

Cathkin High School
Chemistry Department

National 4/5 Chemistry

Unit 3

Chemistry in Society



Learning Outcomes and Summary Notes

Name _____

Class _____

✓ I am confident that I understand this and I can apply this to problems

? I have some understanding but I need to revise this some more

✗ I don't know this or I need help because I don't understand it

National 4 outcomes are in lighter font.

National 5 outcomes are in bold

Metals	Covered (✓)	How well can you do this?		
1. Materials are substances which include metals, ceramics and plastics as well as natural and new substances.		✗	?	✓
2. Chemical and physical properties of materials are linked to their uses.		✗	?	✓
3. Metals are held together by metallic bonding and this is responsible for their electrical conductivity		✗	?	✓
4. Some metals react with oxygen to produce metal oxides		✗	?	✓
5. The formation of metal oxides can be represented by equations showing the ions involved.		✗	?	✓
6. Some metals react with water to produce metal hydroxides and hydrogen.		✗	?	✓

	Covered (✓)	How well can you do this?
7. Metals reacting to produce metal hydroxides and hydrogen can be represented by equations showing the ions involved.		x ? ✓
8. Some metals react with acid to produce salts and hydrogen		x ? ✓
9. Some metals react with acid to produce salts and hydrogen and this can be represented by equations showing the ions involved.		
10. A reactivity series can be deduced by considering reactions of metals.		x ? ✓
11. Metals are extracted from their ores by techniques dependant on their position in the reactivity series.		x ? ✓
12. Metals are extracted from their ores by reduction reactions involving heat, heat and a reducing agent or electricity and these reactions can be represented by equations showing ions.		x ? ✓

	Covered (✓)	How well can you do this?		
13. From the balanced equations for the extraction of metals the reducing agent can be identified.		x	?	✓
14. The percentage of a particular metal in an ore can be calculated.		x	?	✓
15. Metals can be involved in redox, oxidation and reduction reactions which involve the movement of electrons.		x	?	✓
16. Metals corrode when they react with water and oxygen.		x	?	✓
17. Different metals corrode at different rates.		x	?	✓
18. Metals can be protected from corrosion using other metals.		x	?	✓
19. The reactivity of a metal determines how well it will protect another metal from corrosion.		x	?	✓
20. Ferroxyl indicator can be used to show the occurrence of rusting.		x	?	✓

	Covered (✓)	How well can you do this?
21. The reaction of metals with water, oxygen and acids can be shown using balanced ionic equations.		
22. When different metals are connected by an electrolyte, an electric current flows from one metal to the other. This is an electrochemical cell.		x ? ✓
23. Ion electron equations can be written for electrochemical cells involving metals and non-metals.		x ? ✓
24. Comparing the voltage generated by pairs of metals in an electrochemical cell allows an electrochemical series to be constructed.		x ? ✓
25. The electrochemical series can be used to predict the size of voltage and the direction of current.		x ? ✓
26. The reactions which occur in electrochemical cells can be combined to form redox equations.		x ? ✓
27. Fuel cells and rechargeable batteries are technologies which are based on redox reactions.		x ? ✓
	Covered (✓)	How well can you

		do this?
28. An alloy is a mixture of two or more metals.		x ? ✓
29. Alloys are produced to provide metallic substances with different physical properties to pure metals.		x ? ✓
Plastics	Covered (✓)	How well can you do this?

1. Plastics are important molecules made up of long chain molecules called polymers.		x	?	✓
2. Plastics are made by a process called polymerisation.		x	?	✓
3. Polymers can be synthetic or natural.		x	?	✓
4. Plastics can be made by the process of addition or condensation polymerisation.		x	?	✓
5. Examples of addition polymers include polythene, poly(propene) and PVC.		x	?	✓
6. Examples of condensation polymers include polyesters and polyamides.		x	?	✓
7. Plastics are made up of small units called monomers.		x	?	✓
	Covered (✓)	How well can you do this?		

8. The name of a polymer can be worked out from the name of the monomer, for example propene would give poly(propene).			
9. The structure of a polymer can be drawn from the structure of its monomers and vice versa.		x	? ✓
10. The type of polymer can be identified by its structure.		x	? ✓
11. Plastics can be grouped as thermosetting or thermoplastics.		x	? ✓
12. Thermoplastics can be reshaped upon heating whereas thermosetting plastics cannot.		x	? ✓
13. Burning plastics releases harmful gases such as carbon monoxide.		x	? ✓
14. Gases such as hydrogen chloride and hydrogen cyanide are released when certain plastics are burned.		x	? ✓
15. Biodegradable plastics have been developed.		x	? ✓
	Covered (✓)	How well can you do this?	

16. Polymers are engineered to be used for many tasks in a variety of environments.		x	?	✓
17. New materials are constantly being developed to meet the demands of society.		x	?	✓
18. New materials tend to have very specific properties.		x	?	✓
19. Ceramic materials have properties which make them useful components for many modern applications.		x	?	✓

Agrochemicals	Covered (✓)	How well can you do this?		
1. Plants require the correct nutrients to grow and produce sufficient food supplies.		x	?	✓
2. Chemists synthesise substances known as fertilisers to provide plants with the correct nutrients.		x	?	✓
3. Plant growth requires three key elements; Nitrogen, Phosphorus and Potassium which are known as the essential elements.		x	?	✓
4. The percentage composition of an essential element in a fertiliser can be calculated.		x	?	✓
5. Fertilisers can be natural substances such as compost or manure.		x	?	✓
6. Fertilisers can be produced by chemists through neutralisation reactions.		x	?	✓

	Covered (✓)	How well can you do this?
7. Fertilisers can have a serious impact on the environment such as polluting river systems.		x ? ✓
8. The Haber process involves the reaction of nitrogen from the air with hydrogen from methane to produce ammonia gas.		x ? ✓
9. The Haber process is a reversible reaction which means some of the ammonia gas formed will reform nitrogen and hydrogen as the reaction proceeds.		x ? ✓
10. Ammonia is used as a starting material for the production of Nitric acid and ultimately ammonium nitrate fertilisers.		x ? ✓

Chemical Analysis	Covered (✓)	How well can you do this?
1. Chemists carry out many analytical techniques to ensure that our environment remains healthy and safe and issues relating to pollution are tackled.		
2. Analytical techniques carried out by chemists include chromatography, flame tests, pH measurement using indicators/pH meters and separation techniques.		
3. Chemists monitor the environment qualitatively using techniques such as flame testing to identify what is present in a sample.		x ? ✓
4. Chemists monitor the environment quantitatively using techniques such as acid/base titrations to measure the quantity of substances present in a sample.		x ? ✓

Nuclear Chemistry	Covered (✓)	How well can you do this?		
1. Elements were formed when atoms of hydrogen gas were compressed and had enough energy to fuse with other hydrogen atoms producing new larger nuclei.		x	?	✓
2. These fusion reactions are examples of nuclear chemistry and occurred in stars.		x	?	✓
3. The heavier elements were formed from the fusion of lighter elements in stars.		x	?	✓
4. Everyone is exposed to background radiation from various sources at all times.		x	?	✓
5. Background radiation comes from sources such as cosmic rays, animals, rocks, soil and plants.		x	?	✓
6. Radioactive elements become more stable by emitting radiation.		x	?	✓
7. There are 3 types of radiation alpha, beta and gamma.		x	?	✓

	Covered (✓)	How well can you do this?
8. Alpha radiation is a Helium nucleus with the symbol ${}^4_2\text{He}$ or α .		x ? ✓
9. Beta radiation can penetrate thin metal foil, has a mass of 1/2000 and a charge of 1-.		x ? ✓
10. Beta radiation is an electron and has the symbol ${}^0_{-1}\text{e}$ or β .		x ? ✓
11. Gamma radiation can penetrate a large thickness of concrete and has no mass or charge.		x ? ✓
12. Gamma radiation has the symbol γ .		x ? ✓
13. Radioactive decay causes radioactive isotopes to decrease in mass and activity.		x ? ✓
14. The half-life of an isotope is the time taken for the mass or activity of the isotope to decrease by half.		x ? ✓

	Covered (✓)	How well can you do this?
15. The half-life of an isotope is constant.		x ? ✓
16. The half-life of an isotope can be used to date materials.		x ? ✓
17. Nuclear equations can be written to describe nuclear reactions for example ${}^2_1\text{H} + {}^3_1\text{H} \rightarrow {}^4_2\text{He} + {}^1_0\text{n}$		x ? ✓

Materials

It is hard to imagine life without mobile gadgets such as iphones, ipads and MP3 players. Yet twenty years ago these handy gadgets such as the mobile phone were bigger and cost five times as much. Advances in modern materials and **chemistry** have allowed us to develop these gadgets.



Materials are all substances and include **metals**, **ceramics** and **plastics** as well as natural and new substances.

H																			He
Li	Be											B	C	N	O	F		Ne	
Na	Mg											Al	Si	P	S	Cl		Ar	
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br		Kr	
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I		Xe	
Cs	Ba		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At		Rn	
Fr	Ra		Rf	Db	Sg	Bh	Hs	Mt	Uun	Uuu	Uub								
			La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu		
			Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr		

All **metals** lie to the left hand side of the dividing line in periodic table. We are surrounded by metals in life and use them in many different ways due to their chemical and physical properties.

Until the beginning of the thirteenth century only seven metals were known. These metals, known as the **Metals of Antiquity**, were gold, silver, copper, lead, tin, iron and mercury.

Gold (Au) and **Copper (Cu)** were the first metals to be known and used. The chemical and physical properties of metals are linked to their uses

- **Density**

Dense metals are used in a deep-sea diver's belts, while aluminium is used to make aircraft because it has a low density for a metal.

- **Thermal Conductivity**

Metals all conduct heat well because of the close contact of the atoms. e.g. metals are used in cooking utensils and radiators

- **Electrical Conductivity**

Metals all conduct electricity when solid and when molten because electrons can travel easily through the structure. e.g. metals are used for electrical wiring and elements in fires.

- **Malleability and Ductility**

Metals can be beaten into shape (malleable) e.g. the bodies of cars are pressed into shape. Metals can be drawn out into wires (ductile).

- **Strength**

Most metals are strong because of the metallic bond that holds the atoms together. e.g. The Forth Rail Bridge is made from steel.

Alloys

The properties of pure metals can be improved by mixing small amounts of other elements with them. These mixtures of at least one metal with other elements are known as alloys.

For example pure iron is brittle but when mixed with about 1% carbon steel is made that is much stronger. Steel is therefore an alloy of iron and carbon.

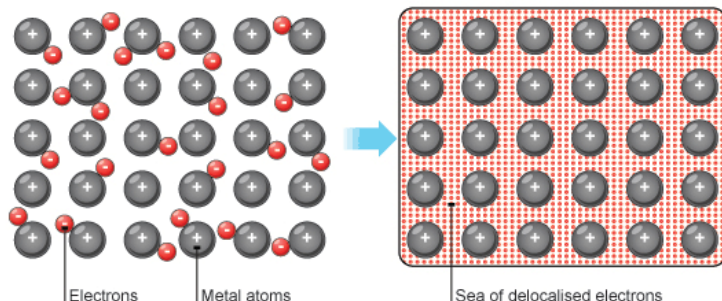
The table below shows some common alloys

Alloy	Main Metal	Other Elements present	Uses	Reason
Stainless steel	Iron	Chromium, Nickel	Sinks, Cutlery	Non-rusting, strong
Mild steel	Iron	Carbon	Girders, Car bodies	Strong, rust resistant
Gold	Gold	Copper	Rings, Electrical contacts	Good conductor, unreactive
Solder	Lead (50%)	Tin (50%)	Joining metals, electrical contacts	Low melting point, good conductor
Brass	Copper	Zinc	Machine bearings,	Hard wearing,

Metallic Bonding

The properties of metals can be explained by the bonding within metals.

Metals are held together by metallic bonding and it is this structure of attractive forces between the metal charged positively charged nuclei of atom and the negatively delocalised electron, which allows for electrical conductivity.



In metals the outer electrons of the atoms can move easily from atom to atom. The electrons within the structure of a metal are said to be **delocalised**. Delocalised electrons are simply electrons that are not confined to one space but can actually move from atom to atom.

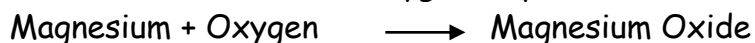
Reactions of Metals

Metals react with a variety of substances to form compounds. Some metals react more readily than others and this is dependant upon their placement in the periodic table.

By looking at a metals reactivity with oxygen, water and acids we can establish a reactivity series.

Metals and Oxygen

Most metals react with oxygen to produce a metal oxide. We can write a word equation for this.



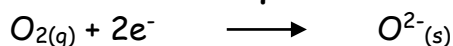
The change from metal atom to metal oxide is known as an oxidation reaction. **Oxidation** means that there has been a loss of electrons. The Magnesium in this case would lose electrons becoming Mg^{2+} . The electrons that have been lost by the Magnesium are gained by Oxygen to produce O^{2-} this reaction is called reduction. **Reduction** is the gain of electrons by a molecule, atom or ion.

The **oxidation equation** for the reaction that takes place is:



OXIDATION

The **reduction equation** for the reaction that takes place is:



REDUCTION

Metals and Water.

Some metals react extremely vigorously with water. In fact they are so reactive they have to be kept away from any water and moisture in the atmosphere. The group 1 metals are stored under oil. These alkali metals when added to water form an alkaline solution. Some other metals react more slowly e.g. when iron becomes wet it rusts.

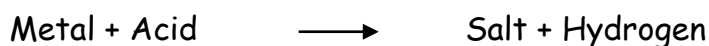
When a metal reacts with water a Metal Hydroxide and Hydrogen gas is produced.

Word Equation

In this reaction the metal is again oxidised whilst the water is reduced to hydrogen gas and hydroxide ions.

Metals and Acid.

Remember that all acids contain **hydrogen ions (H⁺)**. When any metal reacts with an acid a salt and hydrogen gas is produced.

**Reactions of Metals Summary**

Reaction with			
Metal	Oxygen	Water	Dilute Acid
Potassium Sodium Lithium Calcium Magnesium	Metal + Oxygen ↓ Metal oxide	Metal + water ↓ Metal hydroxide + Hydrogen	Metal + Acid ↓ Salt + Hydrogen
Aluminium Zinc Iron Tin Lead			
Hydrogen Copper	No reaction	No reaction	No reaction
Mercury Silver Gold			

Salt Reminder

Sulphuric Acid forms Sulphate Salts

Hydrochloric Acid forms Chloride Salts

Nitric Acid forms Nitrate Salts

Metal Ores

Metals are found in rocks in the Earth's crust. Most of the metals are in these rocks as compounds (**ores**)

- Metal oxides
- Metal sulphides
- Metal carbonates

Only gold, silver and platinum occur as uncombined (native) metals because they are unreactive and because of this these elements were among the first to be discovered.



Common name	Chemical name	Metal present
Haematite	Iron oxide	Iron
Bauxite	Aluminium oxide	Aluminium
Galena	Lead sulphide	Lead
Cinnabar	Mercury sulphide	Mercury
Malachite	Copper(II) carbonate	Copper

The Extraction of Metals

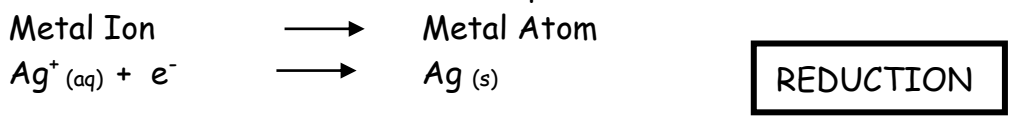
The time of discovery and large scale extraction of a metal can be partly explained by a metal's reactivity.

Heating

Some metals low down in the reactivity series can be extracted by heating alone.

If Silver (I) Oxide is heated silver metal is produced.

Silver oxide is an example of an ionic compound. By heating this ionic compound we produce silver metal which is an atom. This process of extraction is an example of a reduction reaction.



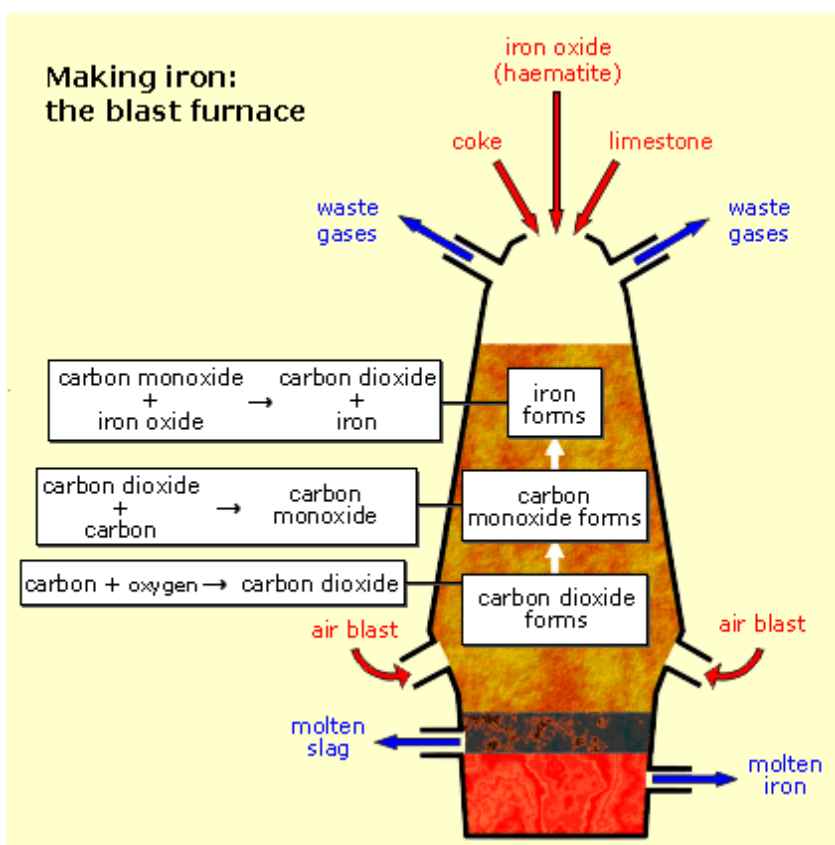
Heating with Carbon (Smelting)

Some metals cannot be extracted by heating alone and so require mixing the metal with carbon and heating. If copper oxide is heated it will not decompose to give copper metal, as the energy supplied by the heat alone is not enough to overcome the copper to oxygen bonds. Carbon is added to copper oxide and "pulls the oxygen away" from the copper.

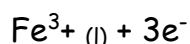
The Blast Furnace - Extraction of Iron

Another metal which is heated with carbon is **Iron**.

Bridges, buildings, cars, railways and many other things are made from iron. Iron is extracted from the earth's crust as an iron ore, **iron (III) oxide**. The iron is then extracted from its ore in the blast furnace.



Iron ore, coke (a source of carbon) and **limestone** are loaded in from the top of the furnace and hot air is blown in from the base. Iron ions in the iron ore are reduced to iron atoms when they gain electrons.



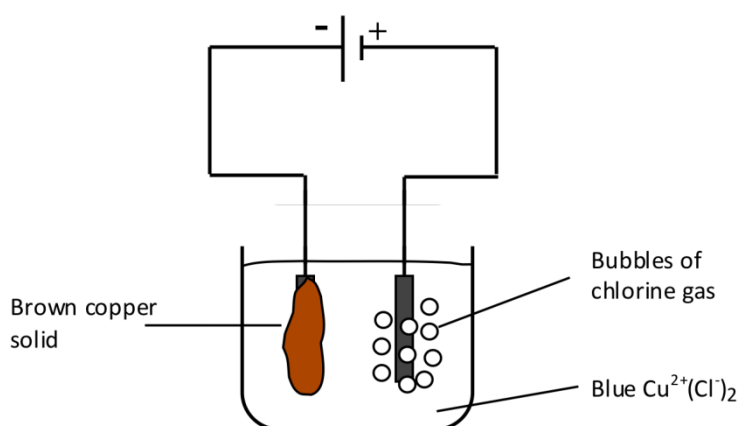
REDUCTION

The form of carbon reacts with the oxygen of the air been blown into the furnace and gives carbon dioxide which then reacts with more coke to give carbon monoxide. It is the carbon monoxide which is named the reducing agent of the process. A reducing agent is a substance which brings about reduction. Reducing agents give up electrons allowing the substances being reduced to gain these electrons.

Using Electricity

The use of electricity to extract a metal is called *electrolysis*. The metals that require electrolysis for extraction are highest up in the reactivity series.

Electrolysis is the breaking down of an ionic compound using electricity. A d.c. supply has to be used so that the products can be identified.



The demand for metals is high and methods are now available to extract all metals from their ores.

The extraction of a metal from its ore is a **reduction**.

It involves metal ions gaining electrons.

The method used to extract a metal depends on the reactivity of the metal.

- The more reactive the metal, the more difficult it is to extract.
- The less reactive the metal, the easier it is to extract.

This means going from the bottom to the top of the reactivity series the more difficult the reduction is.

Summary of the Extraction of Metals

Metal	Method of Extraction
Potassium	Electrolysis
Sodium	
Lithium	
Calcium	
Magnesium	
Aluminium	
Zinc	
Iron	Blast Furnace
Tin	Heat with carbon or carbon monoxide
Lead	
Copper	
Mercury	Heat alone
Silver	

Percentage Composition

Calcium carbonate has the formula CaCO_3 and contains 1 atom of calcium, 1 atom of carbon and 3 atoms of oxygen in the formula unit.

The relative atomic masses of Ca, C and O are respectively 40, 12 and 16.

This gives a formula mass of $40 + 12 + (16 \times 3) = 100$

$$\% \text{ of Calcium} = \frac{\text{Mass of calcium in the formula unit}}{\text{Formula mass}} \times 100$$

$$= \frac{40}{100} \times 100$$

$$= 40\%$$

For carbon and oxygen, the percentages are respectively 12% and 48%

$\% \text{ composition} = \frac{\text{Mass of element}}{\text{Gram formula Mass}} \times 100$

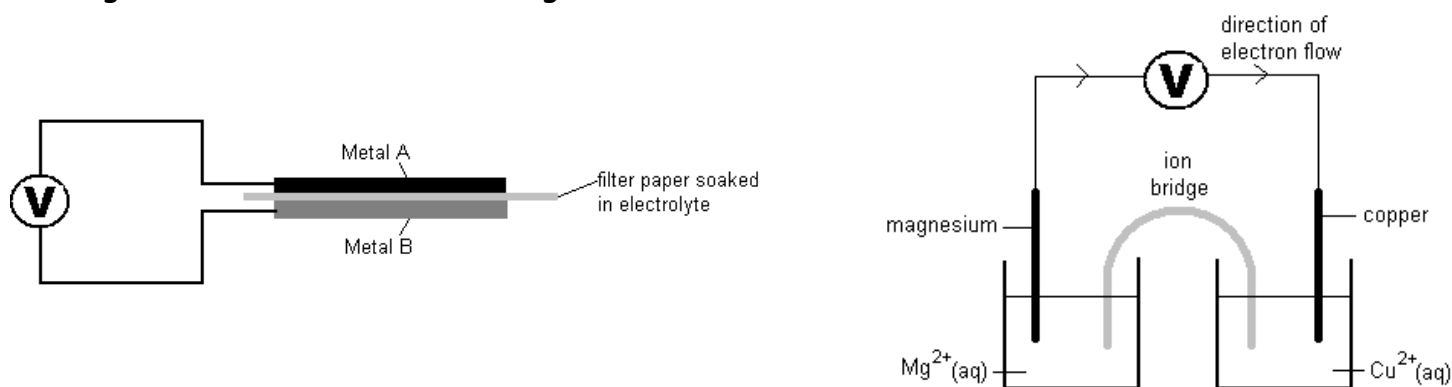
Metals and the Electrochemical Series

An electrochemical cell is a method of creating electricity using metals. Linking different pairs of metals together give different voltages. The **Electrochemical Series**, or **ECS**, is sorted according to the voltages produced by connecting different pairs of metals. The ECS can be found on page 7 of the data booklet.

Metals **high up** in the electrochemical series are more reactive and tend to **lose electrons easily** whereas metals **low down** in the electrochemical series are less reactive and tend to **hold on to their electrons**.

When two different metals are attached, **electrons always flow** from the metal **higher** in the series to the **lower** metal. The further apart the two metals are in the ECS the larger the cell voltage is.

A more complex electrochemical cell can be made by joining two half cells with an ion bridge. By dipping Magnesium and Copper into solutions of their ions and joining the solutions using an ion bridge an electric current will be generated.



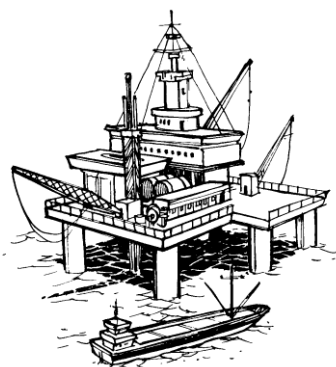
Oxidation and Reduction

The electrochemical series on page 10 of your data booklet shows the ion-electron equations for some common **reduction** reactions.

These equations can be **reversed** to get the **oxidation** reaction.

A memory aid to help you remember what happens to electrons during oxidation and reduction is:

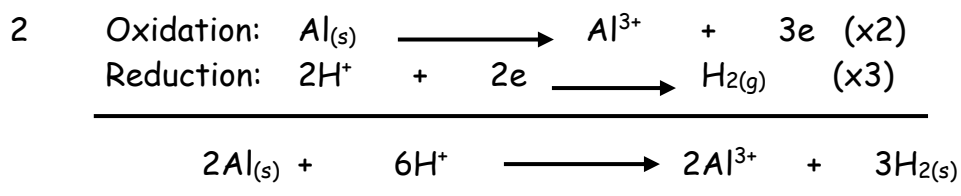
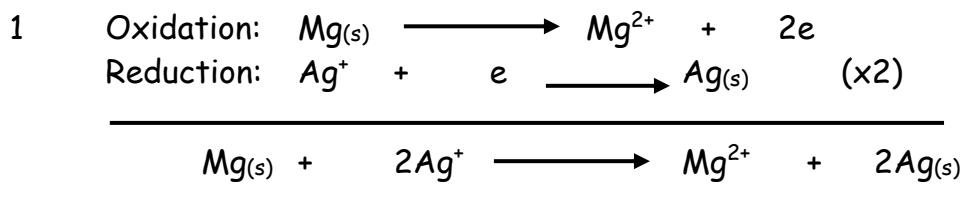
Oxidation
Is
Loss of electrons
Reduction
Is
Gain of electrons



REDOX Reactions

Oxidation and reduction are two halves of the same chemical reaction. The electrons, which are lost by the species being oxidised are gained by the species being reduced. This type of chemical reaction is known as a REDOX reaction.

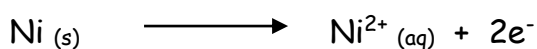
To form the overall redox reaction, the ion-electron equations for the oxidation and reduction must be combined, ensuring that the electrons cancel.

**Chemical Cells involving Non-Metal Ions.**

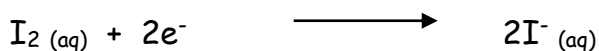
An electric current in a cell is produced by a chemical reaction - a REDOX reaction. The half cells which make up a cell do not always require metals. As long as you have one reactive metal to give away electrons and another substance to accept the electrons then you can construct a cell.

Electrochemical cell with nickel in nickel sulfate and carbon in iodine solution

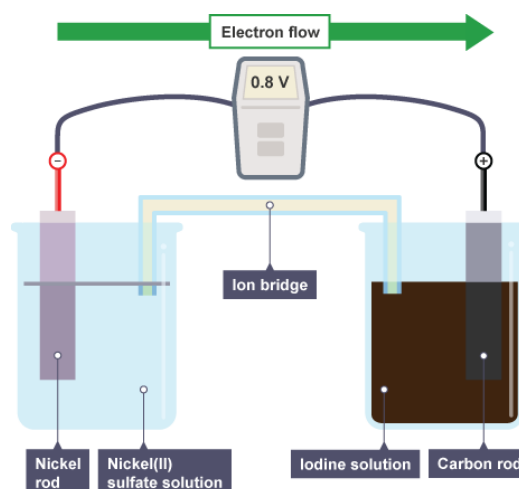
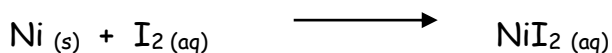
In this reaction the nickel atoms give away electrons and change into nickel (II) ions:



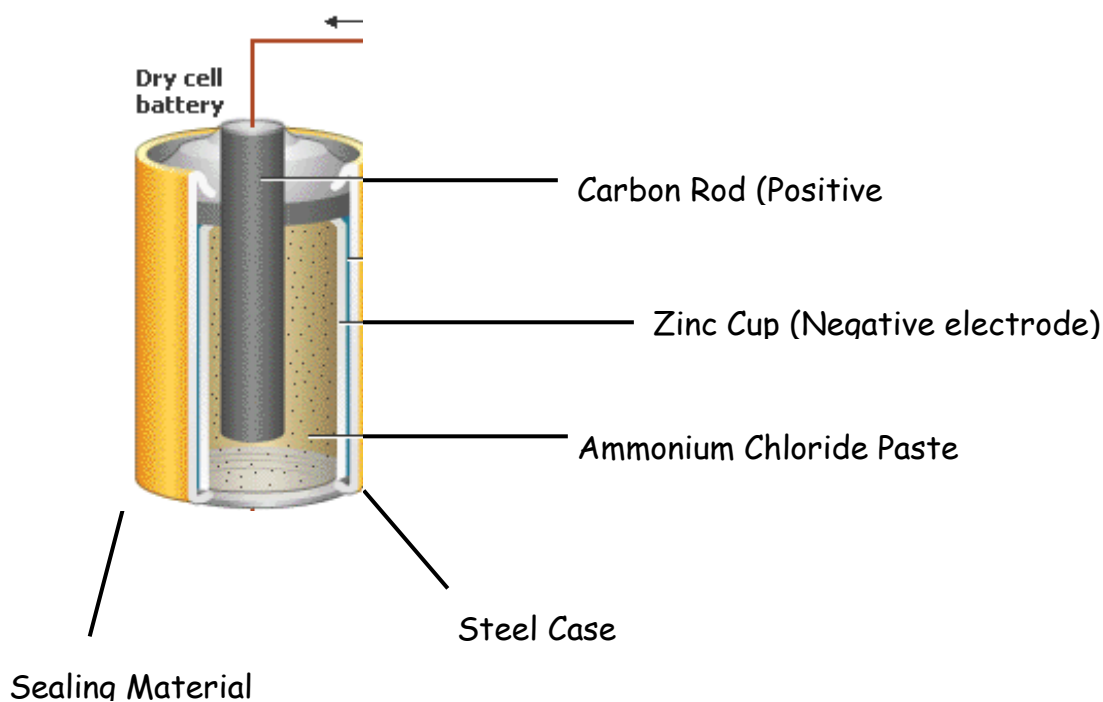
The iodine molecules accept these electrons and change into iodide ions.



The overall equation for the reaction is:



How Do Batteries Work?



Although there are many different types of chemical cell they all work in the same way. Electrons are lost by one substance and gained by another. In rechargeable batteries the direction of electron flow can be reversed, reforming the original chemicals and thus recharging the cell. Some chemical cells, including those in mobile phones & car batteries can be recharged thousands of times.

Fuel Cells

A fuel cell is an electrochemical cell that produces electricity by combining a fuel such as hydrogen with oxygen without burning it.

The use of fuel cells is increasing. They represent a clean technology which will help industries and governments meet CO_2 emission reduction targets.

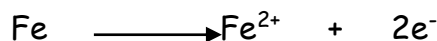
Fuel Cells and Rechargeable Batteries are technologies based on REDOX reactions.

Corrosion

Corrosion is a chemical reaction which happens when the surface of a metal / non metal changes from an element to a compound.

Rusting is the corrosion of iron. It is a very slow reaction so we use Ferroxyl indicator to detect rust quickly.

When iron rusts the iron atoms lose two electrons forming Fe^{2+} ions. The ion-electron half-equation is

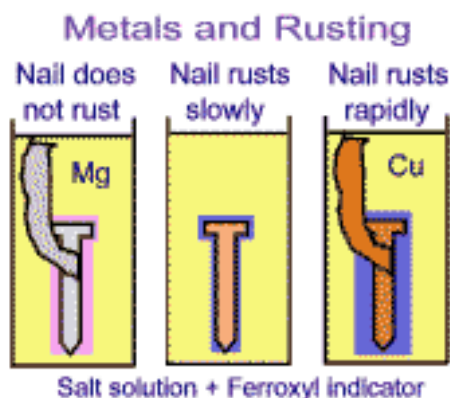


OXIDATION

Ferroxyl indicator turns blue if Fe^{2+} ions are present.

If iron is to rust the metal must come into contact with both oxygen and water. We can slow down the process and prevent rusting by using different methods of protection. The metal can be given physical protection to hinder corrosion. Physical protection means that air and water are prevented from reaching the metal surface. Metal objects can be physically protected by coating them with paint, oil, grease or plastic.

Metals all corrode at different speeds (reactivity series) By placing a more reactive metal into contact with iron, the iron would be protected and the more reactive metal would react. This is known as sacrificial protection.



What are Plastics?

It is difficult to imagine a modern world without plastics. They are used in our homes, schools and hospitals, in fact almost everywhere. A material which is *plastic* is described as being pliable or able to be moulded. Some have very ordinary uses such as the polythene bag. Others have very specialised uses. Many parts of formula 1 racing cars, for instance, are in made from specially designed plastics.



The starting materials for the synthetic plastics industry are obtained from crude oil. When crude oil is refined, various small molecules are obtained which are then used as the building blocks of plastics.

Plastics are described as being **synthetic** (man-made). Some plastics can be melted and drawn out (extruded) into thin threads called fibres. These synthetic fibres are then woven or twisted together to form **fabrics**.

Making a plastic

Plastics are made when small molecules join together to form much larger molecules. The small molecules are called **monomers**. The large molecules formed when the monomers join together are called **polymers**. **Polymerisation** is the name of the process where the monomers join together to make a polymer.

Mono- = one part poly- = many monomers joined together.

Naming Plastics

The name of a polymer can be worked out from the name of the monomer as shown below.

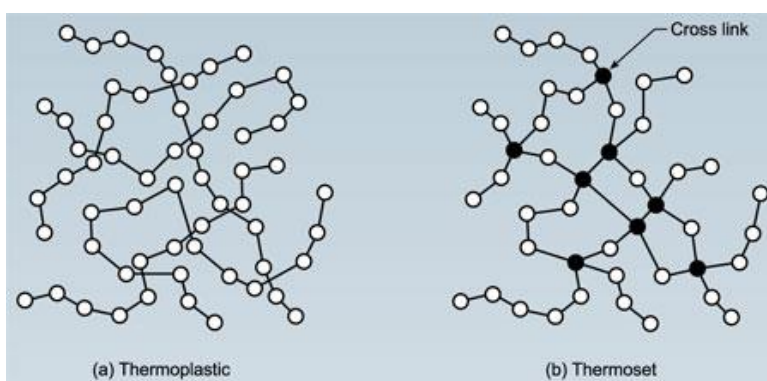
Monomer	Polymer
Ethene	Polyethene (polythene)
Propene	Polypropene
Butane	Polybutene
Styrene	Polystyrene
Vinyl chloride	Polyvinylchloride (P.V.C)

Thermoplastic or thermosetting plastic

A thermoplastic will melt when it is heated and can be reshaped because the polymer chains do not have any cross-links between them.

Thermosetting plastics do not melt when they are heated. They become harder and more brittle. They do have cross-links between the polymers.

Thermoplastic	Use	Thermosetting	Use
Polythene	Plastic bags	Bakelite	Electrical sockets
Polystyrene	Packaging	Melamine	Picnic plates
Nylon	Clothing, ropes, carpets	Polyacrylamide (P.A.M.)	Soft contact lenses



Burning plastics can be dangerous because when they burn they produce toxic gases. The gases given off depend on the composition of the polymer i.e. what elements are present. Most plastics are made up of long chain hydrocarbons, so when they burn Carbon dioxide and Water are produced. In a limited supply of air, however **poisonous Carbon Monoxide** is produced. The more Carbon a plastic contains the smokier the flame will be. This Carbon in the form of **Soot** is harmful if inhaled and damage to the respiratory system can occur.

Examples:

Plastic being burned	Name of poisonous gas
Polyvinylchloride (P.V.C.)	Hydrogen chloride
All hydrocarbon polymers	Carbon monoxide
Polyurethane foam	Hydrogen cyanide

Properties and uses of Plastics

Most plastics have the following important properties with slight variations making some more suitable than others for certain purposes.

- Easily moulded - can be made into different shapes
- Lightweight - they have low densities
- Flexible - they can be bent without breaking
- Durable - hard-wearing
- Insulator - are not good conductors of heat or electricity
- Chemically inert - mostly they are non-biodegradable and do not rot.

New Materials

New materials with very specific properties are constantly being developed.

Biopol is a biodegradable plastic which has been developed. It can be broken down by bacteria in the soil.

Polyethenol is a soluble plastic which is used in hospitals for patients clothing which may be contaminated. The whole bag and contents is put into the washing machine without being opened to protect any infection from spreading.

Ceramic materials have properties which make them useful components for many modern applications.

Polymers can be natural or synthetic (man-made)

Natural polymers	Synthetic polymers
Wool	Polythene
Silk	Polystyrene
Natural rubber	Nylon
Starch	Perspex

Polymers can be classified as addition polymers or condensation polymers

Addition polymers	Condensation polymers
Polythene	Polyester
Polypropene	Polyamides like nylon
P.V.C.	
Polystyrene	Starch
Perspex	Wool

Addition polymers

Addition polymers are made when small **unsaturated** monomers join together to give much larger molecules.

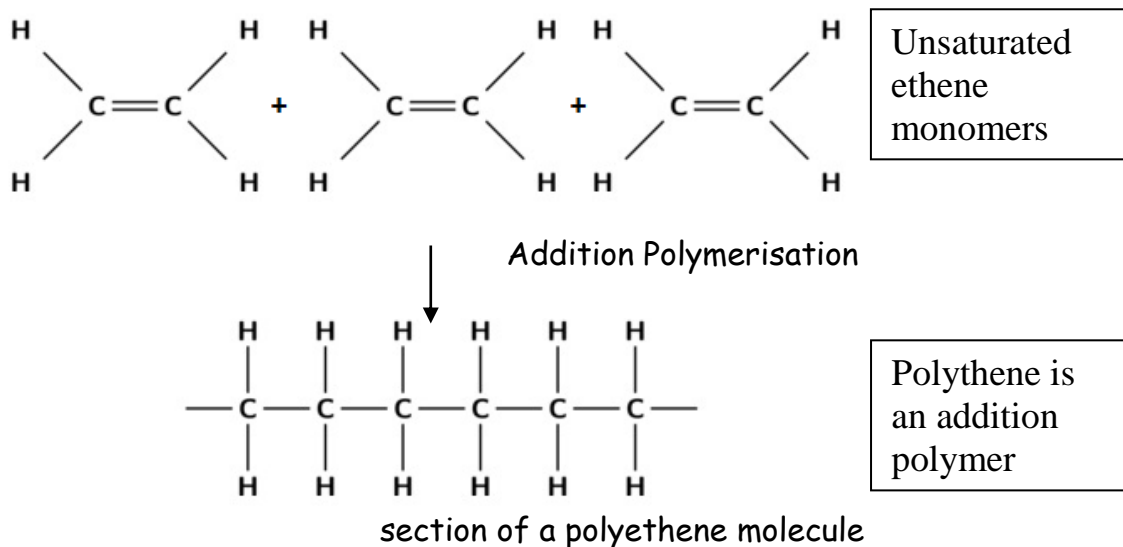
The unsaturated monomers are obtained either by cracking fractions from crude oil or cracking ethane from natural gas.

Unsaturated monomers like ethene have **carbon to carbon double bonds** which open to allow the monomers to join together.

This process is called **addition polymerisation** and the polymer is an **addition polymer**.

Making Polyethene

Polyethene is one of the commonest plastics that we use. Its name is often shortened to polythene. It is formed when thousands of ethane (C_2H_4) molecules add together.

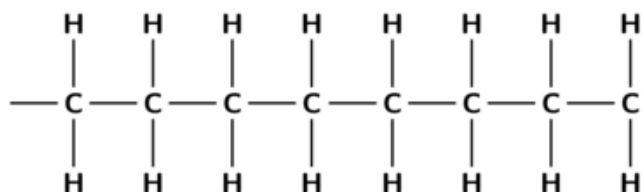


The ethene itself is obtained either by cracking fractions from crude oil or cracking ethane from natural gas.

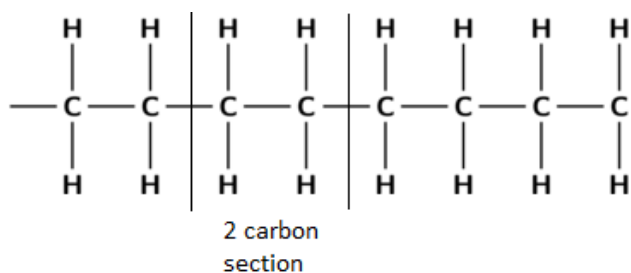
Repeating unit

The monomer which was used to make a polymer structure can be worked out from the **repeating unit**. The following steps help you to locate the repeating unit and then identify the monomer.

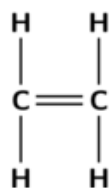
1. Consider the carbon chain of an addition polymer



2. Bracket a 2 carbon repeating unit using a pencil



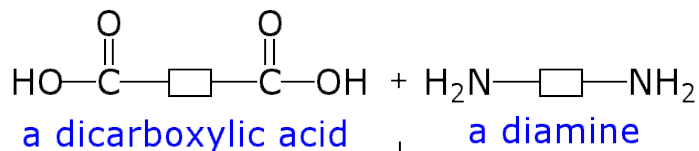
3. Remember, the monomer was an alkene with a double bond between the 2 carbons. The monomer was therefore :



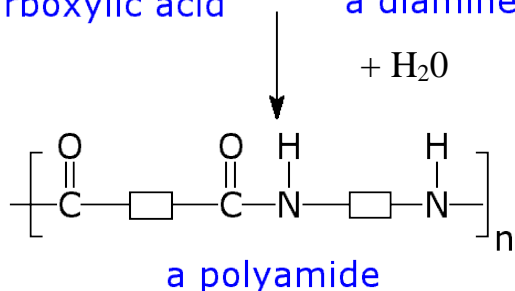
Polymer Structure	Monomer Structure
$ \begin{array}{cccccccc} \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \\ & & & & & & & \\ \cdots & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & \cdots \\ & & & & & & & \\ \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \end{array} $	$ \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{C} = \text{C} \\ \quad \\ \text{H} \quad \text{H} \end{array} $
$ \begin{array}{cccccccc} \text{F} & \text{F} & \text{F} & \text{F} & \text{F} & \text{F} & \text{F} & \text{F} \\ & & & & & & & \\ \cdots & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & \cdots \\ & & & & & & & \\ \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \end{array} $	$ \begin{array}{c} \text{F} \quad \text{F} \\ \quad \\ \text{C} = \text{C} \\ \quad \\ \text{H} \quad \text{H} \end{array} $
$ \begin{array}{cccccccc} \text{F} & \text{F} & \text{F} & \text{F} & \text{F} & \text{F} & \text{F} & \text{F} \\ & & & & & & & \\ \cdots & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & - & \text{C} & \cdots \\ & & & & & & & \\ \text{F} & \text{F} & \text{F} & \text{F} & \text{F} & \text{F} & \text{F} & \text{F} \end{array} $	$ \begin{array}{c} \text{F} \quad \text{F} \\ \quad \\ \text{C} = \text{C} \\ \quad \\ \text{F} \quad \text{F} \end{array} $

Condensation polymers

Condensation polymers are a bit more complicated than addition polymers. When the monomers join together a small molecule, usually water, is produced as well as the polymer. This is why it is called condensation polymerisation.



monomers



Condensation polymer

This type of polymer can be identified as a condensation polymer because it has elements of nitrogen in the backbone. Other condensation polymers may have oxygen in the backbone.



Plants need **three essential elements** to grow successfully. These elements are **nitrogen (N), phosphorus (P), and potassium (K)**. Plants naturally take these in through their roots as soluble compounds. The elements are returned to the soil when the plant dies and decays.

When food crops are harvested these elements never get the chance to return to the soil so farmers need to replace them using chemicals called **fertilisers**. Natural fertilisers like garden **compost** or farmyard **manure** can be used but with the **growing world population** more and more food crops are required.

Chemists can synthesise **artificial fertilisers** to meet this demand. The **percent of each element** in the particular fertiliser can be calculated. It is written on the label as an NPK value e.g. 10.6, 4.4, 1.7 for the plant food "Baby Bio"

Percentage Mass Example

Calculate the percent mass of nitrogen in the fertiliser ammonium phosphate.

Step 1 calculate the formula mass (R.F.M.)

using relative atomic masses (R.A.M.) from

the data book $(\text{NH}_4)_3\text{PO}_4$

$$\text{N} \times 3 = 14 \times 3 = 42$$

$$\text{H} \times 12 = 1 \times 12 = 12$$

$$\text{P} \times 1 = 31 \times 1 = 31$$

$$\text{O} \times 4 = 16 \times 4 = 64$$

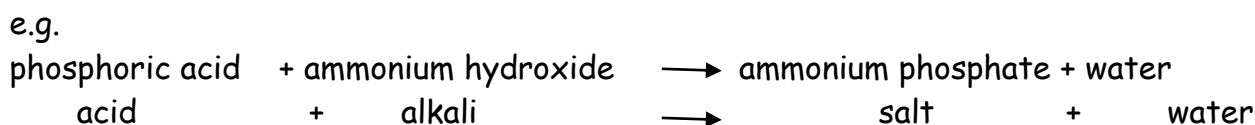
$$\text{R.F.M.} = 149$$

Step 2 calculate the percentage mass

$$\% \text{ N} = \frac{\text{Mass of N in the fertiliser}}{\text{Formula Mass}} \times 100 = \frac{42}{149} \times 100 = 28\%$$

The percent mass of Nitrogen in ammonium phosphate is 28%

Artificial fertilisers like ammonium phosphate can be produced in neutralisation reactions by neutralising phosphoric acid with the alkali ammonium hydroxide. Fertilisers produced in this way are the "salts" in the neutralisation reaction.



Disadvantages

Pollution by fertilisers can be a serious problem. These soluble chemicals can be washed out of the soil into our rivers by the rain and may even find their way into our drinking water.

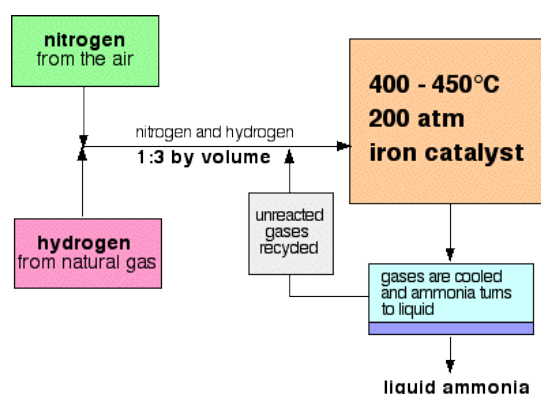
Summary - Agrochemicals

National 5

The Haber Process



Fritz Haber, 1918



The industrial manufacture of **ammonia** is carried out by reacting **nitrogen** from the air with **hydrogen** obtained from natural gas in the **Haber Process**.



Unfortunately the reaction is **reversible** shown by the \rightleftharpoons arrows and any ammonia formed can break up again to form oxygen and nitrogen.

The Haber process maximises the yield of ammonia by

- using a catalyst of iron pellets
- having a moderately high temperature between 400°C to 500°C
- removing liquid ammonia by cooling it as soon as it forms
- recycling any unconverted N₂ and H₂ through the reaction chamber

Ammonia forms the alkali ammonium hydroxide when dissolved in water.

Ammonia is also the starting material for the production of nitric acid in the Ostwald process and ultimately ammonium nitrate fertilisers by neutralising the nitric acid with ammonium hydroxide.

Analytical Chemistry is a subject which spans almost all areas of Chemistry. It is concerned with identifying, measuring and separating the chemicals present in a sample.

Chemists can perform tests on a sample of natural or synthetic matter to first of all identify what chemicals are present. This type of analysis is called Qualitative Analysis. The types of techniques used in Qualitative Analysis can include flame testing and using acid/base indicators. Analytical techniques that measure how much of a chemical is present in a sample are called Quantitative (remember quantity means how much). This type of analysis uses techniques such as acid/base titrations.

Once chemists have identified the type of chemicals in a sample they can then proceed to separate the different chemicals. Separation Techniques vary on what types of chemicals are being separated. Examples include filtration, evaporation and chromatography.

Scientists across the globe use these analytical techniques, amongst others, in a variety of ways. A forensic scientist might want to identify what type of ink a criminal wrote a threatening letter with. Chromatography could solve this problem. A drinks manufacturer might want to monitor how much acid is in their fizzy drinks. They could use an acid/base titration. A scientist checking the quality of sea water might want to remove any solid particles by using filtration. The list goes on.

Remember

Qualitative Analysis = What is present?
Quantitative Analysis = How much is present?

Environmental Scientists are constantly monitoring the quality our environment using a range of chemical tests. They are checking to ensure it is healthy and that contamination and pollution is dealt with.

Water samples are checked regularly to ensure it is safe to drink or a healthy environment for aquatic wild-life. Acid-rain can often cause water to become acidic and therefore not suitable for drinking or living in. Scientists can use an acid/base titration to measure how acidic a sample of water is and can then work on how best to neutralise it.

Water samples are also often checked to find out what if any chemicals are contaminating. For example, some water supplies can be contaminated with nitrates which have washed off of nearby fertilised fields. Sometimes metals can leach into the water supply from industrial plants and can then be absorbed by plants and animals. Even petrol and grit which run off road surfaces during heavy rain can end up in our water supply. Qualitative analysis can find out what is present and can sometimes be used to trace the contamination back to its source.

Soil and plant samples are checked in similar ways to monitor the presence and levels of nutrients, minerals and contaminants. It is important to ensure that land is safe to grow on and that food is safe to eat as some contaminants can pass through the food chain from soil to plant to animal consumer.

In Scotland the water, soil and even the air is analysed and monitored by the Scottish Environmental Protection Agency (SEPA). With over 130 chemists dedicated to collecting and analysing samples year round, the quality and safety of our environment is well regulated.

What it's used for:

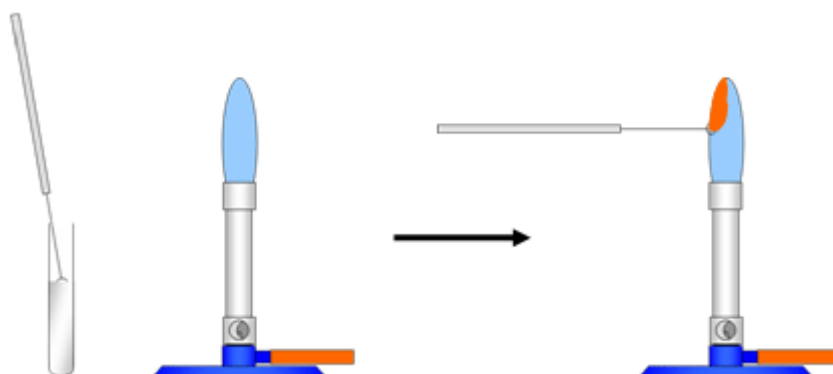
To test for the presence of elements (metal ions) in a sample. Different metal ions burn with different coloured flames.

Apparatus:

Bunsen burner, thin metal loop, test samples, acid, safety glasses.

Method:

- Clean the thin metal loop by dipping it in acid and rinsing it with water.
- Dip the metal loop into a solution or powder of the sample.
- Hold the sample at the edge of the Bunsen flame and observe the change in colour.
- Use the table of flame colours in the data booklet to identify the metal.
- Clean the metal loop with acid and water between samples.

**Flame Colours:**

Metal	Flame Colour
Barium	Pale green
Calcium	Yellow-red
Copper	Green-blue
Lithium	Red
Sodium	Orange
Potassium	Lilac

Type of Analysis: Qualitative

What it's used for:

To test samples to determine whether they contain an acid or an alkali. Some indicators only show whether a sample is acidic or alkaline (litmus) but others can show how acidic or alkaline something is (universal indicator). pH meters can be used to provide an accurate measurement of the acidity/alkalinity of a substance.

Apparatus:

Indicator (e.g. litmus, pH paper, universal indicator) or pH meter, test samples, safety glasses.

Method:

- When using indicator, add a few drops to the test sample and observe any colour change. Compare the colour to the colour chart for this particular indicator. Some (e.g. litmus) might only give a colour for an acid or alkali. Other (e.g. universal indicator) will have a range of colours depending on pH.
- When using pH paper use a dropper to moisten the paper with the test sample. Observe any colour change and compare to the colour chart.
- When using a pH meter the meter should be turned on and the cap removed from the electrode. Immerse the tip of the electrode in the sample and stir gently. Wait until the display settles and record the pH. After use the meter electrode should be rinsed with water.

Display



Electrode

Type of Analysis: Qualitative/Quantitative

Acid/Base Titration

National 5

What it's used for:

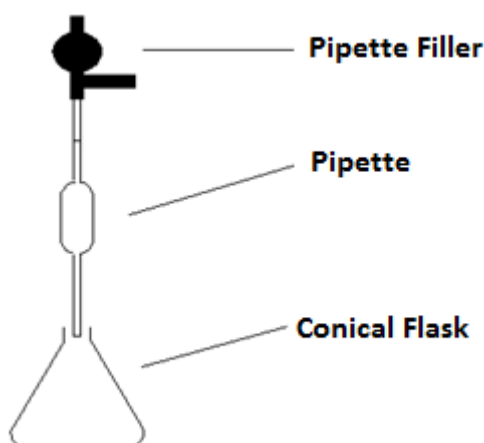
To measure the concentration of acid in a sample, by neutralising with a known volume and concentration of alkali (base).

Apparatus:

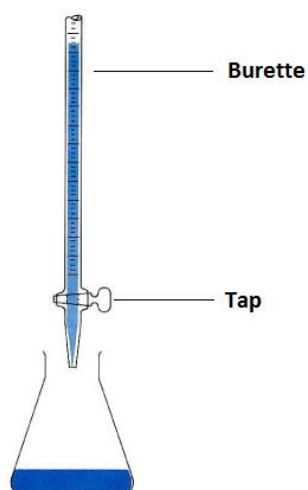
Burette, pipette, pipette filler, conical flask, 2 beakers, clamp stand, white tile, indicator, acid, alkali, funnel, safety glasses.

Method:

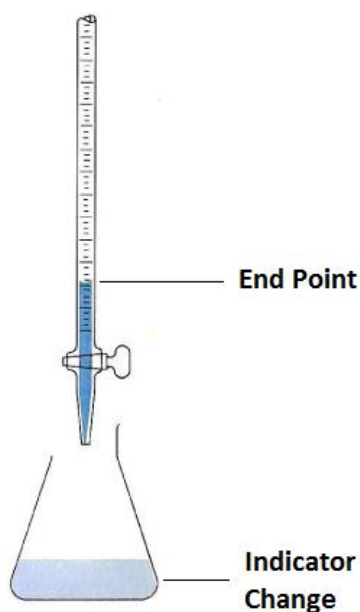
- Pour a small volume of alkali into a clean beaker. A **pipette** is used to measure out an accurate volume of **alkali** solution. The liquid is drawn into the pipette using a filler or bulb until the alkali exactly reaches the mark on the neck of the pipette.
- Release the alkali from the pipette into a clean conical flask. Add a few drops of indicator.



- Pour a small volume of acid into a second clean beaker. Holding the **burette** in a clamp stand, use the funnel pour the **acid** into the burette, ensuring the tap is closed.
- Place the conical flask below the burette, upon a white tile.
- Using the tap to control the flow, add the acid from the burette to the alkali in the conical flask.



- When the indicator changes colour, the end-point of the reaction has been reached and the alkali has been neutralised. Record the volume of acid which has been used.



- The first titration is known as the rough titration. It should be repeated more accurately until two concordant titrations are achieved. This means two accurate titrations where the volume of acid used are within 0.2ml of each other.

Type of Analysis: Quantitative

Filtration

National 4

What it's used for:

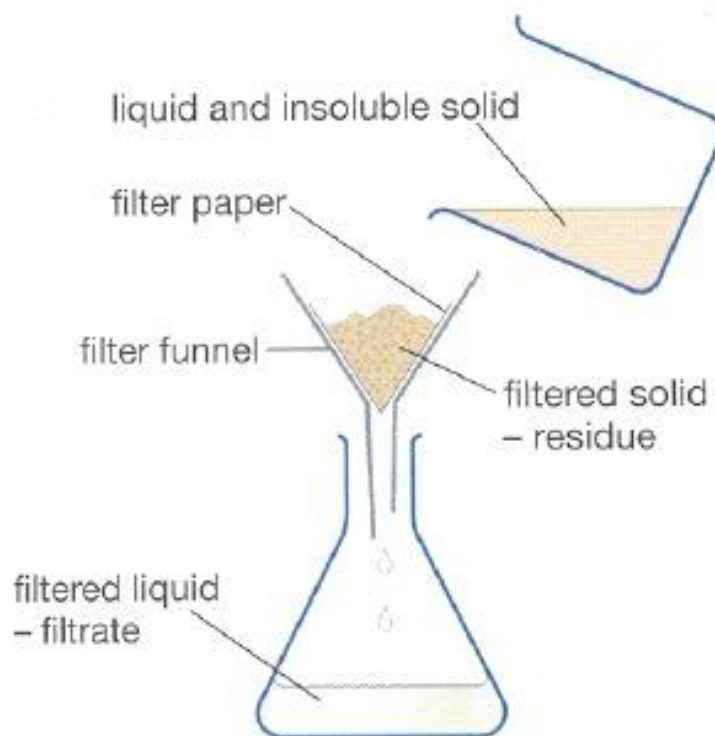
To separate insoluble solids from liquids. Often when two liquids are mixed, a solid or **precipitate** is formed. Filtration can be used to remove it from the solution.

Apparatus:

Filter paper, filter funnel, beaker, conical flask, mixture for separation, safety glasses.

Method:

- Fold the filter paper into a cone and place it in the filter funnel.
- Holding the funnel and paper above a clean conical flask, carefully pour the solution through the funnel.
- The solid precipitate will be held in the folded filter paper. This is the **residue**. The liquid passes through the paper. This is the **filtrate**.



Type of Analysis: Separation

Evaporation

National 4

What it's used for:

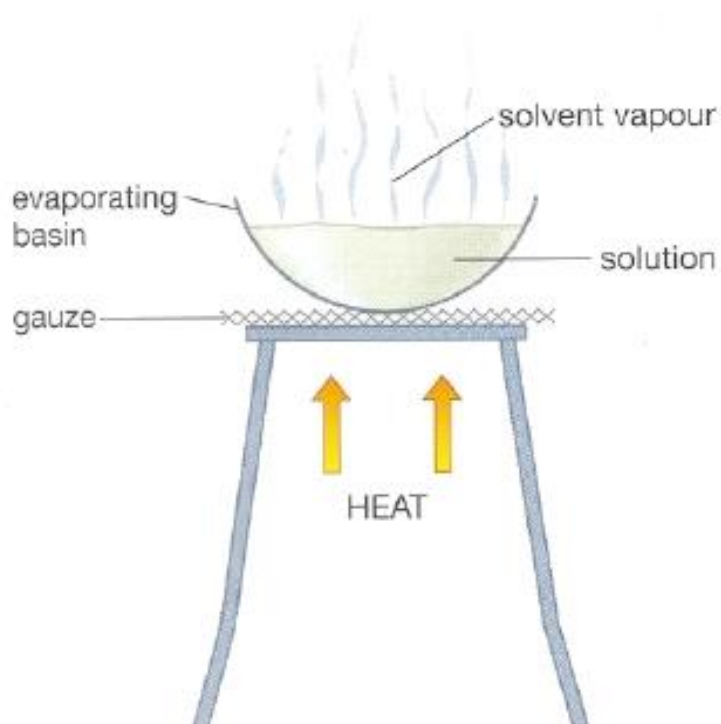
To separate a soluble solid or **solute** from a solution. Many salts and other compounds are often dissolved in a solution. In order to recover them, the **solvent** (liquid) needs to be removed by evaporation.

Apparatus:

Bunsen burner, tripod, evaporating basin, solution for separation, safety glasses.

Method:

- Carefully pour the solution into an evaporating basin.
- Heat the solution over a Bunsen burner until around half of the solution has evaporated. This leaves a more concentrated solution.
- Leave the remaining solution in the basin overnight to evaporate the liquid, leaving behind crystals of the solid.



Type of Analysis: Separation

Chromatography

National 4

What it's used for:

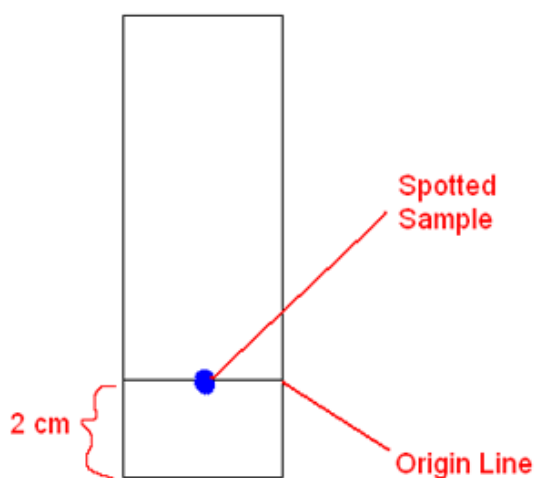
To separate different soluble compounds in a solution. This can be particularly effective in separation the colours in ink or food dye, etc. Some colourless substances like sugars require a developing agent to show their position after chromatography. Scientists can use chromatography to identify which compounds are present in a sample.

Apparatus:

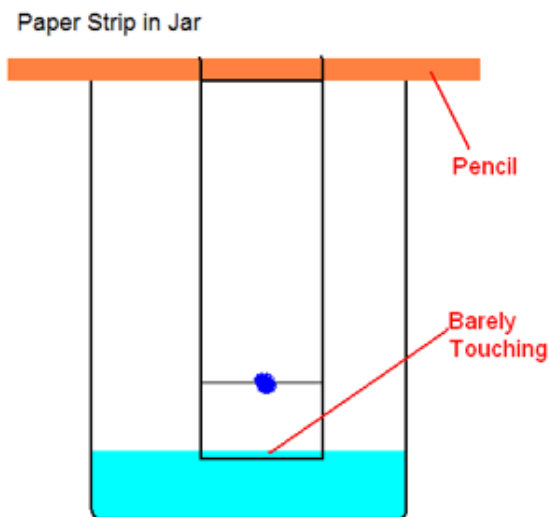
Chromatography paper, beaker, solvent, solution for separation, pencil, ruler, safety glasses.

Method:

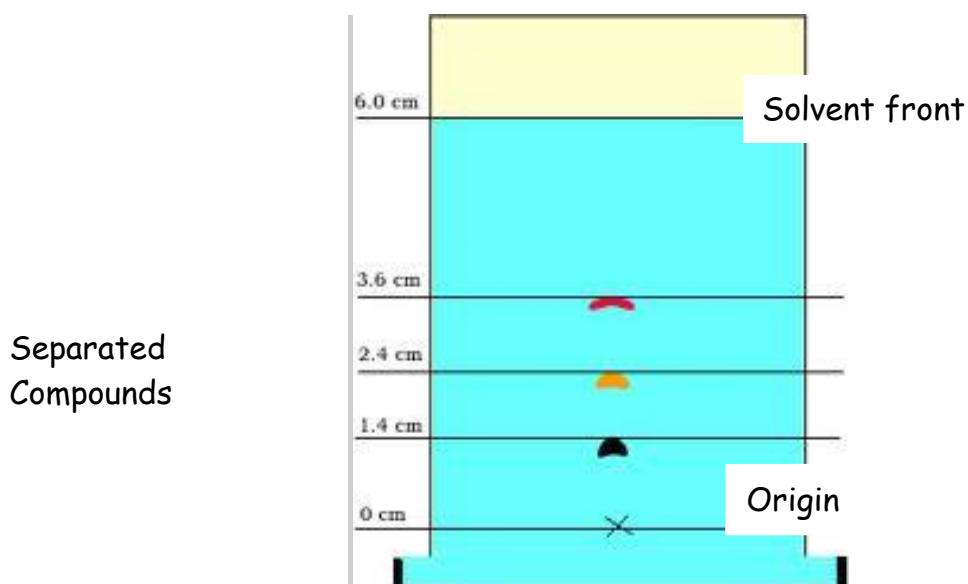
- Carefully draw a straight line in pencil around 2cm from the bottom of the chromatography paper. This is the origin. Carefully place a drop of solution to be separated on the origin line. Attach the top of the paper to a pencil or another support. It must be wider than beaker.



- Pour a small volume of solvent into a beaker. Using a pencil gently lower the paper into the solvent ensuring that the paper does not touch the bottom and that the solvent does not reach the origin line.



- Leave the chromatography to develop and remove the paper when the solvent has moved almost to the top. The distance travelled by the solvent is called the solvent front.
- As the solvent has travelled up the paper it will have carried the soluble compounds in the sample. Different substances will have travelled different distances and so they will separate out.

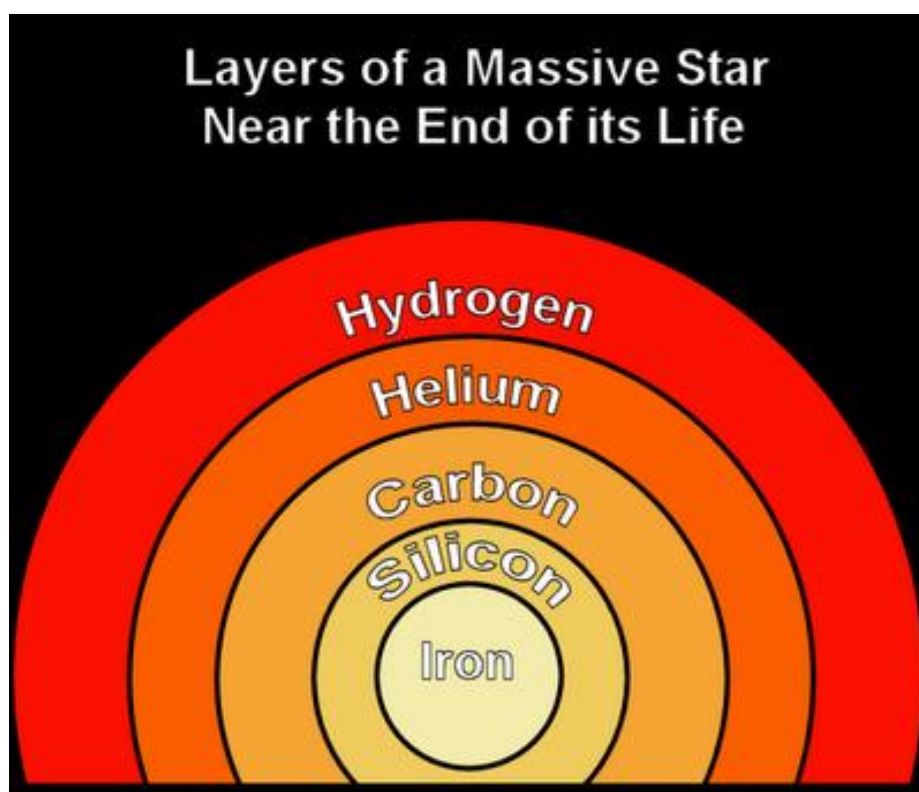


Type of Analysis: Separation/Qualitative

All of the elements which can be naturally found on Earth originated in the stars and were formed in nuclear fusion reactions. Atoms of hydrogen in the centre of stars began to fuse together to form new, larger nuclei. This was possible due to the extremely high temperatures and pressure in the centre of the stars.

Helium was produced when two hydrogen atoms were fused together. The nuclei of helium could then undergo more fusion to produce other elements. Heavier elements such as carbon and oxygen were made by the fusion (joining together) of lighter elements in the stars.

Eventually layers of different elements build up within the star with the heaviest in the centre and the lightest at the surface. When the centre of core of the star is mainly made of iron the star becomes unstable and explodes in what is called a *supernova*. During the explosion the elements from the star continue to fuse together and form the heaviest elements.

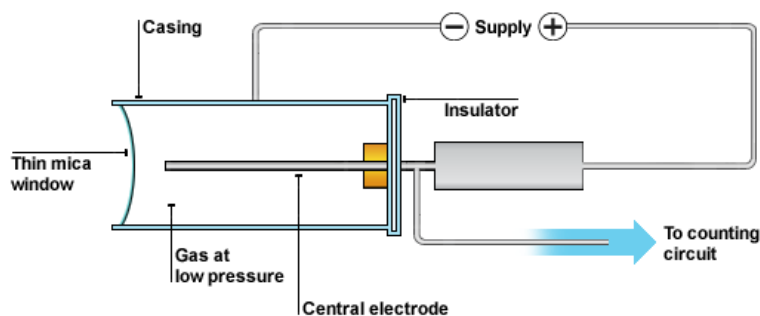


During our lifetime we are continually exposed to some degree of background radiation. Most of this radiation is naturally occurring and has been around since the Earth was formed. This has been added to over the past century or so from artificial sources.

Natural background radiation comes from 3 main sources: space (cosmic radiation), living things, and rocks and soils. Cosmic rays from the Sun and space penetrate the Earth's atmosphere whilst the Earth's crust and some rocks emit radioactive radon gas. Radiation from the soil is absorbed by plants and is in turn consumed by humans and other animals.

Some artificial sources of radiation include medical procedures such as x-rays, nuclear power stations and even some old TV's and luminous watch dials. The radiation emitted from artificial sources is much less than natural sources however. Levels of radiation can be measured using equipment such as a Muller -Geiger Tube.

A Muller-Geiger Tube is a hollow cylinder filled with Argon Gas at low pressure. Inside the tube is an electrode and at one end a thin mica window. A flow of electricity is passed through the casing of the tube and along the electrode. When radiation enters the tube through the window it causes ions to be produced in the gas. These ions allow the gas to conduct electricity and a pulse in voltage is created. These pulses of voltage are amplified and counted. The more voltage pulses counted the more radiation present.



Some elements have isotopes which are unstable. This causes them to spontaneously decay or breakdown into more stable isotopes by releasing energy in the form of radiation. This is called radioactivity. During this process the nuclei of the element is changed. This is different from normal chemical reactions when only the electrons in the outer shells are affected.

There are three main types of radiation; alpha, beta and gamma.

Alpha radiation is when an atom emits (releases) alpha particles. An alpha particle is identical to a helium nucleus. It consists of two protons and two neutrons. It can be written as α or ${}^4_2\text{He}$. An alpha particle can only travel a few cm in air.

Beta radiation happens when an atom emits an electron. Beta particles are slightly more penetrating than alpha particles - they can travel further and pass through thin paper and body tissue. Unlike normal electrons, the beta particle does not come from the outer shells of the atom. It is created in the nucleus when a neutron splits into two particles, a proton and an electron. The electron comes shooting out of the atom at high speed. A beta particle can be written as β or ${}^0_{-1}\text{e}$.

Gamma radiation is different from alpha and beta as there are no particles, only energy being emitted by the atoms. This means that gamma radiation has no mass or charge. Gamma radiation is the most dangerous as it can travel farthest and penetrate thin layers of metal or concrete. Gamma radiation is given the symbol γ .

Type of Radiation	Symbol	Penetration
Alpha	α or ${}^4_2\text{He}$	A few cm of air.
Beta	β or ${}^0_{-1}\text{e}$	Thin paper, a few cm of body tissue.
Gamma	${}^0_0\gamma$	Thin metal foil, concrete.

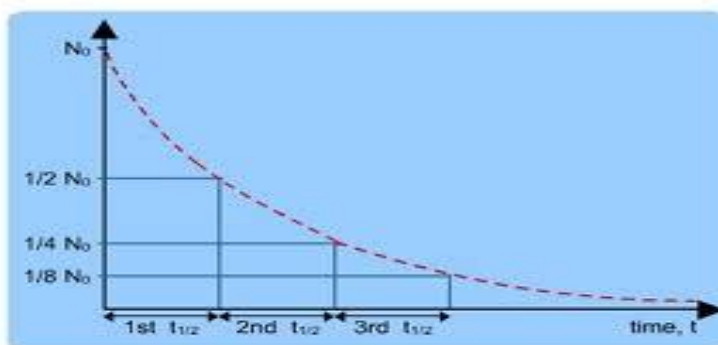
Radioisotope Half-life

National 5

When a radioactive isotope (radioisotope) decays it causes a decrease in the mass and activity of the isotope. The half-life of a radioisotope is the time taken for the mass and activity to decrease by half. Every radioisotope has a half-life and these can vary from seconds to millions of years. This process is repeated for many half-lives. After the first half-life the activity and mass of the isotope is half of the original. After the second half-life it becomes half of the half left after the first. This makes it a quarter of the original.

$$\begin{array}{ccccccc} & \text{1st half-life} & & & \text{3rd half-life} & & \\ & 1 & \rightarrow & 1/2 & \rightarrow & 1/4 & \rightarrow & 1/8 & \rightarrow & 1/16 \\ & & & \text{2nd half-life} & & & & \text{4th half-life} & & \end{array}$$

The half-life of radioisotopes is constant. No matter what mass of radioisotope is present the half-life will be the same. For example 1g or 10g of an identical radioisotope will have the same half-life. The graph below shows how the activity and mass of a radioisotope decays and how half-life can be found.



The half-life of an isotope can be used to determine how old something is. For example all living things on Earth contain carbon isotopes. Scientists can measure the radioactivity of ancient fossils or relics to determine how many half-lives the carbons have undergone. In this way they can work out how old the object is. This is sometimes known as carbon dating.

Half-Life Calculations

National 5

Half-life (symbol $t_{1/2}$) is sometimes involved in calculations. These problems involve three quantities: the half-life, the time the radioactive decay has been measured over, and the quantity or intensity of the radioisotope.

The following examples show how using two of these quantities we can work out the third.

- 1. A radioisotope has a half-life of 5 minutes. How long will it take for the radioactive count to drop to 12.5% of its original value?***

Since we are given a percentage value of the original isotope, we describe the original quantity as being 100% (i.e. the whole amount).

At start	we have 100%	of the original count
After 1 half-life	we have 50%	of the original count
After 2 half-lives	we have 25%	of the original count
After 3 half-lives	we have 12.5%	of the original count

So, it takes 3 half-lives for the count rate to drop to 12.5%. We know that each half-life takes 5 minutes so 3 half-lives is $3 \times 5 = 15$ minutes.

2. A radioisotope has a half life of 6 days. What fraction of the original isotope will be present if a pure sample decays for 24 days?

The sample has half-life of 6 days and has been decaying for 24 days. $24 / 6 = 4$ half-lives. Since we are asked for a fraction of the original isotope, we describe the original quantity as being 1 (i.e. the whole amount).

At start	we have 1	(the original amount)
After 1 half-life	we have $\frac{1}{2}$	of the original amount
After 2 half-lives	we have $\frac{1}{4}$	of the original amount
After 3 half-lives	we have $\frac{1}{8}$	of the original amount
After 4 half-lives	we have $\frac{1}{16}$	of the original amount

So after 4 half-lives, there will be $\frac{1}{16}$ th of the original isotope left.

3. A sample of radioisotope has a count rate measured by a Geiger counter, of 48 counts per minute. 6 hours later the count rate is 3 counts per minute. What is the half-life of the isotope?

We are given the original 'amount' of isotope in counts per minute and should continue with these units.

At start	Count Rate is 48
After 1 half-life	Count Rate is 24
After 2 half-lives	Count Rate is 12
After 3 half-lives	Count Rate is 6
After 4 half lives	Count Rate is 3

In a period of four half-lives the count rate has dropped to 3 counts per minute. This took a total of 6 hours. **So one half-life must be $6 / 4 = 1.5$ hours.**

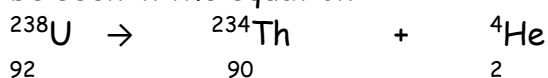
Now try the following examples. They follow the same methods shown above.

- A sample of a radioisotope decays to $\frac{1}{8}$ th of its original activity over a period of 12 days. What is the half-life of the radioisotope?
- A radioisotope has a half-life of 14 hours. How long will it take to decay to 6.25% of its original activity?
- A radioisotope with a half-life of 9 seconds has a count rate of 4 counts per minute at the start of timing. What will the count rate be 18 seconds later?

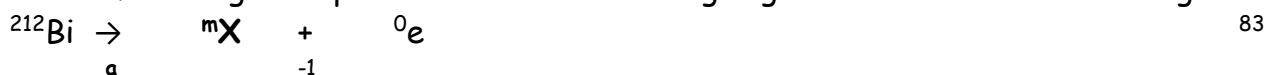
There are two main families of nuclear reaction. There is nuclear fission and nuclear fusion. During nuclear fission heavy nuclei break up into lighter nuclei. In nuclear fusion, the opposite happens. Light nuclei join up to form heavier nuclei.

Nuclear Equations

A nuclear equation is one which shows what happens during a nuclear or radioactive reaction. For example when Uranium - 238 undergoes alpha radiation it loses an alpha particle. This can be seen in the equation:



Notice that the uranium has lost a mass of 4 and an atomic number of 2. This is due to the loss of 2 protons and 2 neutrons. The change in atomic number also means that the element symbol has changed. Remember every element has a different atomic number. In a nuclear equation it is very important that the mass number and atomic number balance on both sides of the arrow. In the following example Bismuth-212 is undergoing beta radiation and emitting a beta particle.



The mass number 'm', atomic number 'a' and element symbol 'X' can be worked out as follows. The mass number was originally 212. During beta emission 0 mass is emitted which means that $m = 212$.

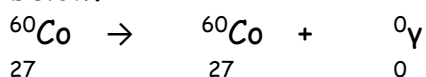
The atomic number was originally 83. During beta emission the atomic number changes by -1. Remember the total atomic number on both sides of the equation must be equal. In other words $83 = a + (-1)$. This simple equation can be solved to find $a = 84$.

With a new atomic number the product of beta emission must now also have a new element symbol. Using the data book the element with the atomic number 84 is found to be Polonium or Po.



During gamma emission the radioisotope does not lose any mass or any charges (no neutrons, protons or electrons are lost). This means that the atomic number and mass numbers of the isotope do not change during gamma emission and since the atomic number remains unchanged so does the symbol.

A wave of energy is given off during gamma emission. The gamma decay of Cobalt-60 is shown below.

Remember:

Total mass number on reactant side = total mass number on product side
Total atomic number on reactant side = total atomic number on product side

Radioactive isotopes can have a wide range of uses. As mentioned earlier scientists and archaeologists can use half-life of radioisotopes to work out how old something is, but the radioisotopes themselves can prove useful in other areas.

Radioisotopes are often used in medicine. Sometimes radioisotopes can be useful in diagnosing conditions. By using radioisotopes doctors can see images of the body which could not be viewed by x-ray or other scans. For example isotopes like Technetium-99 and Iodine-123 can be useful in diagnosing condition in the lungs, kidneys, liver, heart and glands. Another example is the Positron Emission Tomography or PET scan where a radioisotope is injected into the body and the radioactivity detected by a PET camera. These scans are particularly useful in diagnosing cancers. Radioisotopes which are used inside the body like this must have a short half-life to ensure they don't remain in the body for too long.

Radioisotopes can also be useful in treating some cancers. One example is the use of Cobalt-60 isotopes to treat deep tumours. The Cobalt-60 is kept outside the body but give off gamma rays which can enter the body and destroy cancerous cells. When the radioisotope is used externally like this (outside the body) it is important to have a long half-life so that it can be used again without needing to be replaced.

Radioisotopes are also increasingly used in industry. One example is in the manufacture of paper or plastics. Radioisotopes are used to emit beta particles through sheets of paper or plastic film. How thick the paper or plastic is will affect the number of beta particles reaching the detector on the other side. If the paper is too thick, few beta particles will reach the detector. In this case the machine will automatically adjust the rollers through which the paper or plastic passes to make it thinner.

Gamma radiation is being used more frequently as a way to sterilise medical equipment, materials such as wool and even some foods. The gamma rays kill any bacteria or parasites living on or in the target material.