# Topic 7 – Organic Chemistry

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# Topic 7 – Organic Chemistry

## Sub Topics

- Hydrocarbons
- Fractional Distillation
- Uses and Cracking of Crude Oil
- Alkenes and their Reactions
- Addition Polymers
- Alcohols
- Carboxylic Acids
- Condensation Polymers
- Naturally Occurring Polymers

# Hydrocarbons

## Hydrocarbons only contain **Hydrogen** and **Carbon** atoms

A Hydrocarbon is any compound that is formed from C and H atoms only !

So $C_{10}H_{22}$ (decane an alkane) is a hydrocarbon, but $CH_3COOC_3H_7$ (an ester) is not – as it contains O !

## **Alkanes** Have All **C–C Single** Bonds

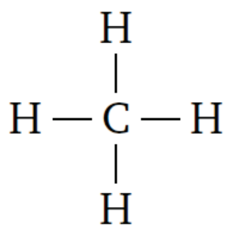
Alkanes are the simplest type of hydrocarbon:

General formula: $C_nH_{2n+2}$

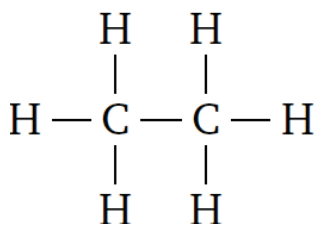
The alkanes are a homologous series – a group of organic compounds that react in a similar way

Alkanes are saturated compounds – each C atom forms 4 single covalent bonds

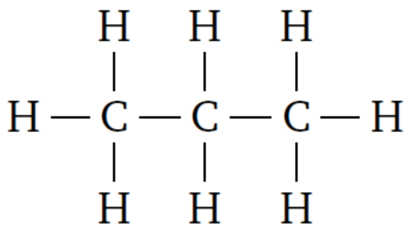
The first 4 alkanes are methane, ethane, propane and butane: (Displayed formula)



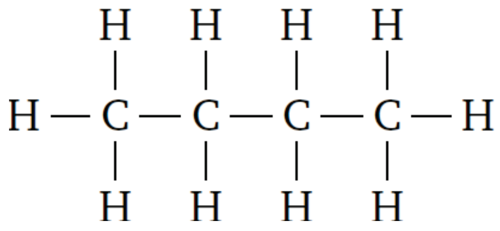
Methane: $CH_4$



Ethane: $C_2H_6$



Propane: $C_3H_8$



Butane: $C_4H_{10}$

# Hydrocarbons

## Hydrocarbon Properties Change as the Chain Gets Longer

As the length of the carbon chain changes, the properties of the hydrocarbon change:

1. The shorter the carbon chain, the more runny (less viscous) the hydrocarbon is.
2. The shorter the carbon chain, the more volatile the hydrocarbon is.
   i.e. it turns into a gas at a lower temperature. Shorter the carbon chain ⇨ the lower the boiling point (b.p. = temperature at which hydrocarbon vaporises or condenses).
3. The shorter the carbon chain, the more flammable (easier to ignite) the hydrocarbon is

The properties of hydrocarbons affect how they're used for fuels.
E.g. short chain hydrocarbons with lower b.p.s are used as
'bottled gases' – stored under pressure as liquids in bottles.

# Hydrocarbons

## **Complete Combustion** Occurs When There's Plenty of **Oxygen**

1. The Complete Combustion of any hydrocarbon in oxygen releases lots of energy.
   The only waste products are carbon dioxide and water vapour.

   Hydrocarbon + Oxygen → Carbon dioxide + Water

2. During combustion both C and H from the hydrocarbon are oxidised
   (N.B. Oxidation can be defined as the gain of oxygen)
3. Hydrocarbons are used as fuels due to the amount of energy released when they combust completely
4. Expected to be able to give a balanced symbol equation for the complete combustion of a simple hydrocarbon fuel when given its molecular formula:

# Hydrocarbons

## **Complete Combustion** Occurs When There's Plenty of **Oxygen**

Write a balanced equation for the complete combustion of methane ($CH_4$)

1. On the LHS: there's 1 C atom so only 1 molecule of $CO_2$ is needed to balance this.

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

2. On the LHS: there are 4 H atoms so only 2 molecule of $H_2O$ are needed to balance them.

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

3. There are 4 O atoms on the RHS 2 Oxygen molecules ($O_2$) are needed to balance them.

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

# Fractional Distillation

## **Crude Oil** is Made Over a **Long Period of Time**

Crude oil is a 'feedstock' to make fuels and plastics. But it is a mixture of hydrocarbons which have to be separated first for each use – Fractional Distillation is the process

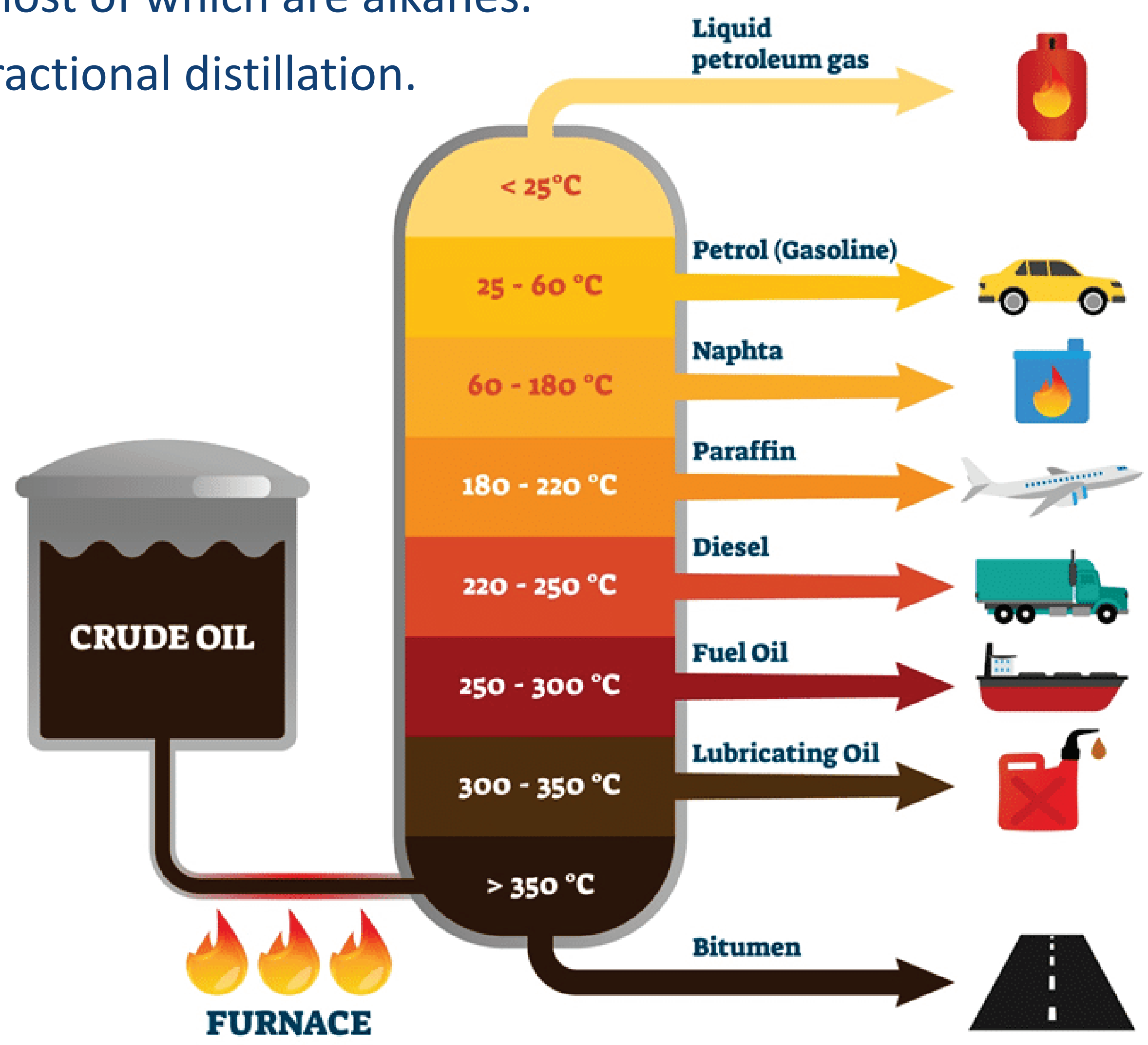
1. Crude oil is a fossil fuel. Formed from the remains of plants and animals (mainly plankton) that died millions of years ago and were buried in mud. Over millions of years, with high temperature and pressure, the remains turn to crude oil, which can be drilled up from the rocks where it's found.
2. Fossil fuels like coal, oil and gas are 'non-renewable fuels' as they take so long to make that they are used up much faster than they can be made. They are Finite Resources which will run out one day.

# Fractional Distillation

## **Fractional Distillation** is Used to Separate **Hydrocarbon Fractions**

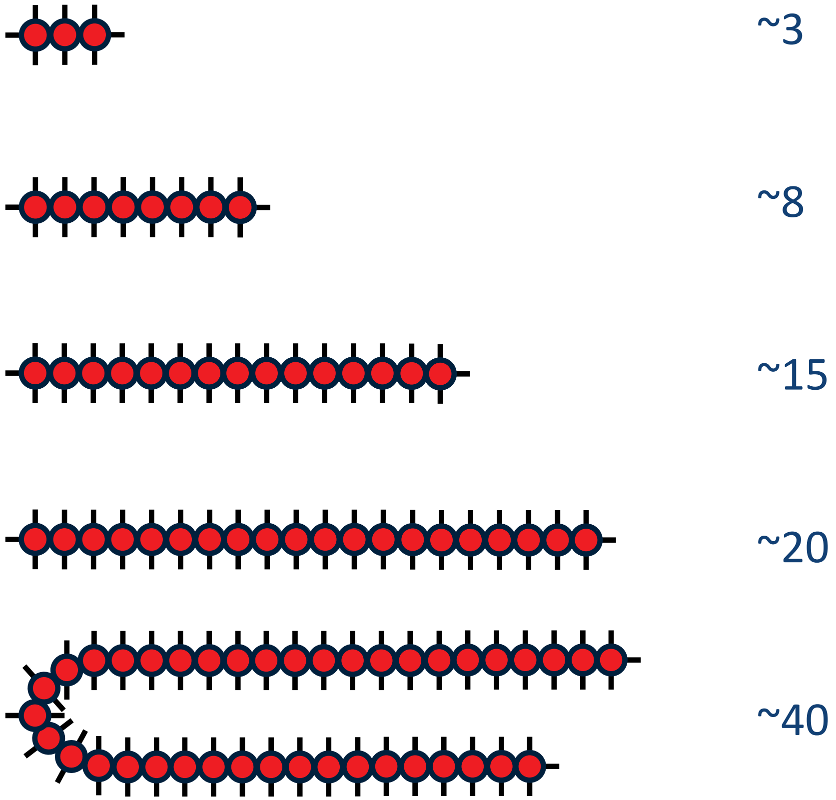
1. Crude Oil is a mixture of many different hydrocarbons, most of which are alkanes.
2. The different compounds in crude oil are separated by fractional distillation.

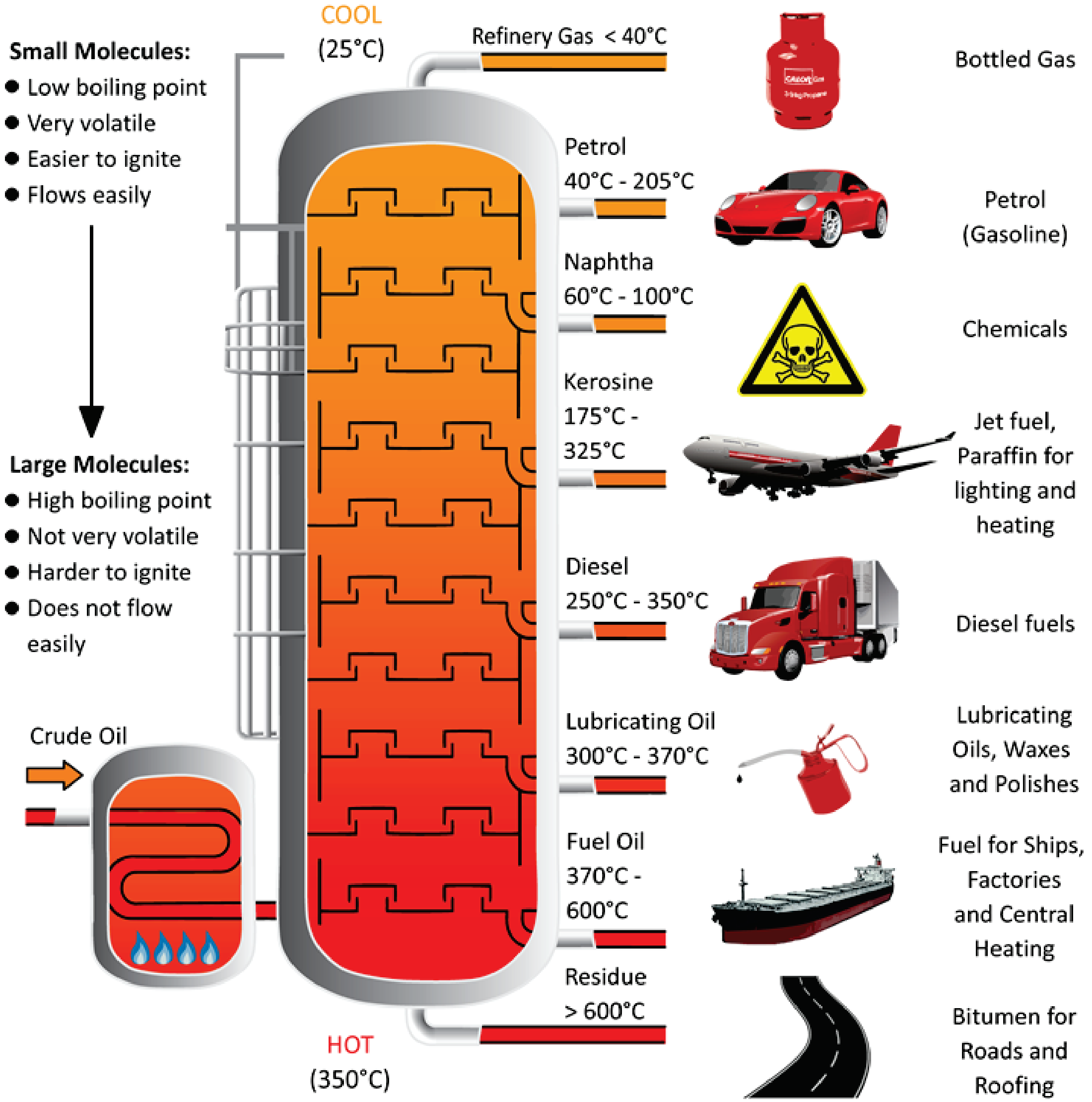
- Oil heated until most turned into gas
  Gases enter a fractionating column
  (liquid drained off)
- Column has a temperature gradient
  (Hot at bottom, cooler towards top)
- Longer hydrocarbons have ↑ b.p.
  They condense back into liquids and drain out early on, near the bottom.
  Shorter hydrocarbons have ↓ b.p.
  They condense and drain out much later on near the top of the column where it is cooler
- End up with crude oil mixture separated out into **Different Fractions.**
  Each fraction contains a mixture of hydrocarbons that all contain a similar number of carbon atoms, so have similar b.p.



# Fractional Distillation

## **Fractional Distillation** is Used to Separate **Hydrocarbon Fractions**



# Uses and Cracking of Crude Oil

## **Crude Oil** has Various Uses Important in Modern Life

1. Oil provides the fuel for most modern transport – cars, trains, planes …
   Diesel oil, kerosene, heavy fuel oil and LPG all come from crude oil
2. The petrochemical industry uses some of the hydrocarbons from crude oil as a feedstock to make new compounds for use in polymers, solvents, lubricants and detergents.
3. All products from crude oil are examples of organic compounds (compounds containing C atoms)
   Reason for such variety of products is because C atoms can bond together to form different groups called homologous series. These groups contain similar compounds with many properties in common.
   E.g. alkanes, alkenes etc.

# Uses and Cracking of Crude Oil

## There are **Different Methods** of **Cracking**

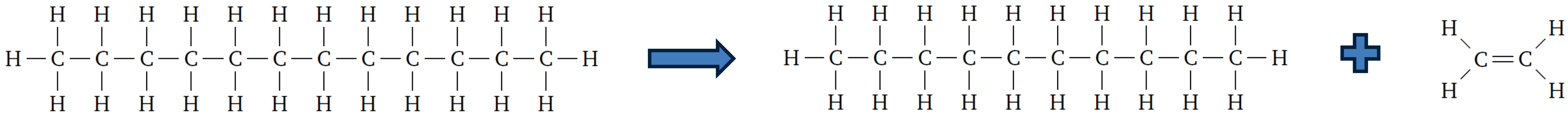
1. Short-chain hydrocarbons are flammable so make good fuels and are in high demand.
   However, long-chain hydrocarbons form viscous liquids like tar which are not useful.
2. As a result, many of the longer alkane molecules produced from fractional distillation are turned into smaller, more useful ones by a process called cracking.
3. As well as alkanes, cracking also produces another type of hydrocarbon – alkenes
   Alkenes are used as a starting material form making many other compounds and polymers.
4. Some of the products of cracking are useful as fuels (e.g. petrol for cars and paraffin for jet fuel)

# Uses and Cracking of Crude Oil

## Cracking – Splitting Up Long-Chain Hydrocarbons

1. Cracking is a thermal decomposition reaction – breaking molecules down by heating them.
2. First step: heat long-chain hydrocarbons to vaporise them (turn into gas)
3. Vapour is then passed over a hot powdered aluminium oxide catalyst.
4. The long-chain molecules split apart on the surface of the catalyst particulates – catalytic cracking!
5. Hydrocarbons can also be cracked if vapourised, mixed with steam and then heated to a very high temperature – known as steam cracking.

long-chain hydrocarbon molecule | Shorter alkane molecule | alkene molecule



Decane (10 C atoms)
[Too much in crude oil]

Octane (8 C atoms)
[Useful for petrol]

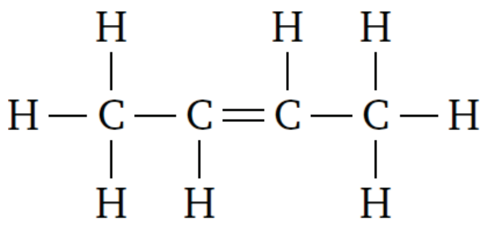
Ethene (2 C atoms)
[Making plastics]

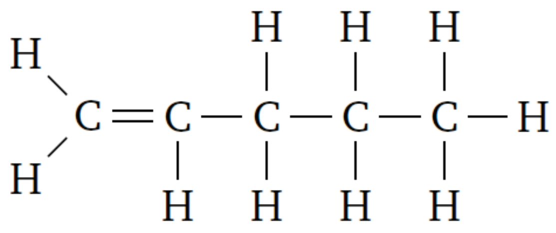
# Alkenes and their Reactions

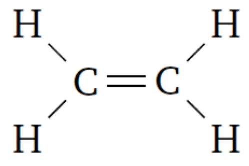
## Alkenes have a C=C Double Bond

1. Alkenes are hydrocarbons which have a Double Bond between two of the C atoms in their chain
2. The C=C double bond means that alkenes have two fewer H atoms compared with alkanes containing the same number of C atoms. This makes them unsaturated
3. The C=C double bond can open up to make a single bond, allowing the two C atoms to bond with other atoms. This makes alkenes reactive – much more reactive than alkanes
4. The 1st four alkenes are ethene (2 C), propene (3 C), butene (4 C) and pentane (5 C)
5. Straight chain alkenes have twice as many H atoms as C atoms

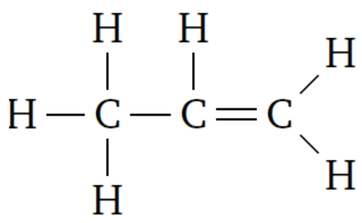
General Formula: $C_nH_{2n}$



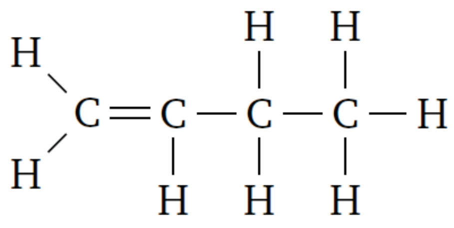




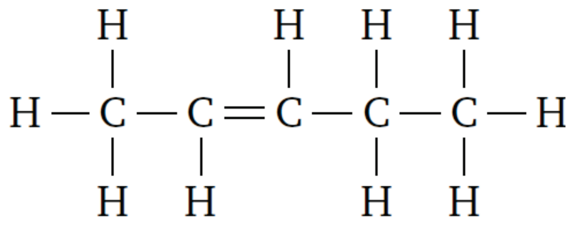
Ethene: $C_2H_4$



Propene: $C_3H_6$



Butene: $C_4H_8$



Pentene: $C_5H_{10}$

# Alkenes and their Reactions

## **Alkenes** Burn With a **Smoky Flame**

1. In a large amount of $O_2$, alkenes combust completely to produce only $CO_2$ and $H_2O$
2. However, when burnt in air they tend to undergo incomplete combustion
   $CO_2$ and $H_2O$ are still produced but so too are C and CO (poisonous gas!)
3. Standard equation for the incomplete combustion of alkenes

   Alkene + Oxygen → Carbon + Carbon monoxide + Carbon dioxide + Water + ENERGY!

4. Incomplete combustion gives a smoky yellow flame, and less energy being released cf. complete combustion
5. E.g. for butene: $C_4H_8 + 5O_2 \rightarrow 2CO + 2\ CO_2 + 4H_2O$

   However, this is just one possibility. The products depend on how much $O_2$ is present.

   Could also be: $C_4H_8 + 3O_2 \rightarrow 2C + 2\ CO + 4H_2O$

   The equation must always balance!