OCR
Oxford Cambridge and RSA

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
BOD	Benefit of doubt given
CON	Contradiction
RE	Rounding error
SF	Error in number of significant figures
ECF	Error carried forward
L1	Level 1
L2	Level 2
L3	Level 3
NBOD	Benefit of doubt not given
SEEN	Noted but no credit given
I	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

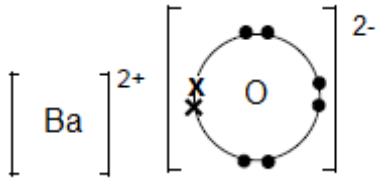
Your first task as an Examiner is to become thoroughly familiar with the material on which the examination depends. This material includes:

- 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.

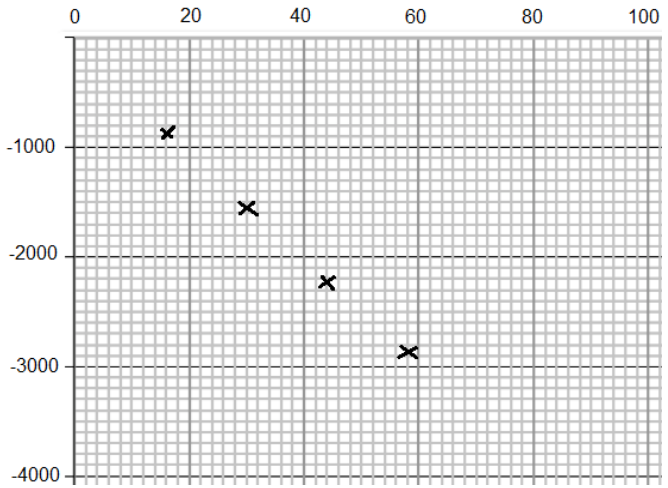
Question			Answer	Marks	Guidance
1	(a)	(i)	Electrostatic attraction between positive and negative ions ✓	1	**ALLOW** oppositely charged ions **ALLOW** cations and anions **ALLOW** '+' for positive and '-' for negative **IGNORE** references to metal and non-metal **IGNORE** references to transfer of electrons
		(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 *Moles of barium oxide* n(BaO) =1.50/153.3 **OR** 9.78×10^{-3} ✓ *Number of barium ions* $(9.78 \times 10^{-3} \times 6.02 \times 10^{23}) = 5.89 \times 10^{21}$ ✓ **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

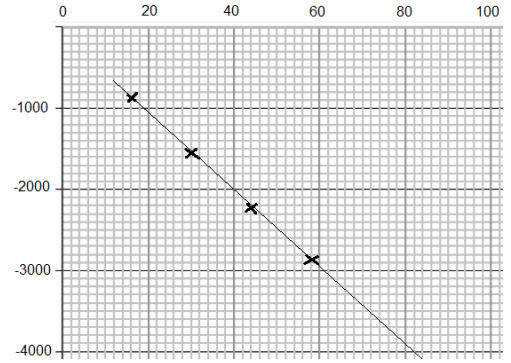
Question			Answer	Marks	Guidance
			because it has ions which are fixed (in position/in lattice) ✓ Barium chloride conducts when in aqueous solution **AND** because it has mobile ions ✓		**ALLOW ions** are held (in position/in lattice) **ALLOW ions** are not mobile **IGNORE** charge carriers **DO NOT 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 $M(BaCl_2)$ = ((137.3 + (35.5 × 2)) = <u>208.3</u> (g mol^{-1}) ✓ 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)	*Products of reaction* **A** = Barium hydroxide/$Ba(OH)_2$ ✓ **B** = Ammonia/NH_3 ✓ *Formula for barium nitride* Ba_3N_2 ✓ *Balanced equation **AND** state symbols* $Ba_3N_2(s) + 6H_2O(l) \rightarrow 3Ba(OH)_2(aq) + 2NH_3(g)$ ✓ 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*			*Please refer to marking instructions on page 5 of mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** All three scientific points are covered in detail and explained thoroughly. *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.* **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. *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..* **Level 1 (1–2 marks)**	6	**Indicative scientific points** **<u>1. Method</u>** • 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 **<u>2. Calculations</u>** • moles of hydrogen 72/24000 = 0.00300 mol • minimum mass of zinc $0.003 \times 65.4 = 0.20$ g • moles of hydrochloric acid $Zn + 2HCl \rightarrow ZnCl_2 + H_2$ $0.00300 \times 2 = 0.00600$ mol • volume/concentration of acid If [HCl(aq)] = 0.1 mol dm^{-3} appropriate volume of acid = $0.006 \times 1000/0.1 = 60$ cm^3 If [HCl(aq)] ≥ 0.3 mol dm^{-3}, too low (≤ 20 cm^3) If [HCl(aq)] ≤ 0.03 mol dm^{-3} too high (≥ 200 cm^3) **<u>3. Processing results</u>** • Plot a graph of volume against time • Draw a tangent at $t = 0$ • Gradient of tangent = initial rate • Gradient = volume/time

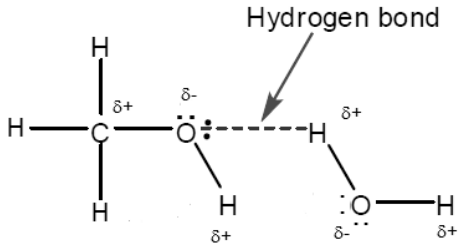
Question			Answer	Marks	Guidance
			There is a description based on at least two of the main scientific points **OR** The candidate explains one scientific point thoroughly with few omissions. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant. 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.* **0 marks** *No response or no response worthy of credit.*		
			Total	**6**	Level 0

Question			Answer	Marks	Guidance
3	(a)	(i)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = –2510 (kJ mol^{-1}) award 4 marks** **IF answer = 2508 / 2507 (kJ mol^{-1}) award 3 marks** *(not rounded to 3SF, ignore sign)* **IF answer = + 2510 (kJ mol^{-1}) award 3 marks** *(incorrect sign)* **IF answer = –2510000 (kJ mol^{-1}) award 3 marks** *(used J instead of kJ)* --- *Moles* $n(C_6H_{14})$ = 0.0150 mol ✓ *Energy* q calculated correctly = 37620 (J) **OR** 37.620 (kJ) ✓ *Calculating* ΔH Correctly calculates ΔH in kJ mol^{-1} **AND** to **3 or more SF** ✓ *Rounding **AND** sign* 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 × 4.18 × 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 ΔH = 37.62/0.015 = 2508 (kJ mol^{-1}) ΔH = 37.6/0.015 = 2507 (kJ mol^{-1}) ΔH = –2510 (kJ mol^{-1}) Final answer must have '**– sign** and **3 SF**

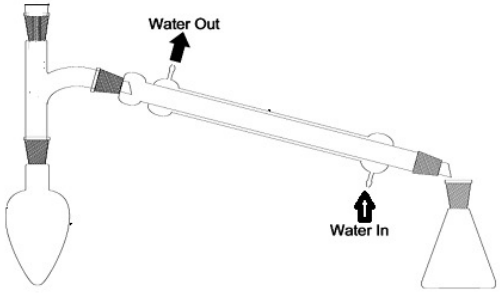
Question			Answer	Marks	Guidance
		(ii)	**Any two from the following:** ✓✓ • Heat released to the surroundings • Incomplete combustion • Non-standard conditions	**2**	**ALLOW** heat loss **ALLOW** incomplete reaction **OR** not everything burns **IGNORE** reference to evaporation
	(b)	**(i)**	Value for butane plotted accurately on the graph ✓	**1**	relative molecular mass = 58 $\Delta_c H^{\ominus}$ = –2877 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** *Estimation of $\Delta_c H^{\ominus}$* extrapolated (straight) line of best fit (see graph) **AND** correctly estimated value $\Delta_c H^{\ominus}$ from graph ✓ *Calculation of energy released* $n(C_5H_{12})$ = 0.0250 mol ✓ *energy released* = 0.0250 × correctly estimated value of $\Delta_c H^{\ominus}$ ✓		$\Delta_c H^{\ominus}$ = –3509 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 $\Delta_c H^{\ominus}$

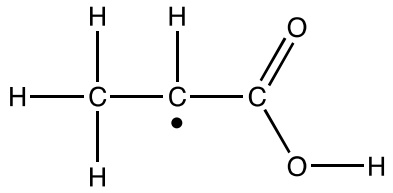
Question	Answer	Marks	Guidance
(c)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF enthalpy change = –3919.5 (kJ mol^{-1}) award 3 marks** **IF enthalpy change = (+)3919.5 (kJ mol^{-1}) award 2 marks** --- *Working for CO_2* ***AND*** *H_2O seen anywhere (1 mark)* 6 × (–)393.5 **AND** 6 × (–)285.8 **OR (–)**2361 **AND (–)**1714.8 **OR (–)**4075.8 ✓ *Calculates $\Delta_c H$* **A further 2 marks** for correct answer **AND** correct sign = (6 × –393.5) + (6 × –285.8) – (–156.3) = – 3919.5 (kJ mol^{-1}) ✓✓	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 a****nswer rounded to 3 SF* **Common incorrect answers are shown below** **ALLOW 2 marks for** $\Delta_c H$ = –3924 *From $\Delta_c H$ = (6 × –394 + 6 × –286) – (–156)* *Data rounded to 3 sig figs* **ALLOW 2 marks for** $\Delta_c H$ = –4232.1 *All data added together* *(6 × –393.5) + (6 × –285.8) + (–156.3)* **ALLOW 1 mark for** $\Delta_c H$ = (+)4232.1
	Total	**13**	

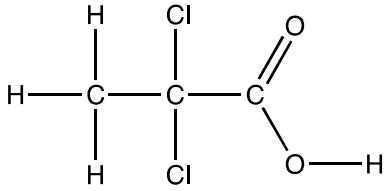
Question			Answer	Marks	Guidance
4	(a)		Displayed formulae of CH_3OH and H_2O **AND** C–O **AND** O–H polar bonds shown on CH_3OH molecule with δ+ and δ– **AND** Both O–H polar bonds shown on H_2O molecule with δ+ and δ– ✓ **Two** lone pairs shown on both oxygen atoms **AND** Hydrogen bond/H-bond labelled 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** *(m/z = 45)* CH_3CHOH^+ ✓ Peak **Y** *(m/z = 88)*	**2**	$C_5H_{12}O$ has lost C_3H_7 **IGNORE** $C_2H_5O^+$ **OR** $C_2H_4OH^+$ *ambiguous* **DO NOT ALLOW** unfeasible fragments e.g. $C_3H_9^+$ (too many H atoms) **ALLOW** correct structural **OR** skeletal **OR** displayed formula **OR** mixture of the above for both structures **IGNORE** $C_5H_{12}O^+$ **ALLOW** $C_5H_{11}OH^+$

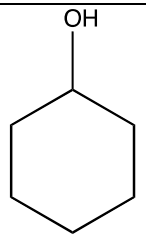
Question			Answer	Marks	Guidance
			$CH_3CH(CH_3)CH(OH)CH_3^+$ **OR** $CH_3CH(OH)CH(CH_3)_2^+$ ✓		+ charge (anywhere on structure) required for each response **ALLOW** one mark if both formulae are correct but with no charge/incorrect charge **ALLOW** one mark if both formulae are correct but incorrectly labelled **X**/**Y**
	(c)*		*Please refer to the marking instructions on page 5 of the mark scheme for guidance on how to mark this question.* **Level 3 (5-6 marks)** A comprehensive explanation with all three scientific points covered thoroughly. *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.* **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. *The description has a line of reasoning presented with some structure and includes correct structural formulae and an accurate diagram of a distillation apparatus.* **Level 1 (1–2 marks)** A simple explanation based on at least two of the main scientific points	**6**	**Indicative scientific points** **<u>1. Oxidation reaction forming aldehyde</u>** • acid/H^+ **AND** dichromate/$Cr_2O_7^{2-}$ • heat **AND** distillation • organic product is butanal/$CH_3CH_2CH_2CHO$ • $CH_3CH_2CH_2CH_2OH + [O] \rightarrow CH_3CH_2CH_2CHO + H_2O$ **<u>2. Oxidation reaction forming carboxylic acid</u>** • acid/H^+ **AND** dichromate/$Cr_2O_7^{2-}$ • heat under reflux • organic product is butanoic acid/ $CH_3CH_2CH_2COOH$ • $CH_3CH_2CH_2CH_2OH + 2[O] \rightarrow CH_3CH_2CH_2COOH + H_2O$ **<u>3. Distillation</u>** • diagram of apparatus with condenser • condenser has water flow • collection of organic product • product is separated to prevent further oxidation (to carboxylic acid)

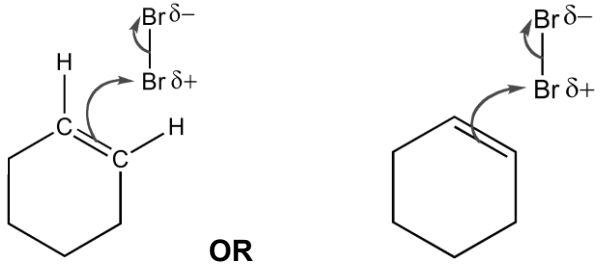
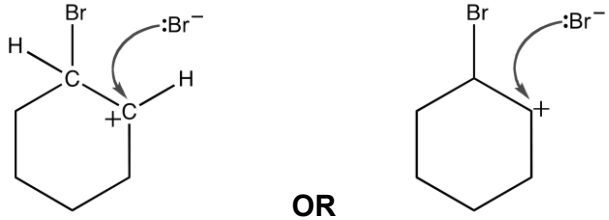
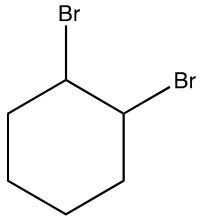
Question			Answer	Marks	Guidance
			OR The candidate explains one scientific point thoroughly with few omissions. *The description may be communicated in an unstructured way but it includes the correct reagents and conditions for the formation of the aldehyde.* *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **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(°) ✓ four **bonded** pairs repel **OR** four **bonds** repel ✓	2	**Mark each point independently** **ALLOW** range 109 – 110° **IGNORE** surrounded by four atoms **IGNORE** four areas of electron charge repel **IGNORE** four electron pairs repel (*one could be lp*) **DO NOT ALLOW** atoms repel
		(ii)	104.5(°) ✓	1	**ALLOW** range 104 – 105°
	(c)		**LOOK ON THE SPECTRUM** for labelled peaks which can be given credit *C=O* 1630 – 1820 (cm^{-1}) **AND** C=O ✓ *O–H* 3200 – 3600 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)	$CH_3CH_2COOH + Cl_2 \rightarrow CH_3CHClCOOH + HCl$ ✓	1	**ALLOW** $C_2H_5COOH + Cl_2 \rightarrow C_2H_4ClCOOH + HCl$ **ALLOW** $C_3H_6O_2 + Cl_2 \rightarrow C_3H_5ClO_2 + HCl$
		(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)	*Propagation step 1* $Cl\bullet + CH_3CH_2COOH \rightarrow CH_3CHCOOH\bullet + HCl$ ✓ *Propagation step 2* $CH_3CHCOOH\bullet + Cl_2 \rightarrow CH_3CHClCOOH + Cl\bullet$ ✓	2	**ALLOW** 1. $Cl\bullet + C_3H_6O_2 \rightarrow C_3H_5O_2\bullet + HCl$ 2. $C_3H_5O_2\bullet + Cl_2 \rightarrow C_3H_5ClO_2 + Cl\bullet$ **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** $C_3H_4Cl_2O_2$ **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** H_3PO_4 **OR** H_2SO_4 **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 *Amount cyclohexene (m/M)* = 1.23/82 **OR** 0.0150 mol ✓ *Amount of bromocyclohexane (m/M)* = 5.50/162.9 **OR** 0.0338 mol ✓ *% yield* = (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 *Theoretical mass yield:* $m(C_6H_{10})$ = 0.0338 × 82 = 2.77 g % yield = (1.23/2.77) × 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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