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 5 outcomes are in bold

Metals	Covered (✓)	How well can you do this?
1. Metals are held together by metallic bonding and this is responsible for their electrical conductivity		✗ ? ✓
2. The formation of metal oxides can be represented by equations showing the ions involved.		✗ ? ✓
3. Metals reacting to produce metal hydroxides and hydrogen can be represented by equations showing the ions involved.		✗ ? ✓
4. Some metals react with acid to produce salts and hydrogen and this can be represented by equations showing the ions involved.		✗ ? ✓
5. Some metals react with acid to produce salts and hydrogen and this can be represented by equations showing the ions involved.		✗ ? ✓

6. 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.		× ? ✓
7. From the balanced equations for the extraction of metals the reducing agent can be identified.		× ? ✓
8.The percentage of a particular metal in an ore can be calculated.		× ? ✓
9. Metals can be involved in redox, oxidation and reduction reactions which involve the movement of electrons.		× ? ✓
10. The reaction of metals with water, oxygen and acids can be shown using balanced ionic equations.		× ? ✓
11. Ion electron equations can be written for electrochemical cells involving metals and non-metals.		× ? ✓
12.The reactions which occur in electrochemical cells can be combined to form redox equations.		× ? ✓
13. Fuel cells and rechargeable batteries are technologies which are based on redox reactions.		× ? ✓

Plastics		
1. Polymers can be synthetic or natural.		× ? ✓
2. Plastics can be made by the process of addition or condensation polymerisation.		× ? ✓
2. Examples of addition polymers include polythene, poly(propene) and PVC.		× ? ✓
4. Examples of condensation polymers include polyesters and polyamides.		× ? ✓
5. The structure of a polymer can be drawn from the structure of its monomers and vice versa.		× ? ✓
6. The type of polymer can be identified by its structure.		× ? ✓

Agrochemicals		
1. The Haber process involves the reaction of nitrogen from the air with hydrogen from methane to produce ammonia gas.		× ? ✓
2. The Haber process is a reversible reaction which means some of the ammonia gas formed will reform nitrogen and hydrogen as the reaction proceeds.		× ? ✓
3. Ammonia is used as a starting material for the production of Nitric acid and ultimately ammonium nitrate fertilisers.		× ? ✓
Chemical Analysis		
1. Chemists carry out many analytical techniques to ensure that our environment remains healthy and safe and issues relating to pollution are tackled.		× ? ✓
2. Chemists monitor the environment qualitatively using techniques such as flame testing to identify what is present in a sample.		× ? ✓
3. Chemists monitor the environment quantitatively using techniques such as acid/base titrations to measure the quantity of substances present in a sample.		× ? ✓

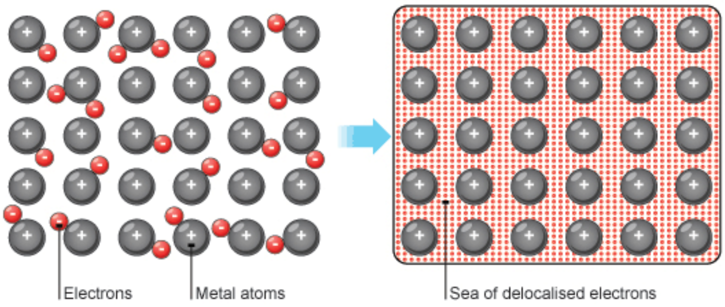
Nuclear Chemistry		
1.Radioactive elements become more stable by emitting radiation.		× ? ✓
2.There are 3 types of radiation alpha, beta and gamma.		× ? ✓
3. Alpha radiation is a Helium nucleus with the symbol $^{4}_{2}He$ or α.		× ? ✓
4. Beta radiation can penetrate thin metal foil, has a mass of 1/2000 and a charge of 1-.		× ? ✓
5. Beta radiation is an electron and has the symbol $^{0}_{-1}e$ or β.		× ? ✓
6. Gamma radiation can penetrate a large thickness of concrete and has no mass or charge.		× ? ✓
7. Gamma radiation has the symbol ϒ.		
8. Radioactive decay causes radioactive isotopes to decrease in mass and activity.		× ? ✓
9. The half-life of an isotope is the time taken for the mass or activity of the isotope to decrease by half.		× ? ✓
10. The half-life of an isotope is constant.		× ? ✓
11. The half-life of an isotope can be used to date materials.		× ? ✓
12. Nuclear equations can be written to describe nuclear reactions for example $^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n$		× ? ✓

National 5

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 positively charged nuclei of the metal atom and the negatively charged 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.

National 5

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.

Metal Ion $\longrightarrow$ Metal Atom

$Ag^{+}_{(aq)} + e^{-} \longrightarrow Ag_{(s)}$

REDUCTION

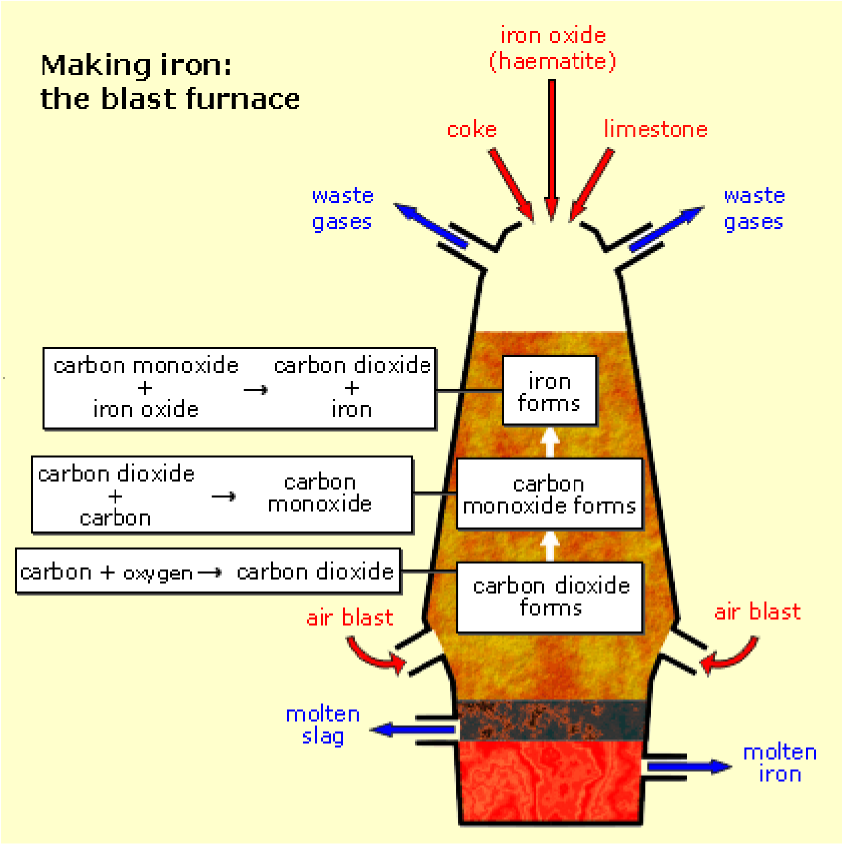
Heating with Carbon (Smelting)

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 earths 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.

$$Fe^{3+}{}_{(l)} + 3e^{-} \longrightarrow Fe_{(s)} \qquad \boxed{\text{REDUCTION}}$$

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

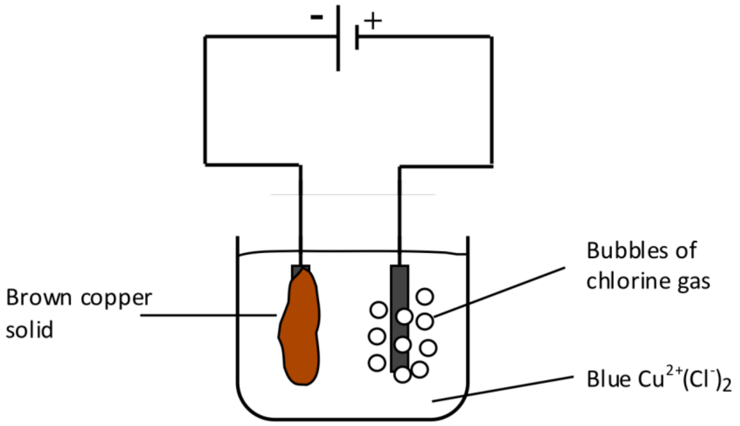
The use of electricity to extract a metal is called electrolysis. The metals that require electrolysis for extraction are highest up in the reactivity series.

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 x 3) = 100

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

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

$$= \mathbf{40\%}$$

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

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

National 5

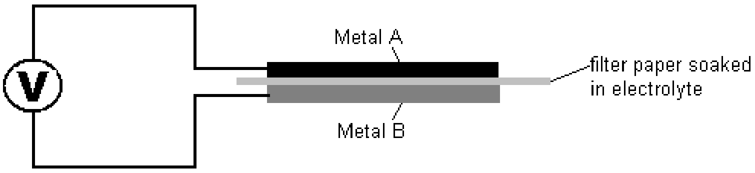
Metals and the Electrochemical Series

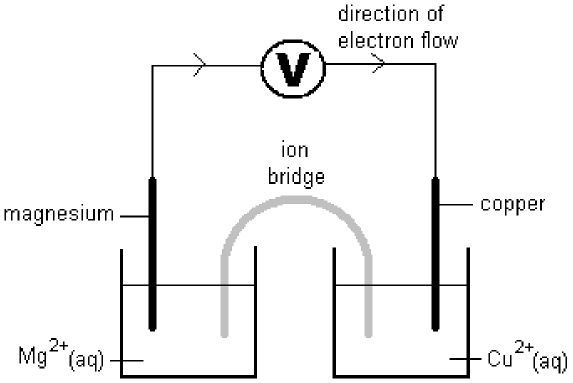
An electrochemical cell is a method of creating electricity using metals. Linking different pairs of metals together give different voltages. The **Electrochemical Series**, or **ECS**, is sorted according to the voltages produced by connecting different pairs of metals. The ECS can be found on page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





National 5

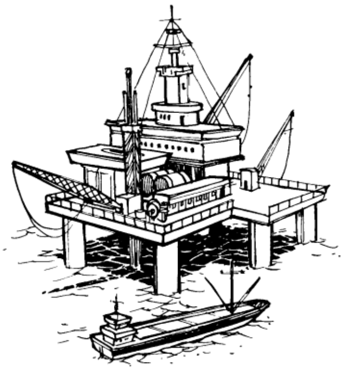
Oxidation and Reduction

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



National 5

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.

1 Oxidation: $Mg_{(s)} \longrightarrow Mg^{2+} + 2e$
Reduction: $Ag^{+} + e \longrightarrow Ag_{(s)}$ (x2)

$$Mg_{(s)} + 2Ag^{+} \longrightarrow Mg^{2+} + 2Ag_{(s)}$$

2 Oxidation: $Al_{(s)} \longrightarrow Al^{3+} + 3e$ (x2)
Reduction: $2H^{+} + 2e \longrightarrow H_{2(g)}$ (x3)

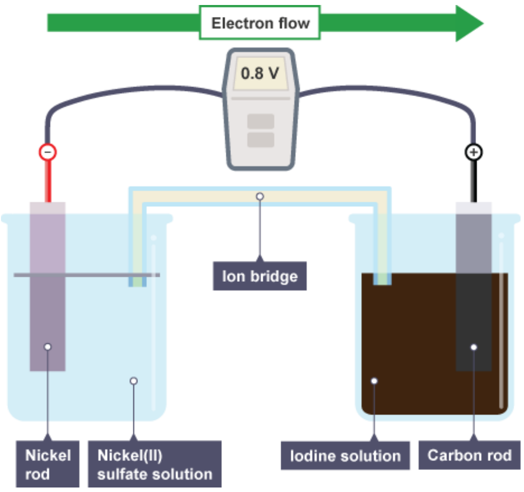
$$2Al_{(s)} + 6H^{+} \longrightarrow 2Al^{3+} + 3H_{2(s)}$$

National 5

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:

$$Ni_{(s)} \longrightarrow Ni^{2+}_{(aq)} + 2e^{-}$$

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

$$I_{2\,(aq)} + 2e^{-} \longrightarrow 2I^{-}_{(aq)}$$

The overall equation for the reaction is:

$$Ni_{(s)} + I_{2\,(aq)} \longrightarrow NiI_{2\,(aq)}$$

Summary – Plastics & Synthetic Fibres

National 5

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

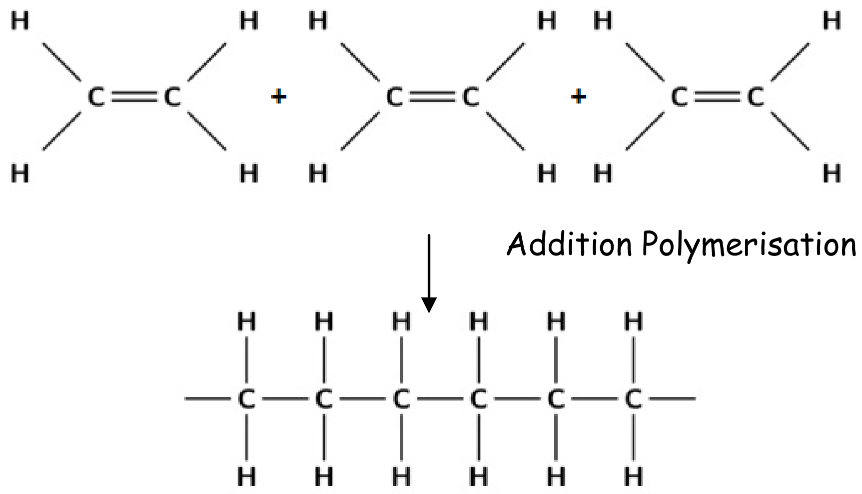
Addition polymers

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.



Unsaturated ethene monomers

Polythene is an addition polymer

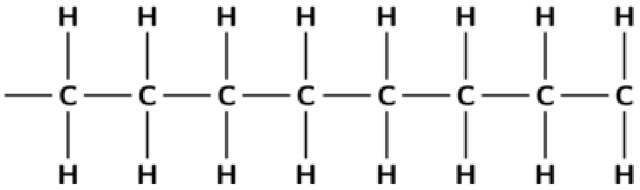
section of a polyethene molecule

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

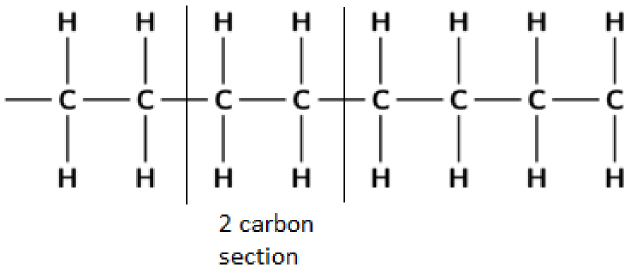
Repeating unit

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.

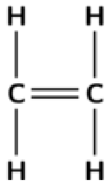
1. Consider the carbon chain of an addition polymer

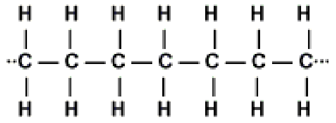
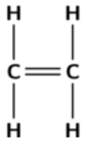
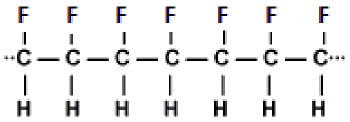
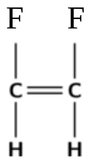
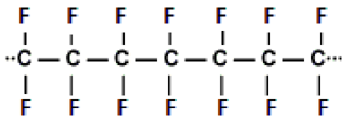
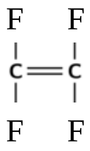


2. Bracket a 2 carbon repeating unit using a pencil



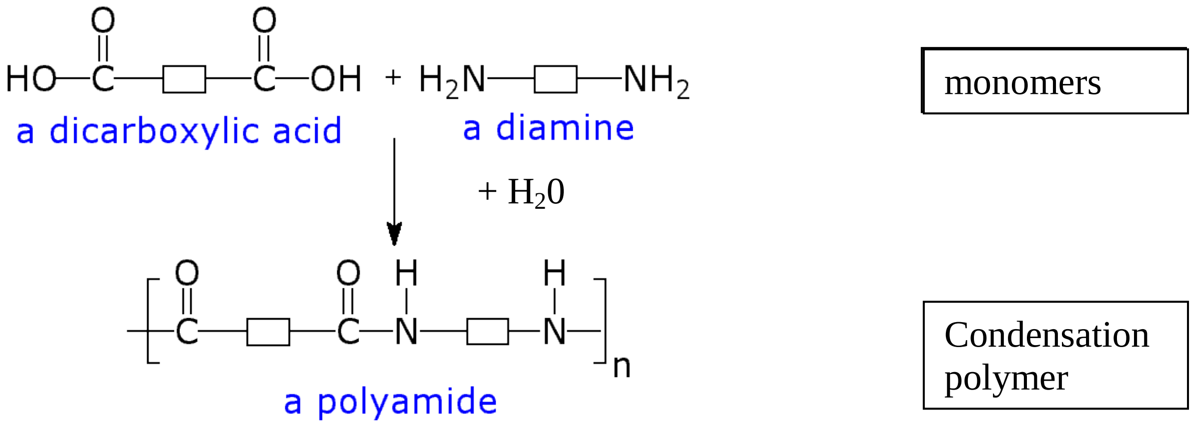
3. Remember, the monomer was an alkene with a double bond between the 2 carbons. The monomer was therefore :



Polymer Structure	Monomer Structure
	
	
	

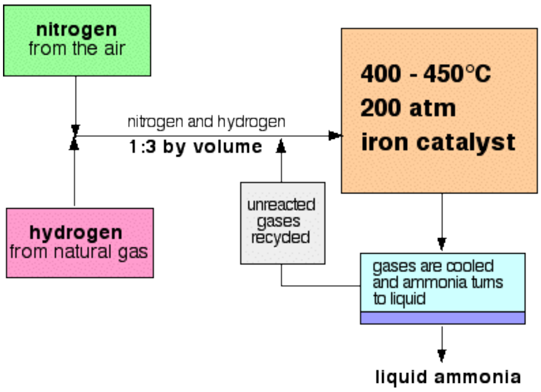
Condensation polymers

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.



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.

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**.

Nitrogen + hydrogen $\rightleftharpoons$ ammonia

$2N_2 + 3H_2 \rightleftharpoons 2NH_3$

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 N_2 and H_2 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

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?

Chemical Analysis and the Environment

National 5

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:

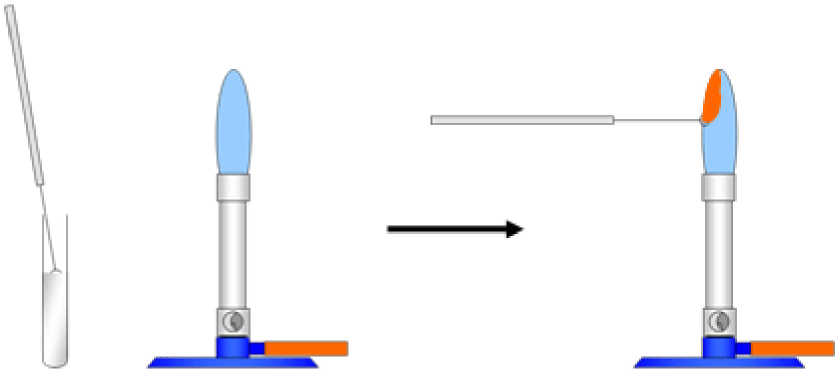
To test for the presence of elements (metal ions) in a sample. Different metal ions burn with different coloured flames.

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	Liliac

Type of Analysis: Qualitative

What it's used for:

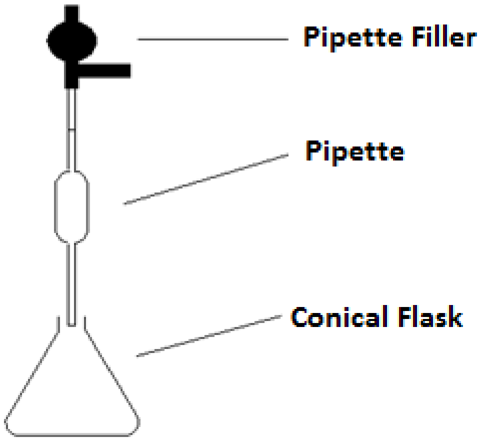
To measure the concentration of acid in a sample, by neutralising with a known volume and concentration of alkali (base).

Apparatus:

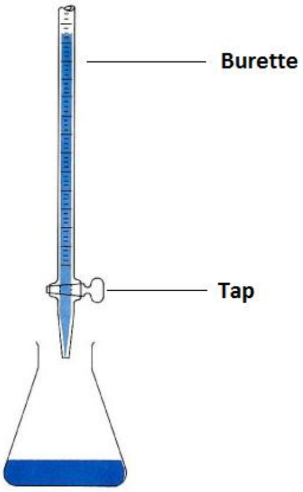
Burette, pipette, pipette filler, conical flask, 2 beakers, clamp stand, white tile, indicator, acid, alkali, funnel, safety glasses.

Method:

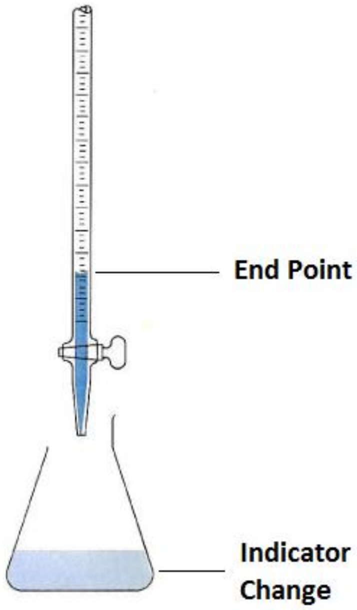
- Pour a small volume of alkali into a clean beaker. A **pipette** is used to measure out an accurate volume of **alkali** solution. The liquid is drawn into the pipette using a filler or bulb until the alkali exactly reaches the mark on the neck of the pipette.
- Release the alkali from the pipette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

<u>Type of Analysis:</u> Quantitative

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 $^{4}_{2}\mathrm{He}$. 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 $^{0}_{-1}\mathrm{e}$.

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 $^{4}_{2}\mathrm{He}$	A few cm of air.
Beta	**β** or $^{0}_{-1}\mathrm{e}$	Thin paper, a few cm of body tissue.
Gamma	$^{0}_{0}\gamma$	Thin metal foil, concrete.

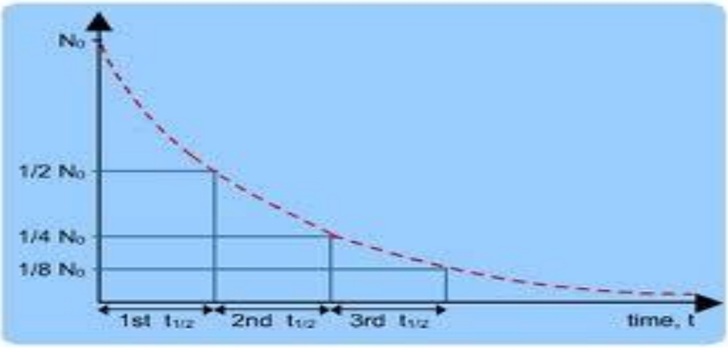
Radioisotope Half-life

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.

1st half-life 3rd half-life
1 → 1/2 → 1/4 → 1/8 → 1/16
2nd half-life 4th half-life

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 with 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. Scientist 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 x 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 1/8 of the original amount
After 4 half-lives we have 1/16 of the original amount

So after 4 half-lives, there will be ***1/16th*** 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. A sample of a radioisotope decays to 1/8th of is original activity over a period of 12 days. What is the half-life of the radioisotope?

b. A radioisotope has a half-life of 14 hours. How long will it take to decay to 6.25% of its original activity?

c. 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?

Nuclear Reactions

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.

$^{3}He \rightarrow {}^{1}_{1}H + {}^{2}H$ Nuclear Fission 2 1

$^{12}C + {}^{4}_{8}He \rightarrow {}^{16}O$ Nuclear Fusion 6 2

Nuclear Equations

A nuclear equation is on 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:

$$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$$

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.

$^{212}Bi \rightarrow {}^{m}_{a}\mathbf{X} + {}^{0}_{-1}e$ 83

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.

$^{212}Bi \rightarrow {}^{\mathbf{212}}_{\mathbf{84}}\mathbf{Po} + {}^{0}_{-1}e$ 83

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.

$$^{60}_{27}Co \rightarrow {}^{60}_{27}Co + {}^{0}_{0}\gamma$$

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

Uses of Radioisotopes

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.