OCR
Oxford Cambridge and RSA

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.

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:

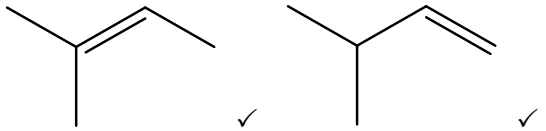
- the specification, especially the assessment objectives
- the question paper
- the mark scheme.

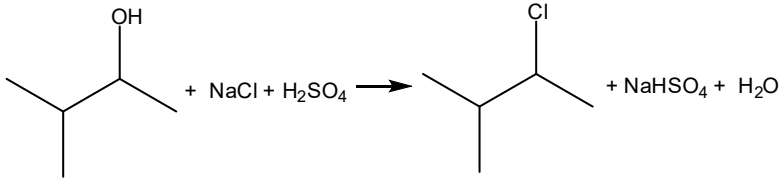
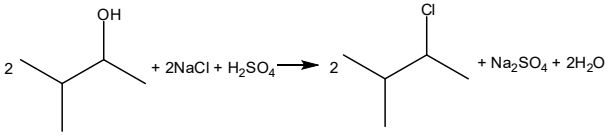
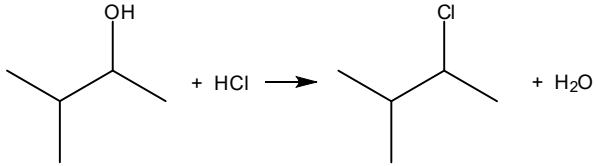
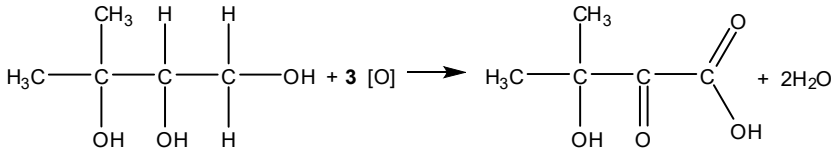
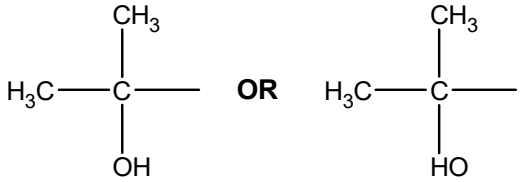
You should ensure that you have copies of these materials.

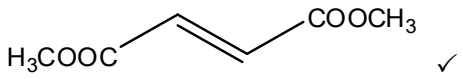
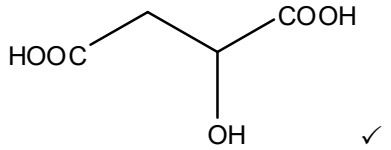
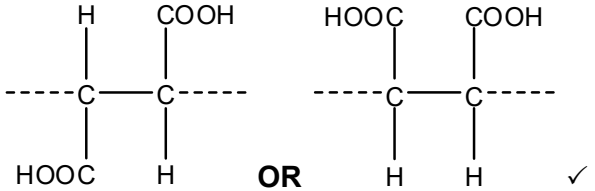
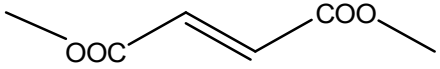
You should ensure also that you are familiar with the administrative procedures related to the marking process. These are set out in the OCR booklet **Instructions for Examiners**. If you are examining for the first time, please read carefully **Appendix 5 Introduction to Script Marking: Notes for New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

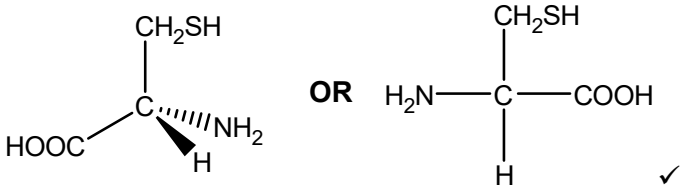
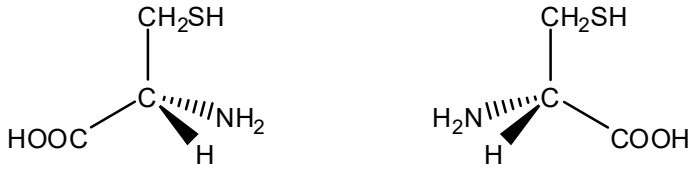
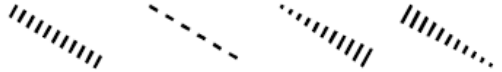
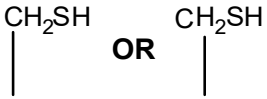
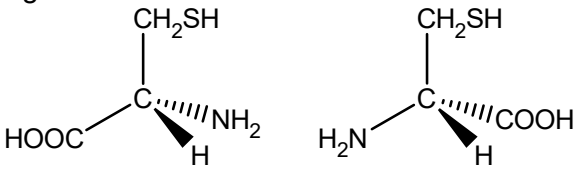
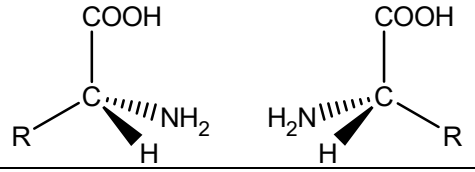
Please ask for help or guidance whenever you need it. Your first point of contact is your Team Leader.

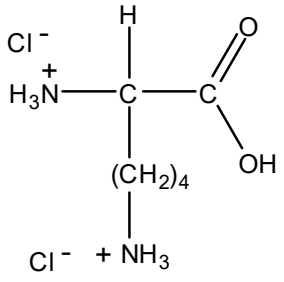
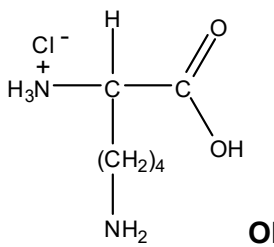
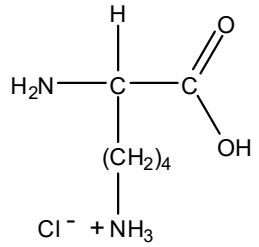
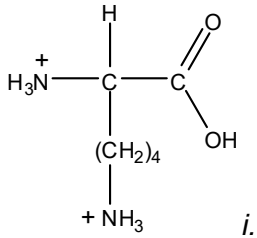
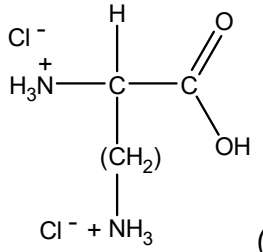
Question	Answer	Marks	Guidance
1	A	1	
2	C	1	
3	B	1	
4	C	1	
5	B	1	
6	B	1	**ALLOW** 4 (This is the number of peaks in the NMR spectrum)
7	C	1	
8	D	1	
9	B	1	
10	C	1	
11	B	1	**ALLOW** 2 (This is the number of straight chain isomers with a chiral C atom)
12	C	1	
13	A	1	
14	B	1	
15	B	1	
	Total	**15**	

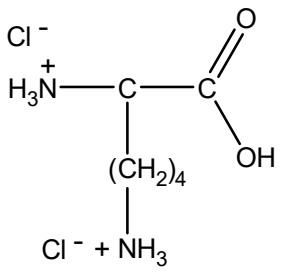
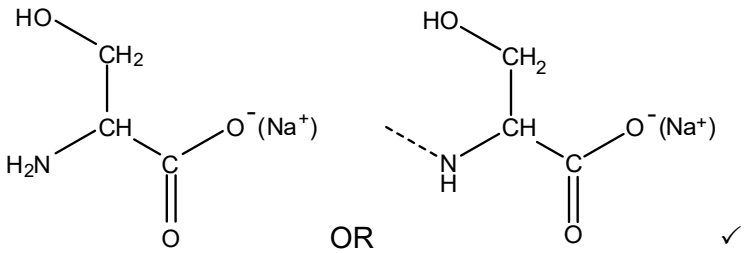
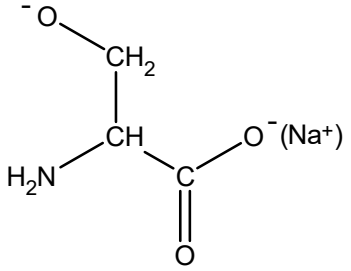
Question			Answer	Marks	Guidance
16	(a)	(i)	3-methylbutan-2-ol ✓	1	**IGNORE** lack of hyphens or addition of commas **ALLOW** 3-methylbutane-2-ol **DO NOT ALLOW** 2-methylbutan-3-ol **OR** 3-methylbut-2-ol **OR** 3-methbutan-2-ol **OR** 3-methybutan-2-ol **OR** 3-methlybutan-2-ol
		(ii)	$(CH_3)_2CHCHOHCH_3$ ✓	1	**ALLOW** brackets around OH e.g. $(CH_3)_2CHCH(OH)CH_3$ **ALLOW** any unambiguous structural formula e.g. $CH_3CH(CH_3)CHOHCH_3$ $CH_3CH(CH_3)CH(CH_3)OH$
		(iii)	One mark for each correct structure.  ✓ ✓	2	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** in either order

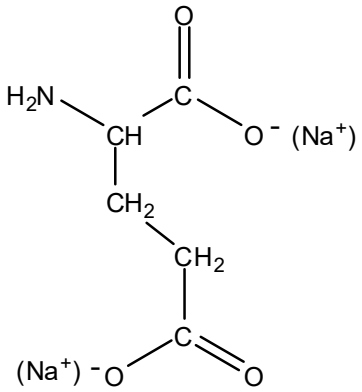
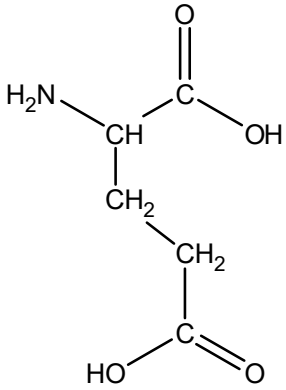
Question			Answer	Marks	Guidance
		(iv)	 Correct haloalkane ✓ Correct balanced equation ✓	2	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** H^+ for H_2SO_4 **ALLOW** equations forming Na_2SO_4  **ALLOW** equations with HCl  **DO NOT ALLOW** equations that form NaOH
	(b)		 Correct organic product ✓ Rest of equation ✓	2	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW any** vertical bond to the tertiary OH group e.g. **ALLOW** 

Question	Answer	Marks	Guidance
(c)	**Product from excess CH_3OH/H_2SO_4**  ✓ **Product from steam, H_3PO_4**  ✓ **Repeat unit of polymer C**  ✓	3	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous e.g  **IGNORE** connectivity in each product **ALLOW** the *E* or *Z* isomer as product from excess CH_3OH/H_2SO_4 'End bonds' **MUST** be shown (do not have to be dotted) **IGNORE** brackets **IGNORE** *n* **ALLOW** more than one repeat unit but has to be a whole number of repeat units
	Total	**11**	

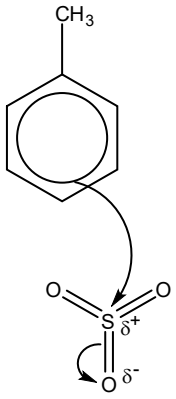
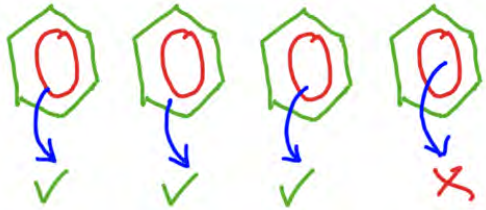
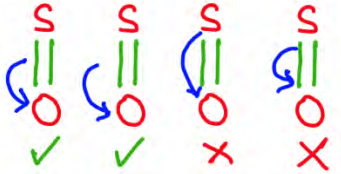
Question			Answer	Marks	Guidance
17	(a)		Correct groups attached to chiral C of cysteine seen **once** e.g.  ✓ Two **3D structures** of cysteine that are mirror images with correct connectivity in both ✓  	**2**	Each structure must have four central bonds with **at least two wedges.** For bond into paper accept:  **ALLOW** bond to any part of the CH_2 of the CH_2SH group e.g. **ALLOW**  **ALLOW** two 3D structures with 2 groups swapped e.g.  **IF** CH_2SH is shown as 'R' **ALLOW** 1 mark for two 3D structures with correct connectivity that are mirror images e.g. 

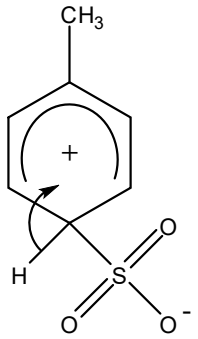
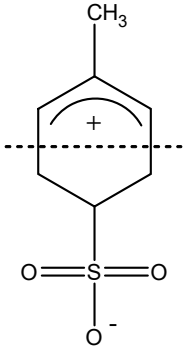
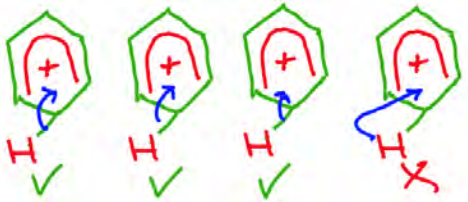
Question	Answer	Marks	Guidance
(b)	Correct salt of lysine with both amine groups protonated  ✓ ✓	2	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **Note:** $C\ell^-$ is **required** *(question asks for salt)* **ALLOW** $NH_3C\ell$ *i.e* charges **not** required **ALLOW** 1 mark for  **OR**  **OR**  *i.e. no* $C\ell^-$ **IF** there is a small slip in the structure **ALLOW 1 mark** for diammonium salt e.g  *(incorrect number of CH_2 in R group)*

Question	Answer	Marks	Guidance
			OR  *(H missing from α C atom)*
(c)	 OR ✓	**3**	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** NH_3 *(question asks for organic products)* **ALLOW** $–COO^-$ **OR** –COONa **DO NOT ALLOW** negative charge on C atom **DO NOT ALLOW** –COO–Na (covalent bond) **BUT ALLOW ECF** if seen in subsequent structures **DO NOT ALLOW** COOH in this structure **DO NOT ALLOW (**sodium) salt of alcohol group i.e. 

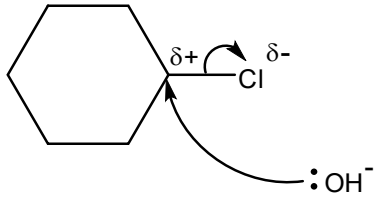
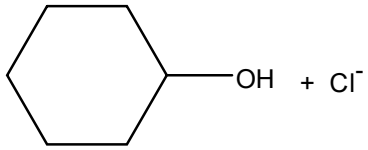
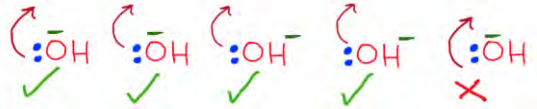
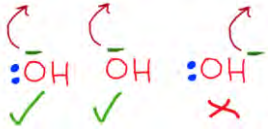
Question			Answer	Marks	Guidance
			 ✓✓ i.e. one mark for each group hydrolysed		**ALLOW** COOH groups in this structure i.e. award 2 marks for  **IGNORE** small slip in carbon chain
			Total	**7**	

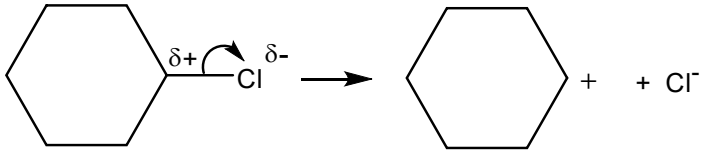
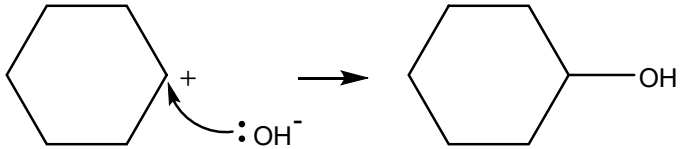
Question			Answer	Marks	Guidance
18	(a)	(i)	**Number of peaks 2 marks** 2-nitrophenol **AND** 3-nitrophenol have **six** peaks/environments/types of carbon ✓ 4-nitrophenol has **four** peaks/environments/types of carbon ✓ **Statement 1 mark** 4-nitrophenol can be distinguished **OR** 2-nitrophenol and 3-nitrophenol cannot be distinguished ✓	3	**IGNORE** any numbers shown on structures **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 **IGNORE** chemical shifts **DO NOT ALLOW ECF** from an incorrect number of peaks/environments/types of carbon
		(ii)	(In phenol) a (lone) pair of electrons on O is(partially) delocalised/donated into the π-system / ring ✓ Electron density increases/is higher (than benzene) ✓ **ORA** (phenol) is more susceptible to electrophilic attack **OR** (phenol) attracts/accepts electrophile/HNO_3 more **OR** (phenol) polarises electrophile/HNO_3 more ✓ **ORA**	3	**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 **IGNORE** charge density **IGNORE** electronegativity **IGNORE** phenol reacts more readily *(no reference to electrophile)* **ALLOW** NO_2^+ for electrophile

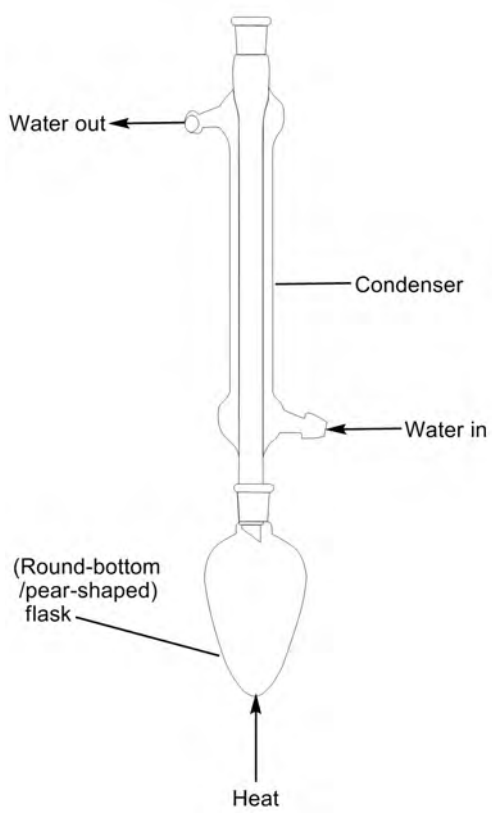
Question	Answer	Marks	Guidance
(b)	Curly arrow from π-bond to S in SO_3 **AND** curly arrow from the S=O bond to O atom ✓  	3	**ANNOTATE WITH TICKS AND CROSSES** **NOTE**: curly arrows can be straight, snake-like, etc. but **NOT** double headed or half headed arrows **1st curly arrow** must • go to the S of SO_3 **AND** • start from, **OR** close to **circle of benzene ring**  **2nd curly arrow** must start from, **OR** be traced back to, **any part of** S=O bond and go to O  **ALLOW 2nd** curly arrow from S=O to any O in SO_3 Intermediate must have correct SO_3^- structure fully displayed

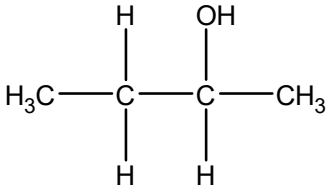
Question			Answer	Marks	Guidance
			Correct intermediate ✓ Curly arrow from C-H bond to reform π-ring ✓ 		**DO NOT ALLOW** the following intermediate:  π-ring must cover more than half of the benzene ring structure **AND** the correct orientation, *i.e.* gap towards C with SO_3^- **ALLOW** + sign anywhere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

Question			Answer	Marks	Guidance
19	(a)		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	2	**Each marking point must be a comparison** **IGNORE** references to halogens as elements: *i.e.* chlorine is less reactive than bromine etc.
			Correct comparison of rate of reaction for at least **two** C–Hal bonds e.g. C–F bond is hydrolysed slow**est** C–I bond is hydrolysed faster than C–Br C–Br has shorter reaction time than C–Cl **OR** Correct comparison of C–Hal bond strength/enthalpy of at least **two** of C–Hal bonds e.g. C–I bond is the weak**est** 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) ✓		**DO NOT ALLOW** chloride, bromide and iodide **IGNORE** references to bond length, polarity and electronegativity

Question	Answer	Marks	Guidance
(b)	Curly arrow from HO^- to carbon atom of C−Cl bond ✓ Dipole shown on C–Cl bond, $C^{\delta+}$ and $Cl^{\delta-}$ **AND** curly arrow from C−Cl bond to Cl atom ✓  **IGNORE** presence of Na^+ but OH^- needed i.e. Na^+OH^-can be allowed if criteria met --- Correct organic product **AND** Cl^- ✓  **IGNORE** presence of Na^+ but Cl^- needed i.e. Na^+Cl^-can be allowed **BUT** NaCl does **NOT** show Cl^-	3	**ANNOTATE ANSWER TICKS AND CROSSES** **NOTE**: curly arrows can be straight, snake-like, etc. but **NOT** double headed or half headed arrows **1st curly arrow** must • go to the C of C−Cl **AND** • start from, **OR** be traced back to **any point across width** of lone pair on O of OH^-  • **OR** start from – charge **on O** of ^-OH ion  *(Lone pair **NOT** needed if curly arrow shown from O^-)* **2nd curly arrow** must start from, **OR** be traced back to, **any part of** C–Cl bond and go to Cl 

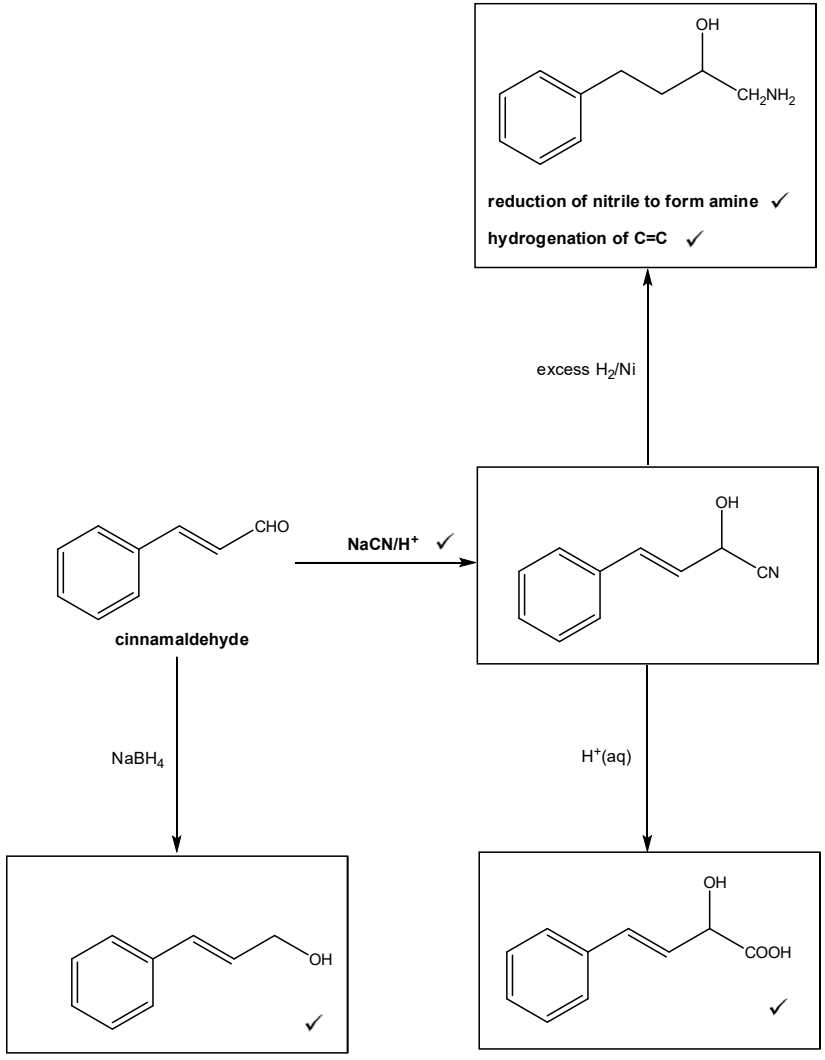
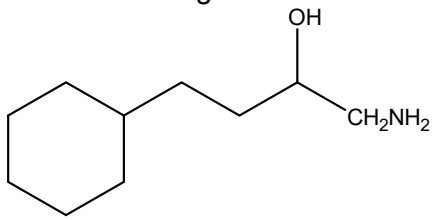
Question	Answer	Marks	Guidance
			--- **ALLOW** S_N1 mechanism **First mark** Dipole shown on C–Cl bond, $C^{\delta+}$ and $Cl^{\delta-}$, **AND** curly arrow from C−Cl bond to Cl atom ✓  **Second mark** Correct carbocation **AND** curly arrow from HO^- to carbocation  Curly arrow must come from lone 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) ✓ **Third mark** Correct organic product **AND** Cl^- ✓ ---

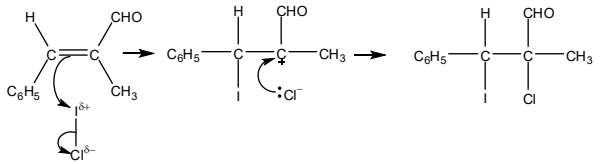
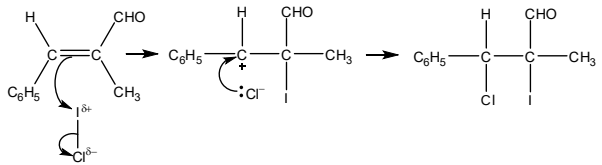
Question			Answer	Marks	Guidance
	(c)	(i)	**Diagram** Diagram showing round bottom/pear shaped flask **AND** upright condenser ✓  **Labels** (Round-bottom/pear-shaped) flask **AND** condenser **AND** water in at bottom and out at top **AND** heat (source) ✓	**2**	**DO NOT ALLOW** conical flask, volumetric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

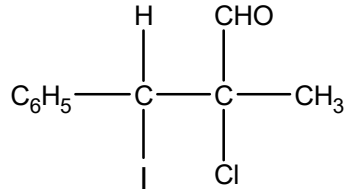
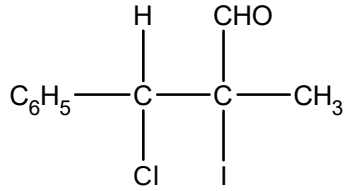
Question			Answer	Marks	Guidance
	(c)	(ii)	**Precipitate G** **1 mark** silver bromide/AgBr **AND** M = 1.88/0.01 = 188 (g mol^{-1}) 188 – 107.9 = 80.1 (so halide is Br^-)✓ **Alcohol F and Haloalkane E** **2 marks** **E** and **F** clearly identified **F/alcohol:** butan-2-ol  **E/haloalkane:** E is haloalkane of C_4H_9X with • same halogen as **G** **AND** • same carbon chain as **F** ✓	**3**	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **Note:** working is **required** for first mark **ALLOW** use of 108 as A_r of Ag **Note: E** and **F** can be identified by correct name or structure **BUT IGNORE** incorrect names
			Total	**10**	

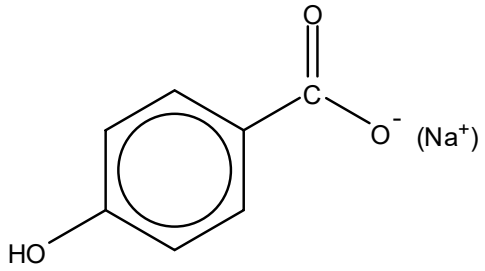
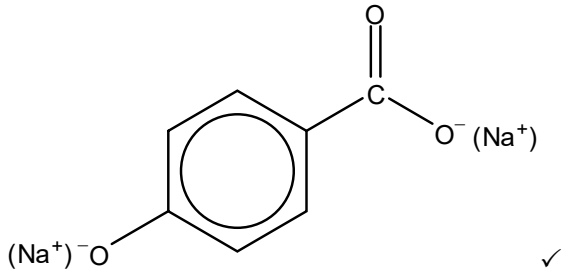
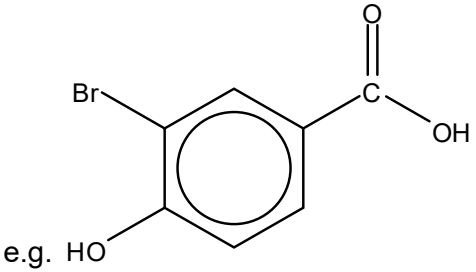
Question			Answer	Marks	Guidance
20	(a)		priority groups/atoms are on different/opposite sides ✓ High(est) priority groups are C_6H_5 **AND** CHO **OR** Lowest priority groups are H and CH_3 ✓	2	**ALLOW** suitable alternatives to 'priority' e.g. groups with highest atomic number or more important groups etc. **ALLOW** high priority groups are diagonal(ly across) **IGNORE** references to relative mass of groups, A_r, M_r, **ALLOW** identification by name e.g aldehyde for CHO phenyl/benzene group for C_6H_5 alkyl for CH_3 **ALLOW** response in terms that O has higher priority than H in context of $–CH_3$ and –CHO **IF** 'priority' is not mentioned **ALLOW** 1 mark for 'C_6H_5 and CHO are on different sides' **OR** H and CH_3 are on different sides
	(b)	(i)	Bromine/ Br_2 **AND** goes colourless/decolourised ✓	1	**Note:** both reagent and observation are required **ALLOW** bromine water/ Br_2(aq)
		(ii)	Tollens' (reagent) **AND** Silver (mirror/precipitate/ppt/solid) ✓	1	**Note:** both reagent and observation are required for the mark. **ALLOW** ammoniacal silver nitrate **OR** Ag^+/NH_3 **ALLOW** black ppt **OR** grey ppt

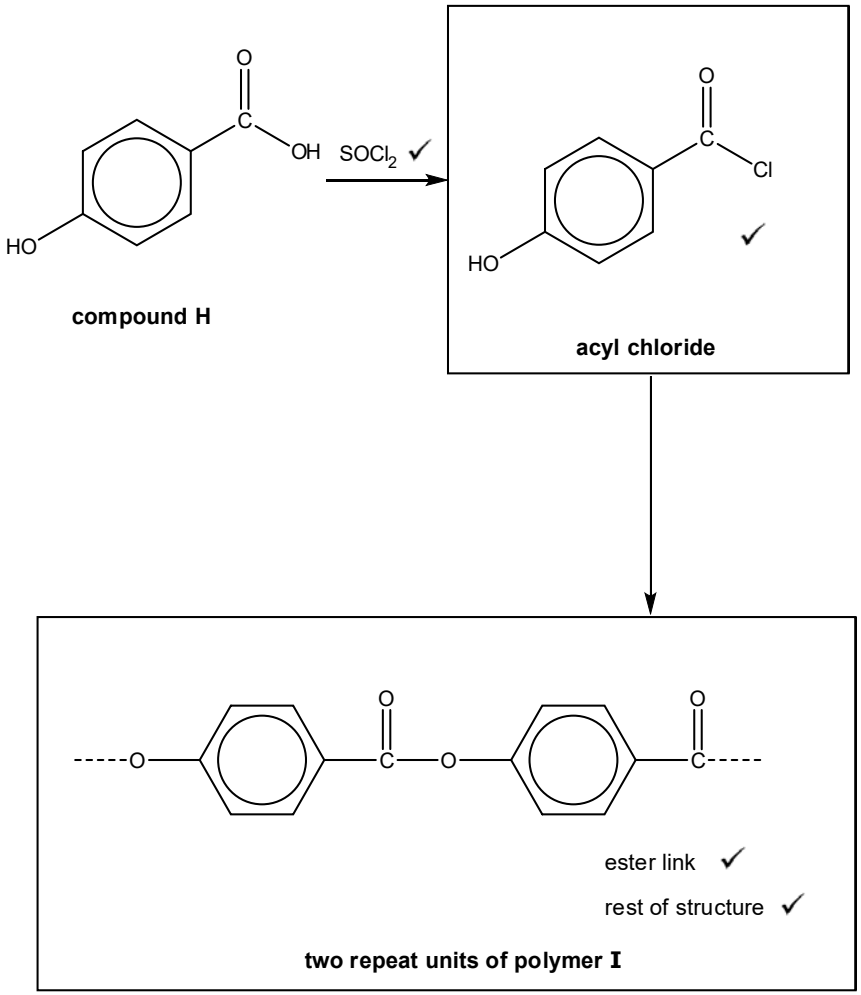
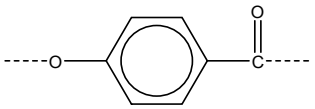
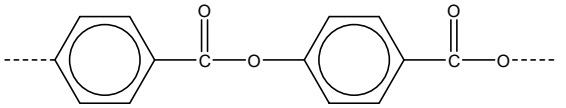
Question			Answer	Marks	Guidance
		(iii)	(Add) 2,4-dinitrophenylhydrazine **AND** orange/yellow/red precipitate✓ Take melting point (of crystals) ✓ Compare to known values/database ✓	3	**ALLOW** errors in spelling **ALLOW** 2,4(-)DNP **OR** 2,4(-)DNPH **ALLOW** Brady's reagent or Brady's Test **ALLOW**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

Question	Answer	Marks	Guidance
(c)	Marks for each correct structure/reagent shown below  	5	**ANNOTATE WITH TICKS AND CROSSES** **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous For reaction with excess H_2/Ni **IGNORE** hydrogenation of benzene ring i.e. the following structure scores two marks  **ALLOW** KCN/H^+ **ALLOW** HCN **ALLOW** H_2SO_4 or HNO_3 or HCl for H^+

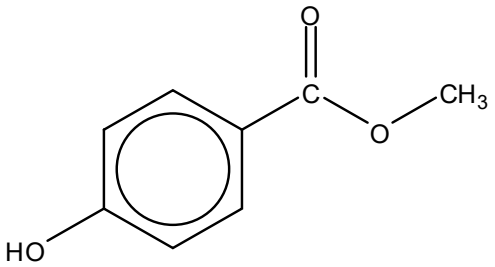
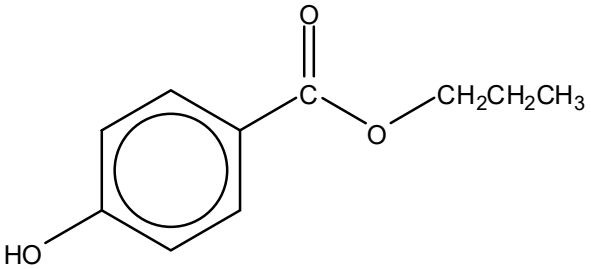
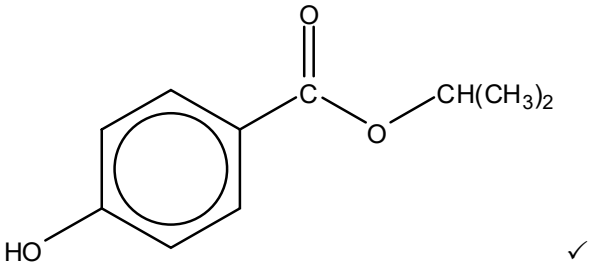
Question	Answer	Marks	Guidance
(d)*	*Please refer to marking instructions on page 5 of mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** An outline of the mechanism for the formation of either product which is mostly correct. **AND** Major and minor products identified with a correct explanation of which product is most/least likely to be formed. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **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. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **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. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.*	6	**Please check all of page 23 which is included with this response. If this page is blank please annotate with SEEN** Throughout: **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above if unambiguous **Indicative scientific points:** **<u>Mechanism for formation of either product.</u>** • 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  **OR** 

Question			Answer	Marks	Guidance
			0 marks *No response or no response worthy of credit.*		**Organic products** • Major/most likely product  • Minor/least likely product  • Major/most likely product is formed from the most stable carbocation intermediate **OR** – C*l* 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**	

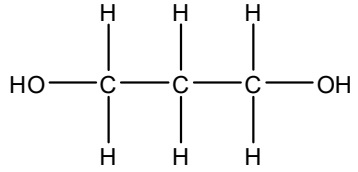
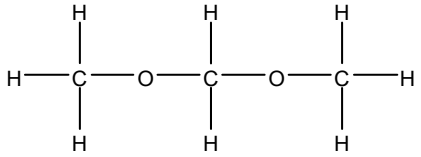
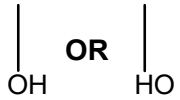
Question			Answer	Marks	Guidance
21	(a)		**Product from Na_2CO_3**  ✓ --- **Product from NaOH(aq)**  ✓ --- **Product from Br_2**  e.g. HO ✓	3	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** $–COO^-$ **OR** –COONa **DO NOT ALLOW** negative charge on C atom **DO NOT ALLOW** –COO–Na (covalent bond) **IGNORE** connectivity of phenol OH group *(marks are for correct conversions)* **ALLOW** 1 mark if top two structures are shown in wrong boxes **ALLOW** substitution of any H from benzene ring **ALLOW** multiple substitution, *i.e.* di-, tri- and tetrabromo products. **IGNORE** connectivity of phenol OH group *(marks are for correct conversions)*

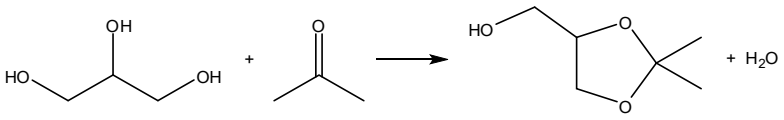
Question	Answer	Marks	Guidance
(b)	One mark for each correct structure/reagent as shown below  	4	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** PCl_5 **OR** PCl_3 for reagent mark. **IGNORE** references to temperature for reagent mark **IGNORE** additional reagents shown with $SOCl_2$/PCl_5/PCl_3 e.g. H_2O, $AlCl_3$, HCl etc. **IGNORE** names *(question asks for structures of organic compounds and formula of reagent)* **DO NOT ALLOW** more than two repeat units **ALLOW** 1 mark for one correct repeat unit e.g.  'End bonds' **MUST** be shown (do not have to be dotted) **ALLOW** the 'O' at either end i.e.  **IGNORE** brackets **IGNORE** *n*

Question			Answer	Marks	Guidance
	(c)	(i)	**FIRST CHECK ANSWER ON ANSWER LINE** **IF answer = 7.5 × 10^{-4} award 2 marks** **----------** **[K] in mol dm^{-3}** $\frac{9.13 \times 10^{-2}}{166}$ = 5.50 × 10^{-4} (mol dm^{-3}) ✓ **[L] from peak areas** 5.50 × 10^{-4} × $\frac{5.9}{4.3}$ **OR** 5.50 × 10^{-4} × 1.37….. = 7.5 × 10^{-4} (mol dm^{-3}) ✓ ***2 SF Required***	**2**	**If there is an alternative answer, Apply ECF** **Alternative method** **[K] in g dm^{-3} with peak area of 5.9** 9.13 × 10^{-2} × $\frac{5.9}{4.3}$ **OR** 9.13 × 10^{-2} × 1.37 = 0.125 **OR** 0.13 (g dm^{-3}) ✓ Calculator: 0.125272093 **[L] in mol dm^{-3}** $\frac{0.125}{166}$ = **7.5 × 10^{-4}** **OR** $\frac{0.13}{166}$ = **7.8 × 10^{-4}** (mol dm^{-3}) ✓ **----------** **Common errors:** **Award 1 mark for:** • 0.099(from $\frac{9.13 \times 10^{-2}}{166}$ × 180) • 6.9 × 10^{-4} (from $\frac{0.125}{180}$) • 7.2 × 10^{-4} (from $\frac{0.13}{180}$) • 7.0 × 10^{-4} (from $\frac{0.\ 25272093}{180}$)

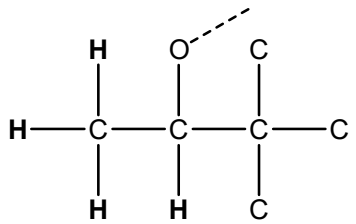
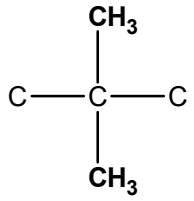
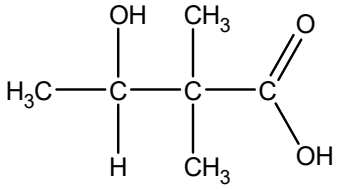
Question			Answer	Marks	Guidance
		(ii)	**ester J**  ✓ **esters L and M**  ✓  ✓	3	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **L** and **M** can be identified either way round **IGNORE** 'C_3H_7' in **L** and/or **M** as ambiguous *(question requires structures)* **IGNORE** connectivity of phenol OH group *(marks are for structures of alkyl groups)*
			Total	**12**	

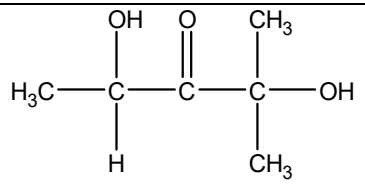
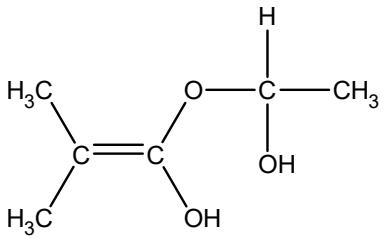
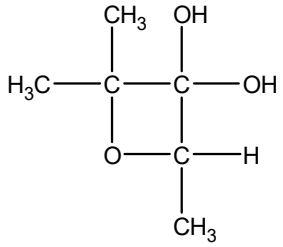
Question			Answer	Marks	Guidance
22	(a)		$C_7H_{16} + 7^1/_2O_2 \rightarrow 7CO + 8H_2O$ **OR** $C_7H_{16} + 4O_2 \rightarrow 7C + 8H_2O$ ✓	1	**ALLOW** multiples **IGNORE** state symbols **ALLOW** equations for incomplete combustion that give CO and/or C with CO_2 e.g $C_7H_{16} + 9O_2 \rightarrow 4CO + 3CO_2 + 8H_2O$ $C_7H_{16} + 6O_2 \rightarrow 4CO + 3C + 8H_2O$
	(b)		**Heptane compared to hexane** heptane (has a longer chain so) has more points of contact / more surface interaction (between molecules) ✓ heptane has stronger/more induced dipole(–dipole) interactions ✓ **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 ✓ **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 ✓	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 *(ambiguous as this term refers to both permanent dipole–dipole interactions and induced dipole–dipole interactions)* **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 *no reference to energy)* **IGNORE** more energy needed to separate molecules **IGNORE** more energy is needed to break bonds

Question	Answer	Marks	Guidance
(c) (i)		5	Consult your team leader if an alternative creditworthy approach is seen
	$n(CO_2) = 2.97/44 = 0.0675$ (mol) ✓		
	$n(H_2O) = 1.62/18 = 0.0900$ (mol)✓		**IGNORE** ratio of CO_2 to H_2O is 3:4
	Ratio of C : H 3 : 8 ✓		**ALLOW** this mark from the correct molecular formula **OR a** correct structure if not shown in working
	Molecular formula $C_3H_8O_2$✓		**DO NOT ALLOW** an incorrect molecular formula
	Structure any correct structure of $C_3H_8O_2$ ✓		Mark independently from molecular formula but structure **MUST** contain 3C, 8H and 2O
	e.g. 		**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous
	OR  etc		**ALLOW any** vertical bond to the OH group e.g. **ALLOW**  **OR** **DO NOT ALLOW** OH^-

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

Question	Answer	Marks	Guidance
(d)*	*Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Compound is a structure of $C_6H_{12}O_3$ that is consistent with **splitting** pattern and **chemical shifts** in NMR spectrum. **AND** Comprehensive reasoning with most of the data analysed. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **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. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **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. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.*	6	**Indicative scientific points:** **Empirical and Molecular Formula** • C : H : O = 54.54/12 : 9.10/1 : 36.36/16 4.545 : 9.10 : 2.273 2 : 4 : 1 • Empirical formula = C_2H_4O • uses *m/z* = 132.0 to determine molecular formula as $C_6H_{12}O_3$ **^{1}H NMR analysis** **Spectrum:** • δ = 4.0 ppm, quartet, 1H, CH_3–**CH**–O • δ = 1.3 ppm, singlet, 6H, **$(CH_3)_2$**–C • δ = 1.2 ppm, doublet, 3H, **CH_3**–CH– **Without D_2O:** • Peak at 11.0 ppm COO**H or OH** • peak at 3.6 ppm O**H** **Note:** Data Sheet shows O-H chemical shift can occur around 11.0 ppm **Structure** **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous Contains

Question	Answer	Marks	Guidance
	0 marks No response or no response worthy of credit.		• region that gives doublet and quartet e.g.  • region that gives singlet e.g.  Examples of structures consistent with splitting and chemical shift in NMR 

Question			Answer	Marks	Guidance
					   **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
			Total	**18**	

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