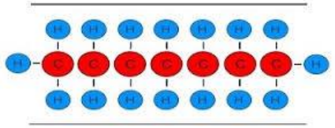
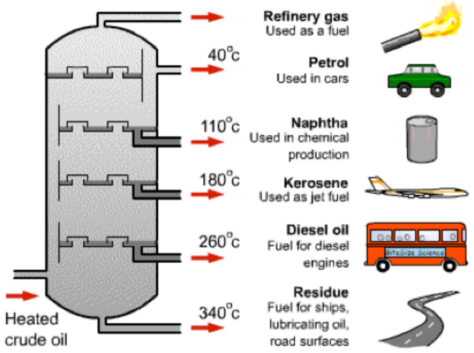
Organic Chemistry

Crude oil and hydrocarbons

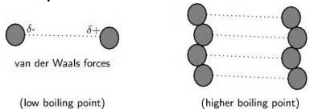
Crude oil is a naturally occurring product that we use to produce products such as petrol, solvents and detergents. It is a **mixture** of long chain molecules made up of **hydrogen** and **carbon** only. The chains are called **hydrocarbons**. The use of a hydrocarbon is determined by the number of carbons in its chain as its properties depend on how long it is.



The different chain length molecules can separated using **fractional distillation**. The crude oil mixture enters a tall column and is heated to a high temperature so that most of the molecules are **vaporised** (turned into a gas). The column is cooler at the top than it is at the bottom. As the gaseous molecules rise up the column they **condense** (turn back into a liquid) when they reach their boiling point. They are then collected and removed. The separated samples are called **fractions**.



Smaller molecules travel further up the column because they have fewer intermolecular forces between their chains. This means that they have lower boiling points and so they condense at lower temperatures and so remain a gas at lower temperatures.



These intermolecular forces also explain why viscosity increases as the chain length gets longer while flammability increases as the chain length gets shorter.

The flammability of the small hydrocarbons means that they are, generally, more useful to us as we use them for fuels. The very long chain hydrocarbons remain as a liquid at the bottom of the column. These are not very useful other than as things such as bitumen, used for road surfacing.

Alkanes

All of the hydrocarbons that we find in crude oil have single carbon-carbon bonds in their chains. We say that they are saturated (they are bonded to as many other atoms as possible) and they belong to a **homologous series** called **alkanes**.

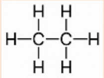
Alkanes have the general formula:

$$C_nH_{2n+2}$$

When we name alkanes the name always ends '-ane' and the start of the name is determined by the number of carbons in the chin as follows:

Number of C in chain	Start of name	Full name
1	Meth-	Methane
2	Eth-	Ethane
3	Prop-	Propane
4	But-	Butane

Worked example:
Name this hydrocarbon



2 carbons: Eth-
All single bonds: -ane
All together: **Ethane**

Combustion of alkanes

In a plentiful supply of oxygen hydrocarbons will burn completely to produce carbon dioxide and water. We can work out how much carbon dioxide and water will be produced by writing the balanced symbol equation. Energy is also

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$
methane + oxygen → carbon dioxide + water

$$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$$
ethane + oxygen → carbon dioxide + water

Incomplete combustion will produce solid carbon (soot), carbon monoxide and unburnt hydrocarbon.

Cracking

Although it is the smaller hydrocarbons that are most useful to us, and so most in demand, a large amount of longer chain hydrocarbons are also separated and collected from fractional distillation. In order to make these into more useful products the chains can be broken into two short chains in a process called cracking. This is an example of **thermal decomposition** (breaking down with heat).

There are two methods that can be used to crack hydrocarbons;
Catalytic cracking: the alkane is brought into contact with a powdered aluminium oxide catalyst at moderate pressure and a temperature of around 500°C.
Steam cracking: the hydrocarbon is mixed with steam and heated to a very high temperature (approximately 850°C).

Both cracking processes result in the formation of two products; an **alkane** and an **alkene**.

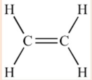
Alkenes

Alkenes are produced as one of the products of cracking. They are also hydrocarbons, but this **homologous** series has the general formula:

$$C_nH_{2n}$$

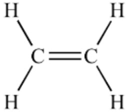
Alkenes are named in a similar way to alkanes. The first part of their name comes from the number of carbons in the chain, but all alkenes have names that end '-ene'.

Worked example:
Name this hydrocarbon



2 carbons: Eth-
Double bonds: -ene
All together: **Ethene**

The formula tells us that alkenes have less hydrogen atoms per carbon than alkanes and so they are **unsaturated** molecules, they contain a carbon – carbon double bond.



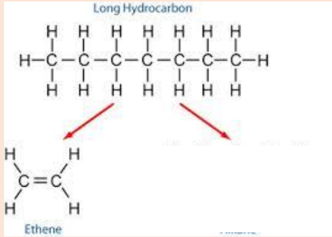
This double bond means that alkenes are more reactive than alkanes.

Although it is the shorter chain alkane that is the desired product of cracking, alkenes are also useful to us. Alkenes can be used as monomers in polymerisation reactions to produce some of the plastics that we use in our everyday lives.

The Products of Cracking

The sum of the carbon and hydrogen atoms in the two products of the cracking process must be the same as the number of atoms that you started with. This means that if we know how what we started with and how many carbons are in one product we can work out what the other product is.

Worked example:



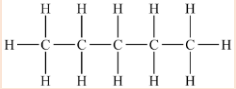
The original molecules contains 7 x C and 16 x H

The alkene produced contains 2 x C and 4 x H. What is the alkane produced?

Simply subtract the number of each atom in the known product from that in the original molecule.

Number of carbon = 7 – 2 = 5
Number of hydrogen = 16 – 4 = 12

Molecular formula: C_5H_{12}
Name: Pentane
Displayed formula:



Testing for Alkenes

If you are unsure if a product is an alkane or an alkene it may be necessary to test a sample. **Bromine water** (a brown/orange solution) is added to the sample of hydrocarbon and then shaken.

If the sample being tested is an alkane there will be no change in the bromine water, it will remain an orange/brown colour. But if it is an alkene then the bromine water will be **decolourised**. This means that the colour will be taken out of the bromine water and it becomes a **colourless** solution.

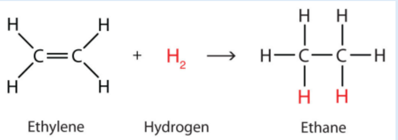
This test works because of the more reactive nature of the alkene due to its double bond. The bromine atoms in the bromine water will add to the carbon atoms on either side of the carbon-carbon double bond in an alkene to produce a saturated molecule.

Chemistry Only

Reactions of Alkenes

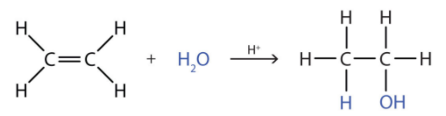
All alkene reactions are addition reactions, resulting in the opening of the carbon-carbon double bond to form a single bond and two new bonds. We have already looked at the addition of bromine across the double bond. Two other common reaction of alkenes are with hydrogen and water.

Hydrogen adds across the double bond to simple form the alkane with the same number of carbon atoms.



This reaction will only happen at 300°C and with the use of a nickel catalyst.

Water can be added across the double bond by reacting an alkene with steam in the presence of a hot phosphoric acid catalyst. This produces an **alcohol** by adding a H to one side of the double bond and an OH to the other side (from H_2O).



Alcohols

A molecule that contains the functional group **–OH** is called an alcohol. Alcohols are a homologous series and there are rules that we can use to name them. The first part of the name comes from the number of carbon atoms in the chain (as with alkanes). Alcohols have the ending **–anol** to their name.

Number of C in chain	Start of name	Full name
1	Meth-	Methanol
2	Eth-	Ethanol
3	Prop-	Propanol
4	But-	Butanol

Alcohols are most commonly known for their use in alcoholic drinks, but they can also be used as fuels.

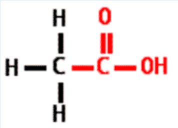
Most ethanol (the alcohol found in drinks) is made by the process of fermentation. This uses sugars from plants and yeast enzymes as a catalyst for the reaction. Because biological catalysts are used the temperature for the reaction must be between 25°C and 40°C so that the enzymes are active, but not denatured.

$C_6H_{12}O_6 \rightarrow 2\ CH_3CH_2OH + 2\ CO_2$

glucose ethanol carbon dioxide

Carboxylic Acids

Alcohols can react with oxidising agents to form members of another homologous series, carboxylic acids. This simply means that more oxygen is added to the molecule. Carboxylic acids have the functional group **– COOH**.



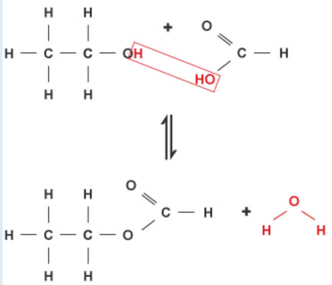
To name carboxylic acids we use the same principles as for the other homologous series. The start of the name comes from the number of carbons in the chain but this time we add the ending **–anoic acid**.

Carboxylic acids are acidic because when they dissolve in water they can separate (**dissociate** or **ionise**) to produce two ions. It is the H+ ions that are responsible for making a solution acidic.

Carboxylic acids are weak acids because only a few of the molecules will dissociate, so there will only be a small number of H+ ions present in the solution.

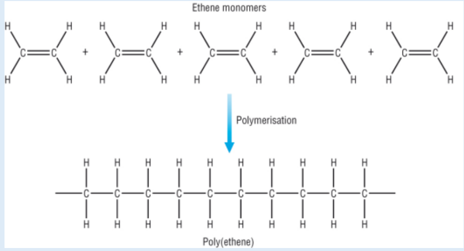
If an alcohol and carboxylic acid are reacted together they produce a molecule called and **ester**. Esters have a bridging –O – bond between the alcohol chain carbons and the carboxylic acid chain carbons. Water is also produced and so this is called a condensation reaction.

Esters are fragrant molecules and are used in perfumes. Every ester has a different smell.

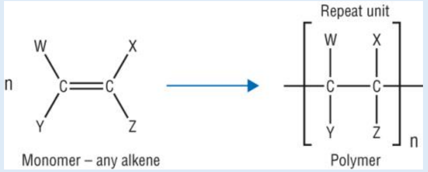


Addition Polymerisation

When small molecules, such as alkenes, react together to form long chain molecules we call these long chain **polymers**. The small molecule, called the **monomer**, is a repeating unit in the polymer. Alkenes are able to join together in a process called addition polymerisation because they can open up their double bonds and join (or add) together to form a chain. The polymer produced is simply named by adding the prefix **'Poly-'** before the name of the alkene.



It would be impractical to have to write out millions of carbon atoms every time we wanted to draw a polymer, so we simplify it by drawing the repeating unit in square brackets. The small 'n' shown outside the brackets simply means 'many'.

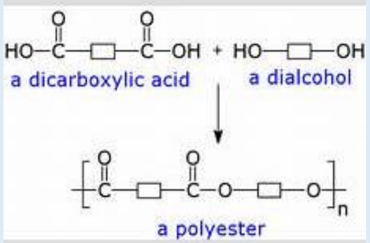


These reactions are used in the production some common plastics such as poly(ethene), plastic bags etc, and poly(propene), plastic furniture, washing up bowls etc.

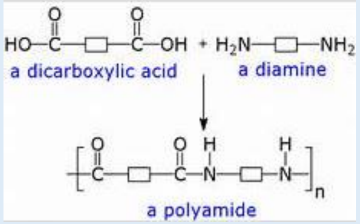
Condensation Polymerisation

When some monomers are joined together to form polymers a second product is also made. This product is water and hence the name 'condensation polymerisation'. These reactions usually involve two different monomer units joining together in a repeating patter. The two monomers need to have different functional groups .

If an alcohol and a carboxylic acid react together we produce an ester. If this reaction happens multiple times to produce a polymer chain, we call the polymer a **polyester** because it has many ester linkages..



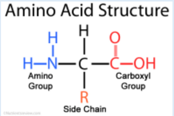
If the monomers are an amine and a carboxylic acid the we call the product a polyamide, because it has many amide linkages. Nylon-6,6 is an example of a polyamide.



Condensation polymerisation is used to produce may of the everyday products that we rely on including fabrics, paints and some plastics.

Naturally Occurring Polymers

Amino acids are naturally occurring molecules that contain two functional groups. They have an amine group at one end of the molecule and a carboxylic acid group at the other.



This means that they can undergo condensation reactions with themselves. Amino acids are considered the building blocks of life because these reactions produce polypeptides, which join together to make proteins in all plants and animals.

DNA

DNA molecules are two polymer chains twisted together into a double helix. Each polymer chain is made up of nucleotides which are made up of a base, a sugar and a phosphate group. There are four bases and the interaction between the bases on each polymer strand holds the two DNA strands together and forms the double helix. These four bases can only interact with others in pairs. Adenine (A) always pairs with thymine (T) and Cytosine (C) always pairs with Guanine (G).