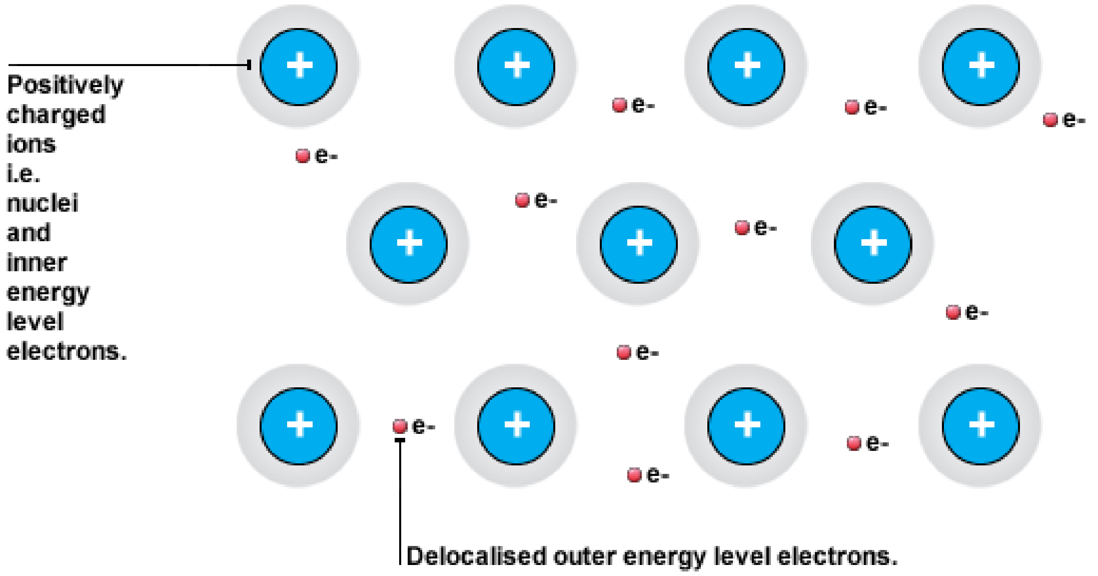
Dalkeith High School
National 5 Chemistry
Unit 3: Chemistry in Society

Key Area: Metals

Learning Statement	☺	😐	☹
Metals are found on the left side of the zig-zag line on the Periodic Table.			
Metallic bonding holds metal atoms together.			
Metallic bonds are the electrostatic attraction between negatively charged delocalised electrons and the positively charged metal ion lattice. 			

Delocalised electrons are electrons that are not 'attached' to a particular atom. They are free to move.			
Physical Properties of Metals			

Strong	Conduct electricity
Are **malleable** (can be shaped)	Conduct heat
Are **ductile** (can be drawn into wires)	High melting and boiling points
Are shiny	Are mostly solid, except mercury.

Unreactive metals such as gold and silver are found uncombined in the Earth's crust. Other metals are found in the ground in the form of metal ores. Metal ores are naturally occurring metal compounds.			
Metals can be extracted from their ores by: **heating**, **heating with Carbon or Carbon monoxide**, or by **electrolysis**.			

Method	Electrolysis	Heat With Carbon	Heat Alone
Metals Made This Way	Potassium Sodium Lithium Calcium Magnesium Aluminium	Zinc Iron Tin Lead Copper	Mercury Silver Gold Platinum
Reason	most reactive metals	medium reactive metals	least reactive metals

The extraction of a metal from an ore is an example of a **reduction** reaction.			

The percentage of a metal in a metal ore can be calculated using the formula:

$$\textbf{Percentage Mass} = \frac{\textbf{Mass of Element in Formula}}{\textbf{Gram Formula Mass}} \times 100\%$$

Calculate mass of 1 mole	Find mass of element	Percentage Fe in Fe_2O_3 calculation
Fe_2O_3 = (2x56) + (3x16) = 112 + 48 = 160g	2 x Fe = (2x56) = 112g	$\frac{112g}{160g}$ x 100 = 70%

Metals can be placed in a reactivity series. The most reactive metals are placed at the top and the least reactive are at the bottom.

Reaction of Metals and Oxygen

When a metal reacts with oxygen, a metal oxide is formed.

Metal + Oxygen → Metal oxide

e.g. Copper + Oxygen → Copper oxide

Reaction of Metals with Water

The Alkali Metals (Group 1) and the Alkaline Earth Metals (Group 2) react with water to form a metal hydroxide (an alkali) and hydrogen gas.

Metal + Water → Metal hydroxide + Hydrogen

e.g. Sodium + Water → Sodium hydroxide + Hydrogen

Reaction of Metals with Acid

The MAZINTL metals (all metals above copper) react with acid to forma metal salt and hydrogen gas.

Metal + Acid → Metal Salt + Hydrogen

e.g. Zinc + Nitric acid → Zinc nitrate + Hydrogen

Copper does not react with dilute acid.

Metal	Potassium	Sodium	Lithium	Calcium	Magnesium	Aluminium	Zinc	Iron	Tin	Lead	Copper	Mercury	Silver	Gold	Platinum
Reaction With Oxygen	Burn In Oxygen to Form Metal Oxide								Slowly React With Oxygen			No Reaction With Oxygen			
Reaction With Water	Fast Reaction With Water				Slow Reaction With Water Faster Reaction With Steam						No Reaction with Water or Steam				
Reaction With Acids	Violent Reaction With Acids				React With Acids				Slow Reaction		No Reaction With Acids				

The reactions of metals can be explained by the loss of gain or electrons in the reaction.

A reaction in which electrons are gained is called **REDUCTION**.

e.g. $Mg^{2+}(aq) + 2e^- \rightarrow Mg(s)$

Reduction reactions will always have the electrons on the left of the arrow.

A reaction in which electrons are lost is called **OXIDATION**.

e.g. $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$

Oxidation reactions will always have the electrons on the right of the arrow.

Reactions in which both reduction and oxidation occur are called Redox reactions.

The mnemonic: **OIL RIG** can be used to remember that **O**xidation **I**s **L**oss and

Reduction **I**s **G**ain of electroms.

A list of reduction reactions can be found on page 10 of the data booklet.

Electrochemical Cells

In a battery, the electricity comes from a chemical reaction.

- Electricity passing along metal wires is a flow of electrons
- Batteries run out when the chemicals in the battery are used up.

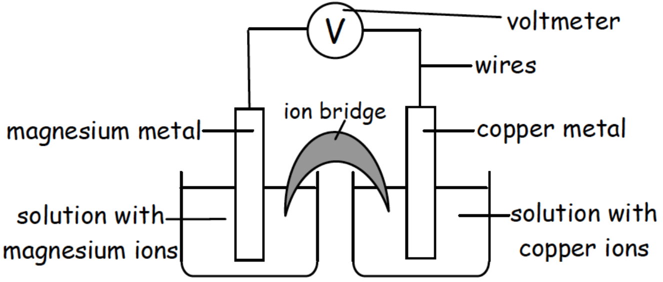
Some batteries are rechargeable.

- Nickel-Cadmium batteries can be recharged.
- Lead acid batteries in cars can be recharged.

Advantages of Batteries	**Advantages of Mains Electricity**
Easy to transport	Costs less than batteries
Low voltage, so safer	

A cell can produce electricity by connecting different metals together with an electrolyte

- a cell is usually created by connecting two different metals in solutions of their metal ions
- a cell can have half-cells which do not involve metal atoms



The voltage produced in a cell depends on:

- The bigger the difference between the metals on the electrochemical series, the bigger the voltage produced.
- Electrons always flow from the most reactive metal to the least reactive metal.

The purpose of the electrolyte is to complete the circuit.

- An electrolyte is an ionic solution usually stored on an ion bridge.
- Ion bridges are usually pieces of filter paper soaked in an ionic solution.
- Positive ions move towards negative charges due to electrostatic attractions.
- Negative ions move towards positive charges due to electrostatic attractions.

Fuel cells use electrochemistry to generate electricity.

Most fuel cells use hydrogen to generate electricity. The hydrogen reacts with water to form water and oxygen.

- The main advantage of using hydrogen fuel cells is that the products are non-polluting.
- The main disadvantage of using hydrogen fuels cells is that hydrogen gas is difficult to store and is explosive.

Displacement reactions are when a metal higher up the electrochemical series pushes one lower down the electrochemical series out of solution.

Higher Up Metals can displace *Lower Down Metal Ions* from Solutions

$$Mg_{(s)} + Cu^{2+}_{(aq)} \longrightarrow Mg^{2+}_{(aq)} + Cu_{(s)}$$

Higher up metal
Lower down metal ion
Magnesium displaces copper

Key Area: Properties of Plastics

Learning Statement	☺	😐	☹

Most plastics and synthetic fibres are made from crude oil.

- Synthetic means that the fibre has been made by scientists and is not naturally occurring.
- Both natural and synthetic fibres are examples of polymers.

There are advantages and disadvantages of using natural or synthetic materials.

Advantages of Plastics over Natural Materials	Disadvantages of Plastics over natural materials
Lightweight and cheap	Plastics made from finite resources (crude oil)
Good thermal and electrical insulating properties	Plastics burn to release toxic gases
Plastics are non-biodegradable and can last a long time compared to natural alternatives	Plastics are non-biodegradable and can be difficult to dispose of

Some plastics release toxic gases when they are burned.

Toxic Gas	Carbon Monoxide	Hydrogen Chloride	Hydrogen Cyanide
Source	All plastics	PVC /Poly(chloroethene)	Polyurethane

A biodegradable plastic is one that can be broken down by organisms such as bacteria.

There are 2 types of plastic: thermoplastic and thermosetting.

- Thermoplastics melt on heating, as their polymer chains are not cross-linked.
- Thermosetting plastics keep their shape on heating, as their chains are cross-linked.

Polymers are large molecules made from smaller molecules called **monomers**.

Name	Definition
monomer	Small molecules which join together to form polymers
polymer	The long chain molecule made by the joining up of monomers
polymerisation	The process where monomers join together to form polymers

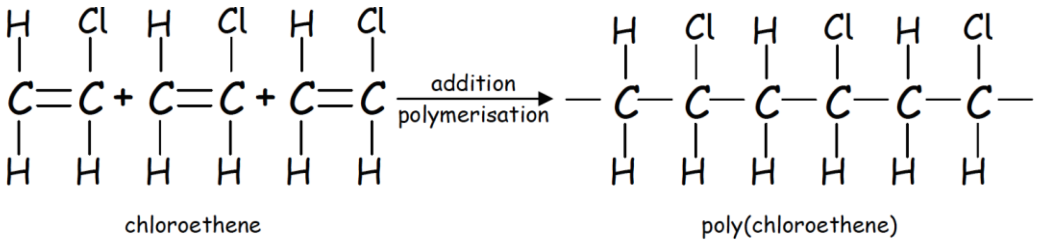
There are 2 types of polymerisation:

- Addition
- Condensation

Addition Polymerisation

In addition polymerisation small unsaturated monomers containing a C=C undergo addition reactions to form a saturated polymer.

e.g.



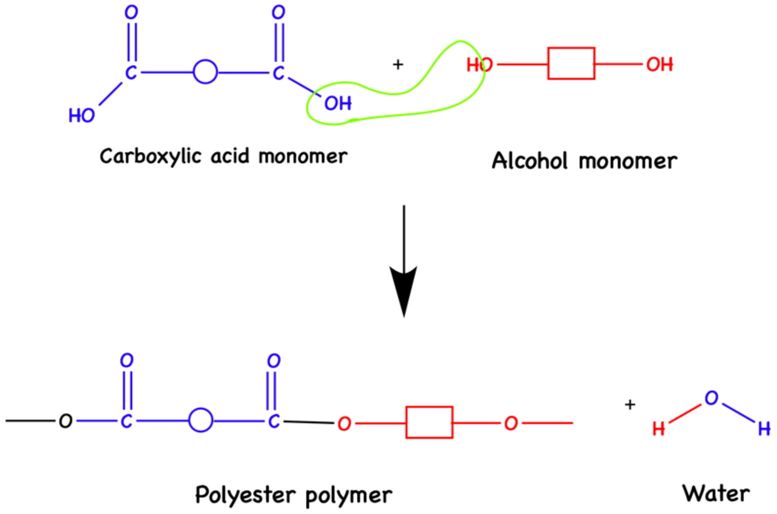
The polymer name starts with poly and then has the name of the monomer in brackets, for example ethene monomers polymerise to make poly(ethene).

Condensation Polymerisation

In condensation polymerisation monomers with functional groups at each end of the molecule undergo condensation reactions to form a polymer and water.

Making Polyester

Polyesters are chains of polymers that contain an ester functional group. They are made from a carboxylic acid monomer and an alcohol monomer.



Creative and Smart Materials Made from Polymers

- **Kevlar** is made by condensation polymerisation and is used in bullet proof vests. It is a very strong fibre but is lighter than any other material with the same strength.
- **Polyvinyl Alcohol (PVA)** is a soluble plastic that can be used to make laundry bags.
- **Poly(acrylate)** is a **hydrogel** that has special water absorbing properties which allows hydrogels to be used in a variety of applications such as nappies, contact lenses and as medical bandages.
- **Colour changing plastics** can be used in food packaging to let consumers know the condition of food inside.
- **Conductive plastics** are currently being researched which allow the development of flexible touch screens and e-paper in the near future.

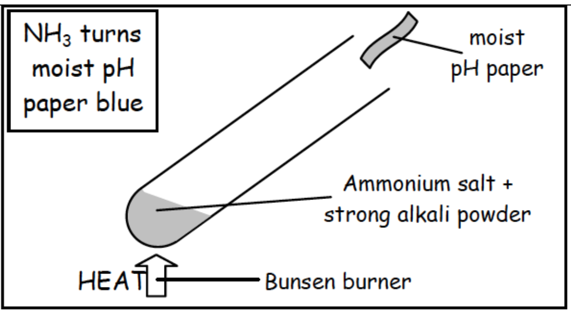
Key Area: Fertilisers

<table>
<tr><th>Learning Statement</th><th>☺</th><th>😐</th><th>☹</th></tr>
<tr><td>The increasing population of Earth has led to a need for more efficient food production to grow enough food to feed the increasing number of people on Earth.</td><td></td><td></td><td></td></tr>
<tr><td>Growing plants require nutrients including compounds of:<table><tr><td>nitrogen (N)</td><td>phosphorus (P)</td><td>potassium (K)</td></tr></table>• Different types of crops need fertilisers containing different proportions of N, P and K.</td><td></td><td></td><td></td></tr>
<tr><td>Decomposition of protein in plants and animal remains recycles nitrogen in the nitrogen cycle.</td><td></td><td></td><td></td></tr>
<tr><td>Fertilisers are substances that restore the essential element for plant growth.
• Fertilisers need to be soluble to be absorbed through plant roots.<table><tr><td>Soluble compounds of</td><td>Ammonium salts</td><td>Potassium salts</td><td>Nitrates</td><td>Phosphates</td></tr></table>• Overuse of fertilisers can result in unused fertiliser being washed into rivers and lochs causing damage to wildlife.</td><td></td><td></td><td></td></tr>
<tr><td>Nitrifying bacteria in plant rood nodules can convert (fix) nitrogen from the air into compounds containing nitrogen.
• Plants with such root nodules include clover, peas and beans.
• The nitrogen compounds formed are nitrates (NO_3).
• These bacterial methods for fixing nitrogen are cheaper than chemical methods.</td><td></td><td></td><td></td></tr>
<tr><td>Synthetic methods can be made from nitrogen compounds such as ammonia (NH_3) and nitric acid (HNO_3).</td><td></td><td></td><td></td></tr>
<tr><td>Ammonia (NH_3) is made by the Haber Process.
$$\text{Nitrogen} + \text{Hydrogen} \rightleftharpoons \text{Ammonia}$$
$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$
• The Haber Process is carried out at moderately temperature as high temperature (450 °C) leads to the breakdown of ammonia into nitrogen and hydrogen.
• Not all the reactants turn into ammonia as eventually the ammonia breaks down as quickly as it is formed.
• The catalyst used in the Haber Process is iron.

** The $\rightleftharpoons$ sign means that the reaction is reversible.**</td><td></td><td></td><td></td></tr>
<tr><td>Ammonia can be converted into ammonium compounds by reacting ammonia with a strong alkali.</td><td></td><td></td><td></td></tr>
</table>

NH_3 can be converted to ammonium compounds:

- The alkali ammonium hydroxide is formed when ammonia is dissolved in water
- $NH_3(g) + H_2O(l) \longrightarrow NH_4^+(aq) + OH^-(aq)$
- ammonia can be prepared in the laboratory by the reaction of ammonium compounds with alkali
  $NH_4^+ + OH^- \longrightarrow NH_3(g) + H_2O$



Ammonia has the following properties.

Colourless gas.	Pungent Smell.	Soluble in Water.	Dissolves to form an alkali.

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Ammonia is NH_3	Ammonium is NH_4^+

Nitric acid is made by the Ostwald Process.

- The Ostwald Process involves the catalytic oxidation of ammonia to form nitric acid.

  Stage 1: Ammonia + Oxygen → Nitrogen monoxide + Water

  Stage 2: Nitrogen monoxide + Oxygen → Nitrogen dioxide

  Stage 3: Nitrogen dioxide + Oxygen + Water → Nitric Acid

- The Ostwald Process is carried out at moderate temperature (900 °C).
- The reaction is exothermic so once started, the reaction does not require further heating.
- A platinum catalyst is used in this process.
- When nitrogen dioxide is dissolved in water, nitric acid is formed.

The percentage mass of elements in fertilisers can be calculated.

e.g. Calculate the percentage mass of nitrogen in ammonium nitrate, NH_4NO_3.

❶Find the GFM	**❷Find the mass of N in the formula**	**❸Divide: ❷mass in formula by ❶GFM**
NH_4NO_3. 2 X N = 2 X 14 = 28 4 X H = 4 X 1 = 4 3 X O = 3 X 16 = 48 **Total = 80 g**	2 X N = 2 X 14 = 28 g	% Mass = 28/80 x 100% **%Mass = 35%**

Key Area: Nuclear Chemistry

<table>
<tr><th>Learning Statement</th><th>☺</th><th>😐</th><th>☹</th></tr>
<tr><td>Atoms of most elements have isotopes.</td><td></td><td></td><td></td></tr>
<tr><td>The nuclei of some of these isotopes are unstable and emit particles or rays called radioactive emissions.</td><td></td><td></td><td></td></tr>
<tr><td>3 types of radioactive emissions are possible:
<table><tr><td>Alpha (α)</td><td>Beta (β)</td><td>Gamma (γ)</td></tr></table></td><td></td><td></td><td></td></tr>
<tr><td>Alpha Particles (α)
Alpha particles are helium ions.
Alpha particles can be represented by:
$$^{4}_{2}\mathrm{He} \quad \text{or} \quad ^{4}_{2}\mathrm{He}^{2+}$$
They are heaviest type of radioactive emission.</td><td></td><td></td><td></td></tr>
<tr><td>Beta Particles (β)
Beta particles are high-energy electrons.
A beta particle can be represented by:
$$^{0}_{-1}\mathrm{e}$$</td><td></td><td></td><td></td></tr>
<tr><td>Gamma Radiation (γ)
Gamma radiation does not exhibit particle-like behaviour.
Gamma radiation is a high-energy ray that can travel long distances and has a high penetration power.</td><td></td><td></td><td></td></tr>
<tr><td>Properties of Radioactive Emissions
<table>
<tr><th>Emission</th><th>Distance Travelled and Penetrating Power</th><th>Charge</th></tr>
<tr><td>Alpha (α)</td><td>Few centimetres in air. Stopped by paper.</td><td>Positive</td></tr>
<tr><td>Beta (β)</td><td>Few metres in air. Stopped by thin aluminium.</td><td>Negative</td></tr>
<tr><td>Gamma (γ)</td><td>Travels kilometres in air. Stopped by thick lead or concrete.</td><td>No charge</td></tr>
</table></td><td></td><td></td><td></td></tr>
<tr><td>Radioactive isotopes are also called radioisotopes.</td><td></td><td></td><td></td></tr>
<tr><td>Radioisotopes have uses in the home, in health and in industry.
Home: Smoke alarms contain the radioisotope Americium-241.
Health: Cancer can be treated using the radioisotope Iodine-131
Industry: Radioisotopes can be used to gauge the thickness of materials.</td><td></td><td></td><td></td></tr>
<tr><td>The fear of radioactivity damaging healthy cells in our bodies, which can lead to cancer, is one of the main reasons people are concerned about the use of radioisotopes.</td><td></td><td></td><td></td></tr>
<tr><td>Radioactive decay is when unstable nuclei breakdown into smaller particles which are more stable.</td><td></td><td></td><td></td></tr>
<tr><td>Nuclear equations can be used to represent radioactive decay.</td><td></td><td></td><td></td></tr>
</table>

<table>
<tr><td>For example: When plutonium-242 decays by an alpha emission, uranium-238 is formed.

$${}^{242}_{94}\text{Pu} \rightarrow {}^{238}_{92}\text{U} + {}^{4}_{2}\text{He}$$</td><td></td><td></td><td></td></tr>
<tr><td>Sometimes you will be given some of the values for a nuclear equation and will have to work the remaining ones.

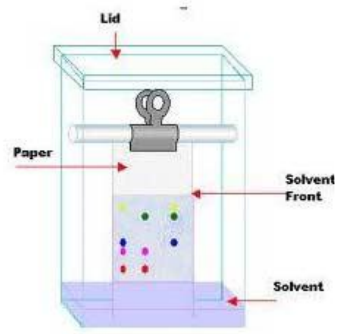
For example:
$${}^{220}_{86}\text{Rn} \rightarrow {}^{a}_{b}\text{X} + {}^{4}_{2}\text{He}$$
Answer: The masses on the top must add up to the same value on each side of the arrow. So a = 220 – 4 = 216. Hence, a = 216.

The atomic numbers on the bottom must add up to the same value on each side of the arrow. So b = 86 – 2 = 84. Hence, b = 84.

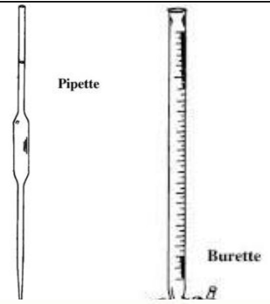
X is the element symbol. The element has atomic number 84 so is Polonium, Po.</td><td></td><td></td><td></td></tr>
<tr><td>The half-life ($t_{1/2}$) is time taken for the activity of a radioactive source to drop by a half.</td><td></td><td></td><td></td></tr>
<tr><td>A decay curve showing activity and time can be plotted to help work out half-life.</td><td></td><td></td><td></td></tr>
<tr><td>The mass of a radioisotope remaining after a certain period of time can also be calculated using half-life.

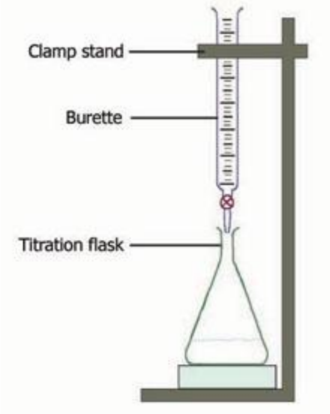
Example: Sodium-24 has a half-life of 15 hours. A sample of 0.8 g of Sodium-24 was found. What mass of Sodium-24 would be left after 60 hours?
<table>
<tr><td>0 h</td><td rowspan="2">→</td><td>15 h</td><td rowspan="2">→</td><td>30 h</td><td rowspan="2">→</td><td>45 h</td><td rowspan="2">→</td><td>60 h</td></tr>
<tr><td>0.8 g</td><td>0.4 g</td><td>0.2</td><td>0.1 g</td><td>0.05 g</td></tr>
</table></td><td></td><td></td><td></td></tr>
<tr><td>Radioisotopes can be used to date materials. Carbon dating of archaeological finds is a common example of this. Fossils can be dated using potassium-argon dating.</td><td></td><td></td><td></td></tr>
</table>

Key Area: Chemical Analysis

Learning Statement	☺	😐	☹
There are two types of chemical analysis: • Qualitative analysis • Quantitative analysis.			
Qualitative analysis allows the presence of a substance to be detected.			
Quantitative analysis allows the presence of a substance to be detected and allows us to work how much of the substance there is.			
Qualitative Analytical Methods **1. Flame Testing** • When metal compounds are placed in a flame, characteristic colours are produced. • Different metals give different colours, therefore the presence of a metal in a compound can be detected using flame colour. • Flame colours can be found in the data booklet on page 6. **2. Precipitation** • Metal ions can also be detected using precipitation reactions. • The colour of the precipitate formed (insoluble solid) allows us to determine which metal ion was present. • Non-metal ions can also be detected using precipitation. **3. Chromatography** • Chromatography can be used to separate mixtures of substances. • Chromatography involves spotting small quantities of a substance on a piece of chromatography paper, then placing this chromatography paper vertically in a solvent. The solvent flows up the paper and separates the single spot for the substance into a spot for each component of the mixture.  • Advanced forms of chromatography are available that allow better separation of mixtures. High Performance Liquid Chromatography (HPLC) and Gas Phase Chromatography (GPC) and Liquid Chromatography Mass Spectrometry (LCMS) are all example of such techniques.			
Quantitative **1. Titration** A titration can be used to determine the concentration of acid or base used in a neutralisation reaction.			

In a titration a pipette is used to transfer a known volume of acid or base into a conical flask. An indicator is then added to the conical flask. The indicator allows the end point of the titration to be easily observed.





A burette is filled with acid or base of a known concentration.

The burette is then used to accurately add known volumes of acid or base into the conical flask. When a colour change is observed, the reaction has reached its end point.

The measurements in a titration are often recorded in a table such as the following:

	1st (Rough)	2nd	3rd
Initial Volume (cm^3)			
End Volume (cm^3)			
Titre (cm^3)			

The average titre can be worked out using concordant values. Concordant values are values that are with 0.2 cm^3 of each other.

Using the values obtained from the titration experiment, the formula:

ACID BASE

$$\frac{V_1C_1}{n_1} = \frac{V_2C_2}{n_2}$$

Where:

V_1 = Volume of acid	V_2 = Volume of base
C_1 = Concentration of acid	C_2 = Concentration of base
n_1 = Number of moles of acid from reaction equation.	n_2 = Number of moles of base from reaction equation.