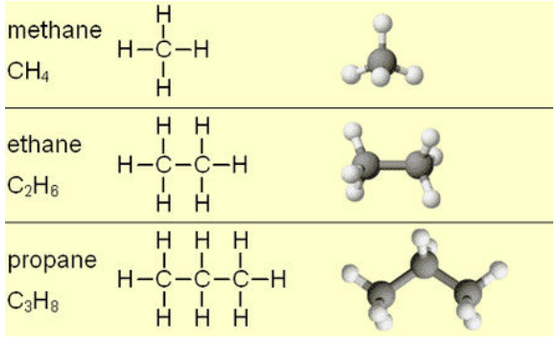
Organic Chemistry - Crude oil

Keyword	Definition
Hydrocarbons	A compound containing only hydrogen and carbon.
Fractional distillation	A way to separate liquids from a mixture of liquids by boiling off the substances at different temperature, then condensing and collecting the liquids.
Fractions	Hydrocarbons with similar boiling points separated from crude oil.
Alkane	A saturated hydrocarbon with the general formula CnH2n+2.
Saturated hydrocarbon	A hydrocarbon with only single bonds between its carbon atoms.
Unsaturated hydrocarbon	A hydrocarbon whose molecules contain at least one carbon-carbon double bond.
Combustion	Burning a fuel in oxygen.
Cracking	The reaction used in the oil in the oil industry to break down large hydrocarbons into smaller, more useful ones.
Thermal decomposition	The breakdown of a compound by heating it.
Polymers	A substance made from very large molecules made up of many repeating units (monomer).
Organic	Compounds that contain carbon covalently bonded to other elements, typically, hydrogen, oxygen and nitrogen.

Or 01. Hydrocarbons:

- Organic molecules made-up of carbon and hydrogen, only.
- Hydrocarbons differ in the number carbon atoms that make up the molecule, e.g.
- C_2H_4 or C_3H_8
- **Hydrocarbon molecules can be represented in several formats:**

Empirical formula Structural formula Atomic diagram



OR 01. Crude Oil

- Finite (it will run out) resource found in rocks underground.
- Remains of plankton, buried in sediments millions of years ago.
- Mixture of many different compounds, mostly hydrocarbons.
- Hydrocarbons are molecules containing only hydrogen and carbon.

Or 03. Complete Combustion

Excess oxygen available. Products are carbon dioxide and water only. For example:

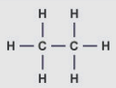
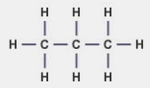
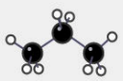
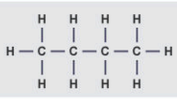
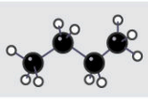
$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

Incomplete Combustion

Insufficient oxygen available. Products include carbon monoxide, carbon (seen visibly as soot) and water. For example:

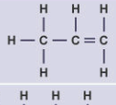
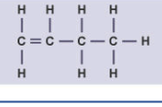
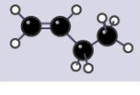
$C_2H_6 + O_2 \rightarrow CO + C + 3H_2O$

Or 01. Alkanes

Alkane	Molecular formula	Structural formula	Ball-and-stick model
Methane	CH_4		
Ethane	C_2H_6		
Propane	C_3H_8		
Butane	C_4H_{10}		

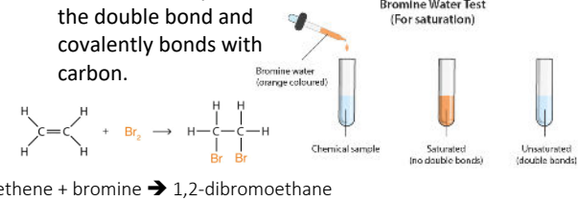
- General formula for alkanes is C_2H_{2n+2}.
- Only single bonds between each carbon atom.
- Each molecule is saturated (no bonds spaces left).

Or 04 Alkenes

Alkene	Molecular formula	Structure (showing all the covalent bonds)	Ball-and-stick model
Ethene	C_2H_4		
Propene	C_3H_6		
Butene	C_4H_8		

- General formula for alkenes is C_2H_{2n}
- One double bond per molecule.
- Each molecule is unsaturated, having a double bond between two carbon atoms.

- The bromine 'opens' the double bond and covalently bonds with carbon.



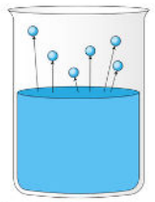
ethene + bromine → 1,2-dibromoethane

Viscosity

How much a liquid resists flowing.

- Longer-chain hydrocarbons are more viscous than shorter-chain hydrocarbons.

Volatility



How easily a liquid evaporates at low temperatures.

- Short-chain hydrocarbons are very volatile.

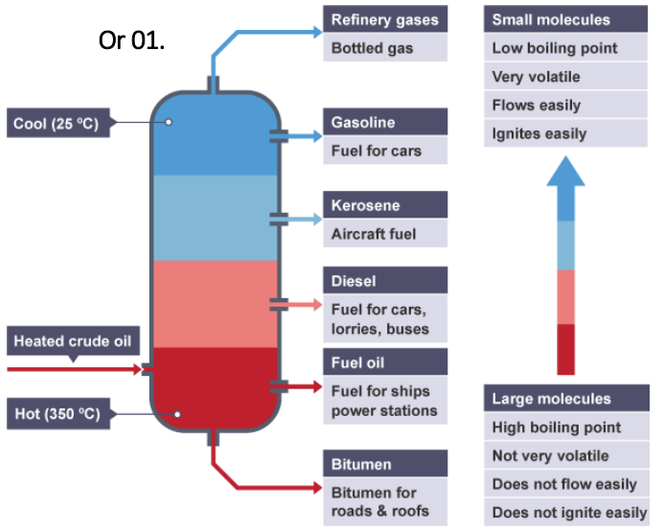
Required Practical:

none

Mathematical Skills:

- *Be prepared to read graphs showing the relationship between boiling point and carbon chain-length. Also, graphs that compare supply and demand of crude oil.*

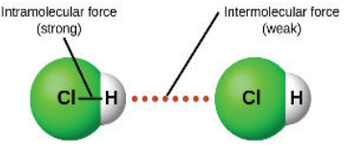
Or 01.



Key Point

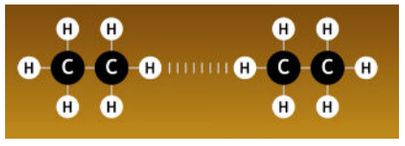
A reminder from the **BONDING** module:

- **Covalent bonds** between atoms are **strong** and the **intermolecular forces** between molecules are **weak**.



Alkanes and boiling point:

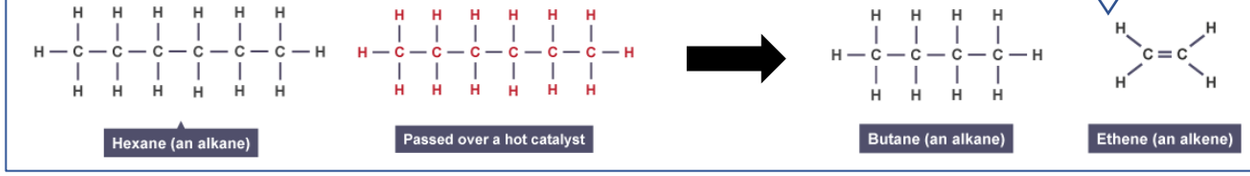
- **Shorter-chain** alkanes have **weaker intermolecular forces** than longer chain hydrocarbons, therefore, have **lower boiling points**.



Or 04. Cracking Hydrocarbons:

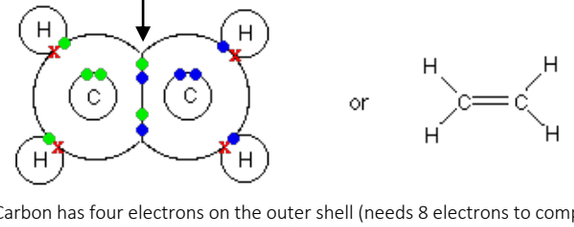
- Shorter-chain (C5-C8) fractions are used to make petrol.
- The demand for shorter-chain fractions is greater than the availability of these fractions.
- Longer-chain fractions can be cracked to meet some of this demand.
- Alkanes that are 'cracked' undergo a Thermal Decomposition reaction.
- Cracking always produces at least one alkene, for example:

A double bond is formed because there are not enough hydrogen atoms to form single bonds on each molecule.



Key Point

A pair of shared electrons is called a **double bond**.



- Carbon has four electrons on the outer shell (needs 8 electrons to complete it)
- The double (covalent) bond is **pair of shared electrons**.
- All of the shared electrons between hydrogen and each carbon atom give each carbon atom a full outer shell.

Relevant Modules:

- Atomic Structure
- Bonding
- Chem of the Atmosphere

Useful YouTube links:

Crude oil Cracking Alkenes

Organic Chemistry – CHEM ONLY

Keyword	Definition
Functional group	A functional gives a group of organic compounds their characteristic chemical properties, e.g. OH ('ol' alcohols).
Homologous series	A group of organic compounds that have the same functional group but differ in the number of carbon atoms that make up the molecule.
Alcohol	The functional group R-OH. Suffix 'ol', e.g. ethan**ol**.
Carboxylic acid	The functional group R-COOH. Suffix 'oic', e.g. ethan**oic** acid.
Ester	The functional group R-COO-R. Duel name with the suffixes, 'yl' 'oate', e.g. eth**yl** ethan**oate**.
Esterification	A reaction between a carboxylic acid and alcohol to produce an ester.
Fermentation	Biochemical reaction that produces ethanol.
Monomer	Smaller (unsaturated) hydrocarbon molecules that bond to form a polymer chain.
Addition Polymer	When the double covalent bond of monomer molecules breaks to be replaced by single carbon-carbon bonds.
Condensation Polymer	Ester link between [monomer] carboxylic acid molecules and diols to release water.
Peptide link	Link between a carboxyl and amine group.

Or 05. Reactions of Alkenes (summary):

- Alkenes are **unsaturated** hydrocarbons with a **C=C** double bond.
- Alkenes end in the suffix 'ene', e.g. ethene, propene and butene.
- The main feature of a reaction with an alkene involves 'opening-up' the double bond to allow bonding with other molecules.

OR 05 Combustion of Alkenes

- The combustion of alkenes produces more smoke compared to alkanes due to **incomplete combustion** and less energy is released per mole. Therefore, alkenes are not used as fuels, whereas, alkanes are. During complete combustion, you get:

ethene + oxygen ➔ carbon dioxide + water

C_2H_4 (g) + $3O_2$ (g) ➔ $2CO_2$ (g) + $2H_2O$ (l)

OR 05 Reaction of alkenes with Hydrogen

- Alkenes will react with hydrogen in the presence of a **catalyst** to form a saturated alkane. For example:

pentene + hydrogen ⇌ pentane

C_5H_{10} (g) + H_2 (g) ⇌ C_5H_{12} (g)

- The reaction is **reversible** and requires high temperatures and pressures.

OR 05 Reaction of alkenes with steam

- Alkenes can be **hydrated** (reacted with steam) in the presence of a catalyst to form alcohols. For example:

ethene + steam ➔ ethanol

C_2H_4 (g) + H_2O (g) ➔ C_2H_5OH (l)

OR 05 Reaction of alkenes with the halogens

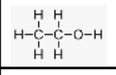
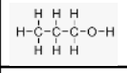
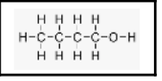
- Alkenes will react with halogens (group 7) to form **halide** compounds.
- The C=C double bond 'opens' to bond with the halides (see bromine test on other side of KO). For example:

pentene + bromine ➔ dibromopentane

C_5H_{10} (g) + Br_2 (g) ➔ $C_5H_4Br_2$ (l)

OR 06 Reactions and uses of alcohol

- Alcohols are a family of organic molecules that have the **–OH** functional group. The first four alcohols are:

Alcohol	Empirical formula	Structural formula
Methanol	CH_3OH	
Ethanol	C_2H_5OH	
Propanol	C_3H_7OH	
Butanol	C_4H_9OH	

- Alcohol have many uses in industry and are of significant importance as feedstock chemicals. They are very soluble in water and will dissolve many other organic compounds. This makes them useful as **solvents** for chemicals used in household products, medicine and industrial processes.
- Ethanol is the alcohol contained in alcoholic drinks and is produced as a product of fermentation (see below).

Reactions of alcohols:

Hydration and fermentation

- Alcohols can be produced by the **hydration** of an alkene with steam (see OR5 above), or by fermentation (using yeast):

glucose (yeast) ➔ ethanol + carbon dioxide

$C_6H_{12}O_6$ (aq) ➔ $2C_2H_5OH$ (aq) + CO_2 (g)

Oxidation

- Alcohols will react with the oxygen in an **oxidising agent**. e.g. potassium dichromate (VI), to form a carboxylic acid. For example:

ethanol + oxygen (from oxidising agent) ➔ ethanoic acid + water

C_2H_5OH + 2[O] ➔ CH_3COOH + H_2O

Sodium

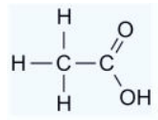
- Alcohols will react with sodium to form **sodium ethoxide** and hydrogen gas. The reaction is very gentle, unlike the violent reaction between sodium and water.

ethanol + sodium ➔ sodium ethoxide + hydrogen

$2C_2H_5OH$ (l) + 2Na (l) ➔ $2C_2H_5ONa$ (l) + H_2 (g)

OR 07 Carboxylic acids and esters

- Carboxylic acids have the functional group **–COOH**, e.g. ethanoic acid has the formula: CH_3CH_2COOH.
- The –COOH group consists of one **C=O** (double covalent bond) and a single **C-OH** bond. As follows:



- Carboxylic acids end in the suffix '**oic**', e.g. ethanoic, propanoic and butanoic acid.
- Carboxylic acids will react with carbonates to form a salt water and carbon dioxide. For example:

ethanoic acid + sodium carbonate ➔ sodium ethanoate + water + carbon dioxide

$2CH_3COOH$ (aq) + Na_2CO_3 (s) ➔ $2CH_3COONa$ (aq) + H_2O (l) CO_2 (g)

- Carboxylic acids are classified as weak acids (when compared to inorganic acids such as hydrochloric and sulfuric acid. **HIGHER paper look here ➔➔**
- Carboxylic acids will react with alcohols in the presence of a sulfuric acid catalyst to form an ester. The reversible reaction is as follows:

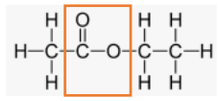
acid + alcohol ⇌ ester + water

e.g.

ethanoic acid + ethanol ⇌ ethyl ethanoate + water

CH_3COOH (aq) + C_2H_5OH (l) ⇌ $CH_3COOC_2H_5$ (aq) + H_2O (l)

- The structural formula for ethyl ethanoate showing the **–COO ester link** is as follows:



Required Practical:

None

Mathematical Skills:

- *Describe the products of reactions in terms of the number of moles present.*
- *Graph analysis and data about different polymers.*

Or 07 Weak acids [HIGHER]

Key Point

- Carboxylic acids are weak acids because they **do not** completely **ionise** when dissolved in water. Strong acids ionise completely to form **H^+ ions**, weak acids only partially ionise producing fewer H^+ ions in solution. As follows:

ethanoic acid ⇌ ethanoate ion + hydrogen ion

CH_3COOH (aq) ⇌ CH_3COO^- (aq) + H^+ (aq)

NOTE: The reaction is **reversible** in which the position of equilibrium lies well over to the left of the reaction.

- In summary, carboxylic acids have a higher pH (meaning a lower concentration of H^+ ions) than a strong acid, resulting in slower reactions with substances like carbonates.

OR 08 - OR 09 Addition and condensation polymerisation

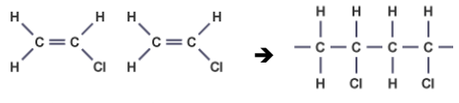
- The two main types of organic polymerisation reactions are **addition polymerisation** and **condensation polymerisation**.

Addition polymerisation

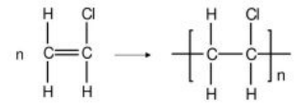
- Addition polymerisation produces plastics which are **polymers** made from the bonding of many unsaturated [**monomer**] hydrocarbon molecules.

e.g.

chloroethene [monomers] ➔ poly(chloroethene) [polymer]

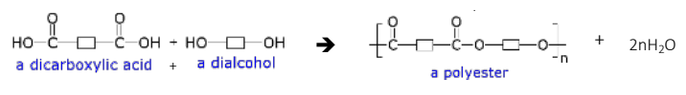


NOTE: the 'n' means that the monomer is repeated many times. The reaction can be written more simply (see right) ➔



Condensation polymerisation

- An example of condensation polymerisation is the reaction between **di-caboxylic acids** (-COOH at each end) and **diols** (alcohol with two -OH groups) producing a **polyester**. All condensation polymerisation reactions produce a polymer and a small molecule, commonly water. As follows:

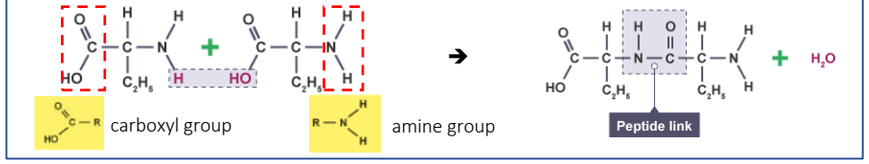


Key points to note:

- The monomers bond together forming **ester links**.
- The carbon chain is not important when writing the reaction, so it is represented as rectangles.

OR 10 Natural polymers

- Examples of natural polymers include: **Polysaccharides** (e.g. starch), **Polypeptides** (protein molecules) and **DNA** (*see **Inheritance** knowledge organiser for DNA structure*].
- **[HIGHER]** Polypeptides are formed from monomer amino acids. The amino acids have two functional groups, one basic (the **amine group –NH_2**) and one acidic (the **carboxylic group –COOH**). The simplest amino acid is called glycine ($C_2H_5NO_2$).
- Amino acid monomers can link together in a **condensation reaction** that forms **peptide links**. As follows:



Relevant Modules:

AQA

- Atomic Structure
- Bonding
- Using resources

Useful YouTube links:

Addition | Condensation | Esters