

7 • Organic chemistry

AQA • GCSE • Chemistry

Organic chemistry: choose the reaction

A refinery can separate crude oil, break large molecules into smaller ones, or use small molecules to make polymers. These are three different processes. Distillation changes which molecules are collected together; cracking changes molecules; polymerisation joins monomers into chains. Choose the process from the evidence, not from the word “heat”.

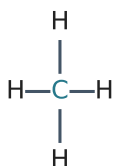
This reference covers AQA 8462 sections 4.7.1–4.7.3. The named organic families and addition polymers are Separate Chemistry content on both tiers. **Higher Tier (HT)** is marked for weak-acid explanations, condensation polymers and amino-acid condensation. Recognising natural-polymer monomers is both-tier content.

Crude oil and alkane structures (4.7.1.1)

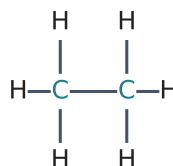
Crude oil is a finite resource found in rocks. It formed from ancient biomass, mainly plankton buried in mud. Formation is too slow to replace present consumption on a human timescale. It is a mixture of many compounds, most of them **hydrocarbons**: compounds containing hydrogen and carbon only. Ethanol contains oxygen, so it is not a hydrocarbon.

Most crude-oil hydrocarbons are **alkanes**. Their open-chain saturated series has general formula C_nH_{2n+2} . Carbon makes four bonds and hydrogen one. A molecular formula counts atoms; a displayed formula shows every atom and bond. The four required names are methane, ethane, propane and butane.

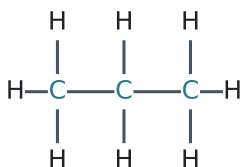
Methane • CH_4



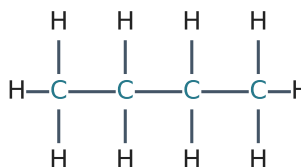
Ethane • C_2H_6



Propane • C_3H_8



Butane • C_4H_{10}

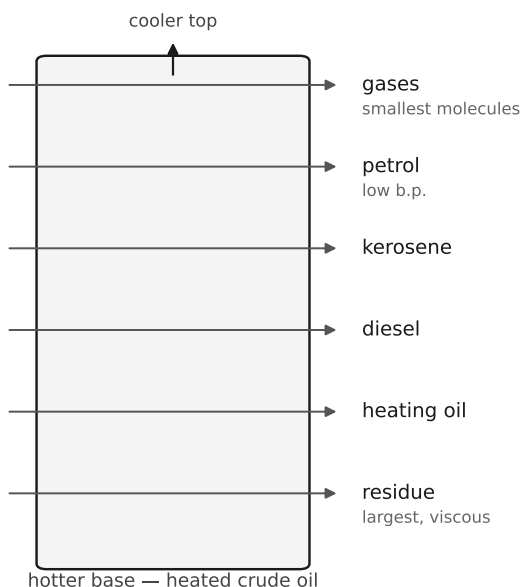


Worked check. A supplied open-chain alkane has six carbon atoms. Its hydrogen count is $H = 2n + 2 = 2 \times 6 + 2 = 14$, giving C_6H_{14} . This does not give a formula for

the whole crude-oil mixture. Names beyond the first four are not required recall here.

Fractions and fuel choices (4.7.1.2–4.7.1.3)

Fractional distillation separates the mixture physically. Heat crude oil so that many components vaporise. Vapours rise through a column that is hotter at the bottom and cooler at the top. Higher-boiling components condense lower down; lower-boiling components rise further before condensing. The lowest-boiling gases can leave at the top. Each **fraction** contains several hydrocarbons with similar boiling points and carbon numbers; it is not one pure compound. Covalent carbon chains are not broken by boiling.



For comparable hydrocarbons, increasing molecule size increases boiling point and **viscosity**, but decreases **flammability**. Viscosity means resistance to flow. A viscous fuel may flow poorly through a narrow supply tube; easy ignition matters for starting a burner. Do not substitute a density trend or claim one property determines every use.

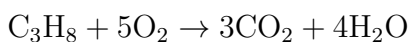
Fractions supply petrol, diesel oil, kerosene, heavy fuel oil and liquefied petroleum gases. They also provide **feedstock**: starting materials for solvents, lubricants, polymers and detergents. Fuels are burned for energy; feedstocks are converted into other useful chemicals.

Worked choice. Fictional fractions P and Q have comparable flow times of 8 s and 24 s. P also ignites more readily. P better meets a stated need for easy flow and ignition. The time ratio $r = 24/8 = 3$ describes this test; it does not prove Q's viscosity is exactly three times P's without a calibrated relation.

Combustion and cracking (4.7.1.3–4.7.1.4)

Complete combustion oxidises carbon to carbon dioxide and hydrogen to water, releasing energy. Start with the fuel formula and balance carbon, then hydrogen, then oxygen. Do not change the formula subscripts to balance an equation.

Worked combustion. Propane contains three C atoms and eight H atoms, so one molecule forms three carbon dioxide and four water molecules. These products contain ten O atoms, requiring five oxygen molecules:



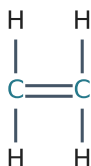
Cracking breaks large hydrocarbons into smaller, more useful molecules. Catalytic cracking passes vaporised hydrocarbons over a hot catalyst. Steam cracking mixes hydrocarbon vapour with steam at a very high temperature. Recall these general conditions, not one compulsory numerical temperature. Products include alkanes and alkenes. Smaller fuels are in high demand; alkenes are chemical feedstock for polymers and other products.

Worked cracking. In $\text{C}_{10}\text{H}_{22} \rightarrow \text{C}_8\text{H}_{18} + \text{X}$, subtract atoms: $C(\text{X}) = 10 - 8 = 2$ and $H(\text{X}) = 22 - 18 = 4$. Thus $\text{X} = \text{C}_2\text{H}_4$, ethene. Both C and H balance. Real cracking can give a mixture; do not claim every large molecule always splits into precisely these two products.

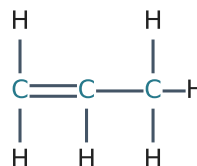
Alkene structures and addition (4.7.2.1–4.7.2.2)

An **alkene** has a carbon–carbon double bond, $\text{C}=\text{C}$. The double bond is its **functional group**, which gives characteristic reactions. Open-chain alkenes with one $\text{C}=\text{C}$ have formula C_nH_{2n} . They are **unsaturated**: two fewer H atoms than the corresponding alkane. Formula alone does not locate the double bond. Butene and pentene below show one terminal-double-bond arrangement.

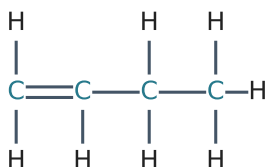
Ethene · C_2H_4



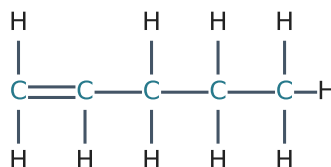
Propene · C_3H_6



Butene · C_4H_8



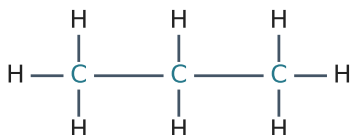
Pentene · C_5H_{10}



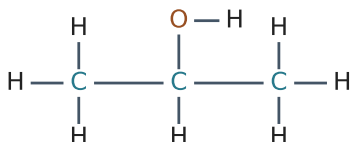
In **addition** , $C=C$ becomes $C-C$ and atoms from the other reactant attach to the two former double-bond carbons. Keep the carbon skeleton and existing hydrogens. Check carbon valency four after drawing.

- Hydrogen: use heated nickel catalyst; one H joins each carbon, making an alkane.
- Water: use steam, high temperature and pressure, with a phosphoric-acid catalyst; H and OH add across $C=C$, making an alcohol. For a longer alkene, show the stated OH position rather than assuming the molecular formula fixes it.
- Halogens: one atom from Cl_2 , Br_2 or I_2 joins each carbon. Chlorine/bromine addition is described at room temperature; do not promise identical speed or completion for iodine. No hydrogen is removed in the addition model.

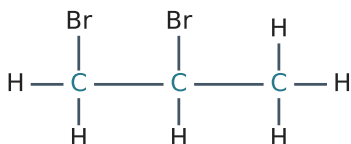
Propene + $H_2 \rightarrow$ propane · heated nickel



Propene + steam $\rightarrow$ shown OH-position product · acid catalyst



Propene + $Br_2 \rightarrow$ dibromo product · no H removed

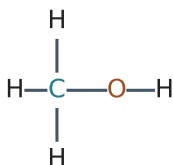


Bromine-water test. In the controlled alkane/alkene comparison, an alkene changes orange bromine water to colourless. The alkane control stays orange under these conditions. This supports unsaturation; it does not uniquely identify ethene. Use approved microscale demonstrations, not independent handling of elemental halogens. Alkenes tend to burn in air with smoky flames because combustion is incomplete. With sufficient oxygen their complete combustion still forms carbon dioxide and water. For ethene, $C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$. Hydrogen addition is a different reaction from burning in oxygen.

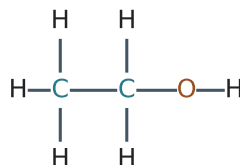
Alcohols and fermentation (4.7.2.3)

Alcohols contain $-OH$. Learn methanol, ethanol, propanol and butanol. The longer examples shown are the primary straight-chain forms; another OH position can change oxidation behaviour.

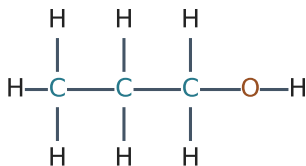
Methanol



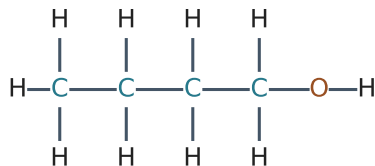
Ethanol



Propanol · primary form shown

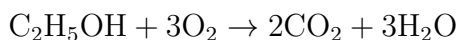


Butanol · primary form shown



Describe four changes for these taught alcohols: sodium gives fizzing as hydrogen forms; combustion releases energy; adding to water gives an aqueous mixture, with mixing behaviour depending on the alcohol and amounts; an oxidising agent converts the taught primary form to its corresponding carboxylic acid. Longer alcohols mix less readily with water than the shorter members. Do not claim unlimited solubility for all four.

Alcohols are fuels, solvents and chemical feedstocks. Their ability to burn supports fuel use, while dissolving suitable substances supports solvent use. Only balanced combustion equations are required here for alcohol reactions. For ethanol, count its own oxygen atom as well as supplied oxygen:



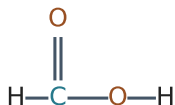
Fermentation makes aqueous ethanol from sugar solution using yeast under warm, oxygen-free conditions. Yeast enzymes convert sugar to ethanol and carbon dioxide. Cold conditions slow enzyme action; excessive heat damages the enzymes/yeast. The product is an ethanol solution, not pure ethanol. Industrial ethene hydration uses steam and a catalyst instead of yeast and sugar.

For a supervised comparison, keep sugar concentration, yeast amount, temperature and collection time matched; include a yeast-free control and record raw gas observations. An approved airlock lets carbon dioxide escape while restricting incoming air. Never tightly seal a gas-producing vessel. Gas alone does not measure ethanol purity or prove every bubble came from fermentation. Written planning does not certify the practical activity.

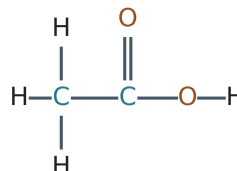
Carboxylic acids and esters (4.7.2.4)

Carboxylic acids contain -COOH , with C=O and O-H attached to the same carbon. That carbon counts in the chain. The first four are methanoic, ethanoic, propanoic and butanoic acids.

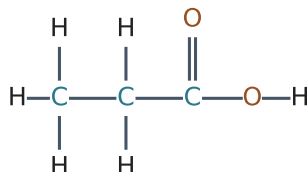
Methanoic acid



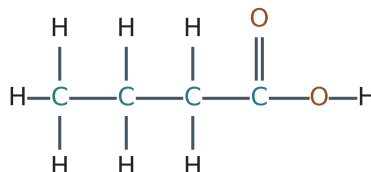
Ethanoic acid



Propanoic acid



Butanoic acid



They dissolve in water to form acidic solutions. With carbonates they form a salt, water and carbon dioxide: fizzing is an observation, and carbon dioxide turns limewater milky. With an alcohol they form an **ester** and water. Ethanoic acid + ethanol gives **ethyl ethanoate** + water. Recognise the ester link C(=O)-O-C ; do not call its entire group an alcohol OH . No other ester name or balanced acid-reaction equation is required recall here. Teacher-approved ester preparation uses selected reagents, controlled warming and safe waste handling.

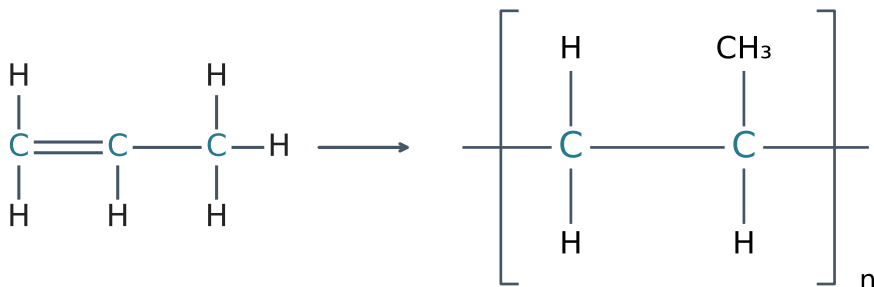
HT: weak means partially ionised. A weak carboxylic acid forms only some hydrogen ions in water. At the same stated molar acid concentration, a strong monoprotic acid produces more H^+ and has a lower pH. Weak does not mean dilute: concentration and fraction ionised are different ideas. Compare like conditions before using pH as evidence of acid strength.

Addition polymers and side groups (4.7.3.1)

Many alkene **monomers** join by **addition polymerisation**. Only the two former C=C carbons become neighbouring backbone positions; attached side groups stay attached. Every monomer atom remains in the **repeating unit**, and no small-molecule by-product forms.

Propene monomer

Repeat: methyl side group retained



C_3H_6 per repeat · all atoms retained · no small by-product

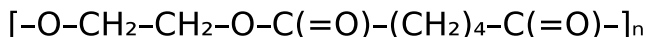
Worked method. Trace the two $\text{C}=\text{C}$ carbons in $\text{CH}_2=\text{CH}-\text{CH}_3$. Replace $\text{C}=\text{C}$ by $\text{C}-\text{C}$; copy the hydrogens and CH_3 side group. Add single continuation bonds through both brackets and write n outside: the interior is $-\text{CH}_2-\text{CH}(\text{CH}_3)-$. Each backbone carbon still has four bonds. Reverse the method to find the monomer: remove continuation bonds and restore $\text{C}=\text{C}$ between those two carbons. Do not put every carbon of the molecule into a three-carbon backbone.

For twelve shown propene-derived units, total carbon count $N_{\text{C}} = 12 \times 3 = 36$: 24 backbone and 12 side-group carbons. Unspecified chain end groups are not included in this repeat-interior count.

HT: condensation and amino acids (4.7.3.2–4.7.3.3)

Condensation polymerisation joins monomers with two functional groups while losing a small molecule, usually water in these examples. One functional group at each end lets the chain extend. A diol with two $-\text{OH}$ groups and a diacid with two $-\text{COOH}$ groups form a **polyester** with repeated ester links.

HT: ethanediol + hexanedioic acid



Ester links: $\text{C}(=\text{O})-\text{O}$ · each actual link releases one H_2O

Ideal repeat interior; finite-chain end groups omitted

The diol contributes $-\text{O}-\text{CH}_2-\text{CH}_2-\text{O}-$; the diacid contributes $-\text{C}(=\text{O})-(\text{CH}_2)_4-\text{C}(=\text{O})-$. Each actual link releases one water molecule. A finite open chain made from three diols and three diacids joins six molecules through five links, losing five waters. Ideal repeating-unit shorthand omits end groups; do not apply its water count blindly to a finite chain or a ring.

An **amino acid** carries an amino group and a carboxylic-acid group. Glycine is $\text{H}_2\text{N}-\text{CH}_2-\text{COOH}$. Condensation forms a **polypeptide**; different amino acids can occur within one chain to make proteins.

HT: glycine has amino and carboxylic-acid groups



Each actual joining link releases one H₂O

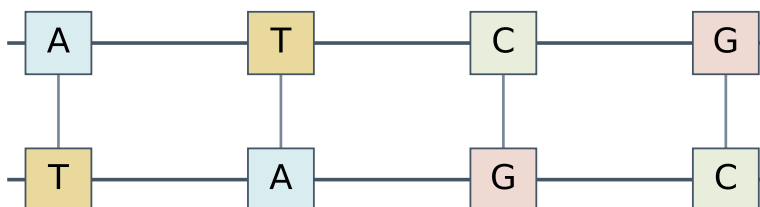
Repeat interior; finite-chain terminal groups omitted

Worked finite-chain check. Four glycine molecules in one open chain make three joining links and three water molecules. If supplied relative masses are glycine 75 and water 18, the chain's relative mass is $M_r = 4 \times 75 - 3 \times 18 = 246$. This calculation uses the supplied model; no additional mechanism is required.

Natural polymers and final checks (4.7.3.4)

Most DNA molecules have two polymer chains made from four types of **nucleotide**, arranged as a **double helix**. DNA encodes genetic instructions. A nucleotide is the whole monomer, not just its base label. Proteins have amino-acid monomers; starch and cellulose both have glucose monomers. Sharing a monomer does not make two polymers identical: their arrangements and roles can differ.

DNA: two chains · four nucleotide types · flattened before twisting



Each base-labelled block represents a whole nucleotide; not to molecular scale

Check yourself: explain physical separation versus cracking; balance a new combustion equation; draw a displayed alkene addition product without losing H; distinguish fermentation from steam hydration; recover a monomer from a repeat; and count actual links in a supplied finite condensation chain. Mark HT explanations separately from both-tier recognition.