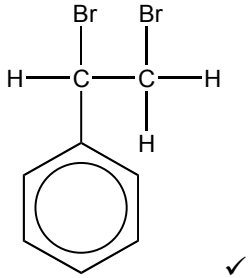
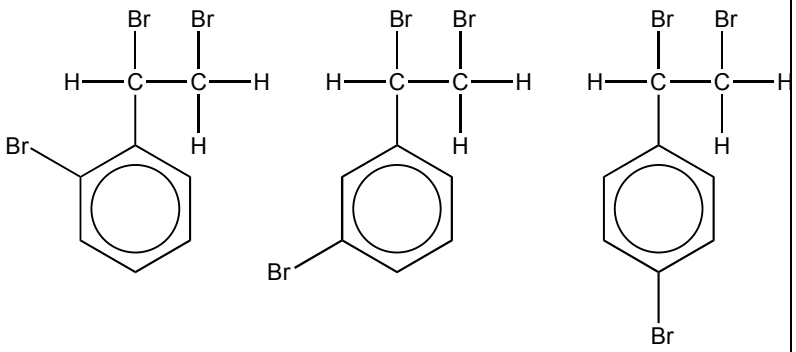
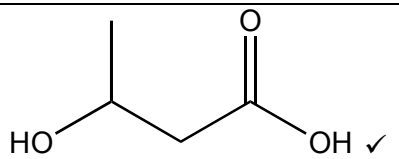
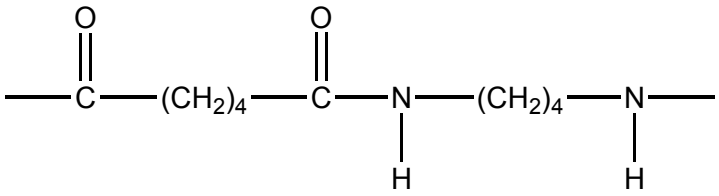
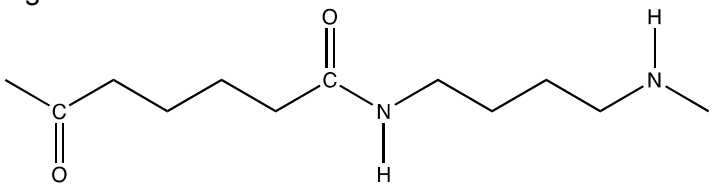
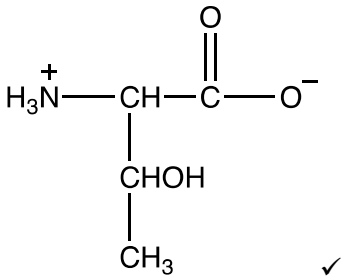
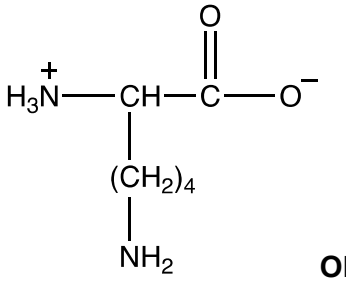
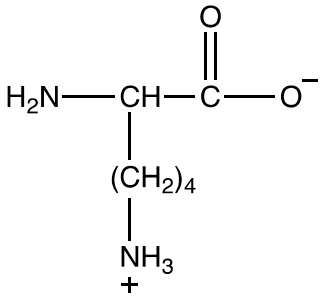
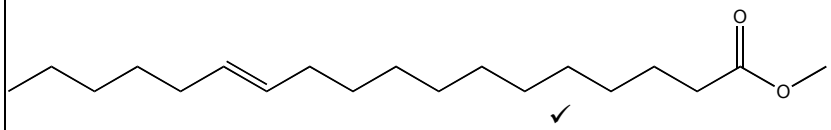
Question			Answer	Marks	Guidance
1	(a)		In benzene, electrons **OR** π-bond(s) are **delocalised** ✓ **QWC** requires delocalised/delocalized **spelled correctly** and used in correct context In alkenes, TT-electrons are **OR** TT-bond is **AND** localised **OR** between two carbons ✓ benzene has a lower electron density **OR** alkene/C=C has a higher electron density ✓ *Comparison* ***essential*** benzene polarises bromine / Br_2 **LESS** **OR** benzene attracts bromine / Br_2 **LESS** **OR** benzene induces a **weaker** dipole in bromine / Br_2 ✓	4	***ANNOTATIONS MUST BE USED*** **ALLOW** diagram with (π-bond) electrons **AND** delocalised **labelled** **IGNORE** benzene has delocalised structure or ring **ALLOW** diagram with π-bond labelled **ALLOW** pi bond for π-bond **π**-bond **OR π-**electrons ***essential*** *for this mark* **IGNORE** charge density **DO NOT ALLOW** electronegativity **ALLOW** Br–Br for Br_2 **ALLOW** electrophile for Br_2 **ALLOW** benzene does **NOT** polarise bromine / Br_2 **OR** alkene/C=C polarises Br_2 **ALLOW** benzene does **NOT** attract bromine / Br_2 **OR** alkene/C=C attracts Br_2 **ALLOW** benzene does **NOT** induce dipole in bromine / Br_2 **OR** alkene/C=C induces dipole in Br_2

Question			Answer	Marks	Guidance
1	(b)	(i)	 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **ALLOW** combination of formulae as long as unambiguous
		(ii)	6 ✓	1	**NO ECF from (i)**
		(iii)	Two of the three structures below with 1 mark for each correct structure ✓✓ 	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **ALLOW** combination of formulae as long as unambiguous Structures must clearly show position of Br on benzene ring in relation to side chain **ALLOW ECF** from **(i)** if **BOTH** Br atoms on same carbon on side chain **DO NOT ALLOW ECF** from **(i)** if **EITHER** bromine has been substituted onto the benzene ring
		(iv)	**reaction 1**: electrophilic addition ✓ **reaction 2**: electrophilic substitution ✓	2	**ALLOW** electrophile addition **ALLOW** electrophile substitution **ALLOW** other phonetic spellings for electrophilic, e.g. electrophylic, etc.
			Total	**10**	

Question			Answer	Marks	Guidance
2	(a)	(i)	photodegradable **OR** light/sunlight/UV ✓	1	**IGNORE** IR/heat **IGNORE** bacteria **DO NOT ALLOW** burn/combustion
		(ii)	 HO OH ✓	1	**DO NOT ALLOW** structure with any C shown (especially as part of C=O) **DO NOT ALLOW** OH—
	(b)	(i)	ammonia/NH_3 **AND** ethanol **OR** ethanolic ammonia ✓	1	**ALLOW** ammonia in a sealed tube **IGNORE** heat **ALLOW** dilute ethanolic ammonia /NH_3 **DO NOT ALLOW** any reference to water or hydroxide ions, e.g. **DO NOT ALLOW** dilute ethanolic NH_3(**aq**) e.g. **DO NOT ALLOW** ethanolic NH_3 + NaOH
		(ii)	**Nitrogen** electron pair/lone pair accepts a proton/H^+ ✓ *Requires position of electron pair on N* $Cl^-H_3N^+(CH_2)_4N^+H_3\,Cl^-$ **OR** $ClH_3N(CH_2)_4NH_3Cl$ ✓	2	**DO NOT ALLOW** Nitrogen/N lone pair accepts hydrogen *proton/H^+ required* **ALLOW nitrogen** donates an electron pair **IGNORE** NH_2 group donates electron pair **ALLOW** + charge (if shown) on N or H of NH_3 e.g. $Cl^-H_3N^+(CH_2)_4NH_3^+Cl^-$ **DO NOT ALLOW** just $H_3N^+(CH_2)_4NH_3^+$ i.e. **2 x** Cl^- **MUST** be included

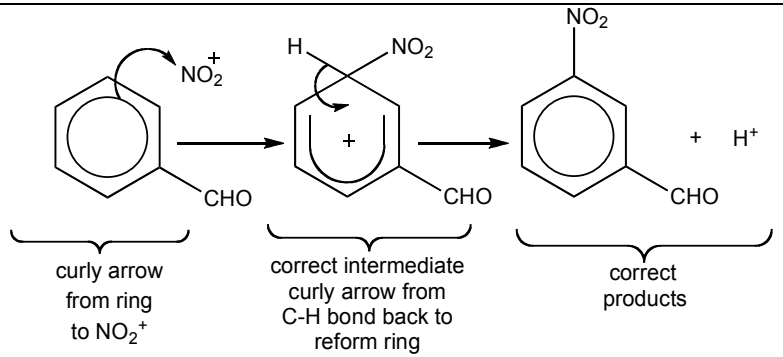
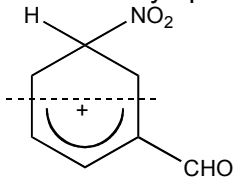
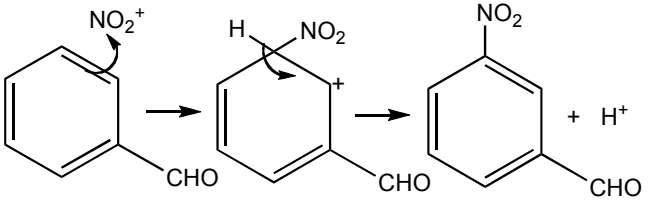
Question			Answer	Marks	Guidance
2		(iii)	1 mark for amide/peptide link correctly displayed within an attempted repeat unit ✓ 1 mark for rest of structure correct including side links ✓ 	2	Minimum requirement is each end of a displayed amide group attached to a carbon atom (could be skeletal) Brackets **not** required **IF** more than one repeat unit has been drawn a single repeat unit **MUST** be identified by brackets or clear label **DO NOT ALLOW 2nd** mark if amide/peptide link wrong *1st mark requires amide group fully displayed* *For 2nd mark, **ALLOW** –CONH– in correct structure* **ALLOW** correct structural **OR** displayed **OR** skeletal formula **ALLOW** combination of formulae as long as unambiguous e.g. 

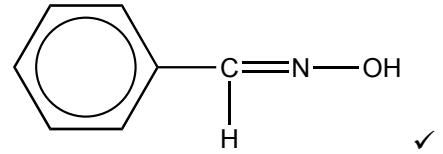
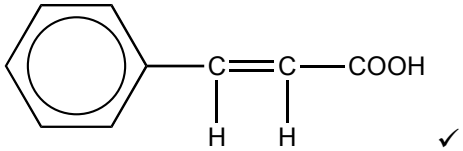
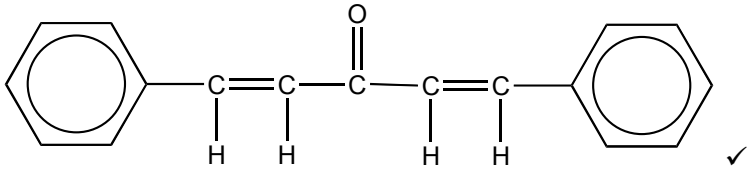
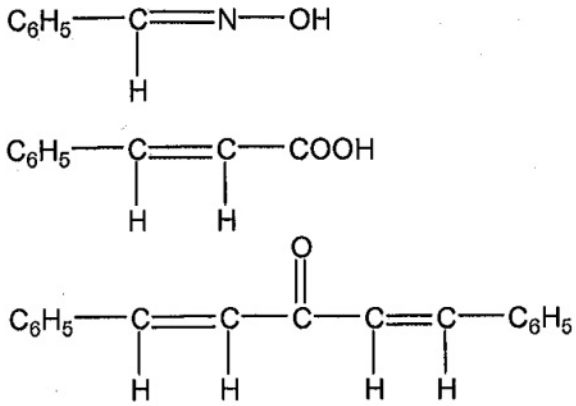
Question			Answer	Marks	Guidance
2	(c)	(i)	One mark for each correct structure  ✓  **OR**  ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **ALLOW** combination of formulae as long as unambiguous **ALLOW** COO^- '–' charge must be on O of COO^- but **ALLOW** + sign shown as $^+NH_3$ **OR** NH_3^+ **BUT** only one NH_2 can be protonated in zwitterion
		(ii)	Zwitterion at pH 9.60/higher pH has **one** NH_2 group **OR** Zwitterion **OR** amino acid at pH 9.60/higher pH has a side chain with an NH_2 group ✓ **Note:** **ASSUME** that 'it' refers to zwitterion	1	**ALLOW** amino acid at 9.60/higher pH has **two** NH_2 groups **ALLOW** amino acid at 9.60/higher pH has more NH_2 groups **ALLOW** amine **OR** amino for NH_2 **IGNORE** CHOH slightly acidic
			Total	**10**	

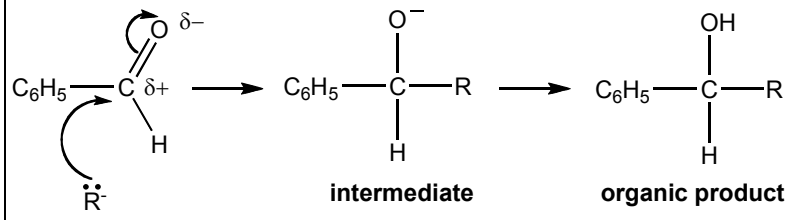
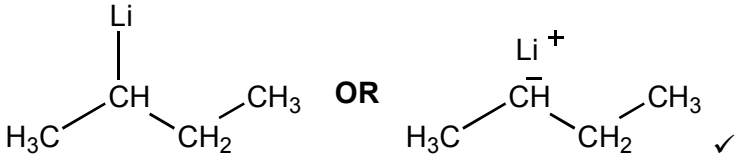
Question			Answer	Marks	Guidance
3	(a)	(i)	 ✓ *cis*-isomer has Hs on same side **OR** *cis*-isomer has branches on same side **OR** *cis*-isomer has same groups on same side **OR** *cis*-isomer has lowest priority groups on same side **OR** *cis*-isomer has highest priority groups on same side ✓	2	**ALLOW** *trans*-isomer has Hs on opposite sides **OR** *trans*-isomer has branches on opposite sides **OR** *trans*-isomer has same groups on opposite sides **DO NOT ALLOW** 'similar groups' for 'same groups' **OR** *trans*-isomer has lowest priority groups on opposite sides **OR** *trans*-isomer has highest priority groups on opposite sides ✓ For explanation, **ALLOW** a clear diagram, *ie*:  *cis* **ALLOW** response in terms of packing, e.g. molecules/chains of *trans*-isomer pack close together **OR** molecules/chains of *cis*-isomer do **not** pack closely together **DO NOT ALLOW** 'carbon atoms' for 'molecules/chains'
		(ii)	heart disease/strokes ✓	1	**ALLOW** any named heart/circulatory complaint e.g. atheroma, atherosclerosis **ALLOW** increase in **bad** cholesterol/LDL **ALLOW** high in LDLs **ALLOW** fat lining arteries **ALLOW** high blood pressure **ALLOW** hypertension **IGNORE** reference to HDLs and cholesterol on its own

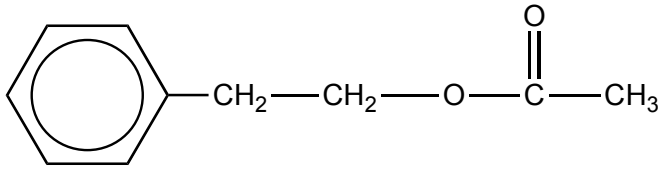
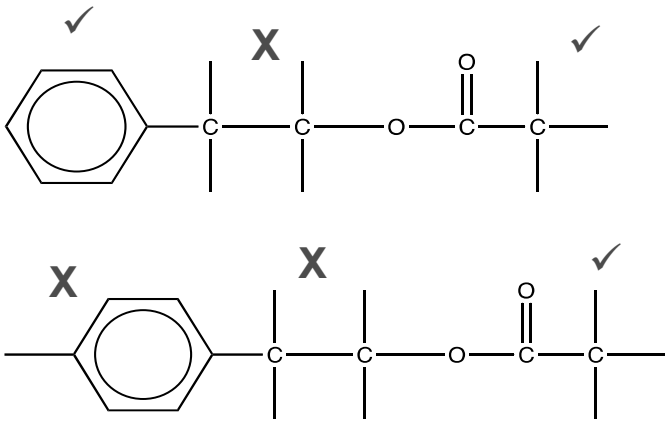
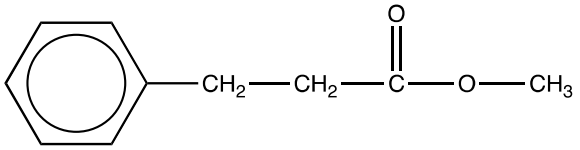
Question			Answer	Marks	Guidance
3	(b)	(i)	27	1	
		(ii)	8	1	
	(c)	(i)	alcohol ✓ ester ✓	2	**IGNORE** OH **OR** hydroxyl **OR** hydroxy **DO NOT ALLOW** phenol **OR** hydroxide **IGNORE** COOR **IF** there is a list with more than two responses, mark wrong responses first, e.g. alcohol, ketone **X**, ether **X** zero marks alcohol ✓, ester, methyl **X** 1 mark ester, hydroxide **X**, ketone **X** zero marks ester ✓, hydroxyl I, ketone **X** 1 mark
		(ii)	ensures correct chirality ✓	1	**ALLOW** enantiomer for optical isomer **ALLOW** produces only one **optical** isomer **ALLOW** stops need/cost/difficulty of separating **optical** isomers **ALLOW** stops formation of the **optical** isomer which may have (harmful) side effects **DO NOT ALLOW** lower doses/dosage needed **DO NOT ALLOW** forms one stereoisomer (could be *E*/*Z*) **DO NOT ALLOW** stereoselectivity

Question			Answer	Marks	Guidance
3		(iii)	**1st step** *reagent*: $NaBH_4$ ✓ *functional groups*: **aldehyde** forms an **alcohol** ✓ *names required* **2nd step** Marks **ONLY** available from correct **hydroxycarboxylic acid** formed in 1st step *reagent*: Acid **OR** H^+ (catalyst) ✓ *functional groups*: **alcohol** and **carboxylic acid / carboxyl group** form an **ester** ✓ *names required*	4	***ANNOTATIONS MUST BE USED*** **ALLOW** H_2/Ni (catalyst) **DO NOT ALLOW** $LiAlH_4$ (*because $LiAlH_4$ reduces COOH*) **IGNORE** type of reaction or conditions **IGNORE** CHO **OR** OH **IGNORE** carbonyl **OR** hydroxyl **OR** hydroxy **DO NOT ALLOW** phenol **OR** hydroxide **ALLOW** named acid/correct formula **IGNORE** dilute/concentrated **IGNORE** OH, COOH, COO, **IGNORE** hydroxyl **OR** hydroxy **DO NOT ALLOW** phenol **OR** hydroxide
			Total	**12**	

Question			Answer	Marks	Guidance
4	(a)		 **M1** ✓ **M2** ✓ **M3** ✓ **M4** ✓ --- **Note**: **ALLOW M1**, **M2 AND M3** for benzene **OR ANY** substituted benzene compound For **M4**, credit **ONLY** the **correct** products --- $HNO_3 + H_2SO_4 \longrightarrow NO_2^+ + H_2O + HSO_4^-$ ✓ $H^+ + HSO_4^- \longrightarrow H_2SO_4$ ✓ **OR** $HNO_3 + 2H_2SO_4 \longrightarrow NO_2^+ + H_3O^+ + 2HSO_4^-$ ✓ $H^+ + HSO_4^- \longrightarrow H_2SO_4$ ✓ **OR** $HNO_3 + H_2SO_4 \longrightarrow H_2NO_3^+ + HSO_4^-$ **AND** $H_2NO_3^+ \longrightarrow NO_2^+ + H_2O$ ✓ $H^+ + HSO_4^- \longrightarrow H_2SO_4$ ✓	6	***ANNOTATIONS MUST BE USED*** --- **Mark 1 (M1)** **ALLOW** curly arrow from the ring **OR** from within the ring --- **Mark 2 (M2)** – intermediate showing delocalisation over less than 6 carbons with the correct orientation **BUT DO NOT ALLOW** intermediate with π system less than halfway up:  --- **Mark 3 (M3)** curly arrow from C–H bond reforming π-delocalised ring in benzene **ALLOW** Kekulé mechanism:  **ALLOW** double bonds shown in other Kekulé arrangement --- **Mark 4 (M4)** **BOTH** correct products: **3**-nitrobenzaldehyde **AND** H^+

Question			Answer	Marks	Guidance
4	(b)		$2\ C_6H_5CHO + KOH \longrightarrow C_6H_5CH_2OH + C_6H_5COOK$ **OR** $2\ C_6H_5CHO + OH^- \longrightarrow C_6H_5CH_2OH + C_6H_5COO^-$ 1 mark for $C_6H_5CH_2OH$ ✓ 1 mark for C_6H_5COOK **OR** C_6H_5COOH **OR** $C_6H_5COO^-$ ✓ 1 mark for complete fully correct balanced equation (i.e. as above) ✓	3	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **ALLOW** combination of formulae as long as unambiguous **ALLOW** use of NaOH instead of KOH throughout, i.e. $2\ C_6H_5CHO + NaOH \rightarrow C_6H_5CH_2OH + C_6H_5COONa$ **ALLOW** $C_6H_5COO^-K^+$
	(c)		 ✓  ✓  ✓	3	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **ALLOW** combination of formulae as long as unambiguous e.g. **ALLOW** 

Question			Answer	Marks	Guidance
4	(d)	(i)	 **intermediate** **organic product** 1 mark for curly arrow from R^- to C of C=O (lone pair not necessary) ✓ 1 mark for correct dipoles on C=O **AND** curly arrow from double bond to $O^{\delta-}$ ✓ 1 mark for correct intermediate with – charge on O ✓ 1 mark for correct product ✓	4	***ANNOTATIONS MUST BE USED*** **IGNORE** connectivity on OH of product Curly arrow **MUST** start from – sign of R^- **OR** from lone pair on R^- lone pair **does not need** to be shown on R^- **IGNORE** any curly arrows shown for **stage 2** i.e. in intermediate
		(ii)	 **OR** ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **ALLOW** combination of formulae as long as unambiguous **IGNORE** C_4H_9Li **OR** $C_4H_9^-Li^-$
			Total	**17**	

Question			Answer	Marks	Guidance
5	(a)	(i)	(number of esters) from number of peaks/retention times **AND** (proportions) from (relative) peak areas ✓	1	**BOTH** points for 1 mark **ALLOW** peak heights **OR** sizes of peaks
		(ii)	(Some esters may have) same retention time ✓	1	**ALLOW** (very) similar retention times **ALLOW** some esters come out at same time
	(b)		**Ester structure 3 marks**  ✓✓✓ **STICKS** IF there are sticks are shown in CH_2CH_2 **OR** in CH_3 **DO NOT AWARD** when first seen **DO NOT ALLOW** sticks on the benzene ring, *Sticks on benzene ring **must** be interpreted as methyl groups* e.g. 	3	***ANNOTATIONS MUST BE USED*** --- **ALLOW** correct structural **OR** displayed **OR** skeletal formula **ALLOW** combination of formulae as long as unambiguous **NO ECF** for structure --- **IF** the structure is **NOT** fully correct, award the following marks: **IF ESTER** shown **AND** contains **ONE** of the following: C_6H_5 **OR** $CH_3C{=}O$ **OR** CH_2CH_2 1 mark ✓ **IF ESTER** shown **AND** contains **TWO** of the following: C_6H_5 **OR** $CH_3C{=}O$ **OR** CH_2CH_2 2 marks ✓✓ **IF ESTER** contains **C_6H_5 AND** CH_2CH_2 **BUT** ester link is reversed 2 marks ✓✓  **DO NOT ALLOW** CH_2CH_2 with H on any adjacent Cs e.g. **DO NOT ALLOW** $CH_2CH_2CH_3$, $CH_2CH_2CH_2$, etc. **IGNORE** any name

Question			Answer	Marks	Guidance
			Mass spectrum 164 linked directly to molecular formula of $C_{10}H_{12}O_2$ **OR** an ester structure with formula $C_{10}H_{12}O_2$ ✓ *This direct link could be seen anywhere in the response* e.g. 164 is $C_{10}H_{12}O_2$ e.g. $C_{10}H_{12}O_2$ = 120 + 12 + 32 = 164 e.g. (164 – 44/COO) = 120; 120 = C_9H_{12} --- **NMR analysis** **QWC** *Triplet must be spelled correctly and used in correct context* Triplet at 2.8 ppm shows an adjacent CH_2 **AND** Triplet at 4.4 ppm shows an adjacent CH_2 ✓ Peak at 2.2 shows C**H_3**–C=O **OR** Peak at 2.2 shows HC–C=O **AND 3** Hs of this type **OR** Peak at 2.2 shows HC–C=O **AND** adjacent to (C with) no Hs✓ Peak at 7.3 shows **5 aromatic Hs OR** shows C_6**H_5** ✓ *5Hs required* Peak at 2.8 shows C_6H_5–C**H OR** C_6H_5–C**H_2** ✓ *Just require C_6H_5–CH as testing environment here* Peak at 4.4 due to **H**C–O **OR** **H_2**C–O ✓ *Just require HC–O as testing environment here*	1 --- 5	***Check back for any responses added to spectrum*** ***Credit responses throughout provided that it is clear which peaks are being referred to*** --- **ALLOW** tolerance on δ values: ± 0.2 ppm Throughout**, ALLOW** for H: proton **OR** H^+ For adjacent CH_2, **ALLOW** (C) adjacent to 2 Hs **ALLOW** There are 2 triplets **AND** triplet shows an adjacent CH_2 For peak at (δ =) 2.2 **ALLOW** singlet **OR** peak labelled 3 For peak at (δ =) 7.3 **ALLOW** peak labelled 5 **OR** multiplet **OR** quintet **OR** hextet **OR** heptet For peak at (δ =) 2.8 **ALLOW** triplet at 2.8 For peak at (δ =) 4.4 **ALLOW** triplet at 4.4
			Total	**11**	