Cracking and alkenes

5.7.1.4 · Chemistry · revision notes

Why and how large hydrocarbon molecules are cracked into smaller, more useful ones, the conditions for catalytic and steam cracking, the bromine water test for alkenes, and balancing cracking equations. Expect supply-and-demand data questions, equations to complete and questions on the lab cracking experiment.

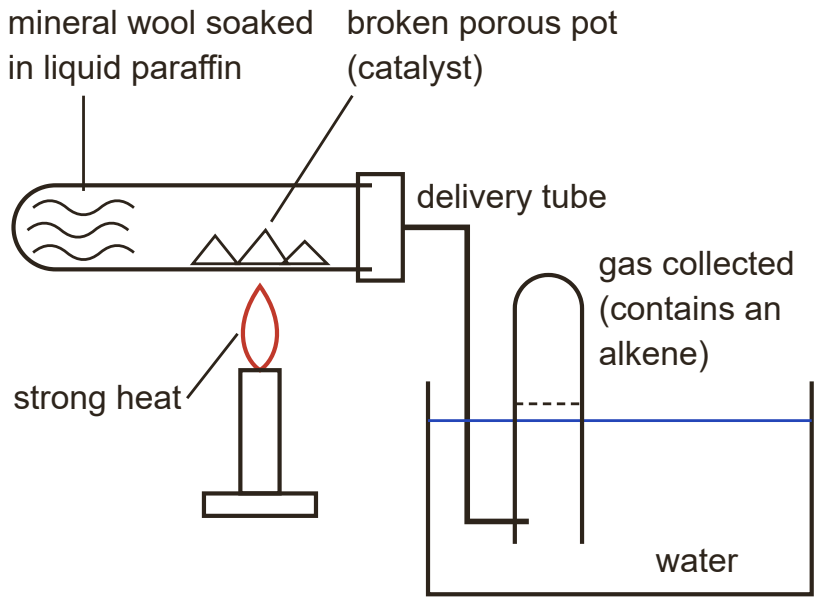
Key facts

- Cracking = breaking large hydrocarbon molecules into smaller, more useful ones (thermal decomposition)
- Steam cracking: vaporise, mix with steam, very high temperature
- Bromine water + alkene: orange → colourless
- Uses: small alkanes as fuels; alkenes to make polymers and other chemicals
- Catalytic cracking: vaporise, then pass over a hot catalyst
- Products: smaller alkanes + alkenes
- Alkenes are more reactive than alkanes
- Balancing: same total C and same total H on both sides

Notes

What cracking is

- **Cracking** breaks down large (long-chain) hydrocarbon molecules into smaller, more useful molecules.
- It is a **thermal decomposition**: heat is used to break the molecules apart.
- **Catalytic cracking**: the hydrocarbons are heated to vaporise them, and the vapour is passed over a **hot catalyst**. You do not need to name the catalyst.
- **Steam cracking**: the hydrocarbon vapour is **mixed with steam** and heated to a **very high temperature**.
- In the lab, paraffin vapour can be passed over heated pieces of broken porous pot, which act as the catalyst. Take the delivery tube out of the water before you stop heating, or cold water is sucked back into the hot tube.



Cracking liquid paraffin in the lab. Take the delivery tube out of the water before you stop heating, to stop suck-back.

The products

- The products are **smaller alkanes** and another type of hydrocarbon called **alkenes**.
- Example: $C_{10}H_{22} \rightarrow C_8H_{18} + C_2H_4$ (an alkane cracks to a smaller alkane and ethene).
- In a balanced cracking equation, the total number of carbon atoms and the total number of hydrogen atoms are the same on both sides.
- Alkenes are **more reactive** than alkanes.

Testing for alkenes

- Shake the substance with **bromine water**.
- Alkene present: the bromine water turns from **orange to colourless**.
- Alkane: no change; the bromine water stays orange.

Why crack hydrocarbons?

- Fractional distillation gives more long-chain hydrocarbons than are needed, and not enough short-chain ones.
- There is a high demand for fuels with small molecules (they are more flammable and flow easily), so some of the products of cracking are used as fuels, e.g. petrol.
- The alkenes are used to make **polymers** and as starting materials for many other chemicals.
- Modern life depends on hydrocarbons: fuels for transport and heating, and materials such as polymers, solvents, lubricants and detergents.

How to answer each type of question

Complete a cracking equation

1 to 2 marks | **Grade 5**

1. Subtract the carbon atoms you can see on the right from the carbon atoms on the left.
2. Do the same for the hydrogen atoms.
3. If there is a number in front of the missing formula, divide the missing atoms by that number.

Example. Complete the equations.
(a) $C_{12}H_{26} \rightarrow C_9H_{20}$ + _____
(b) $C_{20}H_{42} \rightarrow C_{12}H_{26}$ + 2 _____

Model answer.

(a) C_3H_6: 12 − 9 = 3 carbons and 26 − 20 = 6 hydrogens (1)
(b) C_4H_8: 20 − 12 = 8 carbons and 42 − 26 = 16 hydrogens, shared between 2 molecules (1)

Describe the conditions for cracking

2 to 4 marks | **Grade 5**

1. Catalytic cracking: the hydrocarbon is heated to vaporise it, and the vapour is passed over a hot catalyst.
2. Steam cracking: the vapour is mixed with steam and heated to a very high temperature.
3. You do not need to name the catalyst.

Example. Describe the conditions used in catalytic cracking and in steam cracking.

Model answer.

Catalytic cracking: the hydrocarbon is heated so that it vaporises (1) and the vapour is passed over a hot catalyst (1).
Steam cracking: the hydrocarbon vapour is mixed with steam (1) and heated to a very high temperature (1).

Use supply and demand data to explain why cracking is used

2 to 4 marks | Grade 5

1. Find a long-chain fraction whose supply is greater than its demand, and quote both numbers.
2. Find a short-chain fraction whose demand is greater than its supply, and quote both numbers.
3. Say that cracking turns the surplus large molecules into the smaller molecules that are in demand.
4. If there is another mark, mention that the alkenes made are used to make polymers.

Example. A refinery gets these percentages of two fractions from crude oil, compared with the percentages its customers want.

Fraction	Supply in %	Demand in %
Petrol	14	28
Fuel oil	40	22

Use the data to explain why the refinery cracks fuel oil.

Model answer. The supply of fuel oil (40%) is greater than the demand for it (22%) (1). The demand for petrol (28%) is greater than the supply (14%) (1). Cracking breaks the large molecules in fuel oil into smaller molecules that can be used in petrol, so supply matches demand better (1).

Test for an alkene and the lab cracking experiment

1 to 3 marks | Grade 4

1. Name the reagent: bromine water.
2. Give the whole colour change: orange to colourless.
3. In the lab experiment, the delivery tube is removed from the water before heating stops, to prevent suck-back.

Example. A student cracks liquid paraffin and collects the gas produced over water.
(a) Describe a test to show that the gas contains an alkene. Give the result.
(b) Why must the student take the delivery tube out of the water before stopping heating?

Model answer.

(a) Shake the gas with bromine water (1). It turns from orange to colourless (1).
(b) Otherwise cold water is sucked back into the hot boiling tube, which could crack it (1).

Don’t lose marks

- Writing 'clear' instead of 'colourless'. Clear means see-through, and orange bromine water is already clear.
- Getting the colour change backwards. Bromine water starts orange and ends colourless with an alkene.
- Describing fractional distillation when asked about cracking. Cracking breaks molecules; distillation only separates them.
- Leaving out the heating: both methods start by heating the hydrocarbons to vaporise them.

- Not checking that the carbon and hydrogen totals match in a cracking equation.

More tips

Memory tricks

- Cracking turns big molecules into small ones: small alkanes for fuel, alkenes for polymers.
- Catalytic cracking uses a catalyst; steam cracking uses steam. The name tells you the key condition.
- Bromine water: an alkene takes the orange colour away.
- Cracking equations are just counting: C on the left = C on the right, H on the left = H on the right.

Exam technique

- In data questions, quote the numbers for both supply and demand. 'Petrol is in high demand' on its own gets little credit.
- 'Give the result' means the whole colour change: the starting colour and the final colour.
- Learn the two cracking methods as a pair so you can compare them: both vaporise the hydrocarbon; one uses a catalyst, the other steam and a very high temperature.
- 'Explain how modern life depends on hydrocarbons' needs examples: petrol and diesel oil for transport, polymers, solvents, lubricants and detergents.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 — **Define cracking**
Breaking down large hydrocarbon molecules into smaller, more useful molecules.

Grade 4 — **Name the two types of product**
Cracking produces smaller alkanes and another type of hydrocarbon called alkenes.

Grade 4 — **Describe the bromine water test for alkenes**
Shake with bromine water: it turns from orange to colourless if an alkene is present.

Grade 5 — **Describe the conditions for catalytic and steam cracking**
Catalytic: vapour passed over a hot catalyst. Steam: vapour mixed with steam and heated to a very high temperature.

Grade 5 — **Give uses of the products of cracking**
Smaller alkanes are used as fuels such as petrol; alkenes are used to make polymers and many other chemicals.

Grade 5 — **Explain why cracking is needed using data**
The supply of long-chain fractions is greater than demand, and the demand for short-chain fuels is greater than supply.

Grade 6 — **Balance cracking equations**
The total numbers of carbon and hydrogen atoms must be the same on both sides, e.g. $C_{10}H_{22} \rightarrow C_8H_{18} + C_2H_4$.

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