



AQA 7405

Haloalkanes I

C-X POLARITY • OH⁻ • CN⁻ • NH₃ • NUCLEOPHILIC SUBSTITUTION

ORIGINAL EXAM QUESTIONS | TEST IT → EXAM STYLE → HARDER MIXED → STRETCH

TEST IT	EXAM STYLE	HARDER MIXED	STRETCH
8	8	4	2

22 QUESTIONS | 235 TOTAL MARKS

Mapped to AQA Chemistry 7405, section 3.3.3.1: Haloalkanes I

Specification checked 14 October 2026

How to use this pack [START HERE](#)

- 1 Read the command word. State is concise; explain must link cause to effect; draw requires every lone pair, charge and arrow requested.
- 2 Use the dotted lines for written answers and the bordered spaces for mechanisms. Full curly arrows show movement of electron pairs.
- 3 Check atoms, bonds and total charge. A correct mechanism starts each arrow at a lone pair or bond, never at a charge symbol.

Specification route

AQA section	Assessed in this pack
3.3.3.1 — Part I	Polar C-X bonds; nucleophilic substitution with OH ⁻ , CN ⁻ and NH ₃ ; mechanisms, products, reagents and conditions.
Bring forward	Organic names and formulae; lone pairs, heterolytic fission and full curly-arrow conventions.
Reserved for Part II	C-X bond enthalpy and hydrolysis-rate comparisons; elimination; CFCs and ozone depletion.

SECTION A TEST IT*Secure the language, routes and arrow conventions before the longer questions.***QUESTION 1 | TEST IT**

(a) State what is meant by the term haloalkane (halogenoalkane). (2 marks)

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(b) Name $\text{CH}_3\text{CH}_2\text{CH}_2\text{I}$. (1 mark)

.....

(c) Name $\text{CH}_3\text{CHBrCH}_2\text{CH}_3$. (1 mark)

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(d) Classify the haloalkanes in parts (b) and (c) as primary, secondary or tertiary. Justify each classification using the carbon bonded to the halogen. (2 marks)

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(e) State the general formula of an acyclic monohaloalkane. (1 mark)

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QUESTION 2 | TEST IT*Consider the C–Cl bond in chloroethane.*

(a) State the partial charge on C and the partial charge on Cl. (2 marks)

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(b) Explain why the C–Cl bond is polar. (2 marks)

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(c) Define nucleophile. (1 mark)

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(d) For each nucleophile, state the atom that donates the reacting lone pair: OH^- , CN^- and NH_3 . (3 marks)

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QUESTION 3 | TEST IT

(a) State what a full curly arrow represents. (1 mark)

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(b) Define heterolytic fission. (2 marks)

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(c) In the reaction of CH_3Br with OH^- , state the exact start and end point of the arrow that forms the C–O bond. (2 marks)

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- (d) State the exact start and end point of the arrow that breaks the C–Br bond. (2 marks)

QUESTION 4 | TEST IT

1-bromobutane is converted into butan-1-ol.

- (a) Give a suitable reagent. (1 mark)

- (b) State the solvent condition and the heating condition. (2 marks)

- (c) Write an ionic equation for the reaction using structural formulae. (2 marks)

- (d) Name the mechanism and state the nucleophile. (2 marks)

QUESTION 5 | TEST IT

1-iodobutane reacts with hydroxide ions to form butan-1-ol.

- (a) Draw the nucleophilic substitution mechanism. Show the reacting lone pair, both full curly arrows, the organic product and I^- . (5 marks)

Draw the complete mechanism here

QUESTION 6 | TEST IT

1-chlorobutane is converted into a nitrile.

- (a) Give a suitable reagent. (1 mark)

- (b) State the solvent and heating conditions. (2 marks)

- (c) Write the structural formula and name of the organic product. (2 marks)

- (d) State the molecular formula of the product and explain why it has one more carbon atom than the haloalkane. (2 marks)

(e) State which atom in CN^- forms the new bond to the carbon chain.

(1 mark)

QUESTION 7 | TEST IT

Bromomethane reacts with cyanide ions to form ethanenitrile.

(a) Draw the mechanism. Show CN^- with the reacting lone pair on carbon, both full curly arrows, the $\text{C}\equiv\text{N}$ bond and both products.

(5 marks)

Draw the complete mechanism here

QUESTION 8 | TEST IT

1-bromopropane reacts with ammonia to form propan-1-amine.

(a) State the reagent, solvent and heating conditions.

(3 marks)

(b) Write the overall equation using structural formulae.

(3 marks)

(c) Explain the two different roles of the two NH_3 molecules shown in the overall equation.

(2 marks)

(d) Explain why excess ammonia is used.

(1 mark)

SECTION B EXAM STYLE

Apply the specification in linked AQA-style questions with realistic answer space.

QUESTION 9 | EXAM STYLE

1-bromo-3-methylbutane is heated with aqueous potassium hydroxide.

(a) Draw the structural formula of the organic product and give its systematic name.

(2 marks)

(b) Write an ionic equation for the reaction.

(2 marks)

- (c) Draw the nucleophilic substitution mechanism. Show all charges, the reacting lone pair, both full curly arrows and both products. (5 marks)

Draw the complete mechanism here

- (d) Explain why the carbon skeleton of the organic product is unchanged. (1 mark)

QUESTION 10 | EXAM STYLE

1-chloro-2-methylpropane reacts with potassium cyanide.

- (a) Give the solvent and heating conditions. (2 marks)

- (b) Draw the structural formula of the organic product, showing the $\text{C}\equiv\text{N}$ triple bond. Give its systematic name and molecular formula. (4 marks)

- (c) Draw the mechanism. Show the reacting atom and lone pair in CN^- , both full curly arrows, the $\text{C}\equiv\text{N}$ group and both products. (5 marks)

Draw the complete mechanism here

- (d) Explain how the parent chain and locants in the product name are determined. (2 marks)

QUESTION 11 | EXAM STYLE

Bromoethane reacts with excess ammonia in ethanol. The formation of ethylamine occurs in two stages.

- (a) Draw the first stage. Show the lone pair on the nitrogen atom of NH_3 , both full curly arrows, the organic ion and Br^- . (5 marks)

Draw stage 1 here

- (b) State why the organic product of stage 1 has a positive charge and give its formula. (2 marks)

- (c) Draw the second stage using another NH_3 molecule. Show both full curly arrows and both products. (4 marks)

Draw stage 2 here

- (d) Write the overall equation for the conversion of bromoethane into ethylamine. (3 marks)

QUESTION 12 | EXAM STYLE

1-iodopropane can be converted separately into three different products.

- (a) Give the reagent and conditions needed to make propan-1-ol, then write the ionic equation. (4 marks)

- (b) Give the reagent and conditions needed to make butanenitrile, then write the ionic equation. (4 marks)

(c) Give the reagent and conditions needed to make propan-1-amine, then write the overall equation. (5 marks)

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(d) For one of these routes, distinguish clearly between the reagent and the nucleophile. (2 marks)

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QUESTION 13 | EXAM STYLE

Figure 1 shows an apparatus used when a haloalkane is heated under reflux with aqueous hydroxide.

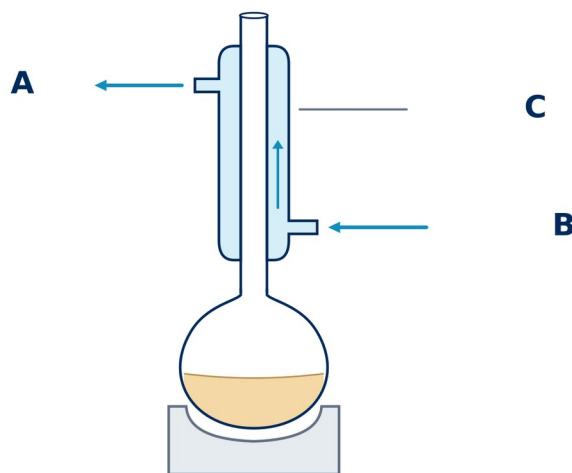


Figure 1

(a) Identify A, B and C. Your answer must state which water connection is the inlet and which is the outlet. (3 marks)

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(b) Explain why heating under reflux is used. (3 marks)

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(c) Explain why the water enters the condenser through the lower connection. (1 mark)

QUESTION 14 | EXAM STYLE

A student writes four statements about the mechanism of $\text{CH}_3\text{CH}_2\text{Br}$ with OH^- . Each statement contains one error.

	Student statement
1	The incoming curly arrow starts at the minus sign written beside OH^- .
2	The incoming curly arrow ends at a hydrogen atom in $\text{CH}_3\text{CH}_2\text{Br}$.
3	The breaking-bond arrow starts at Br and points to the C–Br bond.
4	The other product is a neutral Br atom.

- (a) For each statement, identify the error and state the correct arrow placement or product. (8 marks)

QUESTION 15 | EXAM STYLE

2-bromopropane is used as the starting material in three separate substitution reactions.

- (a) Give the structural formula and systematic name of the product formed with OH^- . (2 marks)

- (b) Give the structural formula and systematic name of the product formed with CN^- . (3 marks)

- (c) Give the structural formula and systematic name of the product formed with NH_3 after proton removal. (2 marks)

- (d) State the number of carbon atoms in each product and explain the difference. (3 marks)

- (e) State one condition that distinguishes the ammonia route from the hydroxide route. (1 mark)

QUESTION 16 | EXAM STYLE

A student proposes the equation $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Cl} + \text{NH}_3 \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2 + \text{HCl}$ for the preparation of butan-1-amine.

- (a) Explain why the proposed equation does not represent the overall reaction under the stated ammonia conditions. (2 marks)

- (b) Write the correct overall equation. (3 marks)

(c) Draw the first substitution stage, including the correct organic intermediate and chloride ion.

(5 marks)

Draw stage 1 here

(d) State the role of the second NH_3 molecule.

(1 mark)

SECTION C HARDER MIXED

Deduce hidden structures, select routes and audit mechanisms without scaffolding.

QUESTION 17 | HARDER MIXED

A primary bromoalkane X has molecular formula $\text{C}_4\text{H}_9\text{Br}$. Reaction of X with CN^- produces 3-methylbutanenitrile.

(a) Deduce the structural formula and systematic name of X. Use the product name to justify the connectivity.

(3 marks)

(b) State the molecular formula of 3-methylbutanenitrile.

(1 mark)

(c) Draw the mechanism for the reaction of X with CN^- . Show the reacting lone pair, both full curly arrows and both products.

(5 marks)

Draw the complete mechanism here

(d) Give the systematic name of the alcohol formed when X reacts with aqueous hydroxide.

(1 mark)

(e) State the reagent and conditions for converting X into the nitrile.

(3 marks)

QUESTION 18 | HARDER MIXED

Four students analyse nucleophilic substitution reactions. Each conclusion is chemically wrong.

- (a) Student A says that $\text{CH}_3\text{CH}_2\text{CH}_2\text{Br} + \text{CN}^-$ forms propanenitrile because the starting haloalkane has three carbon atoms. Identify the error and give the correct product name. (2 marks)

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- (b) Student B draws the incoming arrow for CN^- from nitrogen. Identify the error and state the bond formed in the required product. (2 marks)

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- (c) Student C draws NH_3 attacking through a hydrogen atom and writes the immediate product as a neutral amine. Correct both errors. (4 marks)

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- (d) Student D chooses aqueous KOH to convert 1-iodobutane into pentanenitrile. Give the correct reagent/solvent and explain the carbon-count clue. (3 marks)

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QUESTION 19 | HARDER MIXED

A secondary monochloroalkane Y has general formula $\text{C}_n\text{H}_{2n+1}\text{Cl}$ and $M_r = 92.5$. Use A_r values $\text{C} = 12.0$, $\text{H} = 1.0$ and $\text{Cl} = 35.5$.

- (a) Determine n and hence the molecular formula of Y. (3 marks)

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- (b) Deduce the structural formula and systematic name of Y. (2 marks)

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- (c) Give the systematic names of the products formed separately from Y with OH^- and with NH_3 after proton removal. (2 marks)

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- (d) Draw the mechanism for the reaction of Y with CN^- . Show all requested charges, lone pair, arrows and products. (5 marks)

Draw the complete mechanism here

- (e) Name the nitrile product and explain its locant. (2 marks)

QUESTION 20 | HARDER MIXED

A primary bromoalkane P gives 3-methylpentanenitrile when heated with cyanide ions. The same P gives an alcohol with molecular formula $\text{C}_5\text{H}_{12}\text{O}$ when heated with aqueous hydroxide.

- (a) Deduce the structural formula and systematic name of P. Explain how the nitrile name fixes the carbon skeleton. (3 marks)

- (b) Give the structural formula and systematic name of the alcohol. (2 marks)

- (c) Write the overall equation for P reacting with ammonia and name the organic product. (4 marks)

- (d) Draw the mechanism by which P forms 3-methylpentanenitrile. (5 marks)

Draw the complete mechanism here

- (e) State the reagent, solvent and heating condition for the nitrile route. (3 marks)

SECTION D STRETCH / SYNOPTIC

Connect prior organic and quantitative ideas while remaining inside the Haloalkanes I boundary.

QUESTION 21 | STRETCH / SYNOPTIC

1-iodo-3-methylbutane is converted into 3-methylbutan-1-amine using excess ammonia. Show the full two-stage pathway.

- (a) Draw the first stage, including the lone pair on the nitrogen atom of NH_3 , both full curly arrows, the complete alkylammonium ion and I^- . (5 marks)

Draw stage 1 here

- (b) Draw the second stage using another NH_3 molecule. Show the lone pair over nitrogen, both full curly arrows and both products. (4 marks)

Draw stage 2 here

- (c) Write the overall equation using structural formulae. (3 marks)

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- (d) Give the solvent and heating conditions and explain why a sealed vessel is used. (3 marks)

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- (e) Use electron-pair movement to explain why total charge is conserved across the first stage. (2 marks)

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QUESTION 22 | STRETCH / SYNOPTIC

An unknown haloalkane Z has molecular formula C_4H_9Br . Reaction with aqueous hydroxide gives butan-2-ol as the only structural product considered here.

(a) Deduce the structural formula and systematic name of Z.

(2 marks)

(b) Draw the structural formula of the nitrile formed from Z, showing $C\equiv N$. State its molecular formula and give its systematic name using the nitrile carbon as carbon 1.

(4 marks)

(c) Draw the nucleophilic substitution mechanism for formation of the nitrile.

(5 marks)

Draw the complete mechanism here

(d) Write the overall equation for Z reacting with ammonia and name the organic product.

(4 marks)

(e) Compare the carbon counts of the alcohol, nitrile and amine products and explain the pattern.

(3 marks)

BEFORE YOU TURN OVER — FINAL CHECK

1	Every incoming arrow starts at a lone pair and ends at the carbon bonded to X.
2	Every breaking arrow starts on C–X and ends at X; the leaving species carries a – charge.
3	CN^- bonds through C and adds one carbon; NH_3 bonds through N and first gives RNH_3^+ .
4	Products, charges, reagents and conditions answer exactly what each command word asks.

QUESTIONS END HERE • ANSWERS BEGIN ON THE NEXT PAGE



AQA 7405

Haloalkanes I

ANSWERS & MARK SCHEME

FULLY WORKED • PRECISELY MARKED • BUILT FOR IMPROVEMENT

22 ANSWERS | 235 MARKS

SECTION A TEST IT ANSWERS

Use each marking point to identify exactly where a response gained or lost credit.

QUESTION 1 | TEST IT

7 marks

- (a) An alkane derivative [1] in which one or more H atoms have been replaced by halogen atoms [1]. Accept an equivalent definition using the C-X functional group.
- (b) 1-iodopropane [1].
- (c) 2-bromobutane [1].
- (d) $\text{CH}_3\text{CH}_2\text{CH}_2\text{I}$ is primary because its C-I carbon is bonded to one other carbon [1]. $\text{CH}_3\text{CHBrCH}_2\text{CH}_3$ is secondary because its C-Br carbon is bonded to two other carbons [1].
- (e) $\text{C}_n\text{H}_{2n+1}\text{X}$ [1].

COMMON ERROR Count carbon neighbours of the carbon carrying X. Do not count the total number of carbon atoms in the molecule.

QUESTION 2 | TEST IT

8 marks

- (a) C is δ^+ [1] and Cl is δ^- [1].
- (b) Cl is more electronegative than C [1], so Cl attracts the C-Cl bonding pair more strongly [1].
- (c) An electron-pair donor [1].
- (d) OH^- donates from O [1]; CN^- donates from C in the required nitrile-forming reaction [1]; NH_3 donates from N [1].
- COMMON ERROR** A nucleophile need not be negatively charged. NH_3 is neutral but has an available lone pair on nitrogen.

QUESTION 3 | TEST IT

7 marks

- (a) Movement of a pair of electrons [1].
- (b) A covalent bond breaks [1] and both bonding electrons go to one of the bonded atoms [1].
- (c) The arrow starts at a lone pair on O in OH^- [1] and ends at the carbon bonded to Br [1].
- (d) The arrow starts on the C-Br bond [1] and ends at the Br atom [1].
- COMMON ERROR** An arrow does not start at a negative-charge symbol or at the halogen atom. It starts where the electron pair is located.

QUESTION 4 | TEST IT

7 marks

- (a) NaOH or KOH [1].
- (b) Aqueous solution [1] and heat under reflux [1].
- (c) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br} + \text{OH}^- \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + \text{Br}^-$. Award [1] for the correct organic product and [1] for a balanced equation including Br^- .
- (d) Nucleophilic substitution [1]; OH^- [1].

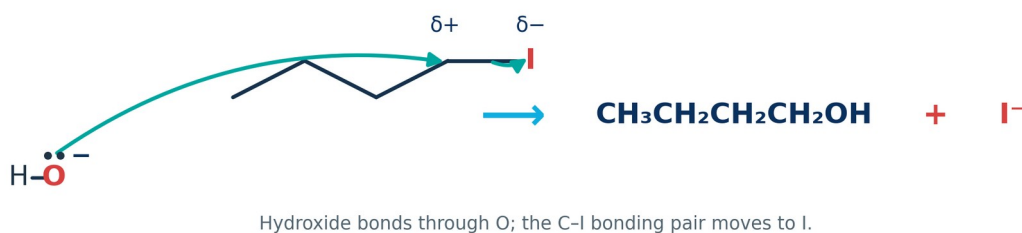
QUESTION 5 | TEST IT

5 marks

- (a) Show a lone pair and negative charge on O in OH^- [1]; a curly arrow from that O lone pair to the carbon bonded to I [1]; a curly arrow from the C-I bond to I [1]; butan-1-ol with the C-O bond in the correct position [1]; I^- [1].

QUESTION 5 | TEST IT

5 marks



COMMON ERROR OH⁻ bonds through oxygen. The incoming arrow must not point to H, and the leaving product is I⁻, not neutral I.

QUESTION 6 | TEST IT

8 marks

- (a) KCN or NaCN [1].
 (b) Aqueous ethanol [1] and heat under reflux [1].
 (c) CH₃CH₂CH₂CH₂CN [1], pentanenitrile [1].
 (d) C₅H₉N [1]. The carbon in CN⁻ becomes part of the organic product [1].
 (e) The carbon atom [1].

COMMON ERROR Include the nitrile carbon in the parent chain and retain the C≡N triple bond.

QUESTION 7 | TEST IT

5 marks

- (a) Show CN⁻ with its reacting lone pair on C [1]; arrow from the C lone pair to the carbon in CH₃Br [1]; arrow from the C-Br bond to Br [1]; CH₃C≡N with the triple bond retained [1]; Br⁻ [1].



COMMON ERROR An arrow from N would give the wrong connectivity for the nitrile product required by AQA.

QUESTION 8 | TEST IT

9 marks

- (a) Excess NH₃ [1] in ethanol [1], heated under pressure in a sealed vessel [1].
 (b) CH₃CH₂CH₂Br + 2NH₃ → CH₃CH₂CH₂NH₂ + NH₄Br. Award [1] for 2NH₃, [1] for the primary amine and [1] for NH₄Br.
 (c) One NH₃ molecule donates its nitrogen lone pair to form the C-N bond [1]. A second NH₃ molecule acts as a base and removes H⁺ from the alkylammonium ion [1].
 (d) It favours reaction with NH₃ and reduces further substitution by the amine product [1].

COMMON ERROR Do not write a one-ammonia equation that produces HBr. The salt product is NH₄Br.

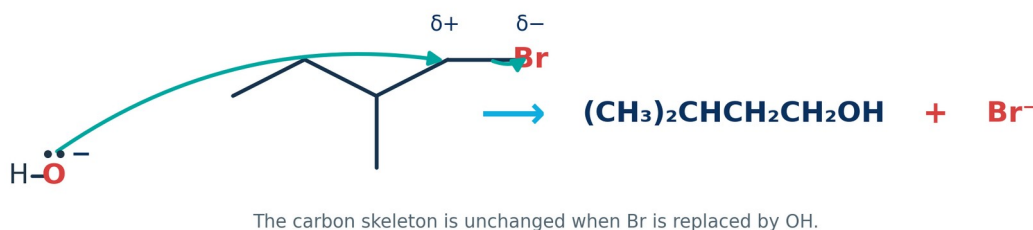
SECTION B EXAM STYLE ANSWERS

Model answers show the terminology, structures and mechanism detail expected by AQA.

QUESTION 9 | EXAM STYLE

10 marks

- (a) CH₃CH(CH₃)CH₂CH₂OH [1], 3-methylbutan-1-ol [1]. Accept the equivalent structure written from the opposite end.
 (b) CH₃CH(CH₃)CH₂CH₂Br + OH⁻ → CH₃CH(CH₃)CH₂CH₂OH + Br⁻. Award [1] for the correct substitution product and [1] for a balanced equation including Br⁻.
 (c) Show OH⁻ with a lone pair on O [1]; arrow from that pair to the carbon bonded to Br [1]; arrow from C-Br to Br [1]; the correctly connected alcohol [1]; Br⁻ [1].



- (d) OH replaces Br at the same carbon; no C-C bond is broken or formed [1].

QUESTION 10 | EXAM STYLE

13 marks

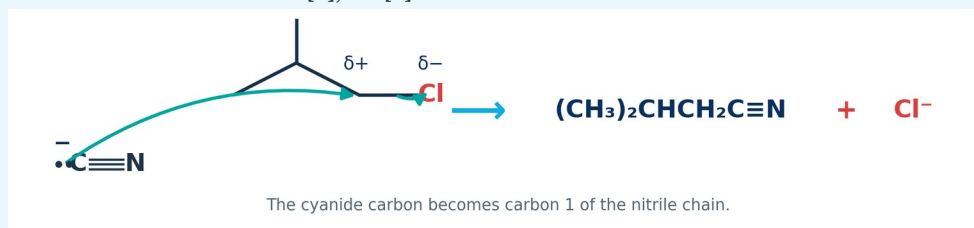
- (a) Aqueous ethanol [1] and heat under reflux [1].

QUESTION 10 | EXAM STYLE

13 marks

(b) $(\text{CH}_3)_2\text{CHCH}_2\text{CN}$ [1]; 3-methylbutanenitrile [1]; $\text{C}_5\text{H}_9\text{N}$ [1]. Award the fourth mark for including the $\text{C}\equiv\text{N}$ triple bond in a displayed or unambiguous structural formula [1].

(c) Show CN^- with the reacting lone pair on C [1]; arrow from that pair to the C bonded to Cl [1]; arrow from C–Cl to Cl [1]; correctly connected nitrile with $\text{C}\equiv\text{N}$ intact [1]; Cl^- [1].



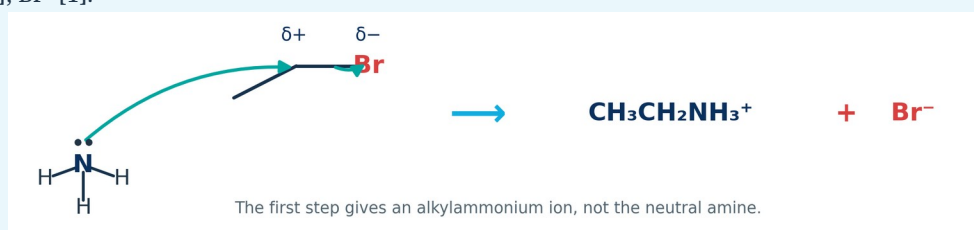
(d) The nitrile carbon is included in the parent chain and is carbon 1 [1]; the longest chain containing it determines the parent name and substituent position [1].

COMMON ERROR For this structure the correct name is 3-methylbutanenitrile, not 2-methylbutanenitrile and not 1-cyano-2-methylpropane.

QUESTION 11 | EXAM STYLE

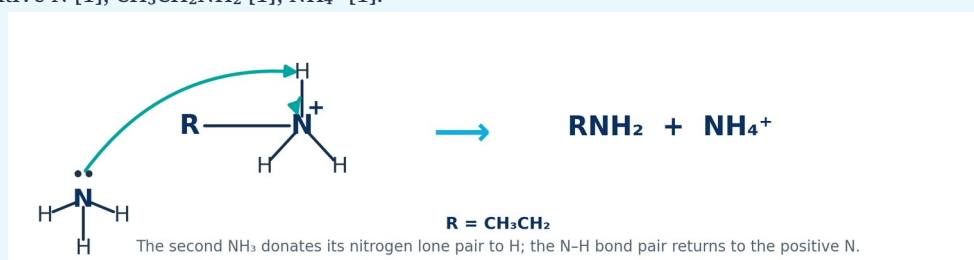
14 marks

(a) Show the lone pair on N in NH_3 [1]; arrow from that pair to the carbon bonded to Br [1]; arrow from C–Br to Br [1]; $\text{CH}_3\text{CH}_2\text{NH}_3^+$ [1]; Br^- [1].



(b) Nitrogen has used its lone pair to form a fourth covalent bond [1], so the intermediate is $\text{CH}_3\text{CH}_2\text{NH}_3^+$ [1].

(c) Arrow from the lone pair on the second NH_3 nitrogen to an H bonded to the positive N [1]; arrow from that N–H bond back to the positive N [1]; $\text{CH}_3\text{CH}_2\text{NH}_2$ [1]; NH_4^+ [1].



(d) $\text{CH}_3\text{CH}_2\text{Br} + 2\text{NH}_3 \rightarrow \text{CH}_3\text{CH}_2\text{NH}_2 + \text{NH}_4\text{Br}$. Award [1] for 2NH_3 , [1] for $\text{CH}_3\text{CH}_2\text{NH}_2$ and [1] for NH_4Br .

COMMON ERROR The first organic product is $\text{CH}_3\text{CH}_2\text{NH}_3^+$. It is not the neutral amine until a second NH_3 molecule removes H^+ .

QUESTION 12 | EXAM STYLE

15 marks

(a) Aqueous NaOH or KOH [1], heat under reflux [1]; $\text{CH}_3\text{CH}_2\text{CH}_2\text{I} + \text{OH}^- \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{OH} + \text{I}^-$ [2].

(b) KCN or NaCN in aqueous ethanol [1], heat under reflux [1]; $\text{CH}_3\text{CH}_2\text{CH}_2\text{I} + \text{CN}^- \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CN} + \text{I}^-$ [2].

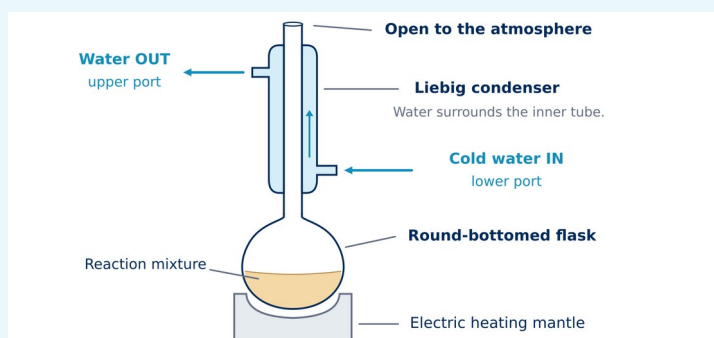
(c) Excess NH_3 in ethanol [1], heat under pressure in a sealed vessel [1]; $\text{CH}_3\text{CH}_2\text{CH}_2\text{I} + 2\text{NH}_3 \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2 + \text{NH}_4\text{I}$ [3].

(d) For example, aqueous NaOH is the reagent [1] and OH^- is the nucleophile [1]. Accept KCN as reagent/ CN^- as nucleophile or excess ethanolic NH_3 as both reagent and nucleophile.

QUESTION 13 | EXAM STYLE

7 marks

(a) A is the water outlet at the upper port [1]; B is the cold-water inlet at the lower port [1]; C is the Liebig condenser / vertical condenser [1].



QUESTION 13 | EXAM STYLE

7 marks

- (b) The mixture can be heated for a prolonged time [1]; vapour rises into the condenser and cools [1]; the liquid returns to the reaction flask, reducing loss of volatile material [1].
- (c) Entering at the bottom keeps the water jacket full and gives effective cooling along the condenser [1].
- COMMON ERROR** Reflux returns condensed material to the same flask. Distillation collects it in a separate receiver.

QUESTION 14 | EXAM STYLE

8 marks

- (a) 1: the tail must start at a lone pair on O [1], not at the charge symbol [1]. 2: the head must end at the carbon bonded to Br [1], because that carbon is δ^+ [1]. 3: the tail must start on the C–Br bond [1] and the head must end at Br [1]. 4: the product is Br^- [1] because Br receives both bonding electrons [1].

QUESTION 15 | EXAM STYLE

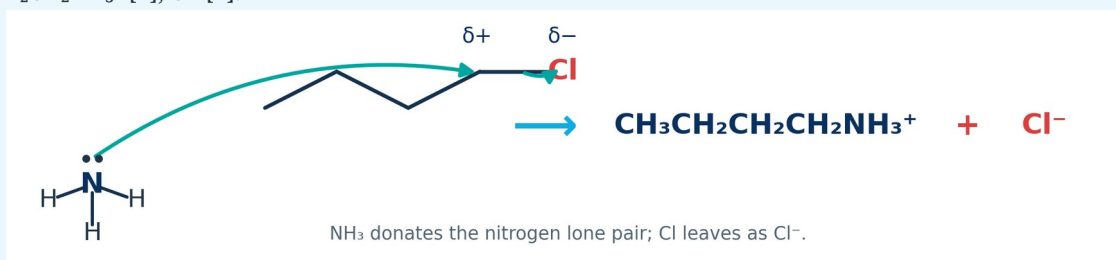
11 marks

- (a) $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$ [1], propan-2-ol [1].
- (b) Correct connectivity, $(\text{CH}_3)_2\text{CH}-\text{C}\equiv\text{N}$ [1]; the $\text{C}\equiv\text{N}$ triple bond shown [1]; 2-methylpropanenitrile [1].
- (c) $\text{CH}_3\text{CH}(\text{NH}_2)\text{CH}_3$ [1], propan-2-amine [1].
- (d) The alcohol and amine each contain three carbons [1]; the nitrile contains four [1] because the carbon in CN^- becomes part of the product [1].
- (e) The ammonia route is heated under pressure in a sealed vessel, whereas the hydroxide route is heated under reflux [1]. Accept excess ethanolic ammonia versus aqueous hydroxide.

QUESTION 16 | EXAM STYLE

11 marks

- (a) The first substitution step forms an alkylammonium ion rather than the neutral amine [1]; a second NH_3 removes H^+ , forming NH_4^+ rather than HCl [1].
- (b) $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Cl} + 2\text{NH}_3 \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_2 + \text{NH}_4\text{Cl}$. Award [1] for 2NH_3 , [1] for the amine and [1] for NH_4Cl .
- (c) Show a lone pair on N in NH_3 [1]; arrow from the N pair to the carbon bonded to Cl [1]; arrow from C–Cl to Cl [1]; $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{NH}_3^+$ [1]; Cl^- [1].



- (d) It acts as a base / proton acceptor [1].

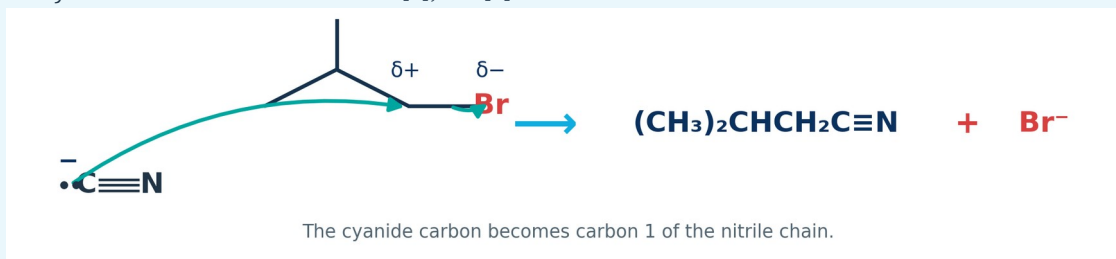
SECTION C HARDER MIXED ANSWERS

These routes make the hidden deductions explicit and then apply the standard chemistry.

QUESTION 17 | HARDER MIXED

13 marks

- (a) X is $(\text{CH}_3)_2\text{CHCH}_2\text{Br}$ [1], 1-bromo-2-methylpropane [1]. Removing the nitrile carbon from 3-methylbutanenitrile and replacing CN by Br gives that carbon skeleton [1].
- (b) $\text{C}_5\text{H}_9\text{N}$ [1].
- (c) Show CN^- with the reacting lone pair on C [1]; arrow from that pair to the carbon bonded to Br [1]; arrow from C–Br to Br [1]; 3-methylbutanenitrile with $\text{C}\equiv\text{N}$ intact [1]; Br^- [1].



- (d) 2-methylpropan-1-ol [1].
- (e) KCN or NaCN [1] in aqueous ethanol [1], heated under reflux [1].

QUESTION 18 | HARDER MIXED

11 marks

- (a) The carbon in CN^- is added to the carbon skeleton [1], so the product is butanenitrile [1].
- (b) The reacting lone pair must be on carbon, not nitrogen [1]; a new C–C bond forms between the haloalkane carbon and the carbon of CN^- [1].
- (c) NH_3 donates the lone pair on nitrogen [1], so the incoming arrow starts at that N lone pair [1]. The immediate organic product is an alkylammonium ion, RNH_3^+ [1], which becomes the neutral amine only after a second NH_3 removes H^+ [1].

QUESTION 18 | HARDER MIXED

11 marks

(d) Use KCN or NaCN in aqueous ethanol [1]; heat under reflux [1]. Pentanenitrile contains one more carbon than 1-iodobutane, so CN^- supplies the additional carbon [1].

QUESTION 19 | HARDER MIXED

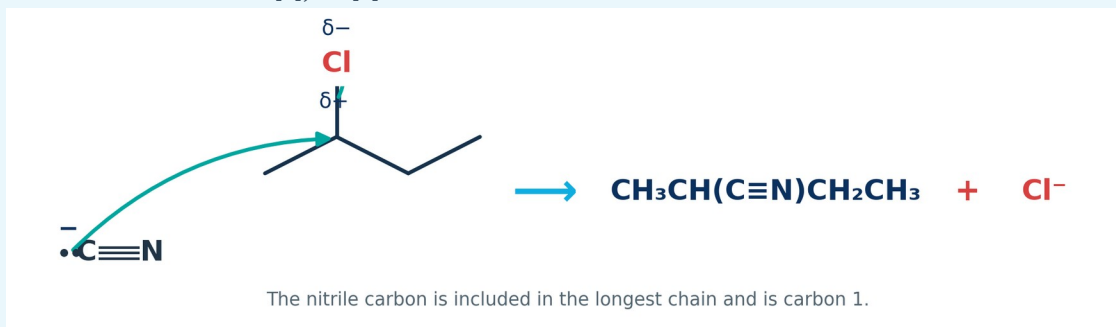
14 marks

(a) $M_r = 12n + (2n + 1) + 35.5 = 14n + 36.5$ [1]. $92.5 = 14n + 36.5$ gives $n = 4$ [1], so Y is $\text{C}_4\text{H}_9\text{Cl}$ [1].

(b) $\text{CH}_3\text{CHClCH}_2\text{CH}_3$ [1], 2-chlorobutane [1]. It is the secondary C_4 monochloroalkane.

(c) Butan-2-ol [1] and butan-2-amine [1].

(d) Show CN^- with the reacting lone pair on C [1]; arrow to the carbon bonded to Cl [1]; arrow from C–Cl to Cl [1]; correctly connected nitrile with $\text{C}\equiv\text{N}$ intact [1]; Cl^- [1].



(e) 2-methylbutanenitrile [1]. The nitrile carbon is carbon 1, making the attacked carbon carbon 2 with a methyl substituent [1].

COMMON ERROR The longest chain must contain the nitrile carbon; it is not simply the longest chain visible in the original haloalkane.

QUESTION 20 | HARDER MIXED

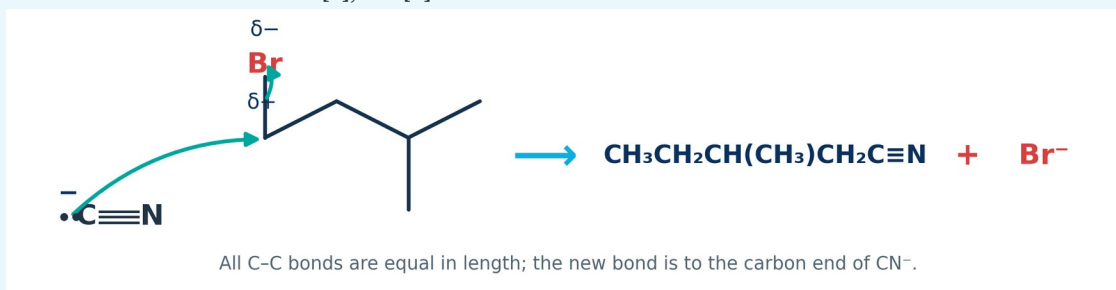
17 marks

(a) P is $\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_3)\text{CH}_2\text{Br}$ [1], 1-bromo-2-methylbutane [1]. Removing the nitrile carbon from 3-methylpentanenitrile and replacing CN with Br gives P [1].

(b) $\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_3)\text{CH}_2\text{OH}$ [1], 2-methylbutan-1-ol [1].

(c) $\text{CH}_3\text{CH}_2\text{CH}(\text{CH}_3)\text{CH}_2\text{Br} + 2\text{NH}_3 \rightarrow \text{CH}_3\text{CH}_2\text{CH}(\text{CH}_3)\text{CH}_2\text{NH}_2 + \text{NH}_4\text{Br}$ [3]; 2-methylbutan-1-amine [1].

(d) Show the C lone pair in CN^- [1]; arrow from that pair to the C bonded to Br [1]; arrow from C–Br to Br [1]; 3-methylpentanenitrile with $\text{C}\equiv\text{N}$ intact [1]; Br^- [1].



(e) KCN or NaCN [1] in aqueous ethanol [1], heated under reflux [1].

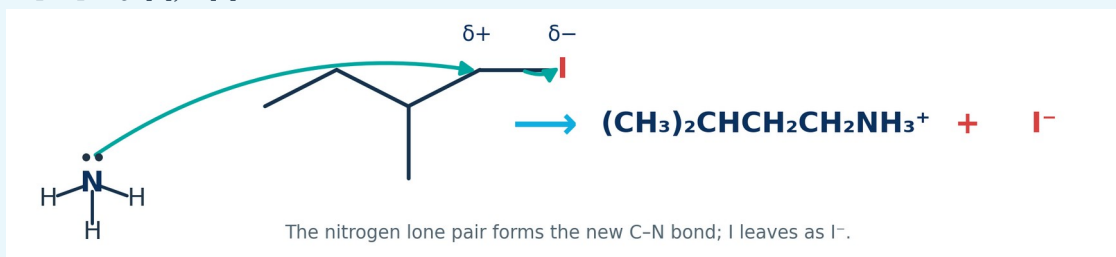
SECTION D STRETCH / SYNOPTIC ANSWERS

Full-credit solutions combine earlier ideas without importing Haloalkanes II content.

QUESTION 21 | STRETCH / SYNOPTIC

17 marks

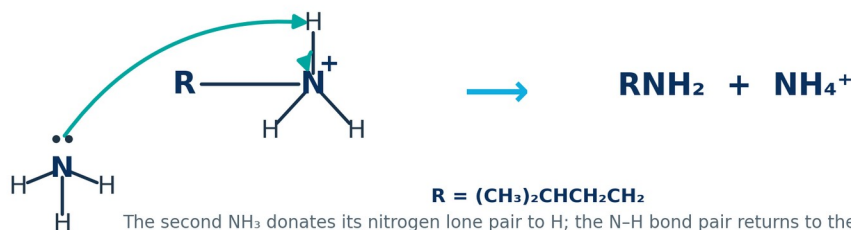
(a) Show the lone pair on N in NH_3 [1]; arrow from N to the carbon bonded to I [1]; arrow from C–I to I [1]; $(\text{CH}_3)_2\text{CHCH}_2\text{CH}_2\text{NH}_3^+$ [1]; I^- [1].



(b) Arrow from the second NH_3 nitrogen lone pair to H on the positive N [1]; arrow from that N–H bond back to the positive N [1]; $(\text{CH}_3)_2\text{CHCH}_2\text{CH}_2\text{NH}_2$ [1]; NH_4^+ [1].

QUESTION 21 | STRETCH / SYNOPTIC

17 marks



(c) $(\text{CH}_3)_2\text{CHCH}_2\text{CH}_2\text{I} + 2\text{NH}_3 \rightarrow (\text{CH}_3)_2\text{CHCH}_2\text{CH}_2\text{NH}_2 + \text{NH}_4\text{I}$. Award [1] for 2NH_3 , [1] for the correct primary amine and [1] for NH_4I .

(d) Use ethanol [1] and heat under pressure [1]; a sealed vessel retains volatile NH_3 in the reaction mixture [1].

(e) NH_3 uses its lone pair to form a fourth N bond, producing a +1 organic ion [1], while the C-I bonding pair moves to I, producing I^- ; the two charges sum to zero [1].

COMMON ERROR Every NH_3 lone pair must be shown directly over or beside nitrogen, never over a hydrogen atom.

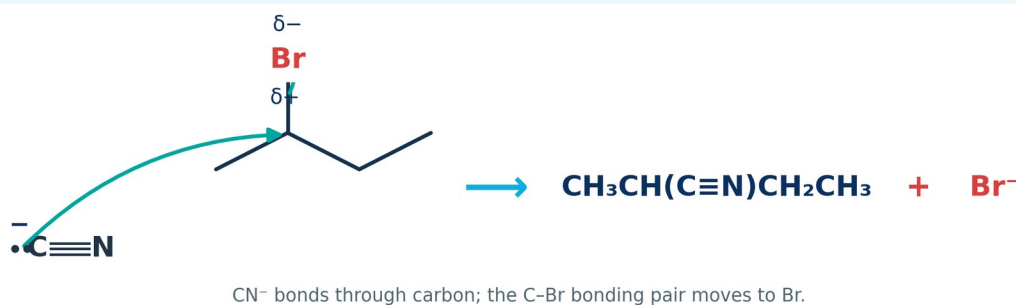
QUESTION 22 | STRETCH / SYNOPTIC

18 marks

(a) $\text{CH}_3\text{CHBrCH}_2\text{CH}_3$ [1], 2-bromobutane [1]. Replacing Br at carbon 2 by OH gives butan-2-ol.

(b) $\text{CH}_3\text{CH}(\text{CN})\text{CH}_2\text{CH}_3$ with $\text{C}\equiv\text{N}$ unambiguous [1]; $\text{C}_5\text{H}_9\text{N}$ [1]; 2-methylbutanenitrile [1]; award [1] for numbering the nitrile carbon as carbon 1.

(c) Show the C lone pair in CN^- [1]; arrow to the carbon bonded to Br [1]; arrow from C-Br to Br [1]; correctly connected nitrile with $\text{C}\equiv\text{N}$ intact [1]; Br^- [1].



(d) $\text{CH}_3\text{CHBrCH}_2\text{CH}_3 + 2\text{NH}_3 \rightarrow \text{CH}_3\text{CH}(\text{NH}_2)\text{CH}_2\text{CH}_3 + \text{NH}_4\text{Br}$ [3]; butan-2-amine [1].

(e) The alcohol and amine each contain four carbon atoms [1]; the nitrile contains five [1] because CN^- contributes its carbon atom to the organic product [1].

COMMON ERROR The nitrile product is named from a new longest chain that includes the nitrile carbon; do not keep the original haloalkane numbering.

FINAL SPECIFICATION COVERAGE AUDIT

AQA / notes strand	Question coverage
Core theory and arrows	Q2-5, Q7, Q9-11, Q14, Q16-22: $\text{C}\delta^+ - \text{X}\delta^-$, nucleophiles, heterolysis, lone pairs, charges and full curly arrows.
Three substitution routes	OH^- : Q4-5, Q9, Q12-15, Q17, Q20, Q22. CN^- : Q6-7, Q10, Q12, Q15, Q17-20, Q22. NH_3 : Q8, Q11-12, Q15-16, Q18, Q20-22.
Conditions and apparatus	Q4, Q6, Q8, Q10, Q12-13, Q17, Q20-21: aqueous/ethanolic media, reflux, pressure and the vertical condenser.
Boundary and sources	No rate/enthalpy trend, elimination or ozone chemistry. Checked against AQA 7405 3.3.3.1, the completed notes and the 2026-27 master map.