Z

AQA A-LEVEL CHEMISTRY NOTEBOOK

ALL THE KEY CONTENT IN 50 PAGES!

CONTENTS

PHYSICAL

INORGANIC

ORGANIC

3.1.1 ATOMIC STRUCTURE

KEY PRINCIPLES:

- **Atom** - simplest particle that forms an **element**.
- Atoms consist of a nucleus which contains **protons** and **neutrons**.
- Atoms are surrounded by **electrons** which swarm around the atom in their relative **sub-shells/orbitals/energy-levels**.
- The different types of orbital that you will be exposed to during your A-Level studies are: **s, p, and d** and they each have a **fixed** number of electrons.
- **Atomic number** - number of protons within an element. Usually the bottom number next to the element in the periodic table.
- **Atomic mass** - number of protons and neutrons within an element. Usually the number above the element in the periodic table.
- **Isotope** - atom with the **same** number of **protons** but a **different** number of **neutrons**.
- For example, you may get 35Cl or 37Cl. Their mass numbers are different because each isotope contains a different number of neutrons.

Subatomic	Relative mass	Relative charge
P		+1
		0
	2000	-1

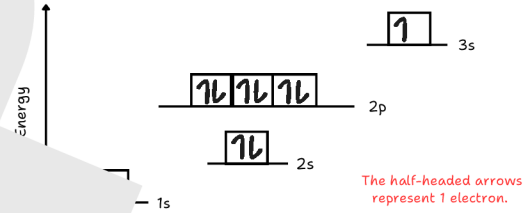
ELECTRON C : :

- Let's take sodium (Na) as
- It consists of 11 electrons.
- S sub-shell - contains a maximum of 2 electrons.
- P sub-shell - contains a ma of 6 electrons.
- b-shell - contains a m of 10 electrons.

2 3s 1

b-shell — Electrons

h sub-shell a fixed number of orbitals. sub-shell has 1 , the p sub-shell has 3 s, and the d sub-shell has 5 orbitals.



TIME OF FLIGHT MASS SPECTROMETRY ( ):

- Determines the **Mr of molecules**, **abundance** and re ass **of isotopes** of elements using a mass spectrometer
- 4-step process: **ionisation**, **acceleration**, **drift**, **de**
- 2 methods of ionisation: **electron impact** and **electros**
- **Electron impact ionisation**: sample injected into machine → sample is vaporised → gaseous sample passed through an electron gun → sample attacked by high energy electro molecules become ionised. Suitable for **small** can cause fragmentation.

$$Na_{(g)} \longrightarrow Na^{+}_{(g)} + e^{-}$$

- **Electrospray ionisation**: sample dissolved in a volatile sample injected through a hypodermic needle to produce a mist → tip of needle is attached to the positive terminal of a voltage power supply → molecules g once they leave the needle. Better limited fragmentation.
- **Remember** to subtract 1 when calcu olecule ionised this way due to the additional H+.

$$Na_{(g)} + H^{+}_{(g)} \longrightarrow NaH^{+}_{(g)}$$

- **Acceleration**: positive io charged plate. The ions larger particles will ha
- **Drift**: sample enters the nd the ion out according to velocity. Low reach t tor first.
- **Detection**: positive ions gain from gatively charged plate. Flow of electrons lectric current. Abundance is determined s current.

TOFMS EQU NS AND WORKE PLE:

- The key eq ou'll need to how t rrange are:

$$KE = \frac{1}{2}mv^2 \qquad t = \sqrt{\frac{m}{2KE}}$$

KE = Kinetic = velocity flight tube (n time of flight (s)

Q - $A^{133}Cs^{+}$ ion has a kinetic energy of 3.65 x akes 2.71 x 10^{-5} s to reach the detector. Calculate the length tube in metres to an appropriate number of significant f ro's constant (L) = 6.022 x 10^{2}

Rearranging:

$$d = t \times v \qquad v = \sqrt{\frac{2KE}{m}}$$

133/1000 = 0.133kg

$m = 0.133 / 6.022 \times 10^{23}$

$m = 2.209 \times 10^{-25}$ kg

$v = \sqrt{\frac{2 \times 3.65 \times 10^{-16}}{2.209 \times 10^{-25}}}$

$v = 5.749 \times 10^{4}$ m s-1

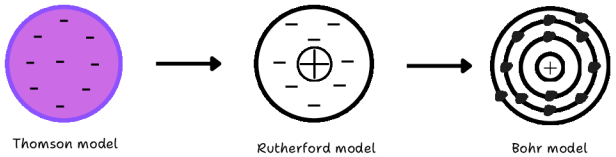
$d = 2.71 \times 10^{-5} \times 5.749 \times 10^{4}$

= 1.56m (to 3.s.f)

EVOLUTION OF THE ATOM:

Model - first model of the atom. Atoms were s small spherical particles which were all ide n their properties if of the same element.

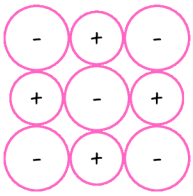
- The **Thomson Model** - further experimenting concluded that atoms contain negatively charged electrons. This led the idea of a 'plum pudding' where the electrons sat in itively charged 'pudding' filled with protons.
- **Rutherford Model** - the atom is mostly empty space with a positively charged nucleus surrounded by negatively charged electrons. The infamous 'gold foil' experiment confirmed this where positively charged alpha particles were fired at a thin sheet of gold. Based on the previous model, it was hypothesised that most particles would be deflected due to the positive centre. However, most passed straight through contradicting the theory. This then became the **nuclear model** of the atom.
- The **Bohr Model** - currently used model and describes how electrons exist in shells which have a fixed energy. It incorporates the ideas from the previous models.



3.1.3 BONDING

IONIC BONDING:

- **Ionic bond** = the strong electrostatic force of attraction between oppositely charged ions.
- They are usually formed between metals and non-metals.
- **Cation** = positively charged ions formed upon loss of electrons from metals e.g. Ca^{2+}.
- **Anion** = negatively charged ions formed by non-metals gaining electrons e.g. Cl^-.
- These ions are held together in a giant ionic lattice structure.



A 2D representative of an ionic lattice structure.

- You may be asked to recall the formulae of ionic compounds. You do this by balancing the charges of the ions involved (page 3).

- Properties of ionic compounds:
- **High melting and boiling points** - strong electrostatic forces of attraction between oppositely charged ions which require a lot of energy to overcome.
- **Brittle** - Layers of ions slide past each other causing the lattice to break as ions of the same charge arrange themselves together.
- **Conduct electricity ONLY when mo... or in solution** - ions dissociate and ar... to carry a charge.

COVALENT + DATIVE COVALENT BONDING:

- **Covalent bond** = the strong electrostatic force of attraction between shared pair(s) of electrons.
- They are usually found ... and **macromolecular**
- **Dative covalent/co-ord... =** formed when the shared p... ...ns in a molecule comes from only ... bonding atoms. An arrow is use... the sharing of electrons.

A schematic showing the formation of a c... ordinate bond between ammonia and hy... to form the ammonium ion. Nitroge... both of its electrons with hydroge...

Worked example:

Q- Magnesium oxide is known f... ...n melting ... and robust structure. Identify the type of chemical bonding ... magnesiu... ...xplain in terms of structure and bonding why ... ...n oxide ex... ...gh melting point.

...ding

Magnesium oxide has a giant io... ...a electro... ...es of attraction exist between the oppositely chargeu... ... overcome. Thus giving it a hig...

Q- When a water molecule reacts with a proton to form... ...ium ion, a co-ordinate bond is formed. Explain how this co-ordinate b... ...is formed.

$H_2O + H^+ \longrightarrow H_3O^+$

A lone p... ...oxygen in the w... ...ecule to the proton.

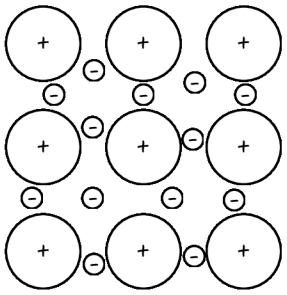
METALLI... ...DING:

- **Metal...** ...electrostatic force... ...ositive metal ions... ...ocalised ... . Arranged in a lat... ...ucture.
- **D... ...d electron...** ...trons that are f... ...nd ...rry a charge.

- Properti...
- **Conduct elec... ...d and ...alten** - due to delo...
- **...lleable** - layers ... slide

... electrostatic ... ions and ... elec...

- The s... ...etallic bonding is depende... ...gs:
  - ...e smaller the ion the ... electrons leading
  - **Charge of meta... ...**he greater the ... the stronger the attraction to the ... electrons.



Metallic bonding forming a lattice structure.

SIM... ...CULES:

- Relatively w... ...uctures.
- Covalent bonds ... ...etween atoms but many weak intermolecular forces.
- ... boiling points.
- ... of electricity.
- ..., water and iodine are examples.

...ACROMOLECULES:

Very strong structures due to many covalent bonds between carbon atoms.

Diamond:
- Each carbon atom forms 4 covalent bonds.
- Tetrahedral lattice structure.
- High melting point due to strong covalent bonds and structure.
- Hard, rigid structure making it favourable to use in cutting tools.
- Non-conductor of electricity as no delocalised electrons.
- Insoluble.

Graphite:
- Each carbon atom forms 3 covalent bonds.
- Flat layers of hexagonal rings bonded by van der Waals forces making it slippery hence often used in lubricants.
- High melting point due to strong covalent bonds within layers.
- Conducts electricity due to delocalised electrons.
- Insoluble.

3.1.5 KINETICS

COLLISION THEORY:

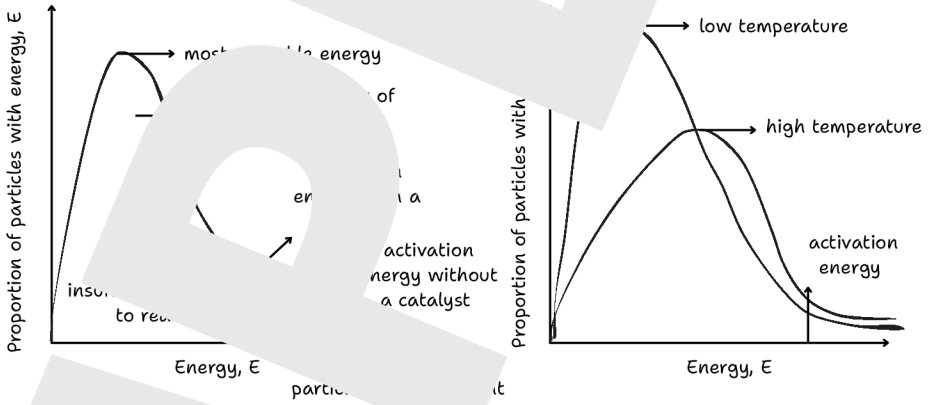
- **Activation energy** = the minimum energy required in order for a reaction to occur.
- In order for a collision to take place between particles, they must be in the **correct orientation** and have **adequate energy to overcome the activation energy.**
- **Collision frequency** = the number of collisions between particles per second.
- **Rate of reaction** = the change in concentration over time.
- Factors affecting collision frequency:

  - Concentration
  - Temperature
  - Pressure
  - Volume
  - Surface area

- **Concentration** = a **higher** concentration means particles are **closer** together, **increasing** the **frequency** of **successful collisions.**
- **Temperature** is the **only** factor that affects collision **energy**. A **higher** temperature means particles have **more energy** and **move faster** hence there are **more frequent successful collisions.**
- **Pressure** = a **higher** pressure means particles are **closer** together therefore there are **more frequent successful collisions.**
- **Volume** = with **more particles** in a **given volume**, they are **closer** together **increasing the frequency of successful collisions.**
- **Surface area** = **increasing** the surface area by crushing a solid into a powder for example, **increases the frequency of successful collisions** as a **greater number of particles are at the surface.**
- Activation energy is **or** by **catalysts.**
- **Catalyst** = provides an **al** **route** with a **lower activati** **energy** therefore a **greater proportion of collisions are successful.** Remains **chemically unchanged** at the end of a reaction.

MAXWELL-BOLTZMANN DISTRIBUTION:

- The Maxwell-Boltzmann distribution used for gas particles.
- If you have a container of gas, all rticles will have differing kinetic energies.
- No particles will have 0 energy.
- The x-axis of the curve is the ene e particl
- The y-axis of the graph describe portion es with energy.
- The peak of the curve is the m ner
- The area under the curve is th s within ainer.
- The activation energy can be found wards of the curve. A catalyst can raise this.
- The area before the activation energy represen icient energy to react.
- The area after the activation energy represents particles wi gy greater than the activation energy which usually results in successful collisions.



REQ

- This pra ives you ne rate of reaction using temperature.
- You may in he 'disappea cross' with sodium thiosulphate solution and hydrochloric
- **Method:**

a known concentration of hydrochloric acid in a h at room temperature using a plastic container. oncentration of sodium thiosulphate solution into a sk.

al flask in the water bath with a piece of paper with a big 'X' drawn on er. You may want to use a thick black marker pen to do this to make

4) Wait for th the solutions to equilibrate with the temperature of the water bath.
5) Record the initial tem ture of the sodium thiosulphate solution in a suitable results

ydrochloric acid to the sodium thiosulphate solution and imer.

6) Rec engin of time it takes for the cross to disappear as well as the final tem e.
7) Pr eaction mixture into a 'stop bath' containing sodium carbonate solution. This eutralisation of the chemicals as sulphur dioxide is a toxic gas.
he experiment at different temperatures by adding water from a kettle to the ath. **Do not exceed 55°C.**
the mean temperatures and the rate of reaction (1/time).
10) h with 1/time on the y-axis and mean temperature on the x-axis.

Worked mple:

Q- The re conc sing the of sodium nate sodium thio hydrochloric ac cloudy solution. Which change will increase the rate of reaction?

easing the of the reaction mixture

C Adding water to the reaction mixture

D Increasing the concentration of hydrochloric acid

The answer is **D**. Increasing concentration will increase the frequency of successful collisions while the other answers decrease the chances of these.

3.1.9 RATE EQUATIONS

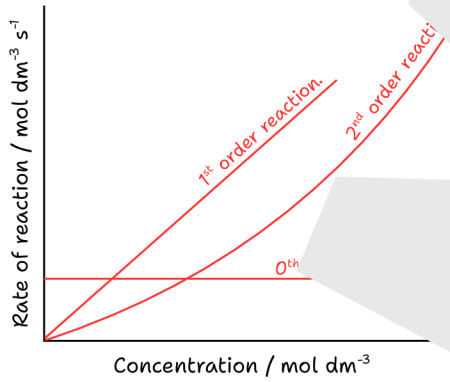
KEY CONCEPTS:

- The rate of a chemical reaction is determined by the **concentration of its reactants.**
- This is expressed using the rate equation:

$$\text{Rate} = k[A]^m[B]^n$$

- k: Rate constant
- $[A]^m$, $[B]^n$: Concentration of reactants A and B / mol dm^{-3}
- Rate: Rate of reaction / mol dm^{-3} s^{-1}
- m and n: Reaction orders m and n

- **Products** are **not** included in the rate equation.
- **Catalysts can be included** in the rate equation.
- The **rate constant, k**, is **temperature dependent.**
- The reaction orders, **m and n**, can **only** be of values **0, 1 or 2.**
- **Reaction order** = the power to which the concentration of a reactant is raised in the rate equation.
- **1st order** = the rate of reaction is directly proportional to [A].
- **2nd order** = the rate of reaction is proportional to [A]^2.
- **0th order** = the rate of reaction is not affected by reactants with this order and so, these reactants do not appear in the equation.
- **Overall order of reaction** = the sum of the orders of reactants in the rate equation.



- You may be required to work out the units for k. Here's an example:

Rate = k [

$$k = \frac{(\text{mo}}{(\text{mol dm}^{-3})\ (\text{mol a}\ldots^{-3})^2}$$

k = mol^{-3} dm^{9} s^{-1}

RATE METH…DS:

- **Continuous …hod** = measures the r… reaction … Measures the … of pr… produced … cants used … n or volume … y-axis of … e is on the x-ax… ate is … s.
- **Initial r…** … measu… nitial rate of re… … c point. W… carrying ou… …iments whe… …ariable is altered whilst … others remain c… …he time taken to reach the set point is the … This allows a graph to be construct… …rder of the reaction can be deduced.

Worked exam…le:

Q- The table below … ne data g… ered from a series of experiments investigatin… of reactio… compounds C and D.

Experim…	…al [C] / m…	[D] / mol dm^{-3}	…te / mol … s^{-1}
1		0.10	… x 10^{-4}
2			…0 x 10^{-4}
3	0.20		2.0 x 10^{-4}

Using the data above, deduce the rate expre… …r the reaction between C and D.

In or… …d the order of a reactant in th… …of questions, choose two exp… …the concentration of yo… …reactant changes but the …others remain …

Looking at ex… …k … …mains constant, and the rate …f 4.

…e, the reaction… …er with respect to C.

…iments 1 and 3, [C] re…ains constant, [D] doubles, and the rate doubles.

T… …the reaction is **first order with respect to D.**

Rate = k [C]^2[D]

…ment 1, calculate a value for k and work out its units.

k = 1.0 x 10^{-4} / [0.20]^2[0.10]

… = 0.025

$$k = \frac{\cancel{\text{mol dm}^{-3}}\ \text{s}^{-1}}{(\text{mol dm}^{-3})^2\ \cancel{(\text{mol dm}^{-3})}}$$

k = 0.025 mol^{-2} dm^{6} s^{-1}

…E-DETERMINING STEP:

- …st step of a chemical reaction. …eaction rate depends on this. …r before the rate-determining step will be the only …ed in the rate equation.
- **Reaction intermediate** = the product from one step of the reaction that then goes on to further reacting to create a product …the overall reaction.
- …**annot** be included in the rate equation. …er of the reactants will be equivalent to the number of …f each reactant in or before the rate-determining step.

…ked example:

Q- The reaction between nitrogen dioxide and carbon monoxide proceeds according to the following equation:

$$NO_{2(g)} + CO_{(g)} \longrightarrow NO_{(g)} + CO_{2(g)}$$

The experimentally determined rate equation for the reaction is: rate = k [NO_2]^2

A proposed two-step mechanism for the reaction is:

Step 1: $NO_2 + NO_2 \longrightarrow NO + NO_3$

Step 2: $NO_3 + CO \longrightarrow NO_2 + CO_2$

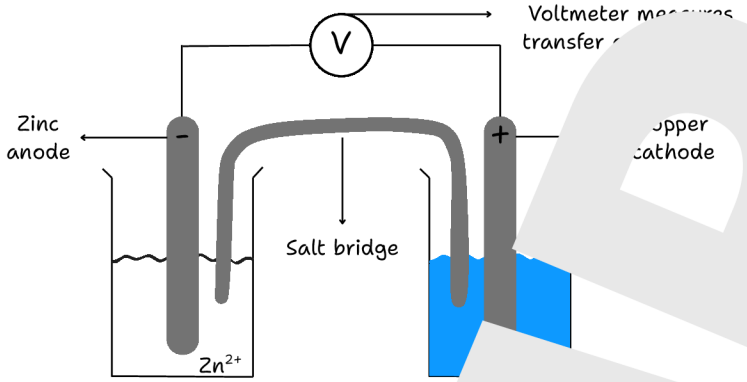
Suggest which one of the two steps is the rate-determining step and explain the reasoning behind your answer.

The answer is **step 1**. This is because only reactants in or before the rate-determining step appear in the rate equation. We can see that NO_2 appears twice in the rate equation and this occurs in step 1 of the mechanism.

3.1.11 ELECTRODE POTENTIALS & CELLS

ELECTROCHEMICAL CELLS:

- Electrochemical cells are composed of two **half-cells** linked together.
- Each half-cell consists of an electrode and a solution of the metal used as the electrode.
- **Electrodes:**
- Provide a surface for a reaction to take place.
- They work by conducting electricity thus allowing the transfer of electrons.
- They must be solid in form.
- They may partake in reactions or remain inert. An example of this is the platinum electrode.
- The **positive** electrode is known as the **cathode**. It is positive a **reduction** occurs at the cathode.
- The **negative** electrode is known as the **anode**. It is negative **oxidation** occurs at the anode.



A visual representation of an electr

- **Salt bridge** = completes the circuit and allow ions to prevent charge build-up around the elec react with charged particles in the solution to prev insoluble salts.
- Half-equations are used to represent the processes insi electrochemical cell:

$Zn_{(s)} \longrightarrow$

This is the process that occurs at the tal electrode is oxidised to zinc ions foun

$Cu^{2+}_{(aq)} + 2e^- \longrightarrow Cu_{(s)}$

This is the process that occurs at the cathode. The copper io gain electrons and are reduced to copper metal.

$Zn_{(s)} + Cu^{2}$

This is the overall redo is the reducing agent whist olution is sing agent.

CONVENTIONAL CELL

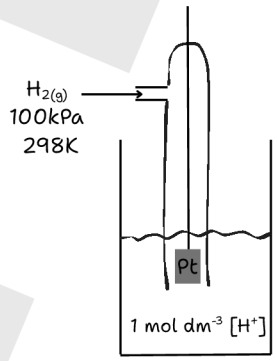
Zn | $Zn^{2+}_{(aq)}$ || Cu

Most reduc e boundary uced half-cell is always on species go the right the ends.

- The spec ue of the lge are the ones that undergo m ndicated b gh oxidation numbers.
- When there a ntical species me state, write them next to each other separated by a then place the phase boundary. Make sure to also inc ox electrode e.g. $Pt_{(s)}$ on either side of the phase bounda ave two ionic solutions.

ELECTRODES:

- re a few different types of electrode.
- **electrod** = An electrode made of a metal erged int ion of the metal's ions. For ple, the crode.
- **electro** electrod ses a gas ion. An e the n electro and consists er ine to allow for the nt.
- **Standard** = known as the primary standar ake comparisons between half-cells. It electrode potential of +0.00 V.
- **Redox electrode** = ally the platinum electrode and is us edox reactions between ionic sol atinum is used because rt and al the movement of pting the reaction.



The standard hydrogen electrode.

CTRODE POTENTIALS:

- **Electrode potential:**
- The standard electrode potential refers to the standard conditions that are required for electrodes. These are: a **temperature of 298K, solutions at 1 mol dm^{-3}, and a pressure of 100kPa.** Make sure you write out these conditions when drawing electrochemical cells.
- Electrode potentials are measured in volts.
- A more positive electrode potential signifies a high chance of the reduction reaction occurring.
- Electrode potentials are written in the **reduction direction ONLY.**
- More positive electrode potentials indicate reactions that undergo reduction easily - this will be the **cathode.**
- Less positive electrode potentials indicate reactions that are more likely to undergo oxidation - this will be the **anode.**
- Half-cell equations can be written more easily like this:

$Zn^{2+}_{(aq)} / Zn_{(s)}$ $E^{\ominus} = -0.76$ V

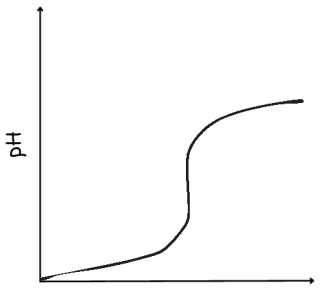
$Cu^{2+}_{(aq)} / Cu_{(s)}$ $E^{\ominus} = +0.34$ V

- From the electrode potentials above, we can see that copper is more likely to undergo reduction and zinc is more likely to undergo oxidation when the two half-cells are connected.
- Therefore, we say that **Cu^{2+} will be reduced by Zn.**
- Explain the reasoning for your answer by saying that the Cu^{2+}/Cu electrode potential is more positive than the Zn^{2+}/Zn electrode potential.

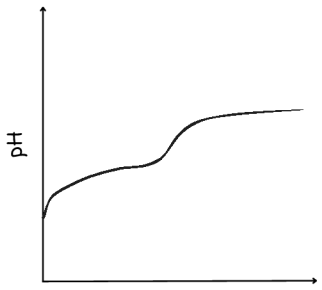
3.1.12 ACIDS & BASES PT. 4

TITRATION CURVES CONTINUED:

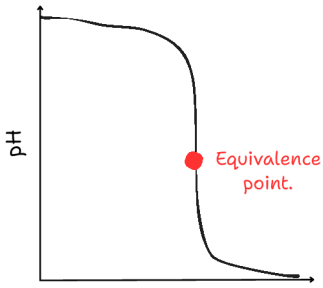
Weak base to strong acid



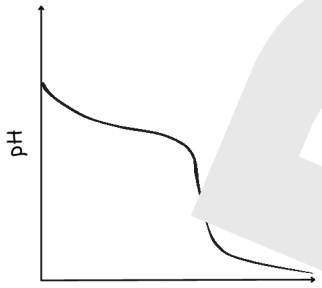
Weak base to weak acid



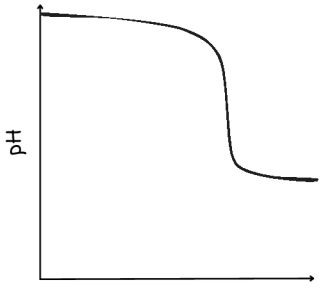
Strong acid to strong base



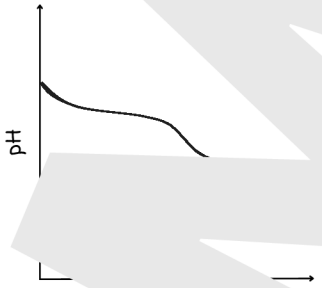
Strong acid to weak base



Weak acid to strong base



Weak a



- The middle point of the vertical section found in each curve is the **equivalence point.**
- The weak acid to weak base titration is excluded from this rule as the vertical section d

- **Half neutralisation**
- We can use strong base ... acid titration ... to find the pH at half neutralisation.
- Volume at half neutralisation ... **of b... ed at the equivalence point / 2.**
- At half neutralisation, half of the ... een used up and half of the salt of the weak acid ... meaning [HA] = [A⁻].
- Putting this in ... K_a equation leads to ...
- Taking the ... oth sides gives us **pH = ... we can use this e... to calculate th... at hal... alisation.**

- Here ar... ranges fo...
- Methyl ... = 3.1-4...
- Phenolp...
- Bromothy...
- Litmus = 4...
- If a question as... ich indicator w... ost suitable for a strong acid-strong base titration, ... bromothymol blue. This is because the pH range fo... hange is around the equivalence point for this titrati... n in the curve.

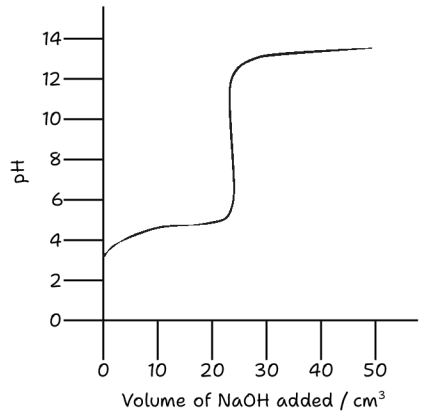
REQUIRED PRACTICAL 9: INVESTIGATING PH CH... WHEN A WEAK ACID REACTS WITH ...ONG B...SE AND WHEN A STR... CID RE... WITH A WEAK BAS...

- ... focus o... acid-strong base t...
- **Method:**

1) Begin by calibrating ... e it well using distilled or deionised wa... e it is completely dry before using.
2) Place the meter in the pH 7.0 buffer solution and give it some time before recordi... pH reading.
3) Repeat steps 1 and 2 for ... r chosen standard solutions.
4) ...ration c... the readings recorded ... s on the x-axis and the acti... ons on the y-axis. Do this on Excel a... f best fit which will provide ... with an equa... djust the pH readings ...rded.
5) ... the burette with a known concentration of the ... base and then fill the burette with this strong ...st below the tap.
6) ...te a known volume of the weak acid into a beaker. ...e a glass rod into the beaker and insert the pH ...ter. Start stirring the solution slowly and record the ...H.
7) ...he strong base from the burette in small ...
8) Aft... dition, allow the solution to mix thoroughly ...efore recording the pH.
9) ...ntinue to add the base until well past the ...e point.
10) ...ph with the volume of base added in cm^3 on ...s and the adjusted pH readings on the y-axis.

Worked example:

...udent titrated 25.0 cm^3 of a weak monoprotic acid (HA) with ... mol dm^{-3} sodium hydroxide. The pH was measured after each addition of sodium hydroxide, and the following titration curve was obtained:



Use the graph to estimate the pK_a of the weak acid.

Half-neutralisation point = 12.5 cm^3. At half neutralisation, [HA] = [A^-], so pH = pK_a. pH is approximately 4.8 therefore pK_a = 4.8.

Suggest a suitable indicator that could be used to determine the end-point of this titration. Justify your choice using the graph.

Phenolphthalein as the pH range for its colour change is 8.3-10.0 which lies within the vertical section of the curve.

Explain why the pH at the equivalence point is greater than 7.

There is no more HA left so A^- reacts with water in a hydrolysis reaction to produce ^-OH ions making the solution basic.

3.2.2 & 3.2.3 GROUP 2 AND GROUP 7

GROUP 2, THE ALKALINE EARTH METALS TRENDS:

- **Atomic radius:** Increases as you descend the group as shielding increases.
- **1st ionisation energy:**
- Decreases as you descend the group.
- Shielding increases therefore there is a weaker attraction between the nucleus and outer shell electrons.
- Less energy is required to remove an electron from the outer shell.
- **Melting point:** Generally decreases as metal ions get larger leading to a lower charge density. This means weaker metallic bonding.

- **Reactions with cold water:** Increases as you descend the group as shielding allows outer electrons to be lost more easily to water.
- **Beryllium** is the only element that does not react with water/steam.

- **Solubility:**
- Group 2 **sulphates** get **less soluble** as you descend the group. **$BaSO_4$ is insoluble** and forms a **white precipitate**.
- Group 2 **hydroxides** get **more soluble** as yo descend the group. **$Mg(OH)_2$ and $Ca(OH)_2$ o insoluble**.

- **Testing for sulphate ions in solutions:**
- Based on $BaSO_4$ being insoluble.
- Mix acidified (with HCl) $BaCl_2$ solution with your chosen solution and if sulphate ions are present in your chosen solution, a white precipitate should form.
- $BaCO_3$ is just like $BaSO_4$. The HCl r carbonate ions so that $BaSO_4$ is d from it.
- If carbonate ions are present, effe would be observed.

Element	Reaction with ter/steam	Equation
Mg	No reacti old wate Burns with ame pr a white	$g_{(s)} + 2H_2O_{(l)} \rightarrow Mg(OH)_{2(s)} +$ $H_{2(g)}$ $Mg_{(s)} +$ $MgO_{(s)} + H_{2(g)}$
Ca	Fizzes and slowly soluble white precip	$) \rightarrow Ca(OH)_{2(s)} +$ $H_{2(g)}$
Sr	Fizzes and forms colourless solution.	$O_{(l)} \rightarrow Sr(OH)_{2(aq)} +$ $H_{2(g)}$
Ba	Fizzes and forms a colourless solution.	$Ba_{(s)} + 2H_2O_{(l)} \rightarrow Ba(OH)_{2(aq)} +$ $H_{2(g)}$

Wor

Q- Barium sulphate i elp doctors view the gut in

Br Explain why bar phate can be safely digested.

F phat le in water. Therefore, barium ions are not released e body and cannot be absorbed.

ibe how yo test for the presence of sulphate ions in a solution. de any reagents and observations.

loric acid to remove carbonates. Then add barium chlor recipitate of barium sulphate will confirm the of sulphate ions.

TRENDS.

m fluorine to iodine exist as diatomic lec $_2$.

g point as you descend the group. This is because the ases hence t are stronger van der Waals forces between a lot of energy is required to overcome these forces.

- **Ele ivity:** Decreases as you descend the group. This is because s and so, a lower ability to attract a pair of electrons

ses as you descend the group as it is correlated with electronegativity. The easier it is to attract a pair of electrons, the more eactive an element is.

PRACTICAL USES OF GROUP 2:

- **$BaSO_4$** = Used in barium meals. It is swallowed to outline the gastrointestinal tract in X-rays to identify any issues. overrides the toxic eff
- **$Mg(OH)_2$** = Milk of m antacid neutralising exc h acid.
- **$Ca(OH)_2$** = Slaked lime ca farme to reduce the acidity of soil.
- **Mg** = Used in titanium extractio

$$TiO_2 + 2Cl_2 + 2C \rightarrow TiCl_4 + 2CO$$
$$TiCl_4 + Mg \rightarrow Ti + 2MgCl_2$$

- An expens due to the high temperat and the pro Mg by electrol
- **SO_2** = C id rain. gases b ss co
- $CaO_{(s)}$ or nto the gases alo emove SO_2

$$CaO_{(s)} + SO_{2(g)} \rightarrow CaSO_{3(s)}$$
$$CaCO_{3(s)} + SO_{2(g)} \rightarrow CaSO_{3(s)} +$$

GENS AS OXIDISING AGENTS:

- **Oxi ower:** Halogens are oxidising agents. This means they get reduced emselves. Oxidising power decreases as you descend the s is because the increased shielding makes it harder to gain .
- **ement reactions:**
- Display the oxidising power of halogens.
- A solution of the halogen is added to a solution of a halide.
- A more reactive halogen will displace a less reactive one.
- **Chlorine** = exists as a **pale yellow-green solution**.
- **Bromine** = exists as an **orange-brown solution**.
- **Iodine** = exists as a **brown solution** but as a **grey/black solid** when not in solution.

	Cl^-	Br^-	I^-
Cl_2	Remains pale yellow-green	Solution turns orange	Solution turns brown
Br_2	Remains orange	Remains orange	Solution turns brown
I_2	Remains brown	Remains brown	Remains brown

A table displaying the displacement reactions of the halogens with halides.

3.2.5 TRANSITION METALS

KEY CONCEPTS:

- The transition metals are located around the middle of the periodic table.
- They have **variable oxidation states** which allows them to form different compounds.
- These compounds tend to be **coloured**.

Ion	Colour of ion in solution	Oxidation state of vanadium
V^{2+}	Violet	+2
V^{3+}	Green	+3
VO^{2+}	Blue	+4
VO_2^{+}	Yellow	+5

- Transition metals are d-block elements that can form one or more stable ions with a partially filled d-orbital.
- The splitting of the d-orbitals and adsorption of visible light cause wavelengths to be transmitted/reflected giving the complexes their distinct colours.
- Zinc is excluded from the transition metals as it has a completely filled d-orbital.
- Transition metals are **good catalysts**.
- Transition metals exist as **complex ions**.
- Make sure you remember the key features highlighted in bold for the exams.

HOMOGENOUS CATALYSTS:

- As the homogenous catalyst is in t… phase as the reactants, an interm… with a lower activation energy i… reaction to proceed.
- Fe^{2+} ions catalyse the reaction betwe… $S_2O_8^{2-}$ ions in the Haber process. The catal… needed because without it there would be high… repulsion between the two negative ions leading to a high activation energy and less chance of collisions occurring.
- This is a two-step proce…

$$S_2O_8^{2-} + 2Fe^{2+} \rightarrow$$

$$2Fe^{3+} + 2I^- \rightarrow \quad I_2$$

$$S_2O_8^{2-} + 2I^- \rightarrow 2SO_4$$

Worked example:

Q- Explai… of d-orbital s… why transitio… omplexes a…

D-orbitals … plex s… levels. Ele… …nt to r… higher … …ne remain… wavelengths … …/reflected, g… complex its colour.

HETEROGENOUS CATALYSTS:

- Transition metals and … …pounds are able to act as catalysts due to their variable oxid… …tes.
- The metals and their … …nds can … both **homogenous** and **heterogenous cat…**
- **Homogeneous cat…** catalyst … …me phas… reactants.
- **Heterogenous c…** …/… …ferent ph… …the reactants.
- **Heterogenous catal…**

1) **Adsorption.** Reactant molec… …onto the surface of the solid catalyst. This … …n the reactant molecules, making them **more reactive.**
2) **Bond breaking and bond forming.**
3) **Desorption.** Product molecules leave the catalyst surface, freeing up active s… for new reactants to adsorb.

- The effi… …he catalyst heavily relie… strength of adsorp…
- The elem… …ength of … on are: **Fe, Ru, Rh, Co, Ni, Pd, and Pt.**

- **Cata… …rters:**
- H… …ysis occurs in … converters.
- … …creases the surfa… area for catalysis and cost-… …mple.
- …ered cata… …o maximise surface area by providing a thin layer … catalysis to… …Pt is an example but is expensive.
- …rogenous … …s can get **poisoned** by impurities which block the … fr… …ion. This reduces the efficiency of the catalyst and … economical disadvantage.

- **The Co…**
- V_2O_5 is the ca… …s and works to produce sulphuric acid … the production … …oxide:

$$O_{2(g)} \rightarrow V_2O_{4(g)} + SO_{3(g)}$$

$$V_2O_{4(s)} + \tfrac{1}{2}\,O_{2(g)} \rightarrow V_2O_{5(s)}$$

$$O_{2(g)} + \tfrac{1}{2}\,O_{2(g)} \rightleftharpoons SO_{3(g)}$$

AUTOCATALYSTS:

…when the product of the reaction is also the catalyst.
…is by Mn^{2+} of $C_2O_4^{2-}$ with MnO_4^-:

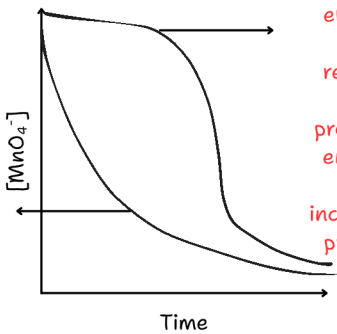
$$4Mn… + MnO_4^-{}_{(aq)} + 8H^+_{(aq)} \rightarrow 5Mn^{3+}_{(aq)} + 4H_2O_{(l)}$$

$$…^{3+}_{(aq)} + C_2O_4^{2-}_{(aq)} \rightarrow 2Mn^{2+}_{(aq)} + 2CO_{2(g)}$$

$$2MnO_4^-{}_{(aq)} + 5C_2O_4^{2-}_{(aq)} + 16H^+_{(aq)} \rightarrow 2Mn^{2+}_{(aq)} + 10CO_{2(g)} + 8H_2O_{(l)}$$

- The reaction rate decreases over time as MnO_4^- gets used up.
- Below is a graph showing the effects of Mn^{2+} being an autocatalyst in its reaction with ethanedioate:

This curve shows the effects without an autocatalyst. The reactant is not getting reused hence the rate of reaction continues to fall steadily.



This curve shows the effects of autocatalysis. At first, the rate of reaction is very slow as there is not enough product which means not enough catalyst. As the amount of product increases, more catalyst is produced so the rate of reaction speeds up.

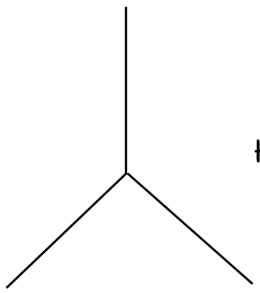
3.3.1 INTRO TO ORGANIC CHEMISTRY

KEY CONCEPTS:

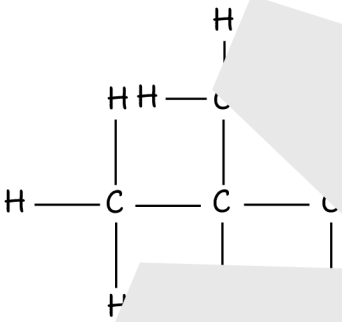
- **Molecular formula** = shows the actual number of each type of atom in a molecule.
- **Empirical formula** = shows the simplest whole number ratio of atoms of each element in a compound.
- **General formula** = represents a homologous series using letters and numbers (algebraic form). An example is C_nH_{2n+2} for alkanes.
- **Structural formula** = shows the arrangement of atoms in 2D form.
- **Displayed formula** = shows all the atoms and bonds in a molecule using lines to represent the bonds.
- **Skeletal formula** = shows the bonds of the carbon skeleton and functional groups attached. Doesn't show carbon and hydrogen atoms attached.
- **Homologous series** = organic compounds with the same general formula, differing physical properties, same chemical properties, and each compound differs by CH_2 from the previous one. For example, alkanes and alkenes.
- **Alkyl group** = contains only carbon and hydrogen atoms (hydrocarbon). Formed from alkanes by removing a hydrogen atom e.g. CH_3, C_2H_5, C_3H_7.
- **Functional group** = atom/group of atoms which give rise to their distinct chemical properties.
- Let's take a look at the different ways to represent methylpropane:

$CH_3CH(CH_3)CH_3$

Structural formula



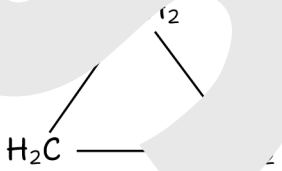
Skeletal formula



- **Nomenclature:**
- When drawing/naming organic compounds, it emphasise the significance of numbers, alphabetical functional groups according to IUPAC.
- Depending on the length of the carbon chain, the alkyl group could fall on different carbons. For example, you could have 2-methylbutane or 3-met
- If you have two alkyl would have to write
- The two alkyl groups co on the sa on atom. In this case you would write of the atom they fall on twice, separated by a ylbutane.
- Numbers and letters are separa
- When naming organic compounds unctional groups, the highest priority functiona first. This is the order of priorit

Carboxyli ester → Aldehyde → Keto cohol → Ar kene → Halo e → A e

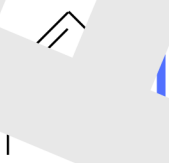
- **Cyclic a** = organi g on the number of carbo



Cyclopro

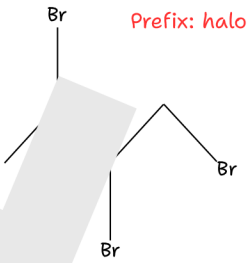
ALKENE:

efix: enyl
Suffix: en



3,4-dimethylpent-2-ene.
Double bonds are between carbon atoms only.

HALOGENOALKANE:

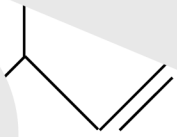


Prefix: halo

ribromobutane.
nalogen atom is attached to a carbon atom.

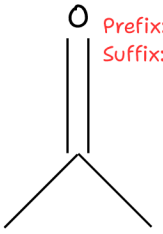
DEHYDE:

ox



ethylpropanal.
is double bonded to on atom attached to drogen. Aldehydes are on the ends of ins.

TONE:

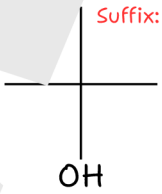


Prefix: oxo
Suffix: one

Propanone.
Ketones are located in the middle of carbon chains. Oxygen is double bonded to a carbon atom.

ALCO

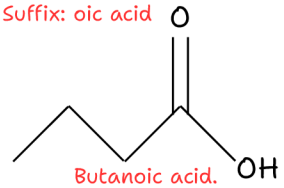
Prefix: hydroxy
Suffix: ol



Methylpropan-2-ol.
The alcohol group (OH) is attached to a carbon atom.

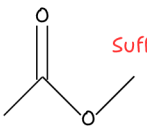
CARBOXYLIC ACID:

Suffix: oic acid



Butanoic acid.
The carboxylic acid group (-COOH) is attached to the end of the carbon chain.

ESTER:

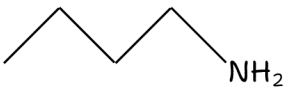


Suffix: oate

Methyl ethanoate.
The ester group (-COO) is found in the middle of carbon chains. The methyl group is attached to the singly bonded O whilst the ethyl group is attached to the double bonded O.

AMINE:

Prefix: amino
Suffix: amine

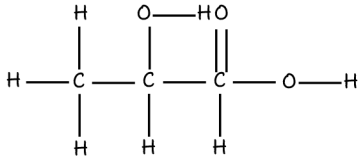


Butylamine.

The amine group is attached to a carbon atom.

Worked example:

What is the name of this compound in IUPAC form?



2-hydroxypropanoic acid.

3.3.3 + 4 HALOGENOALKANES PT 2 & ALKENES

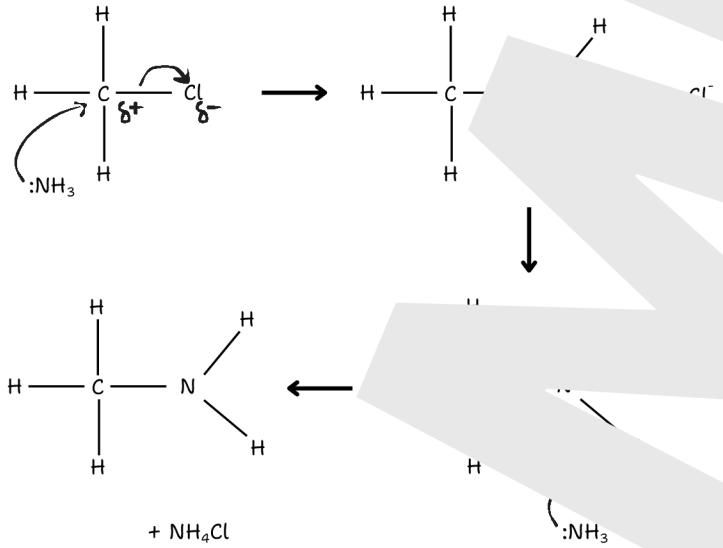
NUCLEOPHILIC SUBSTITUTION REAGENTS AND CONDITIONS:

- **Reagent =** a substance added to a reaction to bring it about e.g. sodium hydroxide, potassium cyanide or ammonia.
- **Reaction conditions** = conditions required to induce the reaction e.g. temperature, pressure, use of a catalyst.

- **Halogenoalkanes with hydroxide ($:^{-}OH$) ions:**
- Reagent = aqueous sodium/potassium hydroxide solution.
- Conditions = reflux in aqueous sodium/potassium hydroxide solution.
- Product = alcohol.

- **Halogenoalkanes with cyanide ($:CN^{-}$) ions:**
- Reagent = aqueous, alcoholic sodium/potassium hydroxide solution.
- Conditions = reflux in aqueous, alcoholic sodium/potassium, hydroxide solution.
- Product = nitrile.

- **Halogenoalkanes with ammonia ($:NH_3$):**
- Reagent = aqueous, alcoholic ammonia (in excess) s
- Conditions = reflux in aqueous, alcoholic ammonia under pressure.
- Products = amine and ammonium halide salt.



Chloromethane becomes m
first, nitrogen becomes p
of electro

ELIMINATION:

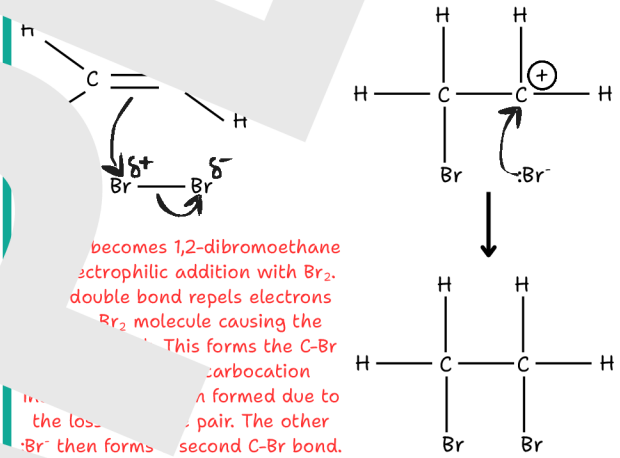
- Elimination is very similar to
- ^{-}OH acts as a **base** not a nucleop
- Reagent = concentrated alcoholic s um hydroxide solution.
- Conditions = in alcoholic sodium/p droxide solution.
- Products **and water.**

e becomes a elimination. ^{-}OH as a base and proton from the carbon adjacent on bonded to the halogen. A lone rom the C-H bond to form a double ween carbon atoms.

ALK INTR UCTION:

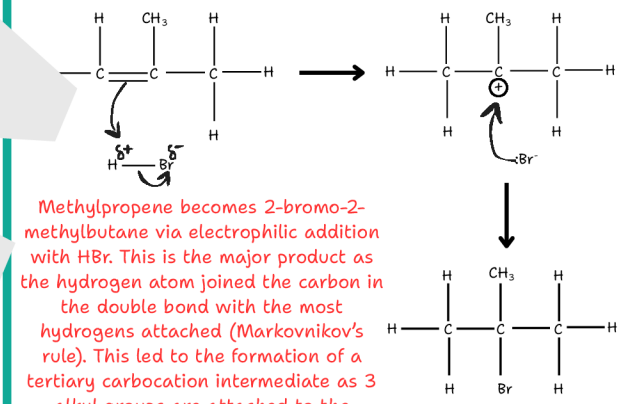
- A re **unsat ydrocar ons** meaning ist of **dc nds** betw on atoms.
- electro , and there is nd them.
- Alke hile are lone pair/electr
- Alkenes undergo reactions.
- The ones we will discus Br_2, HBr, and H_2SO_4.

- **Alkene with Br_2:**
- Reagent = Br_2
- ions = aqueous s bromine water).

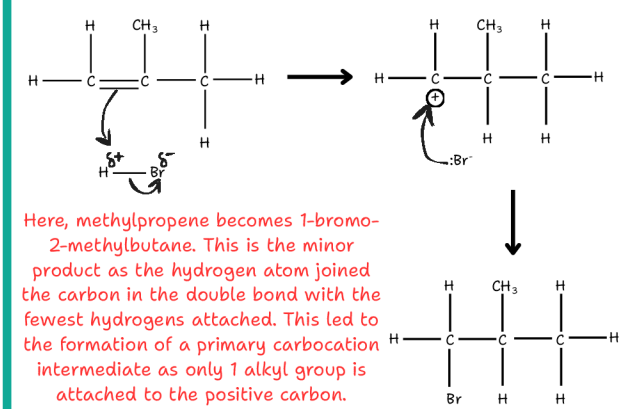


becomes 1,2-dibromoethane ctrophilic addition with Br_2. double bond repels electrons Br_2 molecule causing the This forms the C-Br carbocation n formed due to the los pair. The other :Br⁻ then forms second C-Br bond.

th HBr:
= HBr
ns = aqueous HBr solution.



Methylpropene becomes 2-bromo-2-methylbutane via electrophilic addition with HBr. This is the major product as the hydrogen atom joined the carbon in the double bond with the most hydrogens attached (Markovnikov's rule). This led to the formation of a tertiary carbocation intermediate as 3 alkyl groups are attached to the positive carbon. However a primary carbocation can also be formed..



Here, methylpropene becomes 1-bromo-2-methylbutane. This is the minor product as the hydrogen atom joined the carbon in the double bond with the fewest hydrogens attached. This led to the formation of a primary carbocation intermediate as only 1 alkyl group is attached to the positive carbon.

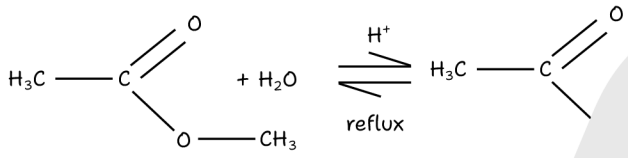
3.3.9 CARBOXYLIC ACIDS & DERIVATIVES PT.2

USES OF ESTERS:

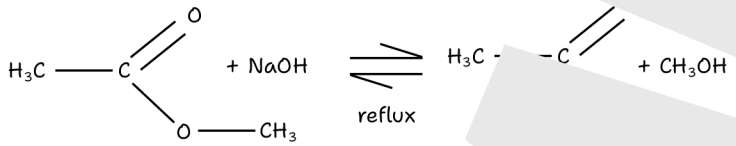
- Esters are sweet smelling making them useful as perfumes or sweeteners in the food industry.
- They are polar molecules making them useful as solvents.
- They can be used as plasticisers to make plastics more flexible due to their short chains.

ESTER HYDROLYSIS:

- Esters can undergo either acid or base hydrolysis.
- **Acid hydrolysis:**
- Ester and water are **refluxed** with a **dilute strong acid** to f… **carboxylic acid** and **an alcohol:**

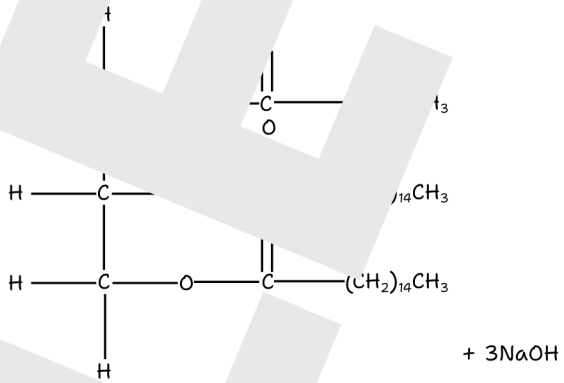


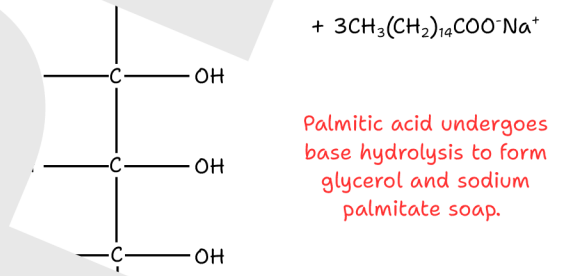
- **Base hydrolysis:**
- Ester and water are **refluxed** with a **dilute alkali** … **carboxylate ion** and **an alcohol:**



SOAP:

- I… undergoes base hydrolysis using NaOH, …rm glycerol and soap:

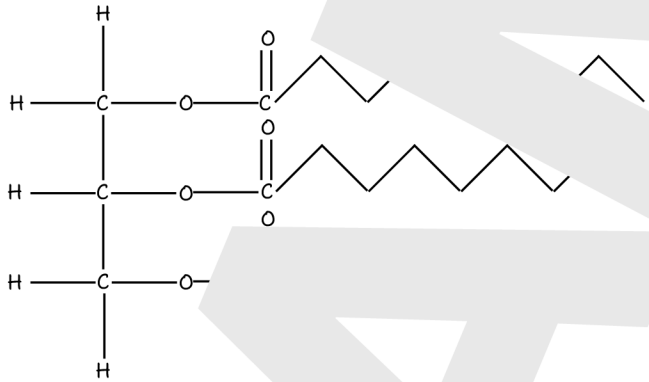




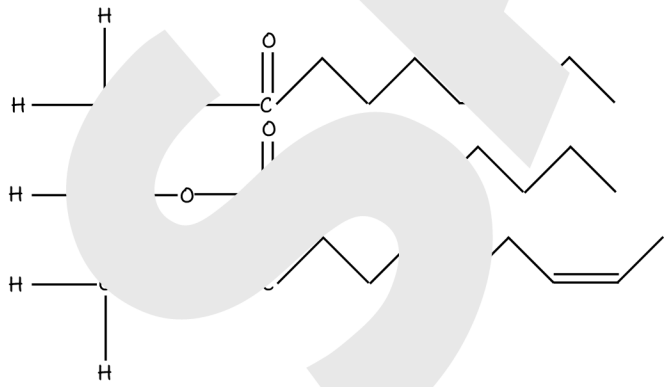
Palmitic acid undergoes base hydrolysis to form glycerol and sodium palmitate soap.

VEGETABLE OILS AND ANIMAL F… …DIESEL:

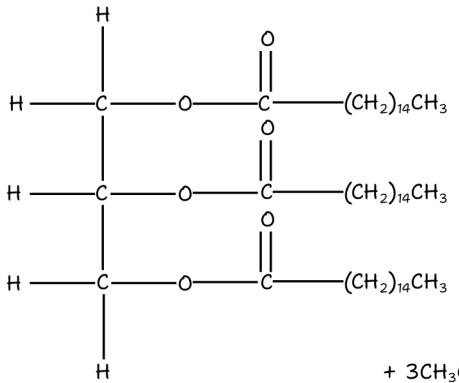
- These are produced via esterification of glycerol (prop… …riol) and long chain **saturated and unsaturated** fatty acids.
- **Fatty acids** are usually **saturated** …giving them high meltin… due to the high number of van der …

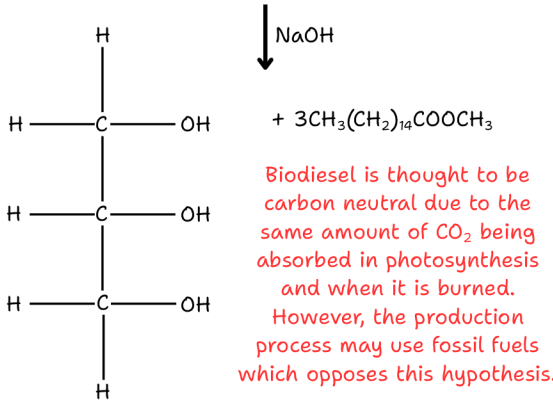


- **Oils** are usually **unsaturated** … l… …ng points as the chains are unable to pack closel…

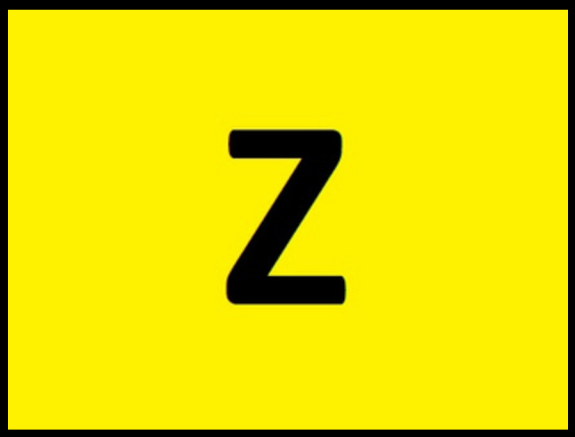


- Biodiesel is a methyl ester made of long-chain fatty acids.
- The fat/oil is is reacted with methanol using a strong alkali catalyst. The products are glycerol and biodiesel:





Biodiesel is thought to be carbon neutral due to the same amount of CO_2 being absorbed in photosynthesis and when it is burned. However, the production process may use fossil fuels which opposes this hypothesis.



MR. ZEE'S RESOURCES