



GCE

Chemistry A

Unit **H432/02**: Synthesis and analytical techniques

Advanced GCE

Mark Scheme for June 2018

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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.

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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:

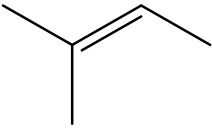
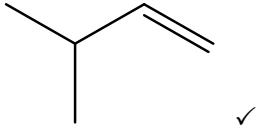
- the specification, especially the assessment objectives
- the question paper
- the mark scheme.

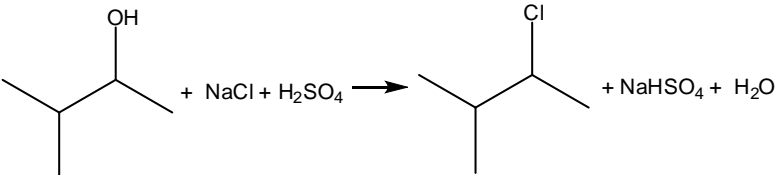
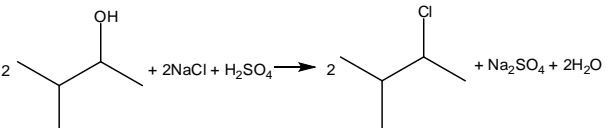
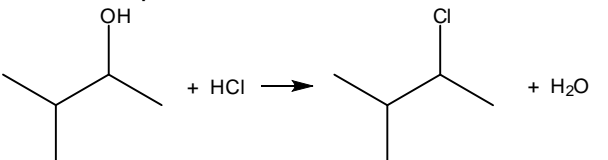
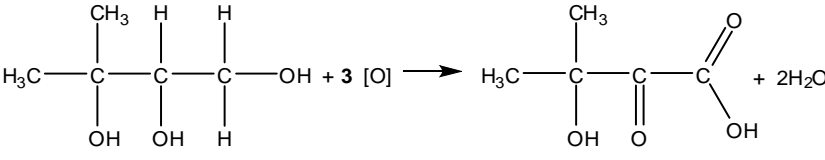
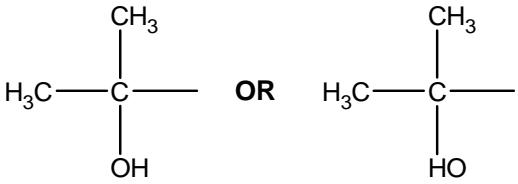
You should ensure that you have copies of these materials.

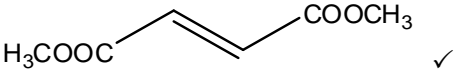
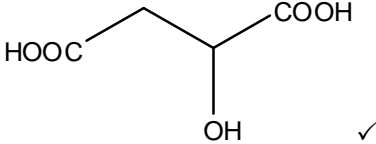
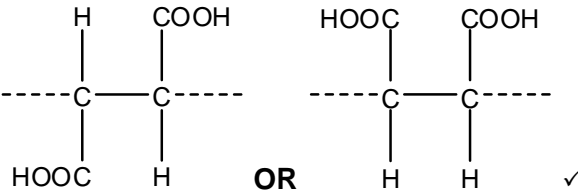
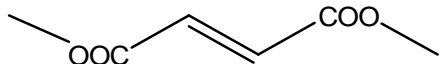
You should ensure also that you are familiar with the administrative procedures related to the marking process. These are set out in the OCR booklet **Instructions for Examiners**. If you are examining for the first time, please read carefully **Appendix 5 Introduction to Script Marking: Notes for New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

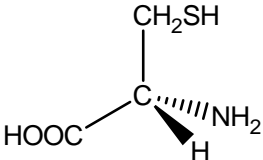
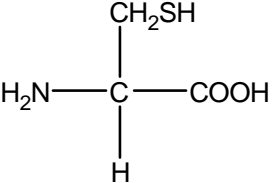
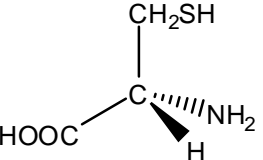
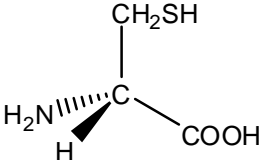

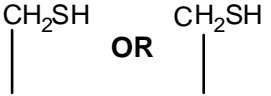
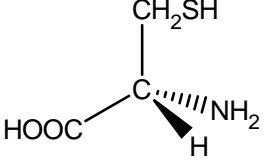
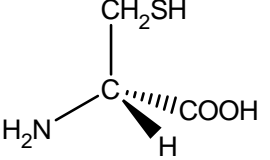
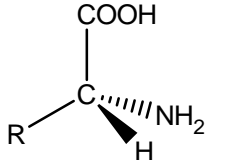
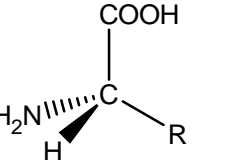
Please ask for help or guidance whenever you need it. Your first point of contact is your Team Leader.

Question	Answer	Marks	Guidance
1	A	1	
2	C	1	
3	B	1	
4	C	1	
5	B	1	
6	B	1	ALLOW 4 (This is the number of peaks in the NMR spectrum)
7	C	1	
8	D	1	
9	B	1	
10	C	1	
11	B	1	ALLOW 2 (This is the number of straight chain isomers with a chiral C atom)
12	C	1	
13	A	1	
14	B	1	
15	B	1	
	Total	15	

Question			Answer	Marks	Guidance
16	(a)	(i)	3-methylbutan-2-ol ✓	1	IGNORE lack of hyphens or addition of commas ALLOW 3-methylbutane-2-ol DO NOT ALLOW <div style="display: flex; justify-content: space-between;"> <div> OR OR OR OR </div> <div> 2-methylbutan-3-ol 3-methylbut-2-ol 3-methylbutan-2-ol 3-methylbutan-2-ol 3-methylbutan-2-ol </div> </div>
		(ii)	$(\text{CH}_3)_2\text{CHCHOHCH}_3$ ✓	1	ALLOW brackets around OH e.g. $(\text{CH}_3)_2\text{CHCH}(\text{OH})\text{CH}_3$ ALLOW any unambiguous structural formula e.g. $\text{CH}_3\text{CH}(\text{CH}_3)\text{CHOHCH}_3$ $\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}(\text{CH}_3)\text{OH}$
		(iii)	One mark for each correct structure. <div style="display: flex; justify-content: space-around; align-items: center;">   </div>	2	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous ALLOW in either order

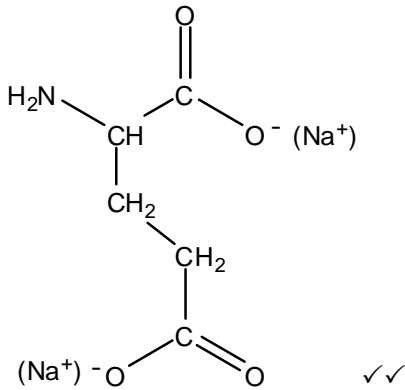
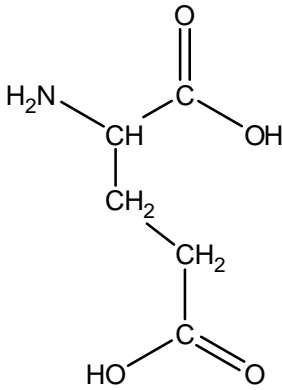
Question	Answer	Marks	Guidance
(iv)	 <p>Correct haloalkane ✓</p> <p>Correctly balanced equation ✓</p>	2	<p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>ALLOW H⁺ for H₂SO₄</p> <p>ALLOW equations forming Na₂SO₄</p>  <p>ALLOW equations with HCl</p>  <p>DO NOT ALLOW equations that form NaOH</p>
(b)	 <p>Correct organic product ✓</p> <p>Rest of equation ✓</p>	2	<p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>ALLOW any vertical bond to the tertiary OH group e.g. ALLOW</p> 

Question		Answer	Marks	Guidance
(c)		<p>Product from excess $\text{CH}_3\text{OH}/\text{H}_2\text{SO}_4$</p> <p></p> <p>Product from steam, H_3PO_4</p> <p></p> <p>Repeat unit of polymer C</p> <p></p>	3	<p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous e.g.</p> <p></p> <p>IGNORE connectivity in each product</p> <p>ALLOW the <i>E</i> or <i>Z</i> isomer as product from excess $\text{CH}_3\text{OH}/\text{H}_2\text{SO}_4$</p> <p>'End bonds' MUST be shown (do not have to be dotted)</p> <p>IGNORE brackets</p> <p>IGNORE <i>n</i></p> <p>ALLOW more than one repeat unit but has to be a whole number of repeat units</p>
		Total	11	

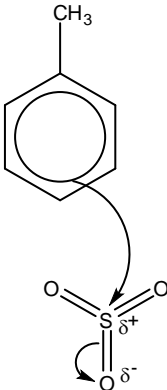
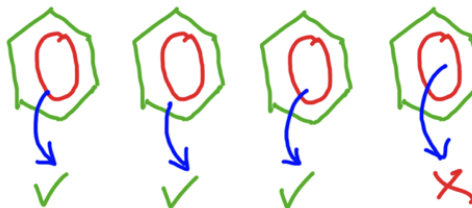
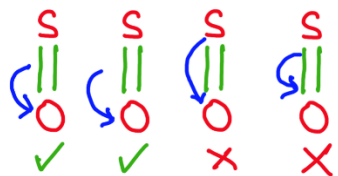
Question	Answer	Marks	Guidance
17 (a)	<p>Correct groups attached to chiral C of cysteine seen once e.g.</p> <div style="text-align: center;">  OR  </div> <p>Two 3D structures of cysteine that are mirror images with correct connectivity in both ✓</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  </div> <div style="text-align: center;">  </div> </div>	2	<p>Each structure must have four central bonds with at least two wedges. For bond into paper accept:</p> <div style="text-align: center;">  </div> <p>ALLOW bond to any part of the CH₂ of the CH₂SH group e.g. ALLOW</p> <div style="text-align: center;">  </div> <p>ALLOW two 3D structures with 2 groups swapped e.g.</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  </div> <div style="text-align: center;">  </div> </div> <p>IF CH₂SH is shown as 'R' ALLOW 1 mark for two 3D structures with correct connectivity that are mirror images e.g.</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;">  </div> <div style="text-align: center;">  </div> </div>

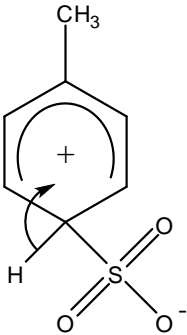
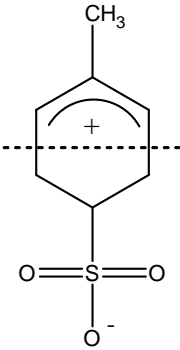
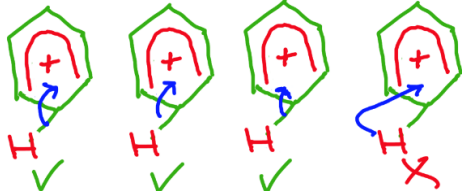
Question	Answer	Marks	Guidance
(b)	<p>Correct salt of lysine with both amine groups protonated</p> $ \begin{array}{c} \text{Cl}^- \\ \\ \text{H}_3\text{N}^+ - \text{C} - \text{C} \begin{array}{l} \text{O} \\ \parallel \end{array} \\ \qquad \qquad \\ (\text{CH}_2)_4 \quad \text{OH} \\ \\ \text{Cl}^- + \text{NH}_3 \quad \checkmark \checkmark \end{array} $	2	<p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>Note: <i>Cl</i>⁻ is required (question asks for salt)</p> <p>ALLOW NH_3Cl i.e charges not required</p> <p>ALLOW 1 mark for</p> <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;"> $\begin{array}{c} \text{Cl}^- \\ \\ \text{H}_3\text{N}^+ - \text{C} - \text{C} \begin{array}{l} \text{O} \\ \parallel \end{array} \\ \qquad \qquad \\ (\text{CH}_2)_4 \quad \text{OH} \\ \\ \text{NH}_2 \end{array}$ </div> <div>OR</div> <div style="text-align: center;"> $\begin{array}{c} \text{H}_2\text{N} - \text{C} - \text{C} \begin{array}{l} \text{O} \\ \parallel \end{array} \\ \qquad \qquad \\ (\text{CH}_2)_4 \quad \text{OH} \\ \\ \text{Cl}^- + \text{NH}_3 \end{array}$ </div> </div> <p>OR</p> <div style="text-align: center;"> $\begin{array}{c} \text{H} \\ \\ \text{H}_3\text{N}^+ - \text{C} - \text{C} \begin{array}{l} \text{O} \\ \parallel \end{array} \\ \qquad \qquad \\ (\text{CH}_2)_4 \quad \text{OH} \\ \\ + \text{NH}_3 \end{array}$ <p>i.e. no <i>Cl</i>⁻</p> </div> <p>IF there is a small slip in the structure ALLOW 1 mark for diammonium salt e.g</p> <div style="text-align: center;"> $\begin{array}{c} \text{Cl}^- \\ \\ \text{H}_3\text{N}^+ - \text{C} - \text{C} \begin{array}{l} \text{O} \\ \parallel \end{array} \\ \qquad \qquad \\ (\text{CH}_2) \quad \text{OH} \\ \\ \text{Cl}^- + \text{NH}_3 \end{array}$ <p>(incorrect number of CH_2 in R group)</p> </div>

Question	Answer	Marks	Guidance
			<p>OR</p> $ \begin{array}{c} \text{Cl}^- \\ \\ \text{H}_3\text{N}^+ - \text{C} - \text{C} \begin{array}{l} \text{// O} \\ \text{\textbackslash OH} \end{array} \\ \\ (\text{CH}_2)_4 \\ \\ \text{Cl}^- + \text{NH}_3 \end{array} $ <p>(H missing from α C atom)</p>
(c)	$ \begin{array}{c} \text{HO}-\text{CH}_2 \\ \\ \text{H}_2\text{N}-\text{CH}-\text{C} \begin{array}{l} \text{\textbackslash O} \\ \text{O}^- (\text{Na}^+) \end{array} \end{array} $ <p>OR</p> $ \begin{array}{c} \text{HO}-\text{CH}_2 \\ \\ \text{---NH}-\text{CH}-\text{C} \begin{array}{l} \text{\textbackslash O} \\ \text{O}^- (\text{Na}^+) \end{array} \end{array} $ <p>✓</p>	3	<p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>IGNORE NH_3 (question asks for organic products)</p> <p>ALLOW ---COO^- OR ---COONa</p> <p>DO NOT ALLOW negative charge on C atom DO NOT ALLOW ---COO---Na (covalent bond) BUT ALLOW ECF if seen in subsequent structures</p> <p>DO NOT ALLOW COOH in this structure DO NOT ALLOW (sodium) salt of alcohol group i.e.</p> $ \begin{array}{c} ^-\text{O}-\text{CH}_2 \\ \\ \text{H}_2\text{N}-\text{CH}-\text{C} \begin{array}{l} \text{\textbackslash O} \\ \text{O}^- (\text{Na}^+) \end{array} \end{array} $

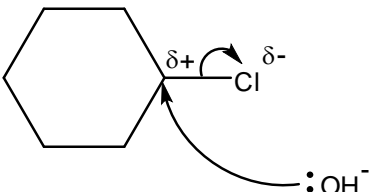
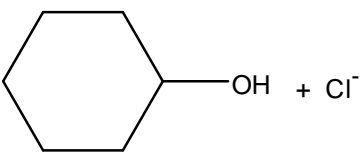
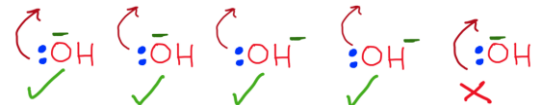
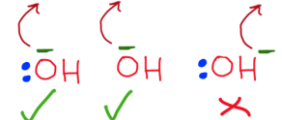
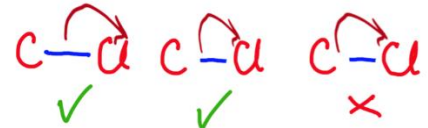
Question	Answer	Marks	Guidance
	 <p>i.e. one mark for each group hydrolysed</p>		<p>ALLOW COOH groups in this structure i.e. award 2 marks for</p>  <p>IGNORE small slip in carbon chain</p>
	Total	7	

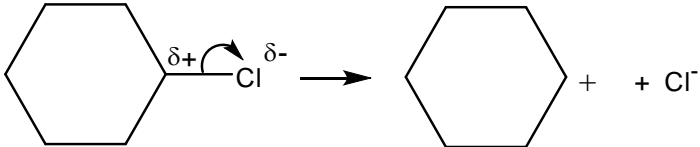
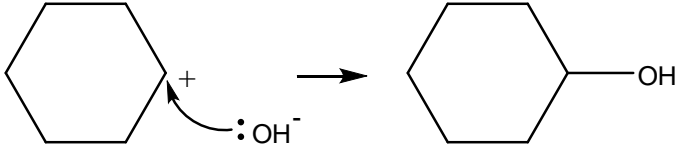
Question			Answer	Marks	Guidance
18	(a)	(i)	<p>Number of peaks 2 marks</p> <p>2-nitrophenol AND 3-nitrophenol have six peaks/environments/types of carbon ✓</p> <p>4-nitrophenol has four peaks/environments/types of carbon ✓</p> <p>Statement 1 mark</p> <p>4-nitrophenol can be distinguished OR 2-nitrophenol and 3-nitrophenol cannot be distinguished ✓</p>	3	<p>IGNORE any numbers shown on structures</p> <p>ALLOW 1 mark only IF a response identifies that all the compounds have 6 peaks/environments/types of C OR all the compounds have 4 peaks/environments/types of carbon</p> <p>IGNORE chemical shifts</p> <p>DO NOT ALLOW ECF from an incorrect number of peaks/environments/types of carbon</p>
		(ii)	<p>(In phenol) a (lone) pair of electrons on O is (partially) delocalised/donated into the π-system / ring ✓</p> <p>Electron density increases/is higher (than benzene) ✓ ORA</p> <p>(phenol) is more susceptible to electrophilic attack OR (phenol) attracts/accepts electrophile/HNO₃ more OR (phenol) polarises electrophile/HNO₃ more ✓ ORA</p>	3	<p>ALLOW the electron pair in the p-orbitals of the O atom becomes part of the π-system / ring ALLOW diagram to show movement of lone pair into ring ALLOW lone pair of electrons on O is (partially) drawn/attracted/pulled/ into π-system / ring IGNORE activating</p> <p>IGNORE charge density IGNORE electronegativity</p> <p>IGNORE phenol reacts more readily (<i>no reference to electrophile</i>)</p> <p>ALLOW NO₂⁺ for electrophile</p>

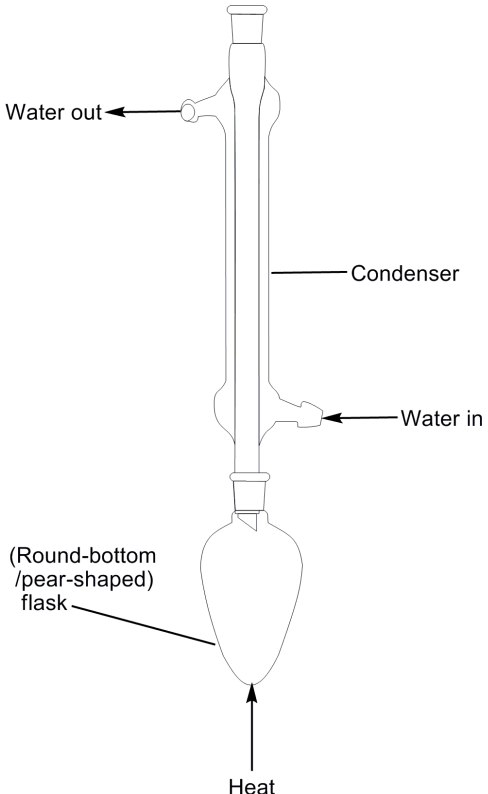
Question	Answer	Marks	Guidance
(b)	<p>Curly arrow from π-bond to S in SO_3 AND curly arrow from the S=O bond to O atom ✓</p> 	3	<p>ANNOTATE WITH TICKS AND CROSSES</p> <p>NOTE: curly arrows can be straight, snake-like, etc. but NOT double headed or half headed arrows</p> <p>1st curly arrow must</p> <ul style="list-style-type: none"> go to the S of SO_3 <p>AND</p> <ul style="list-style-type: none"> start from, OR close to circle of benzene ring  <p>2nd curly arrow must start from, OR be traced back to, any part of S=O bond and go to O</p>  <p>ALLOW 2nd curly arrow from S=O to any O in SO_3</p> <p>Intermediate must have correct SO_3^- structure fully displayed</p>

Question	Answer	Marks	Guidance
	<p>Correct intermediate ✓</p> <p>Curly arrow from C-H bond to reform π-ring ✓</p> 		<p>DO NOT ALLOW the following intermediate:</p>  <p>π-ring must cover more than half of the benzene ring structure AND the correct orientation, <i>i.e.</i> gap towards C with SO_3^-</p> <p>ALLOW + sign anywhere inside the 'hexagon' of the intermediate.</p> <p>DO NOT ALLOW mark for intermediate if CH_3 is missing</p> <p>curly arrow must start from, OR be traced back to, any part of C-H bond and go inside the 'hexagon'</p> 
	Total	9	

Question		Answer	Marks	Guidance
19	(a)	<p>Links rate of reaction to strength of bond/bond enthalpy ✓ e.g. the weaker the bond the faster the reaction stronger bond takes longer to break lower bond enthalpy reacts faster</p> <p>Correct comparison of rate of reaction for at least two C–Hal bonds e.g. C–F bond is hydrolysed slowest C–I bond is hydrolysed faster than C–Br C–Br has shorter reaction time than C–Cl</p> <p>OR</p> <p>Correct comparison of C–Hal bond strength/enthalpy of at least two of C–Hal bonds e.g. C–I bond is the weakest C–I has lower bond enthalpy than C–Br C–Br is broken more easily/readily than C–Cl C–Hal bond strength decreases down group (7) ✓</p>	2	<p>Each marking point must be a comparison</p> <p>IGNORE references to halogens as elements: <i>i.e.</i> chlorine is less reactive than bromine etc.</p> <p>DO NOT ALLOW chloride, bromide and iodide</p> <p>IGNORE references to bond length, polarity and electronegativity</p>

Question	Answer	Marks	Guidance
(b)	<p>Curly arrow from HO^- to carbon atom of C–Cl bond ✓</p> <p>Dipole shown on C–Cl bond, $\text{C}^{\delta+}$ and $\text{Cl}^{\delta-}$ AND curly arrow from C–Cl bond to Cl atom ✓</p>  <p>IGNORE presence of Na^+ but OH^- needed i.e. Na^+OH^- can be allowed if criteria met</p> <hr/> <p>Correct organic product AND Cl^- ✓</p>  <p>IGNORE presence of Na^+ but Cl^- needed i.e. Na^+Cl^- can be allowed BUT NaCl does NOT show Cl^-</p>	3	<p>ANNOTATE ANSWER TICKS AND CROSSES</p> <p>NOTE: curly arrows can be straight, snake-like, etc. but NOT double headed or half headed arrows</p> <p>1st curly arrow must</p> <ul style="list-style-type: none"> go to the C of C–Cl <p>AND</p> <ul style="list-style-type: none"> start from, OR be traced back to any point across width of lone pair on O of OH^-  <ul style="list-style-type: none"> OR start from – charge on O of OH^-  <p>(Lone pair NOT needed if curly arrow shown from O^-)</p> <p>2nd curly arrow must start from, OR be traced back to, any part of C–Cl bond and go to Cl</p> 

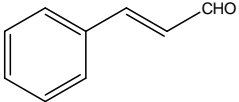
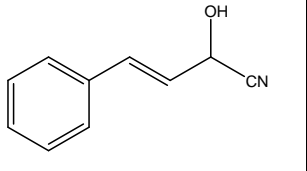
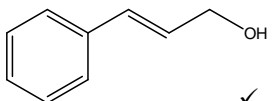
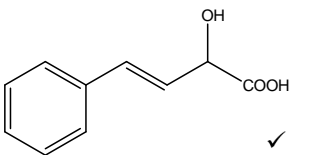
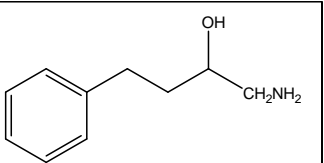
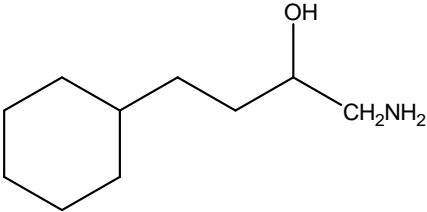
Question	Answer	Marks	Guidance
			<p>-----</p> <p>ALLOW S_N1 mechanism</p> <p>First mark Dipole shown on C–Cl bond, C^{δ+} and Cl^{δ-}, AND curly arrow from C–Cl bond to Cl atom ✓</p>  <p>Second mark Correct carbocation AND curly arrow from HO⁻ to carbocation</p>  <p>Curly arrow must come from lone pair on O of HO⁻ OR OH⁻ OR from minus on O of HO⁻ ion (no need to show lone pair if curly came from negative charge) ✓</p> <p>Third mark Correct organic product AND Cl⁻ ✓</p> <p>-----</p>

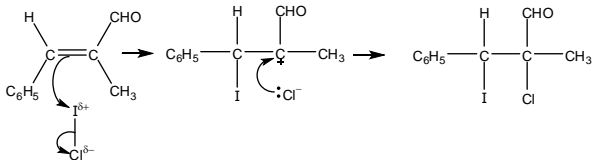
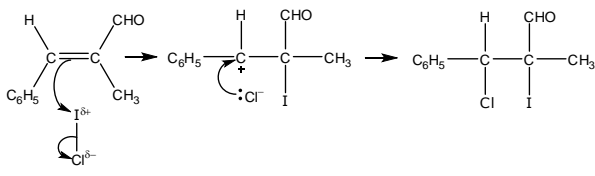
Question	Answer	Marks	Guidance
(c) (i)	<p>Diagram Diagram showing round bottom/pear shaped flask AND upright condenser ✓</p>  <p>(Round-bottom /pear-shaped) flask</p> <p>Condenser</p> <p>Water out</p> <p>Water in</p> <p>Heat</p> <p>Labels (Round-bottom/pear-shaped) flask AND condenser AND water in at bottom and out at top AND heat (source) ✓</p>	2	<p>DO NOT ALLOW conical flask, volumetric flask, beaker in place of round bottom/pear shaped flask</p> <p>DO NOT ALLOW distillation</p> <p>DO NOT ALLOW stopper/bung on top of condenser</p> <p>IGNORE a thermometer in condenser</p> <p>IGNORE a small gap between flask and condenser</p> <p>ALLOW diagram of heating apparatus as an alternative to heat label</p>

Question			Answer	Marks	Guidance
	(c)	(ii)	<p>Precipitate G silver bromide/AgBr AND $M = 1.88/0.01 = 188 \text{ (g mol}^{-1}\text{)}$ $188 - 107.9 = 80.1$ (so halide is Br⁻)✓</p> <p>Alcohol F and Haloalkane E</p> <p>E and F clearly identified</p> <p>F/alcohol: butan-2-ol</p> $ \begin{array}{c} \text{H} \quad \text{OH} \\ \quad \\ \text{H}_3\text{C}-\text{C}-\text{C}-\text{CH}_3 \\ \quad \\ \text{H} \quad \text{H} \end{array} $ <p>E/haloalkane: E is haloalkane of C₄H₉X with</p> <ul style="list-style-type: none"> • same halogen as G <p>AND</p> <ul style="list-style-type: none"> • same carbon chain as F ✓ 	<p>1 mark</p> <p>2 marks</p>	<p>3</p> <p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>Note: working is required for first mark</p> <p>ALLOW use of 108 as A_r of Ag</p> <p>Note: E and F can be identified by correct name or structure BUT IGNORE incorrect names</p>
			Total	10	

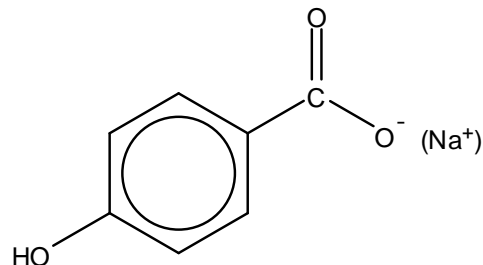
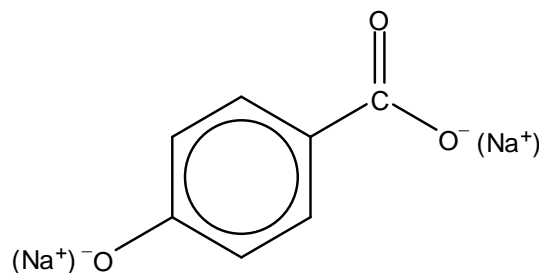
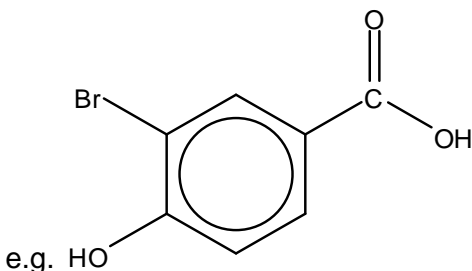
Question			Answer	Marks	Guidance
20	(a)		<p>priority groups/atoms are on different/opposite sides ✓</p> <p>High(est) priority groups are C₆H₅ AND CHO OR Lowest priority groups are H and CH₃ ✓</p>	2	<p>ALLOW suitable alternatives to 'priority' e.g. groups with highest atomic number or more important groups etc.</p> <p>ALLOW high priority groups are diagonal(ly across)</p> <p>IGNORE references to relative mass of groups, A_r, M_r,</p> <p>ALLOW identification by name e.g aldehyde for CHO phenyl/benzene group for C₆H₅ alkyl for CH₃</p> <p>ALLOW response in terms that O has higher priority than H in context of –CH₃ and –CHO</p> <p>IF 'priority' is not mentioned ALLOW 1 mark for 'C₆H₅ and CHO are on different sides' OR H and CH₃ are on different sides</p>
	(b)	(i)	<p>Bromine/ Br₂ AND goes colourless/decolourised ✓</p>	1	<p>Note: both reagent and observation are required</p> <p>ALLOW bromine water/ Br₂(aq)</p>
		(ii)	<p>Tollens' (reagent) AND Silver (mirror/precipitate/ppt/solid) ✓</p>	1	<p>Note: both reagent and observation are required for the mark.</p> <p>ALLOW ammoniacal silver nitrate OR Ag⁺/NH₃</p> <p>ALLOW black ppt OR grey ppt</p>

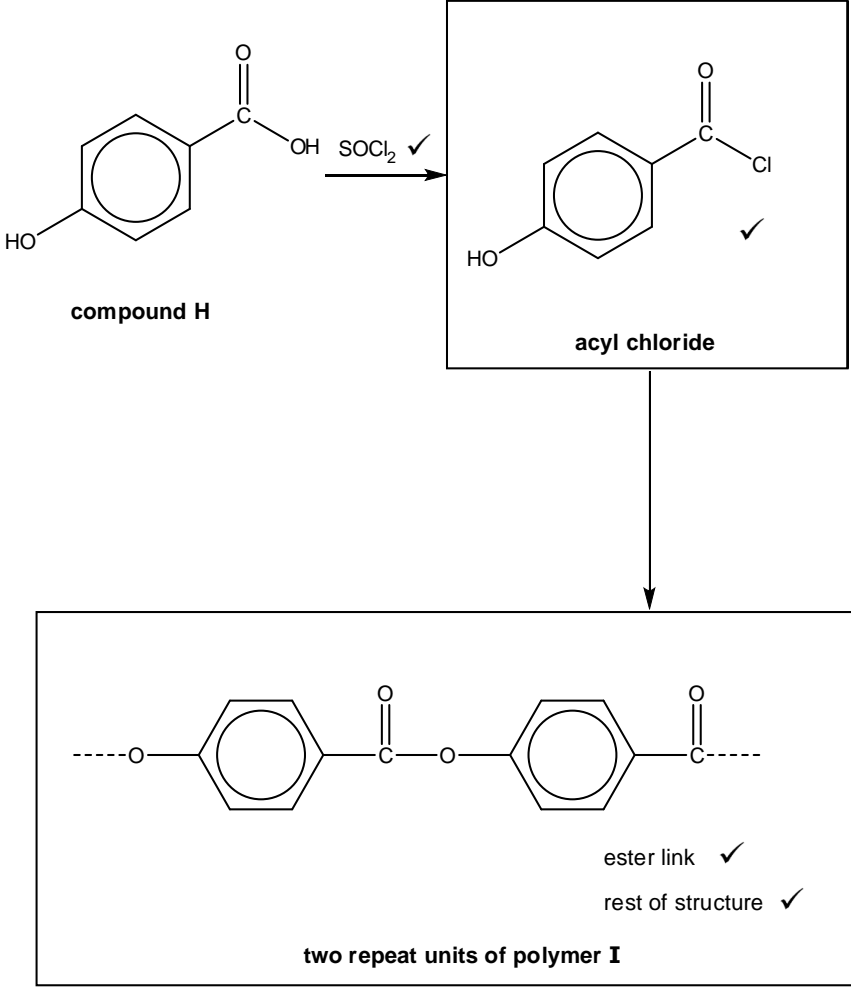

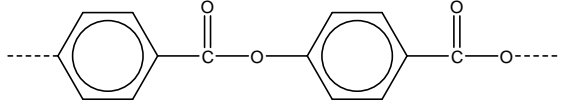
Question			Answer	Marks	Guidance
		(iii)	<p>(Add) 2,4-dinitrophenylhydrazine AND orange/yellow/red precipitate ✓</p> <p>Take melting point (of crystals) ✓</p> <p>Compare to known values/database ✓</p>	3	<p>ALLOW errors in spelling ALLOW 2,4(-)DNP OR 2,4(-)DNPH ALLOW Brady's reagent or Brady's Test ALLOW solid OR crystals OR ppt as alternatives for precipitate</p> <p>Mark second and third points independently of response for first marking point</p> <p>DO NOT ALLOW 2nd and 3rd marks for taking and comparing boiling points OR chromatograms</p>

Question	Answer	Marks	Guidance
(c)	<p>Marks for each correct structure/reagent shown below</p> <div style="display: flex; flex-direction: column; align-items: center;"> <div style="display: flex; align-items: center; margin-bottom: 20px;"> <div style="text-align: center;">  <p>cinnamaldehyde</p> </div> <div style="margin: 0 10px;"> $\xrightarrow{\text{NaCN/H}^+ \checkmark}$ </div> <div style="text-align: center;">  </div> </div> <div style="display: flex; justify-content: space-around; width: 100%;"> <div style="text-align: center;"> $\downarrow \text{NaBH}_4$ <div style="border: 1px solid black; padding: 10px; margin-top: 10px;">  <p style="text-align: right;">\checkmark</p> </div> </div> <div style="text-align: center;"> $\downarrow \text{H}^+(\text{aq})$ <div style="border: 1px solid black; padding: 10px; margin-top: 10px;">  <p style="text-align: right;">\checkmark</p> </div> </div> </div> <div style="display: flex; flex-direction: column; align-items: center; margin-top: 20px;"> <div style="text-align: center;">  <p>reduction of nitrile to form amine \checkmark hydrogenation of C=C \checkmark</p> </div> <div style="margin-top: 10px;"> $\uparrow \text{excess H}_2/\text{Ni}$ </div> </div> </div>	5	<p>ANNOTATE WITH TICKS AND CROSSES</p> <p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>For reaction with excess H_2/Ni IGNORE hydrogenation of benzene ring i.e. the following structure scores two marks</p> <div style="text-align: center; margin: 20px 0;">  </div> <p>ALLOW KCN/H^+ ALLOW HCN ALLOW H_2SO_4 or HNO_3 or HCl for H^+</p>

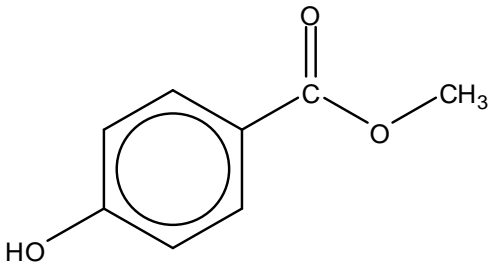
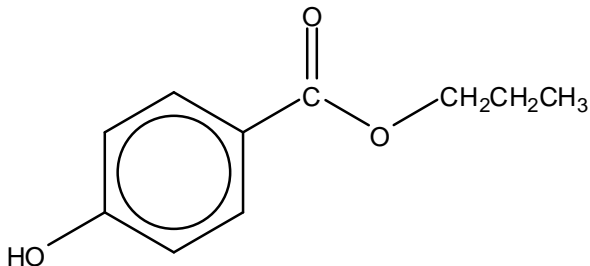
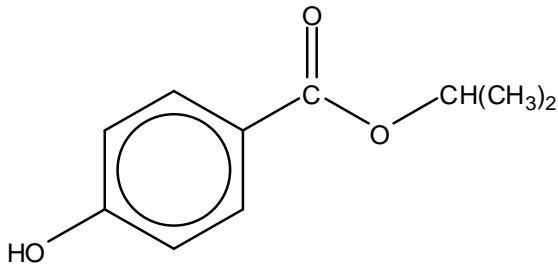
Question	Answer	Marks	Guidance
(d)*	<p><i>Please refer to marking instructions on page 5 of mark scheme for guidance on how to mark this question.</i></p> <p>Level 3 (5–6 marks) An outline of the mechanism for the formation of either product which is mostly correct. AND Major and minor products identified with a correct explanation of which product is most/least likely to be formed.</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i></p> <p>Level 2 (3–4 marks) An outline of the mechanism for the formation of either product but with a few omissions/errors. AND Identifies major/minor product correctly OR Explanation of which product is most/least likely to be formed.</p> <p><i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i></p> <p>Level 1 (1–2 marks) A basic outline of the mechanism for the formation of either product is attempted. OR Basic explanation of which of the products is most/least likely to be formed.</p> <p><i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i></p>	6	<p>Please check all of page 23 which is included with this response. If this page is blank please annotate with SEEN</p> <p>Throughout: ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above if unambiguous</p> <p>Indicative scientific points:</p> <p><u>Mechanism for formation of either product.</u></p> <ul style="list-style-type: none"> • Curly arrow from C=C to attack the I atom of the I-Cl • Correct dipole on I-Cl • Curly arrow from I-Cl bond to Cl • Carbocation with full positive charge on carbon atom • Curly arrow from negative charge on Cl⁻ or lone pair on Cl⁻ to carbon atom with positive charge <div style="text-align: center;">  <p>OR</p>  </div>

Question			Answer	Marks	Guidance
			0 marks <i>No response or no response worthy of credit.</i>		<p>Organic products</p> <ul style="list-style-type: none"> Major/most likely product <div style="text-align: center;"> $\begin{array}{c} \text{H} \quad \text{CHO} \\ \quad \\ \text{C}_6\text{H}_5 - \text{C} - \text{C} - \text{CH}_3 \\ \quad \\ \text{I} \quad \text{Cl} \end{array}$ </div> Minor/least likely product <div style="text-align: center;"> $\begin{array}{c} \text{H} \quad \text{CHO} \\ \quad \\ \text{C}_6\text{H}_5 - \text{C} - \text{C} - \text{CH}_3 \\ \quad \\ \text{Cl} \quad \text{I} \end{array}$ </div> Major/most likely product is formed from the most stable carbocation intermediate OR – Cl is attached to carbon atom with the least hydrogens attached OR the carbon with the most –C atoms attached OR the – I is attached to the carbon atom with most hydrogens attached
			Total	18	

Question		Answer	Marks	Guidance
21	(a)	<p data-bbox="371 266 672 292">Product from Na₂CO₃</p> <div data-bbox="371 316 896 582">  <p data-bbox="862 558 896 582">✓</p> </div> <hr data-bbox="371 614 1232 617"/> <p data-bbox="371 667 705 692">Product from NaOH(aq)</p> <div data-bbox="371 732 929 1005">  <p data-bbox="907 981 929 1005">✓</p> </div> <hr data-bbox="371 1029 1232 1032"/> <p data-bbox="371 1082 616 1107">Product from Br₂</p> <div data-bbox="371 1117 884 1388">  <p data-bbox="371 1356 481 1388">e.g. HO ✓</p> </div>	3	<p data-bbox="1458 233 2051 328">ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p data-bbox="1458 368 2051 464">ALLOW -COO⁻ OR -COONa DO NOT ALLOW negative charge on C atom DO NOT ALLOW -COO-Na (covalent bond)</p> <p data-bbox="1458 504 2051 568">IGNORE connectivity of phenol OH group <i>(marks are for correct conversions)</i></p> <p data-bbox="1458 671 2051 735">ALLOW 1 mark if top two structures are shown in wrong boxes</p> <p data-bbox="1458 1046 2051 1110">ALLOW substitution of any H from benzene ring</p> <p data-bbox="1458 1150 2051 1214">ALLOW multiple substitution, <i>i.e.</i> di-, tri- and tetrabromo products.</p> <p data-bbox="1458 1254 2051 1318">IGNORE connectivity of phenol OH group <i>(marks are for correct conversions)</i></p>

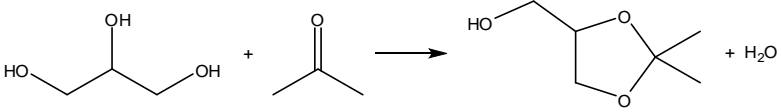
Question	Answer	Marks	Guidance
(b)	<p data-bbox="376 229 1167 256">One mark for each correct structure/reagent as shown below</p> <div data-bbox="376 300 1223 1294">  <p data-bbox="443 600 584 624">compound H</p> <p data-bbox="947 632 1088 655">acyl chloride</p> <p data-bbox="674 1246 994 1270">two repeat units of polymer I</p> <p data-bbox="976 1150 1122 1174">ester link ✓</p> <p data-bbox="976 1190 1178 1214">rest of structure ✓</p> </div>	4	<p data-bbox="1458 229 2051 328">ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p data-bbox="1458 360 1984 464">ALLOW PCl_5 OR PCl_3 for reagent mark. IGNORE references to temperature for reagent mark IGNORE additional reagents shown with $\text{SOCl}_2/\text{PCl}_5/\text{PCl}_3$ e.g. H_2O, AlCl_3, HCl etc.</p> <p data-bbox="1458 568 2051 667">IGNORE names (<i>question asks for structures of organic compounds and formula of reagent</i>)</p> <p data-bbox="1458 735 2051 834">DO NOT ALLOW more than two repeat units ALLOW 1 mark for one correct repeat unit e.g.</p> <div data-bbox="1458 842 1771 943">  </div> <p data-bbox="1458 951 2051 1010">'End bonds' MUST be shown (do not have to be dotted)</p> <p data-bbox="1458 1046 1839 1114">ALLOW the 'O' at either end i.e.</p> <div data-bbox="1458 1121 2018 1222">  </div> <p data-bbox="1458 1225 1693 1289">IGNORE brackets IGNORE n</p>

Question	Answer	Marks	Guidance
(c) (i)	<p>FIRST CHECK ANSWER ON ANSWER LINE IF answer = 7.5×10^{-4} award 2 marks</p> <hr/> <p>[K] in mol dm⁻³ $\frac{9.13 \times 10^{-2}}{166} = 5.50 \times 10^{-4} \text{ (mol dm}^{-3}\text{) } \checkmark$</p> <p>[L] from peak areas $5.50 \times 10^{-4} \times \frac{5.9}{4.3} \text{ OR } 5.50 \times 10^{-4} \times 1.37 \dots$ $= 7.5 \times 10^{-4} \text{ (mol dm}^{-3}\text{) } \checkmark$</p> <p>2 SF Required</p>	2	<p>If there is an alternative answer, Apply ECF</p> <p>Alternative method</p> <p>[K] in g dm⁻³ with peak area of 5.9 $9.13 \times 10^{-2} \times \frac{5.9}{4.3} \text{ OR } 9.13 \times 10^{-2} \times 1.37$ $= 0.125 \text{ OR } 0.13 \text{ (g dm}^{-3}\text{) } \checkmark$ Calculator: 0.125272093</p> <p>[L] in mol dm⁻³ $\frac{0.125}{166} = 7.5 \times 10^{-4}$</p> <p>OR $\frac{0.13}{166} = 7.8 \times 10^{-4} \text{ (mol dm}^{-3}\text{) } \checkmark$</p> <hr/> <p>Common errors: Award 1 mark for:</p> <ul style="list-style-type: none"> • 0.099 (from $\frac{9.13 \times 10^{-2}}{166} \times 180$) • 6.9×10^{-4} (from $\frac{0.125}{180}$) • 7.2×10^{-4} (from $\frac{0.13}{180}$) • 7.0×10^{-4} (from $\frac{0.25272093}{180}$)

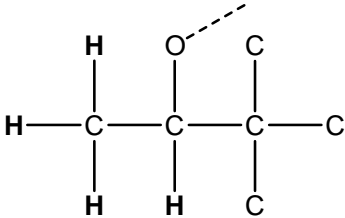
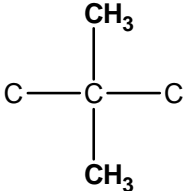
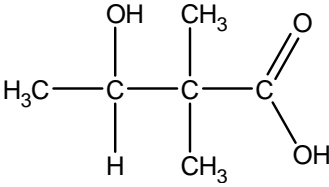
Question			Answer	Marks	Guidance
		(ii)	<p>ester J</p>  <p>esters L and M</p>  	3	<p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>L and M can be identified either way round</p> <p>IGNORE 'C₃H₇' in L and/or M as ambiguous (<i>question requires structures</i>)</p> <p>IGNORE connectivity of phenol OH group (<i>marks are for structures of alkyl groups</i>)</p>
			Total	12	

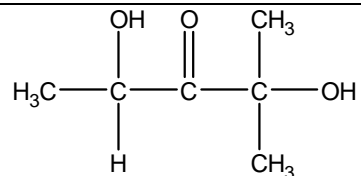
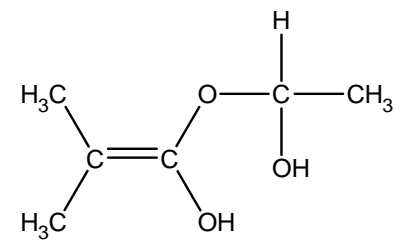
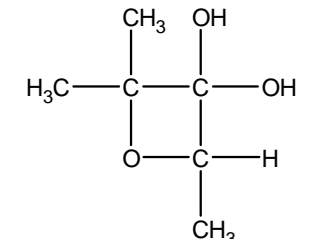
Question		Answer	Marks	Guidance
22	(a)	$\text{C}_7\text{H}_{16} + 7\frac{1}{2}\text{O}_2 \rightarrow 7\text{CO} + 8\text{H}_2\text{O}$ OR $\text{C}_7\text{H}_{16} + 4\text{O}_2 \rightarrow 7\text{C} + 8\text{H}_2\text{O} \checkmark$	1	ALLOW multiples IGNORE state symbols ALLOW equations for incomplete combustion that give CO and/or C with CO ₂ e.g $\text{C}_7\text{H}_{16} + 9\text{O}_2 \rightarrow 4\text{CO} + 3\text{CO}_2 + 8\text{H}_2\text{O}$ $\text{C}_7\text{H}_{16} + 6\text{O}_2 \rightarrow 4\text{CO} + 3\text{C} + 8\text{H}_2\text{O}$
	(b)	<p>Heptane compared to hexane heptane (has a longer chain so) has more points of contact / more surface interaction (between molecules) \checkmark</p> <p>heptane has stronger/more induced dipole(–dipole) interactions \checkmark</p> <p>Pentan-1-ol compared to heptane and/or hexane pentan-1-ol has hydrogen bonds that are strong(er than induced dipole–dipole interactions) OR (alcohols have) hydrogen bonds and induced dipole(–dipole) interactions/London forces \checkmark</p> <p>Energy required to break forces More energy is required to break induced dipole(–dipole) interactions in heptane than hexane OR More energy is required to break hydrogen bonds \checkmark</p>	4	ANNOTATE WITH TICKS AND CROSSES ALLOW ORA throughout ALLOW heptane has more electrons IGNORE IDID ALLOW stronger/more London forces IGNORE van der Waals' forces/VDW for induced dipole–dipole interactions (<i>ambiguous as this term refers to both permanent dipole–dipole interactions and induced dipole–dipole interactions</i>) IGNORE 'pentan-1-ol can form hydrogen bonds with water' ALLOW 'more energy to break intermolecular forces' if intermolecular forces are not stated. IGNORE it is harder to break the intermolecular forces (<i>no reference to energy</i>) IGNORE more energy needed to separate molecules IGNORE more energy is needed to break bonds

Question	Answer	Marks	Guidance
(c) (i)	<p>$n(\text{CO}_2) = 2.97/44 = 0.0675 \text{ (mol)} \checkmark$</p> <p>$n(\text{H}_2\text{O}) = 1.62/18 = 0.0900 \text{ (mol)} \checkmark$</p> <p>Ratio of C : H 3 : 8 \checkmark</p> <p>Molecular formula $\text{C}_3\text{H}_8\text{O}_2 \checkmark$</p> <p>Structure any correct structure of $\text{C}_3\text{H}_8\text{O}_2 \checkmark$</p> <p>e.g.</p> <pre> H H H HO — C — C — C — OH H H H </pre> <p>OR</p> <pre> H H H H — C — O — C — O — C — H H H H </pre> <p>etc</p>	5	<p>Consult your team leader if an alternative creditworthy approach is seen</p> <p>IGNORE ratio of CO_2 to H_2O is 3:4 ALLOW this mark from the correct molecular formula OR a correct structure if not shown in working</p> <p>DO NOT ALLOW an incorrect molecular formula</p> <p>Mark independently from molecular formula but structure MUST contain 3C, 8H and 2O</p> <p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>ALLOW any vertical bond to the OH group e.g. ALLOW</p> <pre> OH HO </pre> <p>DO NOT ALLOW OH—</p>

Question			Answer	Marks	Guidance
	(c)	(ii)	 <p>Carbonyl compound identified as propanone ✓</p> <p>Rest of equation ✓</p>	2	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous

Question	Answer	Marks	Guidance
(d)*	<p><i>Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.</i></p> <p>Level 3 (5–6 marks) Compound is a structure of C₆H₁₂O₃ that is consistent with splitting pattern and chemical shifts in NMR spectrum. AND Comprehensive reasoning with most of the data analysed.</p> <p><i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i></p> <p>Level 2 (3–4 marks) Compound has a feasible chemical structure that is consistent with the splitting pattern in NMR spectrum but may have incorrect molecular formula. AND Reasoning provided with some of the data analysed.</p> <p><i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i></p> <p>Level 1 (1–2 marks) Correct determination of empirical formula and/or molecular formula. OR Analyses most of the NMR data. OR Attempts to determine empirical and/or molecular formula AND analyses some of the NMR data.</p> <p><i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i></p>	6	<p>Indicative scientific points:</p> <p><u>Empirical and Molecular Formula</u></p> <ul style="list-style-type: none"> $\begin{array}{ccccccc} \text{C} : \text{H} : \text{O} & = & 54.54/12 & : & 9.10/1 & : & 36.36/16 \\ & & 4.545 & : & 9.10 & : & 2.273 \\ & & 2 & : & 4 & : & 1 \end{array}$ Empirical formula = C₂H₄O uses $m/z = 132.0$ to determine molecular formula as C₆H₁₂O₃ <p><u>¹H NMR analysis</u></p> <p>Spectrum:</p> <ul style="list-style-type: none"> $\delta = 4.0$ ppm, quartet, 1H, CH₃–CH–O $\delta = 1.3$ ppm, singlet, 6H, (CH₃)₂–C $\delta = 1.2$ ppm, doublet, 3H, CH₃–CH– <p>Without D₂O:</p> <ul style="list-style-type: none"> Peak at 11.0 ppm COOH or OH peak at 3.6 ppm OH <p>Note: Data Sheet shows O–H chemical shift can occur around 11.0 ppm</p> <p><u>Structure</u></p> <p>ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous</p> <p>Contains</p>

Question	Answer	Marks	Guidance
	<p>0 marks No response or no response worthy of credit.</p>		<ul style="list-style-type: none"> region that gives doublet and quartet e.g.  region that gives singlet e.g.  <p>Examples of structures consistent with splitting and chemical shift in NMR</p> 

Question			Answer	Marks	Guidance
					   <p>Note: there may be other possible structures that are consistent with the splitting pattern and chemical shifts in NMR – if an alternative structure is seen, please contact your team leader</p>
			Total	18	

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