C2.1 Structure and bonding

C2 1.1 Chemical bonding

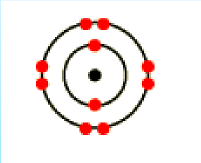
Key words:

A **compound** contains two or more elements which are chemically combined

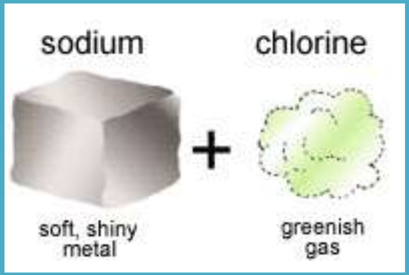
Covalent bonding – sharing electrons

Ionic bonding – transferring electrons

Chemical bonding: involves either transferring or sharing electrons in the highest occupied energy level (*__outer shell__*) of atoms to achieve the electronic structure of a noble gas (*__full outer shell__*)



Compounds are usually very different from the elements that have combined together to make them, for example, Sodium reacting with Chlorine gas to form sodium chloride



HEAT →

$2Na + Cl_2$ → $2NaCl$

Sodium + chlorine → sodium chloride *(new compound)*

Representing ionic bonding

Key words

Ionic bond – The electrostatic force of attraction between positively and negatively charged ions

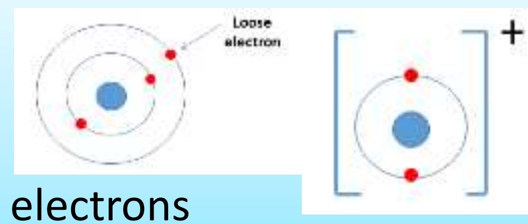
Ion – A charged particle produced by the loss or gain of electrons

Ionic bonds form between METALS and NON-METALS.

Ionic bonding involves the **transfer** of ELECTRONS.

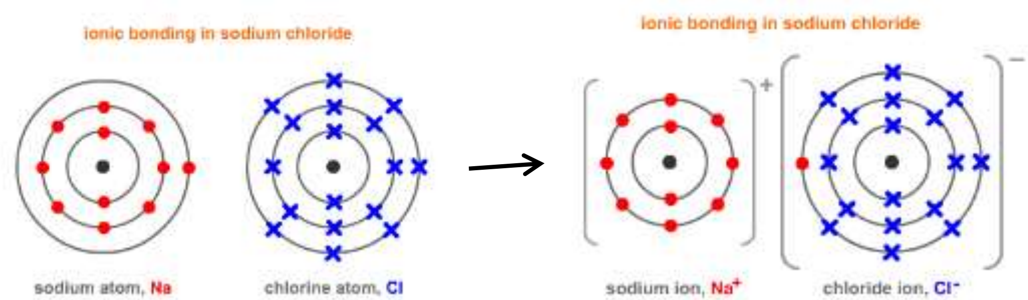
Metallic Ions are POSITIVELY charged (**ANIONS**), they LOSE electrons.

Non-metallic elements are NEGATIVELY charged (**CATIONS**), they GAIN electrons



Representing ionic bonding

- The elements in Group 1 react with the elements in Group 7
- Groups 1 elements can each lose one electron to gain the stable electronic structure of a noble gas
- This electron can be given to an atom from Group 7, which then also achieves the stable electronic structure of a noble gas



The electrostatic attraction between the oppositely charged Na^+ ions and Cl^- ions is called ionic bonding

Common ions

To become positively charged an atom must lose electrons. To become negatively charged and atom must gain electrons.

Positive ions		Charge
ammonium	NH_4^+	1+
potassium	K^+	1+
sodium	Na^+	1+
calcium	Ca^{2+}	2+
magnesium	Mg^{2+}	2+
copper	Cu^{2+}	2+
iron (II)	Fe^{3+}	3+
aluminium	Al^{3+}	3+

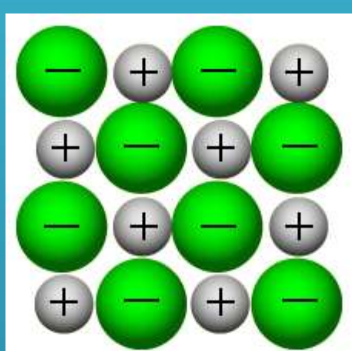
Negative ions		Charge
chloride	Cl^-	1–
bromide	Br^-	1–
iodide	I^-	1–
hydroxide	OH^-	1–
nitrate	NO_3^-	1–
oxide	O^{2-}	2–
carbonate	CO_3^{2-}	2–
sulfate	SO_4^{2-}	2–

C2 1.2 Ionic bonding

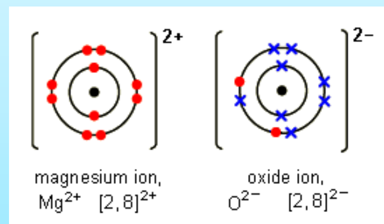
Key words

The ionic bonding between charged particles result in an arrangement of ions called a **giant structure (*giant lattice*)**

Sodium chloride, NaCl, forms when sodium and chlorine react together. It contains oppositely charged ions held together by strong electrostatic forces of attraction – the ionic bonds. The ions form a **regular lattice** in which the ionic bonds act in all directions



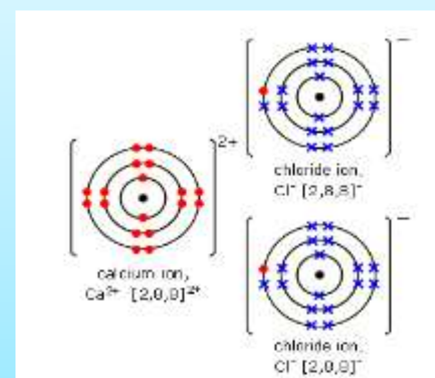
Magnesium oxide: sometimes the atoms reacting need to gain or lose **two electrons** to gain a stable noble gas structure



Magnesium ions have the formula Mg^{2+}, while oxide ions have the formula O^{2-}

Calcium Chloride: each calcium atom (2, 8, 8, 2) needs to lose two electrons but each chlorine atom (2, 8, 7) needs to gain only one electron.

This means that two chlorine atoms react with every one calcium atom, $\mathbf{CaCl_2}$



C2 1.3 Formulae of ionic compounds

Key points

- ✓ The charges on the ions in an ionic compound always cancel each other out (they are neutral)
- ✓ The formula of an ionic compound shows the ratio of ions present in the compound

Ionic compound	Ratio of ions in the compound	Formula of the compound
Sodium chloride	$Na^+ : Cl^-$ 1 : 1	NaCl
Magnesium oxide	$Mg^{2+} : O^{2-}$ 1 : 1	MgO
Calcium chloride	$Ca^{2+} : Cl^-$ 1 : 2	$CaCl_2$

More complicated ions:

Name of ion	Formula of ion
Hydroxide	OH^-
Nitrate	NO_3^-
Carbonate	CO_3^{2-}
sulfate	SO_4^{2-}

Groups of metals

- The atoms of Group 1 elements form 1+ ions, e.g. Li+
- The atoms of group 2 elements form 2+ ions, e.g. Ca2+

Groups of non-metals

- The atoms of Group 7 elements form 1- ions, e.g. F-
- The atoms of Group 6 elements form 2- ions, e.g. S2-

C2 1.4 Covalent bonding

Key words

Covalent bonding – the attraction between two atoms that share one or more pairs of electrons

Simple molecule – simple covalently bonded structures, e.g. HCl or H_2O

Giant covalent structure – huge numbers of atoms held together by a network of covalent bonds, e.g. diamond or graphite

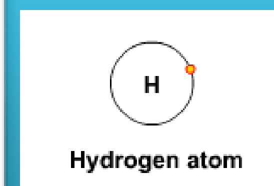
✓When atoms **share** pairs of electrons, they form covalent bonds.

✓These bonds between atoms are **strong**

✓Some covalently bonded substances consist of **simple** molecules such as H_2, Cl_2, O_2, HCl, H_2O, NH_3 and CH_4

✓ Others have **giant** covalent structures (macromolecules), such as diamond, graphite and silicon dioxide

Example: Hydrogen chloride:



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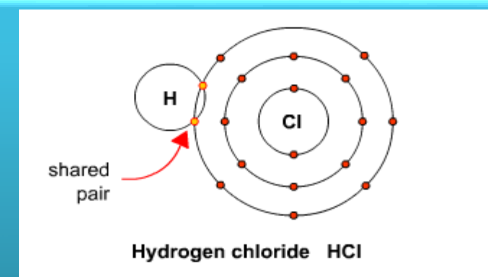
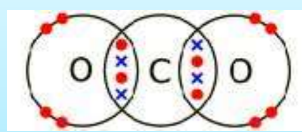
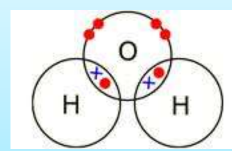


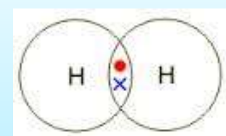
Simples covalent molecules:



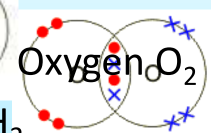
Carbon Dioxide CO_2



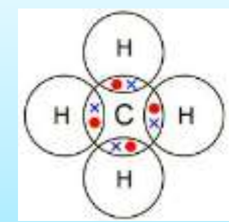
Water H_2O



Hydrogen H_2

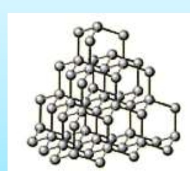


Oxygen O_2

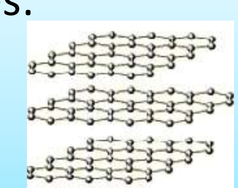


Methane CH_4

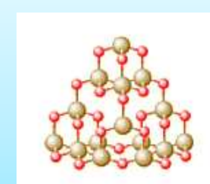
Giant covalent structures:



Diamond



Graphite

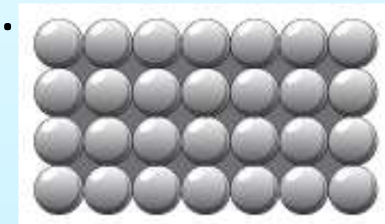


Silicon dioxide

C2 1.5 Metals

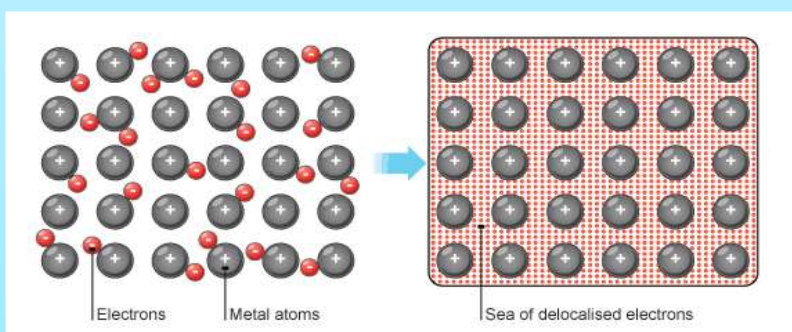
Key points

- ✓ The atoms in metals are built up layer upon layer in a regular pattern, this means they form **crystals.** They are another example of a **giant structure**



- ✓ We can think of **metallic bonding** as positively charged metal ions which are held together by electrons from the outermost shell of each metal atom. Strong electrostatic attraction between the negatively charges electrons and positively charged ions bond the metal ions to each other

- ✓ The **delocalised** electrons are free to move throughout the giant metallic lattice, they form a **'sea' of free electrons**



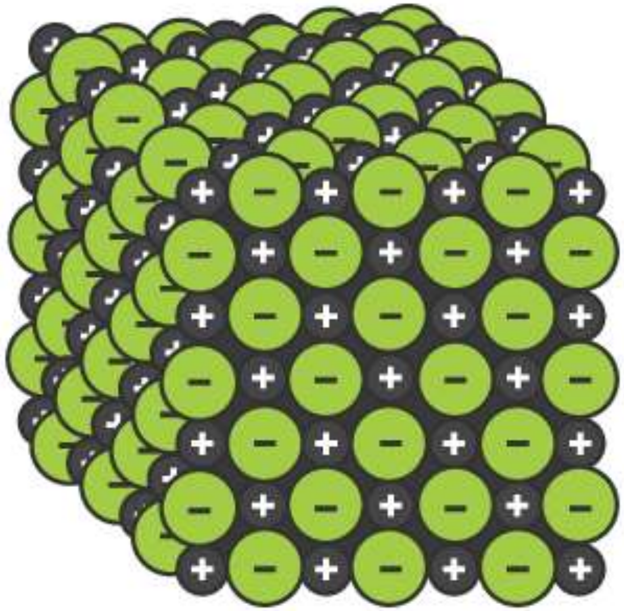
C2.2 Structure and properties

C2 2.1 Giant ionic structures

- Conduct electricity when **MOLTEN** (*melted*) and in an **AQUEOUS SOLUTION** (*dissolved in water*)
- **DO NOT** conduct electricity as a **SOLID**
- Have high **MELTING** and **BOILING** points
- Usually **SOLID** at **ROOM TEMPERATURE**

Ion = an atom with a positive or negative charge.
Cations = metal atoms lose electrons to form positively charged ions called cations.
Anions = Non-metal atoms gain electrons to form negatively ions called anions.

Ionic compounds have a **lattice structure**, with a **regular arrangement of ions**, held together by **electrostatic forces between oppositely charged ions**.



C2 2.2 Simple molecules

<u>Simple covalent molecules:</u>

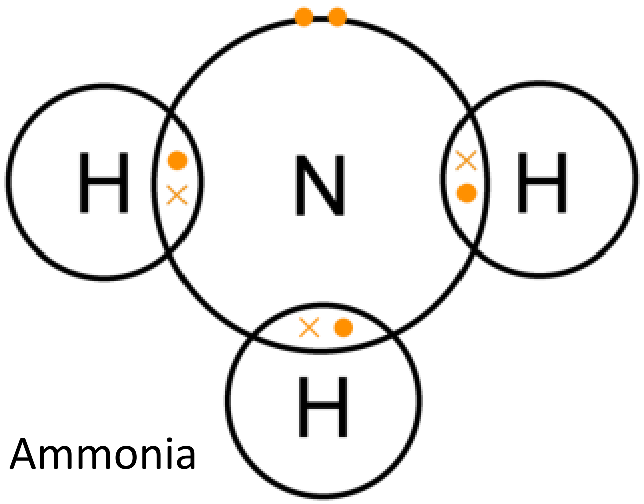
- Low melting point
- Low boiling point
- Poor conductor of electricity

<u>Why?</u>

- Because there are weak intermolecular forces between molecules.

<u>Charge?</u>

- Simple molecules have no overall charge, so they cannot carry electrical charge. Therefore, substances made of simple molecules do not conduct electricty.

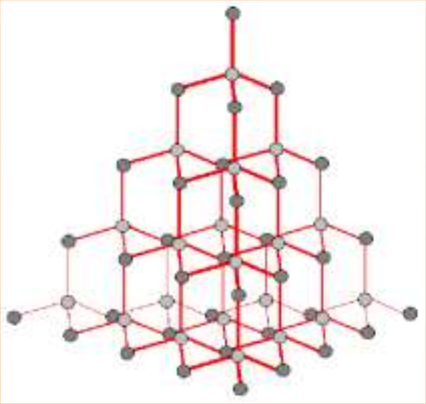


Ammonia

C2 2.3 Giant Covalent structure

DIAMOND

- In diamond, all the electrons in the outer shell of each carbon atom (2.4) are involved in forming covalent bonds.
- Diamond is very **hard** – it is the hardest natural substance, so it is often used to make jewellery and cutting tools.
- Diamond has a **very high melting** and **boiling point** – a lot of energy is needed to break the covalent bonds.
- Diamond **cannot conduct electricity** – there are no free electrons or ions to carry a charge.

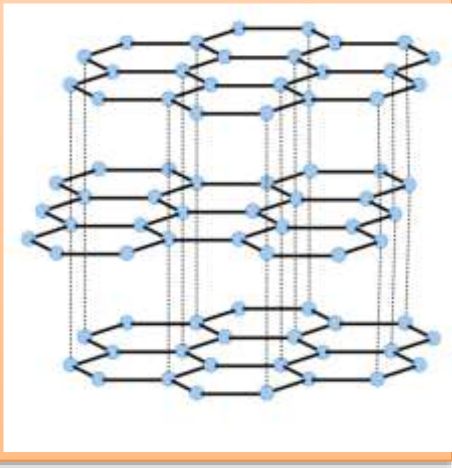


GRAPHITE

•In graphite, only three of the four electrons in the outer shell of each carbon atom (2.4) are involved in covalent bonds.

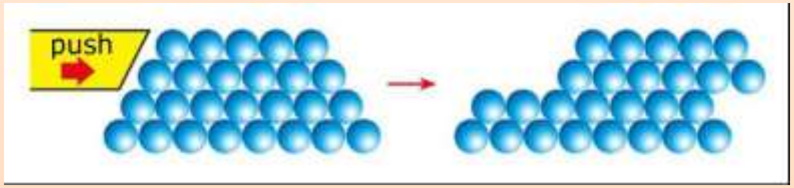
•**Graphite is soft and slippery** – layers can easily slide over each other because the weak forces of attraction are easily broken. This is why graphite is used as a lubricant.

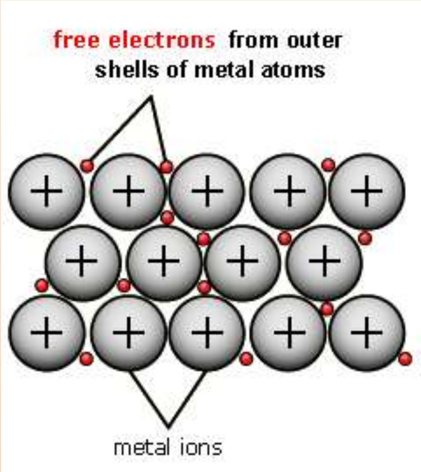
•**Graphite conducts electricity** – the only non-metal to do so. The free electron from each carbon atom means that each layer has delocalized electrons, which can carry charge. It is often used as an electrode for this reason.



C2 2.4 Giant metallic structure

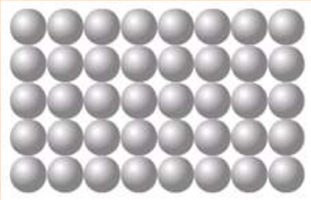
- We can bend and shape metals because the layers of atoms (or ions) in a giant metallic structure can slide over each other

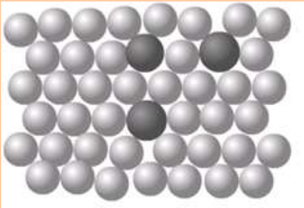




- Delocalised electrons in metals enable electricity and heat to pass through the metal easily

- Alloys are made from two or more different metals. The different sized atoms of the metals distort the layers in the structure, making it more difficult for them to slide over each other, and so make the alloys harder than pure metals

Pure metal: 

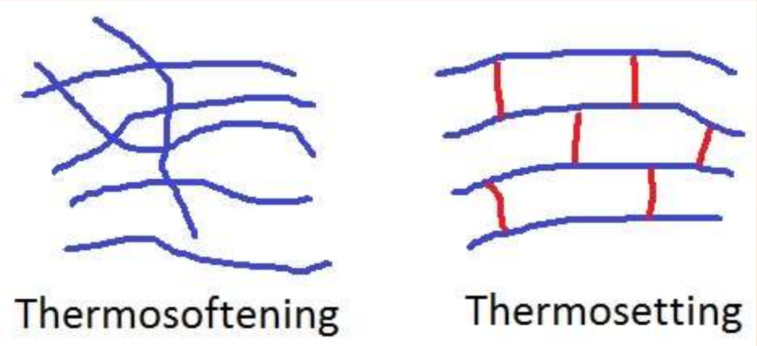
Alloy: 

- If a shape memory alloy is deformed, it can return to its original shape on heating

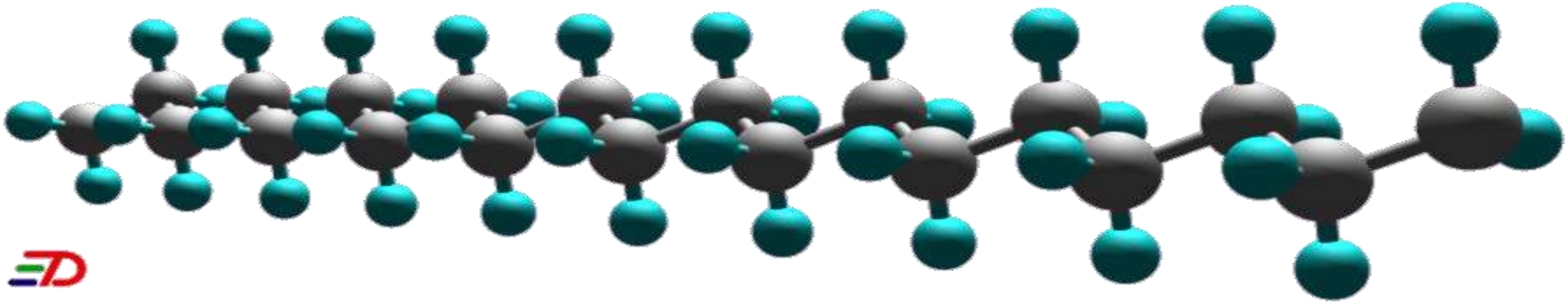
C2 2.5 The properties of polymers

<u>The properties of polymers depend on:</u>

- The monomers used to make it. Eg. Poly(ethene) and Nylon
- The conditions chosen to carry out the reaction. Low density (**LD**) and high density (**HD**) poly(ethene) are produced using different catalysts and reaction conditions.



Thermosoftening polymers consist of individual, tangled polymer chains. **Thermosetting** polymers consist of polymer chains with cross-links between them so that they do not melt when they are heated.



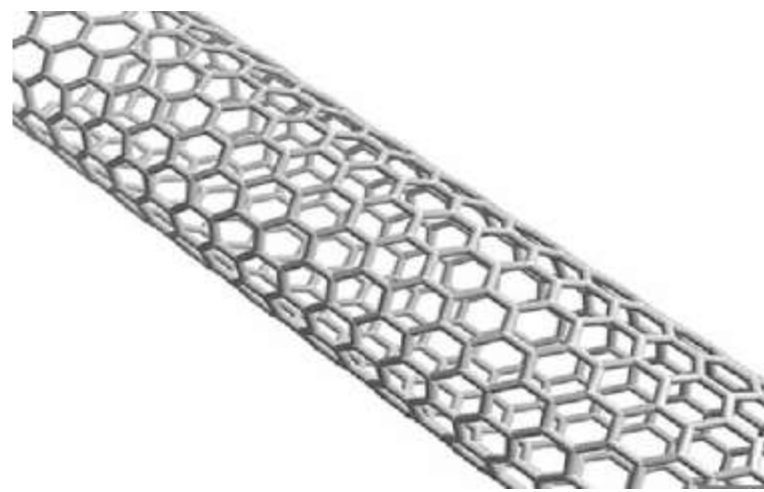
C2 2.6 Nanoscience

Nanoscience is the study of small particles that are between 1 and 100 nanometres in size
1 nanometre (1 nm) = 1 x 10-9 metres (0.000 000 001m or a billionth of a metre)

Nanoparticles show different properties to the same materials in bulk and have a high surface area to volume ratio.

This may lead to the development of new computers, new catalysts, new coatings, highly selective sensors, stronger and lighter construction materials, and new cosmetics such as sun tan creams and deodorants

New developments in nanoscience are very exciting but will need more research into possible issues that might arise from their increased use



C2 3.1 Atomic Structure

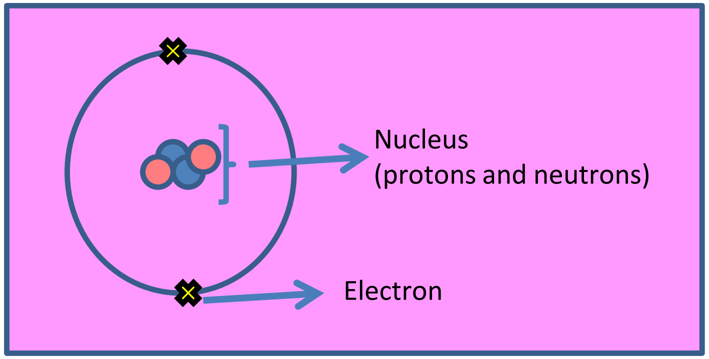
Keywords

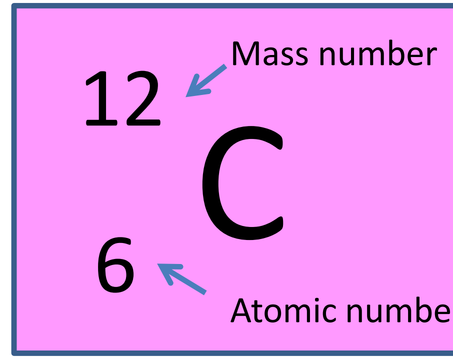
Mass number – **the total number of protons and neutrons in an atoms nucleus**

Atomic number – **the number of protons in an atoms nucleus**

Isotope – **atoms with the same number of protons but different numbers of neutrons.**

Particle	**Relative mass**
Proton	1
Neutron	1
Electron	very small





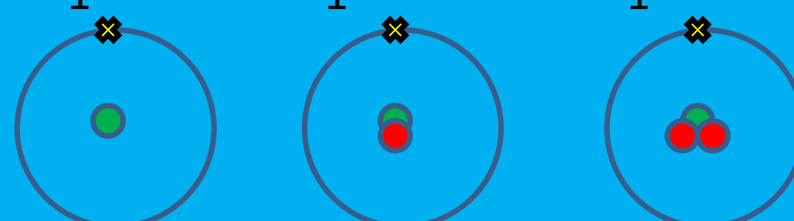
Number of protons = atomic number

Number of electrons = atomic number

Number of neutrons = mass number – atomic number

Isotopes- Same atomic no. different mass no.

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



Protons = 1	Protons = 1	Protons = 1
Electron = 1	Electron = 1	Electron = 1
Neutron = 0	Neutron = 1	Neutron = 2

C2 3.2 Masses of atoms and moles

Keywords

Relative atomic mass (Ar) – mass of an atom compared to the mass of carbon-12.

(Same as an atoms mass number)

Relative formula mass (Mr) - the sum of the relative atomic masses of the atoms in a molecule.

Mole – the relative formula mass of a substance in grams

RELATIVE FORMULA MASS – EXAMPLE 1

NaCl

Ar: Na (23) Cl(35.5)

Mr = 23 + 35.5 = 58.5

EXAMPLE 2

H_2O

Ar: H(1) Cl(16)

Mr = 1 + 1 + 16 = 18

Moles

The mass of 1 mole of carbon - 12 is 12 g.

The mass of 1 mole of NaCl is 58.5 g.

The mass of 1 mole of H_2O is 18 g.

C2 3.3 , 3.4 Percentages and Equations

$$\text{Percentage mass of an element in a compound} = \left[\frac{\text{Number of atoms of element} \times \text{Ar}}{\text{Mr of compound}}\right] \times 100$$

What percentage of the mass of magnesium oxide (MgO) is magnesium?

Ar : Mg (24), O (16)

$$\text{Percentage by mass of magnesium in magnesium oxide} = \left[\frac{1 \times 24}{24+16}\right] \times 100$$

$= 60\ \%$

Chemical equations

$$H_2 + Cl_2 \rightarrow 2HCl$$

✓Chemical equations tell us the number of molecules that are reacted and produced.

✓The total number of atoms on either side of the equation is the same.

$$3\ H_2 + N_2 \rightarrow 2\ NH_3$$

This equation tells us that 3 hydrogen molecules reacts with 1 nitrogen molecule to make 2 ammonia (NH_3) molecules.

C2 Yields

Keywords

Yield – the amount of useful product obtained from a reaction.

Products need to be made as **cheaply** as possible. Chemists need to make sure the reaction creates as much product as possible.

Theoretical Yield

Maximum calculated amount of a product that could be formed from a given amount of reactants.

Actual Yield

The **actual amount** of product obtained from a chemical reaction.

Percentage Yield

$$\text{Percentage yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100$$

Yield is usually **less** than expected – 4 reasons:

1. Reaction may be **incomplete**
2. Some **product** is **lost**
3. Other **unwanted reactions** may occur making a **different product**.
4. Reaction may be reversible

C2 3.6 Reversible reactions

Reversible reaction – a reaction where products can react together to make the original reactants.

$\rightleftharpoons$ This arrow shows a reaction is reversible.

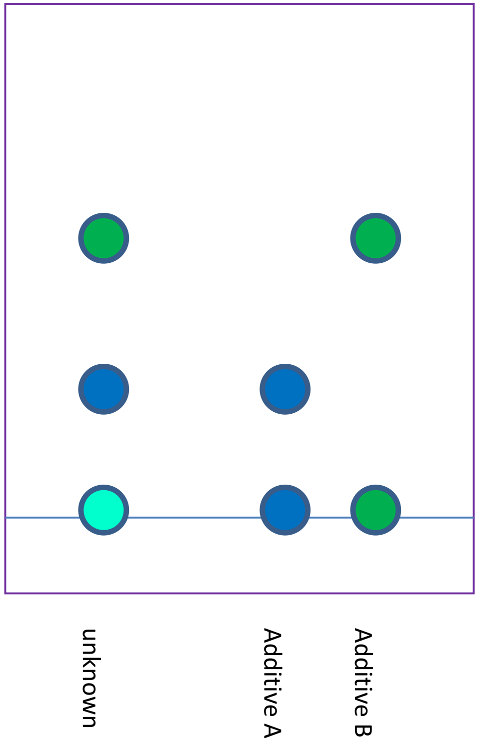
EXAMPLES

in acid				**in alkali**
HLit	$\rightleftharpoons$	H^+	+	Lit^-
Red litmus				**Blue litmus**

	heat			
ammonium chloride	$\rightleftharpoons$	**ammonia**	+	**hydrogen chloride**
NH_4Cl		NH_3	+	HCl

C2 3.7 Analysis Substances

Paper Chromatography - a technique used to separate mixtures of soluble substances.



✓**Paper chromatography can be used to detect additives**

✓Samples are put onto filter paper.

✓The paper is placed in a small amount of solvent (usually water)

✓As the solvent rises the chemicals in the substances separate.

✓The diagram on the left shows a chromatogram.

✓You can see the unknown is a mixture of A and B

Instrumental Methods

Modern instrumental analysis is now preferred in industry.

Advantages are modern instrumental analysis is that it is:

Accurate

Rapid

Sensitive (you can use very small samples.

The main disadvantage is that it is more expensive.

C2 3.8 Instrumental analysis

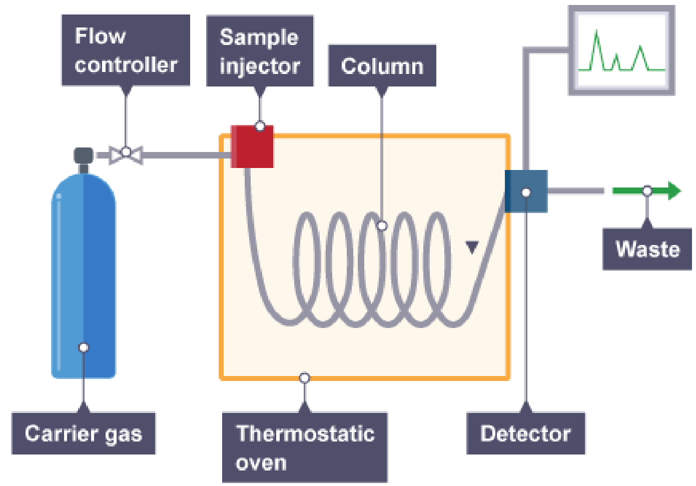
Gas chromatography – this is an instrumental method used to separate compounds.

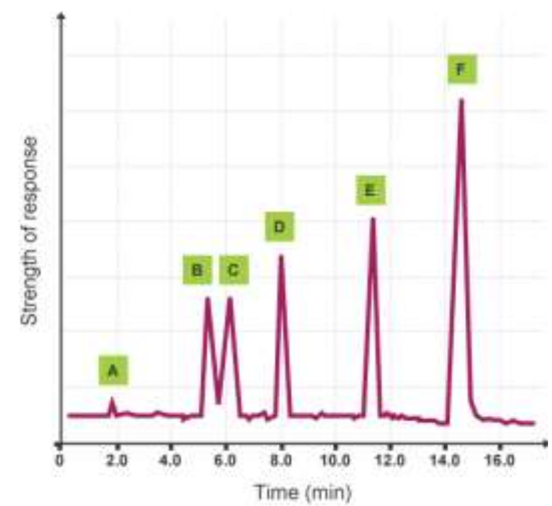
Mass spectrometer – this is an instrumental method used identify substances. It does this by measuring it's relative molecular mass (Mr)

How gas chromatography works+:

1. Mixture is vaporised.
2. A "carrier" gas moves the vapour through the coiled column.
3. The different compounds have different attractions to the material in the column and therefore travel at different speeds.
4. Different compounds are detected at different times, we say they have different retention times.

5. A gas chromatograph is produced as seen on the right.
6. This chromatograph shows there was a mixture of 6 different compounds it also shows most was compound F and least was compound A





C2 4.1 Rates of Reactions

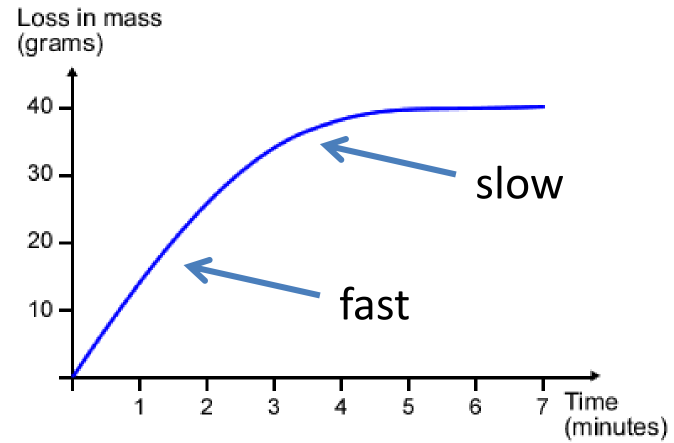
Keywords

- **Rate of reaction** – The speed at which a reaction takes place

Examples

- Fast reactions = Burning, explosions
- Slow reaction = Rusting, apple browning

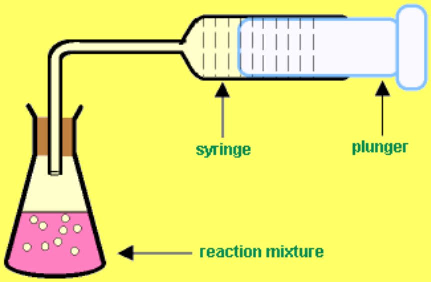
Rate of reaction = **the amount of reactants used or products formed** / **time**



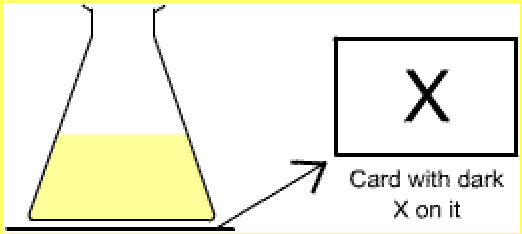
The slope of the line at any given time tells us the rate of a reaction at that time. The steeper the line the faster the reaction.

How to measure the sate of a reaction.

1. Measure the rate at which the mass of a reaction changes if a gas is given off.
2. Measure the volume of gas produced in a reaction at given time intervals.



3. Measure the rate at which a solid appears. Do this by timing how long it takes for a solution to go cloudy.



C2 4.2, 4.3, 4.4 – Collision Theory and changing the rate

Keywords

- **Concentration** – A measure of how much solute is dissolved in a fixed volume of solvent.
- **Surface area**– The total area of all the surfaces of an object or substance

Collision Theory

- For particles to react they need to collide.
- They also need enough energy to react when they collide
- The minimum energy needed is called the activation energy.

Factors affecting Rate

1. Temperature

- Higher temperature = faster reaction

e.g. And egg cooks faster in boiling water than warm water

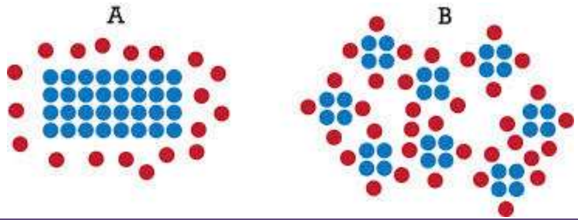
- Particles have more energy = move faster
  - More effective collisions (collide with more energy)
  - Collide more frequently

2. Concentration

- More concentrated = more particles
- More particles = more collisions = faster reaction

3. Surface area (SA)

- Solid broken up into smaller pieces = larger SA
- Greater surface area = faster reaction
- More surface area = more particles on the surface therefore more frequent collisions
- A = Smaller SA (block)
- B = Larger SA (powder)



C2 4.5, 4.6 - Catalysts

Keywords

- **Catalyst** – A substance that speeds up the rate of a reaction without being used up in the reaction

FACTS:

- Many chemical processes use catalysts to increase rate of production of products
- Catalysts help to lower the temperature and pressure needed = less energy needed = saves money
- Different chemical reactions require different catalysts.
- Catalysts lower the activation energy of a reaction.
- Catalysts are normally used as powders or pellets to give them as big surface area as possible.

Catalysts – disadvantages

•Catalysts are often transition metals. These can be toxic. If they get into the environment they can build up in living things.

C2 4.7, 4.9 Exothermic and Endothermic reactions

Facts:
- During a chemical reaction there is usually a transfer of energy between the reactant and the surroundings.

Keywords
- **Endothermic** – reaction that takes heat energy in, decreasing the temperature of the reaction mixture and its surroundings
- **Exothermic** – reaction that releases heat energy, increasing the temperature of the reaction mixture and its surroundings

Endothermic
- Takes in heat energy / temperature decreases.
- Endothermic reactions include:
  - Photosynthesis
  - Dissolving ammonium nitrate
  - Thermal decomposition

Exothermic
- Gives out heat energy / temperature increases
- Most reactions are exothermic
- All combustion reactions are exothermic

  E.g. Methane + Oxygen
- Explosions – release a lot of heat and gases very quickly

Using energy transfers from reactions

Exothermic

- Hand warmers
- Self heating cans.

Endothermic

- Cold packs

C2 4.8 Energy and reversible reactions

In a reversible reaction one reaction is exothermic and the other endothermic.

Energy absorbed = endothermic

$$A + B \rightleftharpoons C + D$$

Energy released = exothermic

The amount of energy absorbed in one direction is always the exact same amount of energy released in the other direction.

Know this example

endothermic

$CuSO_4.5H_2O$	$\rightleftharpoons$	$CuSO_4$	+	$5H_2O$
Hydrated copper sulphate		Anhydrous copper sulphate	+	water
BLUE		**WHITE**		

exothermic

C2 4.5, 4.6 - Catalysts

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C2 5.1 Acids and Alkalis

Keywords

- **Acid** – A substance that produce H^+ ions in water.
- **Alkali** – A soluble base that produces OH^- in water.
- **Base** – A substance that neutralises an acid

pH Scale:

- Universal indicator is used to tell you pH.

pH 1-6- Acid

pH 7- Neutral

pH 8-14 Alkali- An important alkali is ammonium salts which are used as fertilisers

State Symbols

State symbols are used in equations and tell you whether something is a solid, liquid, gas or an aqueous solution

Solid (s)

Liquid (l)

Gas (g)

*Aqueous solution (aq)

*Is when a soluble solid is dissolved in water

C2 5.2 Naming Salts

Keywords

- **Salt:Compound formed when hydrogen in an acid is replaced by metal.**

Salts made when metals react *nitric acid* are called ***nitrates.***

Lithium + Nitric acid → Lithium Nitrate + Hydrogen

Salts made when metals react with *sulfuric acids* are called ***sulfates.***

Potassium + Sulfuric Acid → Potassium Sulfate + Hydrogen

Salts made when metals react with *hydrochloric* **acid** are called ***chlorides.***

Magnesium + Hydrochloric acid → Magnesium Chloride + Hydrogen

C2 5.2-5.3 Making Salts From Acids And bases

Keywords

- **Neutralisation- Reaction between acid and base**
- **Precipitate- An insoluble solid formed by a reaction in a solution.**

Making Soluble Salts- Acid and Metals

Salts can be made by reacting an acid and metal

Acid + Metal → a Salt + Hydrogen

Making Soluble Salts-Acids and Alkalis

Salts can be made by reacting an acid with an alkali.

Acid + Alkali → a Salt + Water

Practical- An indicator can be used to show when the acid and alkali have completed reacted.
Evaporate the water to form salt crystals

Neutralisation symbol equation:
$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

Making Soluble Salts- Acid and Bases

Salts can be made by reacting an acid with a base.

Acid + Bases → a Salt + Water

Practical: A base is added to the acid until no more will react. Any left over solid is filtered off.
Evaporate the water to form salt crystals

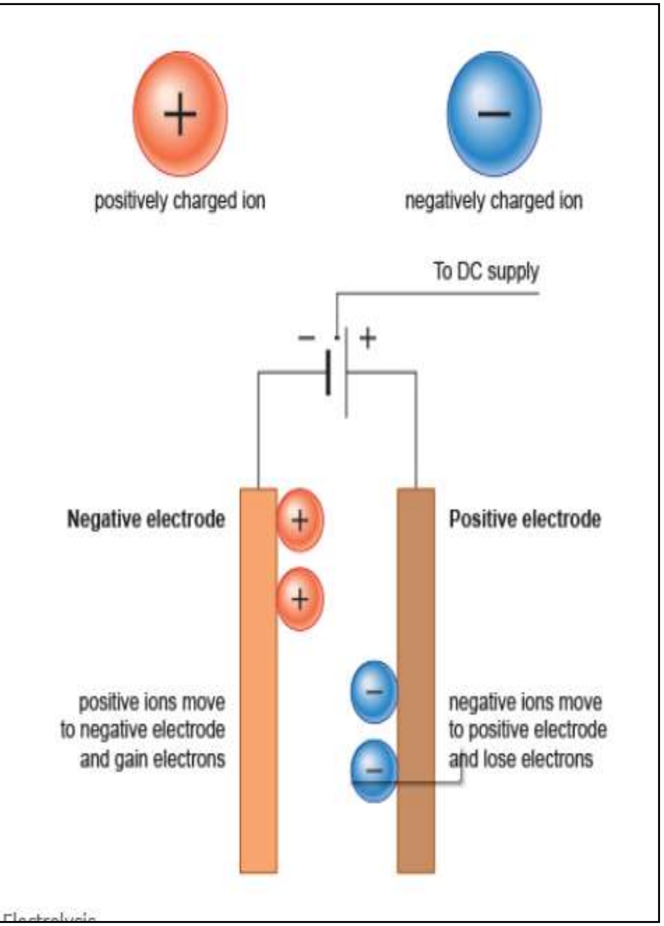
Making Insoluble salts-

Combing two salt solutions can make an insoluble solid form.
The solid formed is called a precipitate.

C2 5.4-5.5 Electrolysis

Keywords

- **Electrolysis: Decomposing a compound into elements using energy from a D.C supply.**
- **Oxidation: Lose Electrons**
- **Reduction:Gain Electrons**



FACTS

To do electrolysis you must dissolve or melt the compound so the ions are free to move.

-Positive ions go to negative electrode and are reduced.

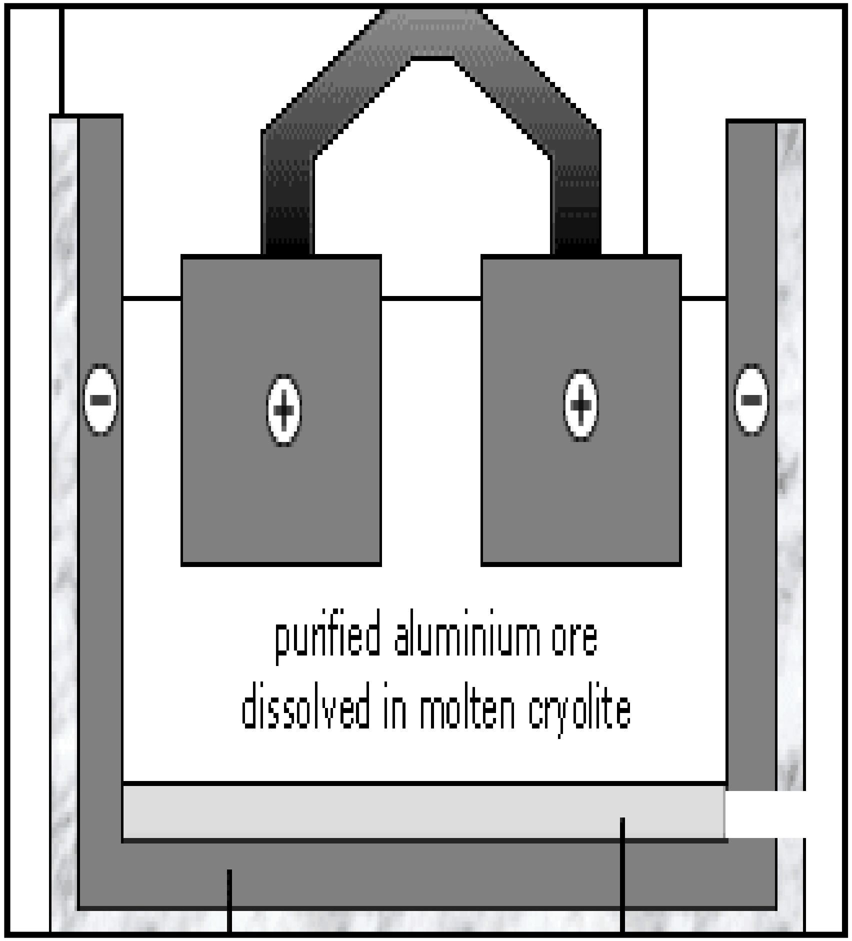
-Negative ions go to the positive electrode and oxidised.

When you do electrolysis with solutions:

At the negative electrode: Metal will be produced on the electrode if it is less reactive than hydrogen. Hydrogen will be produced if the metal is more reactive than hydrogen.

At the positive electrode: oxygen is formed at positive electrode unless you have a halide ion (Cl^-, I^-, Br^-) then you will get chlorine, bromine or iodine formed at that electrode.

C2 5.6 Extraction of Aluminium



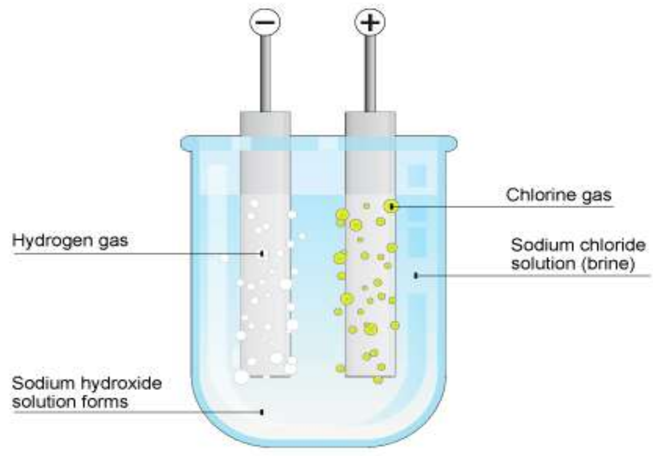
-Aluminum is manufactured by electrolysis of molten aluminum oxide.

-Aluminum oxide has a very high melting point so is mixed with molten cryolite to lower the temperature required to carry out the electrolysis.

-Aluminium goes to the negative electrode and sinks to bottom.

-Oxygen forms at positive electrodes. The oxygen reacts with the carbon electrode making carbon dioxide causing damage. The electrode needs replaced due to this reaction.

C2 5.7-8 Extraction of Aluminium and electroplating



Electrolysis of sodium chloride solution

What will you get if you electrolyse brine?

Brine is Sodium Chloride Solution

Positive electrode- Chlorine gas is formed

Negative electrode- Hydrogen gas is formed

What is left behind in solution: Sodium Ions and Hydroxide ions which make sodium hydroxide.

Uses of the products from the electrolysis of brine

Chlorine Gas- Bleach and PVC

Hydrogen gas- Food industry- making margarine

Sodium hydroxide- Bleach and soap

Electroplating: The coating an object with a thin layer of metal by electrolysis.

This can protect the metal of make it look more attractive.

E.G Jewellery and cutlery