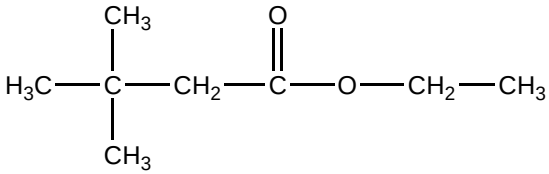
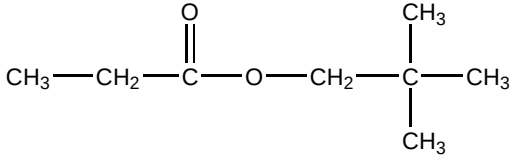
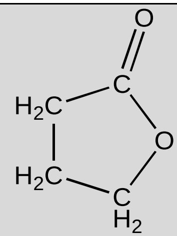
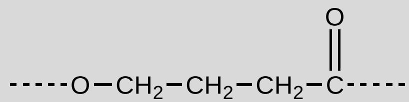
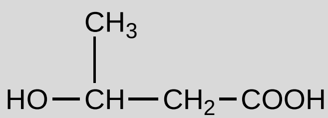
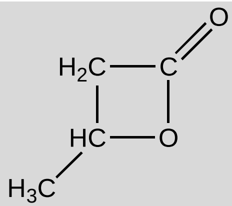
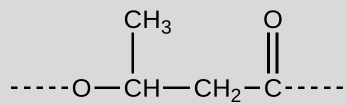
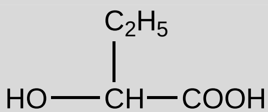
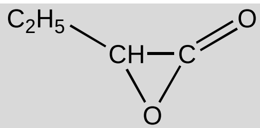
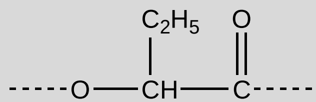
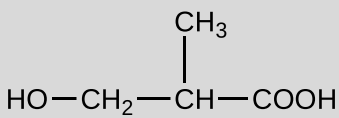
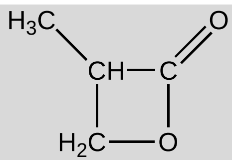
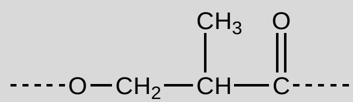
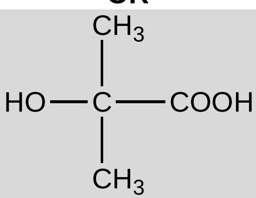
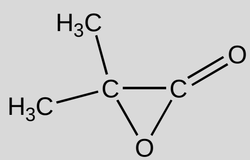
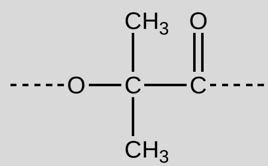
Question			er	Mark	Guidance
1	(a)		$(CH_3CO)_2O + CH_3CH(OH)CH_3 \rightarrow CH_3COOCH(CH_3)_2 + CH_3COOH$ **1st mark** Correct structure of ester: $CH_3COOCH(CH_3)_2$✓ **2nd mark** Equation contains correct formulae for $(CH_3CO)_2O$, $CH_3CH(OH)CH_3$ **AND** CH_3COOH ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **ALLOW** combination of formulae as long as unambiguous **DO NOT ALLOW** molecular formulae **ALLOW** $(CH_3)_2CHOOCCH_3$ **OR** $(CH_3)_2CHOCOCH_3$
	(b)	(i)	(relative) solubility ✓	1	**IGNORE** partition **DO NOT ALLOW** adsorption **OR** absorption
		(ii)	The esters would have similar retention times **AND** similar structures/molecules **OR** same functional groups **OR** similar polarities **OR** similar solubilities ✓ Alcohol would have short retention time **AND** alkane would have long retention time ✓	2	**IGNORE** similar properties

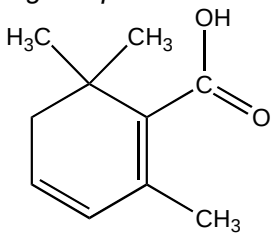
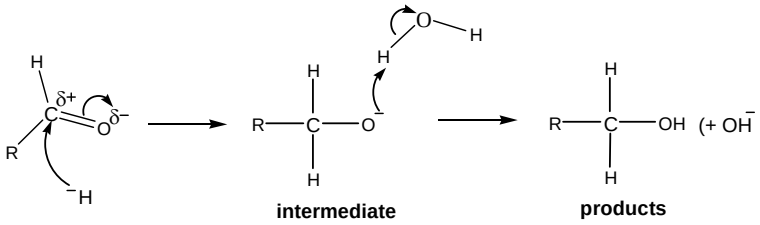
Question			er	Mark	Guidance
	(c)		**Elemental analysis and molecular formula – 2 marks** Use of percentages (to find EF) **AND** 144 ✓ Molecular formula = $C_8H_{16}O_2$ ✓	2 marks	***ANNOTATIONS MUST BE USED*** *Working* C : H : O = 66.63/12 : 11.18/1 : 22.19/16 5.5525 : 11.18 : 1.386875 4 : 8 : 1 Alternative method: carbon: (144 x 66.63/100)/12 = 8 hydrogen: (144 x 11.18/100)/1 = 16 oxygen: (144 x 22.19/100)/16 = 2
			ester structure – 4 marks  ✓✓✓	4 marks	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **ALLOW** combination of formulae as long as unambiguous **NO ECF** from earlier structures If not fully correct award following marks: If structure an ester of formula $C_8H_{16}O_2$ **OR** the organic structure contains $C(CH_3)_3$ ✓ If structure is an ester of formula $C_8H_{16}O_2$ **AND** ester contains $C(CH_3)_3$ ✓✓ If structure is an ester of formula $C_8H_{16}O_2$ **AND** ester contains $O–CH_2C(CH_3)_3$ **AND** ester contains CH_3CH_2COO ✓✓✓ *i.e. If the ester link is reversed*  **IGNORE** any name

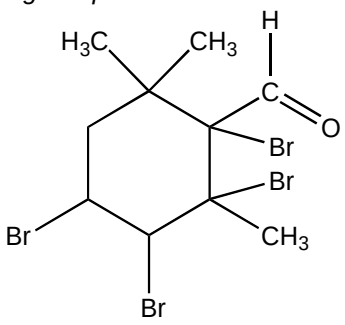
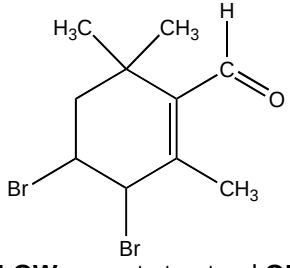
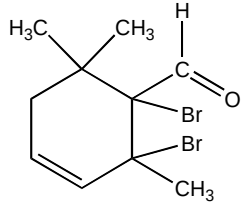
Question			er	Mark	Guidance
			NMR analysis – 4 marks Triplet (at δ 1.3) shows an adjacent CH_2 **OR** triplet (at δ 1.3) shows (C with) 2 adjacent Hs/protons ✓ *(because of splitting: so triplet)* Peak at (δ) 2.2 shows H adjacent to C=O **AND** adjacent to (C with) no hydrogens ✓ *(because of no splitting: so singlet)* Peak at (δ) 4.2 shows H–C–O **AND** adjacent CH_3 OR 3 adjacent Hs/protons ✓ *(because of splitting: so quartet)* Peak at (δ) 0.9 show 3 x CH_3 ✓ *(because of singlet and area 9)*	4 marks	**NOTE: Each peak can be identified from:** • its δ value: ± 0.2 ppm • a range, eg 'the peak between 2 and 3' • its relative peak area (CARE two peaks have an area of 2) • its splitting (CARE: two peaks are singlets) • labelling on the spectrum **----------** **QWC: triplet** must be spelled correctly **ALLOW** neighbouring Hs for adjacent to Hs For peak at (δ) 2.2 **ALLOW** singlet at (δ) 2.2 **ALLOW** singlet labelled 2 For peak at (δ) 4.2 **ALLOW** quartet (labelled 2) **----------** ***Check back for any responses added to spectra*** ***ADD ^ MARK TO THE SPECTRUM PAGE TO SHOW THAT IT HAS BEEN LOOKED AT***
			Total for 4(c)	10	
			Total	**15**	

Question			Answer	Mark	Guidance
2	(a)		propane-1,2,3-triol ✓	1	**ALLOW** absence of 'e' after 'propan' **ALLOW** 1,2,3-propanetriol **ALLOW** absence of hyphens 1, 2 and 3 must be clearly separated: **ALLOW** full stops: 1.2.3 **OR** spaces: 1 2 3 **DO NOT ALLOW** 123
2	(b)	(i)	methanol **OR** ethanol **AND** renewable ✓	 1	**BOTH points required for the mark** **ALLOW** correct structural **OR** displayed **OR** skeletal formula **DO NOT ALLOW** molecular formulae **ALLOW** easy/cheap to manufacture/produce as alternative for renewable/from plants/from fermentation/burns more easily/efficiently
	(b)	(ii)	equilibrium shifts to right ✓	1	**ALLOW** equilibrium shifts in forward direction **ALLOW** more products form **ALLOW** greater yield **OR** fully reacts **OR** goes to completion **DO NOT ALLOW** improves atom economy

Question			Answer	Mark	Guidance
2	(c)		$CH_3CH_2COOH + CH_3CH_2OH \rightarrow CH_3CH_2COOCH_2CH_3 + H_2O$ ✓ $(CH_3CH_2CO)_2O + CH_3CH_2OH \rightarrow CH_3CH_2COOCH_2CH_3 + CH_3CH_2COOH$ ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **ALLOW** combination of formulae as long as unambiguous **DO NOT ALLOW** molecular formulae **ALLOW** further esterification, *ie* $(CH_3CH_2CO)_2O + 2CH_3CH_2OH \rightarrow 2CH_3CH_2COOCH_2CH_3 + H_2O$ ***ALLOW*** *linear formula for anhydride,* ie $CH_3CH_2COOCOCH_2CH_3$ If incorrect carboxylic acid/anhydride/alcohol is used, **ALLOW ECF** for second equation

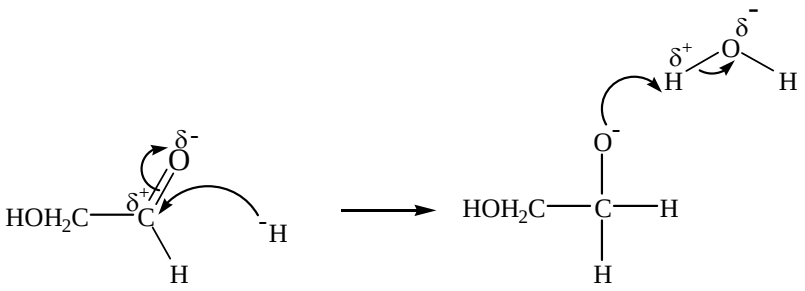
Question			Answer A	Answer B	Answer C	Mark	Guidance
2	(d)		$HO-CH_2-CH_2-CH_2-COOH$			3	Mark **A**, **B** and **C** independently ie • **A** can be **any** of the alternatives in the 1st column • **B** can be **any** of the alternatives in the 2nd column • **C** can be **any** of the alternatives in the 3rd column **ALLOW** correct structural **OR** displayed **OR** skeletal formula **ALLOW** combination of formulae as long as unambiguous **DO NOT ALLOW** molecular formulae **ALLOW** correct names for **A**, **B** and **C** **For B** accept diester **For C**, **IGNORE** '*n*' **OR** brackets (even if wrong); **ALLOW** solid side bonds Minimum is **one** correct repeat unit. Polymer must be open at both ends
			OR	**OR**	**OR**		
							
			OR	**OR**	**OR**		
							
			OR	**OR**	**OR**		
							
			OR	**OR**	**OR**		
							
					Total	**8**	

Question			Answer	Mark	Guidance
3	(a)		*observation*: silver **OR** Ag ✓ *type of reaction*: oxidation✓ *organic product*:  ✓	3	**ALLOW** black **OR** grey **ALLOW** redox **ALLOW** correct structural **OR** displayed **OR** skeletal formula **ALLOW** combination of formulae as long as unambiguous **DO NOT ALLOW** molecular formulae **ALLOW** carboxylate, $–COO^-$
3	(b)		 1 mark for curly arrow from H^- to C of C=O ✓ 1 mark for correct dipole on C=O **AND** curly arrow from double bond to $O^{\delta-}$ ✓ 1 mark for correct intermediate with negative charge on O **AND** curly arrow from O^- to H of H–O–H **AND** curly arrow from H–O to O of H–O–H ✓ 1 mark for correct **organic** product ✓	4	***ANNOTATIONS MUST BE USED*** **ALLOW** mechanism showing curly arrows from lone pair on H^- and O^- of intermediate Dipole not required on H–O–H **DO NOT ALLOW** incorrect dipole on H–O–H **ALLOW** 1 mark for correct intermediate with '–' charge on O **AND** curly arrow from O^- to H^+ **IGNORE** missing OH^- **DO NOT ALLOW** incorrect second product

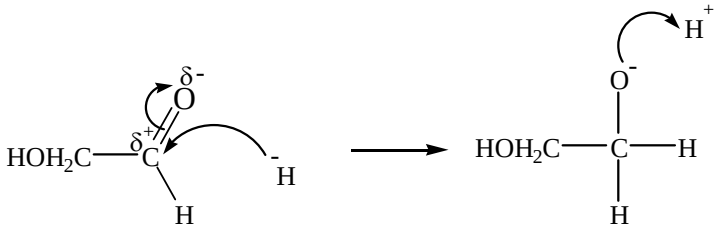
Question			er	Mark	Guidance
3	(c)		*reagent*: Br_2 ✓ *observation*: decolourised **OR** orange to colourless ✓ *organic product*: ✓ 	3	**DO NOT ALLOW ECF** from incorrect reagent, eg 2,4-DNP **DO NOT ALLOW** goes clear **ALLOW** red/orange/yellow/brown in any combination **ALLOW** organic product from reaction of one of the double bonds only, ie  **OR**  **ALLOW** correct structural **OR** displayed **OR** skeletal formula **ALLOW** combination of formulae as long as unambiguous **DO NOT ALLOW** molecular formulae ***ALTERNATIVE reagents*** **For 1st mark,** **ALLOW** H_2 **OR** Cl_2 **OR** I_2 **OR** HCl **OR** HBr **OR** HI **OR** H_2O **For 2nd mark**, there **must** be a statement of no change **OR** no observation or similar that implies there is no visible change **EXCEPT** for I_2 which has an observation of 'decolourised' **OR** brown to colourless **For 3rd mark,** correct organic product must be shown that could be from reaction of both or one of the double bonds.
			Total	**10**	

Question			Expected Answers	Marks	Additional Guidance
4	(a)	(i)	silver mirror ✓	1	**ALLOW** Ag(s) **OR** Ag mirror **OR** precipitate **OR** ppt **OR** solid **ALLOW** brown **OR** black **OR** grey
		(ii)	$HOCH_2COOH$ ✓	1	**ALLOW** $CH_2OHCOOH$ **OR** CH_2OHCO_2H **OR** $HOCH_2CO_2H$ **OR** displayed **OR** skeletal formula **OR** $HOCH_2COO^-$ **DO NOT ALLOW** C_2H_4O **OR** 2-hydroxyethanoic acid
	(b)		$HOCH_2CHO + 3[O] \rightarrow HOOCCOOH + H_2O$ reagents ✓ both products ✓	2	**ALLOW** displayed/skeletal formula/COOHCOOH ✓✓ if molecular formula used $C_2H_4O_2 + 3[O] \rightarrow C_2H_2O_4 + H_2O$ max = 1 ✓ **Any correctly balanced equation for partial oxidation** can score 1 mark ✓ $HOCH_2CHO + [O] \rightarrow HOCH_2COOH$ **OR** $HOCH_2CHO + 2[O] \rightarrow OHCCOOH + H_2O$ **OR** $HOCH_2CHO + [O] \rightarrow OHCCHO + H_2O$ **OR** $HOCH_2CHO + 2[O] \rightarrow HOOCCHO + H_2O$
	(c)	(i)	$HOCH_2CH_2OH$ ✓	1	**ALLOW** $HO(CH_2)_2OH$ **OR** $(CH_2OH)_2$ **OR** skeletal formula **OR** displayed formula **DO NOT ALLOW** molecular formula ($C_2H_6O_2$)
		(ii)	curly arrow from H^- to $C^{\delta+}$ ✓ dipoles and curly arrow from C=O bond to O ✓ intermediate ✓ curly arrow from intermediate to $H^{\delta+}$ in H_2O/ H^+ and if H_2O is used it must show the curly arrow from the O–H bond to the O ✓ *lone pairs are not essential*	4	**ALLOW** curly arrow to C even if dipole missing or incorrect **ALLOW** maximum of 3 marks if incorrect starting material is used See page 36 for detailed mechanisms – ***Alternative 3*** scores all 4 marks even though the intermediate is not shown

Alternative 1

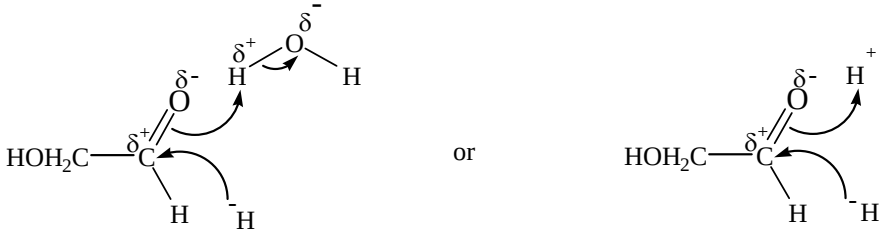


Alternative 2

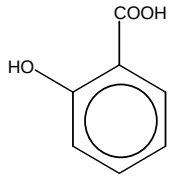
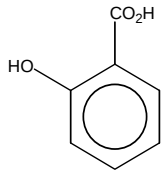
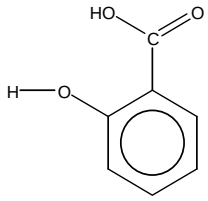
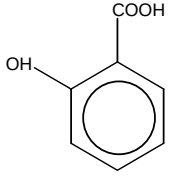
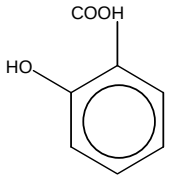
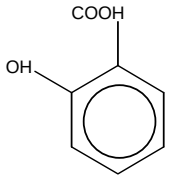
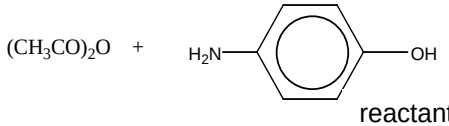
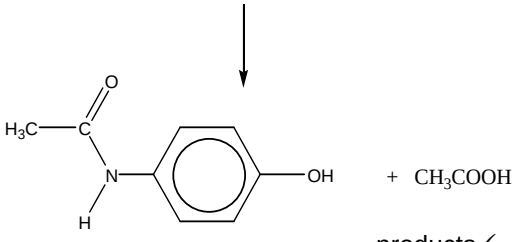
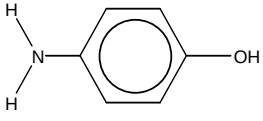


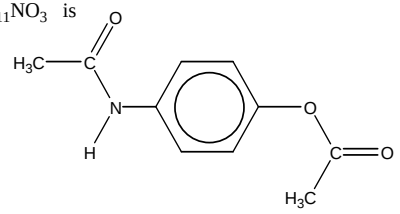
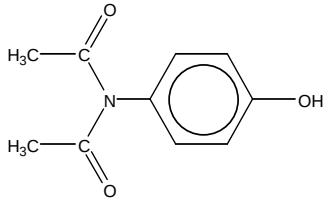
products are not required

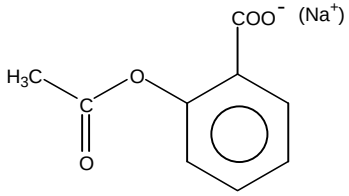
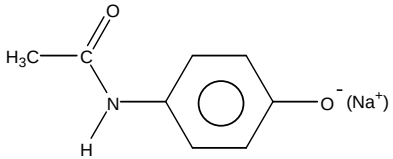
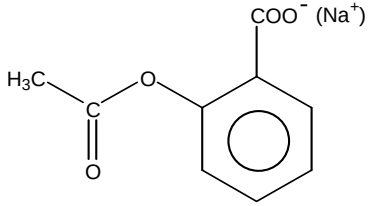
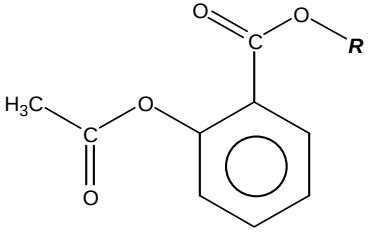
Alternative 3

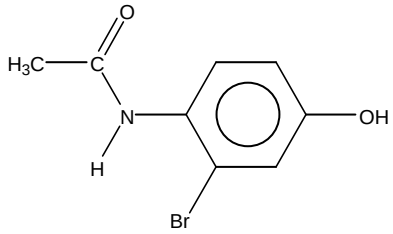


			Total	**9**	

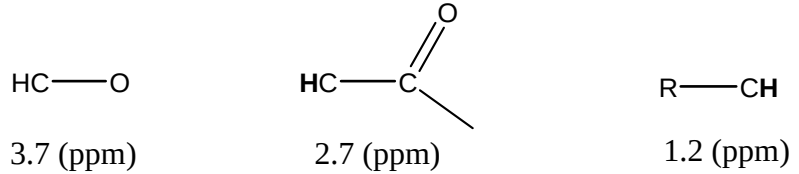
Question			Expected Answers	Marks	Additional Guidance
5	(a)		 ✓	1	**ALLOW**  or  **DO NOT ALLOW** incorrect bond linkage  or  or 
	(b)	(i)	equation  reactants ✓  products✓	2	**ALLOW** $(CH_3CO)_2O + H_2NC_6H_4OH \rightarrow CH_3CONHC_6H_4OH + CH_3COOH$ **ALLOW**  **DO NOT ALLOW** molecular formulae

		(ii)	$C_{10}H_{11}NO_3$ is  or  ✓	**1**	**ALLOW** amide shown as either $CH_3CONH–$ **OR** $H_3CCONH–$ **OR** $CH_3COHN–$ **OR** $H_3CCOHN–$ **ALLOW** ester shown as either $–OCOCH_3$ **OR** $–OOCCH_3$
		(iii)	to ensure t at there are no (harmful) side effects ✓	**1**	**ALLOW** impurities reduce effectiveness (of drug) **OR** might be toxic **OR** avoids litigation **OR** harmful **OR** hazardous **ALLOW** to ensure that the drug/active component is safe **IGNORE** dangerous **OR** nasty **OR** can kill **OR** increased dosage
	(c)		(aspirin contains) ester **AND** carboxylic acid ✓ (paracetamol contains) amide **AND** phenol ✓	**2**	**IGNORE** arene or benzene or aromatic or phenyl or methyl but any other group loses the mark **ALLOW** carboxyl group **DO NOT ALLOW** acid **IGNORE** arene or benzene or aromatic or phenyl or methyl but any other group loses the mark **ALLOW** peptide **ALLOW** hydroxy(l) **DO NOT ALLOW** hydroxide or alcohol **DO NOT ALLOW** amine
	(d)	**(i**		**3**	**ALLOW** hydrolysis by $H^+(aq)$ or H^+ or $HCl(aq)$ or HCl or $H_2SO_4(aq)$

			Na **OR** NaOH ✓  from aspirin ✓  from paracetamol ✓		or H_2SO_4 to give hydroxybenzoic acid + ethanoic acid with aspirin ✓ and ammonium salt of 4-aminophenol + ethanoic acid with paracetamol ✓ **ALLOW** hydrolysis by $OH^-(aq)$ or NaOH(aq) and other alkali leading to hydrolysis to give carboxylate salt and phenoxide salt on the ring + ethanoate with aspirin ✓ and 4-aminophenoxide ion + ethanoate ion with paracetamol ✓ **ALLOW** HNO_3 (and H_2SO_4) to give NO_2 in one or more positions on the ring in both aspirin and paracetamol ✓✓ **DO NOT ALLOW** NH_3 but correct ammonium salts can be awarded 2 marks ECF **DO NOT ALLOW** H_2O but correct products can be awarded 2 marks ECF if no reagent there cannot be any marks for the products If reagent selected is incorrect but would react with **either** aspirin or paracetamol **ALLOW** ✓ ECF for the correct organic product
		(ii)	**aspirin only** $NaHCO_3$ **OR** Na_2CO_3 **OR** metal oxide ✓  ✓	**2**	**ALLOW** Mg, carbonates, NH_3 **ALLOW** alcohols (***R***OH) to give ester if no reagent there cannot be any marks for the products  If reagent selected is incorrect but would react with **BOTH** aspirin and paracetamol **ALLOW** ✓ ECF for the correct organic product
		(iii)	**paracetamol only**		**ALLOW** Br_2 water

			Br_2 ✓  ✓	**2**	**ALLOW** one or more Br at **any** position on the ring **DO NOT ALLOW** Br substitution of OH **ALLOW** acyl chloride or acid anhydride and corresponding ester **ALLOW** $FeCl_3$ to form a purple <u>complex ion</u> (structure not required) **ALLOW** diazonium and structure showing azo group substituting one of the Hs in the ring if no reagent there cannot be any marks for the products If reagent selected is incorrect but would react with **BOTH** aspirin and paracetamol **ALLOW** ✓ ECF for the correct organic product
			Total	**14**	

Question			Expected Answers	Marks	Additional Guidance
6	(a)		**infrared – 1 mark only** shows (very broad) peak between 2500–3300 (cm^{-1}) (due to O–H bond) ✓	3	**ALLOW** (very broad) peak around 3000 (cm^{-1}) **OR** any stated value between 2500 and 3300 (cm^{-1}) for O–H **DO NOT ALLOW** peak in range 3200–3550 (cm^{-1}) **IGNORE** any reference to C=O or C–O as both are also present in an ester **OR** to fingerprint region
			^{13}C NMR – 2 marks $(CH_3)_2CHCH_2COOH$ has 4 peaks (due to 4 different C environments) ✓ $(CH_3)_3CCOOH$ has 3 peaks (due to 3 different C environments) ✓		**ALLOW** '*^{13}C NMR detects the number of/different C environments*' for 1 ✓, suitable example for the 2nd mark
	(b)		**splitting pattern** explains any two in terms of '*n* + 1 rule' for two marks ✓✓ Explains any one peak for 1 mark ✓ • *singlet* therefore adjacent C (if any) has no Hs • *multiplet* **OR** split into 7 therefore adjacent Cs have lots of/6 Hs • *doublet* therefore adjacent C is bonded to 1H *must spell **one** of multiplet / heptet, singlet, doublet correctly* **max = 2 marks**	6	**1 mark** for correct ester if two splitting patterns are correctly analysed **ignore** the third **ALLOW** singlet because next or bonded to an O **ALLOW** multiplet/heptet because next to 2 CH_3s **ALLOW** doublet because next to a CH
			chemical shifts		**ALLOW** tolerance on δ values; 3.6–3.8, 2.6–2.8 and 1.1–1.3

			two marks if any two absorptions are identified correctly ✓✓ one mark if any one absorption is identified correctly ✓ • peak ~3.7 (ppm) – bonded to an O • peak ~2.7 (ppm) – indicates it is next to a C=O • peak ~1.2 (ppm) – bonded to other Cs **OR** part of a chain **max = 2 marks** compound identified as $(CH_3)_2CHCOOCH_3$ ✓✓ **2 marks** compound identified as $CH_3COOCH(CH_3)_2$ ✓ **1 mark**		(ppm) **ALLOW** any two gets 2 marks, any one scores 1 mark  **ALLOW** peaks labelled on the spectrum **ALLOW** singlet must be bonded to O, multiplet to C=O and doublet to CH or R for both chemical shift marks if two chemical shifts are correctly identified **IGNORE** the third
			Total	**9**	