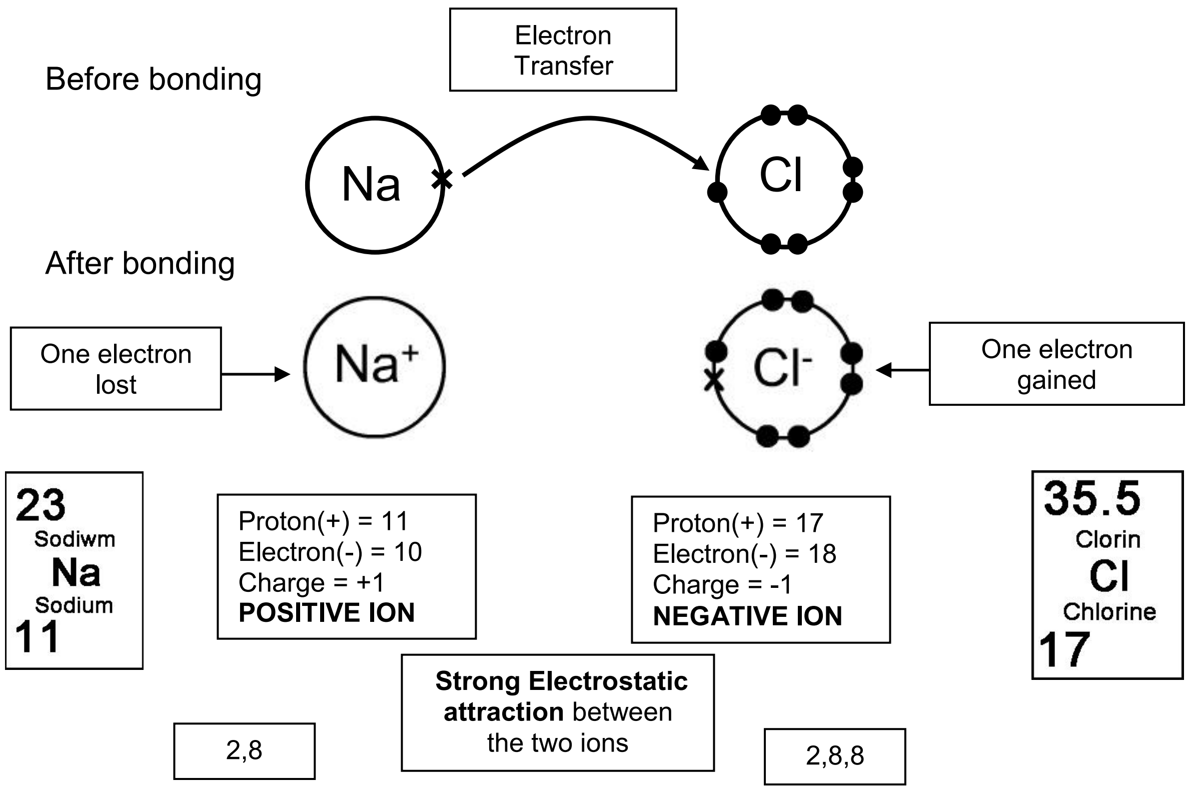
Bonding and Structure

When a chemical reaction occurs new bonds are formed. The can form by the **transfer of electrons** or by the **sharing of electrons.**

Ionic Bonding

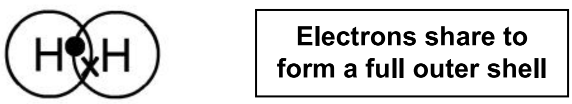
Charged particles called **ions** are formed when electrons are transferred between atoms during chemical bonding.

e.g.
When sodium chloride (NaCl) forms, one electron is transferred to chlorine. This will form a **full stable outer shell** (like noble gasses) for the two particles ('atom').



Covalent Bond

When hydrogen gas(H_2) forms electrons are shared between two atoms to form a molecule. There is **no charge** on molecules.



Ionic Bonding

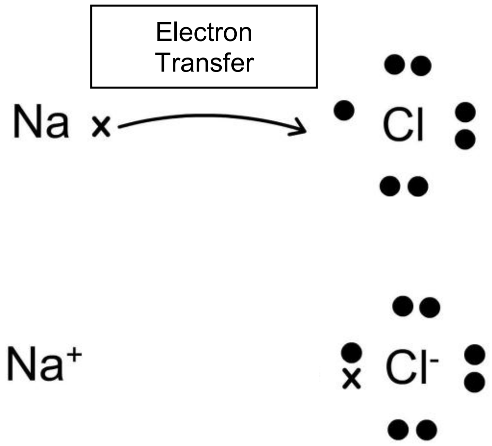
Here is the information needed to draw ionic bonding diagrams.

Check the ionic charges by using the ions table at the back of the examination paper.

Sodium Chloride (NaCl) **Group 1 with Group 7**

Before Bonding

After bonding

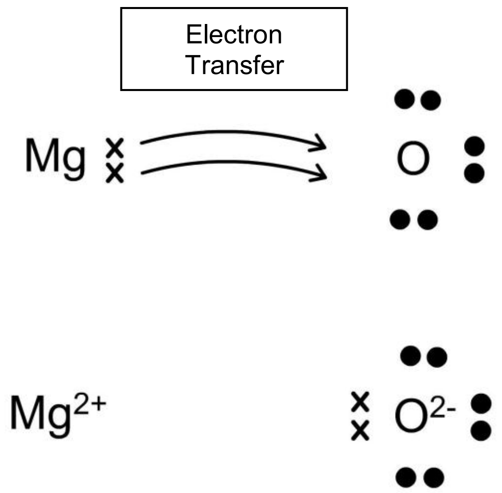


Strong electrostatic charge between the ions

Magnesium oxide (MgO) **Group 2 with Group 6**

Before Bonding

After bonding

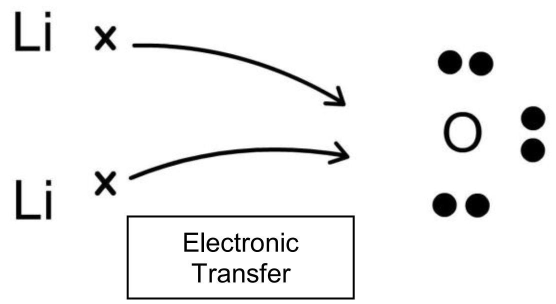


Strong electrostatic charge between the ions

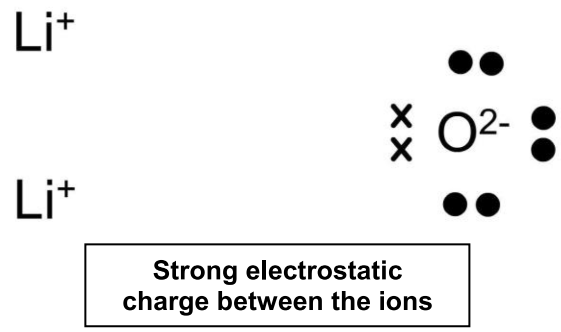
MgO has a higher melting point than NaCl as the charges are greater – there is more attraction between ions

Lithium Oxide (Li_2O) **Group 1 with Group 6**

Before Bonding

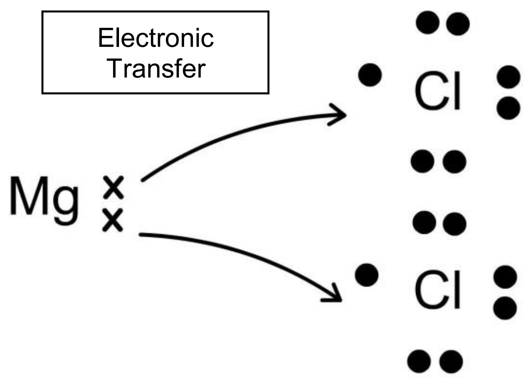


After bonding

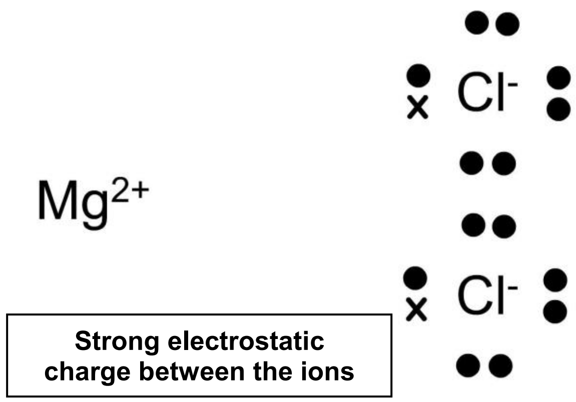


Magnesium Chloride ($MgCl_2$) **Group 2 with Group 7**

Before Bonding

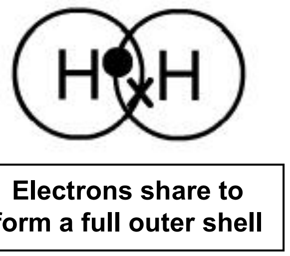


After bonding

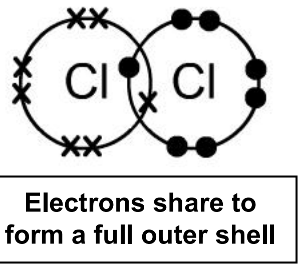


Covalent Bonds

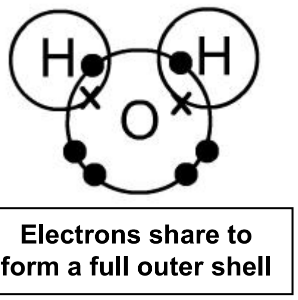
Hydrogen (H_2)



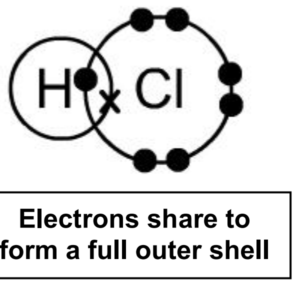
Chlorine (Cl_2)



Water (H_2O)

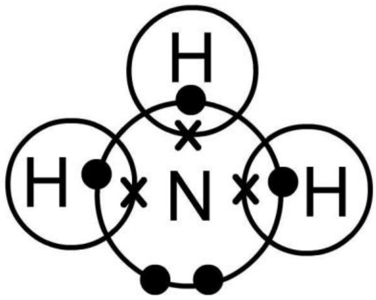


Hydrogen Chloride (HCl)

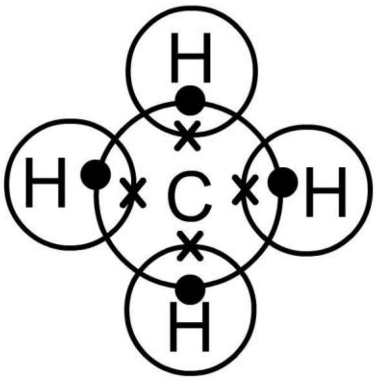


Covalent Bonding

Ammonia (NH_3)

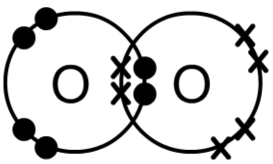


Methane (CH_4)

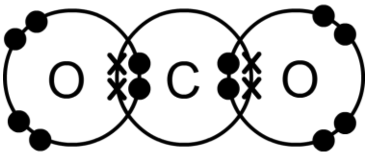


Covalent examples with double bonds (Higher Tier)

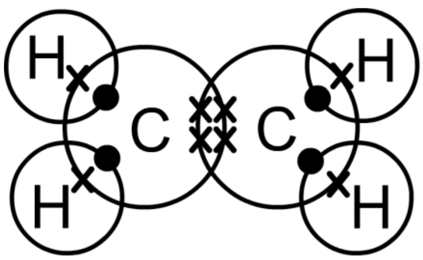
Oxygen (O_2)



Carbon Dioxide (CO_2)

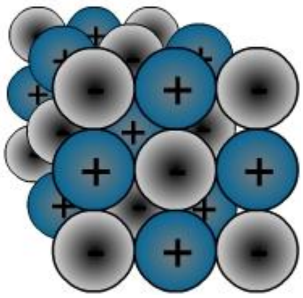


Ethene (C_2H_4)



Simple and Giant structures

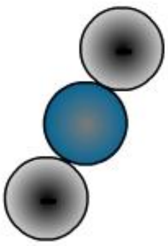
Giant ionic structure(e.g. sodium chloride, magnesium oxide),



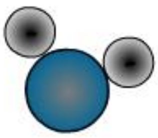
High Melting and Boiling points
Solubility = Dissolved in water

Simple molecular structure (e.g. carbon dioxide, water)

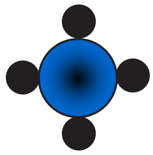
Low Melting and Boiling points
Solubility = Dissolved in water



CO_2



H_2O (water)

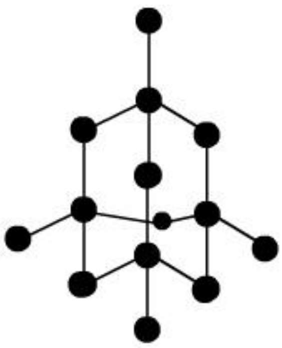


CH_4 (methane)

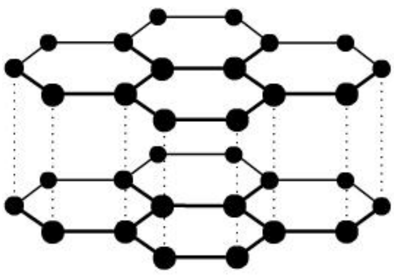
As the forces between molecules are weak the melting and boiling points are low

Giant covalent structure (e.g. diamond, graphite),

Very High Melting and Boiling points
Solubility = Does not dissolve in water

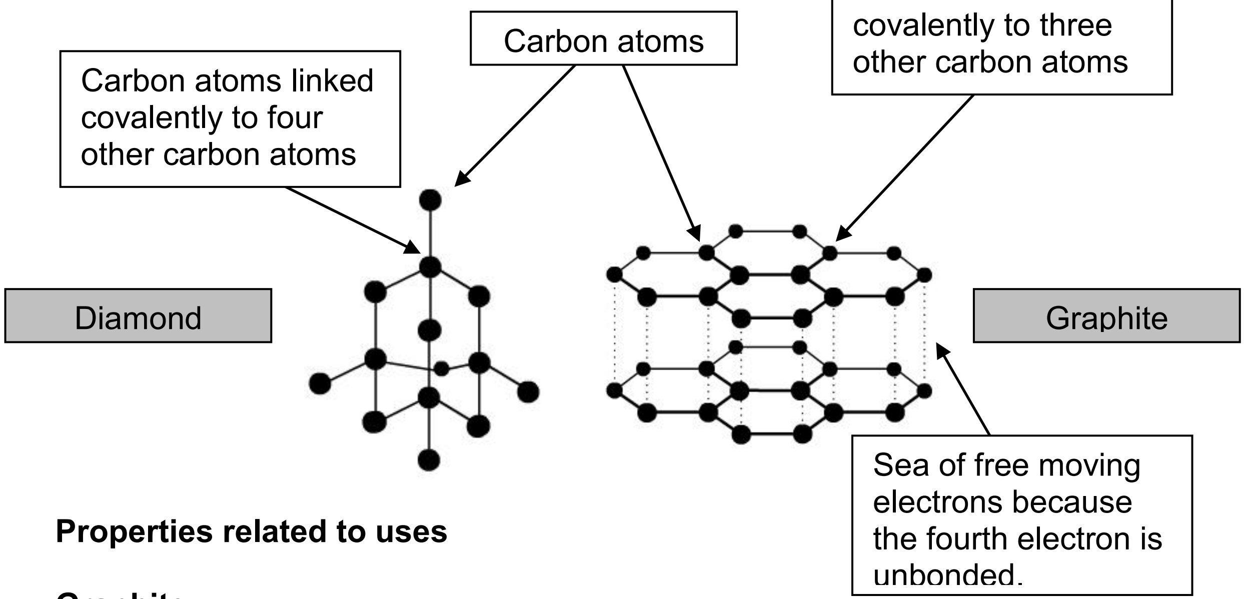


Diamond



Graphite

Diamond and Graphite



Properties related to uses

Graphite

Appearance	Grey/black shiny solid
Hardness	very soft
Conductivity	Conducts electricity
Melting point	Very high over 3600ºC

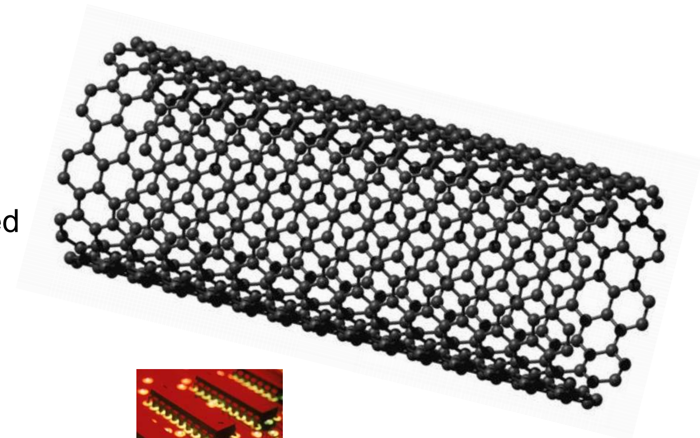
Uses	Pensil lubricants

Diamond

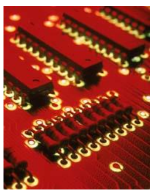
Appearance	Transparent/crystalline
Hardness	very hard
Conductivity	Electrical insulator
Melting point	Very high over 3500ºC

Uses
Gemstones
Glass cutting, Drill bits

Carbon nanotubes



- They are roles of carbon hexagons similar to graphite.
- They conduct electricity / used in semi-conductors
- The have a very small diameter which is about 10,000 times less than a human hair.
- They are extremely strong.
- Very low density
- They are proposed to be used in **small electronic circuits**



Materials

The uses of everyday materials depends on their properties.

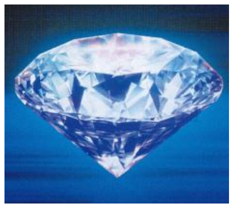
Aluminium

Low density

Ceramic

Hardness, strength

Diamond



Hardness, lusture

Aluminium Oxide

Low friction and wear

Teflon

Low friction high Mpt

Glass

Hardness transmits light

The properties of all materials, are determined by:-

the types of atoms present,
the types of bonding between the atoms,
and the way the atoms are packed together

Metals are giant structures with free electrons

Metallic bonds are strong, so metals can maintain a regular structure and usually have high melting and boiling points.

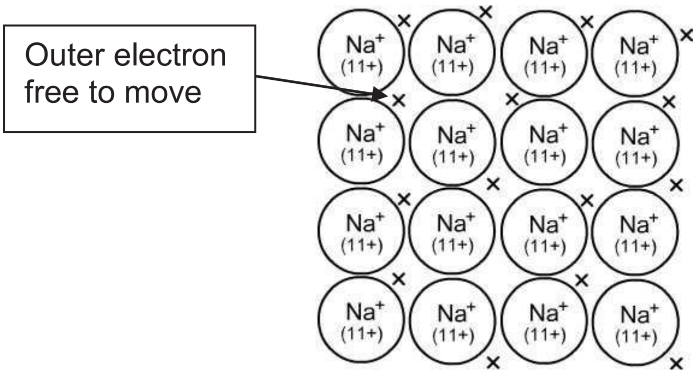
Outer shell electrons of metals are free to move.

The strength of bond in a metal is the force of attraction between the metal ions and free moving electrons.

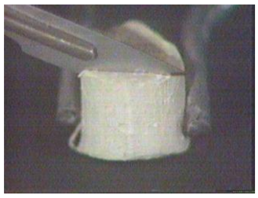
More free electrons and more protons in the ions increase the strength of a metal.

Metallic bonding

Free electrons allow electricity to be carried as well as heat energy.



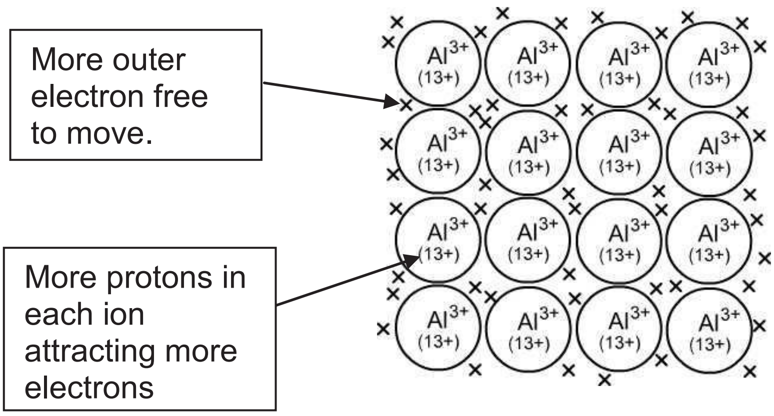
Sodium metal



These electrons allow metals to conduct electricity and conduct heat.

Metals are also malleable (hit into shape) and ductile (drawn into wires) because the free electrons allow the metal atoms to slide over each other.

Having more free electrons in the outer shell e.g. Aluminium compared to sodium above and more protons in each nucleus the forces of attraction for the free electrons is greater. This makes the metal stronger.



Aluminium metal

Smart Materials

The term *smart material* has been given to a range of **modern** materials.

A variety of smart materials exist which can change shape and colour, retain shape after bending and can expand greatly with different liquids.

This means that their **properties** change.

The materials properties change with a change in the surroundings, such as changes in **temperature**, **light**, **pH**.

Thermochromic Paint

This smart material has the ability to change colour with a change in temperature.

The boat seen in this t shirt appears because thermochromic paint has been used. Under cold conditions the pigments are white, but when heated in warm weather, or if the person becomes warmer the pigments change colour to reviles a picture of a boat.

Photochromic Paint

This material has the ability to change colour with a change in the light strength.

The sunglass lenses become darker when exposed to strong light and become lighter in weak light

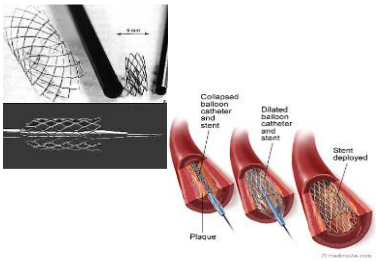
Smart Materials

Shape memory alloy

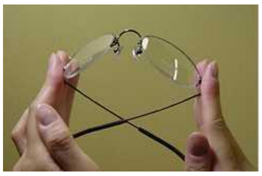
This smart material is a mixture of metals (alloy) that retains its original shape when heated

A mixture of nickel and titanium make up the alloy called **NiTi** or **nitinol**.

This metal can be bent into any shape at low temperature, but when heated it can remember its original shape so it bends back very quickly. It can be used as a **coffeepot thermostat**.



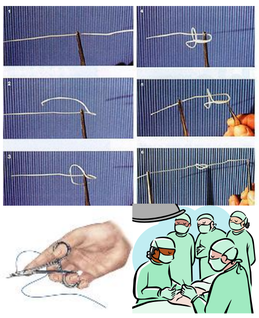
Stents are metal structures that can be inserted in veins to prevent them from sticking together. The stents are cooled to below 37C so they change shape and become thinner, when inserted into the vein it warms up to body temperature and changes shape to open the vein.



This alloy can also be used in super elastic **spectacle frames**. These retain their original shape after bending them.

Shape memory polymer

This smart material is a form of plastic that can retain its original shape when heated. These **could** be used for:-

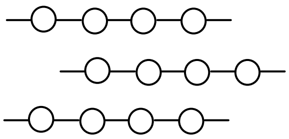


Surgical stutures are threads of smart polymer that can tighten to the right tension automatically when heated.

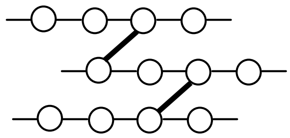
Car bumpers could be made from this material. If the car body such as bumpers were dented, on heating they would regain their original shape.

Polymer gels

This smart material is a form of plastic with cross linkage (see diagram below) that can swell or shrink with different liquids.



No cross linkage across polymer

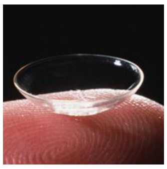


Cross linkage across polymer

These gels can swell to **1000 times** their volume depending on the **temperature or pH**.

Artificial snow - this smart material expands greatly by adding water. It can also shrink by heating.

Nappies - this smart material is similar to artificial snow and expands greatly when it becomes wet.



Contact Lens - within these lenses there is a smart material which prevents them from drying up. They can then be used for weeks instead of days.

Artificial muscles - gels can be used to swell and shrink creating an artificial muscle.

Robot actuators - gels can be used to swell and shrink creating movement.

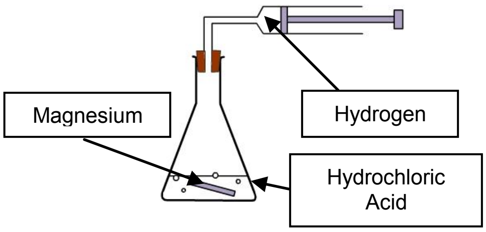
Toxic Chemical absorber - gels can be used to block dangerous chemicals in the body.

Rates of Reactions

It means the speed of a reaction

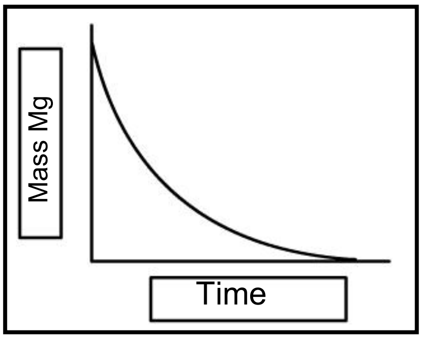
There are four ways 2 increase the rate of the reaction on the right..

1. change **concentration** of the acid (acid strength)
2. change **temperature** of the acid
3. change **surface area** of the magnesium (crush into powder)
4. use a **catalyst**

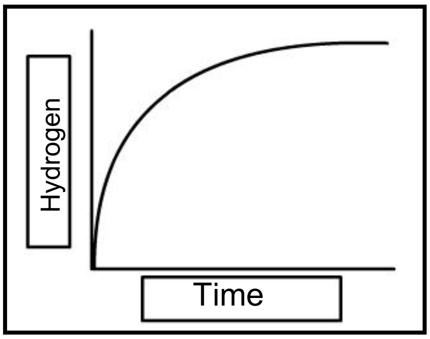


magnesium + hydrochloric acid ⟶ magnesium chloride + hydrogen

Reactants	Products
The substances that react together.	The substances that are produced.



The reactants are used up

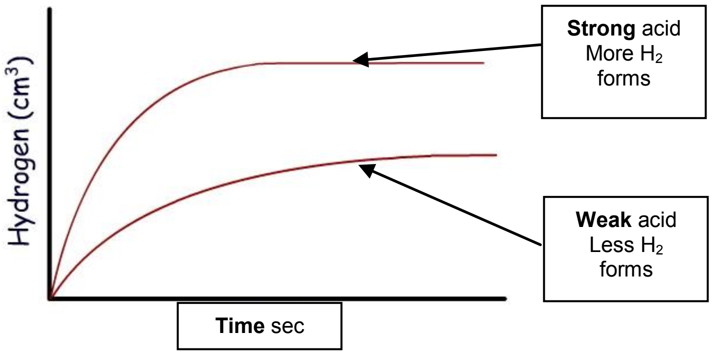


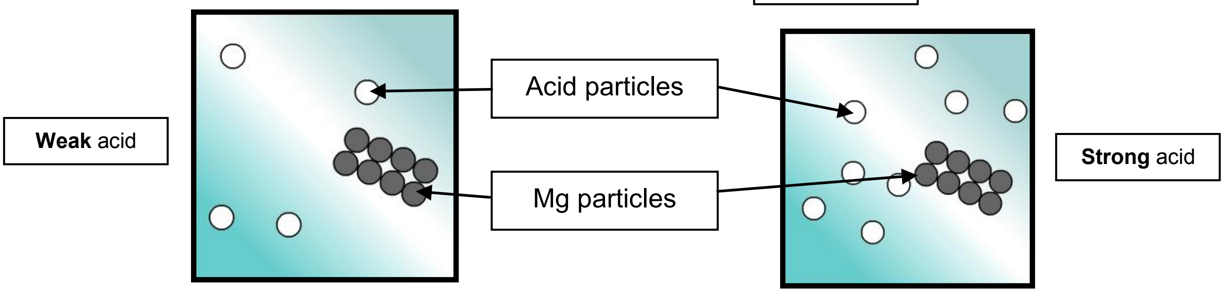
The products form

Collision Theory: Particles must collide with enough energy – these are called successful collisions

Change concentration

If the strength of the acid is weak, it will take more time for the hydrogen to be produced.



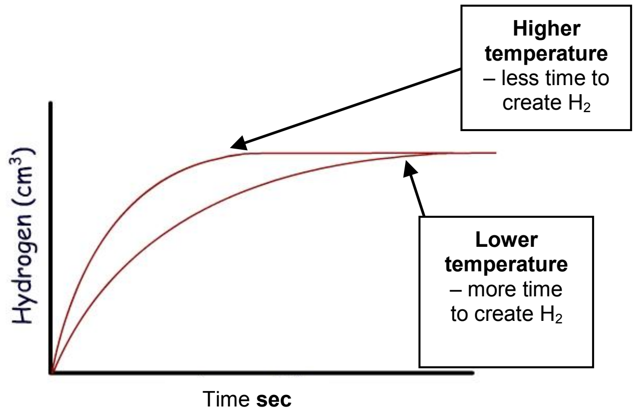


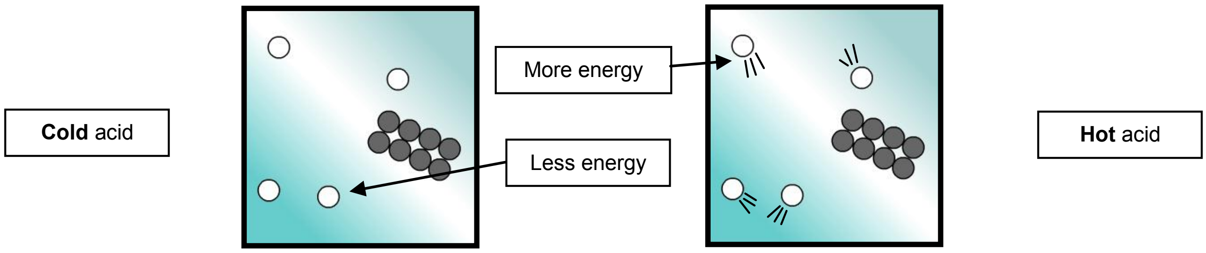
As there are **less acid particles** in weak acid the chance of them colliding with magnesium successfully is lower.

Rates of Reaction	It means the speed of a reaction

Change temperature

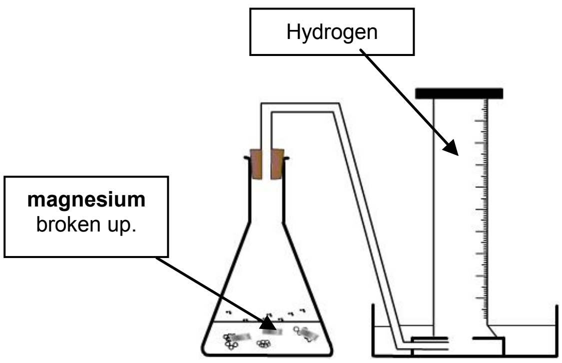
If the temperature of the acid is higher, it will take less time for hydrogen to be produced

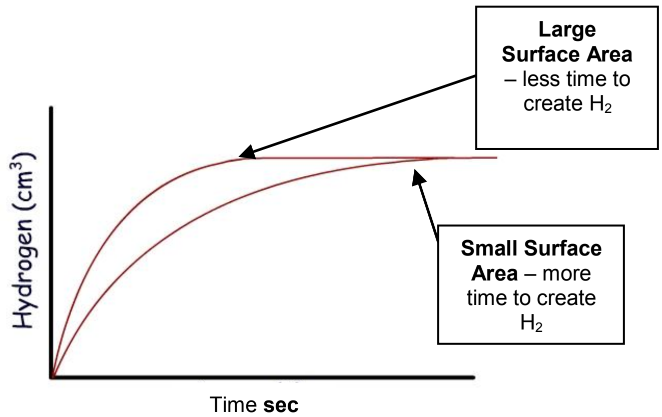




When the temperature is higher the particles have **more energy**. As a result the particles collide more frequently. The collisions have more energy – there are more successful collisions.

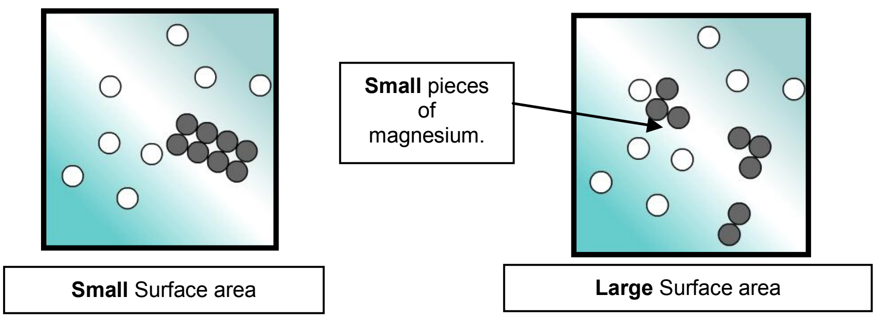
Change Surface Area





If magnesium is cut into **little pieces**, there will be more surface area for the acid to react

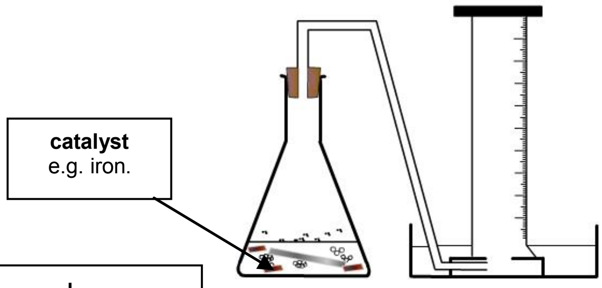
There is **more chance** for the particles to collide successfully if the **surface area is large.**



Rates of Reaction | It means the speed of a reaction

Using a Catalyst

If a catalyst (e.g. iron) is added to the acid and magnesium the reaction will be faster.



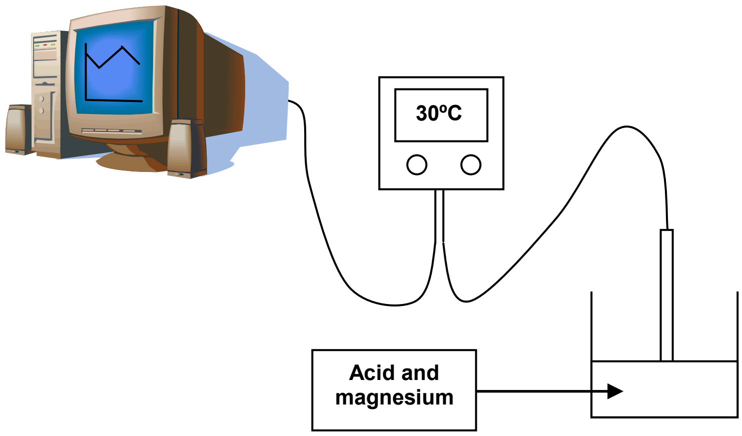
Catalyst

a substance that speeds up a reaction but is not used up (e.g. if 1g of catalyst is used, there will be 1g of catalyst left)
A catalyst can be reused over and over.

Different catalysts are used for different reactions. e.g. manganese oxide is a catalyst which is used to create oxygen quickly from hydrogen peroxide.

The development of better catalysts is extremely important as it can lead to new ways of making materials that may use less energy, use renewable raw materials or use fewer steps.

Using Sensors



Advantages of using sensors

Recording advantages
A number of results per second can be collected

Instant showing of results
Screen to show results instantly

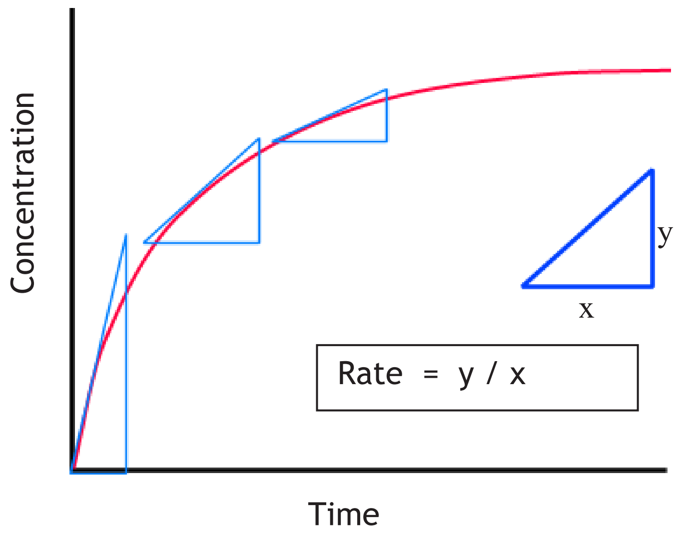
Long term collection of results
(Can collect results day and night without a break)

Types of sensors

- Light sensors
- Temperature sensors
- pH sensors
- Gas sensors

Calculating rate of reaction

By drawing a tangent to the curve we can calculate the rate at any point, the steeper the tangent the faster the reaction.

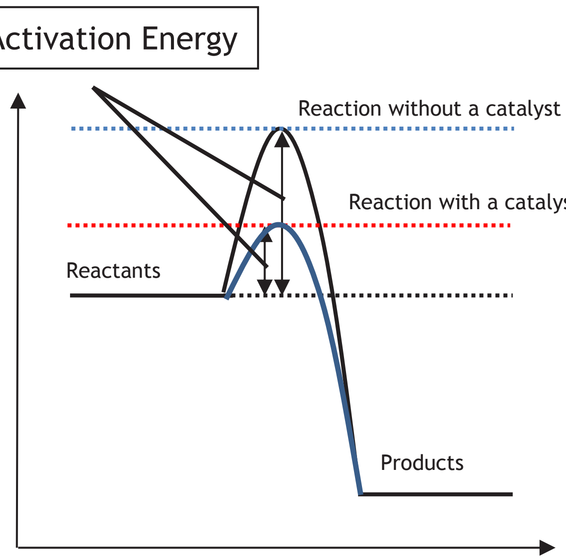


More about temperature

The energy of a collision is very important, only those collisions that have enough energy lead to reaction (these are known as successful collisions). The minimum energy required for a reaction to take place is called the Activation energy.

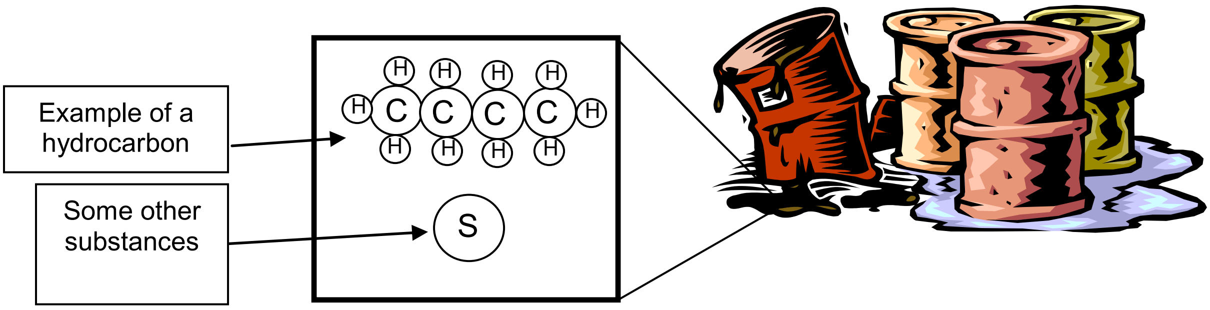
More about Catalysts

A catalyst reduces the activation energy, it provides an alternative pathway for the reaction



Fractional Distillation

Crude oil is a mixture of different substances, most of them being hydrocarbons

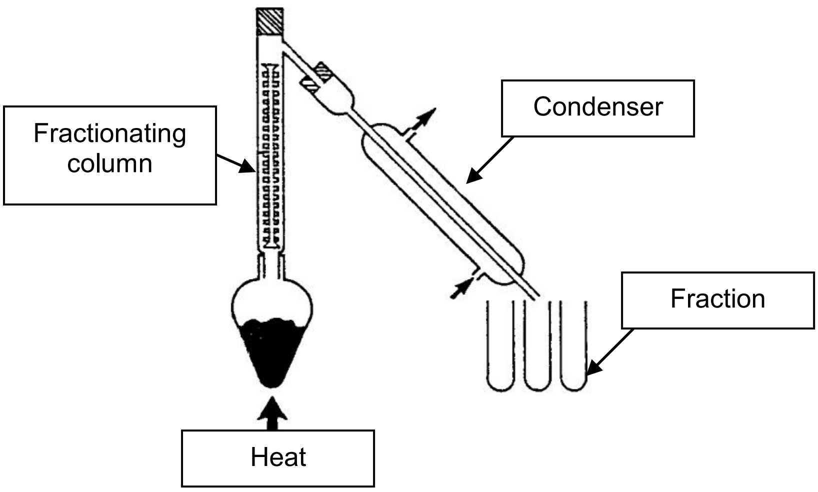


Hydrocarbons are molecules which contain the elements hydrogen and carbon only.

Fractional Distillation – it is possible to separate hydrocarbons by fractional distillation because hydrocarbons boil at different temperature ranges

Fractional Distillation in a laboratory

The reaction is carried out in a fume cupboard as poisonous gases such as sulphur dioxide can form.



As some of the hydrocarbons have similar boiling points a group of them will collect together. **Fraction** is the name given to a group of hydrocarbons that collect this way.

The hydrocarbon boiling point increases with the size of the carbon chain.

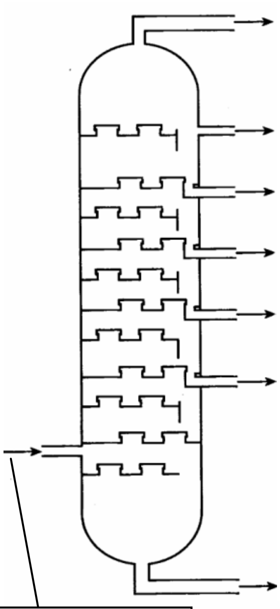
In the industrial process the crude oil is vaporized. The vapour is let into the column where it is hot at the bottom an cools up the column. The fractions with shorter chains have lower boiling points and can condense higher up the column. The longer hydrocarbons condense at a lower level in the column.

Fractional Distillation

Crude oil is separated into fractions

The process is called **Fractional Distillation**

Fractionating column



Heated Crude oil

Fraction	Number of carbon atoms in a chain	Boiling point range / ˚C	Use
Gas	1 – 4	-160 to 25	Fuel
Petrol	4 – 12	40 to 100	Car fuel
Naphtha	7 – 14	100 to 150	Chemicals
Kerosene	11 – 15	150 to 250	Jet fuel
Diesel oil	15 – 19	250 to 350	Heating fuel
Lubricating oil	20 – 30	over 350	Car oil
Bitumen	C30 – above	over 400	Road pitch

Crude oil is separated into less complex mixtures, these are called fractions. Fractions contain hydrocarbons with **boiling points in the same range**, e.g. the petrol fraction has hydrocarbons with boiling points in the range 40-100 ˚C

Long chain hydrocarbons are at the **bottom** of the column as they do not boil until a very high temperature.

Some of the fractions are used as **fuels** (e.g. kerosine - aeroplane fuel) others are further processed by **cracking**.

Properties of the fractions

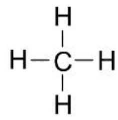
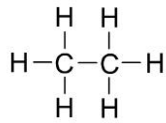
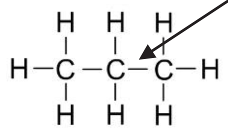
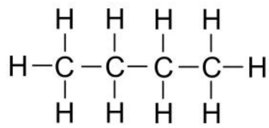
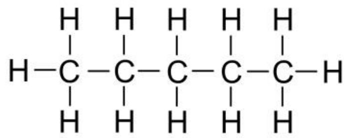
Short chain → Long chain

As the length of the chain increases:

1. The colour of the fraction turns from colourless - yellow - brown.
2. They are harder to ignite.
3. They burn dirtier.
4. They get more viscous

Alkanes

These are hydrocarbons with **single covalent bonds** between the carbon atoms. They are referred to as **saturated hydrocarbon** for this reason. Alkanes have the general formula $\mathbf{C_nH_{2n+2}}$

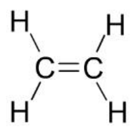
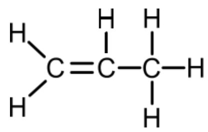
Name	Formula	Structural Formula
Methane	CH_4	
Ethane	C_2H_6	
Propane	C_3H_8	
Butane	C_4H_{10}	
Pentane	C_5H_{12}	

Single bond

Alkanes are fairly unreactive, they combust well only.

Alkenes

When there are **double bonds** between two carbon atoms the name given to the group is **alkenes**. For this reason they are described as **unsaturated** molecules. Alkenes have the general formula $\mathbf{C_nH_{2n}}$

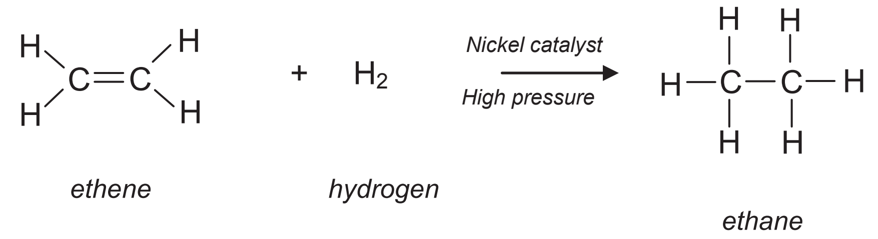
Name	Formula	Structural formula
Ethene	C_2H_4	
Propene	C_3H_6	

As a result of the double bond the alkenes are very reactive molecules, the double bond can be broken to form single bonds with other atoms (addition reaction).

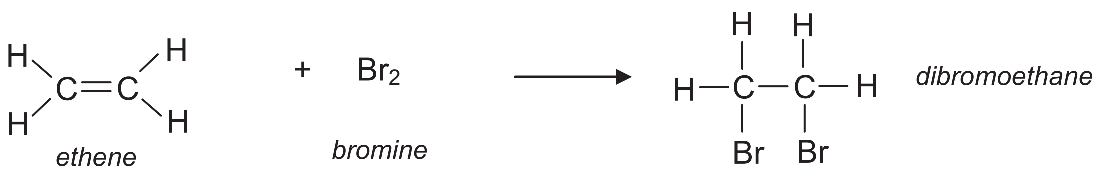
Alkenes - Addition Reactions

Reaction with Hydrogen (Hydrogenation) (Higher Tier)

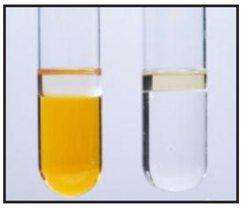
Can you write the equation for propene?



Reaction with Bromine Water (Higher Tier)



This reaction is a way of identifying alkenes. Brown bromine water turns colourless

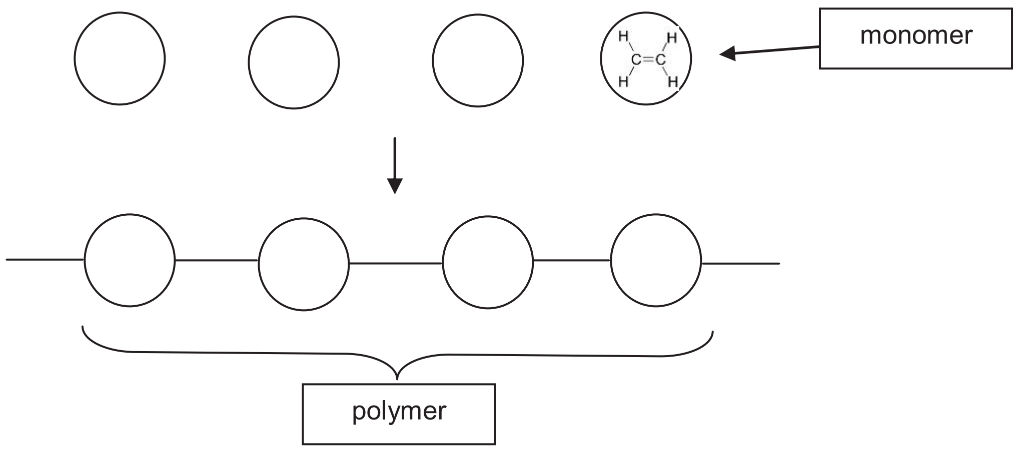


Addition Polymerisation

Creating Plastics

When small **reactive** molecules such as ethene react together in a chemical reaction a long chain molecule is formed called a **polymer**.

Monomer is the name given to small reactive organic molecule

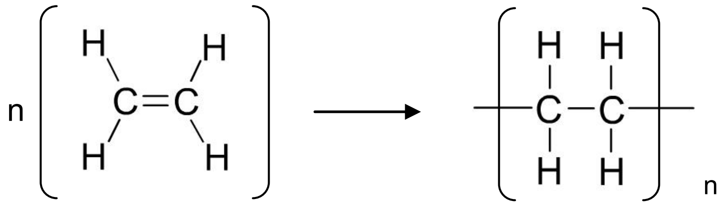


The process whereby **monomers link** to create a polymer is **polymerisation**.

The type of polymerisation that happen here is **addition polymerisation** as there is only **one product** formed

Addition Polymerisation

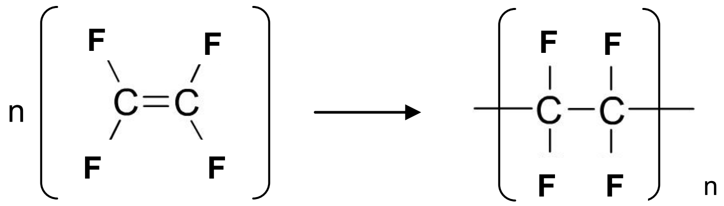
The process of making **poly(ethene)** is an example of addition polymerisation. The unsaturated monomers used are **ethene**.



ethene polythene

$$n(H_2C{=}CH_2) \longrightarrow \left(CH_2 - CH_2\right)_n$$

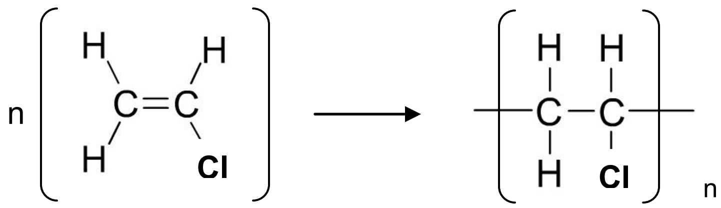
PTFE / Poly(tetrafluoroethene) /Teflon



Tetrafluoroethene Poly(tetrafluoroethene)

$$n(F_2C{=}CF_2) \longrightarrow \left(CF_2 - CF_2\right)_n$$

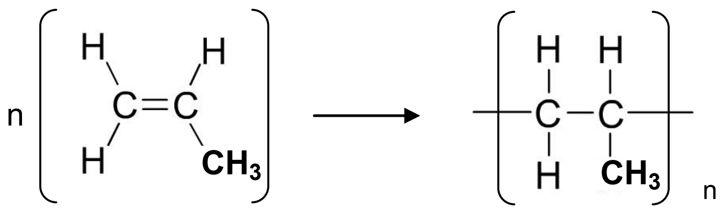
Polyvinyl chloride (PVC)



Vinyl chloride Polyvinylchloride

$$n(H_2C{=}CHCl) \qquad \left(CH_2 - CHCl\right)_n$$

Polypropene



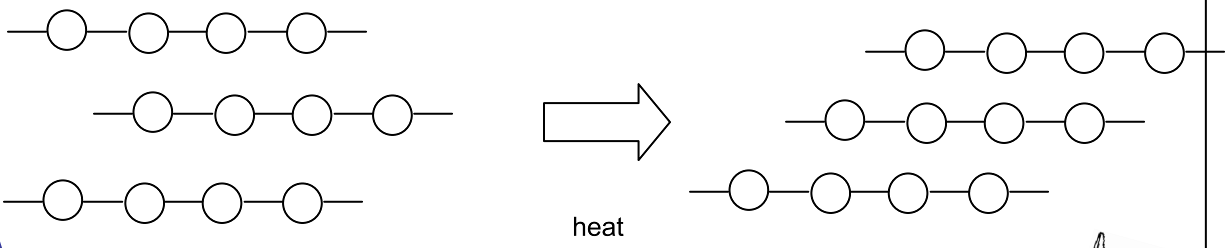
propene Polypropene

$$n(H_2C{=}CHCH_3) \qquad \left(CH_2 - CHCH_3\right)_n$$

Types of Plastics

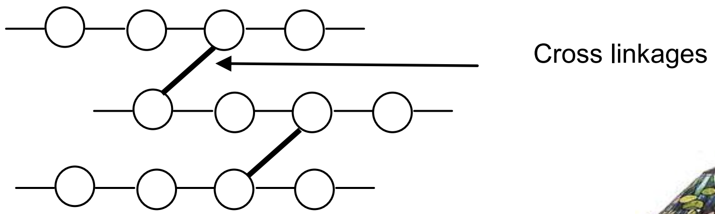
Plastics are classed on the basis of their reaction on **heating**, there are 2 types

Thermoplastics – when these are heated they lose their shape. This is because the hydrocarbon chains are not linked together, as they are heated the chains slide over each other causing the plastic to melt. Poly(ethene), polypropylene, PTFE and PVC are examples



e.g. plastic bags, home containers e.g. domestos bottle

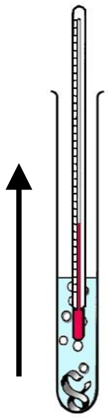
Thermoset – these have strong covalent bonds between chains. The **cross linkages** make the structure rigid, because of this they do not melt upon heating. They can only be heated once into shape Bakelite and melamine are examples



E.g. saucepan handles, Electrical light fittings;

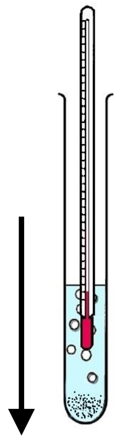
Energy in reactions

Changes in temperature happen often during chemical reactions.



Exothermic reactions

A reaction where temperature rises.
e.g. magnesium and acid



Endothermic Reaction

A reaction where temperature falls.
e.g. ammonium nitrate and acid

Here is a reaction for making ammonia

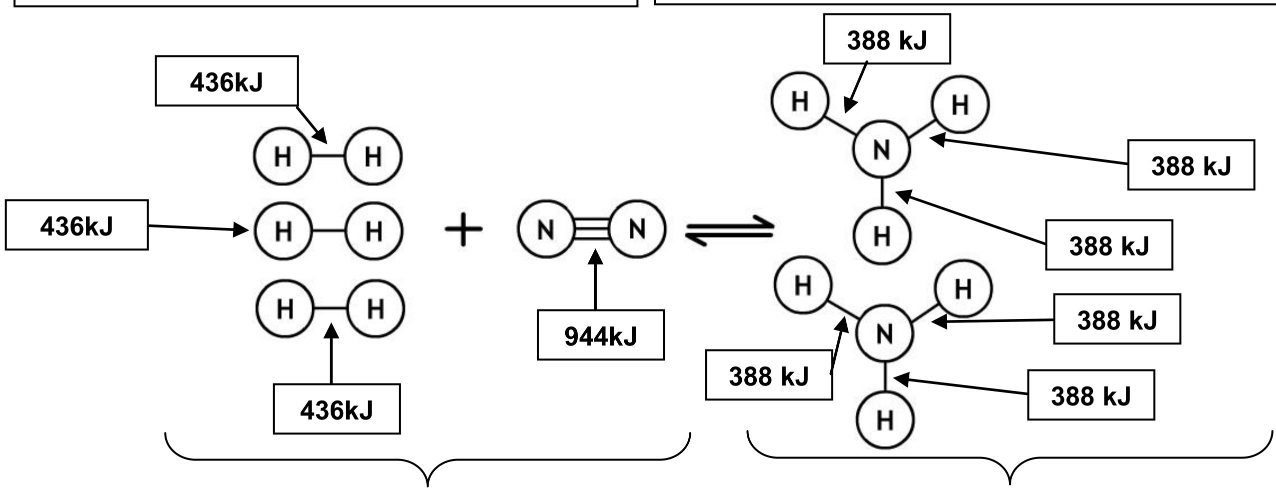
Hydrogen + Nitrogen $\rightleftharpoons$ Ammonia

$3\,H_2(g) + N_2(g) \rightleftharpoons 2\,NH_3(g)$

To create the product ammonia its is necessary to break bonds between hydrogen and nitrogen (the reactants).

To **break bonds** energy in **required**.

Creating bonds **releases** energy.



Bonds Broken
436 + 436 + 436 + 944 = 2252kJ

Bonds Made
388 x 6 = 2328kJ

Overall Energy Change = Bonds broken – Bonds made

In an **endothermic** reaction the number would be **positive**.

2252 - 2328 = -76kJ

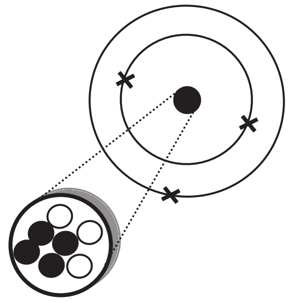
Exothermic Reaction
- Because energy is released (negative number)

Chemical Calculations

Every atom has different mass. This is determined by the number of protons and neutrons in the nucleus.

A lithium atom has a mass of **7**.

3 protons and 4 neutrons



Relative atomic mass (A_r) is a way of saying how heavy different atoms are compared to each other.

The $\mathbf{A_r}$ of Lithium is 7 and that of Carbon is 12. We use the top number to determine this; this is called the mass number

Relative formula mass or **relative molecular mass** ($\mathbf{M_r}$) is the mass for a compound (e.g. $MgCl_2$) so the masses for each element are

Mass numbers →

Mg	**Cl**	**Cl**	
24 +	35	+ 35	= **94**

What is the molecular mass of ammonium sulphate $(NH_4)_2SO_4$?
(N=14, S=32, O=16, H=1)

Calculate $(NH_4)_2$ first		= 14+1+1+1+1 = 18 x 2 =	36
		S=	32
	4 oxygen atoms	16 x 4 =	64
		Mr=	***132***

Calculating % composition

After calculating M_r it is possible to calculate % composition, this shows how much of a specific element is in a compound in percentage form

e.g. % Mg in $MgCl_2$ = $\dfrac{\text{total } M_r \text{ of Mg in } MgCl_2 \text{ x } 100}{M_r\, MgCl_2}$

$\dfrac{24}{94}$ x 100 = 25.5 %

Calculating Reacting Masses

By using relative atomic masses and (Ar) and relative molecular masses (Mr) it is possible to calculate how much of a product is produced or how much reactants are needed.

e.g. (product calculation)

What is the mass of **magnesium oxide** is produced when 60g of magnesium is burned in air?

Symbol Equation

$$2Mg + O_2 \rightarrow 2MgO$$

Mr =	2×24 48	2 (24+16) 80

Therefore 48g (or tonnes) will produce 80g

1g $80 \div 48 = 1.67$g

60g will produce $60 \times 1.67 = 100.2$g

e.g. (reactant calculation)

What is the mass of **magnesium** needed to produce 90g of magnesium oxide?

$$2Mg + O_2 \rightarrow 2MgO$$

Mr =	2×24 48	2 (24+16) 80

Therefore 48g (or tonnes) will produce 80g

Or *80g of MgO will be produced with 48g of Mg*

1g $48\div80=0.6$g

90g will produce $90 \times 0.6 = 54$g

Determining the formula of a compound from experimental data

When 4 g of copper oxide is reduced in a steam of hydrogen, 3.2 g of copper remains.

1. Work out how much oxygen was contained in the compound

$$4 - 3.2 = 0.8 \text{ g}$$

	Cu	O
Divide with Ar	$\frac{3.2}{64}$	$\frac{0.8}{16}$
Divide with smallest	$\frac{0.05}{0.05}$	$\frac{0.05}{0.05}$
Whole number	1	1
	1 Cu	1 O

Formula = CuO

Example 2

Find the formula of iron oxide produced when 44.8g of iron react with 19.2g of oxygen. (Ar Fe = 56 and O = 16)

	Fe	O
Mass	44.8	19.2
Divide with Ar	44.8÷56	19.2÷16
	0.8	1.2
Divide with the smallest value	0.8÷0.8	1.2 ÷0.8
	1	1.5

A formula must have whole numbers therefore

	Fe	O
	2	3

Formula = Fe_2O_3

Calculating reactants or product masses

	Reactants				Products		
	$NaOH$	+	HCl	→	$NaCl$	+	H_2O
	23+16 + 1		1 + 35		23+35		1+1+16
	40		36		58		18
		76				76	
Units		g / tones				g / tones	

Calculating the percentage yield

When we want to create a chemical, the aim is to work carefully and to produce the maximum amount possible.

The amount formed or yield is calculated in percentage. It is very unlikely that 100% yield will be achieved e.g. some might be stuck in filter paper, evaporating dish, the product might react with the air.

Example

Magnesium metal dissolves in hydrochloric acid to form magnesium chloride.

$$\mathbf{Mg_{(s)} + 2HCl_{(aq)} \quad MgCl_{2(aq)} + H_{2(g)}}$$

24g **95g**
(24 + 35.5 + 35.5)

(a) What is the **maximum theoretical mass** of magnesium chloride which can be made from 12g of magnesium?

12g 95/2 = **47.5g**

(b) If only **47.0g** of purified magnesium chloride was obtained after crystallising the salt from the solution, what is the % yield of the salt preparation?

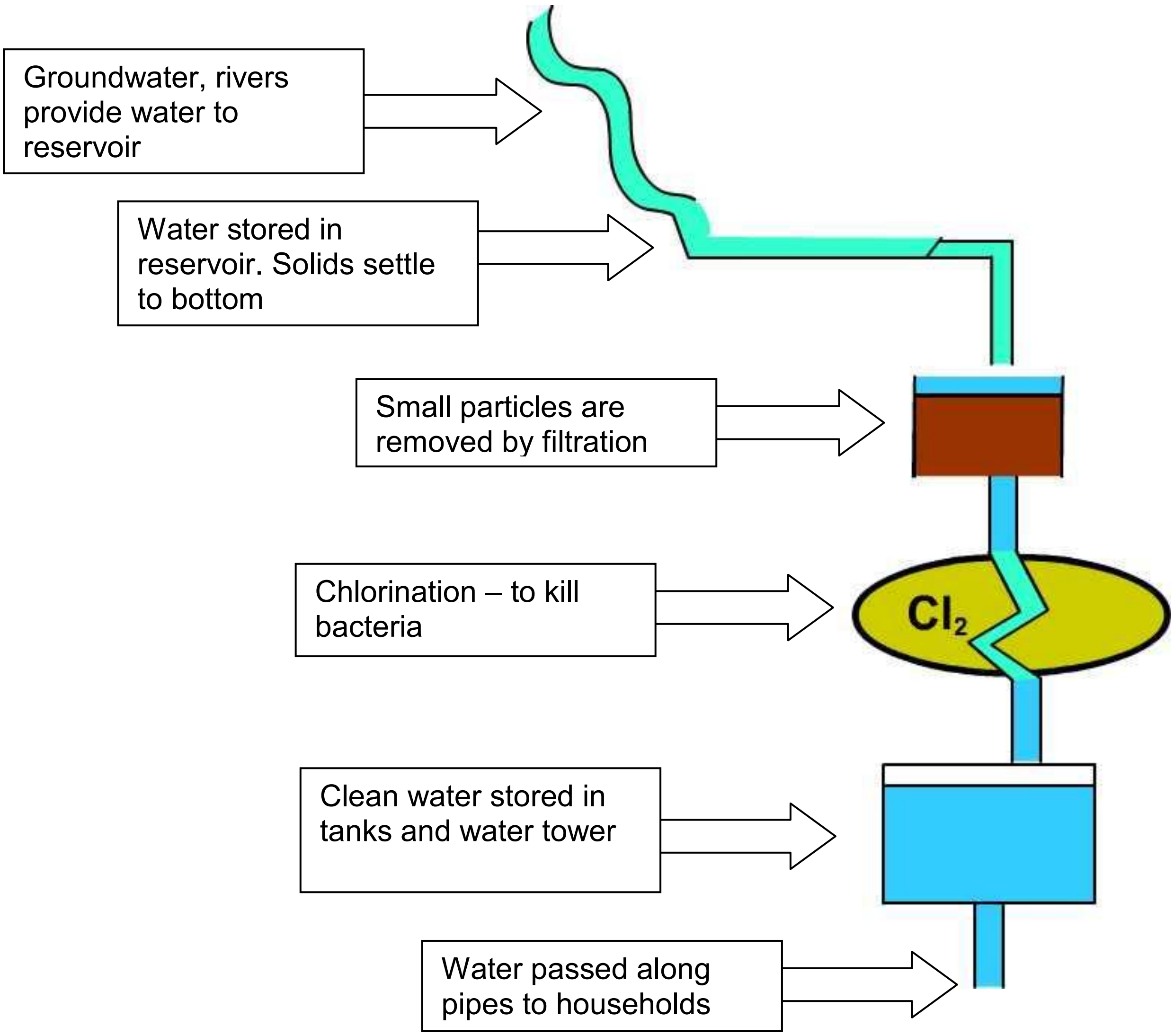
$$\textbf{\% yield} = \frac{\text{actual amount obtained x 100}}{\text{maximum possible}}$$

$$\textbf{\% yield} = \frac{47.0 \times 100}{47.5} = \mathbf{98.9\%} \text{ (to 1 decimal place)}$$

Water

Water is necessary for life to exist. The quality of life depends on the availability of clean water. Water in this country is made drinkable by treating rainwater.

Here are the steps involved in making water drinkable.



Fluoride ions are added to water to strengthen children's teeth in some areas.

Fluoride is not added to water supplies in Wales.

Water Preservation

Although there is ample water on Earth, only a very small fraction is safe for drinking. With an increasing population and developing industry our need for water is larger than ever.

The need for water

We use 150 litres of water each on average every day. The water comes from natural underwater storage, rivers and different reservoirs. During dry conditions when there is not enough rain there is a strain on the water supply – areas will experience drought.

Shortage of water problems arise when there is more demand than supply of water, which is a threat to life and the environment. Water cost may increase if future climate changes cause shortage of water in the UK. Using less water in the future is very important.

Here are some ways of decreasing our use of water.

- Use washing machines and dish washers only when they are full.
- Having a shower instead of a bath.
- Use waste water for plants and to wash the car.
- Repair dripping taps.
- Do not allow the water to run excessively (e.g. when brushing teeth)

Desalination - It is possible to desalinate sea water to supply drinking water.

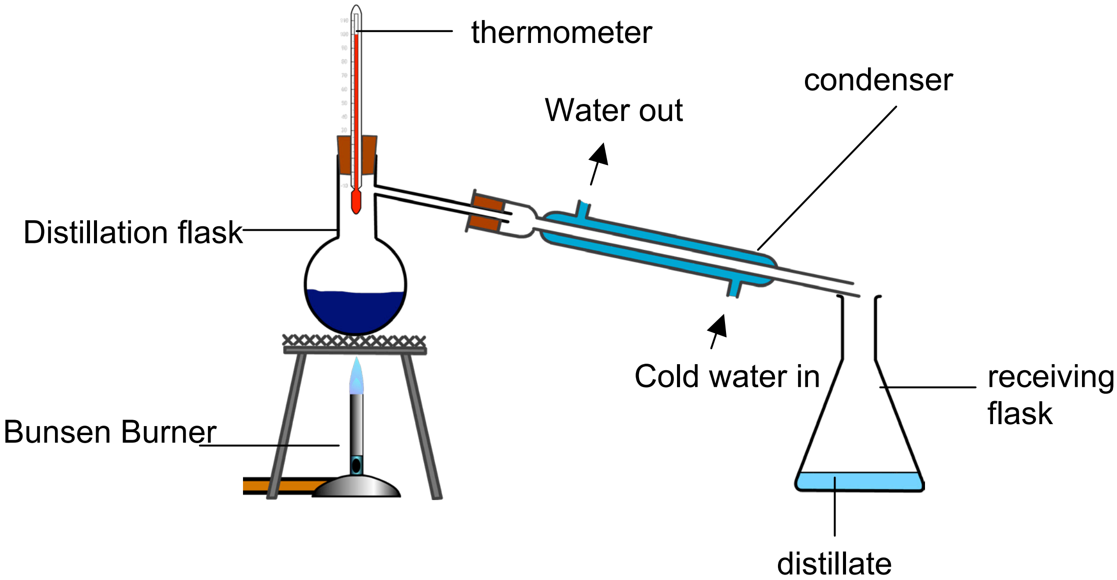
To desalinate sea water distillation of sea water by boiling is used. Boiling uses large amounts of energy which is costly. Due to this the process is not viable in many parts of the world.

If a country is to use desaliantion they need to ensure

- a renewable means of creating heat energy where no carbon dioxde is created (greenhouse effect)
- sea nearby.

Distillation – Separating water and miscible liquids.

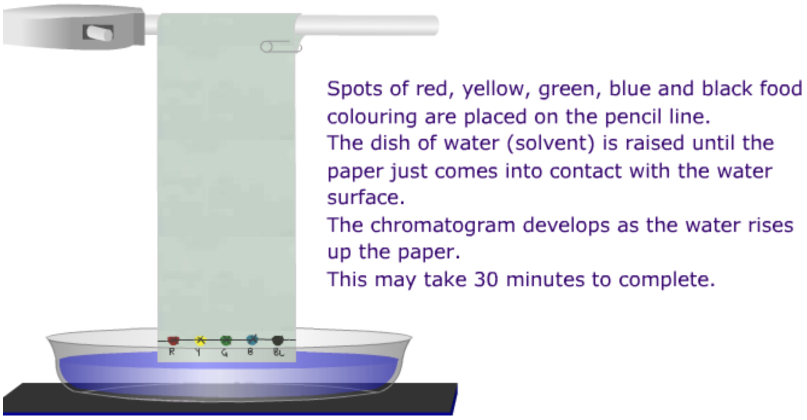
Pure liquids have specific boiling points, e.g. water boils ar 100°C. Ethanol boils at 78°C. Water and ethanol are miscible (when two liquids mix together easily without separating into layers.)

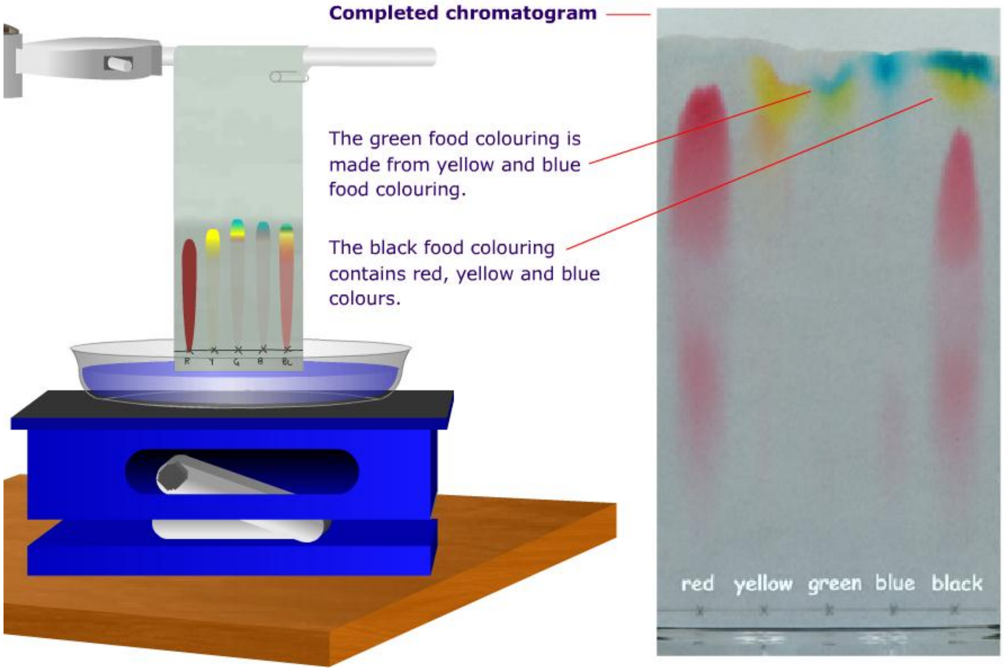


If a mixture of miscible liquids exist it is possible to separate them by distilation. In a mixture of ethanol and water, the ethanol would boil and evaporate first (as it has the lower boiling point) leaving the water behind. The ethanol would condense on the cold wall of the condeser.

Chromatography

Pigments in ink can be separated using paper chromatography.



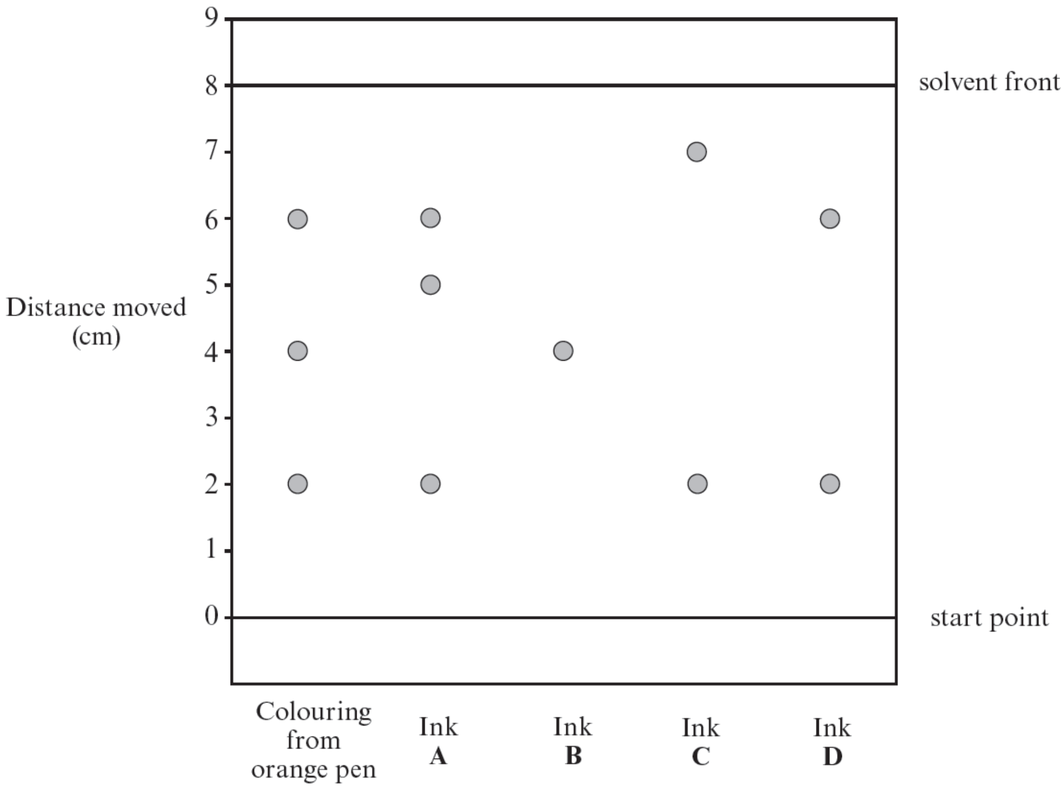


The most soluble substance will be transported furthest by the solvent.

Chromatography

The distance that a substance travels allows scientists to recognise a substance. Am R_f value is calculated

$$R_f \text{ Value} = \frac{\text{distance the substance has traveled}}{\text{distance the solvent has traveled}}$$



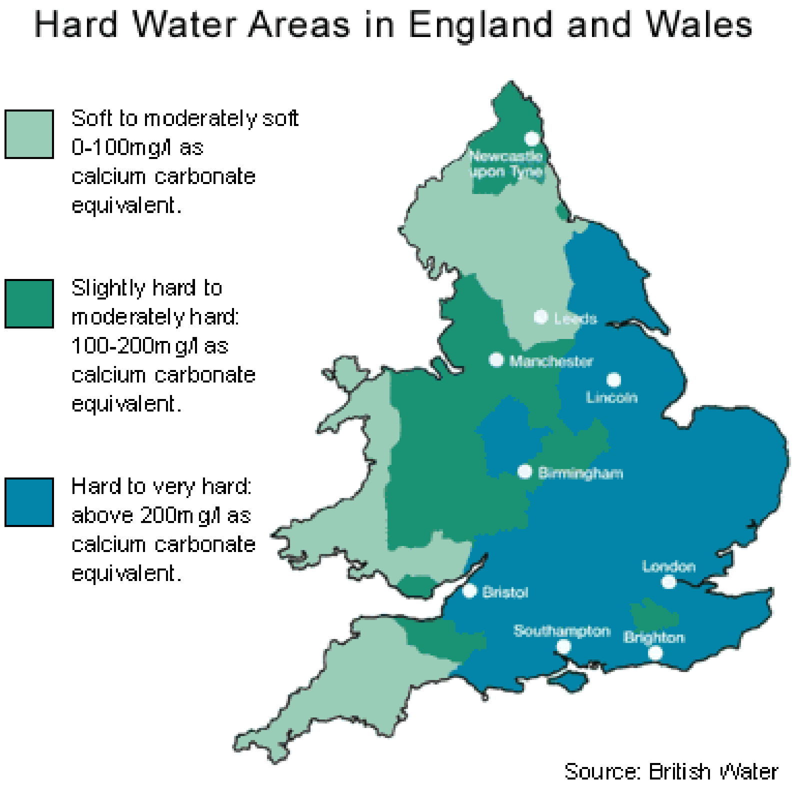
e.g. The R_f value for ink B = 4/8 = 0.5

Gas Chromatography (Higher Tier)
This method is very useful as it gives quantitative information - that is the amount of substance present. Chemical analysts use the method to identify e.g. the amount of a pollutant in water or air, it is also used to identify the amount of an illegal drug in blood.

Types of drinking water.

Depending on the type of rocks a region has, water can be of two types :-

Hard water and Soft water



Hard Water

If rainwater passes along **limestone** (calcium carbonate) rocks on its way to a reservoir, *calcium ions Ca^{2+}* will collect in the water. Other ions such as *magnesium ions Mg^{2+}* can also collect in water. These additional ions make the water hard.

Soap in hard water **does not** readily **lather**, **scum** is formed

Hardness in water is defined as difficulty in producing a lather with soap.

There are two types of hard water:

Temporary hard water and **permanently hard water**

Temporary hard water

Calcium and Magnesium hydrogen carbonates form *temporary hard water* because when this water is **boiled**, hardness is **removed**.

Hydrogen carbonates are decomposed.

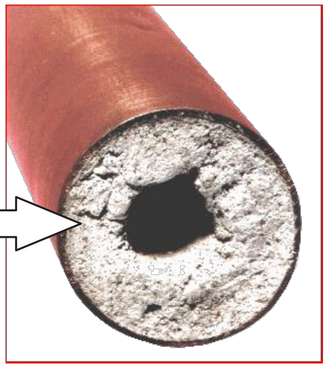
Lime scale furring up a kettle element

Magnesium and Calcium become *magnesium carbonate* and calcium carbonate which are insoluble. This lime scale collects on kettles as 'fur'.

Permanently hard water

When insoluble calcium and magnesium sulfates or carbonate exists in water it is called permanently hard water.

Lime scale clogs up hot water pipe



Treating permanently hard water.

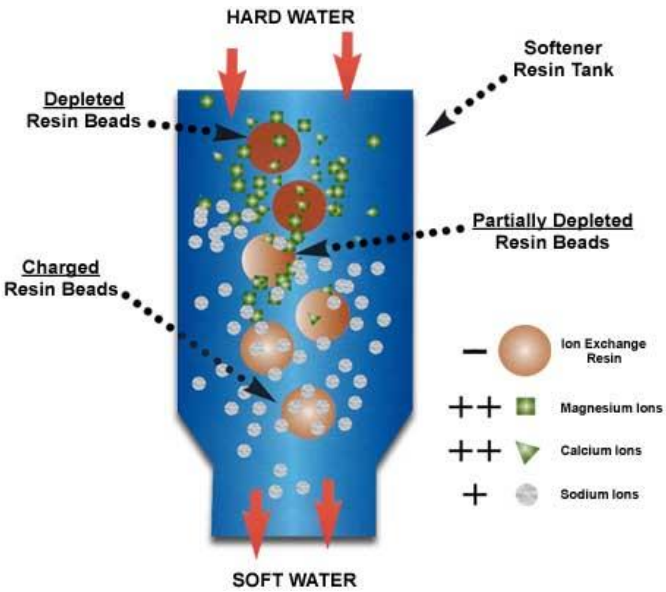
1. Adding **sodium carbonate** (washing soda).

sodium carbonate + calcium sulfate ⟶ calcium carbonate + sodium sulfate

Calcium ions are removed as solid Calcium carbonate making the water softer

2. **Ion exchange column**

   When hard water is passed along negatively charged particles within a container, the positive ions of magnesium and calcium in hard water are attracted and held there, they are replaced with sodium ions. Water leaves the container soft.



Advantages and Disadvantages of hard water

Advantages

1. Strengthens teeth
2. Reduces the risk of heart disease
3. Some people prefer the taste of hard water

Disadvantages

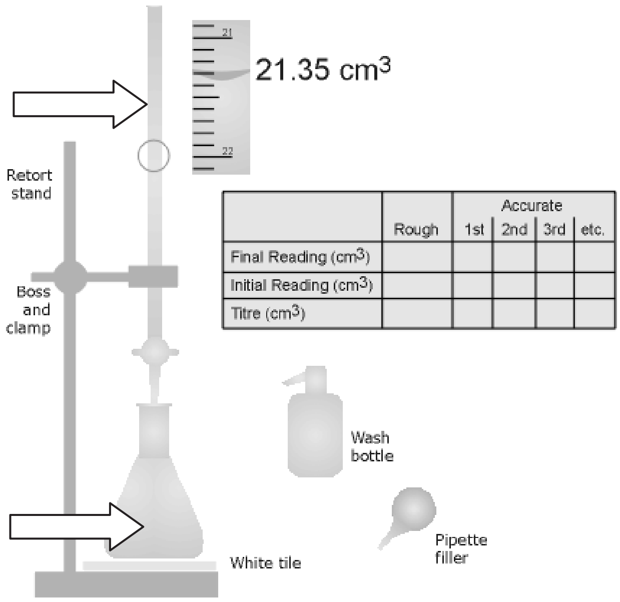
1. **Lime scale** on kettles make them less efficient at boiling water and therefore waste energy. Hot water pipes can also block up with lime scale.
2. Removing scale can be expensive.
3. More soap is needed with hard water.
4. Ion exchange water softeners release sodium ions which can be unsuitable for some uses.
5. Ion exchange units need to be ‘cleaned’ out of magnesium and calcium ions when it has filled up (usually with sodium chloride (salt))

Experiments to determine the amount of hardness of water.

A **buret** is the apparatus used to measure the amount of soap solution needed.

The amount of water to be tested is kept the same in the **conical flask**.

Buret – filled with soap solution



	Rough	Accurate 1st	2nd	3rd	etc.
Final Reading (cm^3)					
Initial Reading (cm^3)					
Titre (cm^3)					

Conical flask with known volume of water e.g. hard water

Soap solution is added every 1 cm^3 to the water and the flask shaken to try and form lather (bubbles). When lather starts to form the soap solution is added every 0.5 cm^3 until it stays permanently. The amount of soap solution can be determined using the buret.

Soft water lathers easily therefore little amount of soap solution is used.

Hard water lathers slowly therefore more soap solution is needed.

Experiment to determine if water is permanently hard or temporarily hard.

If two samples of water seem to be **hard water** from the above experiment, samples of both types of water could be **boiled**.

The same experiment as above could then be undertaken.

If the water is still difficult to lather then the water is permanently hard.

Solubility curves

Soluble solids dissolve more readily when heated.

Every solid has a different rate of solubility. The diagram below shows that potassium nitrate dissolved more readily than copper sulphate at any temperature above 0ºC.

e.g.

The amount of copper sulphate that dissolves at 40ºC is 24 g in 100 cm^3 water.

The amount of potassium nitrate that dissolves at 40ºC is 60 g in 100 cm^3 water.

Notice that the standard amount of water used is 100 cm^3 or 100 g.

This graph shows the maximum amount of solid that will dissolve at any temperature.

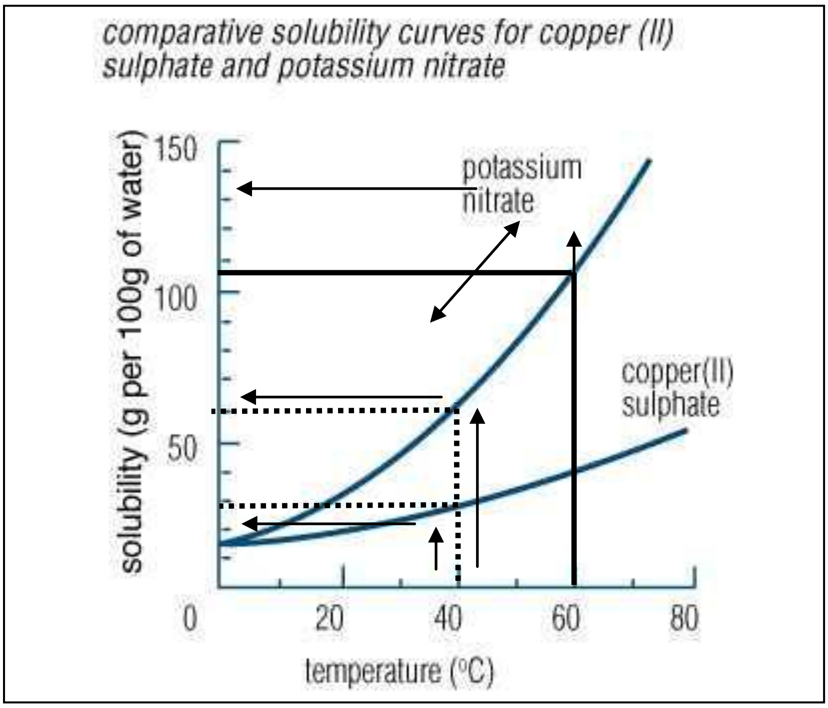
A **saturated solution** is the maximum amount of solid that will dissolve at a particular temperature.

The amount of copper sulphate that dissolves at 60ºC is 107 g in 100 cm^3 water.

If a saturated solution of copper sulphate at 60ºC was to cool down to 40ºC not as much solid would be able to dissolve.

It is possible to work out how much less would dissolve by subtracting:

107 g – 60 g = **47 g** of solid would appear on the bottom of the beaker.



FORMULAE FOR SOME COMMON IONS

POSITIVE IONS		NEGATIVE IONS	
Name	Formula	Name	Formula
Aluminium	Al^{3+}	Bromide	Br^{-}
Ammonium	NH_4^{+}	Carbonate	CO_3^{2-}
Barium	Ba^{2+}	Chloride	Cl^{-}
Calcium	Ca^{2+}	Fluoride	F^{-}
Copper(II)	Cu^{2+}	Hydroxide	OH^{-}
Hydrogen	H^{+}	Iodide	I^{-}
Iron(II)	Fe^{2+}	Nitrate	NO_3^{-}
Iron(III)	Fe^{3+}	Oxide	O^{2-}
Lithium	Li^{+}	Sulphate	SO_4^{2-}
Magnesium	Mg^{2+}		
Nickel	Ni^{2+}		
Potassium	K^{+}		
Silver	Ag^{+}		
Sodium	Na^{+}		

PERIODIC TABLE OF ELEMENTS

1	2					Group						3	4	5	6	7	0
								$^{1}_{1}$H Hydrogen									$^{4}_{2}$He Helium
$^{7}_{3}$Li Lithium	$^{9}_{4}$Be Beryllium											$^{11}_{5}$B Boron	$^{12}_{6}$C Carbon	$^{14}_{7}$N Nitrogen	$^{16}_{8}$O Oxygen	$^{19}_{9}$F Fluorine	$^{20}_{10}$Ne Neon
$^{23}_{11}$Na Sodium	$^{24}_{12}$Mg Magnesium											$^{27}_{13}$Al Aluminium	$^{28}_{14}$Si Silicon	$^{31}_{15}$P Phosphorus	$^{32}_{16}$S Sulphur	$^{35}_{17}$Cl Chlorine	$^{40}_{18}$Ar Argon
$^{39}_{19}$K Potassium	$^{40}_{20}$Ca Calcium	$^{45}_{21}$Sc Scandium	$^{48}_{22}$Ti Titanium	$^{51}_{23}$V Vanadium	$^{52}_{24}$Cr Chromium	$^{55}_{25}$Mn Manganese	$^{56}_{26}$Fe Iron	$^{59}_{27}$Co Cobalt	$^{59}_{28}$Ni Nickel	$^{64}_{29}$Cu Copper	$^{65}_{30}$Zn Zinc	$^{70}_{31}$Ga Gallium	$^{73}_{32}$Ge Germanium	$^{75}_{33}$As Arsenic	$^{79}_{34}$Se Selenium	$^{80}_{35}$Br Bromine	$^{84}_{36}$Kr Krypton
$^{86}_{37}$Rb Rubidium	$^{88}_{38}$Sr Strontium	$^{89}_{39}$Y Yttrium	$^{91}_{40}$Zr Zirconium	$^{93}_{41}$Nb Niobium	$^{96}_{42}$Mo Molybdenum	$^{99}_{43}$Tc Technetium	$^{101}_{44}$Ru Ruthenium	$^{103}_{45}$Rh Rhodium	$^{106}_{46}$Pd Palladium	$^{108}_{47}$Ag Silver	$^{112}_{48}$Cd Cadmium	$^{115}_{49}$In Indium	$^{119}_{50}$Sn Tin	$^{122}_{51}$Sb Antimony	$^{128}_{52}$Te Tellurium	$^{127}_{53}$I Iodine	$^{131}_{54}$Xe Xenon
$^{133}_{55}$Cs Caesium	$^{137}_{56}$Ba Barium	$^{139}_{57}$La Lanthanum	$^{179}_{72}$Hf Hafnium	$^{181}_{73}$Ta Tantalum	$^{184}_{74}$W Tungsten	$^{186}_{75}$Re Rhenium	$^{190}_{76}$Os Osmium	$^{192}_{77}$Ir Iridium	$^{195}_{78}$Pt Platinum	$^{197}_{79}$Au Gold	$^{201}_{80}$Hg Mercury	$^{204}_{81}$Tl Thallium	$^{207}_{82}$Pb Lead	$^{209}_{83}$Bi Bismuth	$^{210}_{84}$Po Polonium	$^{210}_{85}$At Astatine	$^{222}_{86}$Rn Radon
$^{223}_{87}$Fr Francium	$^{226}_{88}$Ra Radium	$^{227}_{89}$Ac Actinium															

Key:

Mass number → A

X ← Element Symbol

Atomic number → Z

Name