Topic 7 AQA Chemistry - Organic Chemistry

- Triple Science Content only in purple
- Triple Science and Higher Content Only in blue

Crude oil:

- Crude oil is a **fossil fuel** formed from the remains of ancient marine organisms (plankton) that were buried in mud and exposed to **heat and pressure** over millions of years.

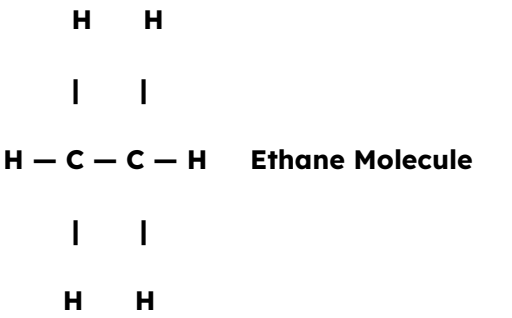
- It is a **mixture of hydrocarbons** — molecules made up only of **hydrogen and carbon atoms**.

- Crude oil is **non-renewable** and **finite** — once used, it cannot be replaced on a human timescale.

- Fractional distillation separates the different hydrocarbons in crude oil.
- Most of these hydrocarbons are alkanes.

Hydrocarbon- molecule containing Hydrogen and Carbon atoms covalently bonded together and have the general formula: $C_n H_{2n+2}$

The first 4 alkanes are methane, ethane, propane and butane



Ethane Molecule

Each carbon (C) makes four single covalent bonds.
Each hydrogen (H) makes one bond.

There are six hydrogen atoms total.

Ethane is a saturated alkane, meaning only single C–C and C–H bonds are present.

Crude oil is not only used for fuels — it's also a **feedstock for the petrochemical industry.**

Petrochemical Feedstocks:

- **Used to make polymers (plastics), solvents, lubricants, detergents, and pharmaceuticals.**
- **Many everyday materials come from crude oil products.**

Crude oil is therefore vital for both energy and manufacturing industries.

However,

- When burning crude oil, sometimes hydrocarbons e.g petrol can contain bits of sulfur
- When burnt, this sulfur can react with the oxygen in the air producing Sulfur Dioxide
- This can lead to **acid rain**

Similarly,

- When the engine of a car is very hot, it can cause the **nitrogen and oxygen in the air to react**
- Forming **Nitrogen Dioxide**
- This can also lead to **Acid Rain**

Fractional Distillation-

- Crude Oil is heated at the bottom
- The different Hydrocarbons have different boiling points
- The shorter chained hydrocarbons have lower boiling points, so are obtained/tapped off at the top of the fractionating column
- Longer chained hydrocarbons have longer melting points, so obtained at the lower side of fractionating column

Properties of hydrocarbons

Property	Short-Chain Hydrocarbons	Long-Chain Hydrocarbons
Boiling point	Low	High
State at room temp	Gas or liquid	Viscous liquid or solid
Volatility (how easily it evaporates)	High	Low
Viscosity	Low (runny)	High (thick)
Flammability	High (burn easily)	Low (harder to ignite)
Cleanliness of flame	Burns with a clean blue flame	Smoky, yellow flame (incomplete combustion)

Complete Combustion and incomplete combustion

When hydrocarbons burn in **plenty of oxygen**, they produce **carbon dioxide and water**.

Word equation:

Hydrocarbon + Oxygen→ Carbon Dioxide + Water

Example:

Methane+Oxygen→CarbonDioxide+Water

Energy is released as heat and light.

If there is **not enough oxygen**, **incomplete combustion** occurs, producing:

- **Carbon monoxide (CO)** – toxic gas
- **Soot (C)** – tiny carbon particles
- **water**

Example:

$2CH_4+3O_2 \rightarrow 2CO+4H_2O$

Cracking

Hydrocarbons are **cracked to produce smaller, more useful molecules.**

Why Is Cracking Needed?

- Fractional distillation produces more **long-chain hydrocarbons** than we need.
- Short-chain hydrocarbons (like petrol and LPG) are more **useful and valuable.**
- Cracking converts long-chain hydrocarbons into **shorter, more useful ones.**

The process:

Two main methods:

1. **Thermal Cracking:**

- Hydrocarbons are heated to **high temperatures (around 700–900°C)**.
- Often **no catalyst** is used.

2. **Catalytic Cracking:**
   - Hydrocarbons are vaporised and passed over a **hot catalyst** (e.g., aluminium oxide).
   - Occurs at **lower temperatures** and **faster rate**.

The products of cracking: Alkanes and Alkenes

Alkenes: **Unsaturated Hydrocarbons** (meaning they have double bonds between the carbons) and have the general formula **Cn H 2 n**

Alkanes: **Saturated Hydrocarbons** (no double bonds), and have general formula Cn H2n+2

Let's talk about Alkenes-

The first 4 alkenes are :

Ethene - C_2H_4

Propene - C_3H_6

Butene - C_4H_8

Pentene - C_5H_{10}

o Alkenes react with bromine water, turning it from orange to colourless.

o Alkenes are used for producing other chemicals (e.g. polymers)

Reactions of Alkenes

Because of the **double bond**, alkenes are **more reactive** than alkanes.

1. Combustion

Alkenes burn in air, but **incomplete combustion** is common, producing a **smoky flame** and less energy than alkanes.

2. Addition Reactions

The **C=C double bond** can open up, allowing **atoms to add** across it.

a) Hydrogenation

- Alkenes react with **hydrogen gas** in the presence of a **nickel catalyst** at about **200°C**.
- Converts alkenes → **alkanes**.

$C_2H_4 + H_2 \rightarrow C_2H_6$

b) Hydration

- Alkenes react with **steam** (H_2O) in the presence of a **phosphoric acid catalyst** to form **alcohols**.

$C_2H_4 + H_2O \rightarrow C_2H_5OH$

c) Reaction with Halogens

- Alkenes react with **halogens (Cl_2, Br_2, I_2)** to form **saturated compounds** (dihaloalkanes).

$C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$

This reaction is used as a **test for alkenes — bromine water** turns **from orange to colourless**.

Uses of Alkenes

- Feedstock for making polymers (e.g., polyethene, polypropene).
- Used to make alcohols, detergents, and other organic chemicals.

Let's talk about Alcohols-

Alcohols

Contain the functional group **–OH**

The first 4 Alcohols are methanol, ethanol, propanol and butanol.

Name	**Formula**	**Displayed Formula**	**Notes**
Methanol	CH3OH	CH3–OH	Simplest alcohol
Ethanol	C2H5OH	CH_3–CH_2–OH	In alcohol drinks
Propanol	C3H7OH	CH_3–CH_2–CH_2–OH	A Solvent
Butanol	C4H9OH	CH_3–CH_2–CH_2–CH_2–OH	Fuel and Solvent

Reactions of Alcohols-

Combustion:

Alcohol + Oxygen → Carbon dioxide + Water

Example:

C2H5OH + 3O2 → 2CO2 + 3H2O

Reaction with Sodium:

Alcohol + Sodium → Sodium alkoxide + Hydrogen

Example:

2C2H5OH + 2Na → 2C2H5ONa + H2

Oxidation (to form carboxylic acids):

Alcohol + Oxygen → Carboxylic acid + Water

Example:

CH3CH2OH → CH3COOH + H2

Reactions of these:

- In a **complete combustion reaction** they produce carbon dioxide and water.
- Have a pH of 7 in water - neutral.
- They react with **sodium** to produce hydrogen and a salt
- They react with **oxidising agents** to form carboxylic acids

Uses: All 4 can be used as fuels

- methanol: anti-freeze, making biodiesel.
- Ethanol: Solvent and fuel

Producing ethanol:

- Ethanol can be produced by fermentation of sugar with yeast.

- Conditions:
- 35°C
- Anaerobic (without oxygen)
- Use yeast enzyme as a catalyst

EQUATION- Sugar → ethanol + carbon dioxide

Carboxylic Acids-

General formula: $C_nH_{2n+1}COOH$
Functional group: –COOH (carboxyl group)

Examples:

- Methanoic acid – $HCOOH$
- Ethanoic acid – CH_3COOH
- Propanoic acid – C_2H_5COOH
- Butanoic acid – C_3H_7COOH

Reactions of Carboxylic Acids

1. **With Carbonates:**
   Carboxylic acid + Carbonate → Salt + Water + Carbon dioxide
   Example:
   $2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COONa + H_2O + CO_2$

2. **With Alkalis (Neutralisation):**
   Carboxylic acid + Base → Salt + Water
   Example:
   $CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O$

3. **With Alcohols (Esterification):**
   Carboxylic acid + Alcohol ⇌ Ester + Water
   Example:
   $CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$

Esters

Formation (Esterification):

- Made by reacting a carboxylic acid with an alcohol using concentrated sulfuric acid as a catalyst.

- Example:
  Ethanoic acid + Ethanol ⇌ Ethyl ethanoate + Water
  $CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$

Carboxylic acids are also weak acid -

Weak acid definition- solution that only partially ionises/ slightly dissociates.

Properties and Uses of Esters

Property	Use
Pleasant, fruity smell	Used in perfumes and flavourings
Volatile	Evaporate easily, good for fragrances
Solvents	Used in paints, inks, and glues

Polymers-

Addition Polymerisation-

Alkenes have their double bonds broken to form a repeating chain unit of unsaturated **polyalkenes.**

Condensation polymerisation-

Involves **2** functional groups such as **alcohol and carboxylic acids (make a polyester)**

Join to form **water** as a by product

Amino Acids-

- Have **two different** functional groups in a molecule (an amine group and a carboxylic acid group)

- They react by **condensation polymerisation** to produce **polypeptides**

DNA

- **DNA contains and codes genetic instructions for the development and functioning of living organisms and viruses**
- **Contains two polymer chains, made from four different monomers called nucleotides, in the form of a double helix**