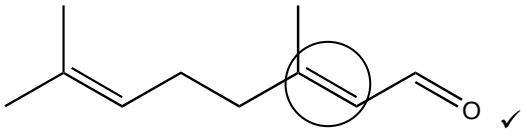
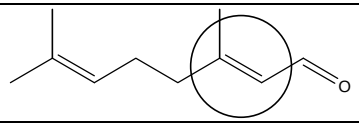
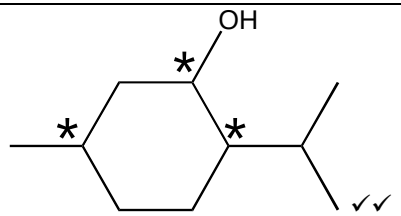
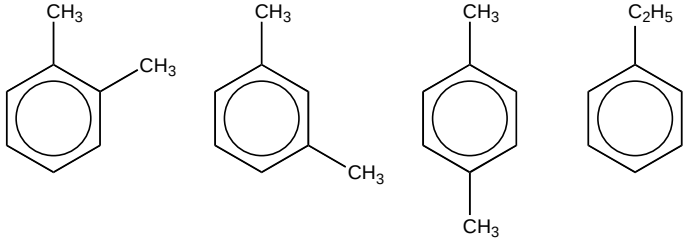
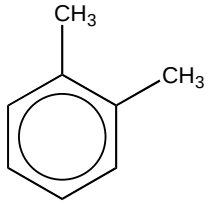
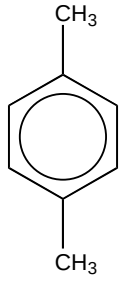
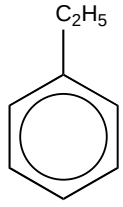
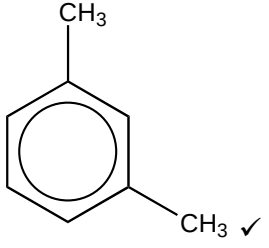
Question			Answer	Mark	Guidance
1	(a)	(i)	Adsorption ✓(onto the stationary phase) ***Quality of Written Communication*** 'Adsorption' must be spelled correctly	1	**ALLOW** adsorbtion or adsorb(s) or adsorbed spelled correctly at least once **DO NOT ALLOW** anything that begins with ab...
	(a)	(ii)	0.2 ✓	1	**ALLOW** any value in the range 0.1 – 0.3 **IGNORE** significant figures **DO NOT ALLOW** fraction/percent as final answer
	(a)	(iii)	Spot may contain more than one compound/component ✓	1	**ALLOW** compounds have similar R_f values/adsorptions **OR** compounds have not (fully) separated **OR B** is spread over a large region **OR** compounds are similar **IGNORE** retention times
	(b)	(i)	GC separates the components/compounds **AND** MS is compared to a database/reference ✓	1	**ALLOW** chromatography for GC **ALLOW** they have different retention times **ALLOW** MS analyses compounds/gives structural information/gives different mass spectra **ALLOW** (uses) fragmentation patterns/fragments/peaks/parts of the compound **DO NOT ALLOW** MS identifies compounds (in question) **DO NOT ALLOW** molecular ion alone/M_r etc.
		(ii)	nerol and geraniol **AND** they are stereoisomers **OR** primary alcohols ✓	1	Compounds **AND** reason required for the mark **ALLOW** they are *E*/*Z* isomers **OR** *cis-trans* isomers **ALLOW** straight-chain alcohols **OR** unsaturated alcohols
		(iii)	stereoisomers have the same structural formula **AND** different 3D arrangements ✓	1	**BOTH** points required for the mark **ALLOW** different arrangements in space
		(iv)	 ✓	1	Circle must include the correct C=C double bond **AND** must not extend further than the adjacent atoms in the main chain, ie limit is:

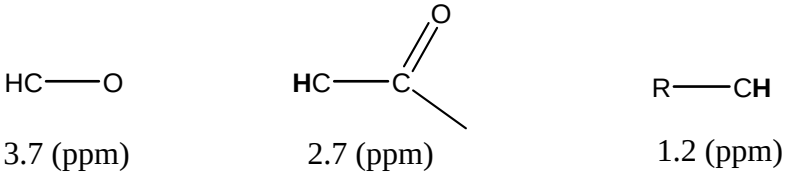
Question			er	Mark	Guidance
					
	(b)	(v)	 ✓✓	2	**ALL THREE** chiral centres required for 2 marks **ANY TWO** chiral centres required for 1 mark If more than three asterisks are shown, mark incorrect asterisk(s) first
	(c)		Correctly calculates amount of myrcene = 34/136 **OR** 0.25 (mol) ✓ Correctly calculates 60% yield of menthol = 0.25 × 60/100 **OR** 0.15 (mol) ✓ Correctly calculates mass of menthol = 0.15 × 156 = 23.4 (g) ✓	3	***ANNOTATIONS MUST BE USED*** **ALLOW** amount of myrcene × 60/100 **ALLOW** amount of menthol × 156 **ALLOW** alternative approach based on reacting masses (using same **ECF** principles as above): correctly calculates mass of myrcene that could be obtained from 34 g myrcene: mass = 34 × 156/136 = 39 (g) × 156 ✓; ÷ 136 ✓ 60% of 39 g = 39 × 60/100 = 23.4 (g) ✓ **ALLOW** final answer to 2 or more significant figures correctly rounded Correct answer of 23.4 (g) with no working scores all 3 marks
			Total	**12**	

Question			Answer	Mark	Guidance
2	(a)		a **singlet** for position 2 **OR** a **singlet** because it has no adjacent H's✓ A **triplet** for positions 4 and 6 ***OR** a **triplet** because it has 2 adjacent H's* ✓ A **quintet** for position 5 **OR** a **quintet** because it has four adjacent H's ✓ ***Quality of Written Communication*** singlet **OR** triplet **OR** quintet **OR** pentet **OR** multiplet (see Guidance) must be spelled correctly at least once	3	***ANNOTATIONS MUST BE USED*** **ALLOW** a response that implies a single peak **OR** 'no splitting' **ALLOW** a response that implies a splitting into three **DO NOT ALLOW** implications of more than one triplet **ALLOW** 'pentet' **OR** a response that implies a splitting into five **OR** multiplet **ALLOW** 1 mark for singlet and triplet and quintet/pentet/multiplet with no identification of protons Any suggestion that the oxygens cause a splitting scores a maximum of 2 marks. • All 3 remaining splitting patterns correct 2 marks. • Any 2 correct 1 mark. **IF** number labels for protons in diagram are **not** identified, **ALLOW** identification by chemical shifts for 2 marks max: • singlet at 3.3–4.2 **AND** a triplet at 3.3–4.2 ✓ • quintet/pentet/multiplet at 0.7–2.0 ✓ Clear and unambiguous identification of the protons other than by position number should be credited, *ie* 'CH_2 between two oxygens'

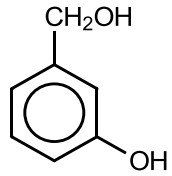
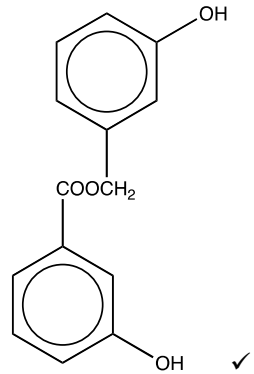
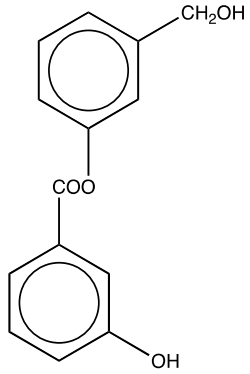
	(b)		***ANY 5 marks plus correct structure (in box)***		***ANNOTATIONS MUST BE USED***
			Molecular ion/M^+ peak at (*m*/*z* of) 106 ✓		**ALLOW** molecular mass **OR** relative molecular mass
			Fragment peak at 91 is $C_6H_4–CH_3^+$ / $C_6H_5–CH_2^+$ ✓		**ALLOW** $C_6H_4–CH_3$/$C_6H_5–CH_2$ **ALLOW** peak at 91 represents loss of CH_3
			Molecular formula is C_8H_{10} (or implied, *ie* any one of the structures below) ✓		**ALLOW** correct structural **OR** displayed **OR** skeletal formula **ALLOW** combination of formulae as long as unambiguous **ALLOW** a correct name eg a dimethylbenzene
			 ✓		**ALL FOUR** structures needed for 1 mark **ALLOW** correct names
			^{13}C NMR spectrum shows 5 C environments ✓		**ALLOW** NMR spectrum shows five different types of carbon **DO NOT ALLOW** 'NMR spectrum has five peaks' – the mark is for realising what the peaks show, not for just describing the spectrum
			Peak near 20 is a C attached at another carbon, **C**–C **OR** peaks at ~125–140 for aromatic **C**s ✓		

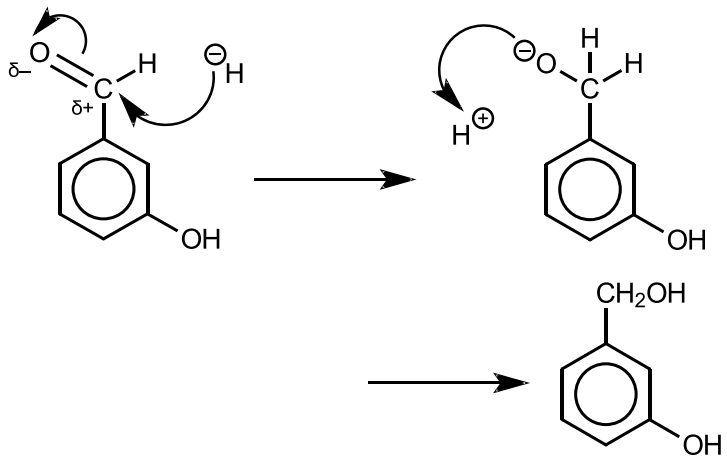
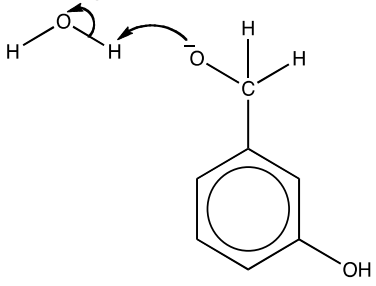
Question			er	Mark	Guidance
	(b)		Number of peaks for other three isomers matched to structures: *Any 2 correct for 2 marks* ✓✓ *1 correct for 1 mark* ✓    4 peaks 3 peaks 6 peaks Correct structure shown:  ✓	6	**ALLOW** 'carbon environments' for peaks
			Total	**9**	

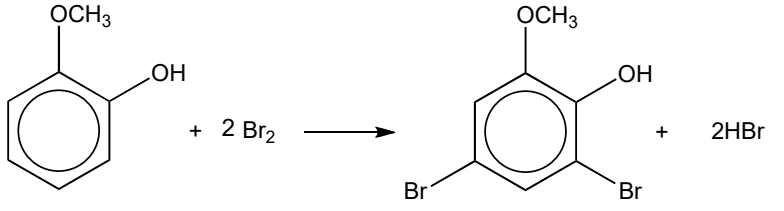
Question			Expected Answers	Marks	Additional Guidance
3	(a)		**infrared – 1 mark only** shows (very broad) peak between 2500–3300 (cm^{-1}) (due to O–H bond) ✓	3	**ALLOW** (very broad) peak around 3000 (cm^{-1}) **OR** any stated value between 2500 and 3300 (cm^{-1}) for O–H **DO NOT ALLOW** peak in 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

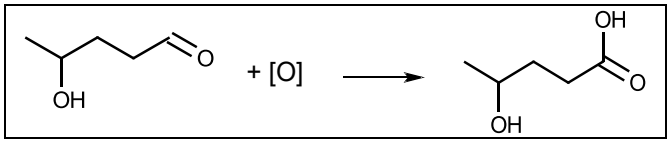
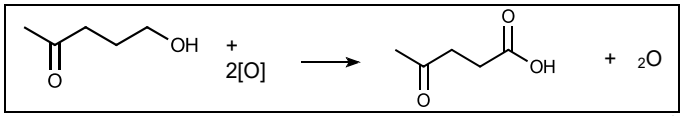
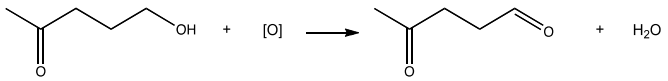
			two marks if any two absorptions are identified correctly ✓✓ one mark if any one absorption is identified correctly ✓ • peak ~3.7 (ppm) – bonded to an O • peak ~2.7 (ppm) – indicates it is next to a C=O • peak ~1.2 (ppm) – bonded to other Cs **OR** part of a chain **max = 2 marks** compound identified 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**	

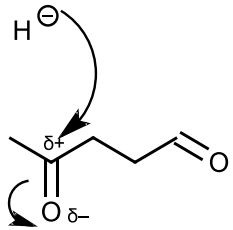
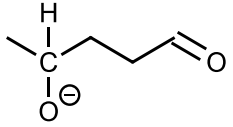
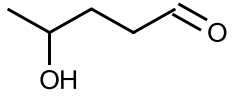
Question			Answer	Mark	Guidance
4	(a)		(Relative) solubility (in stationary phase) ✓	1	**ALLOW** how well the compound dissolves **IGNORE** retention time **AND** partition **DO NOT ALLOW** adsorption **OR** absorption
	(b)	(i)	Compound **B** **AND** M^+/molecular ion peak (at *m*/*z*) = 124 ✓	1	**ALLOW** Mr = 124 **IGNORE** compound B because *m*/*z* = 124 **ALLOW** $C_7H_8O_2^+$ = 124 **OR** $C_7H_8O_2$ = 124 **ALLOW** peak at (m/z =) 109 due to $HOC_6H_4O^+$ **ALLOW** peak at (m/z =) 109 due to loss of CH_3 **IGNORE** reference to other peaks in the spectrum
		(ii)	Compound (B) is less soluble in the stationary phase/ liquid	1	**ORA** Answer refers to the first compound to emerge from the column **ALLOW** compound (B) is more soluble in mobile phase/gas **ALLOW** compound interacts less with stationary phase/liquid **OR** compound interacts more with mobile phase/gas **IGNORE** compound adsorbs less **IGNORE** compound is not very soluble (comparison needed) **IGNORE** volatility **OR** reactivity

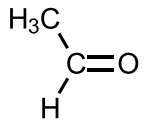
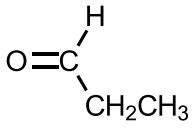
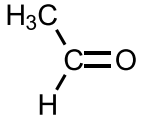
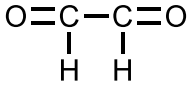
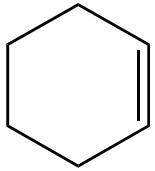
Question			Answer	Mark	Guidance
	(c)	(i)	reagent = $K_2Cr_2O_7$ **AND** H_2SO_4 ✓	3	**ALLOW** acidified dichromate **ALLOW** H^+/any acid **IGNORE** concentration of acid **ALLOW** $Na_2Cr_2O_7$ /$Cr_2O_7^{2-}$ **/**(potassium **OR** sodium) dichromate((VI)) **ALLOW** acidified MnO_4^- **ALLOW** Tollens' reagent/ammoniacal silver nitrate **IGNORE** conditions
			compound C =  ✓		**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW ECF** from incorrect **compound C** Check positions of OH groups
			ester =  ✓		**ALLOW** esterification of phenol group 

Question	Answer	Mark	Guidance
(ii)	curly arrow from H^- to $C^{\delta+}$ ✓ dipole **AND** curly arrow from C=O bond to O ✓ correct intermediate **AND** curly arrow to H^+ ✓ 	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** curly arrow must come from lone pair on H or negative charge on H curly arrow must come from the bond, not the carbon atom curly arrow must come from lone pair on O or negative charge on O and go to H or positive charge on H **Where circles have been placed round charges, this is for clarity only and does not indicate a requirement** **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW** for second stage  **IF** H_2O is used it **MUST** show the curly arrow from the negative charge or lone pair on the oxygen atom of the intermediate to H in H_2O **AND** from the O—H bond to the O in H_2O. **Dipole not required on water molecule** Penalise missing –OH on intermediate only **IGNORE** product – already given credit in part (i)

Question			Answer	Mark	Guidance
	(d)		 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW** disubstitution at any positions on benzene ring
			Total	**10**	

Question			Answer	Mark	Guidance
5	(a)		**FIRST** react **all** with Tollens' reagent **AND** silver mirror/ppt/solid (formed) with compound **D** **OR** with Fehling's/Benedict's solutions **AND** (brick-red/orange) solid/precipitate (formed) with compound **D** ✓ ***NOTE**: eliminates **D***  ✓ **THEN** react **C** and **E** with H_2SO_4/H^+ **AND** $K_2Cr_2O_7$/ $Cr_2O_7^{2-}$/$Na_2Cr_2O_7$ **AND** colour change **OR** green colour with compound **C** **OR** no change **OR** no reaction **OR** no green colour with compound **E** ✓  ✓	4	**ALLOW** ammonia + silver nitrate for reagent **ALLOW** black solid/ppt **ALLOW** 'the aldehyde gives a silver mirror' **ALLOW** solid **OR** crystals **OR** ppt as alternatives for precipitate **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous **DO NOT ALLOW** molecular formulae for organic structures **IGNORE** all references to 2,4-dinitrophenylhydrazine/Brady's **ACCEPT** acidified dichromate **ALLOW** blue/green blue **IGNORE** equation for oxidation of **D** **ALLOW** equation for partial oxidation 

Question	Answer	Mark	Guidance
			ALLOW alternative sequences e.g. **FIRST** react **all** with H_2SO_4 **AND** $K_2Cr_2O_7$ colour change with **C** and **D** *eliminates **E*** At least one correct equation and structure of one product from either reaction required for the second mark. **NB** several possible products for the oxidation of **D** **THEN** react **C** and **D** with Tollens' …… *distinguishes between **C** and **D***
(b)	 curly arrow from H^- to $C^{(\delta+)}$ of correct C=O group ✓ dipole correct **AND** curly arrow from C=O bond to $O^{(\delta-)}$ ✓  correct intermediate with negative charge on O ✓  correct product ✓	**4**	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous First curly arrow must come from either a lone pair on H or negative charge on H **IF** aldehyde reduced **OR** both carbonyls reduced **DO NOT AWARD** first mark (second, third and fourth marks can be awarded **ECF**) **IGNORE** lack of C—H if entirely skeletal **IGNORE** curly arrows in second stage Apply ecf to error in structure e.g. CH_2 missing from the chain or –COOH/-COH instead of –CHO **IGNORE** other products

Question			Answer	Mark	Guidance
	(c)		<table><tr><th>Compound</th><th>C</th><th>D</th><th>E</th></tr><tr><td>Number of peaks</td><td>5</td><td>5</td><td>4</td></tr></table> **all** correct ✓	1	
	(d)	(i)	• pent-2-ene  **AND**  ✓ • hexa-2,4-diene  ✓  ✓	3	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous **ALLOW** C_2H_5CHO and CH_3CHO
	(d)	(ii)	 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous
			Total	13	