Organic chemistry

Pearson Edexcel · International GCSE · Chemistry

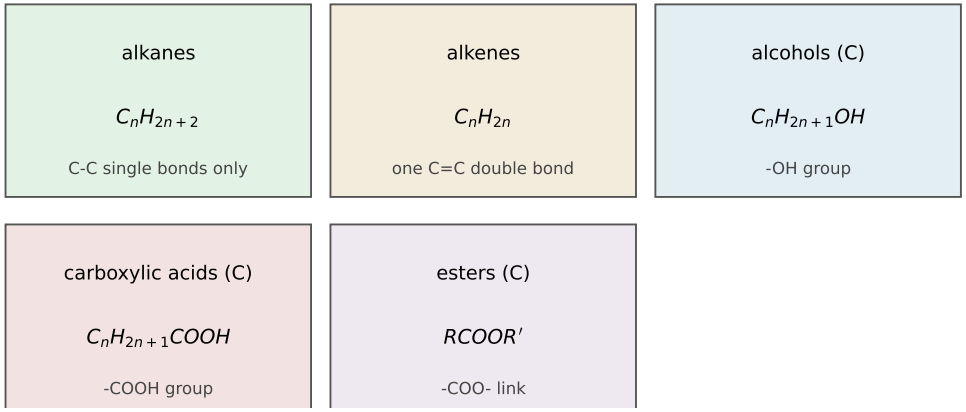
Carbon's family tree

Crude oil is a mixture of hydrocarbons – compounds of carbon and hydrogen only – built from the smallest molecules in the gas fraction to the tars of bitumen. This section organises them into families, follows crude oil from well to fraction, and then meets each family in turn: the unreactive alkanes, the double-bonded alkenes, and (C) the alcohols, acids, esters and polymers that come after.

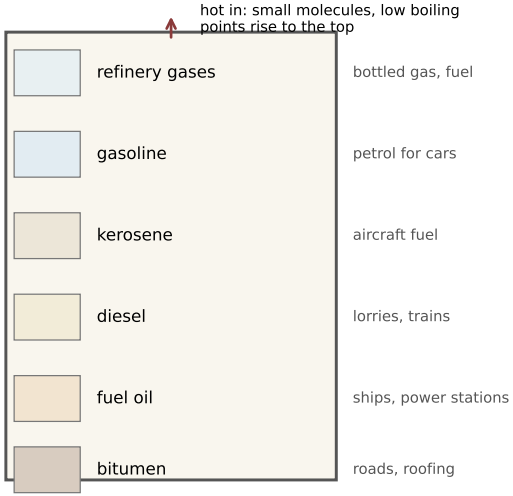
Edexcel International GCSE Chemistry 4CH1, Section 4 (statements 4.1–4.50C) closes the course. C-suffixed statements are Chemistry-only.

Introduction and crude oil

A **hydrocarbon** holds hydrogen and carbon only. Molecules are drawn as empirical, molecular, general, structural and **displayed formulae**. A **homologous series** shares a general formula and **functional group**, members differing by CH_2; **isomerism** – **isomers** share a molecular formula with different structures. IUPAC naming runs to six carbons.



Crude oil separates by **fractional distillation**: the furnace vaporises the oil, and vapours rise up the column, cooling as they go – small molecules with low boiling points collect at the top, large viscous molecules at the bottom.



Fractions darken and thicken down the column (rising boiling point and viscosity). **Complete combustion** gives $CO_2 + H_2O$; **incomplete combustion** also gives carbon monoxide – poisonous because it reduces the blood's oxygen-carrying capacity – and soot. In engines, hot air makes nitrogen and oxygen combine into oxides of nitrogen; sulfur impurities burn to SO_2; both gases dissolve in rain making it acidic (acid rain damages leaves, lakes and buildings). **Cracking** converts long-chain alkanes to alkenes + shorter alkanes over silica/alumina at 600–700 °C – because the refinery's supply of long fractions outstrips demand while short fractions are wanted.

Alkanes and alkenes

Alkanes (C_nH_{2n+2}) are **saturated** – only single C–C bonds. Methane, ethane, propane, butane, pentane. With halogens in **ultraviolet light** they substitute one hydrogen: $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$ (substitution).

Alkenes (C_nH_{2n}) carry **C=C** – **unsaturated**. With bromine they add across the double bond to a dibromoalkane (addition): $C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$. **Bromine water** distinguishes them: decolourised (orange → colourless) by an alkene, unchanged by an alkane.

Alcohols, acids and esters (C)

Alcohols carry **–OH**: methanol, ethanol, propan-1-ol, butan-1-ol. Complete combustion of ethanol produces carbon dioxide and water. Ethanol oxidises to ethanoic acid by microbial oxidation in air or by warming with potassium dichromate(VI) in dilute sulfuric acid. Ethanol is made by **ethene + steam** over a phosphoric acid catalyst (≈300 °C, 60–70 atm) or by **fermentation** of glucose with yeast enzymes in the absence of air at ≈30 °C – the optimum for the enzymes, and no oxygen so the

yeast produces ethanol not water.

Carboxylic acids carry **–COOH**: methanoic, ethanoic, propanoic, butanoic. Their solutions react with metals (giving H_2) and carbonates (giving CO_2) like other acids; vinegar is dilute ethanoic acid.

Esters carry **–COO–**: ethanol + ethanoic acid, with an acid catalyst, give **ethyl ethanoate** and water (esterification). Given an alcohol and an acid, join the acid's –COOH to the alcohol's –O–. Esters are volatile, sweet-smelling, used as flavourings and perfumes.

Synthetic polymers

Addition polymers form when many alkene **monomers** join, opening their C=C bonds.

monomer: ethene repeat unit of poly(ethene)

$$H_2C = CH_2 \longrightarrow -[CH_2 - CH_2]-_n$$

open the C=C double bond, draw the two bonds out to the brackets

Draw the repeat unit of poly(ethene), poly(propene), poly(chloroethene), PTFE; from a repeat unit, close the two bonds back into a C=C to recover the monomer. Disposal problems: these addition polymers resist many chemical reactions and do not readily biodegrade, and burning can release toxic gases. (C) **Condensation polymerisation**: a dicarboxylic acid + a diol link ester bonds, releasing water – a **polyester** ; some (biopolyesters) biodegrade.

Check yourself

1. Define hydrocarbon, homologous series and isomerism.
2. Name the six main fractions of crude oil in boiling-point order.
3. Write the products of complete and incomplete combustion of a hydrocarbon.
4. Give two pollutant gases from burning fuels and one source of each.
5. Why is cracking necessary?
6. Write the equation for methane reacting with chlorine in UV light, naming the reaction type.
7. How does bromine water distinguish an alkene from an alkane?
8. (C) Name the two methods of manufacturing ethanol with one condition for each.
9. (C) Which alcohol and acid make ethyl ethanoate, and what else forms?
10. (C) What monomers make a polyester, and what small molecule is released?

Answers: 1 a compound of hydrogen and carbon only; a family with the same general formula and functional group, differing by CH_2; molecules with the same molecular formula but different structures; 2 refinery gases, gasoline, kerosene, diesel, fuel oil, bitumen; 3 complete: carbon dioxide + water; incomplete adds carbon monoxide (and soot); 4 carbon monoxide – incomplete combustion; sulfur dioxide – burning sulfur impurities; oxides of nitrogen – hot engine air; 5 supply of long-chain fractions exceeds demand while short fractions and alkenes are in short supply; 6 $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$ – substitution (photo, UV); 7 the alkene decolourises orange bromine water; the alkane leaves it orange; 8 (C) ethene + steam, phosphoric acid catalyst, ~300 °C, 60–70 atm; fermentation of glucose with yeast, no air, ~30 °C; 9 (C) ethanol + ethanoic acid – water also forms (acid catalyst); 10 (C) a dicarboxylic acid and a diol; water is released at each ester link.