

HSC 2026 CHEMISTRY SOLUTIONS

FULLY WORKED SOLUTIONS · 2026 HSC CHEMISTRY EXAMINATION · MARK IT, COUNT IT, COMMENT IT

These are Sigma Science's suggested answers and marking, written on exam day. NESA's official marking guidelines will be published later and may differ in places. The questions are not reproduced here: have your copy of the 2026 HSC Chemistry paper beside you.

1 • Mark

Mark your answers against each solution and its marking criteria. In Section II each numbered step is worth one mark (the two long responses are marked holistically): tick the box when your answer has it. If an earlier step was wrong, still tick later steps done correctly with your own value.

2 • Count

Add up all of your marks: write each question's mark in the score tracker below, then total them out of 100.

3 • Comment

Comment your raw mark on our post! See how you compare with everyone else who sat the paper.

SECTION I ANSWER KEY

tick the ones you got right

1	B ☐	2	A ☐	3	A ☐	4	B ☐	5	C ☐	6	B ☐	7	D ☐	8	D ☐	9	A ☐	10	C ☐
11	A ☐	12	C ☐	13	C ☐	14	B ☐	15	D ☐	16	A ☐	17	D ☐	18	B ☐	19	B ☐	20	A ☐

SCORE TRACKER

write your mark for each question

Sec I	Q21	Q22	Q23	Q24	Q25	Q26	Q27	Q28	Q29	Q30	Q31	Q32	Q33	Q34	Q35	Q36
/20	/2	/4	/4	/3	/8	/5	/5	/5	/5	/3	/7	/7	/5	/4	/8	/5

TOTAL _____ **/ 100**

SECTION I · MULTIPLE CHOICE

Each answer is boxed. “Why not the others?” explains every distractor: read it even when you got the question right.

1 Naming the family of three alcohols

B

Ethanol, propan-1-ol and butan-1-ol all have the same functional group (–OH) and the same general formula, $C_nH_{2n+1}OH$, and each member differs from the next by one $-CH_2-$ unit. That is a **homologous series**.

WHY NOT THE OTHERS? A, C and D are not chemical terms for a family of compounds.

2 Which cation precipitates with chloride

A

Silver chloride is insoluble ($K_{sp} = 1.77 \times 10^{-10}$): $Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$, a **white precipitate**.

WHY NOT THE OTHERS? B, C and D: iron(III) chloride, sodium chloride and ammonium chloride are all soluble. Of the common cations, only Ag^+ and Pb^{2+} precipitate with Cl^- .

3 Changing conditions for an endothermic equilibrium

A

The forward reaction is endothermic. Raising the temperature favours the reaction that absorbs heat, so by Le Chatelier’s principle the equilibrium **shifts to the right**.

WHY NOT THE OTHERS? B: I_2 is a product, so adding it shifts the equilibrium to the left. C: there are 2 mol of gas on each side, so changing the volume has no effect on the position of equilibrium. D: a catalyst speeds up the forward and reverse reactions equally; the position does not change.

4 Gypsum to plaster

B

$CaSO_4 \cdot 2H_2O \rightarrow CaSO_4 \cdot \frac{1}{2}H_2O + \frac{1}{2}H_2O$. Heating removes water of crystallisation: **dehydration**.

WHY NOT THE OTHERS? A: addition reactions add atoms across a double bond. C: hydration is the reverse (it is what happens when plaster sets). D: no oxidation states change (Ca +2, S +6, O –2).

5 Identifying a conjugate acid–base pair

C

A conjugate pair differs by exactly one H^+ : $H_2PO_4^- \rightleftharpoons H^+ + HPO_4^{2-}$.

WHY NOT THE OTHERS? A: H_2O and H_2O_2 differ by an O atom. B: HCO_3^- and CO_2 differ by OH^- (the conjugate base of HCO_3^- is CO_3^{2-}). D: $Fe(OH)_2$ and $Fe(OH)_3$ differ by OH and by the oxidation state of iron.

6 Dissolving sodium acetate in water

B

Sodium acetate dissolves completely. The acetate ion is the conjugate base of a weak acid, so it reacts with water: $CH_3COO^- + H_2O \rightleftharpoons CH_3COOH + OH^-$. $[OH^-]$ increases, so **the pH increases** (a basic salt).

WHY NOT THE OTHERS? A: no gas is produced. C: all sodium salts are soluble. D: the solution stays colourless.

7 Writing the equation from an equilibrium expression

D

Products go on the top and reactants on the bottom, with the powers as the coefficients: $4\text{NH}_3 + 5\text{O}_2 \rightleftharpoons 4\text{NO} + 6\text{H}_2\text{O}$. The reaction is homogeneous and $[\text{H}_2\text{O}]$ appears in the expression, so every species is a gas: **$\text{H}_2\text{O}(\text{g})$** .

WHY NOT THE OTHERS? A: a pure liquid is left out of K_{eq} , so $\text{H}_2\text{O}(\text{l})$ cannot appear in the expression (and the system would not be homogeneous). B and C are reverse reactions, so their expressions are inverted (B also has the wrong coefficients and is not balanced).

8 First test for Ca^{2+} in water

D

Adding sodium hydroxide gives a **white precipitate** of calcium hydroxide ($K_{\text{sp}} = 5.02 \times 10^{-6}$), which narrows down the cation. A flame test (brick red) would then confirm it.

WHY NOT THE OTHERS? A: the pH does not identify a cation. B: Ca^{2+} is colourless, so colourimetry cannot detect it (AAS would). C: adding acid to look for a gas tests for an anion (carbonate), not a cation.

9 Concentration–time graph for a decrease in volume

A

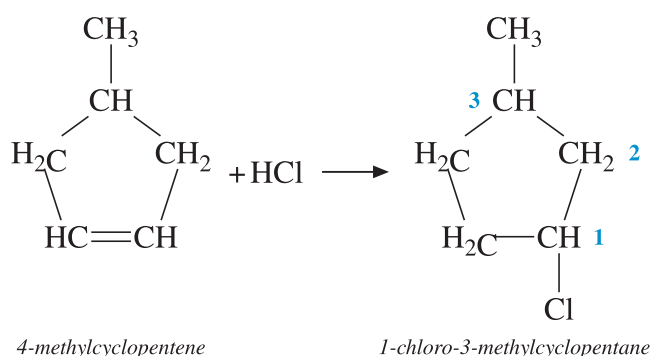
Halving the volume (or any decrease) increases **every** concentration instantly, so all three lines jump up at t . The system then shifts towards fewer moles of gas ($4 \text{ mol} \rightarrow 2 \text{ mol}$), to the right: $[\text{N}_2]$ and $[\text{H}_2]$ fall gradually and $[\text{NH}_3]$ rises to a new equilibrium.

WHY NOT THE OTHERS? B: no sudden jump, just gradual changes: a temperature change (a decrease, favouring the exothermic forward reaction). C: $[\text{NH}_3]$ drops suddenly: NH_3 was removed. D: only $[\text{N}_2]$ jumps: N_2 was added.

10 Adding HCl to 4-methylcyclopentene

C

HCl adds across the $\text{C}=\text{C}$ bond (an addition reaction): one alkene carbon gains H and the other gains Cl. Numbering from the carbon bearing Cl, the methyl group is on C3: **1-chloro-3-methylcyclopentane**. The two alkene carbons are equivalent, so only one structural product forms (whichever carbon gains the Cl).



H adds to one alkene carbon and Cl to the other. Number the ring from the C bearing Cl (C1) the short way round to the $\text{CH}(\text{CH}_3)$: the methyl group is on C3.

WHY NOT THE OTHERS? A: alkenes react readily with hydrogen halides. B: adding HCl uses up the $\text{C}=\text{C}$ and keeps the methyl group, but 4-chlorocyclopentene still has a $\text{C}=\text{C}$ and has no methyl group. D: a dichloro product needs Cl_2 , not HCl.

11 Structure and properties of LDPE and HDPE

A

LDPE has many branches, so its chains cannot pack closely and regularly. This less ordered (less crystalline) structure lets more light through, so LDPE is **translucent**. The same loose packing gives LDPE its lower density, weaker dispersion forces, greater flexibility and lower tensile strength.

WHY NOT THE OTHERS? B: LDPE is flexible because it has *more* branching, not less. C: LDPE has the *lower* tensile strength, and the forces involved are intermolecular, not intramolecular. D: HDPE is made of mostly unbranched chains, which pack closely and make it denser.

12

Empirical formula from percentage composition

C

Mole ratio: C $40.0/12.01 = 3.33$; H $6.70/1.008 = 6.65$; O $53.3/16.00 = 3.33$. That is 1 : 2 : 1, so the empirical formula is CH_2O . **Ethanoic acid**, $\text{CH}_3\text{COOH} = \text{C}_2\text{H}_4\text{O}_2$, is $(\text{CH}_2\text{O})_2$.

WHY NOT THE OTHERS? A: methanol, CH_4O , is 37.5% C. B: propanone, $\text{C}_3\text{H}_6\text{O}$, is 62.0% C. D: methyl ethanoate, $\text{C}_3\text{H}_6\text{O}_2$, is 48.6% C.

13

Solubility of PbBr_2 with a common ion

C

$\text{PbBr}_2(\text{s}) \rightleftharpoons \text{Pb}^{2+}(\text{aq}) + 2\text{Br}^{-}(\text{aq})$, and $K_{\text{sp}} = [\text{Pb}^{2+}][\text{Br}^{-}]^2 = 6.60 \times 10^{-6}$. The NaBr gives $[\text{Br}^{-}] \approx 0.500 \text{ mol L}^{-1}$ (the extra from PbBr_2 is negligible), so $s = 6.60 \times 10^{-6} / 0.500^2 = \mathbf{2.64 \times 10^{-5} \text{ mol L}^{-1}}$.

WHY NOT THE OTHERS? A: $(K_{\text{sp}}/4)^{1/3}$, the solubility in pure water. B: divides by 0.500 without squaring. D: halves K_{sp} instead of dividing by $[\text{Br}^{-}]^2$.

14

Identifying a liquid from permanganate and bromine water

B

Purple MnO_4^{-} was decolourised, so the liquid was oxidised: an alkene, a primary or secondary alcohol, or an aldehyde. Bromine water stayed brown, so there is no $\text{C}=\text{C}$, which rules out the alkene. **2-methylpropanal**, an aldehyde, is oxidised to 2-methylpropanoic acid.

WHY NOT THE OTHERS? A: an alkene decolourises the permanganate too, but it would also decolourise bromine water (Br_2 adds across the $\text{C}=\text{C}$). C: a tertiary alcohol has no H on the carbon bearing the OH, so it is not oxidised and the permanganate stays purple. D: a carboxylic acid cannot be oxidised further.

15

Calculating K_{eq} for SO_3 formation

D

$K = [\text{SO}_3]^2 / ([\text{SO}_2]^2 [\text{O}_2]) = (5.0 \times 10^{-2})^2 / ((3.0 \times 10^{-3})^2 \times 3.5 \times 10^{-3}) = \mathbf{7.9 \times 10^4}$

WHY NOT THE OTHERS? A: $1/K$, the value for the reverse reaction. C: leaves out the powers (4.8×10^3 , closest to 4.7×10^3). B: the reciprocal of C.

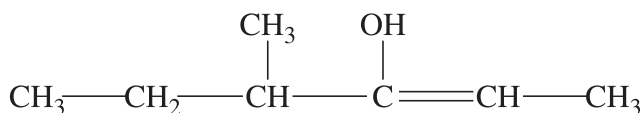
16

Matching a triplet to a proton position

A

The signal has three peaks in a 1 : 2 : 1 ratio, a triplet. By the $n + 1$ rule the protons have 2 neighbouring H. That fits the CH_3 at **position A**, which is next to a CH_2 .

B: doublet C: singlet
next to CH (1 H) O–H



A: triplet
next to CH_2 (2 H)

D: quartet
next to CH_3 (3 H)

Splitting at each labelled position ($n + 1$ rule).
Only position A is a triplet.

WHY NOT THE OTHERS? B: this CH_3 is next to one H (a CH), so it is a doublet. C: the O–H proton is a singlet. D: the $=\text{CH}-$ is next to a CH_3 (3 H), so it is a quartet.

17

Percentage of iron by colourimetry

D

From the calibration line (gradient ≈ 0.0257 per mg mL^{-1}), $A = 0.37$ gives $[\text{Fe}^{3+}] \approx 14.4 \text{ mg mL}^{-1}$ in the diluted solution. Undo the dilution (10.0 mL made up to 25.0 mL, a factor of 2.5): 36.0 mg mL^{-1} in the 250.0 mL solution. Mass of Fe = $36.0 \times 250.0 = 9.0 \times 10^3 \text{ mg} = 9.0 \text{ g}$, so % Fe = $9.0/20.54 \times 100 = 44\%$. Any reading from 14.0 to 14.6 mg mL^{-1} gives 43–44%.

WHY NOT THE OTHERS? B (18%): leaves out the dilution factor of 2.5 (3.6 g of Fe). A (9.0%): 9.0 is the mass of iron in grams; it still has to be divided by the 20.54 g sample. C (22%): half the correct mass (4.5 g of Fe), e.g. from a dilution factor of 1.25 instead of $25.0/10.0 = 2.5$.

18

Which 0.1 mol L^{-1} acid has the lowest pH

B

HCl is strong and monoprotic: $[\text{H}^+] = 0.10$, $\text{pH} = 1.00$. H_2SO_4 : the first ionisation is complete ($0.10 \text{ mol L}^{-1} \text{H}^+$), and HSO_4^- ($\text{p}K_{\text{a}2} = 1.9$) ionises further, adding about 0.010 mol L^{-1} . So $[\text{H}^+] \approx 0.11$ and $\text{pH} \approx 0.96$, the **lowest**.

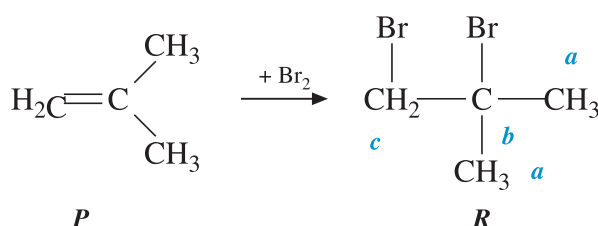
WHY NOT THE OTHERS? C: H_3PO_4 is weak ($\text{p}K_{\text{a}1} = 2.2$): $\text{pH} \approx 1.7$. D: $\text{H}_4\text{P}_2\text{O}_7$ is only partly ionised in its first step ($\text{p}K_{\text{a}1} = 0.9$) and the later steps add little: $\text{pH} \approx 1.1$. A: $\text{pH} 1.00$, higher than H_2SO_4 because HCl has only one H^+ to give.

19

 ^{13}C NMR of the bromine addition product

B

$M = 56$ for a hydrocarbon gives C_4H_8 . A weak IR absorption at 1662 cm^{-1} is a $\text{C}=\text{C}$ bond, and two singlets mean two H environments with no neighbours: **2-methylpropene**, $\text{CH}_2=\text{C}(\text{CH}_3)_2$ (but-2-ene would give a doublet and a quartet; but-1-ene has four H environments). Br_2 adds to give 1,2-dibromo-2-methylpropane, $(\text{CH}_3)_2\text{CBr}-\text{CH}_2\text{Br}$. Its carbons are CH_2Br , CBr and two equivalent CH_3 : **3 peaks**.



P: neither the $=\text{CH}_2$ nor the CH_3 protons have H on the next carbon, so both signals are singlets. *R*: carbon environments *a*, *b*, *c*; the two CH_3 carbons (*a*) are equivalent, so **3 peaks**.

WHY NOT THE OTHERS? A: 2 is the number of proton environments in *P* (its two singlets), not the carbon environments in *R*. C: treats the two equivalent CH_3 carbons as different. D: *R* has only 4 carbons.

20

Phenolphthalein and mixing acid and base

A

Pouring 50 mL of HCl (0.005 mol H^+) into 100 mL of NaOH (0.010 mol OH^-) leaves 0.005 mol OH^- in excess. The indicator came from X, so Y turns **pink**. Then 50 mL of Y (one third, 0.0017 mol OH^-) goes into the 50 mL of HCl left in X (0.005 mol H^+): X is still acidic, so it stays **colourless**, and Y stays basic and pink.

WHY NOT THE OTHERS? B: Y would hold $0.025 \text{ mol excess OH}^-$, so the 50 mL poured back carries 0.0083 mol OH^- into X (0.005 mol H^+), making X basic and pink. C: Y starts with 0.010 mol H^+ and receives only 0.005 mol OH^- , so it never turns pink. D: the first pour works (0.015 mol OH^- into 0.010 mol H^+ leaves 0.005 mol OH^- , so Y turns pink), but the 50 mL left in X still holds 0.015 mol OH^- . The 50 mL poured back brings indicator (and more OH^-), so X turns pink at the second pour.

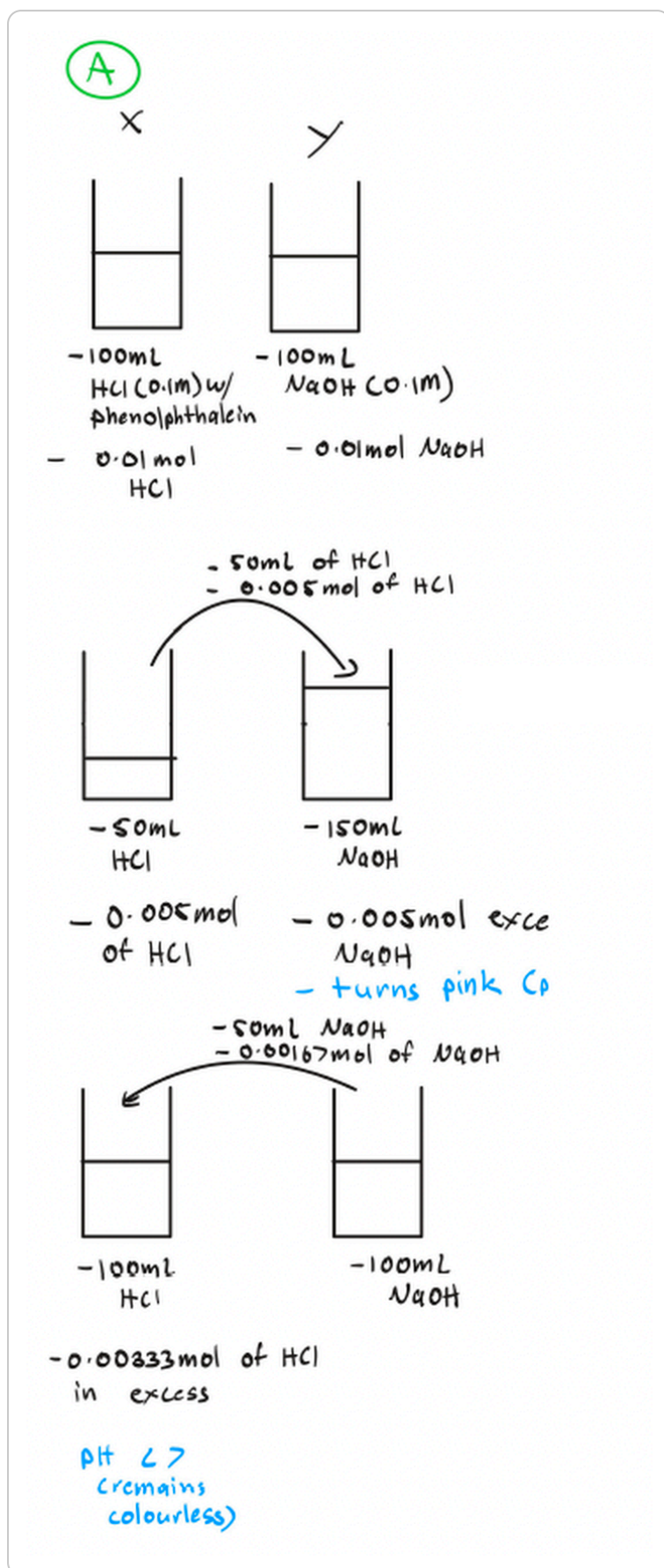
020 WORKED DIAGRAM Step-by-step handwritten working by @zadrova from Conquer HSC, on the next page →

20

Phenolphthalein and mixing acid and base: worked diagram

CONTINUED FROM PAGE 4

Handwritten working by @zadrova from Conquer HSC. Thank you!

**1 START**

X: 100 mL of 0.1 mol L^{-1} HCl with phenolphthalein, so 0.010 mol HCl.

Y: 100 mL of 0.1 mol L^{-1} NaOH, so 0.010 mol NaOH.

2 POUR 50 ML OF X INTO Y

0.005 mol HCl neutralises 0.005 mol of the NaOH, leaving 0.005 mol NaOH in excess in 150 mL. The indicator came with the acid, so Y turns **pink**.

3 POUR 50 ML OF Y BACK INTO X

50 mL is a third of Y: about 0.0017 mol NaOH goes into the 0.005 mol HCl left in X.

About 0.0033 mol HCl remains in excess, so $\text{pH} < 7$ and X stays **colourless**. Answer A.

SECTION II

Each numbered step is one mark, except in Questions 32 and 35, which are marked holistically: there the steps are a checklist of what a top-band answer covers. Tick the box on the right if your answer has that step. Follow-through applies: if an earlier value was wrong, tick a later step when it is done correctly with your value. A different valid method or wording earns the same marks. In these solutions, significant figures are marked in Question 34 only. Data are from the 2026 data sheet and periodic table.

21

Net ionic equation for cadmium sulfide

2

MARKS

MARKING CRITERIA	MARKS
Provides the correct balanced net ionic equation: $\text{Cd}^{2+}(\text{aq}) + \text{S}^{2-}(\text{aq}) \rightarrow \text{CdS}(\text{s})$	2
Provides an equation with ONE error (e.g. a wrong ion charge such as Cd^+ , or a spectator ion included) OR the correct formulae of both reactant ions only	1

SAMPLE ANSWER, MARK BY MARK

1	REACTANT IONS	$\text{Cd}^{2+}(\text{aq}) + \text{S}^{2-}(\text{aq})$	☐
2	PRODUCT	$\rightarrow \text{CdS}(\text{s})$, with atoms and charges balanced (1 : 1)	☐

WHERE MARKS ARE LOST

- Writing Cd^+ or S^- : cadmium(II) means Cd^{2+} .
- Including spectator ions (e.g. Na^+ , NO_3^-) in a net ionic equation.

22

Method for measuring the heat of neutralisation

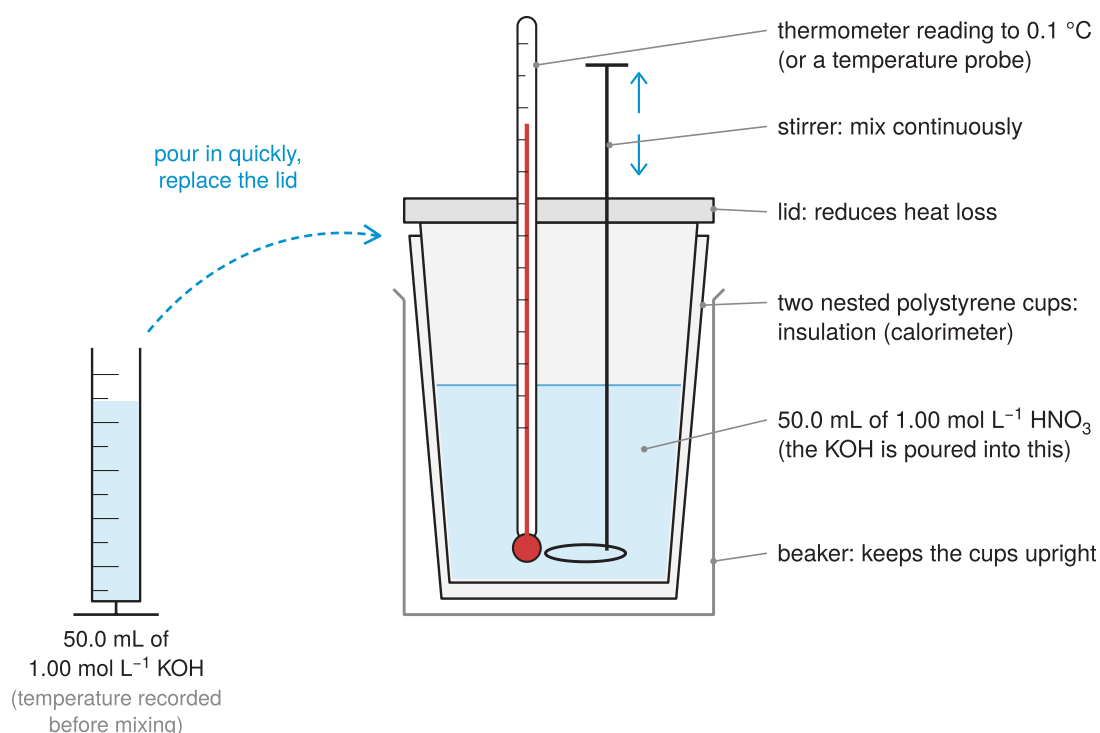
4
MARKS

MARKING CRITERIA	MARKS
Describes a valid calorimetry method, including ALL of the following: <ul style="list-style-type: none"> equipment: an insulated calorimeter with a lid (e.g. two nested polystyrene cups), a thermometer reading to 0.1 °C or a temperature probe, a stirrer, and a measuring cylinder or pipette measured, equal volumes of the two solutions (e.g. 50.0 mL of each), with the initial temperature of BOTH solutions recorded before mixing the solutions mixed quickly, the lid replaced and the mixture stirred, with the temperature monitored and the maximum temperature recorded the data to record (volumes or mass of solution, initial and maximum temperatures) AND repetition of the experiment 	4
Describes a method that includes THREE of the above	3
Describes a method that includes TWO of the above	2
Provides some relevant information (e.g. names a calorimeter, or says to measure the temperature change)	1

SAMPLE ANSWER, MARK BY MARK

1 EQUIPMENT

an insulated calorimeter (two nested polystyrene cups with a lid), a thermometer reading to 0.1 °C (or a temperature probe and data logger), a stirrer, and 50.0 mL pipettes or measuring cylinders ☐



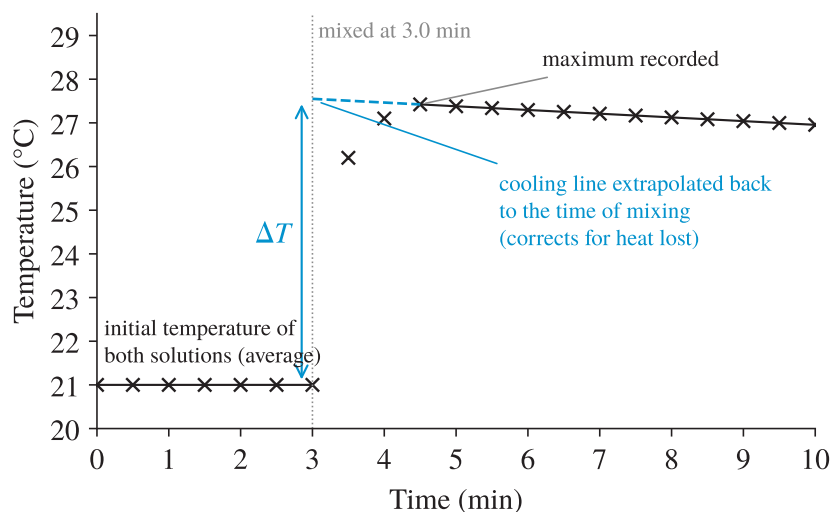
2 MEASURE

50.0 mL of 1.00 mol L⁻¹ HNO₃ into the calorimeter and 50.0 mL of 1.00 mol L⁻¹ KOH into a separate beaker. Let both reach room temperature, then record the initial temperature of each solution (rinse and dry the thermometer in between; if they differ, use the average as the initial temperature) ☐

→ equal moles (0.0500 mol), so all of both reactants react

3 MIX

pour the KOH into the acid quickly, replace the lid and stir continuously. Record the temperature every 15–30 s and note the **maximum temperature** reached (or extrapolate the cooling curve back to the moment of mixing to correct for heat lost)

**4 DATA AND RELIABILITY**

record the volumes (mass of solution ≈ 100 g, taking a density of 1.00 g mL^{-1}), the initial and maximum temperatures (ΔT), and repeat at least twice more, averaging ΔT

→ for higher accuracy, also find the heat capacity of the calorimeter first, by calibrating it with an electric heater or a reaction of known ΔH ; c for water is on the data sheet

WHERE MARKS ARE LOST

- Recording the temperature of only one solution before mixing.
- Using an uninsulated glass beaker with no lid: heat loss makes ΔT (and ΔH) too small.
- Not stirring, or not recording the *maximum* temperature.
- Spending lines on $q = mc\Delta T$: no calculations were required, so they earn no marks.

23**Dissociation of NaCl in water: ion–dipole interactions****4**
MARKS

MARKING CRITERIA	MARKS
Describes the dissociation, including ALL of the following: <ul style="list-style-type: none"> • water is polar: O is δ^- and H is δ^+ (O is more electronegative than H) • ion–dipole attractions: the δ^- O ends of water molecules are attracted to Na^+ and the δ^+ H ends to Cl^- • these ion–dipole attractions overcome the electrostatic (ionic) attractions in the lattice, so the ions are pulled out and become surrounded by water molecules (hydrated) and disperse • a labelled diagram showing water correctly oriented around BOTH Na^+ (O inwards) and Cl^- (H inwards), with δ^+/δ^- or the ion–dipole attraction labelled The first two points may be credited from clearly labelled features of the diagram (δ^+/δ^- labels, orientation, a labelled attraction); the diagram point needs BOTH ions drawn correctly.	4
Provides THREE of the above	3
Provides TWO of the above	2
Provides some relevant information (e.g. states that water is polar, or that NaCl separates into Na^+ and Cl^- ions)	1

SAMPLE ANSWER, MARK BY MARK**1 WATER IS POLAR**

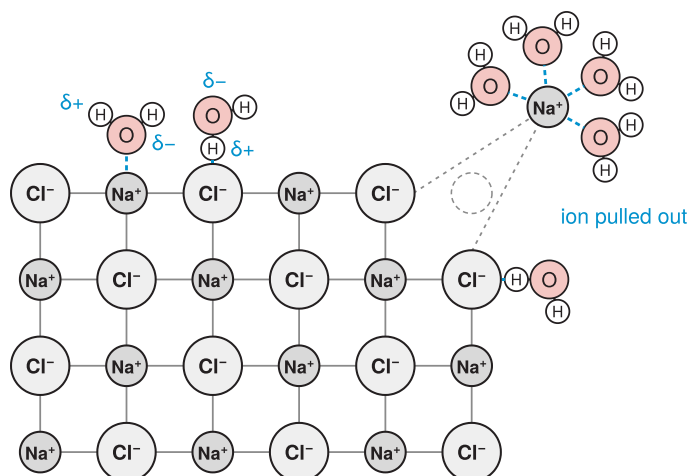
water is a bent molecule with polar O–H bonds (O is more electronegative than H): the O atom carries a partial negative charge (δ^-) and the H atoms partial positive charges (δ^+)

2 ION-DIPOLE ATTRACTIONS

water molecules orient around the ions at the surface of the lattice: the δ^- O ends are attracted to Na^+ ions and the δ^+ H ends are attracted to Cl^- ions

3 IONS LEAVE THE LATTICE

when these ion-dipole attractions (with the kinetic energy of the water molecules) overcome the strong electrostatic attraction between Na^+ and Cl^- in the lattice, the ions are pulled out, starting at the edges and corners. Each ion is surrounded by a shell of water molecules (hydrated) and disperses through the solution: $\text{NaCl}(s) \rightarrow \text{Na}^+(aq) + \text{Cl}^-(aq)$



NaCl lattice (one layer)

1 Water molecules collect at the surface:

δ^- O ends face Na^+ , δ^+ H ends face Cl^-

2 Ion-dipole attractions (with collisions

from moving water molecules) overcome the ionic attractions holding an edge or corner ion in the lattice

3 The ion leaves surrounded by water

(hydrated) and disperses; the next layer of ions is exposed

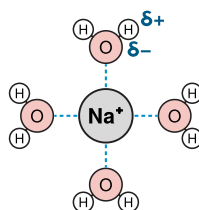
----- ion-dipole attraction

—— ionic attraction in the lattice

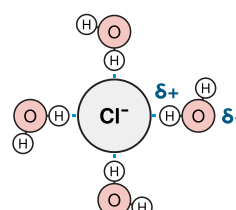
..... ionic attraction being overcome

4 LABELLED DIAGRAM**Hydrated Na^+ ion**

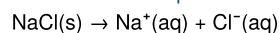
δ^- oxygen ends point towards Na^+

**Hydrated Cl^- ion**

δ^+ hydrogen ends point towards Cl^-



----- ion-dipole attraction



→ label the ions, δ^+ and δ^- on water, the correct orientation, and the ion-dipole attractions

WHERE MARKS ARE LOST

- Drawing water with H pointing towards Na^+ (the orientation must be O towards cations, H towards anions).
- Saying the NaCl 'molecules' break apart: NaCl is an ionic lattice.
- Calling the attraction hydrogen bonding: it is an ion-dipole attraction.

24

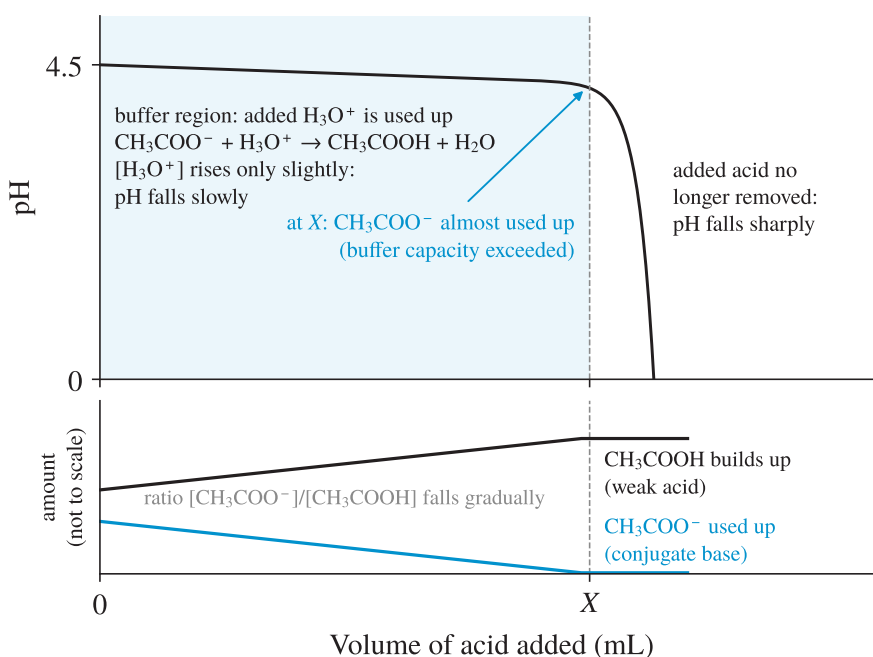
Shape of the buffer curve before X mL

3
MARKS

MARKING CRITERIA	MARKS
Explains the shape of the curve from 0 to X mL, including ALL of the following: <ul style="list-style-type: none"> the buffer equilibrium, $\text{CH}_3\text{COOH} \rightleftharpoons \text{CH}_3\text{COO}^- + \text{H}^+$ (or with H_2O and H_3O^+), with both the weak acid and its conjugate base present the added H^+ (H_3O^+) reacts with CH_3COO^- (an equation, or the equilibrium shifting left), so $[\text{H}^+]$ rises only slightly and the pH falls only slightly the gradual decrease: CH_3COO^- is used up and CH_3COOH builds up, so $[\text{CH}_3\text{COO}^-]/[\text{CH}_3\text{COOH}]$ slowly falls, until near X the acetate is almost used up (buffer capacity reached) 	3
Provides TWO of the above	2
Provides some relevant information (e.g. 'a buffer resists changes in pH', or identifies the weak acid and its conjugate base)	1

SAMPLE ANSWER, MARK BY MARK

- 1 BUFFER EQUILIBRIUM** $\text{CH}_3\text{COOH}(aq) + \text{H}_2\text{O}(l) \rightleftharpoons \text{CH}_3\text{COO}^-(aq) + \text{H}_3\text{O}^+(aq)$, with large amounts of both the weak acid and its conjugate base present ☐
- 2 ADDED ACID IS NEUTRALISED** the added H_3O^+ reacts with the acetate ions, $\text{CH}_3\text{COO}^-(aq) + \text{H}_3\text{O}^+(aq) \rightarrow \text{CH}_3\text{COOH}(aq) + \text{H}_2\text{O}(l)$ (the equilibrium shifts left, by Le Chatelier's principle), so $[\text{H}_3\text{O}^+]$ barely changes and the pH falls only very slightly from 4.5 ☐
- 3 GRADUAL FALL TOWARDS X** each addition converts some CH_3COO^- into CH_3COOH , so the ratio $[\text{CH}_3\text{COO}^-]/[\text{CH}_3\text{COOH}]$ slowly decreases and the pH drifts down. Near X the acetate is almost used up (the buffer capacity is reached), so the pH starts to fall faster; beyond X the added acid is no longer neutralised and the pH drops sharply ☐



WHERE MARKS ARE LOST

- Saying the pH 'stays constant': the graph shows a slight decrease.
- Describing the buffer without an equation, or without saying which species reacts with the added acid (the conjugate base).

25 (a)

Producing ethanol from renewable resources

2
MARKS

MARKING CRITERIA	MARKS
Outlines the production of ethanol by fermentation of sugars (glucose) from a renewable plant source (e.g. sugar cane, corn), using yeast under anaerobic conditions, AND provides the balanced equation $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$	2
Outlines fermentation of sugars from a renewable source OR provides the correct balanced fermentation equation	1

SAMPLE ANSWER, MARK BY MARK

1 FERMENTATION	grow crops such as sugar cane, corn or wheat. Their sugars (or starch broken down to glucose) are fermented by yeast under anaerobic conditions at about 35–37 °C, and the ethanol is separated by fractional distillation → for the mark: a renewable plant source AND fermentation by yeast (anaerobic); starch or cellulose from plant waste can first be hydrolysed to glucose	☐
2 EQUATION	$C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$ (yeast)	☐

WHERE MARKS ARE LOST

- Giving the hydration of ethene: ethene comes from crude oil, so it is not renewable.
- Leaving out yeast or the anaerobic condition.

25 (b)

Effect of 10% ethanol on the energy from combustion

3
MARKS

MARKING CRITERIA	MARKS
Explains the effect of the ethanol on the energy released, including ALL of the following: <ul style="list-style-type: none"> • a correct calculation of the energy from 1 L of E10: $0.90 \times 35\,293 + 0.10 \times 23\,412 = 3.41 \times 10^4$ kJ (or an equivalent calculation, e.g. from the heats of combustion and densities) • a comparison with octane: E10 releases less energy per litre ($\approx 1.19 \times 10^3$ kJ L⁻¹, about 3.4%, less) • a reason: ethanol releases much less energy per litre than octane because it is partly oxidised (it contains an O atom) 	3
Provides TWO of the above (e.g. a correct calculation and comparison with no reason, or a reason and comparison with an incorrect calculation)	2
Provides some relevant information (e.g. states that E10 releases less energy, with no calculation)	1

SAMPLE ANSWER, MARK BY MARK

1 ENERGY FROM 1 L OF E10	0.90 L octane + 0.10 L ethanol: $0.90 \times 35\,293 + 0.10 \times 23\,412 = 31\,764 + 2\,341 = 3.41 \times 10^4$ kJ L ⁻¹ → also correct: working from the heats of combustion and densities. Octane: $750/114.22 = 6.566$ mol L ⁻¹ $\times 5470 = 35\,916$ kJ L ⁻¹ (the table's 35 293 does not quite match its own data); ethanol: $789/46.07 \times 1367 = 23\,412$ kJ L ⁻¹ . Then E10 = $0.90 \times 35\,916 + 0.10 \times 23\,412 = 3.47 \times 10^4$ kJ L ⁻¹ , 3.5% less than octane. Use the same basis for both fuels.	☐
2 COMPARISON	octane releases 35 293 kJ L ⁻¹ , so E10 releases about 1.19×10^3 kJ less per litre, a decrease of about 3.4%	☐
3 EXPLANATION	ethanol releases about one-third less energy per litre than octane because it is already partly oxidised: it contains an oxygen atom, so less energy is released when it burns. Adding ethanol therefore lowers the energy per litre, and a car uses slightly more E10 per kilometre	☐

WHERE MARKS ARE LOST

- Using heats of combustion per mole without converting to the same volume of fuel.
- Averaging the two values (50/50) instead of weighting 90% octane and 10% ethanol.

25 (c)

Comparing E10 with octane: two environmental considerations

3
MARKS

MARKING CRITERIA	MARKS
Compares E10 with octane for TWO relevant environmental considerations (e.g. net CO ₂ /greenhouse emissions; products of incomplete combustion such as CO and soot; land, water and fertiliser use; renewability or the impacts of extracting crude oil), stating for EACH how E10 differs from (or is similar to) octane and why, AND qualifies the comparison (e.g. only 10% is ethanol, more fuel is burnt per km, or growing and processing the crop releases CO ₂)	3
Compares E10 with octane for TWO considerations without a qualification, OR compares them for ONE consideration with a qualification	2
Provides some relevant information (e.g. describes one consideration for only one fuel, or states that ethanol is renewable)	1

SAMPLE ANSWER, MARK BY MARK

1 CARBON DIOXIDE	both fuels release CO ₂ when burnt. The ethanol in E10 comes from plants that absorbed CO ₂ by photosynthesis as they grew, so it is close to carbon neutral, whereas octane releases carbon locked away in fossil fuels for millions of years. So E10 adds less net CO ₂ (a greenhouse gas) per litre than octane	☐
2 SECOND CONSIDERATION	compare E10 with octane for a second consideration, for example: combustion products : ethanol contains oxygen, so E10 burns more completely than octane, producing less carbon monoxide, soot (particulates) and unburnt hydrocarbons; OR resources and land : octane comes from crude oil, which is non-renewable and whose extraction and transport risk oil spills and habitat damage, while the ethanol in E10 is renewable but needs farmland, water and fertiliser (land clearing, fertiliser run-off, competition with food crops) → any relevant second consideration earns this mark if both fuels are compared and a reason is given	☐
3 QUALIFYING THE COMPARISON	the benefit is limited: only 10% of E10 is ethanol, about 3.5% more fuel is burnt per kilometre (part (b)), and growing, harvesting, fermenting and distilling the crop uses fossil fuels, so the ethanol is not fully carbon neutral → a clear comparison of E10 against octane for each consideration is needed	☐

WHERE MARKS ARE LOST

- Calling ethanol 'carbon neutral' without explaining photosynthesis, or without any qualification.
- Describing only E10 (or only octane): 'compare' needs both, with similarities or differences.
- Saying ethanol produces no CO₂.

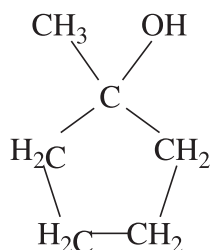
26 (a) Structures A and B from hydrating 1-methylcyclopentene

2
MARKS

MARKING CRITERIA	MARKS
Draws BOTH correct structures: A = 1-methylcyclopentan-1-ol (OH and CH ₃ on the same ring carbon) AND B = 2-methylcyclopentan-1-ol (OH on the ring carbon next to the CH bearing the CH ₃)	2
Draws ONE correct structure, OR draws both alcohols but in the wrong boxes	1

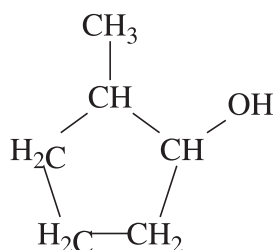
SAMPLE ANSWER, MARK BY MARK

1 STRUCTURE A

**1-methylcyclopentan-1-ol**

a tertiary alcohol: the C bearing the OH has no H, so acidified MnO₄⁻ cannot oxidise it (no reaction)

2 STRUCTURE B

**2-methylcyclopentan-1-ol**

a secondary alcohol, oxidised to the ketone C

→ the paper names C '1-methylcyclopentanone'; its IUPAC name is 2-methylcyclopentan-1-one

WHERE MARKS ARE LOST

- Swapping A and B: the pathway ending in 'No reaction' must give the tertiary alcohol.
- Drawing B with the OH on a carbon that does not lead to the ketone shown.

26 (b) IR and NMR differences between A and C

3
MARKS

MARKING CRITERIA	MARKS
Accounts for an IR difference AND an NMR difference, including ALL of the following: <ul style="list-style-type: none"> • IR: A has a broad O–H absorption (3230–3550 cm⁻¹) that C lacks, and/or C has a C=O absorption (1680–1750 cm⁻¹) that A lacks • NMR: a correct difference, e.g. ¹³C: C has a C=O peak at 190–220 ppm and A a C–O peak at 50–90 ppm; or 4 ¹³C peaks for A vs 6 for C; or ¹H: the CH₃ is a singlet in A but a doublet in C • each difference linked to the structures: A keeps its –OH group (a tertiary alcohol, not oxidised), while in C the –OH of B has been oxidised to a C=O group (or, for peak counts/splitting, the symmetry or neighbouring H of each molecule) 	3
Identifies a correct IR difference AND a correct NMR difference without linking them to the structures, OR accounts for ONE difference	2
Identifies ONE correct spectroscopic difference	1

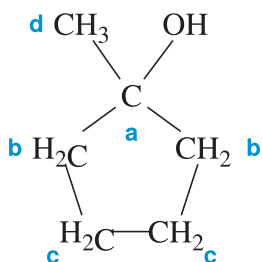
SAMPLE ANSWER, MARK BY MARK

1 IR

A (an alcohol) shows a broad O–H absorption at 3230–3550 cm⁻¹ and no C=O peak.
 C (a ketone) shows a strong, sharp C=O absorption at 1680–1750 cm⁻¹ and no broad O–H peak

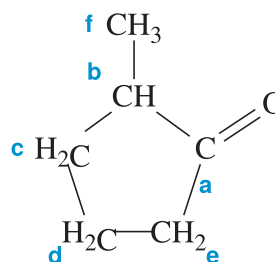
2 ¹³C NMR

C has a peak at 190–220 ppm for its ketone C=O carbon, which A lacks. A instead has a peak at 50–90 ppm for the carbon bonded to the OH

**A: 1-methylcyclopentan-1-ol**

symmetrical: the two b and the two c carbons are equivalent → 4 ¹³C peaks (a at 50–90 ppm)

¹H: CH₃ is a singlet (C bearing it has no H)

**C: 2-methylcyclopentan-1-one**

no symmetry: every carbon is different → 6 ¹³C peaks (a, C=O, at 190–220 ppm)

¹H: CH₃ is a doublet (next to one H on b)

→ other NMR differences also accepted: A is symmetrical (the two CH₂ next to the C–OH are equivalent, as are the other two), giving 4 ¹³C peaks, while C has no symmetry and gives 6; or ¹H NMR: A shows an O–H singlet and its CH₃ is a singlet (on a C with no H), while in C the CH₃ is a doublet (next to one H)

3 LINKING TO STRUCTURE

link each difference to the structures: A keeps its –OH group, because it is a tertiary alcohol that acidified MnO₄[–] cannot oxidise, so it shows O–H and C–O signals. In C the –OH of the secondary alcohol B has been oxidised to a C=O (carbonyl) group, so C shows C=O signals and no O–H. (For peak counts or splitting, the reason is the symmetry of A, or the single H next to the CH₃ in C.)

**WHERE MARKS ARE LOST**

- Giving IR or NMR values without saying which compound shows them.
- Comparing A with B instead of A with C.
- Quoting the C–O range for C: C has no C–O single bond.

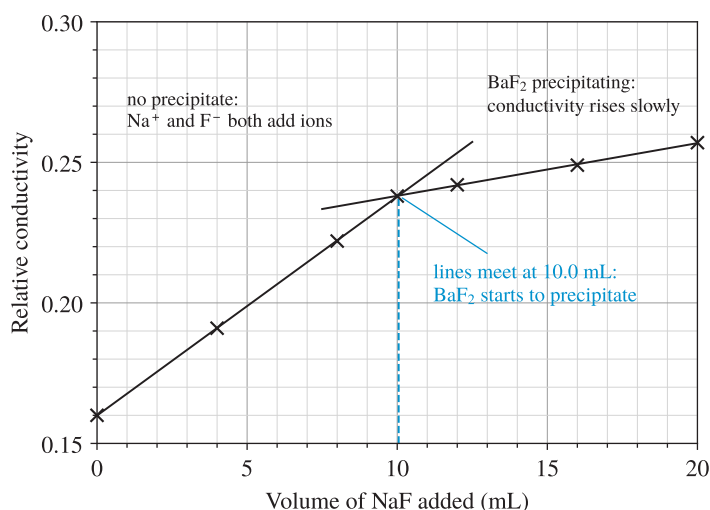
27

 K_{sp} of barium fluoride from conductivity data5
MARKS

MARKING CRITERIA	MARKS
Provides ALL of the following: <ul style="list-style-type: none"> a graph with all seven points plotted accurately and two ruled lines of best fit (one through 0–10 mL, one through 12–20 mL) extended until they intersect the intersection read as ≈ 10.0 mL of NaF (accept 9.8–10.3 mL) and identified as the point where BaF_2 just starts to precipitate (solution just saturated, $Q = K_{sp}$) a balanced equation with states, e.g. $\text{BaF}_2(\text{s}) \rightleftharpoons \text{Ba}^{2+}(\text{aq}) + 2\text{F}^{-}(\text{aq})$ (or the precipitation equation), and $K_{sp} = [\text{Ba}^{2+}][\text{F}^{-}]^2$ $[\text{Ba}^{2+}]$ and $[\text{F}^{-}]$ at the intersection, both $\approx 9.9 \times 10^{-3} \text{ mol L}^{-1}$ (1.0×10^{-2} if the 10 mL volume change is ignored) K_{sp} correctly calculated from these values: $\approx 9.7 \times 10^{-7}$ (accept 9×10^{-7} to 1.1×10^{-6}, consistent with the volume read) 	5
Provides FOUR of the above, e.g. correct graph, equation and concentrations, but $[\text{F}^{-}]$ not squared, or K_{sp} calculated as $4s^3$	4
Provides THREE of the above	3
Provides TWO of the above	2
Provides ONE of the above, e.g. the graph only, OR the equation and K_{sp} expression only	1

SAMPLE ANSWER, MARK BY MARK

1 GRAPH



plot all seven points, then draw two ruled straight lines of best fit (0–10 mL and 12–20 mL) and extend them until they cross. The 10.0 mL point lies on both lines, so it can go with either set

2 READING THE GRAPH

the lines meet at **10.0 mL** of NaF. Before this, NaF adds Na^{+} and F^{-} ions and the conductivity rises steeply. After it, BaF_2 precipitates, removing F^{-} and Ba^{2+} as Na^{+} is added, so the conductivity rises slowly. At the break the solution is just saturated, so $Q = K_{sp}$

3 EQUATION

$\text{BaF}_2(\text{s}) \rightleftharpoons \text{Ba}^{2+}(\text{aq}) + 2\text{F}^{-}(\text{aq})$, $K_{sp} = [\text{Ba}^{2+}][\text{F}^{-}]^2$
 → the precipitation equation, $\text{Ba}^{2+}(\text{aq}) + 2\text{F}^{-}(\text{aq}) \rightarrow \text{BaF}_2(\text{s})$, is equally acceptable alongside the K_{sp} expression

4 CONCENTRATIONS

$n(\text{F}^{-}) = 1.0 \times 0.0100 = 0.010 \text{ mol}$ in 1.010 L, so $[\text{F}^{-}] = 9.9 \times 10^{-3} \text{ mol L}^{-1}$; $[\text{Ba}^{2+}] = 0.010/1.010 = 9.9 \times 10^{-3} \text{ mol L}^{-1}$

5 K_{sp}

$K_{sp} = (9.9 \times 10^{-3})(9.9 \times 10^{-3})^2 = \mathbf{9.7 \times 10^{-7}}$
 → ignoring the 10 mL volume change gives 1.0×10^{-6} , which is also reasonable. Answers from about 9×10^{-7} to 1.1×10^{-6} fit, depending on where your lines meet. The literature value for BaF_2 is lower (about 1.8×10^{-7} at 25 °C), but you must use the data given

WHERE MARKS ARE LOST

- Drawing one curve through all the points instead of two straight lines.
- Taking the end point as where all the Ba^{2+} has precipitated: the break is where precipitation *starts*.
- Forgetting to square $[\text{F}^-]$ (that gives about 1×10^{-4}).
- Using $K_{\text{sp}} = 4s^3$: the F^- comes from the NaF, not from dissolving BaF_2 , so $[\text{F}^-] \neq 2[\text{Ba}^{2+}]$ ($4s^3$ gives 3.9×10^{-6}).

28 (a)

Monomers of PET

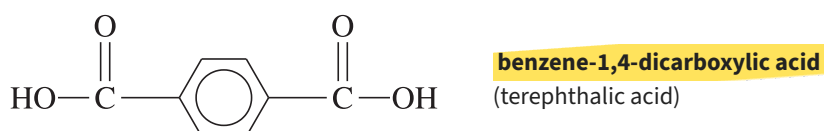
2

MARKS

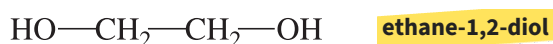
MARKING CRITERIA	MARKS
Draws correct structures of BOTH monomers (either order): <ul style="list-style-type: none"> • benzene-1,4-dicarboxylic acid (terephthalic acid), $\text{HOOC}-\text{C}_6\text{H}_4-\text{COOH}$, with the two $-\text{COOH}$ groups opposite each other (1,4) on the benzene ring • ethane-1,2-diol, $\text{HO}-\text{CH}_2-\text{CH}_2-\text{OH}$ Each must be a complete molecule with every atom of both functional groups shown; names are not required	2
Draws ONE correct monomer	1

SAMPLE ANSWER, MARK BY MARK

1 MONOMER A



2 MONOMER B



→ each ester link forms from a $-\text{COOH}$ and an $-\text{OH}$, with loss of H_2O

WHERE MARKS ARE LOST

- Drawing a monomer with only one functional group: each monomer must have two to build a chain.
- Putting the two $-\text{COOH}$ groups next to each other (1,2) or at 1,3 on the ring: in PET they are opposite each other (1,4).
- Copying the repeat unit: a monomer is a complete molecule, so draw $-\text{COOH}$ and $-\text{OH}$ with their H atoms, not open bonds or brackets.

28 (b)

Effect of ethanol on PET chain length

3

MARKS

MARKING CRITERIA	MARKS
Explains the effect on chain length by providing ALL of the following: <ul style="list-style-type: none"> • ethanol is monofunctional: it has only ONE $-\text{OH}$ group • it undergoes condensation (esterification) with a $-\text{COOH}$ group at the end of a growing chain (or on a benzene-1,4-dicarboxylic acid molecule), forming an ethyl ester end, $-\text{COOCH}_2\text{CH}_3$, with no $-\text{OH}$ or $-\text{COOH}$ left, so that end cannot react further (the chain is capped) • so chains stop growing earlier and the average chain length (and average molar mass) of the PET decreases 	3
Provides TWO of the above, e.g. states that the average chain length decreases because ethanol has only one $-\text{OH}$ group, without explaining that the ester end it forms cannot react further	2
Provides ONE of the above, e.g. states that the chains are shorter, OR that ethanol has one $-\text{OH}$ group	1

SAMPLE ANSWER, MARK BY MARK

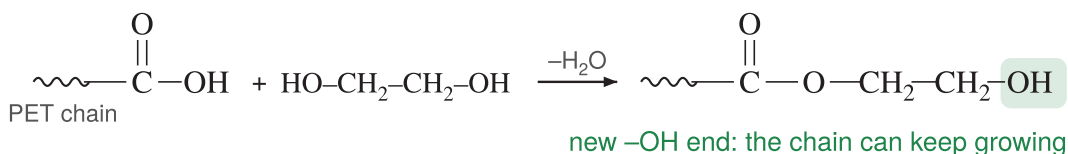
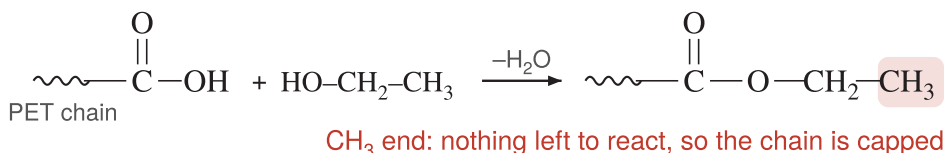
1 ETHANOL HAS ONE OH

ethanol is monofunctional: it has only one $-\text{OH}$ group



2 IT CAPS A CHAIN

it reacts with the -COOH group at the end of a growing chain to form an ethyl ester end: $\sim\text{COOH} + \text{CH}_3\text{CH}_2\text{OH} \rightarrow \sim\text{COOCH}_2\text{CH}_3 + \text{H}_2\text{O}$. That end has no -OH or -COOH left, so the chain cannot grow any further there

**With ethane-1,2-diol (normal growth)****With ethanol (monofunctional)****3 SHORTER CHAINS**

ethanol competes with ethane-1,2-diol for the acid groups, so more chains are stopped early: the **average chain length (degree of polymerisation) and molar mass decrease**, and the more ethanol, the shorter the chains

**WHERE MARKS ARE LOST**

- Saying ethanol 'breaks' the polymer.
- Not explaining why the chain stops: the end group can no longer react.

29**Formula of hydrated oxalic acid by back titration****5**

MARKS

MARKING CRITERIA	MARKS
Correctly determines the formula $\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$, showing ALL of the following: <ul style="list-style-type: none"> Trial 1 (33.00 mL) left out as not concordant; mean titre 29.70 mL; $n(\text{HCl}) = 2.970 \times 10^{-3} \text{ mol} = n(\text{KOH in excess})$ in the 25.0 mL aliquot excess KOH scaled to 250.0 mL ($\times 10 = 2.970 \times 10^{-2} \text{ mol}$) and subtracted from the total 0.1250 mol: KOH reacted = 0.0953 mol $n(\text{H}_2\text{C}_2\text{O}_4) = 0.0953 \div 2 = 0.04765 \text{ mol}$, using the 1 : 2 ratio from a balanced equation $M = 6.00 \div 0.04765 = 125.9 \text{ g mol}^{-1}$ and $n = (125.9 - 90.04) \div 18.02 = 1.99 \approx 2$ the formula $\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$ 	5
Provides FOUR of the above, e.g. a fully correct method but with 33.00 mL included in the mean, OR without the $\times 10$ scaling	4
Provides THREE of the above, e.g. correctly calculates $n(\text{H}_2\text{C}_2\text{O}_4) = 0.04765 \text{ mol}$ but goes no further	3
Provides TWO of the above, e.g. correctly calculates the KOH that reacted (0.0953 mol) but goes no further	2
Provides ONE of the above, e.g. the mean titre and moles of HCl	1

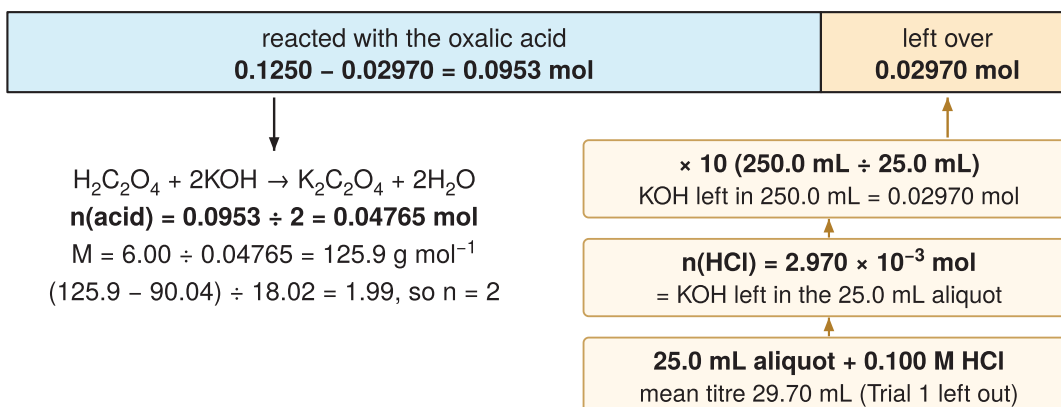
SAMPLE ANSWER, MARK BY MARK**1 TITRE AND MOLES OF HCl**

Trial 1 (33.00 mL) is an outlier: it is more than 3 mL above trials 2–4, which agree within 0.20 mL, so leave it out. Mean of the rest = $(29.60 + 29.80 + 29.70)/3 = 29.70 \text{ mL}$. $n(\text{HCl}) = 0.100 \times 0.02970 = 2.970 \times 10^{-3} \text{ mol} = n(\text{KOH in excess})$ in 25.0 mL.
 $\text{KOH(aq)} + \text{HCl(aq)} \rightarrow \text{KCl(aq)} + \text{H}_2\text{O(l)}$



2 KOH THAT REACTED	excess KOH in 250.0 mL = $2.970 \times 10^{-3} \times 10 = 2.970 \times 10^{-2}$ mol. Total KOH = $0.500 \times 0.2500 = 0.1250$ mol, so KOH that reacted with the acid = $0.1250 - 0.02970 = 0.0953$ mol	☐
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Total KOH added = $0.500 \times 0.2500 = 0.1250$ mol (an excess)



found by SUBTRACTION (never measured directly)

found by TITRATION (read upwards)

3 MOLES OF ACID	$\text{H}_2\text{C}_2\text{O}_4(\text{aq}) + 2\text{KOH}(\text{aq}) \rightarrow \text{K}_2\text{C}_2\text{O}_4(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$, so $n(\text{acid}) = 0.0953/2 = 0.04765$ mol	☐
4 MOLAR MASS	$M = 6.00/0.04765 = 125.9 \text{ g mol}^{-1}$. $M(\text{H}_2\text{C}_2\text{O}_4) = 90.04$, so the water accounts for 35.9 g mol^{-1} , and $n = 35.9/18.02 = 1.99 \approx 2$	☐
5 FORMULA	$\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$	☐

WHERE MARKS ARE LOST

- Including the 33.00 mL outlier in the average.
- Forgetting the $\times 10$ to scale from the 25.0 mL aliquot to the 250.0 mL solution.
- Using a 1 : 1 ratio: oxalic acid is diprotic.

30

Boiling points of propanone and propanamide

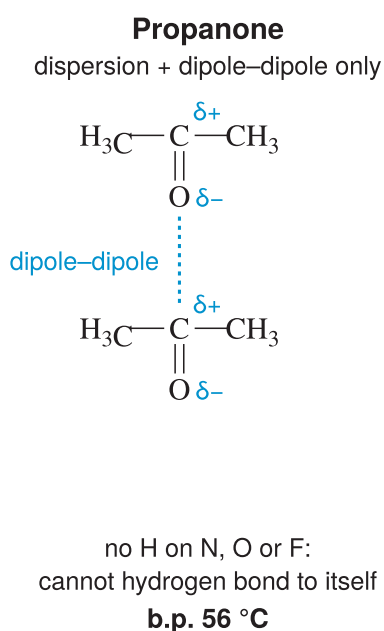
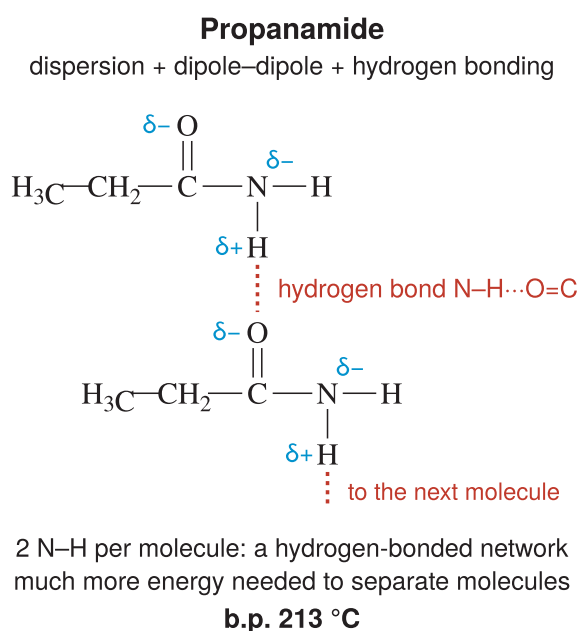
3
MARKS

MARKING CRITERIA	MARKS
Explains why propanamide has the higher boiling point, with reference to the strength of ALL the intermolecular forces in BOTH compounds: <ul style="list-style-type: none"> identifies the forces in each: dispersion and dipole–dipole in both; hydrogen bonding (N–H...O=C) in propanamide only, as propanone has no H bonded to N, O or F compares the weaker forces: dispersion slightly stronger in propanamide (more electrons: 40 vs 32), dipole–dipole of similar strength in both (polar C=O), so these cannot account for the large difference hydrogen bonds are much stronger than the other forces, so much more energy is needed to separate propanamide molecules: higher boiling point 	3
Provides TWO of the above, e.g. identifies all the forces in both compounds and explains that hydrogen bonding needs more energy to overcome, without comparing the dispersion or dipole–dipole forces	2
Provides ONE of the above, e.g. states that propanamide has hydrogen bonding, the strongest force, so it has the higher boiling point	1

SAMPLE ANSWER, MARK BY MARK

1 FORCES IN EACH COMPOUND

propanone: dispersion forces and dipole–dipole forces (polar C=O). Propanamide: dispersion forces, dipole–dipole forces **and hydrogen bonding**: its N–H bonds (H bonded to a highly electronegative N) are attracted to the lone pairs on the C=O oxygen (or N) of a neighbouring molecule, N–H...O=C. Propanone has no H on N, O or F, so it cannot hydrogen bond with itself



2 WEAKER FORCES COMPARED

propanamide (73 g mol⁻¹, 40 electrons) has slightly more electrons than propanone (58 g mol⁻¹, 32 electrons), so slightly stronger dispersion forces. Both have a polar C=O, so their dipole–dipole forces are similar in strength (if anything, slightly stronger in the more polar propanamide). These small differences cannot explain a 157 °C difference in boiling point

3 HYDROGEN BONDING DECIDES IT

hydrogen bonds are much stronger than dipole–dipole and dispersion forces. Each propanamide molecule has two N–H bonds and a C=O oxygen with lone pairs, so it hydrogen bonds to several neighbours at once. Far more energy is needed to separate propanamide molecules, so its boiling point is much higher (213 °C vs 56 °C)

WHERE MARKS ARE LOST

- Leaving out dispersion forces: the question asks for all the forces.
- Saying covalent bonds break on boiling.
- Saying propanone hydrogen bonds: its H atoms are all bonded to C.

31(a)**[OH⁻] in 0.75 mol L⁻¹ sodium hypochlorite****3**

MARKS

MARKING CRITERIA	MARKS
Correctly calculates [OH ⁻] = 5.1 × 10 ⁻⁴ mol L ⁻¹ , showing ALL of the following: <ul style="list-style-type: none"> • ClO⁻(aq) + H₂O(l) ⇌ HClO(aq) + OH⁻(aq) and/or K_b = [HClO][OH⁻]/[ClO⁻] • the assumption that x is negligible compared with 0.75, so [ClO⁻] ≈ 0.75 mol L⁻¹ (ClO⁻ is a weak base). [HClO] = [OH⁻] (OH⁻ from water negligible) and 25 °C are also valid, but not enough on their own • [OH⁻] = √(3.45 × 10⁻⁷ × 0.75) = 5.1 × 10⁻⁴ mol L⁻¹ 	3
Provides TWO of the above, e.g. a correct [OH ⁻] with no assumption stated	2
Provides ONE of the above, e.g. the hydrolysis equation or K _b expression only	1

SAMPLE ANSWER, MARK BY MARK

1 EQUILIBRIUM	ClO ⁻ (aq) + H ₂ O(l) ⇌ HClO(aq) + OH ⁻ (aq), K _b = [HClO][OH ⁻]/[ClO ⁻]	☐
2 ASSUMPTIONS	[HClO] = [OH ⁻] = x (OH ⁻ from the self-ionisation of water is negligible), and ClO ⁻ is a weak base, so x is tiny compared with 0.75 and [ClO ⁻] ≈ 0.75 mol L ⁻¹ (and the solution is at 25 °C, where the given K _b applies) → the mark needs the x ≪ 0.75 assumption. NaClO is also assumed to dissociate completely, so [ClO ⁻] _{initial} = 0.75 mol L ⁻¹	☐
3 [OH⁻]	x ² = 3.45 × 10 ⁻⁷ × 0.75 = 2.59 × 10 ⁻⁷ , so [OH⁻] = 5.1 × 10⁻⁴ mol L⁻¹ → check: 5.1 × 10 ⁻⁴ is 0.07% of 0.75, so the assumption holds	☐

WHERE MARKS ARE LOST

- Treating NaClO as a strong base ([OH⁻] = 0.75).
- Not stating the assumptions, which the question asks for.

31(b)**Volume of chlorine from the accident****4**

MARKS

MARKING CRITERIA	MARKS
Correctly calculates the volume of chlorine, showing ALL of the following: <ul style="list-style-type: none"> • a balanced equation with correct states: NaClO(aq) + 2HCl(aq) → Cl₂(g) + NaCl(aq) + H₂O(l), or 2H⁺(aq) + Cl⁻(aq) + ClO⁻(aq) → Cl₂(g) + H₂O(l) • n(HCl) = 12.0 × 2.5 = 30 mol and n(NaClO) = 0.75 × 1.00 = 0.75 mol • NaClO identified as the limiting reagent (it needs only 1.5 mol HCl), so n(Cl₂) = 0.75 mol • V = 0.75 × 24.79 = 18.6 L (at 25 °C and 100 kPa) 	4
Provides THREE of the above, e.g. a correct calculation with states missing from the equation, OR HCl taken as limiting (372 L), OR 22.71 L mol ⁻¹ used (17.0 L)	3
Provides TWO of the above	2
Provides ONE of the above	1

SAMPLE ANSWER, MARK BY MARK

1 EQUATION	NaClO(aq) + 2HCl(aq) → Cl ₂ (g) + NaCl(aq) + H ₂ O(l) → the net ionic equation, 2H ⁺ (aq) + Cl ⁻ (aq) + ClO ⁻ (aq) → Cl ₂ (g) + H ₂ O(l), is also accepted	☐
2 MOLES	n(HCl) = 12.0 × 2.5 = 30 mol; n(NaClO) = 0.75 × 1.00 = 0.75 mol	☐

3 LIMITING REAGENT	0.75 mol NaClO needs only 1.5 mol HCl, so HCl is in excess and NaClO is limiting: $n(\text{Cl}_2) = 0.75 \text{ mol}$	☐
4 VOLUME	$V = 0.75 \times 24.79 = 18.6 \text{ L}$ (19 L to 2 significant figures) → this is a maximum: it assumes all the NaClO reacts and all the Cl_2 escapes as gas (none stays dissolved)	☐

WHERE MARKS ARE LOST

- Using the HCl as the limiting reagent (gives $3.7 \times 10^2 \text{ L}$).
- Using 22.71 L mol^{-1} : that is for 0°C , and the question says 25°C .
- Leaving out states, or balancing with 1 HCl.

32**Conditions for making propyl butanoate, and safety****7**
MARKS

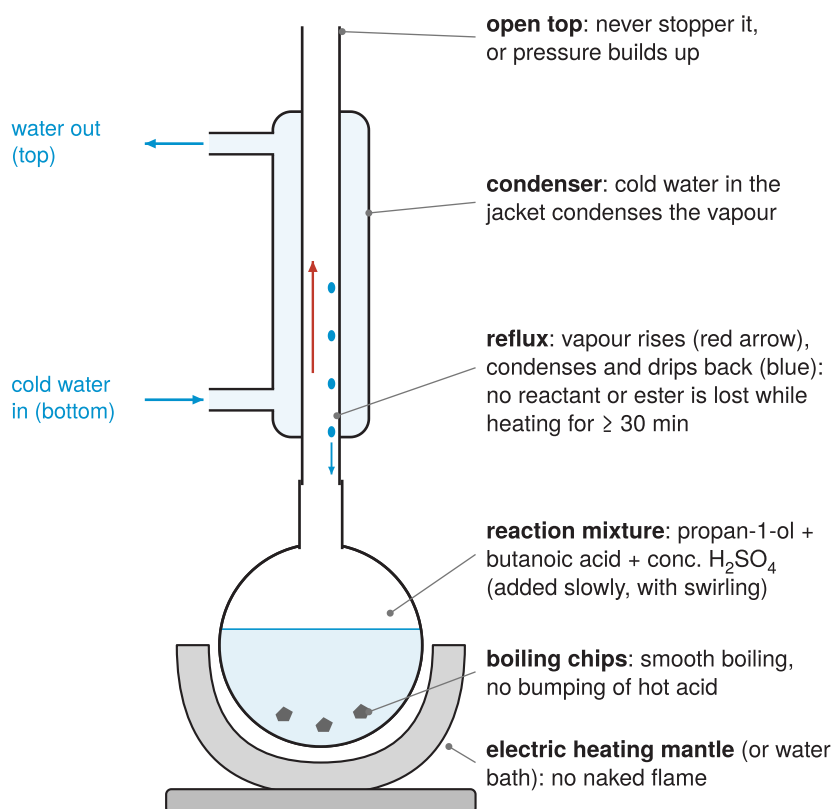
MARKING CRITERIA	MARKS
<p>Provides a coherent, well-organised response that justifies ALL of the following, linking each to rate or yield:</p> <ul style="list-style-type: none"> heating (collision theory): particles collide more often and a greater proportion of collisions have energy $\geq E_a$, so the slow esterification reaches equilibrium in a practical time temperature and equilibrium: the forward reaction is exothermic, so a higher temperature slightly favours the reverse reaction (lowers K), but $\Delta H = -3.6 \text{ kJ mol}^{-1}$ is so small that the loss in yield is minor compared with the gain in rate concentrated H_2SO_4 as a catalyst (lower E_a, faster, yield unchanged) AND as a dehydrating agent (removes H_2O, equilibrium shifts right, yield increases) reflux for $\geq 30 \text{ min}$: the volatile reactants and ester are condensed and returned, so heating can continue without loss until equilibrium is reached <p>AND explains TWO safety considerations other than PPE, each giving the hazard, the precaution and why it works (e.g. flammable vapours: electric heating mantle or water bath, no naked flame, never seal the condenser; corrosive conc. H_2SO_4 that releases heat on mixing: add slowly with swirling; boiling chips to prevent bumping)</p> <p>7: all of the above. 6: ONE weakness, e.g. the small ΔH is not linked to the minor effect on yield, OR only one role of H_2SO_4 is explained, OR one safety consideration is named but not explained</p>	6–7
<p>5: Explains at least FOUR of the five conditions above (heating and collision theory; temperature and equilibrium; catalyst; dehydrating agent; reflux and time) AND explains at least ONE safety consideration other than PPE</p> <p>4: Explains at least THREE of the five conditions AND identifies at least ONE safety consideration other than PPE, OR explains all five conditions but gives no valid safety consideration</p>	4–5
<p>3: Explains TWO of the conditions (e.g. heating increases the rate because more collisions have energy $\geq E_a$; H_2SO_4 removes water so the equilibrium shifts right), OR explains ONE condition AND ONE safety consideration</p> <p>2: Describes ONE condition and its effect on rate or yield, OR identifies two safety considerations without explaining them</p>	2–3
Provides some relevant information, e.g. states that H_2SO_4 is a catalyst, or names one hazard. (Stating that a higher temperature increases the yield of this exothermic reaction is incorrect; PPE earns no credit.)	1

CHECKLIST FOR A TOP-BAND ANSWER

MARKED HOLISTICALLY A top-band answer covers all 7 points below, linked into a logical, well-organised response; markers place the whole answer in a band rather than adding up points.

1 COLLISION THEORY	heating increases the kinetic energy of the particles, so they collide more often and a much larger fraction of collisions have energy $\geq E_a$. Esterification is very slow at room temperature, so heating greatly increases the rate	☐
2 TEMPERATURE AND EQUILIBRIUM	the forward reaction is slightly exothermic ($\Delta H = -3.6 \text{ kJ mol}^{-1}$), so by Le Chatelier a higher temperature very slightly favours the reverse reaction. ΔH is so small that the yield barely changes with temperature, so the large gain in rate far outweighs the tiny loss in yield	☐

3 CATALYST	concentrated H_2SO_4 is a catalyst: it provides an alternative pathway with lower E_a , so equilibrium is reached faster (a catalyst alone does not change the yield)	☐
4 DEHYDRATING AGENT	concentrated H_2SO_4 also absorbs the water produced, lowering $[\text{H}_2\text{O}]$, so the equilibrium shifts right and the yield of ester increases. Using an excess of one reactant (e.g. propan-1-ol) also shifts it right → equation: $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH} + \text{CH}_3\text{CH}_2\text{CH}_2\text{OH} \rightleftharpoons \text{CH}_3\text{CH}_2\text{CH}_2\text{COOCH}_2\text{CH}_2\text{CH}_3 + \text{H}_2\text{O}$	☐
5 REFLUX, AT LEAST 30 min	the condenser condenses the vapours of the volatile reactants and ester and returns them to the flask, so the mixture can boil for a long time without losing material. Heating for at least 30 minutes lets the system reach equilibrium, giving the maximum yield. The separating funnel then recovers as much ester as possible: it is insoluble in water and forms a separate upper layer, and washing with Na_2CO_3 removes leftover acid	☐



6 SAFETY 1: FLAMMABILITY	propan-1-ol and propyl butanoate are volatile and flammable, so heat with an electric heating mantle or water bath (no naked flame), and keep the top of the condenser open: never seal the apparatus, or pressure builds up	☐
7 SAFETY 2: CONCENTRATED ACID	concentrated H_2SO_4 is highly corrosive and gives out heat when mixed, so add it slowly, a few drops at a time, with swirling, and add boiling chips to stop bumping spraying hot acid → also accepted: vent the separating funnel often (CO_2 pressure when washing with Na_2CO_3); use a fume hood for the pungent butanoic acid vapour; have water and sodium hydrogen carbonate ready for acid spills	☐

WHERE MARKS ARE LOST

- Saying a higher temperature increases the yield of an exothermic reaction.
- Saying the catalyst increases the yield: only the dehydrating action does.
- Giving PPE (safety glasses, gloves, lab coat), which the question excludes.
- Listing a hazard without explaining how to manage it, or why.

33 (a) Gibbs free energy for the combustion of glucose

2
MARKS

MARKING CRITERIA	MARKS
Correctly calculates $\Delta G = -2881 \text{ kJ mol}^{-1}$ (ΔS converted to $0.262 \text{ kJ mol}^{-1} \text{ K}^{-1}$) AND concludes that the reaction is spontaneous because $\Delta G < 0$	2
Provides a correct substitution into $\Delta G = \Delta H - T\Delta S$ OR correctly calculates ΔG without a valid conclusion, OR calculates ΔG with ONE error (e.g. ΔS not converted, $-80\ 879$) and draws the conclusion that follows from it	1

SAMPLE ANSWER, MARK BY MARK

1 CALCULATION	$\Delta G = \Delta H - T\Delta S = -2803 - 298 \times 0.262 = -2803 - 78.1 = -2881 \text{ kJ mol}^{-1}$ → convert ΔS to kJ: $262 \text{ J} = 0.262 \text{ kJ}$	☐
2 CONCLUSION	$\Delta G < 0$, so the reaction is spontaneous at 298 K	☐

WHERE MARKS ARE LOST

- Not converting ΔS from J to kJ: $-2803 - 298 \times 262$ gives -8.09×10^4 , a meaningless mix of kJ and J.

33 (b) Why combustion of glucose is not an equilibrium reaction

3
MARKS

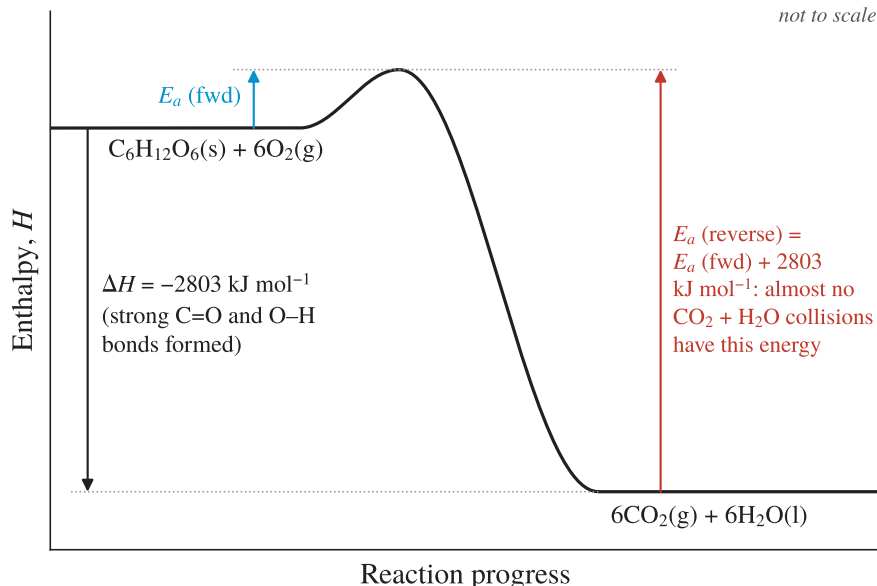
MARKING CRITERIA	MARKS
Provides ALL of the following: <ul style="list-style-type: none"> enthalpy and bond energy: $\Delta H < 0$ because much more energy is released forming the strong C=O and O-H bonds in CO_2 and H_2O than is absorbed breaking the bonds in glucose and O_2 entropy and Gibbs free energy: $\Delta S > 0$, so with $\Delta H < 0$, $\Delta G = \Delta H - T\Delta S$ is negative at every temperature and the reverse reaction ($\Delta G > 0$) is never spontaneous not an equilibrium: the reverse reaction does not occur to a measurable extent (K extremely large; reverse E_a enormous), so the forward and reverse rates never become equal and the reaction goes to completion 	3
Provides TWO of the above	2
Provides ONE of the above, OR some relevant information (e.g. $\Delta H < 0$ and $\Delta S > 0$, or the reaction goes to completion)	1

SAMPLE ANSWER, MARK BY MARK

1 ENTHALPY AND BOND ENERGY	the reaction is very exothermic: much more energy is released forming the strong C=O and O-H bonds in CO_2 and H_2O than is absorbed breaking the bonds in glucose and O_2 ($\Delta H = -2803 \text{ kJ mol}^{-1}$)	☐
2 ENTROPY AND GIBBS FREE ENERGY	$\Delta S > 0$: one large molecule of solid glucose and 6O_2 (7 particles) become 12 smaller molecules ($6\text{CO}_2 + 6\text{H}_2\text{O}$), so the products are more disordered and $-T\Delta S$ is negative. With $\Delta H < 0$ as well, ΔG is negative at every temperature, and the reverse reaction has $\Delta G = +2881 \text{ kJ mol}^{-1}$, which is never spontaneous	☐

3 NOT AN EQUILIBRIUM

the products are 2803 kJ mol^{-1} lower in energy than the reactants, so the activation energy of the reverse reaction ($E_a \text{ forward} + 2803 \text{ kJ mol}^{-1}$) is enormous and almost no collisions between CO_2 and H_2O molecules can react. The reverse reaction does not occur to any measurable extent ($K \approx 10^{505}$), so the forward and reverse rates never become equal, and in an open system the CO_2 escapes. The reaction goes to completion: it is irreversible, not an equilibrium (the reverse needs a large energy input, as in photosynthesis)

**WHERE MARKS ARE LOST**

- Only saying the reaction 'goes to completion' without using ΔH , ΔS , bond energy and ΔG .
- Saying ΔS is negative.

34**Phosphate concentration in ppm by gravimetric analysis****4**

MARKS

MARKING CRITERIA	MARKS
Correctly calculates the concentration of phosphate ions as $1.74 \times 10^4 \text{ ppm}$, expressed to THREE significant figures (0.842 g, 25.0 mL and 1.00 g mL^{-1} are all 3 s.f.)	4
Correctly calculates the concentration but NOT to three significant figures (e.g. 17 444 ppm or $1.7 \times 10^4 \text{ ppm}$), OR calculates the concentration to 3 s.f. with ONE error (e.g. 2 : 1 ratio omitted, $8.72 \times 10^3 \text{ ppm}$; mass of P used instead of PO_4^{3-} , $5.69 \times 10^3 \text{ ppm}$; formula CoPO_4 used, $2.08 \times 10^4 \text{ ppm}$)	3
Correctly calculates the moles of PO_4^{3-} ($4.592 \times 10^{-3} \text{ mol}$) or their mass (0.436 g), OR completes the method to ppm with ONE error and not to 3 s.f.	2
Correctly calculates the molar mass ($366.73 \text{ g mol}^{-1}$) or the moles ($2.296 \times 10^{-3} \text{ mol}$) of $\text{Co}_3(\text{PO}_4)_2$, OR gives the correct formula $\text{Co}_3(\text{PO}_4)_2$ or precipitation equation	1

SAMPLE ANSWER, MARK BY MARK

1 FORMULA AND MOLES OF PRECIPITATE	cobalt(II) phosphate is $\text{Co}_3(\text{PO}_4)_2$: $3\text{Co}^{2+}(\text{aq}) + 2\text{PO}_4^{3-}(\text{aq}) \rightarrow \text{Co}_3(\text{PO}_4)_2(\text{s})$. $M = 3(58.93) + 2(30.97 + 4 \times 16.00) = 366.73 \text{ g mol}^{-1}$; $n = 0.842/366.73 = 2.296 \times 10^{-3} \text{ mol}$	☐
2 MOLES AND MASS OF PHOSPHATE	$n(\text{PO}_4^{3-}) = 2 \times 2.296 \times 10^{-3} = 4.592 \times 10^{-3} \text{ mol}$; $m = 4.592 \times 10^{-3} \times 94.97 = 0.4361 \text{ g}$ → keep at least 4 significant figures until the final answer	☐
3 ppm	mass of the water sample = $25.0 \text{ mL} \times 1.00 \text{ g mL}^{-1} = 25.0 \text{ g}$; $\text{ppm} = 0.4361/25.0 \times 10^6 = 17\,444 \text{ ppm}$ → or in mg kg^{-1} : $436.1 \text{ mg} \div 0.0250 \text{ kg}$	☐

- 4 3 SIGNIFICANT FIGURES** the data (0.842 g, 25.0 mL, 1.00 g mL⁻¹) all have 3 significant figures, so give the answer to 3 s.f.: **1.74 × 10⁴ ppm** ☐
- significant figures are assessed in this question: 17 444 ppm or 1.7 × 10⁴ ppm loses this mark

WHERE MARKS ARE LOST

- Writing cobalt(II) phosphate as CoPO₄ or Co₂(PO₄)₃.
- Forgetting the 2 : 1 ratio of PO₄³⁻ to Co₃(PO₄)₂.
- Using the mass of P instead of the mass of PO₄³⁻.
- Rounding intermediate values: $n = 2.30 \times 10^{-3}$ mol gives 0.437 g and 1.75 × 10⁴ ppm. Round only the final answer.
- Writing 17 400 ppm: the trailing zeros leave the number of significant figures unclear; write 1.74 × 10⁴ ppm.

35**Identifying seven ions from qualitative tests****8**
MARKS

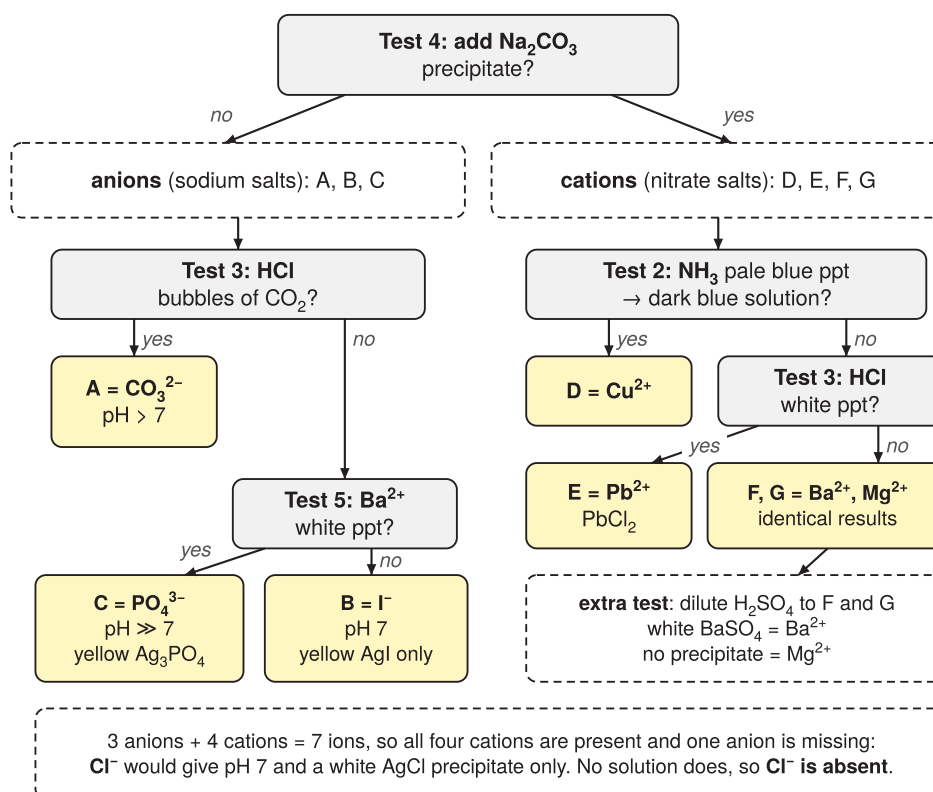
MARKING CRITERIA	MARKS
<p>Provides ALL of the following:</p> <ul style="list-style-type: none"> A = CO₃²⁻ (pH > 7; CO₂ bubbles with HCl; white precipitates with Ba²⁺ and Ag⁺), B = I⁻ (pH 7; yellow AgI is its only reaction), C = PO₄³⁻ (pH >> 7; white Ba₃(PO₄)₂; yellow Ag₃PO₄; no gas with HCl), D = Cu²⁺ (pale blue Cu(OH)₂ that dissolves in excess NH₃ to a deep blue solution; green/blue-green carbonate) and E = Pb²⁺ (the only white precipitate with HCl, PbCl₂), each justified by the test results F and G are Ba²⁺ and Mg²⁺ but cannot be told apart, because their results are identical (assigning them in a definite order does not meet this point) Cl⁻ is absent, with a reason (it would give pH 7 and only a white AgCl precipitate, and no solution does; 3 anions + 4 cations = 7) an additional test that distinguishes Ba²⁺ from Mg²⁺, with the expected observation for EACH ion (e.g. dilute H₂SO₄ or Na₂SO₄: white BaSO₄ with Ba²⁺, no precipitate with Mg²⁺; flame test: pale green with Ba²⁺, no colour with Mg²⁺) <p>8: all of the above. 7: ONE omission, e.g. Cl⁻ absence stated without a reason, an observation for only one of Ba²⁺/Mg²⁺, or one of A–E with incomplete justification</p>	7–8
<p>6: Identifies all five of A–E with justification AND recognises the F/G ambiguity AND provides ONE of: Cl⁻ absent; a valid additional test with observations for both ions</p> <p>5: Identifies at least FOUR of A–E with justification AND recognises the F/G ambiguity AND provides ONE of those two points, OR identifies all five of A–E with justification and the F/G ambiguity but neither of those two points</p>	5–6
<p>4: Identifies at least FOUR ions with justification, OR THREE ions with justification plus the F/G ambiguity or a valid additional test</p> <p>3: Identifies THREE ions with justification, OR five or more ions without justification</p>	3–4
Identifies TWO ions, each with a supporting observation, OR three or four ions without justification	2
Provides some relevant information, e.g. identifies one ion from a correct observation, or links one observation to the correct precipitate	1

CHECKLIST FOR A TOP-BAND ANSWER

MARKED HOLISTICALLY A top-band answer covers all 8 points below, linked into a logical, well-organised response; markers place the whole answer in a band rather than adding up points.

1 A = CO₃²⁻	basic (pH > 7), fizzes with HCl (CO ₃ ²⁻ (aq) + 2H ⁺ (aq) → CO ₂ (g) + H ₂ O(l)), and gives white BaCO ₃ and white Ag ₂ CO ₃ precipitates	☐
2 B = I⁻	neutral, and its only reaction is a yellow precipitate with AgNO ₃ (AgI); no precipitate with Ba ²⁺	☐
3 C = PO₄³⁻	strongly basic (pH >> 7), no gas with HCl (so not carbonate), a white Ba ₃ (PO ₄) ₂ and a yellow Ag ₃ PO ₄ precipitate	☐
4 D = Cu²⁺	a little NH ₃ gives pale blue Cu(OH) ₂ , which dissolves in excess to form the deep blue complex [Cu(NH ₃) ₄] ²⁺ ; it gives a green to blue-green copper carbonate with Na ₂ CO ₃	☐

- 5 E = Pb²⁺** the only solution to give a white precipitate with HCl (PbCl₂); white Pb(OH)₂ with NH₃ and white PbCO₃ with Na₂CO₃ ☐
- 6 F AND G = Mg²⁺ AND Ba²⁺** identical results: neutral, a faint white precipitate with NH₃, a white carbonate with Na₂CO₃, and no reaction with HCl, Ba(NO₃)₂ or AgNO₃. They are the remaining cations, Mg²⁺ and Ba²⁺, but these tests cannot tell them apart ☐
- 7 Cl⁻ IS ABSENT** D–G all precipitate with Na₂CO₃, so they are the four cations (Ba²⁺, Cu²⁺, Mg²⁺ and Pb²⁺ are all present) and A–C are the only three anions, so one anion is missing. Cl⁻ would give a neutral solution whose only reaction is a *white* AgCl precipitate with AgNO₃; no solution does this, so chloride is the ion that is not present ☐



- 8 ADDITIONAL TEST** add dilute H₂SO₄ (or Na₂SO₄) to F and G: Ba²⁺ gives a white BaSO₄ precipitate (Ba²⁺ (aq) + SO₄²⁻ (aq) → BaSO₄(s)); Mg²⁺ does not (MgSO₄ is soluble). Also accepted: add NaOH(aq), which gives a heavy white Mg(OH)₂ precipitate (K_{sp} 5.61 × 10⁻¹²) but little or none with Ba²⁺ (Ba(OH)₂ is fairly soluble, K_{sp} 2.55 × 10⁻⁴); or a flame test: Ba²⁺ gives a pale green flame and Mg²⁺ no colour ☐

WHERE MARKS ARE LOST

- Assigning F and G to Mg²⁺ and Ba²⁺ in a definite order: the data cannot separate them.
- Recommending a test that does not distinguish them (e.g. Na₂CO₃ or NH₃ again), or giving a test without the expected observation for *each* ion.
- Missing that one of the eight possible ions (Cl⁻) is not present.
- Identifying ions without quoting the observations that justify them.

36

Identifying the haloalkane from its mass and ^1H NMR spectra5
MARKS

MARKING CRITERIA	MARKS
Provides the correct name (3-chloropentane) AND structural formula, justified with reference to ALL of: <ul style="list-style-type: none"> molecular ion peaks at m/z 106 and 108 in a 3 : 1 ratio, the ^{35}Cl : ^{37}Cl ratio, so one Cl atom $106 - 35 = 71 = \text{C}_5\text{H}_{11}$, so the formula is $\text{C}_5\text{H}_{11}\text{Cl}$ three proton environments in a 6 : 4 : 1 ratio (11 H), so a symmetrical molecule each NMR peak assigned by its shift, integration and splitting: A (0.95 ppm, 6H, triplet) $2 \times \text{CH}_3$ next to CH_2; B (1.70 ppm, 4H, multiplet) $2 \times \text{CH}_2$; C (3.60 ppm, 1H, multiplet) the CH bonded to the electronegative Cl 	5
Provides the correct name and structural formula with justification missing ONE of the above (e.g. no isotope-ratio reasoning, or one NMR peak not assigned), OR full justification with only the name or only the structure correct	4
Provides the correct name and structural formula with limited justification, OR deduces $\text{C}_5\text{H}_{11}\text{Cl}$ from the mass spectrum and assigns at least TWO NMR peaks but gives an incorrect isomer	3
Identifies Cl from the 3 : 1 M : M+2 ratio AND deduces $\text{C}_5\text{H}_{11}\text{Cl}$, OR gives the correct name or structure without justification, OR correctly assigns TWO NMR peaks	2
Provides some relevant information, e.g. identifies the halogen as Cl, or states that there are three proton environments	1

SAMPLE ANSWER, MARK BY MARK

1 CHLORINE ISOTOPES	the molecular ion peaks at m/z 106 and 108 are in about a 3 : 1 ratio ($\approx 42 : 13$), the ratio of ^{35}Cl to ^{37}Cl : the halogen is one Cl atom (the small 107 peak is from ^{13}C)	☐
2 MOLECULAR FORMULA	$106 - 35 = 71 = \text{C}_5\text{H}_{11}$, so the formula is $\text{C}_5\text{H}_{11}\text{Cl}$ (saturated). Fragments fit: $71 = \text{C}_5\text{H}_{11}^+$ (loss of Cl), $77/79$ (3 : 1) = $\text{C}_3\text{H}_6\text{Cl}^+$ (loss of C_2H_5), $29 = \text{C}_2\text{H}_5^+$	☐
3 PEAK A	0.95 ppm, 6H, triplet: two equivalent CH_3 groups, each next to a CH_2 . Three environments in a 6 : 4 : 1 ratio (11 H) mean a symmetrical molecule	☐
4 PEAKS B AND C	B, 1.70 ppm, 4H, multiplet: two equivalent CH_2 groups, each between a CH_3 and the CH. C, 3.60 ppm, 1H, multiplet: one CH bonded to the electronegative Cl (deshielded, high shift), next to two CH_2 groups (4 neighbouring H)	☐
<p> A 0.95 ppm, 6H, triplet: $2 \times \text{CH}_3$, each next to a CH_2 (2 H, so $2 + 1 = 3$ peaks) B 1.70 ppm, 4H, multiplet: $2 \times \text{CH}_2$, each next to CH_3 (3 H) and CH (1 H) C 3.60 ppm, 1H, multiplet: the CH bonded to Cl (deshielded), next to 4 H dashed line: mirror symmetry, so only 3 environments in a 6 : 4 : 1 ratio </p>		
5 NAME AND STRUCTURE	3-chloropentane , $\text{CH}_3\text{CH}_2\text{CHClCH}_2\text{CH}_3$: the displayed structural formula is drawn in step 4 → draw the structural formula in full, as in step 4: a condensed formula alone may not earn the structure mark	☐

WHERE MARKS ARE LOST

- Identifying the halogen as Br: Br gives M and M+2 peaks in a 1 : 1 ratio.
- Choosing 1-chloropentane or 2-chloropentane: each has 5 proton environments, not 3. The only other C₅H₁₁Cl isomer with 3 environments, 2-chloro-2-methylbutane, would give 6 : 2 : 3 (with a 6H singlet) and has no H on the C–Cl carbon, so no peak near 3.6 ppm.
- Not linking the integration ratio 6 : 4 : 1 to the symmetry of the molecule.