4.7 Organic Chemistry

Crude oil

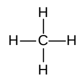
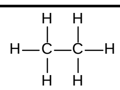
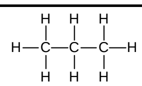
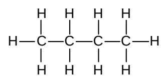
Crude oil is a finite resource found in rocks. Crude oil is the remains of an ancient biomass consisting mainly of plankton that was buried in mud.

Crude oil is a **mixture** of a very large number of compounds. Most of the compounds in crude oil are **hydrocarbons**, which are molecules made up of **hydrogen** and **carbon** atoms **only**.

Alkanes

Most of the hydrocarbons in crude oil are hydrocarbons called alkanes. Alkanes **only** contain **single** covalent bonds and are classed as **saturated** hydrocarbons

The general formula for the homologous series of alkanes is **C_nH_{2n+2}**

Name of Alkane	n (number of carbons)	Molecular formula	Displayed Formula
Methane	1	CH_4	
Ethane	2	C_2H_6	
Propane	3	C_3H_8	
butane	4	C_4H_{10}	

Physical properties of hydrocarbons
Some properties of hydrocarbons depend on the size of their molecules. These properties influence how hydrocarbons are used as fuels.
- **Boiling points** and **viscosity** of hydrocarbons **increase** as the molecules get bigger (because the intermolecular forces become larger as the molecules become bigger)
- **Volatility** (how easily a liquid vaporises) and **Flammability** of the fuels **decrease** as the molecules get bigger.

Combustion of Hydrocarbons
The combustion of hydrocarbon fuels releases energy. During combustion, the carbon and hydrogen in the fuels are **oxidised**.

The **complete** combustion of a hydrocarbon produces carbon dioxide and water. (needs a plentiful supply of air)

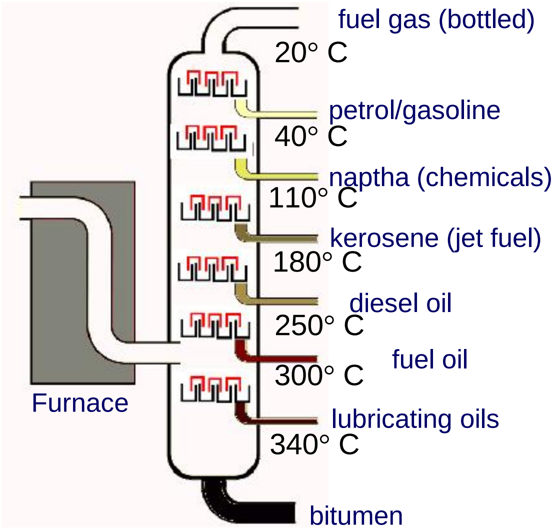
hydrocarbon + oxygen → carbon dioxide + water
e.g. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

Fractional distillation of crude oil - how it works
The many hydrocarbons in crude oil may be separated into fractions, each of which contains molecules with a similar number of carbon atoms, by **fractional distillation**.
- Oil is pre-heated then passed into column.
- Some of the oil **evaporates**
- **Vapours rise** up the column and **cool**
- Some vapours **condense** , separate and flow out the column in a pipe
- Some vapours stay as gases and rise out the top of the column
- Each fraction has a **different boiling point** and condenses at **different levels** in the fractionating column
- The temperature of column decreases upwards
- Boiling point depends on size of molecules.
- Small molecules condense at the top at lower temperatures
- and big molecules condense at the bottom at higher temperatures

The fractions can be processed to produce fuels and feedstock for the petrochemical industry. Many of the fuels on which we depend for our modern lifestyle, such as petrol, diesel oil, kerosene, heavy fuel oil and liquefied petroleum gases, are produced from crude oil.

Many useful materials on which modern life depends are produced by the petrochemical industry, such as solvents, lubricants, polymers, detergents.

The vast array of natural and synthetic carbon compounds occur due to the ability of carbon atoms to form families of similar compounds.



Cracking

Larger hydrocarbons can be broken down (cracked) to produce **smaller**, more useful molecules.

The cracking process involves **heating the hydrocarbons** to **vaporise** them.
The vapours are either
- passed over a **hot catalyst**
- or **mixed with steam** and heated to a **very high temperature**

Uses of cracking products
- There is a high demand for fuels with small molecules and so some of the products of cracking are useful as fuels.
- Alkenes are used to produce polymers and as starting materials for the production of many other chemicals.

Cracking reactions are **thermal decomposition** reactions.

The products of cracking include alkanes and unsaturated hydrocarbons called alkenes

Be able to complete balanced equations for cracking reactions.
Example:
decane → pentane + pentene
$C_{10}H_{22} \rightarrow C_5H_{12} + C_5H_{10}$

Alkenes

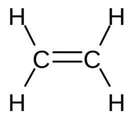
Alkenes are hydrocarbons with **a double carbon-carbon bond**. Alkene molecules are **unsaturated** because they contain two fewer hydrogen atoms than the alkane with the same number of carbon atoms.

The general formula for the homologous series of alkenes is **C_nH_{2n}**

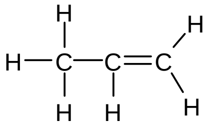
Alkenes are **more reactive** than alkanes. Alkenes react with **bromine water**, turning it from **orange to colourless.**

It is the generality of reactions of functional groups that determine the reactions of organic compounds.

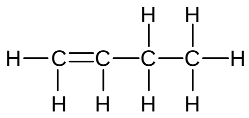
The first four members of the **homologous series** of alkenes are ethene, propene, butene and pentene.



Ethene is C_2H_4



Propene is C_3H_6



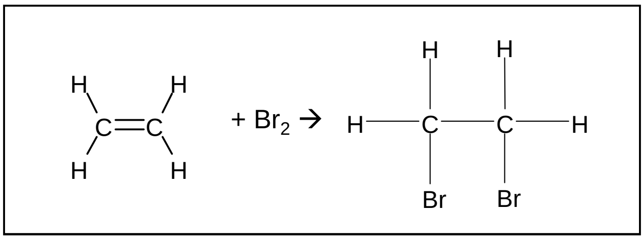
butene is C_4H_8

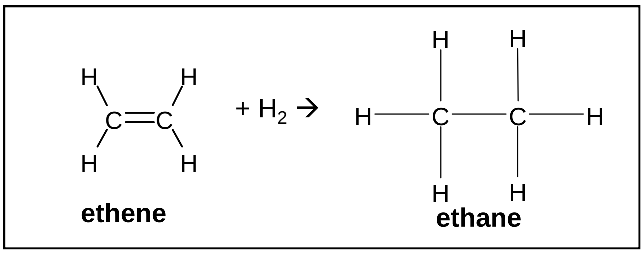
Combustion of Alkenes

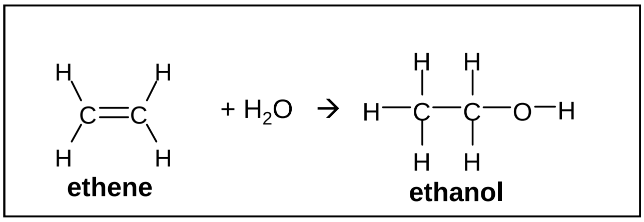
Alkenes react with oxygen in combustion reactions in the same way as other hydrocarbons, but they tend to burn in air with smoky flames because of incomplete combustion.

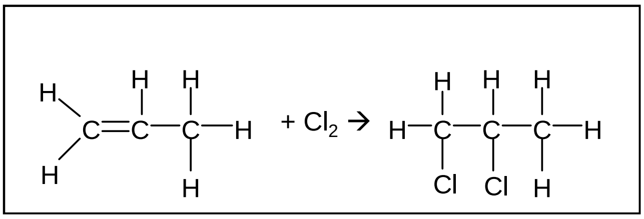
Addition Reactions of Alkenes

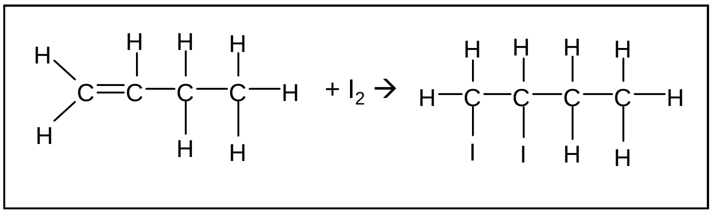
Alkenes react with hydrogen, water and the halogens, by the addition of atoms across the carbon-carbon double bond so that the double bond becomes a single carbon-carbon bond.











Alcohols

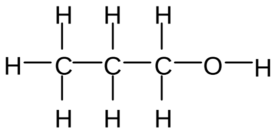
Chemistry only

Alcohols contain the functional group **–OH**.

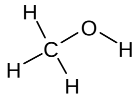
Alcohols can be represented in the following forms:

CH_3CH_2OH

Or



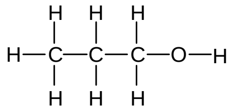
Methanol, ethanol, propanol and butanol are the first four members of a homologous series of alcohols.



Methanol

CH_3CH_2OH

ethanol



propanol

$CH_3CH_2CH_2CH_2OH$

butanol

Methanol, ethanol, propanol and butanol:
- dissolve in **water** to form a **neutral** solution
- react with **sodium** to produce **hydrogen**
- burn in air

Complete Combustion

In excess oxygen alcohols will burn with complete combustion

$CH_3CH_2OH(l) + 3\,O_2(g) \rightarrow 2CO_2(g) + 3\,H_2O(l)$

Reactions with oxidising agents

Alcohols can be **oxidised** to **carboxylic acids** by oxidising agents (such as potassium dichromate)
Ethanol can be oxidised to ethanoic acid, either by chemical oxidising agents, or by oxygen in the air

Uses of Alcohols

Alcohols are used as a fuels and solvents, and ethanol is the main alcohol in alcoholic drinks.

Fermentation

Aqueous solutions of ethanol are produced when sugar solutions are fermented using yeast.

glucose → ethanol + carbon dioxide

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

The conditions needed are:
- yeast
- no air
- temperatures 30 – 40°C

The **optimum temperature** for fermentation is around 38°C

At lower temperatures the reaction is too slow.

At higher temperatures the yeast dies and the enzymes denature.

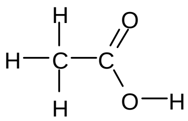
Fermentation is done in an **absence of air** because the presence of air can cause extra reactions to occur. It oxidises the ethanol produced to ethanoic acid (vinegar).

Carboxylic Acids

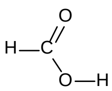
Carboxylic acids have the functional group –COOH.

The structures of carboxylic acids can be represented in the following forms:

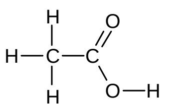
CH_3COOH or



The first four members of a homologous series of carboxylic acids are methanoic acid, ethanoic acid, propanoic acid and butanoic acid.



methanoic acid



ethanoic acid

CH_3CH_2COOH

propanoic acid

$CH_3CH_2CH_2COOH$

butanoic acid

Carboxylic acids:
- dissolve in water to produce **acidic solutions**
- react with **carbonates** to produce **carbon dioxide**
- react with **alcohols** in the presence of an **acid catalyst** to produce **esters.**

Carboxylic acids are weak acids

Carboxylic acids do **not ionise completely** when dissolved in water and so are weak acids

Aqueous solutions of weak acids have a **higher pH** value than aqueous solutions of strong acids with the same concentration.

Esters

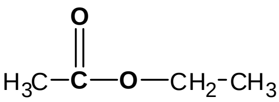
Esters are made from the reaction of **carboxylic acids** with **alcohols** in the presence of an **acid catalyst** (sulfuric acid).

Ethyl ethanoate is the ester produced from ethanol and ethanoic acid

$CH_3COOH + CH_3CH_2OH \rightarrow CH_3COOCH_2CH_3 + H_2O$

Ethyl ethanoate

Esters have the functional group –COO–



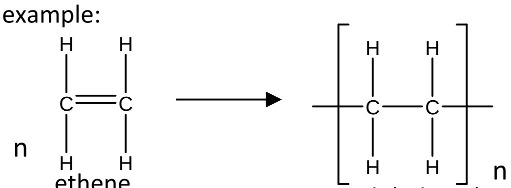
Addition Polymerisation.

Chemistry only

Alkenes can be used to make polymers such as poly(ethene) and poly(propene) by addition polymerisation.
In addition polymerisation reactions, many small molecules (monomers) join together to form very large molecules (polymers).

In these reactions, the **double bonds** open up and **many small** unsaturated **molecules** (monomers, which are usually alkenes) **join together** to form **very large** saturated molecules (polymers).

For example:

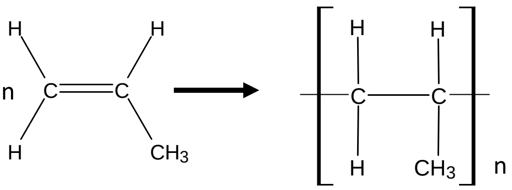


ethene

poly(ethene)

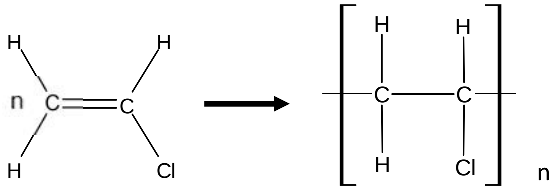
(the n stands for many molecules)

In addition polymers the repeating unit has the same atoms as the monomer because no other molecule is formed in the reaction.



propene

poly(propene)



chloroethene

poly(chloroethene)

Condensation Polymerisation

Condensation polymerisation involves monomers with **two functional** groups. When these types of monomers react they join together, usually losing small molecules such as **water**, and so the reactions are called **condensation reactions**.

The simplest condensation polymers are produced from **two different monomers** with **two of the same functional groups** on each monomer

For example:

Monomer 1

$HO-CH_2-CH_2-OH$

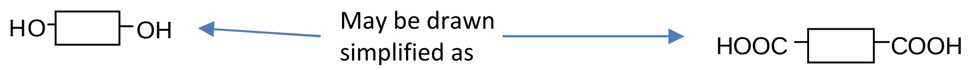
ethanediol

reacts with

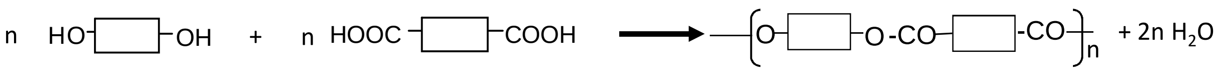
Monomer 2

$HOOC-CH_2-CH_2-CH_2-CH_2-COOH$

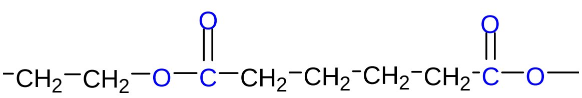
Hexanedioic acid



Polymerise to form a polyester



This shows the main bonds present in the repeating unit.
Learn the ester linkage.
This is a poly(ester)



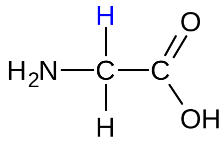
Amino acids and Proteins

Chemistry only

Amino acids have **two different** functional groups in a molecule.

Amino acids react by **condensation polymerisation** to produce **polypeptides.**

For example: the amino acid glycine is **H_2NCH_2COOH** and polymerises to produce the **polypeptide $(-HNCH_2CO-)n$** and **n H_2O**



glycine

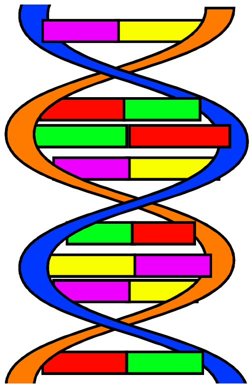
Different amino acids can be combined in the same chain to produce **proteins**.

DNA

Chemistry only

DNA (deoxyribonucleic acid) is a large molecule essential for life.
DNA encodes **genetic instructions** for the **development and functioning** of living organisms and viruses.

Most DNA molecules are **two polymer chains**, made from **four** different **monomers called nucleotides,** in the form of a **double helix.**



Other naturally occurring polymers important for life include proteins, starch and cellulose

Monomer	Polymer
nucleotide	DNA
Amino acid	Protein
Glucose	Starch
Glucose	Cellulose