Organic chemistry

Model answers and marking points

GCSE science 6-mark questions

This topic online

1 Crude oil pumped from under the North Sea is a thick, dark mixture of many different hydrocarbons. At a refinery it is separated into fractions such as petrol, kerosene and bitumen.

Describe how crude oil is separated into fractions in a fractionating column. (6 marks)

Model answer

First the crude oil is heated to a high temperature so that most of it evaporates into a vapour. The vapour is then passed into the bottom of a tall fractionating column. The column has a temperature gradient: it is hottest at the bottom and coolest at the top.

The vapour rises up the column and cools as it goes. Each hydrocarbon condenses back into a liquid when it reaches a height where the temperature is below its boiling point. Hydrocarbons with long chains and large molecules have high boiling points, so they condense near the bottom. Hydrocarbons with short chains have low boiling points, so they condense near the top, and the smallest ones leave the top as gases.

The liquids are collected on trays at different heights and piped away. Each fraction contains hydrocarbons with a similar number of carbon atoms, so they have similar boiling points. The very biggest molecules, such as bitumen, never boil and are drained from the bottom of the column.

Marking points (credit any 6 relevant points, linked in a sensible order)

- crude oil is heated until most of it boils and turns into vapour
- the vapour is fed into the bottom of the fractionating column
- the column is hot at the bottom and gets cooler towards the top (temperature gradient)
- vapour rises up the column
- each hydrocarbon condenses when it reaches a level that is below its boiling point
- hydrocarbons with large molecules have high boiling points and condense near the bottom
- hydrocarbons with small molecules have low boiling points and condense higher up or leave the top as gases
- the liquid fractions are collected at different heights through trays and pipes
- each fraction is a mixture of hydrocarbons with a similar number of carbon atoms and similar boiling points
- very large molecules such as bitumen do not boil and are removed from the bottom as a liquid or residue

How it is marked

- 5-6 marks: gives the full sequence from heating to collection, links the temperature gradient to boiling points and explains where large and small molecules end up.
- 3-4 marks: describes heating, rising vapour and condensing at different heights, but the link between molecule size, boiling point and position is incomplete.
- 1-2 marks: makes one or two correct statements, for example that crude oil is heated or that fractions come off at different levels, with no clear sequence.

What loses marks

- saying the column is hottest at the top
- saying the fractions boil at different heights instead of condensing
- claiming each fraction is a single pure compound
- not linking chain length to boiling point

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2 A student at a sixth form in Leeds looks up some properties of four alkanes.

Alkane	Formula	Boiling point in °C	How it flows at 20 °C	How it burns
propane	C_3H_8	-42	gas	clean blue flame, lights instantly
octane	C_8H_{18}	126	runny liquid	lights easily
hexadecane	$C_{16}H_{34}$	287	thicker liquid	hard to light, some smoke
icosane	$C_{20}H_{42}$	343	waxy solid	very hard to light, smoky

Use the data to describe how the properties of alkanes change as the number of carbon atoms increases. Use your knowledge to suggest which of these alkanes would be most useful as a fuel for a camping stove.

(6 marks)

Model answer

As the number of carbon atoms in the alkane increases, the boiling point increases. Propane with 3 carbons boils at -42 °C, but icosane with 20 carbons boils at 343 °C. The alkanes also become more viscous as the chain gets longer: propane is a gas, octane is a runny liquid, hexadecane is a thicker liquid and icosane is a waxy solid.

Flammability goes down as the chain gets longer. Propane lights instantly, while hexadecane and icosane are hard to light. The longer alkanes also burn with a smokier flame, which suggests incomplete combustion producing soot.

All four fit the general formula C_nH_{2n+2}, so the changes are caused by chain length.

I would choose propane for a camping stove. It is a gas at 20 °C because its boiling point is well below room temperature, so it comes out of the canister ready to burn. It lights instantly and burns with a clean blue flame, so it heats food quickly and produces little soot. It can be kept as a liquid under pressure in a small canister, which is easy to carry.

Marking points (credit any 6 relevant points, linked in a sensible order)

- as the number of carbon atoms increases the boiling point increases (from -42 °C for propane to 343 °C for icosane)
- as the chain gets longer the alkane becomes more viscous (gas to runny liquid to thick liquid to solid)
- as the chain gets longer the alkane becomes less flammable and harder to ignite
- longer chains burn with a smokier flame, suggesting incomplete combustion
- propane is a gas at room temperature because its boiling point is below 20 °C
- all four are alkanes with the general formula C_nH_{2n+2}
- propane would be best for a camping stove
- propane lights instantly and burns with a clean flame, so it gives heat quickly with little soot
- propane can be stored as a liquid under pressure in a small canister and comes out as a gas

How it is marked

- 5-6 marks: describes all three trends using figures from the table, and chooses a fuel with reasons that are clearly linked to the data.
- 3-4 marks: describes two trends with some reference to the data and makes a sensible choice of fuel with at least one reason.
- 1-2 marks: states one trend or makes a choice of fuel without a reason drawn from the data.

What loses marks

- describing trends without quoting any values from the table
- saying viscosity decreases with chain length

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- choosing icosane because it has the most carbon atoms or 'more energy'
- giving the choice of fuel without linking it to flammability or boiling point

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3 A refinery in Fawley, Hampshire, produces the following amounts of three fractions each day, and has orders for the amounts shown.

Fraction	Carbon atoms per molecule	Amount produced in tonnes	Amount ordered in tonnes
petrol	5-10	1800	3200
diesel	12-20	2400	2600
heavy fuel oil	20-40	2900	900

The manager, Priya Shah, wants to spend money on a new catalytic cracker. Evaluate whether this is a good idea. Use the data and your knowledge of cracking.

(6 marks)

Model answer

The data show the refinery has a mismatch between supply and demand. It produces 1800 tonnes of petrol but 3200 tonnes are ordered, so it is 1400 tonnes short. It produces 2900 tonnes of heavy fuel oil but only 900 tonnes are ordered, so 2000 tonnes are left over. Diesel is nearly balanced, only 200 tonnes short.

Cracking breaks long chain hydrocarbons into shorter ones. In catalytic cracking the vapour is passed over a hot catalyst. The heavy fuel oil, with 20-40 carbons, could be cracked to make shorter alkanes in the petrol range. For example $C_{20}H_{42} \rightarrow C_8H_{18} + 6C_2H_4$. This turns an unwanted surplus into a product that customers want.

Cracking also produces alkenes such as ethene. These are valuable because they are used to make polymers and other chemicals, so they give a second product to sell.

Against this, the cracker is expensive to build and cracking needs high temperatures, so it uses a lot of energy.

Overall I think it is a good idea, because the surplus of heavy fuel oil is large and both petrol and alkenes are in demand, so the extra sales should cover the cost.

Marking points (credit any 6 relevant points, linked in a sensible order)

- the refinery makes 1400 tonnes less petrol than is ordered
- the refinery makes 2000 tonnes more heavy fuel oil than is ordered
- diesel supply and demand are close (200 tonnes short)
- cracking breaks long chain hydrocarbons into shorter, more useful ones
- catalytic cracking uses a hot catalyst; steam cracking uses high temperature and steam
- cracking heavy fuel oil would turn surplus into petrol that can be sold
- cracking also makes alkenes, which can be sold to make polymers and other chemicals
- example equation: a long alkane gives a shorter alkane plus an alkene, for example $C_{20}H_{42} \rightarrow C_8H_{18} + 6C_2H_4$
- against: cracking needs a lot of energy and the cracker costs money to build and run
- conclusion: worthwhile because the surplus is large and petrol and alkenes are in demand

How it is marked

- 5-6 marks: uses the data to identify the mismatch for petrol and heavy fuel oil, explains what cracking does and its products, weighs a cost against the benefits and reaches a justified conclusion.
- 3-4 marks: identifies a mismatch from the data and explains that cracking makes shorter molecules, with a conclusion that is only partly supported.
- 1-2 marks: makes a simple point, such as cracking breaks up big molecules or petrol is in short supply, with no real evaluation.

What loses marks

- not doing the subtraction to show the size of the shortage and surplus

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- saying cracking joins small molecules together
- forgetting that cracking also makes alkenes
- giving no conclusion or a conclusion with no reason

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4 **Higher tier | Separate science only**

Poly(propene) is used to make food tubs. Some polyester fibres used in fleece jackets are made from a diol and a dicarboxylic acid.

Compare how addition polymers like poly(propene) and condensation polymers like polyesters are formed.

(6 marks)

Model answer

Both types of polymerisation join many small monomer molecules together to make very long chain molecules.

The monomers are different. Addition polymers such as poly(propene) are made from alkene monomers that contain a C=C double bond. Condensation polymers such as polyesters are made from monomers that each have two functional groups. For a polyester these are a diol, with two -OH groups, and a dicarboxylic acid, with two -COOH groups.

The way the monomers join is different. In addition polymerisation the double bond in each monomer opens up and the monomers bond to each other in a chain. In condensation polymerisation an -OH group on one monomer reacts with a -COOH group on another to form an ester link.

The products are different. Addition polymerisation makes only the polymer, so the repeating unit has the same atoms as the monomer. Condensation polymerisation makes the polymer and also a small molecule, water, every time a link forms, so the repeating unit has fewer atoms than the two monomers added together.

Also, addition polymers are usually made from a single type of monomer, but polyesters are usually made from two different monomers.

Marking points (credit any 6 relevant points, linked in a sensible order)

- addition polymers are made from monomers that contain a C=C double bond (alkenes such as propene)
- condensation polymers are made from monomers that have two functional groups each
- for a polyester the monomers are a diol (two -OH groups) and a dicarboxylic acid (two -COOH groups)
- in addition polymerisation the double bond opens and many monomers join in a chain
- in condensation polymerisation the functional groups react with each other to link the monomers
- addition polymerisation gives only one product, the polymer
- condensation polymerisation gives the polymer and a small molecule, such as water, for each link made
- addition polymers usually come from one type of monomer; polyesters usually use two different monomers
- the repeating unit of an addition polymer has the same atoms as the monomer; the repeating unit of a condensation polymer has fewer atoms than the monomers combined
- both join many small monomer molecules into long chain molecules

How it is marked

- 5-6 marks: compares the monomers, the way they link and the products point by point, including the small molecule given off and the number of monomer types.
- 3-4 marks: gives correct features of both types but the comparison is uneven, or misses the small molecule lost in condensation.
- 1-2 marks: gives one or two correct facts about one type of polymerisation only.

What loses marks

- describing each process separately with no comparison words
- forgetting that water (or another small molecule) is lost in condensation polymerisation
- saying the diol or acid contains a C=C double bond

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- saying addition polymerisation also gives off water

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5 Kofi has three unlabelled bottles. He knows that one contains ethanol, one contains ethanoic acid solution and one contains hexene. He does three tests on a small sample from each bottle.

Bottle	Add bromine water and shake	Add sodium carbonate	Add a small piece of sodium
A	stays orange	no change	slow bubbling
B	turns colourless	no change	no change
C	stays orange	fizzes	fast bubbling

Suggest which substance is in each bottle. Explain your reasoning using the results.

Separate science only

(6 marks)

Model answer

Bottle B is hexene. Hexene is an alkene, so it has a C=C double bond. Alkenes react with bromine water and turn it from orange to colourless, which is what happened with B. A and C stayed orange, so they do not contain a C=C bond.

Bottle C is ethanoic acid. It fizzed with sodium carbonate. Carboxylic acids react with carbonates to make a salt, water and carbon dioxide gas, which causes the fizzing. It also bubbled quickly with sodium, giving hydrogen, because it is an acid.

Bottle A is ethanol. It did not fizz with sodium carbonate because ethanol is not acidic. However it did bubble slowly with sodium, because alcohols react with sodium to give hydrogen gas and a salt called sodium ethoxide. This reaction is slower than with ethanoic acid.

Hexene did not react with sodium or sodium carbonate, which fits because it has no -OH or -COOH group.

Kofi could check that the gas from the sodium tests is hydrogen by holding a lighted splint at the mouth of the test tube and listening for a squeaky pop.

Marking points (credit any 6 relevant points, linked in a sensible order)

- bottle B is hexene
- hexene is an alkene with a C=C double bond, so it decolourises bromine water (orange to colourless)
- ethanol and ethanoic acid have no C=C bond, so bromine water stays orange with A and C
- bottle C is ethanoic acid
- carboxylic acids react with carbonates to give carbon dioxide, so C fizzes
- ethanoic acid reacts with sodium giving hydrogen, and the reaction is faster as it is an acid
- bottle A is ethanol
- alcohols react with sodium to give hydrogen gas, so A bubbles, but ethanol does not react with carbonates
- ethanol is not acidic so there is no fizzing with sodium carbonate
- the gas from sodium could be confirmed as hydrogen with a lighted splint (squeaky pop)

How it is marked

- 5-6 marks: identifies all three bottles correctly and links each identification to the specific results, naming the gases and the functional group responsible.
- 3-4 marks: identifies at least two bottles correctly with some reasons from the results.
- 1-2 marks: identifies one bottle, usually hexene from bromine water, with little or no reasoning.

What loses marks

- identifying the bottles without using the results as evidence
- saying ethanol decolourises bromine water
- naming carbon dioxide as the gas made with sodium
- mixing up which test shows an acid

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