

Organic Chemistry

IGCSE Chemistry ■ Topic 11

IGCSE Chemistry



What we will cover

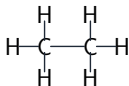
- 1 Homologous series & naming
- 2 Fuels & fractional distillation
- 3 Alkanes & cracking
- 4 Alkenes
- 5 Alcohols & acids
- 6 Polymers



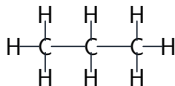
Homologous series and formulae



methane



ethane



propane



each step adds a CH_2 unit

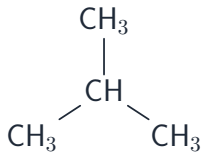
general formula $\text{C}_n\text{H}_{2n+2}$

- The **molecular formula** shows how many of each atom there are, for example C_2H_6 .
- The **displayed formula** shows every atom and every bond drawn out in full.
- The **structural formula** shows how the atoms are arranged without drawing every bond, for example $\text{CH}_3\text{CH}_2\text{OH}$.
- The **general formula** works for a whole family, for example $\text{C}_n\text{H}_{2n+2}$ for alkanes.

Structural isomers



butane (straight chain)

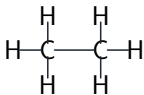


2-methylpropane (branched)

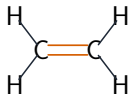
both have the formula C_4H_{10} : same formula,
different structure (structural isomers)

Structural isomers: butane and 2-methylpropane share the formula C_4H_{10} but have different structures

Saturated, unsaturated and isomers



ethane C_2H_6
saturated: single
C–C bond



ethene C_2H_4
unsaturated:
C=C double bond

- Learn each **homologous series** by its functional group and general formula: alkanes $\text{C}_n\text{H}_{2n+2}$, alkenes C_nH_{2n} , alcohols $-\text{OH}$, carboxylic acids $-\text{COOH}$.
- The **bromine water test** for unsaturation: an alkene (with its $\text{C}=\text{C}$) turns orange bromine water colourless; an alkane leaves it orange.
- **Cracking** breaks large, less useful alkanes into smaller alkanes and alkenes, using heat and a catalyst.

Naming organic compounds

endings = family

-ane alkane, -ene alkene,
-ol alcohol, -oic acid

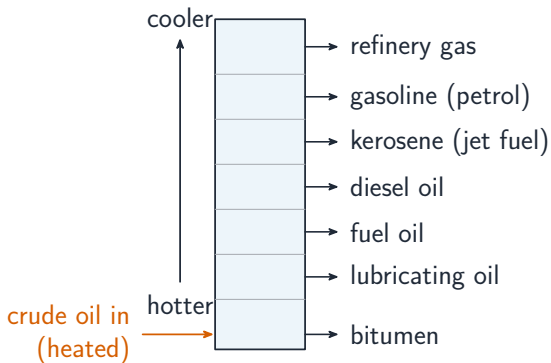
prefixes = carbons

meth- 1, eth- 2,
prop- 3, but- 4

A number locates the group: but-1-ene vs but-2-ene; propan-1-ol vs propan-2-ol.



Fuels: fractional distillation



up the column: smaller molecules,
lower boiling points, more volatile

Petroleum is split into **fractions** by boiling point in a tall column.

Top (cool): short chains, more **volatile** , low **viscosity** . Bot-
tom (hot): long chains, **bitu-
men** .

Separating crude oil

The fractionating column

Crude oil is heated and fed into a **fractionating column** that is hot at the bottom and cool at the top.

Why it works

Longer molecules have stronger forces between them, so a longer **chain length** means a higher boiling point – and it condenses lower down.

Top to bottom

Refinery gases, petrol, naphtha, kerosene, diesel, fuel oil, bitumen.

Cracking

Long fractions in surplus are cracked into short ones in demand, giving alkenes for plastics as well as petrol.

One property – chain length – explains the order, the boiling points, the viscosity and how easily each fraction burns.

The fractions, top to bottom

Fraction	What it is used for
refinery gas	gas for heating and cooking
gasoline (petrol)	fuel for cars
naphtha	raw material for making chemicals
kerosene (paraffin)	fuel for aircraft
diesel oil	fuel for lorries and some cars
fuel oil	fuel for ships and home heating
bitumen	surfacing roads and roofs

Going **up** the column the chains get shorter: lower boiling point, higher **volatility** , lower **viscosity** , and they burn more easily.

Alkanes

combustion

burn in $\text{O}_2 \rightarrow \text{CO}_2 + \text{water}$

substitution

+ Cl_2 in **UV light**

Alkanes are **saturated** & generally unreactive. $\text{CH}_4 + \text{Cl}_2 \rightarrow \text{CH}_3\text{Cl} + \text{HCl}$ (a photochemical reaction).

Cracking

large alkane molecule



heat + catalyst



smaller alkane + alkene (C=C)

Cracking breaks a big alkane into a smaller alkane + an **alkene**, using heat & a catalyst. It makes useful small molecules & alkenes for plastics.



Alkenes and the bromine test

shake with orange bromine water



alkene:
turns colourless



alkane:
stays orange

The $C=C$ makes alkenes reactive (**addition reactions**).

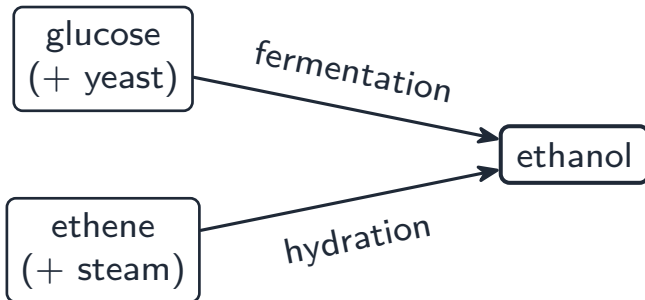
Test: shake with orange **bromine water**. An alkene **decolourises** it; an alkane does not.

Alcohols and ethanol

Ethanol (-OH) two ways:

- **fermentation** of glucose (yeast; renewable, slow)
- **hydration** of ethene (steam + catalyst; fast, pure)

Used as a fuel & **solvent** .



Two routes to ethanol, and what it becomes

Fermentation

Sugar with yeast at about 30°C , no air – renewable, slow, and it gives a dilute product.

Hydration

Ethene plus steam over a catalyst – fast and pure, but it starts from crude oil.

Oxidation

Ethanol oxidises to **ethanoic acid** – which is what turns wine into **vinegar**.

Elsewhere in the topic

A **substitution reaction** swaps one atom for another – methane and chlorine under **ultraviolet light** – and **nickel** is the catalyst that adds hydrogen to an alkene.

Compare the two routes on the same three axes: raw material, energy, and purity of product.

Making ethanol, and making ethanoic acid

fermentation

glucose with yeast, about 30°C , no air – slow, batch, and it uses a renewable feedstock

hydration of ethene

steam over a phosphoric acid catalyst, high temperature and pressure – fast, continuous, and it uses crude oil

the trade

fermentation is renewable and impure; hydration is pure and depends on a finite resource

oxidation of ethanol

gives ethanoic acid, using acidified **potassium manganate(VII)** or potassium dichromate(VI)

the acid's reactions

with metals, carbonates and alkalis – like any acid, and the salts formed are called **ethanoates**

lubricating oil

one of the crude-oil fractions – used for lubricants, waxes and polishes

The two routes to ethanol is a standard compare-and-evaluate question. Name the conditions for each **and** say which resource it depends on.

Carboxylic acids and esters

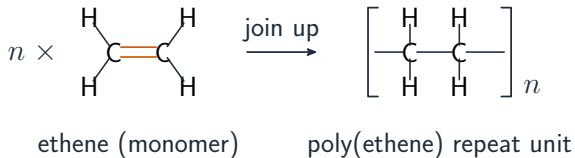


Carboxylic acids ($-\text{COOH}$) react with metals, bases & carbonates (giving ethanoates).

Acid + alcohol $\xrightarrow{\text{catalyst}}$ an **ester** + water.



Polymers



A **polymer** joins many **monomers** .

- **addition** – alkenes join, no other product
- **condensation** – water lost (nylon, PET)

Many plastics do not break down.

Fuels



The three **fossil fuels** are **coal** , **natural gas** and **petroleum** . **Methane** is the main part of natural gas; petroleum is a mixture of **hydrocarbons** – compounds of hydrogen and carbon *only*.

Plastics and the environment



Most plastics are non-biodegradable, so waste plastic collects on beaches and in the oceans for hundreds of years

The two condensation polymers, and the plastic problem

polyamides

made from a dicarboxylic acid and a diamine; **nylon** is one

polyesters

made from a dicarboxylic acid and a diol; PET is one, and it can be recycled

what is lost

a small molecule – water, or HCl – at every link formed

why plastics persist

most are non-biodegradable, so they build up in landfill sites

in the sea

they collect in the oceans and harm sea life

burning them

releases carbon dioxide, and toxic gases from some plastics

Two functional groups per monomer is what makes a chain possible. That is why a diacid needs a diamine or a diol, not a simple alcohol.

Two condensation polymers, two linkages

Condensation polymerisation

Condensation polymerisation joins monomers and expels a small molecule – usually water – at each join.

Ester linkage

A diol plus a dicarboxylic acid gives a polyester, joined by the **ester linkage** —COO— .

Amide linkage

A diamine plus a dicarboxylic acid gives a polyamide (nylon), joined by the **amide linkage** —CONH— .

The repeat unit

Draw the **repeat unit** with a bond crossing each bracket – that is what shows the chain continues.

Addition polymers keep every atom; condensation polymers lose a small molecule at every link. That is the whole difference.

Proteins

They are made from **amino acid** monomers joined in long chains.

Exam tips

- Learn each **homologous series** by its functional group and general formula: alkanes C_nH_{2n+2} , alkenes C_nH_{2n} , alcohols $-OH$, carboxylic acids $-COOH$.
- The **bromine water test** for unsaturation: an alkene (with its $C=C$) turns orange bromine water colourless; an alkane leaves it orange.
- **Cracking** breaks large, less useful alkanes into smaller alkanes and alkenes, using heat and a catalyst.
- Two routes to **ethanol**: fermentation of glucose (renewable but slow and impure) and adding steam to ethene (fast and pure, but from petroleum).
- **Addition** polymerisation joins unsaturated monomers with no other product; **condensation** polymerisation joins monomers and loses a small molecule (usually water) each time.



Worked example – alkane or alkene?

Two colourless liquids are ethane and ethene. Give a test that tells them apart.

- Add **aqueous bromine** and shake.
- Ethene has a **C=C double bond**: it **adds** bromine across it.
- The bromine is **decolourised** (orange → colourless): ethene.
- Ethane is **saturated** – no double bond – so the bromine **stays orange**.

“Decolourised” means **orange** → **colourless**, not “turns white”. Unsaturated = has C=C = decolourises bromine water.

Topic 11 – key takeaways

1

Series

same functional group; differ by CH_2

2

Fuels

fractional distillation by boiling point

3

Alkenes

$\text{C}=\text{C}$; decolourise bromine water

4

Polymers

addition (alkenes) & condensation

Check yourself

- 1 What is the general formula of the alkanes?
- 2 How are crude oil fractions separated?
- 3 What does an alkene do to bromine water?
- 4 What two things join in addition polymerisation?



Answers 1. C_nH_{2n+2} 2. fractional distillation 3. decolourises it (orange to colourless)
4. many alkene monomers