Properties of hydrocarbons

4.7.1.3 · Organic chemistry · revision notes

How the size of a hydrocarbon molecule affects its boiling point, viscosity and flammability, why this decides how it is used as a fuel, and how to write balanced equations for complete combustion. Expect data-table questions, 'compare' questions and 'write a balanced equation' questions.

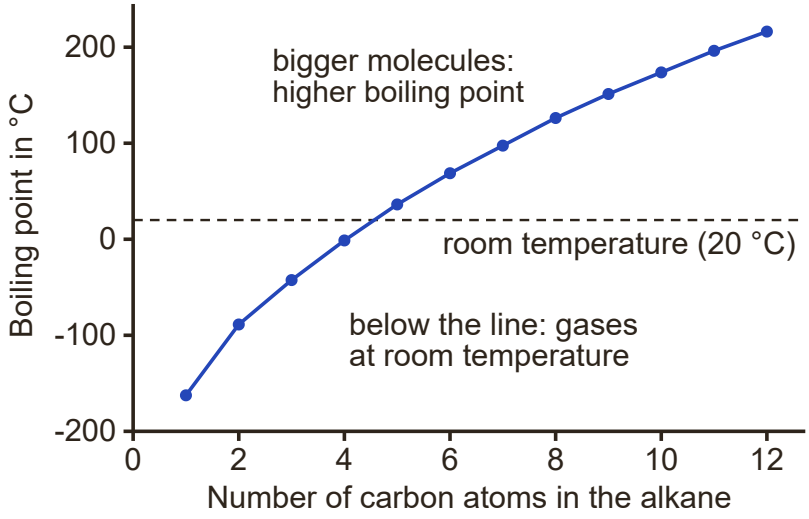
Key facts

- Bigger molecules → higher boiling point
- Bigger molecules → less flammable
- Complete combustion: hydrocarbon + oxygen → carbon dioxide + water
- $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
- Higher boiling point = stronger intermolecular forces, not stronger covalent bonds
- Bigger molecules → more viscous (flow less easily)
- Viscosity: how thick a liquid is (high viscosity = flows slowly)
- Combustion releases energy; the C and H in the fuel are oxidised
- $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

Notes

Properties depend on molecule size

- Some properties of hydrocarbons depend on the size of their molecules (the number of carbon atoms).
- As the molecules get **bigger**: the **boiling point increases**, the **viscosity increases** (the liquid is thicker and flows less easily) and the **flammability decreases** (they are harder to set alight).



Boiling points of the alkanes C_1 to C_{12}: they rise as the molecules get bigger.

- So small hydrocarbons are gases or runny liquids that ignite easily, and large ones are thick liquids or solids that are hard to ignite.
- Why the boiling point rises: larger molecules have stronger **intermolecular forces** (forces between molecules), so more energy is needed to overcome them. The covalent bonds inside the molecules do not break when a hydrocarbon boils.

Using the properties

- These properties decide how a hydrocarbon is used as a fuel.
- Hydrocarbons with small molecules make good fuels: they are very flammable and flow easily. Petrol is an example.
- Hydrocarbons with large molecules are less useful as fuels, because they are viscous and hard to ignite.
- To compare viscosity, time how long the same volume of each hydrocarbon takes to flow out of a funnel or burette. The longer it takes, the higher the viscosity.

Complete combustion

- Burning (combustion) of hydrocarbon fuels releases energy.
- During combustion, the carbon and hydrogen in the fuel are **oxidised**: they combine with oxygen.
- **Complete combustion** (in plenty of oxygen): hydrocarbon + oxygen → carbon dioxide + water.
- Example: $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$
- To balance: (1) put the number of C atoms in front of CO_2; (2) put half the number of H atoms in front of H_2O; (3) count the O atoms on the right and halve that number for O_2; (4) if you get a half, double everything.
- Example: C_2H_6 gives $2CO_2 + 3H_2O$, which has 7 O atoms, so $3½O_2$. Doubling: $2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$.

How to answer each type of question

Compare the properties of two hydrocarbons

1 to 3 marks | Grade 4

1. Decide which hydrocarbon has the bigger molecules.
2. State how each property compares, using 'higher', 'more viscous' and 'less flammable'.

Example. Hydrocarbon A has 6 carbon atoms in each molecule. Hydrocarbon B has 20 carbon atoms in each molecule.
Compare the boiling point, viscosity and flammability of A and B.

Model answer. B has a higher boiling point than A (1). B is more viscous than A (1). B is less flammable than A (1).

Write a balanced combustion equation

1 to 2 marks | Grade 6

1. Write the formulae: hydrocarbon + $O_2 \rightarrow CO_2 + H_2O$.
2. Balance carbon, then hydrogen.
3. Count the O atoms on the right, then balance O_2. Double everything if you get a half.

Example. Heptane, C_7H_{16}, is one of the hydrocarbons in petrol.
Write a balanced equation for the complete combustion of heptane.

Model answer.

Correct formulae: $C_7H_{16} + O_2 \rightarrow CO_2 + H_2O$ (1)

Balanced: $C_7H_{16} + 11O_2 \rightarrow 7CO_2 + 8H_2O$ (1)

(Check: (7 × 2) + 8 = 22 O atoms on the right, which is $11O_2$.)

Use data to choose a fuel

2 to 3 marks **Grade 5**

1. Compare each boiling point with room temperature (about 20 °C) to find the state.
2. Use molecule size to judge flammability and viscosity.
3. Quote the data in your answer.

Example. The table gives data for three hydrocarbons.

Hydrocarbon	Formula	Boiling point in °C
P	C_3H_8	−42
Q	$C_{10}H_{22}$	174
R	$C_{18}H_{38}$	317

Which hydrocarbon would be best as the fuel for a gas barbecue? Explain your answer.

Model answer. P (1). Its boiling point (−42 °C) is below room temperature, so it is a gas (1). It has the smallest molecules, so it is the most flammable and ignites easily (1).

Explain the trend in boiling point

2 to 3 marks **Grade 5**

1. Say that the molecules are larger.
2. Say that the intermolecular forces (forces between the molecules) are stronger.
3. Say that more energy is needed to overcome these forces.

Example. Explain why dodecane, $C_{12}H_{26}$, has a higher boiling point than hexane, C_6H_{14}.

Model answer. Dodecane molecules are larger (1). So the intermolecular forces between dodecane molecules are stronger (1). So more energy is needed to overcome these forces (1). (Writing about breaking covalent bonds loses the last two marks.)

Don’t lose marks

- Saying larger molecules are more flammable 'because there is more fuel'. They are less flammable.
- Explaining boiling points by breaking covalent bonds. Boiling overcomes the weak forces between molecules.
- Giving carbon monoxide or soot as products of complete combustion. They come from incomplete combustion.
- Changing a formula to balance an equation, e.g. writing CO_3. Only change the numbers in front.
- Doubling only some terms when clearing a half, e.g. $2C_2H_6 + 7O_2 \rightarrow 2CO_2 + 3H_2O$.

More tips

Memory tricks

- Think honey and petrol: long chains are like honey (thick, hard to light); short chains are like petrol (runny, catch fire easily).
- Two up, one down: boiling point and viscosity go up with size; flammability goes down.
- Balancing order: C, then H, then O. Oxygen goes last because O_2 is on its own.
- Odd number of O atoms on the right? Double every number in the equation.
- Alkane check: n carbons need (3n + 1) ÷ 2 molecules of O_2. Propane: (9 + 1) ÷ 2 = 5.

Exam technique

- 'Compare' means say how the two are different, using comparative words: higher, more viscous, less flammable.
- When you use data, quote the numbers with units, e.g. 'its boiling point, −42 °C, is below room temperature'.
- After balancing an equation, count every atom on both sides. It takes 20 seconds and catches most slips.
- Use the words 'viscosity' and 'flammability' rather than 'thickness' and 'burns better'.

What each grade needs

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

Grade 3

Name the products of complete combustion
A hydrocarbon burns completely in oxygen to form carbon dioxide and water.

Grade 4

Recall how properties change with molecule size
Bigger molecules: higher boiling point, higher viscosity and lower flammability.

Grade 5

Choose a suitable fuel using property data
For example, a fuel for a gas stove must have a boiling point below room temperature and be very flammable.

Grade 5

State what happens to the fuel in combustion
The carbon and hydrogen in the fuel are oxidised, and energy is released.

Grade 5

Explain the boiling point trend using intermolecular forces
Larger molecules have stronger forces between the molecules, so more energy is needed to overcome them.

Grade 6

Balance complete combustion equations
Balance C, then H, then O; if you need half an O_2, double every number.

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