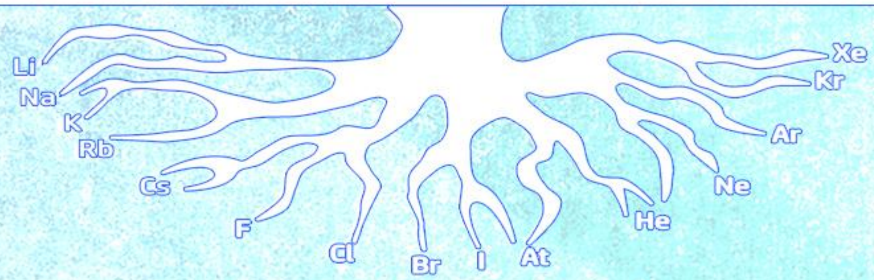
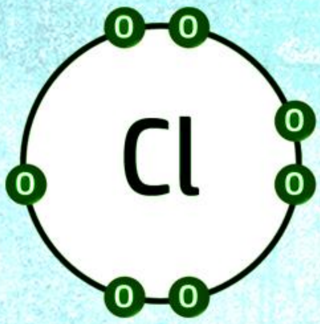
Mr Barnes Teaches Chemistry

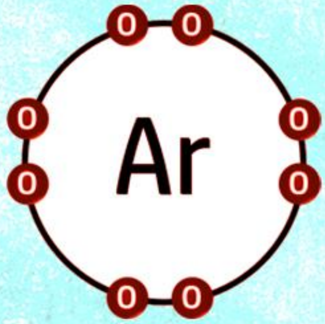
THE CHEMISTREE OF KNOWLEDGE



THE ALKALI METALS

THE HALOGENS





THE NOBLE GASES

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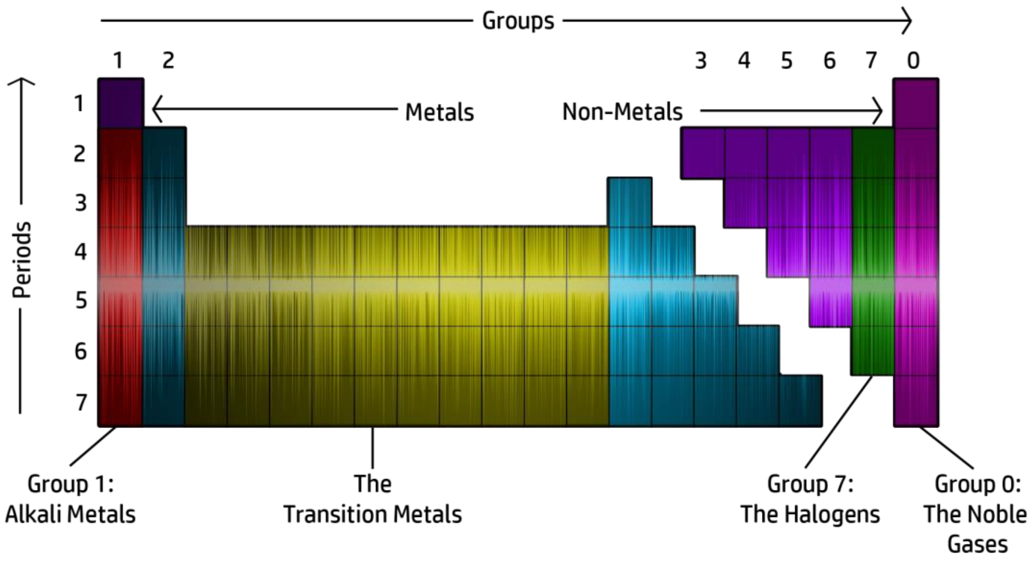
PAPER 2 REVISION GUIDE

AfL 15: The Alkali Metals and the Noble Gases:



A. The Alkali Metals

- The Alkali Metals are found in group 1 of the Periodic table and contain lithium, sodium, potassium, rubidium, caesium and francium.
- They all have one electron on the outer shell – this makes them really reactive because they only need to lose one electron to become chemically stable.
- All alkali metals are **soft** (easy to cut) and have **low melting points**

B. Reactions with water:

When the alkali metals are added to water, they react the same way – they have similar chemical properties:

- They produce hydrogen gas – seen as **fizzing/effervescence**
- They **move** around on **top** of the water

When the alkali metals react with water, they produce a hydroxide and hydrogen:

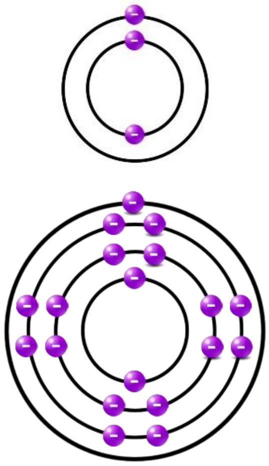
Potassium	+	Water	→	Potassium hydroxide	+	hydrogen
2K		$2H_2O$		2KOH		H_2

However, you can see that reactivity increases down the group. This is shown in the following way:

- Lithium moves slowly on the water, producing a small amount of hydrogen
- Sodium does the same, but moves more, gives off more gas and **melts** (remember – low melting point!)
- Potassium gives off a lot of gas, melts and **sets on fire** with a **lilac** flame

C. Why does reactivity INCREASE as you go down group 1?

The reason for this increase in reactivity is down to the electronic configuration:



- As you go down the group, the atom has **more shells of electrons**.
- There is **more electron shielding**.
- The **outer** electron is **further away from the nucleus**.
- The **force of attraction** between the **outer electron** and the **positive nucleus** is weaker.
- It is **easier to lose the outer electron** – therefore more reactive!

D. The Noble Gases

- The **Noble Gases** are found in group 0 of the Periodic table and contain helium, neon, argon, krypton, xenon and radon.
- They all have full outer shells – this makes them **inert** **(unreactive)** because they don't need to lose or gain electrons.
- They are all **monatomic** – which means they go around on their own.
- All noble gases are **gases** and have **low melting points and boiling points.**

E. Uses of the Noble Gases:

Use:	**Noble Gases involved:**	**Reason:**
Filament lamps and flash photography filaments	Mainly **argon**, as well as krypton and xenon	Non-flammable – and the noble gas will not react with the filament (oxygen will!)
Welding	Argon and Helium	Provides an inert atmosphere – stops the hot metal from reacting with oxygen.
Airships / party balloons	Helium	Less dense than air. Non-Flammable – won't set on fire like hydrogen will.

F. Properties of the Noble Gases:

The noble gases all seem similar, but the physical properties do change as you go down the group:

- Boiling point and Melting point increases down the group
- Density increases as you go down the group
- You can use the information about these densities to predict the properties of different noble gases.

AfL 16: The Halogens and Displacement Reactions:

A. The colour and state of the halogens:

They are all **diatomic** – meaning they go around in (covalently bonded) pairs – F_2, Cl_2, Br_2, I_2, At_2.

There are only three halogens that you need to know the colour and state for:

Halogen:	**Colour:**	**State: (at room temp)**
Chlorine, Cl_2	Green	Gas
Bromine, Br_2	Brown	Liquid
Iodine, I_2	Black	Solid

As you go down group 7, the melting points and boiling points **increase**. You can tell this because the states change from gases to solids as you go down the group.

B. The displacement of the halogens:

As you go down group 7, reactivity decreases. This can be proved using displacement reactions.

If you take a salt containing chlorine, bromine and iodine – for example potassium chloride, potassium bromide and potassium iodide – and react them with their elements (Cl_2, Br_2 and I_2), the following will occur:

Element:	**Potassium chloride, KCl**	**Potassium bromide, KBr**	**Potassium Iodide, KI**
Chlorine water, Cl_2 (colourless)	No reaction	Reaction (turns orange)	Reaction (turns brown)
Bromine water, Br_2 (orange)	No reaction	No reaction	Reaction (turns brown)
Iodine water, I_2 (brown)	No reaction	No reaction	No reaction

As you can see from the table above:

- Chlorine reacts with potassium bromide and potassium iodide
- This tells us that chlorine is **more reactive** than bromine and iodine.
- Bromine reacts with potassium iodide, but not with potassium chloride.
- This tells us that bromine is **more reactive** than iodine, but **less reactive** than chlorine.
- Iodine reacts with neither, so it is **less reactive than both.**

When a displacement reaction occurs, the more reactive metal displaces (swaps) with the less reactive metal in the compound:

Chlorine	+	Potassium Bromide	→	Potassium Chloride	+	Bromine
Cl_2	+	$2KBr$	→	$2KCl$	+	Br_2

You will know if bromine forms, because the solution will change from colourless to orange.

You will know if iodine forms, because the solution will change from colourless to brown.

C. Displacement reactions and Redox:

The displacement reactions seen on the previous page are all examples of redox reactions.

The element (e.g. Cl_2) is always gain electrons and are **reduced** and the compounds halogen (e.g. K**Br**) is always oxidised, as the lose electrons.

Watch the video on the right for more information and written half equations.

D. The test for chlorine:

- If you wanted to prove that a gas was chlorine, add **damp blue litmus paper to it**.
- Damp **blue** litmus paper turns **red**, then **bleaches**.

E. Metal Halides:

When the halogens react with metals, they form metal halides. The reactions are all similar, depending on what group you are reacting with:

- Group 1 metals give the general formula of MH – one metal and one halogen
- Group 2 metals give the general formula of MH_2 – one metal and two halogens
- Group 3 metals give the general formula of MH_3 – one metal and three halogens

Examples:

Group 1:	Sodium **2Na**	+	Iodine **I_2**	→	Sodium Iodide **2NaI**
Group 2:	Magnesium **Mg**	+	Bromine **Br_2**	→	Magnesium Bromide **$MgBr_2$**
Group 3:	Aluminium **2Al**	+	Chlorine **$3Cl_2$**	→	Aluminium Chloride **$2AlCl_3$**

F. Hydrogen Halides:

When the halogens react with hydrogen, the same reaction occurs - hydrogen halides are formed.

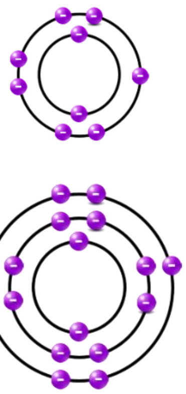
Hydrogen		Chlorine		Hydrogen Chloride
$H_{2\,(g)}$	+	**$Cl_{2\,(g)}$**	→	**$2HCl_{(g)}$**

All the hydrogen halides are gases, and when they dissolve into water, they form an aqueous solution which is acidic.

- Hydrogen chloride, $HCl_{(g)}$, dissolves to form hydrochloric acid, $HCl_{(aq)}$.
- The hydrogen ion, H^+, is what makes the solution acidic.

G. Why does reactivity DECREASE as you go down group 7?

The reason for this decrease in reactivity is down to the electronic configuration:



- As you go down the group, the atom has **more shells of electrons**.
- There is **more electron shielding**.
- The **outer** electron is **further away from the nucleus**.
- The **force of attraction** between the **outer electron** and the **positive nucleus** is weaker.
- It is **harder to gain the outer electron** – therefore less reactive!

AfL 17: Rates of Reaction & Collision Theory:

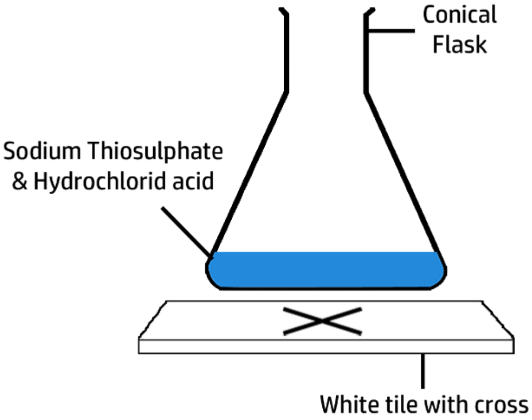
A. Rates of Reaction: The Core Practicals

The rate of reaction is how fast a reaction can happen. There are two practicals you need to know to investigate rates of reaction:

1. The Disappearing Cross

Sodium thiosulfate + hydrochloric acid → sodium chloride + water + sulfur dioxide + sulfur

$Na_2S_2O_{3\,(aq)} + 2HCl_{\,(aq)} \rightarrow 2NaCl_{\,(aq)} + H_2O_{\,(l)} + SO_{2\,(g)} + S_{\,(s)}$



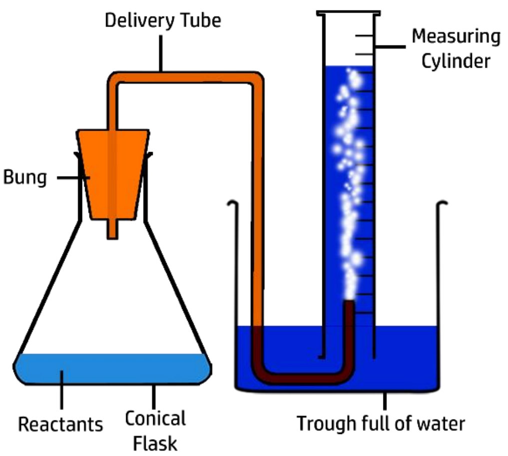
Method:
- Measure out 50cm^3 of sodium thiosulfate
- Measure out 5cm^3 of hydrochloric acid.
- Place a conical flask on a white tile with a cross on it.
- Add the sodium thiosulfate to the hydrochloric acid and start the timer.
- Once the cross is no longer visible, stop the timer.

Variables:
- Independent Variable: Concentration OR Temperature
- Dependent Variable: Time for cross to disappear
- Control Variable: Volume of acid/thiosulfate

2. Gas collection – Acid and Marble chips

Calcium carbonate + hydrochloric acid → calcium chloride + carbon dioxide + water

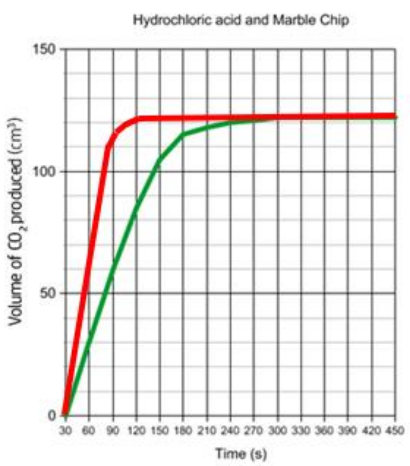
$CaCO_{3\,(s)} + 2HCl_{\,(aq)} \rightarrow CaCl_{2\,(aq)} + CO_{2\,(g)} + H_2O_{\,(l)}$



Method:
- Measure out 50cm^3 of hydrochloric acid
- Measure out 5g of marble chip
- Add the hydrochloric and marble chip to a conical flask and add the bung.
- Start the timer.
- Stop the timer when 50cm^3 of carbon dioxide gas has been produced.

Variables:
- Independent Variable: Concentration, surface area OR Temperature
- Dependent Variable: Time to produce 50cm^3 of gas
- Control Variable: Volume of acid/mass of marble chip

B. Rates and graphs:



Rate Graphs:
- If you **increase** the temperature / concentration / surface area, the reaction will be quicker, and the rate graph will be **steeper as shown in red on the left**
- If you **decrease** the temperature / concentration / surface area, the reaction will be slower, and the rate graph will be **shallower as shown in green on the left**
- Note that in both situations, the total volume at the end **is always the same – the flat bit should always be at the same level.**

Rate calculations:
- To calculate the rate of a reaction, take the volume of gas produced in cm^3 and divide it by the time (s).
- Unit: cm^3/s

C: What is needed for a reaction to occur?

For a reaction to occur, two things must happen:

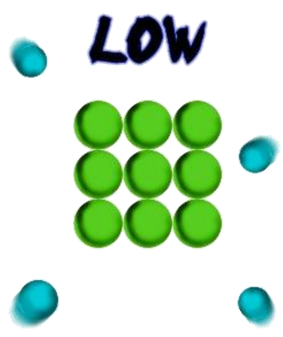
1. A collision between two reactants
2. The collision must have enough energy to break the bonds of the reactants (Called the activation energy)

D. Increasing the rate of reaction:

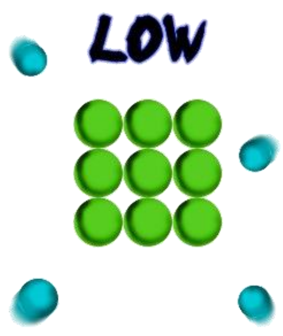
To make a reaction go faster, there are 5 things you can do:

1. Increase the **temperature**
2. Increase the **concentration**
3. Increase the **pressure**
4. Increase the **surface area**
5. Use a **catalyst**

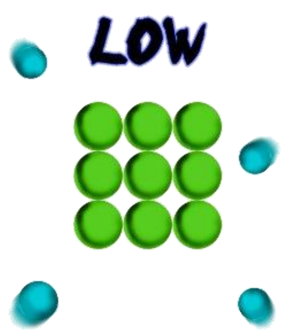
E. Collision Theory: Temperature

Low Temperature	Explanation:	High Temperature
	• If you increase the temperature, the particles have more **kinetic energy**, meaning they are moving faster and with more energy. • This means that when the particles **collide**, there is enough energy for a successful reaction to occur. • The **more successful collisions per second**, the faster the rate of reaction.	

F. Collision Theory: Concentration / Pressure

Low Concentration	Explanation:	High Concentration
	• If you increase the concentration, there are **more particles in the same volume**. This means there are **more frequent collisions** – increasing the rate of reaction. • If you increase the pressure, the particles are pushed closer together – this also means **more frequent collisions**.	

G. Collision Theory: Surface Area

Low Surface Area	Explanation:	High Surface Area
	• If you increase the surface area of a solid, you break it up into **smaller pieces**. This means that there is **a larger surface area to volume ratio** – more solid is exposed to the acid. • This will mean that the higher the surface area to volume ratios, there are **more frequent collisions** and a faster rate of reaction.	

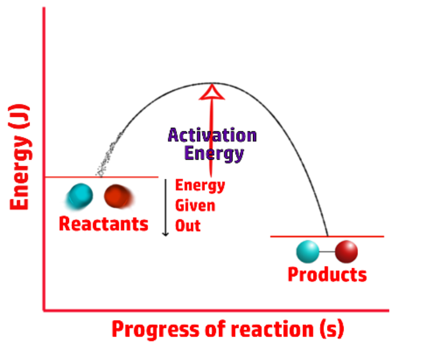
AfL 18: Energy in Reactions:

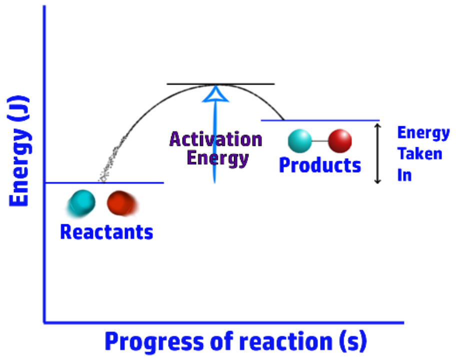
A. Exothermic and Endothermic:

The activation energy is the energy required to start a reaction. If there is not enough energy, a collision will not be successful.

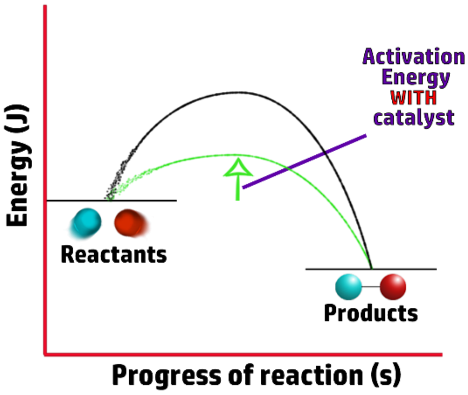
- To start a reaction there must be enough energy to make **collisions successful**.
- This can be drawn on Reaction Profiles, like the ones seen below.
- A reaction profile is a graph that shows the energy of the reactants and products, as well as the changes in energy.

Factor:	Reaction Profile:	Explanation

Exothermic:		- In an **exothermic** reaction, heat is given out to the surroundings.
		- This means that:
		  - The temperature **increases**.
		  - **Heat** energy is given **out**.
		  - The products have **less** energy than the reactants.
		- This is shown on the energy reaction profile on the left

Endothermic:		- In an **endothermic** reaction, heat is taken in from the surroundings.
		- This means that:
		  - The temperature **decreases**.
		  - **Heat** energy is taken **in**.
		  - The products have **more** energy than the reactants.
		- This is shown on the energy reaction profile on the left

B. Catalysts:

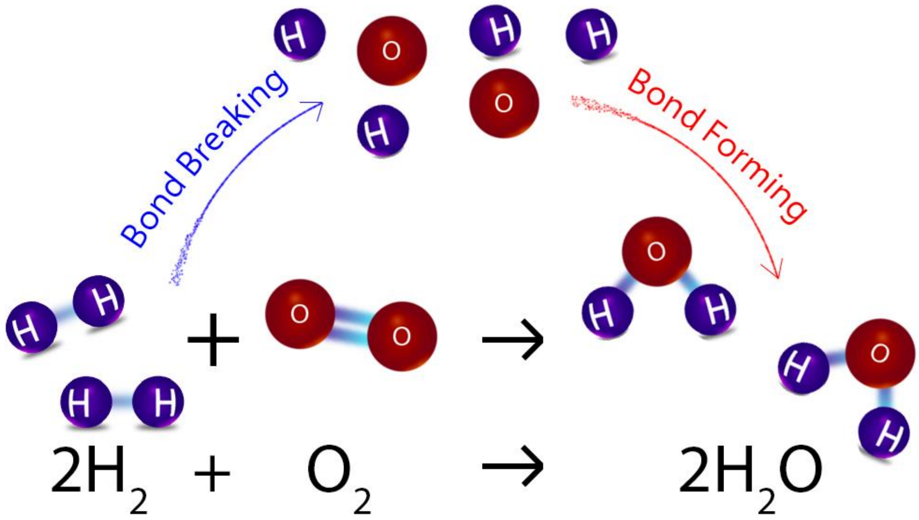


- Catalysts are chemicals that **speed up a chemical reaction** but **remain unchanged** at the end of the reaction.
- The mass will stay the same, and the chemical composition will also stay the same.
- This means that catalysts can be **reused**.
- Catalysts work by **lowering the activation energy** (by providing a different route for a reaction), so that **more collisions are successful**.
- **Catalytic converters** in car exhausts contain a **platinum** catalyst which converts harmful gases (nitrous oxides) into safer ones.

Enzymes:

- **Enzymes**, which are **biological catalysts**, are used to speed up reactions such as **alcoholic** drink production, **respiration**, **photosynthesis** and **protein synthesis**.
- Enzymes contain an **active site**, where the reactant molecule (the **substrate**) bonds in a *lock and key* type mechanism.
- Enzymes can be **denatured** if the pH or temperature changes.

C. Bond Breaking and Bond Forming:



There are two key things to remember that occur in **every chemical reaction**:

- Bond breaking is **endothermic** – you put **in** heat energy to break the bonds.
- Bond forming is **exothermic** – heat energy is given **out** to the surroundings.

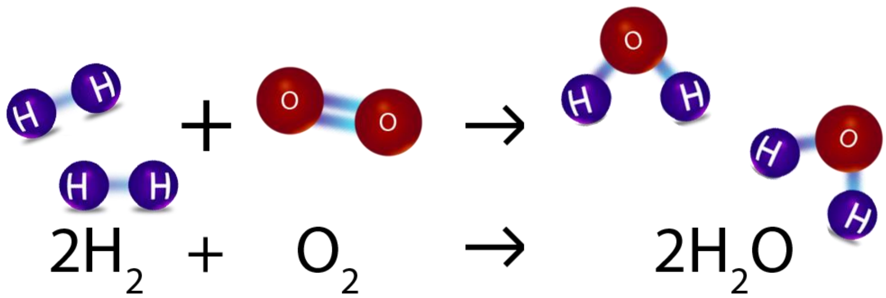
For a reaction to be **exothermic** over all, more energy must be given out (when bonds form) than taken in (when bonds are broken). This can be seen on the reaction profile on P8. The products have less energy because energy has been **given out** to the surroundings.

For a reaction to be **endothermic** over all, more energy must be **taken in** (when bonds are broken) than given out (when new bonds are formed). This can be seen on the endothermic reaction profile on P8. The products have more energy because energy has been **taken in** from the surroundings.

D. Bond Energy Calculations

You can calculate the energy given in/out in a reaction and use it to work out if a reaction is exothermic or endothermic:

To work out the bond energy, you will be given a table in the exam – this will show the energy needed to break a bond – in $kJmol^{-1}$.



Covalent bond:	Bond Energy ($kJmol^{-1}$)
H-H	436
O=O	498
O-H	464

In the above diagram, you are breaking two H-H bonds ($436kJmol^{-1}$) and one O=O bond ($498kJmol^{-1}$). Therefore, the total energy to break bonds is: 436 + 436 + 498 = $1370kJmol^{-1}$.

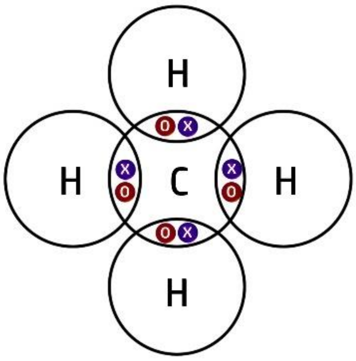
When new bonds are being formed – you are breaking two H-O bonds for every H_2O molecule, so the total energy given out forming new bonds is: 464 + 464 + 464 + 464 = $1856kJmol^{-1}$

- The total energy change is the energy to break bonds ($1370kJmol^{-1}$) minus the total energy given out ($1856kJmol^{-1}$)
- Total energy change = 1370 – 1856 = **$-486kJmol^{-1}$**.
- If the energy change is **negative**, it is **exothermic**. If **positive**, it is **endothermic**.

AfL 19: Fuels and Hydrocarbons:

A. Hydrocarbons:

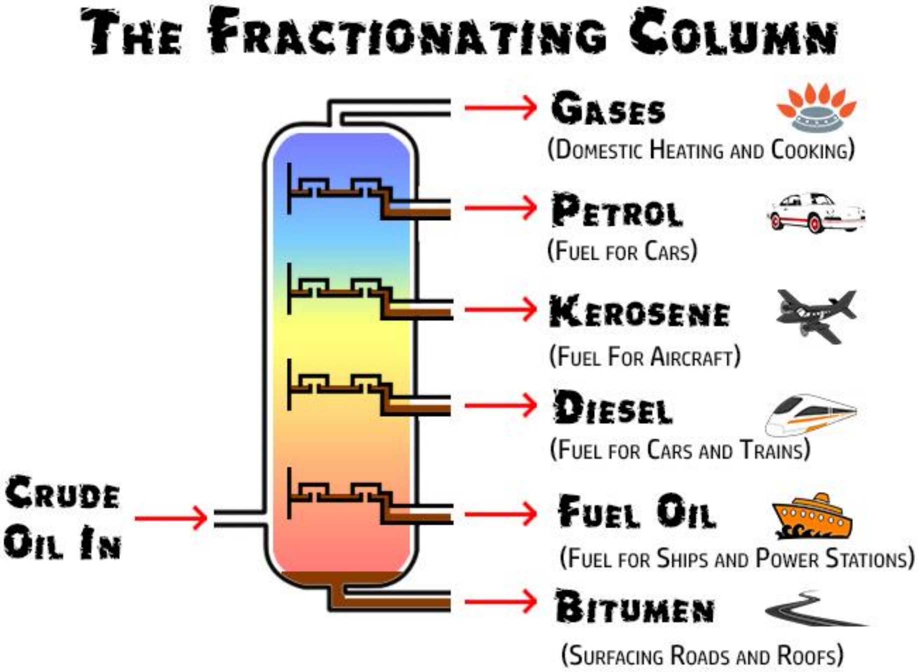
Crude oil is a mixture of hydrocarbons, formed from the remains of dead plants and animals over millions of years.



- A **hydrocarbon** is a compound containing hydrogen and carbon atoms **only**.
- Carbon atoms have a valence of 4, meaning they can make **4 covalent bonds.**
- This high valency leads to many hydrocarbons being formed, ranging from 1 carbon to hundreds of them.
- This can also lead to the hydrocarbons forming chains and rings.

B. What is Fractional Distillation?

- Crude oil contains many different fuels, with different uses. We cannot just put crude oil into our cars, for example – it needs to be separated into the different **fractions**.
- This is done using **fractional distillation** – which means separating into their fractions using their *boiling points*.



C. How Fractional Distillation Works:

- The crude oil is vapourised and added to the column
- The fractionating column is hottest at the bottom and coolest at the top.
- The vapours rise throughout the column until they fall **below** their boiling point – they then **condense**.
- The liquid falls into the tray and is collected.
- The rest of the hydrocarbons will move up the column, and the process continues until you are left with just the gases at the top.

D. Properties of the fractions of crude oil:

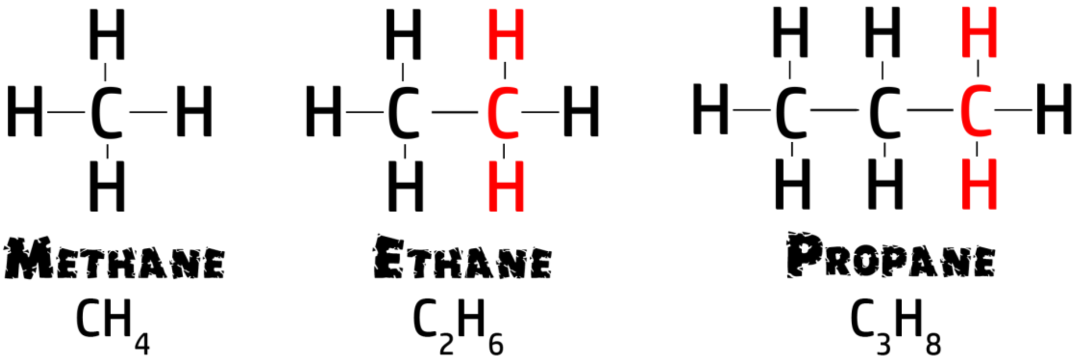
- The **gases** at the **top** of the column are the **easiest to ignite**, have the **lowest boiling points**, have the **smallest chain lengths** (less carbon atoms) and are the **least viscous** (flow more easily).
- The **bitumen** at the **bottom** of the column is the **hardest to ignite**, has the **highest boiling points**, has the **largest chain lengths** (more carbon atoms) and are the **most viscous** (thick and doesn't flow easily).

E. Homologous Series

A homologous series is any group of chemicals that have:

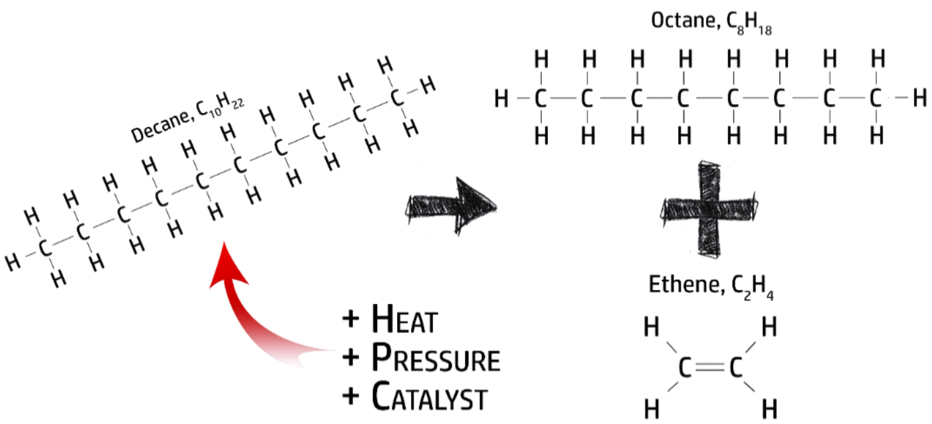
- **similar chemical properties**,
- a **gradual change** in **physical properties** (boiling points and melting points),
- the same **general formula**,
- and extra CH_2 in their molecular formulae each time a carbon is added.

For example: Alkanes:



- These are called homologues series because the general formula is C_nH_{2n+2}.
- For example, when n=2, the molecule is $C_2H_{(2x2)+2} = C_2H_6$.
- This formula works by adding in a Carbon and 2 Hydrogens (CH_2) each time.

F. Cracking



When a large-chained alkane is put under **heat and pressure** with a **catalyst**, they are broken down into short chained alkanes and alkenes.

In the above reaction, Decane, $C_{10}H_{22}$, is broken down into Octane, C_8H_{18}, and Ethene, C_2H_4:

$$C_{10}H_{22} \rightarrow C_8H_{18} + C_2H_4$$

You will notice that the amount of carbon and hydrogen atoms above are the same for both the reactants and products. This is called the **conservation of mass**.

The reason we need to do this is to meet the demand of the shorter chained alkanes and alkenes.

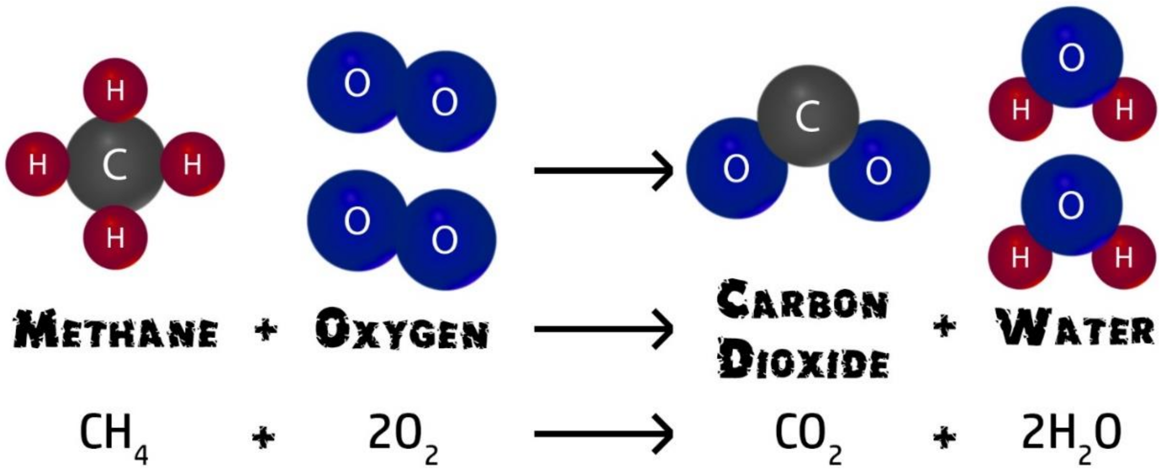
- In general, long chained alkanes - like bitumen - are available in large amounts and we don't need as much of them. **They have a larger supply than demand**.
- In general, short chained alkanes – like petrol – are in demand. **There is more demand than supply**, so we break down larger alkanes to meet the demand.
- Alkenes, such as ethene, are used to make **polymers** and are extremely useful.

AfL 20: Human Impact on the Earth:

A. Complete and incomplete Combustion

Combustion is the reaction of any fuel with oxygen to form heat and light energy. There are two types of combustion – **complete** and **incomplete** combustion.

1. Complete Combustion:



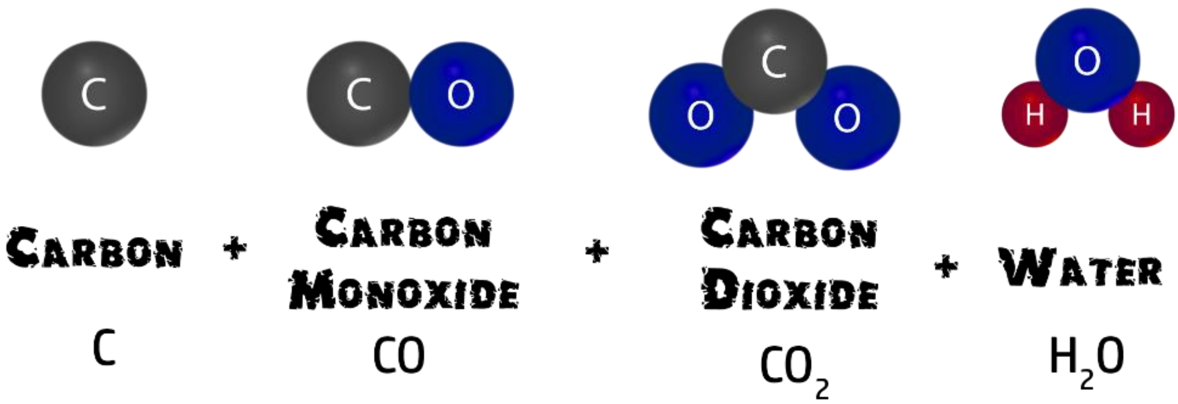
Complete combustion is where a fuel reacts with **lots of oxygen**, giving out **lots of energy** as well as producing *carbon dioxide* and *water*.

Writing balanced equations for this is easy – as long as you know the formula for the fuel (which will usually be given) – the rest of the equation is always the same. Then it just needs balancing!

Example: Propane, C_3H_8

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

2. Incomplete Combustion:



Incomplete combustion occurs when there is **not enough oxygen**. Water is still formed, but instead of just carbon dioxide, carbon monoxide and carbon (soot) are produced as well.

B. The Dangers of Incomplete Combustion

The problem with soot:

- Soot blocks pipes carrying away waste gases from a boiler.
- It blackens buildings.
- It can cause breathing problems if it collects in the lungs.

The problem with carbon monoxide:

- Carbon monoxide is a toxic gas – which means it is poisonous.
- It binds to the **haemoglobin** in the red blood cells, taking up space needed by the oxygen.
- This reduces the amount of oxygen reaching the cells and lowers the amount of **respiration** occurring.
- This makes people **sleepy** and can cause them to become **unconscious** – and can lead to **death**.

C. The Formation of Acid Rain

Rainwater is naturally acidic – the carbon dioxide in the atmosphere dissolves in the rain water and forms a very weak acid.

When **impurities** in fossil fuels – **sulfur** – are heated, they react with the oxygen to form sulfur dioxide:

$$S + O_2 \rightarrow SO_2$$

The sulfur dioxide gas then dissolves into the water in the clouds to form sulfurous acid, H_2SO_3, which then **oxidises** (reacts with oxygen) to form sulfuric acid, H_2SO_4 – Acid Rain!

Step 1: Water + sulfur dioxide → sulfurous acid

$$H_2O + SO_2 \rightarrow H_2SO_{3\,(aq)}$$

Step 2: Sulfurous acid + oxygen → sulfuric acid

$$2H_2SO_3 + O_2 \rightarrow 2H_2SO_{4\,(aq)}$$

D. The Effect of Acid Rain

Acid rain has the following effects:

- It makes the soil **acidic** – which stops some plants from growing.
- It **acidifies** the rivers and lakes – killing fish and insects and stopping eggs from hatching.
- It **weathers** statues made from sedimentary rock.
- It **corrodes** metallic structures.

E. Oxides of Nitrogen:

Car engines can get extremely hot. When this happens, they react with the nitrogen in air and produce nitrogen oxides – such as nitrogen oxide, NO, or nitrogen dioxide, NO_2.

- These gases are pollutants and can cause acid rain by forming nitric acid, HNO_3, when dissolved in the rain water.
- Nitrogen dioxide, a red/brown gas, is toxic and can cause respiratory diseases such as bronchitis.
- Catalytic converters can be used to convert this back into nitrogen – a harmless gas.

F. Hydrogen as a fuel:

Hydrogen can be used as a fuel, instead of fossil fuels.

- **Advantage:** It only produces water and a lot of energy: $2H_2 + O_2 \rightarrow 2H_2O$ – no CO_2!
- **Disadvantage:** The engine is expensive, and so is making the hydrogen gas. It is also hard to store.

AfL 21: The Earth's Sea and Atmosphere:

A. How did the Earth's Early Atmosphere form?

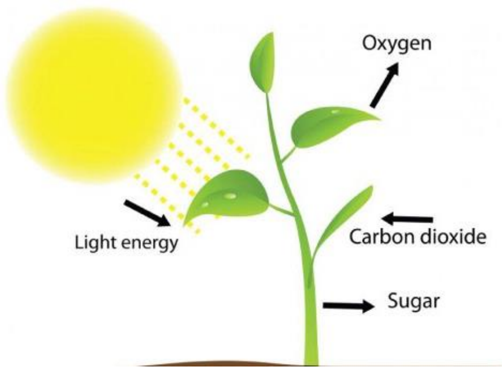
- Volcanoes produced the gases in the early atmosphere.
- We are sure of this because Venus has lots of volcanoes and an atmosphere full of carbon dioxide.
- The volcanoes give out carbon dioxide and water vapour (as well as small amounts of methane, nitrogen and ammonia)

B. What happened to the water vapour?

- Eventually, the Earth started to cool.
- When the Earth cooled, the water vapour **condensed** into a liquid – water.
- This liquid eventually formed the oceans.

C. How did Carbon Dioxide levels decrease?

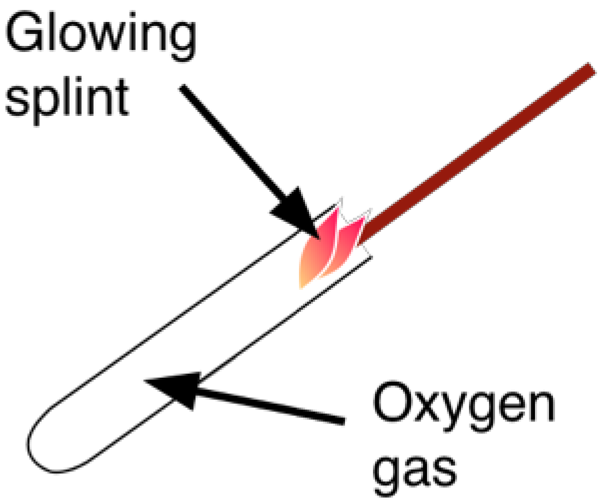
- There are three main ways that CO_2 levels decreased:
  1. The carbon dioxide started to **dissolve** into the newly formed oceans.
  2. The carbon dioxide in the oceans was absorbed by small creatures and ended up as **animal shells** or **sedimentary rock**.
  3. Once **primitive plants** formed, they absorbed carbon dioxide and produced oxygen in a process called **photosynthesis**.



- We know there was **no oxygen** in the Early Atmosphere because there is lots of **iron pyrite** in ancient rock – a chemical that only forms when there is **no oxygen**.

D. The test for oxygen:

- Simple! Oxygen **relights** a **glowing** splint!
- Take a splint, light it and then blow it out – make sure it is still **glowing**.
- Put the glowing splint into your oxygen and, if oxygen is present, the splint will **relight**!
- Why? The oxygen accelerates combustion, so even the tiniest bit of energy can set the splint on fire again!

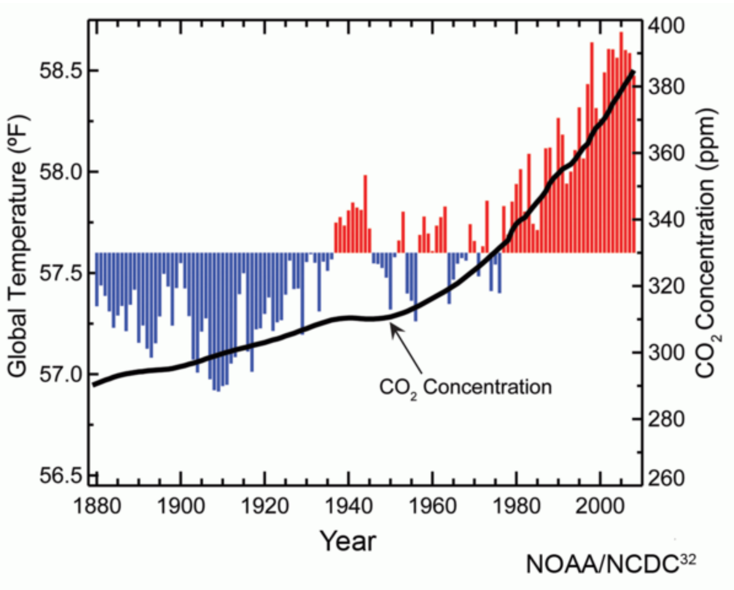


E. Today's Atmosphere

- When the sun emits heat and light rays, some is absorbed by the Earth's surface, warming it up.
- The Earth will then emit heat rays which travel through the atmosphere.
- The more greenhouse gases there are, the more heat gets trapped in the atmosphere.
- This helps to keep the Earth warm, but as carbon dioxide levels continue to increase, this can lead to global warming.

F. The link between carbon dioxide and climate change:

- Since 1850 there has been an increase in fossil fuel usage (from the industrial revolution).
- This increase in carbon dioxide in the atmosphere has happened at the same time as the increase in temperature of the Earth.
- There is a **strong correlation** between increasing CO_2 levels and increasing temperature levels.
- Correlation does not mean a **causal link**.
- Scientists must collect data and use it to explain the evidence for there to be a causal link (where one thing **causes** another).



G. The effects of climate change:

- We add greenhouse gases to the atmosphere in the following ways:
  - **Drilling for oil**: When we drill for oil, it can release stores of methane – a powerful greenhouse gas.
  - **Farming**: Cows have bacteria in their gut to digest grass. This also produces methane.
  - **Combustion**: Burning fossil fuels produces lots of carbon dioxide and water vapour.
  - **Deforestation**: Cutting down trees reduces the amount of photosynthesis, meaning carbon dioxide levels increase
- The increase of carbon dioxide levels results in:
  - **The ice caps melting**: This means animals cannot survive and either must migrate or become extinct.
  - **Sea levels rising**: Increased flooding
  - **Extreme weather**: Heavy rainfall, powerful storms, droughts, heat waves, etc...

AfL 25: Testing for Ions:

A. Testing for Cations:

Test one: Flame tests

Get a **clean** wire loop and add some of your sample to it. Add it to the flame and note the colour. Different metals have different coloured flames.

Metal	Cation	Flame colour:
Lithium	Li^{+}	Red
Sodium	Na^{+}	Yellow
Potassium	K^{+}	Lilac
Calcium	Ca^{2+}	Orange-Red
Copper(II)	Cu^{2+}	Blue/Green

Test two: Sodium Hydroxide

Precipitation reactions involving sodium hydroxide often form coloured hydroxide precipitates. Simply add some sodium hydroxide to an unknown precipitate

Metal	Cation	Flame colour:
Iron (II)	Fe^{2+}	Green
Iron (III)	Fe^{3+}	Brown
Copper(II)	Cu^{2+}	Blue
Calcium	Ca^{2+}	White*
Aluminium	Al^{3+}	White*
Ammonium	NH_4^{+}	Colourless Gas*

B. Confirmatory Tests:

*Both aluminium and calcium give a white precipitate, meaning you can't prove which is which. To do that, add **excess** sodium hydroxide. If the precipitate **dissolves**, aluminium is present. If it doesn't dissolve, it is calcium.

*When sodium hydroxide is added to a solution containing ammonium ions, and **heated**, a gas (ammonia) is given off with a sharp smell. A **confirmatory** test for ammonium is to add damp red litmus paper – it will go blue in the presence of ammonia.

C. Testing for Anions:

There are 5 anions you need to know the test for:

Anion		Test:	Positive Result:
Carbonate, CO_3^{2-}		Add dilute HCl. Any gas should be bubbled through limewater.	Limewater goes cloudy.
Sulfate, SO_4^{2-}		Add dilute HCl*. Add a few drops of barium chloride. A precipitate of barium sulfate will form.	White precipitate
Halides:	Chloride, Cl^-	Add dilute HNO_3*. Add a few drops of silver nitrate. If a halide is present (except fluoride which is soluble), a precipitate will form.	White
	Bromide, Br^-		Cream
	Iodide, I^-		Yellow

* Adding an acid to the halide/sulfate ensures that there are no carbonate ions in the solution.

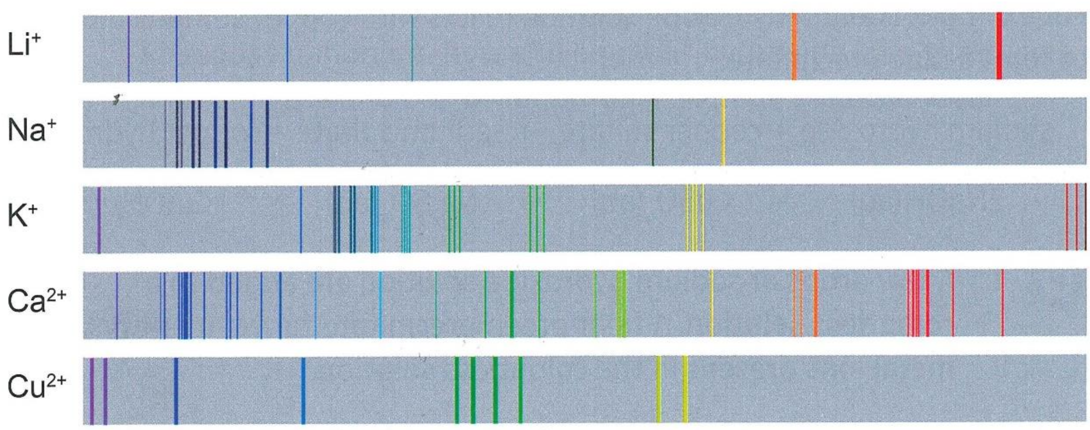
D. Flame Photometry:

It is better to use machines, such as flame photometry, instead of flame tests because:

- They are more sensitive. (They can detect much smaller amounts)
- They are more accurate. (They give values closer to the true values)
- They give results faster.

Flame photometers measure light intensity of flame colours and determines the concentration of a metal ion in solution.

This then produces an **emission spectra**, such as the ones below:



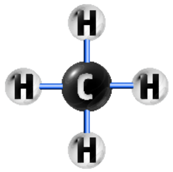
These are much more **accurate** than using our eyes.

AfL 26: Alkanes, Alkenes and Alcohols

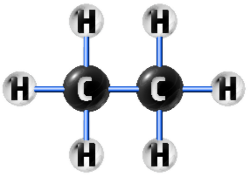
Alkanes & alkenes are examples of hydrocarbons – compounds made up of hydrogen & carbon only.

A. Alkanes:

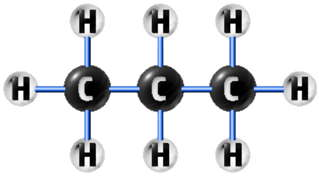
Alkanes have the general formula of C_nH_{2n+2}. They are **saturated** hydrocarbons – meaning all the carbon-carbon bonds are **single** bonds.



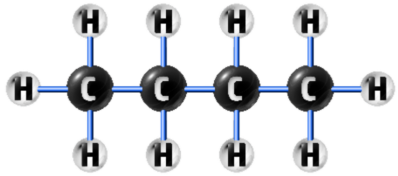
CH_4
Methane



C_2H_6
Ethane



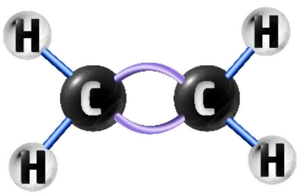
C_3H_8
Propane



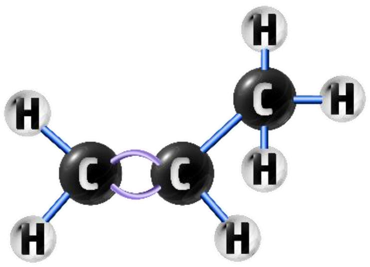
C_4H_{10}
Butane

B. Alkenes:

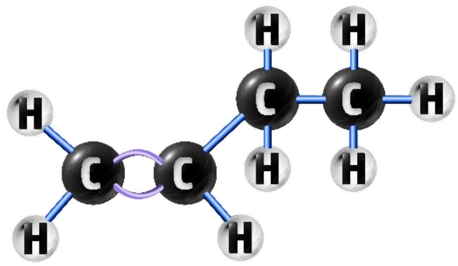
Alkenes have the general formula of C_nH_{2n}. They are **unsaturated** hydrocarbons – meaning they contain at least one **double** bond. The double bond is their **functional group**.



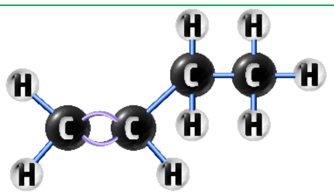
C_2H_4
Ethene



C_3H_6
Propene



C_4H_8
Butene

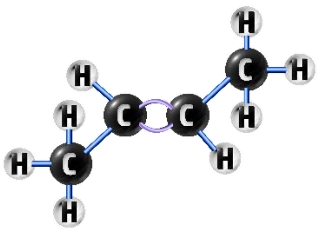


But-1-ene
C_4H_8

Alkenes can have **isomers** – which is a chemical with the same molecular formula, but different structure.

For example, butane can have two isomers – but-1-ene and but-2-ene.

In but-2-ene, the carbon is attached to the **second** carbon



But-2-ene
C_4H_8

C. Combustion of alkanes and alkenes:

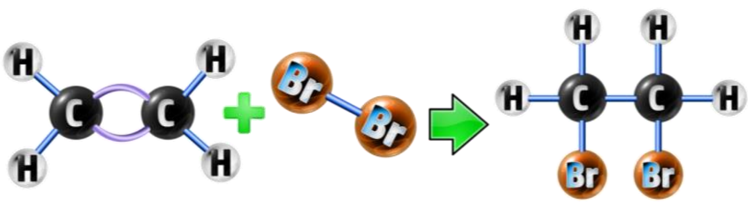
Alkanes and alkenes both react the same as any fuel – producing carbon dioxide and water vapour in complete combustion, as well as carbon monoxide and soot in incomplete combustion.

$$C_2H_4 + 2O_2 \rightarrow 2CO_2 + 2H_2O$$

D. The test for alkanes and alkenes

To find out if you have an alkane or an alkene, add **orange** bromine water. In an **alkene**, the bromine water will change from **orange** to colourless. In an alkane, it will stay **orange**.

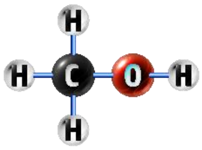
When added to an alkene, an **addition** reaction occurs. The double bond is broken, and the bromine reacts with the alkene to form a bromo-alkane.



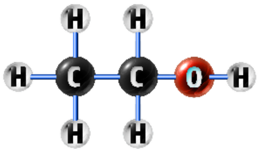
Ethene + bromine → 1,2-dibromoethane
$C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$

D. Alcohols:

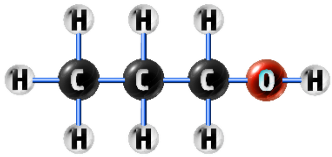
Alcohols have the general formula of $C_nH_{2n+1}OH$. They have the -OH functional group:



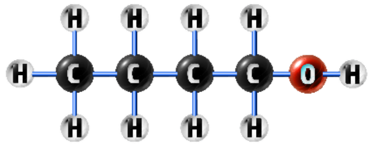
CH_3OH
Methanol



C_2H_5OH
Ethanol



C_3H_7OH
Propanol



C_4H_9OH
Butanol

All alcohols have similar chemical properties. During complete combustion, they produce carbon dioxide and water vapour:

Ethanol + oxygen → carbon dioxide + water

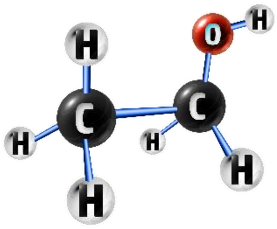
$$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$$

They also all oxidise to form carboxylic acids and react with metals, such as sodium:

Sodium + ethanol → Sodium ethoxide + hydrogen

$$2Na + 2C_2H_5OH \rightarrow 2C_2H_5ONa + H_2$$

E. Ethanol Production:



Alcohol is used as a solvent in cosmetics, as well as for medicinal drugs and varnishes. Ethanol is also used as a fuel and in alcoholic drinks.

Ethanol is produced from sugars, usually from fruits. This sugar undergoes fermentation, where yeast is added and the enzymes in yeast break down the glucose into carbon dioxide and ethanol:

Glucose → ethanol + carbon dioxide

Fermentation uses **anaerobic respiration**, so the volume of oxygen must be controlled. It also only produces about 15% ethanol, because the higher concentrations kill the yeast.

To produce high concentrations, distillation is then used to evaporate and collect the ethanol (which evaporates at 78°C), leaving behind the water which doesn't boil until you reach 100°C.

F. Investigating the combustion of different alcohols.

1. Measure the mass of an alcohol burner and cap.
2. Add 100cm^3 of cold water to a conical flask and record the temperature.
3. Light the wick and heat the water, increasing the temperature by 40°C.
4. Replace the cap, re-measure the mass and work out the change in mass.
5. Calculate the amount of alcohol need to raise the temperature by 1°C:

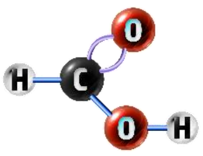
    = Change in mass / change in temperature
6. Repeat for different alcohols.

Conclusion: The shorter the chain length, the more energy produced per gram used.

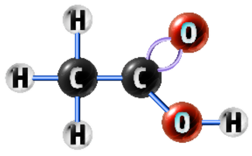
AfL 27: Carboxylic Acids and Polymerisation

A. Carboxylic Acids:

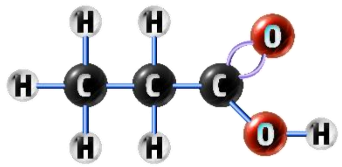
Carboxylic acids have the general formula of **$C_nH_{2n+1}COOH$**. They have the -COOH functional group.



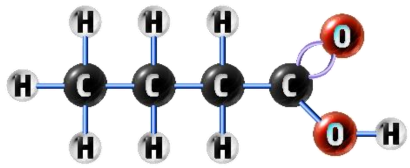
$HCOOH$
Methanoic acid



CH_3COOH
Ethanoic acid

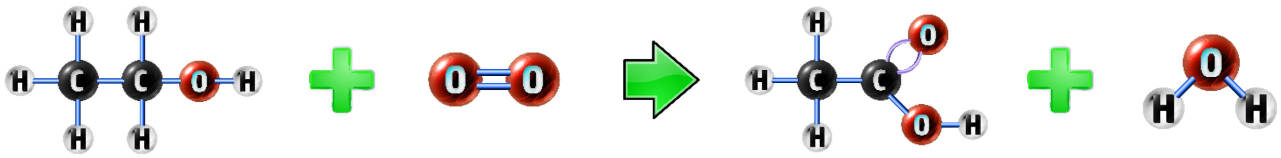


C_2H_5COOH
Propanoic acid



C_3H_7COOH
Butanoic acid

Carboxylic acids form when alcohols react with oxygen in the air:



Ethanol C_2H_5OH + Oxygen O_2 → Ethanoic acid CH_3COOH + Water H_2O

B. Reactions of Carboxylic Acids:

Carboxylic acids all react the same ways as normal acids:

- They all form solutions with a pH less than 7.
- They all react with metals to produce a salt and hydrogen

Ethanoic acid + sodium → sodium ethanoate + hydrogen
$2CH_3COOH + 2Na \rightarrow 2NaCH_3COO + H_2$

- They all react with bases to form a base and water

Ethanoic acid + Magnesium hydroxide → sodium ethanoate + water
$2CH_3COOH + Mg(OH)_2 \rightarrow Mg(CH_3COO)_2 + 2H_2O$

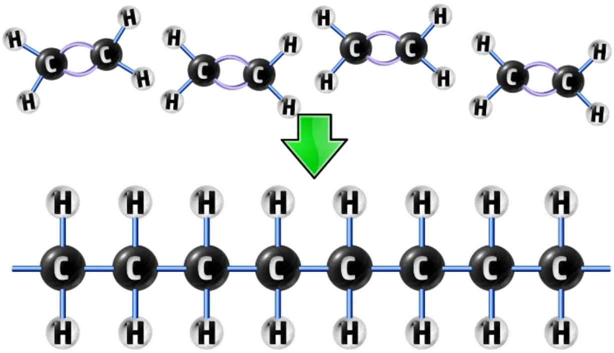
- They all react with carbonate to form a salt, water and carbon dioxide.

Ethanoic acid + calcium carbonate → calcium ethanoate + water + carbon dioxide
$2CH_3COOH + CaCO_3 \rightarrow Ca(CH_3COO)_2 + H_2O + CO_2$

C. Uses of Polymers

Polymer:	Common Name:	Use	Explanation
Poly(ethene) $[C_2H_4]_n$	Polythene	Plastic bags, bottles, clingfilm	Flexible, cheap, good insulator
Poly(propene) $[C_3H_6]_n$	Polypropylene	Buckets, crates, bowls, ropes, carpets	Flexible, does not shatter
Poly(chloroethene) $[C_2H_3Cl]_n$	PVC	Window frames, gutters, pipes	Tough, good insulator for electric wires
Poly(tetrafluoroethene) $[C_2F_4]_n$	Teflon	Non-stick coating for frying pans	Tough, slippery
Poly(ethylene terephthalate)	PET	Plastic furniture, carpets, fleece	Strong, lightweight, shatter resistant.

D. Addition Polymerisation:

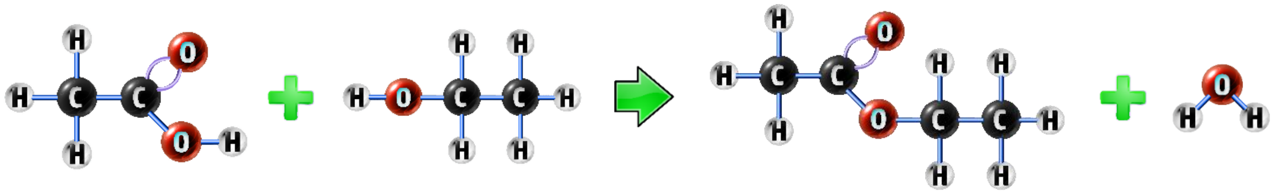


Addition polymerisation is where many monomers are joined to make a large-chained molecule called a polymer.
During polymerisation, one of the **double bonds** between the carbons is broken and joined to another monomer.

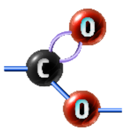
E. Condensation Polymerisation:

PET is an example of a condensation polymer. Condensation polymerisation involves two monomers joining and eliminating water.

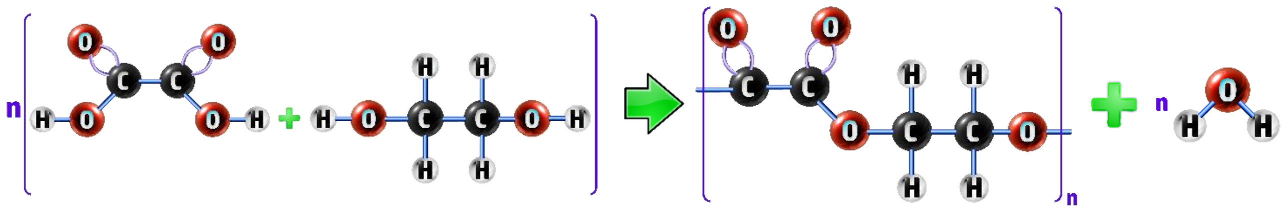
An example of a condensation reaction is the formation of Esters – which have the functional group -COO-:



Ethanoic acid CH_3COOH + Ethanol C_2H_5OH → Ethyl Ethanoate $CH_3COOC_2H_5$ + Water H_2O



A polyester is a long-chained molecule that contains many ester links (see left).
To form a polyester, both carboxylic acid and alcohol need to have the same functional group at either side of the molecule:



Two carboxylic acid groups + Two alcohol groups → Repeating unit of a polyester + Water H_2O

F. The Problems with Polymers:

Polymers are non-biodegradable which means it will take 1000's of years for them to decompose.
There are three ways of disposing of polymers:

Method:	Advantages:	Disadvantages:
Burying in Landfills	✻ Quick to dispose of.	✻ Landfills fill up ✻ Non-biodegradable so won't decompose.
Burning	✻ Quick to dispose of.	✻ Burning produces carbon dioxide – which is a greenhouse gas. ✻ Some plastics produce toxic gases.
Recycling	✻ We don't run out of our oil which is a finite resource. ✻ Codes can be used to help to sort the plastics more easily.	✻ It takes time & money to sort the plastics into groups. ✻ Some plastics cannot be recycled and end up in landfills. ✻ The polymers then need cleaning, chipping and melting to form the new product.

AfL 28: Nanoparticles and Choosing Materials

A. Ceramics and Glass:

Ceramics are hard non-metal compounds (giant covalent) that are unaffected by heat. Examples include glass and china.

Physical Properties:

- Chemically Unreactive
- Hard/stiff
- Brittle (Easily smashed)
- Poor conductors of heat/electricity

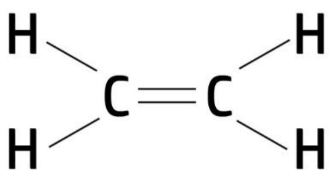
Glass:	**Clay ceramics:**
	
Glass is made by melting sand and allowing it to cool/solidify. They don't form a regular patter and don't form crystals, making them **transparent**.	Clay ceramics are made by clay being heated to high temperatures, forming crystals. This makes them **opaque**.

B. Polymers and Metals:

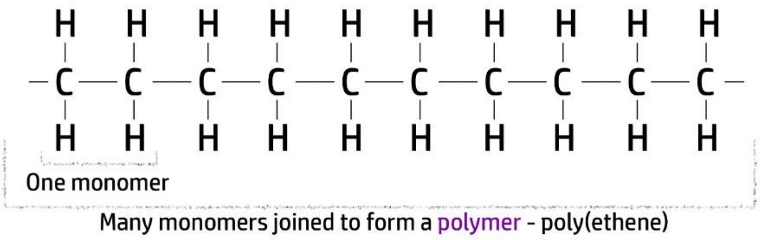
Polymers and metals can be adapted for different uses.

A **polymer** - a **long chain** of smaller molecules called **monomers** – can be changed using plasticisers.

For example, Polyvinylchloride (**PVC**) is an example of a polymer. It can be made into rigid PVC -using **plasticisers** - which is useful in underground pipes and window frames, and flexible PVC, which is used in indoor pipes and waterproof flooring.



Monomer: Ethene



Polymer: Poly(ethene)

Most metals are **malleable** – can be hammered into shape – and sometimes need to be strengthened. To do this, we can turn them into **alloys** – which are stronger.

C. Composite Materials:

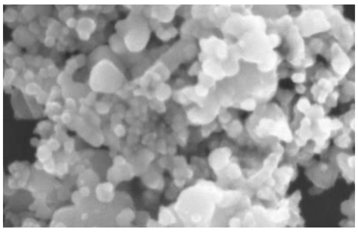
Composite materials are mixtures of more than one material, combined together to give it different properties.

Most composites have a reinforcement part and a matrix part.

- **Reinforcement**: The substance bound together by the matrix.
- **Matrix**: The substance that binds the reinforcement material together

	Manufacture:	Reinforcement:	Matrix:	Combined Properties:
Concrete	Sand, Cement, Aggregate and water are mixed. When it sets, chemical reactions occur and bond the components together	**Sand and aggregate**	**Cement**	Strong Good insulator
Fibreglass	Thin glass fibres and a polymer resin are reacted together	**Glass fibres** (brittle, low density and high tensile strength)	**Polymer Resin** (hardwearing but not strong)	Lightweight Strong Tough
Reinforced Steel	Concrete can be compressed, but when used in beams it can crack. Steel is used to reinforce the concrete.	**Steel** (High tensile strength and compressive strength)	**Concrete** (Dense, strong, and cheap)	Strong in tension and in compression Cheaper than just steel
Laminates	Wood is stronger along the grain than across it. Laminates consist of layers of wood at right angles to each other.	**Cellulose fibres**	**Lignin Polymer**	High tensile strength

D. Nanoparticles:


Titanium dioxide nanoparticles

Nanoparticles contain a few hundred atoms and are 1-100nm in diameter. They are smaller than cells.

Nanoparticles have a large surface area to volume ratio – which means that more surfaces are 'exposed'.

To calculate the surface area to volume ratio, you need to calculate the surface area and the volume:

- **Surface area** = number of sides x height of side x width of side
- **Volume** = height of side x width of side x depth of side
- **Surface area to volume ratio** = surface area / volume

Use:	Explanation:	Risks:
Sunscreen	It absorbs harmful ultraviolet rays which cause skin cancer. It is transparent because the particles are very small, so doesn't leave white marks.	We don't know the risks of nanoparticles because they are a new technology. Concerns are: The small size allows them to be breathed in / absorbed into cell membranes. The large surface area to volume ratio may allow them to catalyse harmful reactions.
Detergents	Large surface area-to-volume ratio makes them good for catalysts. The nanoparticles catalyse the breakdown of dirt, keeping clothes clean.	