Alkanes

OCR A Chemistry A H432 | Specification-led student notes

SPEC → CRACK IT → WORKED EXAMPLE → TEST IT → DONE

SPECIFICATION COVERAGE

OCR A REF	THIS PACK TEACHES	TAUGHT / TESTED
4.1.2(a), (b)	Saturation, sigma bonds, free rotation and tetrahedral shape	Section 1
4.1.2(c)	Boiling points, chain length, branching and London forces	Section 2
4.1.2(d), (e)	Low reactivity, complete and incomplete combustion, fuels and CO	Sections 3–4
4.1.2(f)	UV, homolytic fission and radical substitution with Cl_2 and Br_2	Sections 5–7
4.1.2(g)	Mixtures from further substitution and different substitution positions	Section 8
Combined application	Original exam-style practice and complete worked answers	Tests 9–10 and answers

YOUR AIM Explain how alkane bonding affects properties, then use radical equations to explain substitution and its limitations.

LESSON BOUNDARY Builds on Introduction to Organic Chemistry I and II. This pack covers OCR 4.1.2 Alkanes. Alkene reactions are taught separately.

Mapped to OCR A H432 specification version 3.1 (May 2026)

1. Bonding and shape

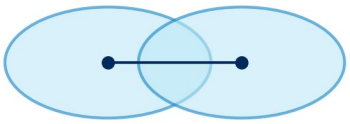
SPEC 4.1.2(a), (b) Saturated hydrocarbons, σ bonds, free rotation and tetrahedral shape.

CRACK IT Every carbon forms four bonds. Around each carbon, the four bonding pairs repel into a tetrahedral arrangement.

Alkanes are saturated hydrocarbons: they contain only carbon and hydrogen, with only single carbon–carbon bonds. Open-chain alkanes have the general formula C_nH_{2n+2}.

Each C–C and C–H bond is a sigma (σ) bond, formed by direct overlap of orbitals between the bonding atoms. Rotation about a C–C single bond can occur without breaking the bond.

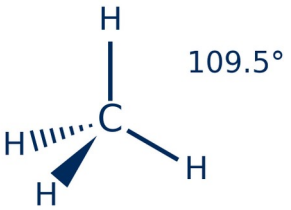
A sigma (σ) bond



Direct overlap between the nuclei

Each C–C and C–H bond is a σ bond

Methane is tetrahedral



Wedge: towards you | Dashes: away

Methane has four bonding pairs and no lone pairs around carbon. The pairs repel equally and arrange as far apart as possible: a tetrahedron with H–C–H angles of 109.5°. Each carbon in a larger alkane is also approximately tetrahedral.

WORKED EXAMPLE

QUESTION How many sigma bonds are there in ethane, CH_3CH_3?

COUNT Six C–H bonds + one C–C bond = seven σ bonds.

EXAM CHECK A flat structural formula does not show the actual 3D shape. Use a solid wedge and a dashed bond when asked for a 3D diagram.

TEST IT 1 (a) Give the molecular formula of pentane and its total number of σ bonds. [2]
(b) Draw methane in 3D. State and explain its bond angle. [4]

[6 marks]

✓ DONE WHEN You can link four bonding pairs to a tetrahedral arrangement and count all C–C and C–H sigma bonds.

2. Boiling points and branching

SPEC 4.1.2(c) Explain boiling-point trends using induced dipole–dipole interactions (London forces).

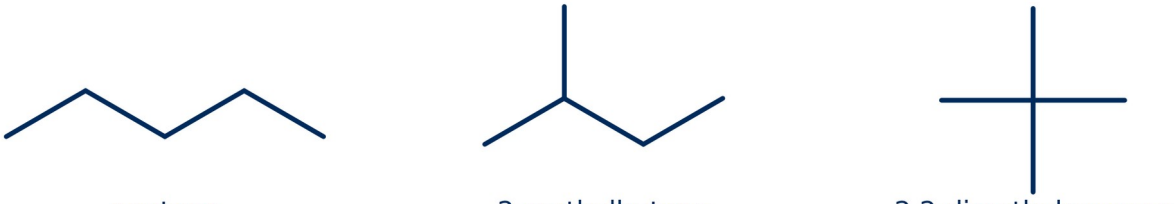
CRACK IT Boiling separates molecules. It overcomes intermolecular forces; it does not break the covalent bonds inside each molecule.

Longer chains have higher boiling points

As alkane chain length increases, the molecules have more electrons. Their electron clouds are more polarisable, so stronger London forces act between molecules. More energy is needed to overcome these forces, giving a higher boiling point.

More branching lowers the boiling point for isomers

For alkanes with the same molecular formula, increased branching gives more compact molecules and less surface contact between them. London forces are weaker, so less energy is needed to separate the molecules.



pentane	2-methylbutane	2,2-dimethylpropane
highest boiling point	intermediate	lowest boiling point

WORKED EXAMPLE

QUESTION Why does pentane have a higher boiling point than 2,2-dimethylpropane?

ANSWER Both are C_5H_{12} and have the same number of electrons. Pentane is less branched, so molecules make more surface contact. Stronger London forces require more energy to overcome.

EXAM CHECK Compare electron number for different chain lengths. For isomers, compare branching and contact area. Do not say a branched isomer has fewer electrons.

TEST IT 2 (a) Explain why heptane has a higher boiling point than pentane. [3]
(b) Explain why 2,2-dimethylpropane has a lower boiling point than pentane. [3]

[6 marks]

✓ DONE WHEN You can connect the structural difference to London-force strength, the energy needed and the boiling point.

3. Low reactivity and complete combustion

SPEC 4.1.2(d), (e) Explain low reactivity and complete combustion of alkanes as fuels.

CRACK IT Strong, almost non-polar bonds make alkanes relatively unreactive. Once ignited, they can still react rapidly with oxygen.

The C–C and C–H sigma bonds have high bond enthalpies, so breaking them requires a large energy input. Their very low polarity also means they attract polar or charged reagents only weakly.

Alkanes are useful fuels because combustion is exothermic. With sufficient oxygen, complete combustion forms carbon dioxide and water. Ignition supplies the energy needed to start the reaction.

alkane + oxygen → carbon dioxide + water

WORKED EXAMPLE

QUESTION Balance the complete combustion of hexane, C_6H_{14}.

CARBON One C_6H_{14} needs $6CO_2$.

HYDROGEN Fourteen H atoms need $7H_2O$.

OXYGEN Products contain 12 + 7 = 19 O atoms, so use 19/2 O_2.

WHOLE-NUMBER EQUATION Multiply every coefficient by two:

$$2C_6H_{14} + 19O_2 \rightarrow 12CO_2 + 14H_2O$$

EXAM CHECK Balance C, then H, then O. Keep formulae unchanged. Water may be steam in a flame or liquid after cooling; use the conditions stated if state symbols are requested.

TEST IT 3 (a) Give two reasons for the low reactivity of alkanes. [2]
(b) Write a balanced equation for the complete combustion of propane. [2]
(c) State the energy change that makes alkanes useful as fuels. [1]

[5 marks]

✓ **DONE WHEN** You can explain low reactivity and balance complete combustion without changing chemical formulae.

4. Incomplete combustion and carbon monoxide

SPEC 4.1.2(e) Explain incomplete combustion in limited oxygen and the dangers of carbon monoxide.

CRACK IT Limited oxygen can produce carbon monoxide or solid carbon, as well as water. Real flames can form a mixture of products.

When oxygen is insufficient for complete combustion, some carbon is not fully oxidised to CO_2. Carbon monoxide (CO) and/or soot (C) can form. Water is still a product.

WORKED EXAMPLE

QUESTION Ethane burns to form carbon monoxide and water only. Balance the equation.

CARBON AND HYDROGEN $C_2H_6 + O_2 \rightarrow 2CO + 3H_2O$

OXYGEN Five O atoms are needed on the right, so use 5/2 O_2.

ANSWER $2C_2H_6 + 5O_2 \rightarrow 4CO + 6H_2O$

A SOOT EXAMPLE $CH_4 + O_2 \rightarrow C + 2H_2O$

Why carbon monoxide is dangerous

Carbon monoxide is toxic because it binds strongly to haemoglobin, reducing the blood's ability to carry oxygen. Cells receive less oxygen for respiration. CO is colourless and odourless, so it can build up without being noticed.

EXAM CHECK CO is carbon monoxide; CO_2 is carbon dioxide. Explain reduced oxygen transport, rather than just saying "it is poisonous". Do not confuse carbon monoxide with visible soot.

TEST IT 4 (a) Butane burns to produce carbon monoxide and water only. Write a balanced equation. [2]
(b) Explain why carbon monoxide is toxic. [2]
(c) State the condition that favours incomplete combustion. [1]

[5 marks]

✓ DONE WHEN You can balance an equation for the stated products and explain how CO reduces oxygen transport.

5. UV light starts radical substitution

SPEC 4.1.2(f) Use UV radiation, homolytic fission and radical equations with the correct dots.

CRACK IT A radical is a species with an unpaired electron. The dot shows that electron; it does not represent an ionic charge.

Alkanes react with chlorine or bromine by radical substitution in ultraviolet (UV) light. A halogen atom replaces a hydrogen atom in the alkane. A hydrogen halide forms as the other product.

$$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl \quad \text{(UV light)}$$

Initiation breaks the halogen–halogen bond

UV radiation supplies energy for homolytic fission of the Cl–Cl or Br–Br bond. Each atom takes one electron from the shared pair, producing two radicals.

$$Cl_2 \rightarrow 2Cl\bullet \quad \text{(UV light)}$$

$$Br_2 \rightarrow 2Br\bullet \quad \text{(UV light)}$$

WORKED EXAMPLE

QUESTION Explain why $Cl_2 \rightarrow 2Cl^-$ is not an initiation equation.

ANSWER Homolytic fission produces neutral chlorine radicals, Cl•, not chloride ions. Each Cl atom receives one bonding electron; no charge is created.

EXAM CHECK Write the radical dot every time the species is a radical. OCR requires radical equations here; half-headed curly arrows are not required.

TEST IT 5 (a) Define a radical. [1]
(b) Write the initiation equation for bromination of an alkane. [1]
(c) Explain the role of UV light and how the bond breaks. [3]

[5 marks]

✓ DONE WHEN You can distinguish a radical from an ion and show two radicals forming by homolytic fission.

6. The radical chain mechanism

SPEC 4.1.2(f) Describe initiation, propagation and termination in alkane halogenation.

CRACK IT Initiation makes radicals. Propagation uses a radical and regenerates one. Termination removes radicals when two combine.

WORKED EXAMPLE Chlorination of methane

INITIATION UV breaks the chlorine bond homolytically.

$$Cl_2 \rightarrow 2Cl\bullet$$

PROPAGATION 1 A chlorine radical removes H from methane.

$$Cl\bullet + CH_4 \rightarrow HCl + CH_3\bullet$$

PROPAGATION 2 The methyl radical reacts with chlorine.

$$CH_3\bullet + Cl_2 \rightarrow CH_3Cl + Cl\bullet$$

The Cl• is regenerated, so it can react with another methane molecule.

TERMINATION Any two radicals can combine:

$$Cl\bullet + Cl\bullet \rightarrow Cl_2$$

$$CH_3\bullet + Cl\bullet \rightarrow CH_3Cl$$

$$CH_3\bullet + CH_3\bullet \rightarrow CH_3CH_3$$

Adding the two propagation equations cancels Cl• and CH_3•. This gives the overall substitution equation: $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$.

EXAM CHECK One radical appears on each side of a propagation equation. A termination equation has two radicals on the left and no radicals on the right.

TEST IT 6 Ethane reacts with chlorine under UV light.
(a) Write the two propagation equations forming chloroethane. [2]
(b) Write the termination equation in which two ethyl radicals combine. [1]
(c) Explain why propagation is described as a chain reaction. [1]

[4 marks]

✓ **DONE WHEN** You can write all three stages and show regeneration of a radical in propagation.

7. Bromination at a chosen carbon

SPEC 4.1.2(f) Apply radical substitution to a specified product using clear structural or skeletal formulae.

CRACK IT First identify which C–H bond is replaced. Put the radical dot on that carbon in the intermediate.

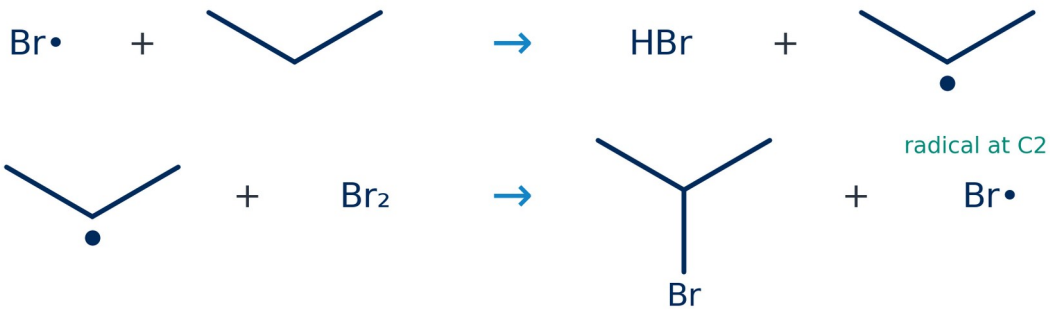
To form 2-bromopropane, remove one H from carbon 2 of propane. The intermediate is $CH_3–C•H–CH_3$. It reacts with Br_2 to put Br at the same carbon and regenerate Br•.

WORKED EXAMPLE The two propagation steps

QUESTION Show how propane forms 2-bromopropane.

1 Br• removes H from carbon 2, producing HBr and an alkyl radical.

2 The alkyl radical reacts with Br_2, producing the bromoalkane and Br•.



The initiation equation is $Br_2 \rightarrow 2Br•$ in UV light. One possible termination is the carbon-2 radical combining with Br• to form 2-bromopropane.

EXAM CHECK The radical dot must identify the correct carbon. Use structural or skeletal formulae when requested; a molecular formula alone cannot show the substitution position.

TEST IT 7 Butane reacts with bromine in UV light to form 1-bromobutane. Use structural formulae.

(a) Write the initiation equation. [1]

(b) Write both propagation equations. [2]

(c) Write the termination equation between a butyl radical and Br• that forms this product. [1]

[4 marks]

✓ DONE WHEN You can transfer the mechanism to a different alkane without moving the radical to the wrong carbon.

8. Why substitution produces mixtures

SPEC 4.1.2(g) Explain mixtures from further substitution and from substitution at different positions.

CRACK IT There are two separate reasons: more than one H can be replaced, and an H can be replaced at different positions in a chain.

Further substitution

A monosubstituted product still has C–H bonds, so it can react again. With methane and chlorine, successive substitution can give:

$$CH_4 \rightarrow CH_3Cl \rightarrow CH_2Cl_2 \rightarrow CHCl_3 \rightarrow CCl_4$$

Each arrow represents another substitution with Cl_2 under UV light, producing HCl. The sequence can leave a mixture of products. An excess of alkane relative to halogen favours monosubstitution but does not guarantee a pure product.

Substitution at different positions

In butane, $CH_3CH_2CH_2CH_3$, replacing H on an end carbon gives 1-chlorobutane. Replacing H on either inner carbon gives 2-chlorobutane. The two ends are equivalent, as are the two inner carbons.

WORKED EXAMPLE

QUESTION Why is chlorination of butane a poor method for making pure 1-chlorobutane?

ANSWER Substitution can occur at different carbon positions, giving 1-chlorobutane and 2-chlorobutane. Further substitution can also form compounds containing two or more chlorine atoms. The desired product must be separated from a mixture.

EXAM CHECK "A mixture forms" is the outcome. Explain the two causes. Do not assume different substitution products form in equal amounts.

TEST IT 8 (a) Name the three different monobromo structural isomers obtainable from pentane. [3]
(b) Give two reasons why radical substitution may give a mixture rather than one pure organic product. [2]

[5 marks]

✓ **DONE WHEN** You can distinguish positional isomers from products of further substitution.

9. Mixed exam-style practice

SPEC Apply 4.1.2(a)–(g). These are original practice questions; indicative answers follow.

Answer without looking back. Show complete equations, the necessary radical dots and enough explanation to connect cause to effect.

TEST IT 9 Hexane and 2,2-dimethylbutane both have the molecular formula C_6H_{14}.
(a) State the general formula of open-chain alkanes. [1]
(b) Explain why hexane has the higher boiling point. [3]
(c) Hexane burns to form carbon monoxide and water only. Write the balanced equation. [2]
(d) Explain one danger of this combustion product. [2]

[8 marks]

TEST IT 10 A student writes: “Ethane reacts with bromine in sunlight by heterolytic fission. Initiation is $Br_2 \rightarrow 2Br^-$. The final products are bromoethane and hydrogen.”
(a) Correct the bond-fission term and initiation equation. [2]
(b) Write the overall equation using structural formulae. [1]
(c) Write both propagation equations. [2]
(d) Write one termination equation that makes butane. [1]

[6 marks]

10. Worked answers 1 to 4

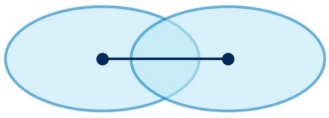
SPEC Check the chemistry and the reasoning. Mark allocations are indicative for these original questions.

TEST IT 1 Bonding and shape [6 marks]

(a) C_5H_{12} [1]. There are 12 C–H + 4 C–C = 16 σ bonds [1].

(b) A correct tetrahedral methane drawing with two plain bonds, one solid wedge and one dashed bond [1]. Angle 109.5° [1]. Four bonding pairs and no lone pairs around carbon [1]; the pairs repel equally and arrange as far apart as possible [1].

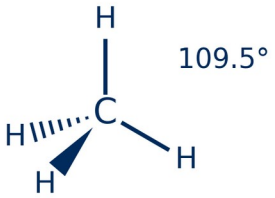
A sigma (σ) bond



Direct overlap between the nuclei

Each C–C and C–H bond is a σ bond

Methane is tetrahedral



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TEST IT 2 Boiling points [6 marks]

(a) Heptane has more electrons than pentane [1], so its molecules experience stronger London forces [1]. More energy is needed to overcome these intermolecular forces [1].

(b) 2,2-Dimethylpropane is more branched and has less surface contact between molecules [1]. London forces are weaker [1], so less energy is needed to overcome them [1].

TEST IT 3 Reactivity and complete combustion [5 marks]

(a) C–C and C–H bonds have high bond enthalpies / need much energy to break [1]. These sigma bonds have very low polarity [1].

(b) $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$. Correct products [1]; balanced equation [1].

(c) Combustion is exothermic / releases energy to the surroundings [1].

TEST IT 4 Incomplete combustion [5 marks]

(a) $2C_4H_{10} + 9O_2 \rightarrow 8CO + 10H_2O$. Correct products [1]; balanced equation [1]. An equation with all coefficients halved is also valid.

(b) CO binds strongly to haemoglobin [1], reducing the blood's capacity to transport oxygen [1].

(c) Limited / insufficient oxygen [1].

EXAM CHECK A boiling-point explanation must refer to intermolecular forces. A low-reactivity explanation must refer to the bonds within the alkane.

11. Worked answers 5 to 7

SPEC Radical dots and the carbon skeleton are part of the answer, not optional decoration.

TEST IT 5 Initiation [5 marks]

(a) A radical is a species with an unpaired electron [1].

(b) $Br_2 \rightarrow 2Br\bullet$ [1].

(c) UV supplies energy to break the Br–Br bond [1]. It undergoes homolytic fission [1], with each Br atom taking one electron from the bonding pair [1].

TEST IT 6 Chlorination of ethane [4 marks]

(a) $Cl\bullet + CH_3CH_3 \rightarrow HCl + CH_3CH_2\bullet$ [1]

$CH_3CH_2\bullet + Cl_2 \rightarrow CH_3CH_2Cl + Cl\bullet$ [1]

(b) $CH_3CH_2\bullet + \bullet CH_2CH_3 \rightarrow CH_3CH_2CH_2CH_3$ [1]

(c) A chlorine radical is regenerated in propagation, so it can react with another ethane molecule and continue the sequence [1].

TEST IT 7 Bromination of butane [4 marks]

(a) $Br_2 \rightarrow 2Br\bullet$ [1] (UV light).

(b) $Br\bullet + CH_3CH_2CH_2CH_3 \rightarrow HBr + CH_3CH_2CH_2CH_2\bullet$ [1]

$CH_3CH_2CH_2CH_2\bullet + Br_2 \rightarrow CH_3CH_2CH_2CH_2Br + Br\bullet$ [1]

(c) $CH_3CH_2CH_2CH_2\bullet + Br\bullet \rightarrow CH_3CH_2CH_2CH_2Br$ [1]

The terminal carbon loses H and carries the radical dot, so Br attaches at carbon 1.

EXAM CHECK A dot after a terminal CH_2 group denotes its carbon radical. For a radical on an internal carbon, write the dot beside that carbon, as in $CH_3–C\bullet H–CH_3$, or use a clear skeletal drawing.

Check every mechanism in the same order

Check atoms first, then the radical dots. Initiation turns one halogen molecule into two radicals. Each propagation step uses one radical and forms one radical. Termination combines two radicals into a molecule with no unpaired electrons.

STAGE	RADICALS BEFORE	RADICALS AFTER
Initiation	0	2
Propagation	1	1
Termination	2	0

12. Worked answers 8 to 10

SPEC Use full explanations for comparison questions and full equations for mechanism questions.

TEST IT 8 Mixtures [5 marks]

(a) 1-Bromopentane, 2-bromopentane and 3-bromopentane [1 each]. Numbering from the other end does not create additional structural isomers.

(b) Substitution can occur at different positions in the carbon chain [1]. Further substitution can replace more than one H atom with halogen [1].

TEST IT 9 Combined application [8 marks]

(a) C_nH_{2n+2} [1].

(b) Hexane is less branched and has greater surface contact between molecules [1]. It has stronger London forces [1], so more energy is required to overcome them [1]. Both isomers have the same number of electrons.

(c) $2C_6H_{14} + 13O_2 \rightarrow 12CO + 14H_2O$. Correct products [1]; balanced equation [1].

(d) CO binds strongly to haemoglobin [1], reducing oxygen transport in the blood [1].

TEST IT 10 Correcting a mechanism [6 marks]

(a) Homolytic fission [1]. $Br_2 \rightarrow 2Br\bullet$ [1]. UV in sunlight supplies the required energy.

(b) $CH_3CH_3 + Br_2 \rightarrow CH_3CH_2Br + HBr$ [1]. The other product is hydrogen bromide, not H_2.

(c) $Br\bullet + CH_3CH_3 \rightarrow HBr + CH_3CH_2\bullet$ [1]

$CH_3CH_2\bullet + Br_2 \rightarrow CH_3CH_2Br + Br\bullet$ [1]

(d) $CH_3CH_2\bullet + \bullet CH_2CH_3 \rightarrow CH_3CH_2CH_2CH_3$ [1].

EXAM CHECK An overall equation and a mechanism answer different questions. If asked for both, give both. Include the hydrogen halide in the overall equation.

YOUR TOTAL _____ **/ 54** **TOPIC TO REVISIT** _____

Choose one answer you changed. Explain the chemistry behind the correction in a sentence, then redo it without looking.

13. Alkanes mastery check

SPEC Use this page after completing and correcting the practice questions.

Tick a statement only when you can do it without looking at the worked examples.

CAN I DO THIS?	CHECK
Define a saturated hydrocarbon and use C_nH_{2n+2} for an open-chain alkane.	☐
Explain sigma bonding, free rotation and tetrahedral 109.5° geometry.	☐
Explain chain-length and branching effects on boiling point using London forces.	☐
Explain low reactivity using high bond enthalpies and very low polarity.	☐
Balance complete and incomplete combustion equations for the stated products.	☐
Explain why carbon monoxide reduces oxygen transport.	☐
Use UV, homolytic fission and radical dots correctly.	☐
Write initiation, two propagation steps and possible termination equations.	☐
Place the radical on the carbon that forms the requested substitution product.	☐
Explain both causes of a mixture in radical substitution.	☐

✓ **DONE WHEN** You can explain the properties, write the equations and adapt radical substitution to an unfamiliar alkane.

Final equation check

Are all atoms balanced? Are the products appropriate for the stated conditions? Does every radical have a dot? Have you preserved the carbon skeleton? Have you included HCl or HBr when writing the overall substitution equation?

Specification and exam guidance

Scope checked against OCR Chemistry A H432 specification, version 3.1 (May 2026), section 4.1.2, printed page 33. The practice questions and indicative answers in this booklet are original CrackingChem material, not OCR questions or official mark schemes.

Official specification: ocr.org.uk/images/171720-specification-accredited-a-level-gce-chemistry-a-h432.pdf

OCR H432/02 examiner reports, June 2023 (Question 16) and June 2024 (Question 18), informed the reminders about radical-dot placement and writing the overall equation.

2023 report: ocr.org.uk/Images/703623-examiners-report-synthesis-and-analytical-techniques.pdf
2024 report: ocr.org.uk/Images/726409-examiners-report-synthesis-and-analytical-techniques.pdf