Organic Chemistry

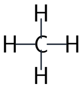
IGCSE Chemistry ▪ Topic 11

IGCSE Chemistry

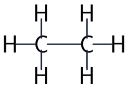
What we will cover

1 Families

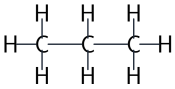
Homologous series and formulae



methane
CH_4



ethane
C_2H_6



propane
C_3H_8

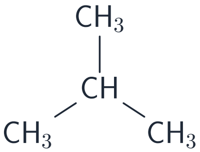
each step adds a CH_2 unit general formula C_nH_{2n+2}

- The **molecular formula** 分子式 shows how many of each atom there are, for example C_2H_6.
- The **displayed formula** 结构式 shows every atom and every bond drawn out in full.
- The **structural formula** 结构简式 shows how the atoms are arranged without drawing every bond, for example CH_3CH_2OH.
- The **general formula** 通式 works for a whole family, for example

Structural isomers

$$CH_3{-}CH_2{-}CH_2{-}CH_3$$

butane (straight chain)

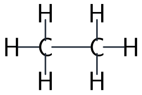


2-methylpropane (branched)

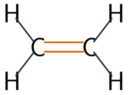
both have the formula C_4H_{10}: same formula, different structure (structural isomers)

> 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 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.

Naming organic compounds

endings = family

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

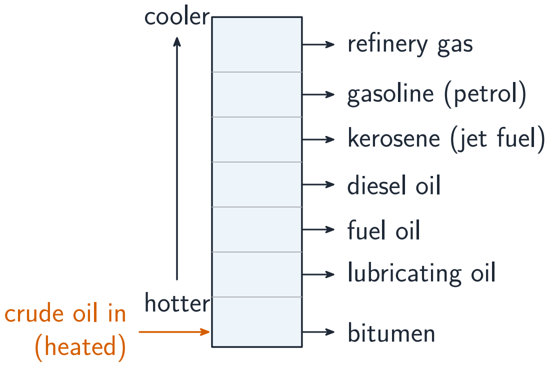
prefixes = carbons

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.

2 Fuels and alkanes

Fuels: fractional distillation



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

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

> Top (cool): short chains, more **volatile** 挥发性, low **viscosity** 黏度. Bottom (hot): long chains, **bitumen** 沥青.

Separating crude oil

The fractionating column	Crude oil is heated and fed into a **fractionating column** 分馏塔 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** 链长 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** 挥发性, lower **viscosity** 黏度, and they burn more easily.

Alkanes

combustion 燃烧

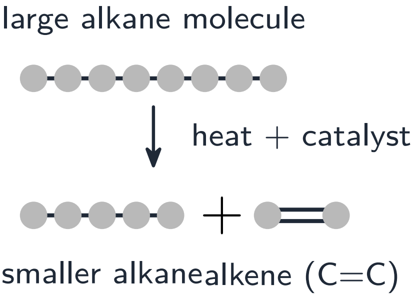
burn in $O_2 \rightarrow CO_2 + \text{water}$

substitution 取代反应

$+ Cl_2$ in **UV light** 紫外线

Alkanes are saturated & generally unreactive. $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$ (a photochemical reaction).

Cracking

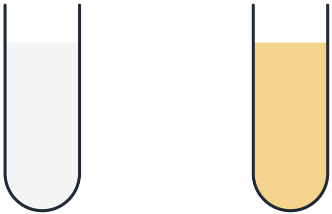


Cracking 裂化 breaks a big alkane into a smaller alkane + an alkene, using heat & a catalyst. It makes useful small molecules & alkenes for plastics.

3 Alkenes, alcohols, acids

Alkenes and the bromine test

shake with orange bromine water



alkene:
turns colourless

alkane:
stays orange

The C=C makes alkenes reactive (**addition reactions** 加成反应).

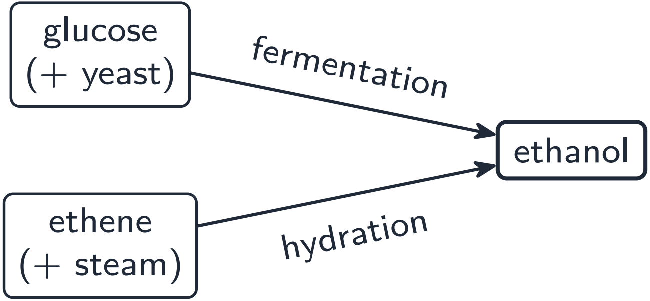
> Test: shake with orange **bromine water** 溴水. An alkene decolourises it; an alkane does not.

Alcohols and ethanol

Ethanol 乙醇 (–OH) two ways:

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

Used as a fuel & **solvent** 溶剂.



Two routes to ethanol, and what it becomes

Fermentation	Sugar with yeast at about $30\,^{\circ}\mathrm{C}$, 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** 乙酸 – which is what turns wine into **vinegar** 醋.
Elsewhere in the topic	A **substitution reaction** 取代反应 swaps one atom for another – methane and chlorine under **ultraviolet light** 紫外线 – and **nickel** 镍 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 氧化 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

$$\boxed{\text{carboxylic acid}} + \boxed{\text{alcohol}} \xrightarrow{\text{acid catalyst}} \boxed{\text{ester}} + \text{water}$$

Carboxylic acids 羧酸 (–COOH) react with metals, bases & carbonates (giving ethanoates).

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

4 Polymers

Polymers

ethene (monomer) poly(ethene) repeat unit

A **polymer** 聚合物 joins many **monomers** 单体.

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

Many plastics do not break down.

Fuels

The three **fossil fuels** 化石燃料 are **coal** 煤, **natural gas** 天然气 and **petroleum** 石油. **Methane** 甲烷 is the main part of natural gas; petroleum is a mixture of **hydrocarbons** 碳氢化合物 – 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 聚酰胺	made from a dicarboxylic acid and a diamine; **nylon** 尼龙 is one
polyesters 聚酯	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** 填埋 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** 缩聚 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** 酯键 −COO−.
Amide linkage	A diamine plus a dicarboxylic acid gives a polyamide (nylon), joined by the **amide linkage** 酰胺键 −CONH−.
The repeat unit	Draw the **repeat unit** 重复单元 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 氨基酸** 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.

5 Recap

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 $\rightarrow$ colourless): ethene.
- Ethane is saturated – no double bond – so the bromine stays orange.

"Decolourised" means orange $\rightarrow$ 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

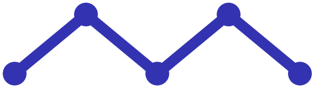
C=C; decolourise bromine water

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