

GCE

Chemistry A

Unit **H032/02**: Depth in chemistry

Advanced Subsidiary GCE

Mark Scheme for June 2017

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

OCR will not enter into any discussion or correspondence in connection with this mark scheme.

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Annotations available in RM Assessor

Annotation	Meaning
	Correct response
	Incorrect response
	Omission mark
	Benefit of doubt given
	Contradiction
	Rounding error
	Error in number of significant figures
	Error carried forward
	Level 1
	Level 2
	Level 3
	Benefit of doubt not given
	Noted but no credit given
	Ignore

Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

Annotation	Meaning
DO NOT ALLOW	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
()	Words which are not essential to gain credit
—	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

Subject-specific Marking Instructions**INTRODUCTION**

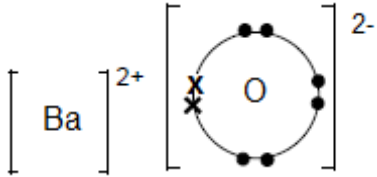
Your first task as an Examiner is to become thoroughly familiar with the material on which the examination depends. This material includes:

- the specification, especially the assessment objectives
- the question paper
- the mark scheme.

You should ensure that you have copies of these materials.

You should ensure also that you are familiar with the administrative procedures related to the marking process. These are set out in the OCR booklet **Instructions for Examiners**. If you are examining for the first time, please read carefully **Appendix 5 Introduction to Script Marking: Notes for New Examiners**.

Please ask for help or guidance whenever you need it. Your first point of contact is your Team Leader.

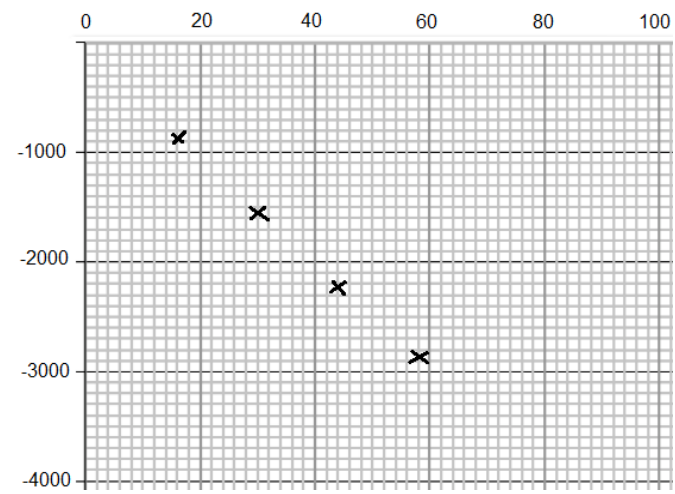
Question	Answer	Marks	Guidance
1 (a) (i)	Electrostatic attraction between positive and negative ions ✓	1	ALLOW oppositely charged ions ALLOW cations and anions ALLOW '+' for positive and '-' for negative IGNORE references to metal and non-metal IGNORE references to transfer of electrons
	(ii)  Ba shown with either 0 or 8 electrons AND O shown with 8 electrons with 6 dots and 2 crosses (or vice versa) ✓ Correct charges on both ions ✓	2	For first mark, if eight electrons are shown around Ba, the 'extra' electrons around O must match the symbol chosen for the electrons for Ba. IGNORE inner shells Circles not required Brackets not required
	(iii) FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = 5.89×10^{21} award 2 marks for calculation <i>Moles of barium oxide</i> $n(\text{BaO}) = 1.50/153.3$ OR 9.78×10^{-3} ✓ <i>Number of barium ions</i> $(9.78 \times 10^{-3} \times 6.02 \times 10^{23}) = 5.89 \times 10^{21}$ ✓ 3 SF AND standard form required	2	ALLOW 0.00978 up to calculator value 0.009784735 ALLOW ECF from incorrect moles of BaO Common incorrect answers are shown below IF 137.3 is used for the molar mass ALLOW 1 mark total for 6.58×10^{21} (0.010924981 mol) OR 6.56×10^{21} (0.0109 mol) IF 153 is used for the molar mass ALLOW 1 mark total for 5.90×10^{21}
(b) (i)	Barium chloride does not conduct electricity when solid AND	2	IGNORE use of 'free' instead of 'mobile' ALLOW ions are not free to move

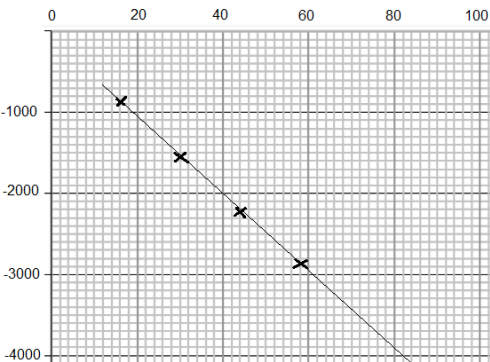
Question			Answer	Marks	Guidance
			because it has ions which are fixed (in position/in lattice) ✓ Barium chloride conducts when in aqueous solution AND because it has mobile ions ✓		ALLOW ions are held (in position/in lattice) ALLOW ions are not mobile IGNORE charge carriers DO NOT ALLOW electrons moving ALLOW one mark for comparison that does not identify (s) and (aq).
		(ii)	Test for sulfate/ SO_4^{2-} ✓ <u>White</u> precipitate forms (when barium chloride solution is mixed with a solution containing sulfate ions) ✓	2	IGNORE hydrochloric acid ALLOW white solid IGNORE cloudy DO NOT ALLOW test result linked to incorrect anion
		(iii)	FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = 2 award 2 marks $M(\text{BaCl}_2) = ((137.3 + (35.5 \times 2)) = \underline{208.3} \text{ (g mol}^{-1}\text{)})$ ✓ $244.3 - 208.3 = 36$ AND $36/18 = 2$ ✓	2	ALLOW 208 (g mol ⁻¹) ALLOW ECF for incorrectly calculated molar mass provided the final answer is rounded to nearest whole number
	(c)	(i)	$(1s^2) 2s^2 2p^6$ ✓	1	IGNORE $1s^2$ seen twice ALLOW upper case letters AND subscripts
		(ii)	<i>Products of reaction</i> A = Barium hydroxide/ Ba(OH)_2 ✓ B = Ammonia/ NH_3 ✓ <i>Formula for barium nitride</i> Ba_3N_2 ✓ <i>Balanced equation AND state symbols</i> $\text{Ba}_3\text{N}_2(\text{s}) + 6\text{H}_2\text{O}(\text{l}) \rightarrow 3\text{Ba(OH)}_2(\text{aq}) + 2\text{NH}_3(\text{g})$ ✓ State symbols are required	4	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC ALLOW one mark for correct products incorrectly labelled Formulae must be correct No ECF from any incorrect formula ALLOW multiples Correct equation with state symbols scores 4 marks
			Total	16	

Question	Answer	Marks	Guidance
2*	<i>Please refer to marking instructions on page 5 of mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) All three scientific points are covered in detail and explained thoroughly. <i>The method is logically structured and clear calculations are shown for an appropriate mass of metal and suitable volume of acid. The drawing of a tangent and determination of the gradient is communicated well.</i> Level 2 (3–4 marks) Candidates cover all three scientific points but explanations may be incomplete. OR Two of the scientific points are described thoroughly with no omissions. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence. e.g. there are clear calculations to justify mass and acid volume supported by some working and units; a simple description for determining initial rate related to tangent but no detail of how to measure gradient..</i> Level 1 (1–2 marks)	6	Indicative scientific points 1. Method • measure mass of (excess) zinc (using 2 decimal place balance) • measure volume of hydrochloric acid (using measuring cylinder) • mix zinc and acid in flask • measure gas volume at time intervals 2. Calculations • moles of hydrogen $72/24000 = 0.00300 \text{ mol}$ • minimum mass of zinc $0.003 \times 65.4 = 0.20 \text{ g}$ • moles of hydrochloric acid $\text{Zn} + 2\text{HCl} \rightarrow \text{ZnCl}_2 + \text{H}_2$ $0.00300 \times 2 = 0.00600 \text{ mol}$ • volume/concentration of acid If $[\text{HCl(aq)}] = 0.1 \text{ mol dm}^{-3}$ appropriate volume of acid = $0.006 \times 1000/0.1 = 60 \text{ cm}^3$ If $[\text{HCl(aq)}] \geq 0.3 \text{ mol dm}^{-3}$, too low ($\leq 20 \text{ cm}^3$) If $[\text{HCl(aq)}] \leq 0.03 \text{ mol dm}^{-3}$ too high ($\geq 200 \text{ cm}^3$) 3. Processing results • Plot a graph of volume against time • Draw a tangent at $t = 0$ • Gradient of tangent = initial rate • Gradient = volume/time

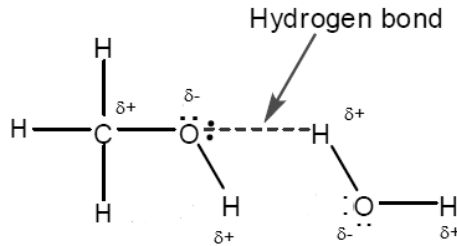
Question			Answer	Marks	Guidance
			There is a description based on at least two of the main scientific points OR The candidate explains one scientific point thoroughly with few omissions. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant. e.g. 'add zinc and acid and measure volume (no mass, volume or time intervals); calculations that have little structure, absent units and little working.</i> 0 marks <i>No response or no response worthy of credit.</i>		
			Total	6	Level 0

Question			Answer	Marks	Guidance
3	(a)	(i)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = $-2510 \text{ (kJ mol}^{-1}\text{)}$ award 4 marks IF answer = 2508 / 2507 (kJ mol^{-1}) award 3 marks <i>(not rounded to 3SF, ignore sign)</i> IF answer = + 2510 (kJ mol^{-1}) award 3 marks <i>(incorrect sign)</i> IF answer = $-2510000 \text{ (kJ mol}^{-1}\text{)}$ award 3 marks <i>(used J instead of kJ)</i> ----- <i>Moles</i> $n(\text{C}_6\text{H}_{14}) = 0.0150 \text{ mol}$ ✓ <i>Energy</i> q calculated correctly = 37620 (J) OR 37.620 (kJ) ✓ <i>Calculating ΔH</i> Correctly calculates ΔH in kJ mol^{-1} AND to 3 or more SF ✓ <i>Rounding AND sign</i> calculated value of ΔH rounded to 3 SF AND ‘-’ sign ✓	4	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC moles = $1.29/86.0$ IGNORE trailing zeros $q = 200 \times 4.18 \times 45.0$ ALLOW correctly rounded to 3 sig figs: 37.6 kJ ALLOW ECF from incorrect q ALLOW ECF from incorrect molar mass or incorrect moles of hexane to 3 SF or more correctly rounded IGNORE sign at this intermediate stage IGNORE working $\Delta H = 37.62/0.015 = 2508 \text{ (kJ mol}^{-1}\text{)}$ $\Delta H = 37.6/0.015 = 2507 \text{ (kJ mol}^{-1}\text{)}$ $\Delta H = -2510 \text{ (kJ mol}^{-1}\text{)}$ Final answer must have ‘-’ sign and 3 SF

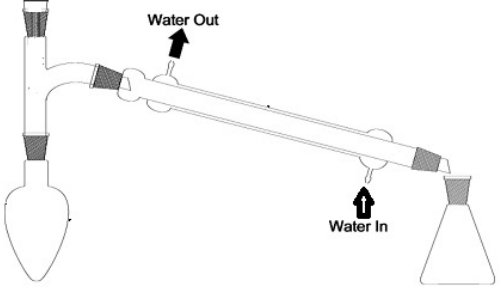
Question			Answer	Marks	Guidance
		(ii)	Any two from the following: ✓✓ - Heat released to the surroundings - Incomplete combustion - Non-standard conditions	2	ALLOW heat loss ALLOW incomplete reaction OR not everything burns IGNORE reference to evaporation
	(b)	(i)	Value for butane plotted accurately on the graph ✓	1	relative molecular mass = 58 $\Delta_c H^\ominus = -2877 \text{ kJ mol}^{-1}$  Check accuracy: - There must be a visible point - Vertically: touching the 58 line - Horizontally: between 2800 and 2900
		(ii)	FIRST, CHECK THE ANSWER ON ANSWER LINE	3	relative molecular mass = 72

Question	Answer	Marks	Guidance
	IF energy released = 87.5 (minimum) to 90 (maximum) AND line is extrapolated to 72 (molar mass) award 3 marks IF energy released <87.5 OR > 90.0 check the estimated value of $\Delta_c H^\ominus$ from the graph <i>Estimation of $\Delta_c H^\ominus$</i> extrapolated (straight) line of best fit (see graph) AND correctly estimated value $\Delta_c H^\ominus$ from graph ✓ <i>Calculation of energy released</i> $n(\text{C}_5\text{H}_{12}) = 0.0250 \text{ mol}$ ✓ <i>energy released</i> $= 0.0250 \times \text{correctly estimated value of } \Delta_c H^\ominus$ ✓		$\Delta_c H^\ominus = -3509 \text{ kJ mol}^{-1}$  Expected value within range: (-3500 to (-)3600 (kJ mol^{-1})) moles = $1.80/72.0$ IGNORE sign ALLOW ECF from incorrectly calculated moles of pentane OR incorrectly estimated $\Delta_c H^\ominus$

Question	Answer	Marks	Guidance
(c)	FIRST, CHECK THE ANSWER ON ANSWER LINE IF enthalpy change = $-3919.5 \text{ (kJ mol}^{-1}\text{)}$ award 3 marks IF enthalpy change = $(+3919.5 \text{ (kJ mol}^{-1}\text{)})$ award 2 marks <i>Working for CO₂ AND H₂O seen anywhere (1 mark)</i> $6 \times (-393.5 \text{ AND } 6 \times (-285.8$ OR $(-2361 \text{ AND } (-1714.8$ OR $(-4075.8 \quad \checkmark$ <i>Calculates $\Delta_c H$</i> A further 2 marks for correct answer AND correct sign $= (6 \times -393.5) + (6 \times -285.8) - (-156.3)$ $= -3919.5 \text{ (kJ mol}^{-1}\text{)} \quad \checkmark\checkmark$	3	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC IF there is an alternative answer, check to see if there is any ECF credit possible ALLOW 3 marks for $\Delta_c H = -3920$ FINAL answer rounded to 3 SF Common incorrect answers are shown below ALLOW 2 marks for $\Delta_c H = -3924$ <i>From $\Delta_c H = (6 \times -394 + 6 \times -286) - (-156)$</i> <i>Data rounded to 3 sig figs</i> ALLOW 2 marks for $\Delta_c H = -4232.1$ <i>All data added together</i> $(6 \times -393.5) + (6 \times -285.8) + (-156.3)$ ALLOW 1 mark for $\Delta_c H = (+)4232.1$
	Total	13	

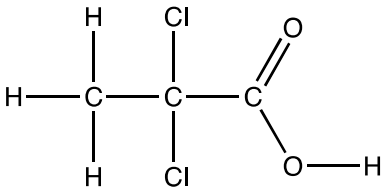
Question		Answer	Marks	Guidance
4	(a)	Displayed formulae of CH₃OH and H₂O AND C–O AND O–H polar bonds shown on CH₃OH molecule with δ⁺ and δ[–] AND Both O–H polar bonds shown on H₂O molecule with δ⁺ and δ[–] Two lone pairs shown on both oxygen atoms AND Hydrogen bond/H-bond labelled and in the correct position between the H on water and the oxygen lone pair on methanol ✓	2	Must be displayed formulae  IGNORE δ⁺ shown on other H atoms ALLOW hydrogen bond between the H on methanol (OH) and the oxygen lone pair on water
	(b)	(i) 3-methylbutan-2-ol ✓	1	ALLOW 3-methyl-2-butanol ALLOW 3-methylbutane-2-ol ALLOW absence of hyphens IGNORE commas DO NOT ALLOW 2-methylbutan-3-ol
		(ii) Peak X (<i>m/z</i> = 45)	2	C₅H₁₂O has lost C₃H₇ IGNORE C₂H₅O⁺ OR C₂H₄OH⁺ <i>ambiguous</i> DO NOT ALLOW unfeasible fragments e.g. C₃H₉⁺ (too many H atoms) ALLOW correct structural OR skeletal OR displayed formula OR mixture of the above for both structures
		CH₃CHOH⁺ ✓ Peak Y (<i>m/z</i> = 88)		IGNORE C₅H₁₂O⁺ ALLOW C₅H₁₁OH⁺

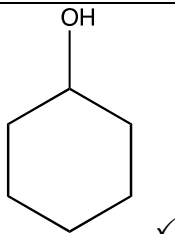
Question	Answer	Marks	Guidance
	$\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}(\text{OH})\text{CH}_3^+$ OR $\text{CH}_3\text{CH}(\text{OH})\text{CH}(\text{CH}_3)_2^+$	✓	+ charge (anywhere on structure) required for each response ALLOW one mark if both formulae are correct but with no charge/incorrect charge ALLOW one mark if both formulae are correct but incorrectly labelled X/Y
(c)*	<i>Please refer to the marking instructions on page 5 of the mark scheme for guidance on how to mark this question.</i> Level 3 (5-6 marks) A comprehensive explanation with all three scientific points covered thoroughly. <i>There is a well-developed description with a logical structure including correct chemical equations and an explanation with a clear line of reasoning including a fully labelled diagram.</i> Level 2 (3-4 marks) The candidate attempts all three scientific points but explanations are incomplete. OR Explains two scientific points thoroughly with no omissions. <i>The description has a line of reasoning presented with some structure and includes correct structural formulae and an accurate diagram of a distillation apparatus.</i> Level 1 (1-2 marks) A simple explanation based on at least two of the main scientific points	6	Indicative scientific points 1. Oxidation reaction forming aldehyde - acid/H^+ AND dichromate/$\text{Cr}_2\text{O}_7^{2-}$ - heat AND distillation - organic product is butanal/$\text{CH}_3\text{CH}_2\text{CH}_2\text{CHO}$ $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + [\text{O}] \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CHO} + \text{H}_2\text{O}$ 2. Oxidation reaction forming carboxylic acid - acid/H^+ AND dichromate/$\text{Cr}_2\text{O}_7^{2-}$ - heat under reflux - organic product is butanoic acid/ $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$ $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + 2[\text{O}] \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{COOH} + \text{H}_2\text{O}$ 3. Distillation - diagram of apparatus with condenser - condenser has water flow - collection of organic product - product is separated to prevent further oxidation (to carboxylic acid)

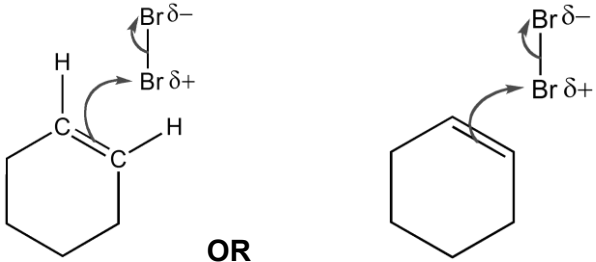
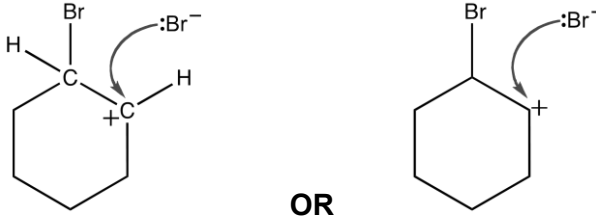
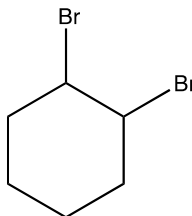
Question	Answer	Marks	Guidance
	OR The candidate explains one scientific point thoroughly with few omissions. <i>The description may be communicated in an unstructured way but it includes the correct reagents and conditions for the formation of the aldehyde.</i> <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks – No response or no response worthy of credit.		
	Total	11	

Question			Answer	Marks	Guidance
5	(a)		$C_nH_{2n}O_2$ OR $C_nH_{2n+1}COOH$ ✓	1	
	(b)	(i)	Tetrahedral AND $109.5(^{\circ})$ ✓ four bonded pairs repel OR four bonds repel ✓	2	Mark each point independently ALLOW range $109 - 110^{\circ}$ IGNORE surrounded by four atoms IGNORE four areas of electron charge repel IGNORE four electron pairs repel (<i>one could be lp</i>) DO NOT ALLOW atoms repel
		(ii)	$104.5(^{\circ})$ ✓	1	ALLOW range $104 - 105^{\circ}$
	(c)		LOOK ON THE SPECTRUM for labelled peaks which can be given credit $C=O$ $1630 - 1820\text{ (cm}^{-1}\text{)}$ AND $C=O$ ✓ $O-H$ $3200 - 3600\text{ cm}^{-1}$ AND $O-H$ ✓ Any two structures of compound B from ✓✓ CH_3COCH_2OH $CH_2(OH)CH_2CHO$ $CH_3CH(OH)CHO$	4	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC ALLOW wavenumber values that identify the peak within the range $1630 - 1820$ ALLOW carbonyl OR aldehyde OR ketone for $C=O$ ALLOW wavenumber values that identify the peak within the range $3200 - 3600$ ALLOW alcohol for $O-H$ IGNORE other bonds ALLOW correct structural OR skeletal OR displayed formula OR mixture of the above IGNORE names Penalise incorrect connectivity once only

Question			Answer	Marks	Guidance
	(d)	(i)	Ultraviolet (radiation)/UV ✓	1	ALLOW sunlight IGNORE temperature
		(ii)	$\text{CH}_3\text{CH}_2\text{COOH} + \text{Cl}_2 \rightarrow \text{CH}_3\text{CHClCOOH} + \text{HCl}$ ✓	1	ALLOW $\text{C}_2\text{H}_5\text{COOH} + \text{Cl}_2 \rightarrow \text{C}_2\text{H}_4\text{ClCOOH} + \text{HCl}$ ALLOW $\text{C}_3\text{H}_6\text{O}_2 + \text{Cl}_2 \rightarrow \text{C}_3\text{H}_5\text{ClO}_2 + \text{HCl}$
		(iii)	one electron from the bond (pair) goes to each atom/chlorine/radical ✓	1	ALLOW the breaking of a covalent bond where each atom keeps one of the bonding electrons IGNORE particle for atom ALLOW one electron from the bond goes to each product / species DO NOT ALLOW molecule or compound for atom IGNORE homolytic fission equations
		(iv)	<i>Propagation step 1</i> $\text{Cl}\cdot + \text{CH}_3\text{CH}_2\text{COOH} \rightarrow \text{CH}_3\text{CHCOOH}\cdot + \text{HCl}$ ✓ <i>Propagation step 2</i> $\text{CH}_3\text{CHCOOH}\cdot + \text{Cl}_2 \rightarrow \text{CH}_3\text{CHClCOOH} + \text{Cl}\cdot$ ✓	2	ALLOW 1. $\text{Cl}\cdot + \text{C}_3\text{H}_6\text{O}_2 \rightarrow \text{C}_3\text{H}_5\text{O}_2\cdot + \text{HCl}$ 2. $\text{C}_3\text{H}_5\text{O}_2\cdot + \text{Cl}_2 \rightarrow \text{C}_3\text{H}_5\text{ClO}_2 + \text{Cl}\cdot$ ALLOW dot at any position on the radical ALLOW 1 mark if both equations correct but any dots omitted from radicals
		(v)	 ✓	1	Dot shown in correct position ALLOW –OH

Question			Answer	Marks	Guidance
		(vi)	Any structure with two or more Cl atoms on alkyl chain (provided that one Cl is at C-2) e.g.  ✓	1	ALLOW correct structural OR skeletal OR displayed formula OR mixture of the above DO NOT ALLOW C₃H₄Cl₂O₂ ALLOW further substitution into any or all of the 4 positions occupied by H atoms in the alkyl group, provided that at least one Cl is at C-2
			Total	15	

Question			Answer	Marks	Guidance
6	(a)	(i)	 Acid (catalyst) AND heat ✓	2	ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous ALLOW (heat under) reflux ALLOW H₃PO₄ OR H₂SO₄ OR H⁺ DO NOT ALLOW other named acids IGNORE concentration/pressure IGNORE water/steam
		(ii)	FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = 44.4(%) award all 3 marks for calculation <i>Amount cyclohexene (m/M)</i> = 1.23/82 OR 0.0150 mol ✓ <i>Amount of bromocyclohexane (m/M)</i> = 5.50/162.9 OR 0.0338 mol ✓ <i>% yield</i> = (0.0150/0.0338) × 100 = 44.4(%) ✓ Final answer must be to 3 significant figures	3	If there is an alternative answer, check to see if there is any ECF credit possible ALLOW 3 SF: 0.0338 up to calculator value of 0.033763044 correctly rounded Common ECFs (2 marks) - Incorrect M_r → incorrect moles of cyclohexene - Incorrect M_r → incorrect moles of 2-bromocyclohexane e.g. ALLOW two marks for use of incorrect mass of bromocyclohexane with other calculations correct e.g. (5.50/163) = 0.033742331 → 44.5% ALLOW calculation in mass <i>Theoretical mass yield:</i> $m(\text{C}_6\text{H}_{10}) = 0.0338 \times 82 = 2.77 \text{ g}$ $\% \text{ yield} = (1.23/2.77) \times 100 = 44.4\%$
	(b)			4	ANNOTATE ANSWER WITH TICKS AND

Question	Answer	Marks	Guidance
	Curly arrow from double bond to Br of Br–Br ✓ Correct dipole shown on Br–Br AND curly arrow showing breaking of Br–Br bond ✓  OR Correct carbocation with + charge on C with 3 bonds AND curly arrow from Br[−] to C⁺ of carbocation ✓  OR Correct product:  ✓		CROSSES ETC Curly arrow must start from bond and go to correct atom DO NOT ALLOW any other partial charges e.g. shown on double bond DO NOT ALLOW missing H on displayed formulae (penalise once only) DO NOT ALLOW δ+ on C of carbocation. Curly arrow must come from a lone pair on Br[−] OR from the negative sign of Br[−] ion (then lone pair on Br[−] ion does not need to be shown) IGNORE wording if diagrams are correct Maximum of two marks for mechanism based on incorrect structure of cyclohexene
	Total	9	

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