Topic 7: Organic chemistry

AQA GCSE Chemistry (8462), topic 4.7

Organic chemistry: choose the reaction

- explain how **crude oil** is separated into fractions, and how the properties of hydrocarbons change with chain length;
- balance combustion equations and explain why **cracking** is needed;
- (chemistry only) describe the reactions of alkenes, alcohols and carboxylic acids;

Organic chemistry: choose the reaction (2)

- (chemistry only) draw **addition** polymers from their monomers and back again;
- (chemistry only, higher tier) explain condensation polymers, and recognise the monomers of natural polymers.

Crude oil and the alkanes

- **Crude oil** is a finite resource found in rocks.
- It formed over millions of years from the remains of plankton buried in mud, so it is not being replaced as fast as we use it.
- **Crude oil** is a mixture of a very large number of compounds.
- Most of them are each a **hydrocarbon** : a compound of hydrogen and carbon only.

Fractional distillation and fuels

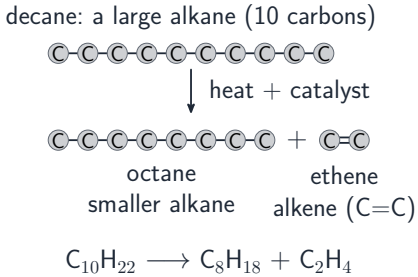
- the boiling point increases;
- the **viscosity** increases: the liquid is thicker and flows less easily;
- the **flammability** decreases: it is harder to set alight.

$$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$$

Cracking and alkenes

- **Crude oil** contains more large hydrocarbons than we need, and fewer small ones such as petrol. **Cracking** breaks long **hydrocarbon** molecules into shorter, more useful ones.
- In catalytic **cracking**, the vapour is passed over a hot catalyst; in steam cracking, it is mixed with steam at a very high temperature.
- Cracking makes smaller alkanes, which are useful fuels, and alkenes, which are used to make polymers and other chemicals.
- **Worked example 4.** Balance $\mathrm{C_{10}H_{22}} \rightarrow \mathrm{C_8H_{18}} + \mathrm{X}$.

Figure: Cracking and alkenes



- Heat and a catalyst break the chain.
- One product is always an **alkene**.

Reactions of alkenes (chemistry only)

- With hydrogen, using a nickel catalyst at about 60 °C, an **alkene** becomes an **alkane**.
- With steam, at a high temperature and pressure with a phosphoric acid catalyst, it becomes an **alcohol**: H adds to one carbon and OH to the other.
- With chlorine, bromine or iodine, one halogen atom adds to each carbon. This is why alkenes decolourise bromine water.

Alcohols (chemistry only)

- react with sodium, fizzing as hydrogen is given off;
- burn in air, releasing energy, so they are used as fuels;
- dissolve in water to form a neutral solution (the smaller ones mix completely);
- are oxidised to carboxylic acids by oxidising agents: ethanol becomes ethanoic acid, which is why wine turns to vinegar if it is left open.

$$\mathrm{C_2H_5OH} + 3\mathrm{O_2} \rightarrow 2\mathrm{CO_2} + 3\mathrm{H_2O}$$

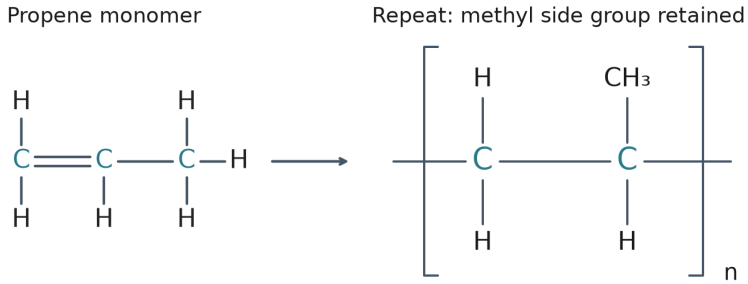
Carboxylic acids and esters (chemistry only)

- Each **carboxylic acid** contains the –COOH group.
- The carbon in this group counts as part of the chain.
- The first four are methanoic, ethanoic, propanoic and butanoic acid; ethanoic acid is the acid in vinegar.
- Carboxylic acids dissolve in water to make acidic solutions.

Addition polymers (chemistry only)

- **Alkene** molecules can join together into very long chains.
- Each small molecule is a **monomer** , and this kind of reaction is **addition polymerisation** .
- The double bonds open and the monomers join end to end.
- All the atoms of the **monomer** stay in the polymer, and nothing else is made.

Figure: Addition polymers (chemistry only)



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

- Only the two C=C carbons enter the backbone; the methyl side group remains.
- All **monomer** atoms remain; no small by-product forms.

Condensation polymers and natural polymers (chemistry only)

- DNA is two polymer chains wound into a **double helix** ; each chain is made from four different monomers, each a **nucleotide** . DNA carries the genetic instructions for living things.
- Proteins are polymers of amino acids.
- Starch and cellulose are both polymers of glucose, but the glucose units are joined differently, so starch stores energy in plants while cellulose makes their cell walls.

Figure: Condensation polymers and natural polymers (chemistry only)

HT: ethanediol + hexanedioic acid

$$HO\text{–}CH_2\text{–}CH_2\text{–}OH \quad + \quad HOOC\text{–}(CH_2)_4\text{–}COOH$$

$$\downarrow$$

$$[\text{–}O\text{–}CH_2\text{–}CH_2\text{–}O\text{–}C(=O)\text{–}(CH_2)_4\text{–}C(=O)\text{–}]_n$$

Ester links: C(=O)–O · each actual link releases one H_2O

Ideal repeat interior; finite-chain end groups omitted

- Diol and diacid residues alternate through **ester** links.
- Each actual condensation link releases one water molecule.

Figure: Condensation polymers and natural polymers (chemistry only)

HT: glycine has amino and carboxylic-acid groups

$$H_2N\text{–}CH_2\text{–}C(=O)\text{–}OH \longrightarrow [\text{–}NH\text{–}CH_2\text{–}C(=O)\text{–}]_n$$

–NH_2: amino group
–COOH: acid group

Peptide link across repeats:
C(=O)–NH

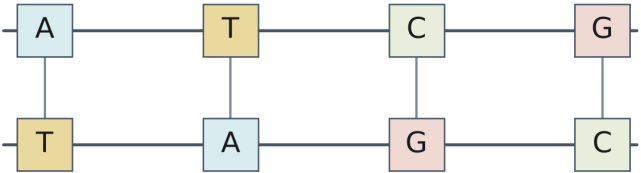
Each actual joining link releases one H_2O

Repeat interior; finite-chain terminal groups omitted

- Glycine has amino and carboxylic-acid groups; different amino acids can share a protein chain.
- The repeat interior omits finite-chain terminal groups.

Figure: Condensation polymers and natural polymers (chemistry only) · ·

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



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

- Most DNA has two nucleotide-polymer chains arranged as a **double helix**.
- Each base-labelled block represents a whole **nucleotide**.

Sources for this lesson

- AQA, *GCSE Chemistry (8462) specification*, section 4.7.
- ICI, laboratory notebook of E. W. Fawcett and R. O. Gibson (27 March 1933), and Royal Society of Chemistry, "The discovery of polythene" (National Historic Chemical Landmark, Northwich).
- J. R. Whinfield and J. T. Dickson, British patent 578,079 (1941), the first **polyester** (PET).
- J. D. Watson and F. H. C. Crick, "Molecular structure of nucleic acids", *Nature* (25 April 1953).

Common errors

- Saying **fractional distillation** breaks molecules; that is **cracking**. Distillation only separates them.
- Saying a **fraction** is a single compound; it is a mixture with similar boiling points.
- Saying bigger hydrocarbons are more flammable; they are less flammable.

Common errors (2)

- Losing atoms when drawing an **addition** product; every atom of both reactants stays.
- Putting every carbon of the **monomer** into the polymer backbone; side groups like CH_3 hang off the chain.
- Saying **condensation polymerisation** gives off nothing; a small molecule such as water is lost at each link.
- Forgetting that fermentation needs no oxygen.

Key terms

- **Hydrocarbon**: a compound made of hydrogen and carbon only.
- **Alkane**: a saturated **hydrocarbon** with only single bonds, general formula C_nH_{2n+2}.
- **Alkene**: a hydrocarbon with a C=C double bond, general formula C_nH_{2n}.

Key terms (2)

- **Cracking**: breaking long **hydrocarbon** molecules into shorter, more useful ones.
- **Functional group**: the group of atoms that decides how a compound reacts.
- **Monomer**: a small molecule that can join with others to make a polymer.

Key terms (3)

- **Addition polymerisation**: the joining of **alkene** monomers by opening their double bonds.
- **Condensation polymerisation**: the joining of monomers with two functional groups, giving off a small molecule.

Check yourself

- 1.
- Write the formula of the **alkane** with 8 carbon atoms. 2.
- Why do the fractions condense at different heights in the column? 3.
- Balance the complete combustion of butane, C_4H_{10}. 4.