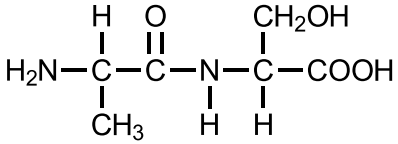
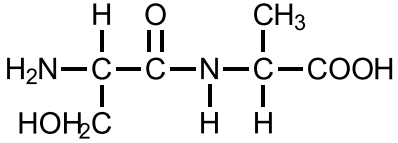
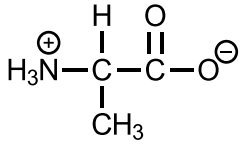
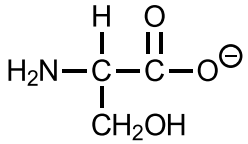
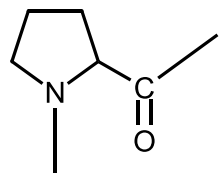
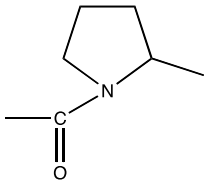
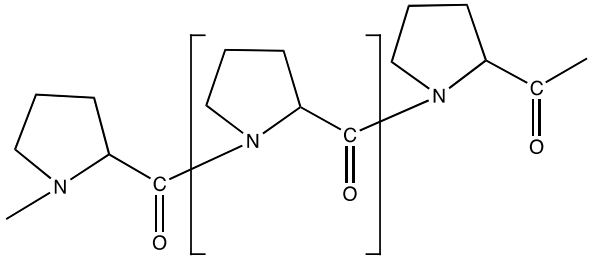
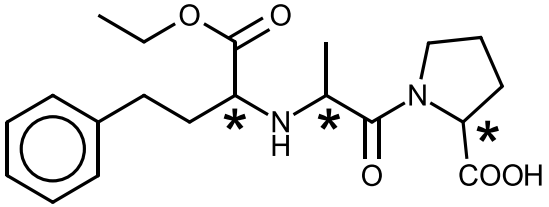
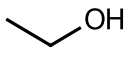
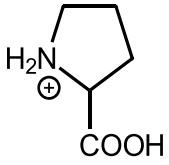
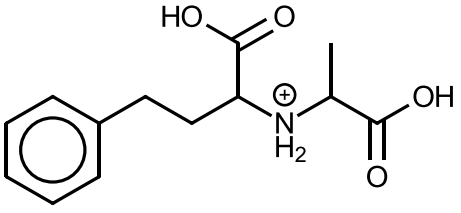
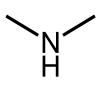
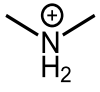
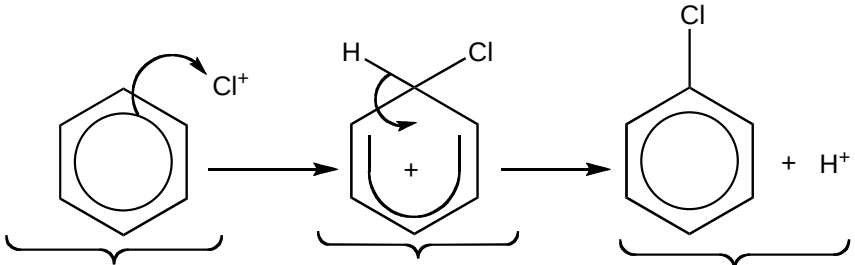
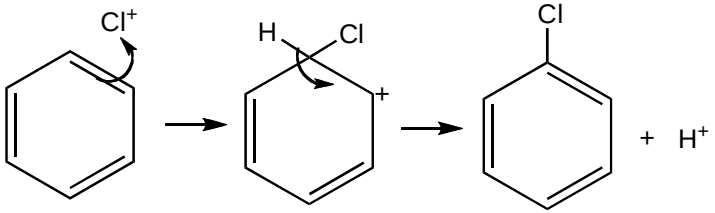
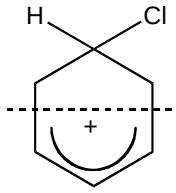
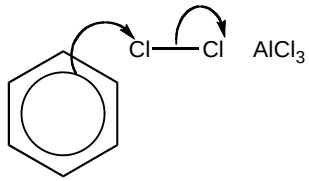
Question			Answer	Mark	Guidance
1	(a)	(i)	 ✓  ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous **DO NOT ALLOW** peptide chains
	(a)	(ii)	alanine at pH 6.0  ✓ serine at pH 10.0  ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous **ALLOW** + charge on N or H: *i.e.* $^{+}NH_3$ or NH_3^{+} **DO NOT ALLOW** '–' charge on C *i.e.* ^{-}COO **DO NOT ALLOW** if structure is incomplete

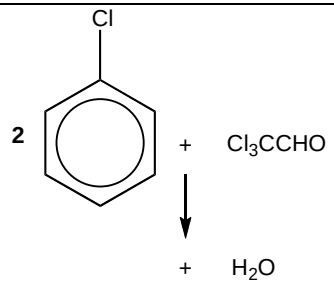
Question			Answer	Mark	Guidance
	(a)	(iii)	 ✓ **OR** 	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous **IGNORE** bond angles **DO NOT ALLOW** more than one repeat unit **ALLOW** end bonds shown as - - - - - **DO NOT ALLOW** if structure has no end bonds **IGNORE** brackets unless they are used to pick out the repeat unit from a polymer chain **IGNORE** *n* 

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Mark</th><th>Guidance</th></tr>
<tr><td></td><td>(b)</td><td></td><td>
<table>
<tr><td colspan="3">^{1}H NMR spectrum for serine</td></tr>
<tr><td>chemical shift, δ /ppm</td><td>relative peak area</td><td>splitting pattern</td></tr>
<tr><td>2.0 to 3.0</td><td>1</td><td>triplet</td></tr>
<tr><td>3.3 to 4.2</td><td>2</td><td>doublet</td></tr>
</table>
One mark for each correct row ✓✓
</td><td>2</td><td>ALLOW δ values ± 0.2 ppm, as a range or a value within the range

ALLOW a response that implies a splitting into three for a triplet/into two for a doublet</td></tr>
<tr><td></td><td>(c)</td><td>(i)</td><td> 
✓</td><td>1</td><td>ALL correct for one mark</td></tr>
<tr><td></td><td>(c)</td><td>(ii)</td><td>any two from:
no/fewer side effects
increases the (pharmacological) activity/effectiveness
Reduces/stops the need for/cost/difficulty in separating stereoisomers/optical isomers
✓✓</td><td>2</td><td>IGNORE toxic/harmful
IGNORE a response that implies a reduced dose
IGNORE “it takes (less) time to separate”</td></tr>
</table>

Question			Answer	Mark	Guidance
	(c)	(iii)	 ✓ one mark for ethanol  ✓ one mark for proline with NH **OR** NH_2^+  ✓ one mark for remaining fragment with  or  ✓ **Fourth** mark for structure of **both** ions shown correctly with NH_2^+	**4**	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous **ALLOW** + charge on H of NH_2 groups, *i.e.* NH_2^+ **IGNORE** negative (counter) ions
	(c)	(iv)	idea of separating (the components/compounds) **AND** idea of (identifying compounds by) comparison with a (spectral) database ✓	**1**	**ALLOW** (identifies compounds) using fragmentation (patterns)/fragment ions (but **IGNORE** molecular ions) **IGNORE** retention times
			Total	**15**	

Question			Answer	Mark	Guidance
2	(a)		$AlCl_3 + Cl_2 \longrightarrow AlCl_4^- + Cl^+$ ✓  curly arrow from π-bond to Cl^+ ✓ correct intermediate ✓ curly arrow from C–H bond back to reform π-ring ✓ correct products ✓ $H^+ + AlCl_4^- \longrightarrow AlCl_3 + HCl$ ✓ **Note**: 1st curly arrow should start within the ring or on the ring --- **Note: ALLOW** mechanism using Kekulé structures:  	6	***ANNOTATIONS MUST BE USED*** **DO NOT ALLOW** the following intermediate:  π-ring must be more than 1/2 way up **AND** 'horseshoe' the right way up, *ie* gap towards C with Cl **ALLOW** + sign anywhere inside the 'hexagon' of intermediate **ALLOW** 1st curly arrow starting within the hexagon **ALLOW** mechanism with Cl–Cl----$AlCl_3$ for 1st 2 marks, ie  Second curly arrow to either –Cl or $AlCl_3$ **Note**: If Br^+ is used, **DO NOT ALLOW** 1st mechanism mark but all other marks available by **ECF**

Question			er	Mark	Guidance
	(b)	(i)	 **1st mark**: reactants, correctly balanced, ✓ *ie* **2** C_6H_5Cl + Cl_3CCHO **2nd mark**: product, (correctly balanced) ✓ *ie* H_2O	**2**	**Each mark is independent of the other** **ALLOW** C_6H_5Cl for chlorobenzene **ALLOW** any unambiguous structure for Cl_3CCHO, e.g. CCl_3CHO **BUT** ….. **DO NOT ALLOW** CCl_3COH **Standalone mark** **Standalone mark**
		(ii)	6 ✓	**1**	
	(c)		substitution/nitration/NO_2 at different positions (on the ring) **OR** forms different isomers **OR** multiple substitution/nitration ✓	**1**	**ALLOW** examples, e.g. 1-chloro-2-nitrobenzene and 1-chloro-2-nitrobenzene **ALLOW** 'it' for nitro group **ALLOW** examples, e.g. 1-chloro-2,3-dinitrobenzene **IGNORE** nitrate/NO_3
	(d)		In phenol, (lone) pair of electrons on O is (partially) **delocalised** into the ring ✓ **QWC**: delocalised/delocalized/delocalise, etc must be spelt correctly in the correct context for benzene **OR** phenol at least once electron density increases/is high ✓ **ORA** Cl_2/electrophile is (more) polarised ✓ **ORA**	**3**	***ANNOTATIONS MUST BE USED*** **ALLOW** diagram to show movement of lone pair into ring but **delocalised** ring must be mentioned **ALLOW** lone pair of electrons on O is (partially) drawn/ attracted/pulled into **delocalised** ring **IGNORE** 'activates the ring' **DO NOT ALLOW** charge density or electronegativity **ALLOW** Cl_2 is (more) attracted **OR** Cl_2 is not polarised by benzene **OR** induces dipoles (in chlorine/electrophile)
			Total	**13**	

<table>
<tr><th colspan="3">Question</th><th>Expected Answers</th><th>Marks</th><th>Additional Guidance</th></tr>
<tr><td>3</td><td>a</td><td></td><td colspan="2">Alternative approaches</td><td rowspan="3">4</td><td rowspan="3">ALLOW ammoniacal $AgNO_3$/ $Ag^+(NH_3)_2$ / $Ag^+(NH_3)$
ALLOW acidified dichromate OR Fehlings as an alternative to Tollens – observation ‘turn green’ OR ‘red precipitate’ respectively
ALLOW acidified manganagate(VII) and observation as either brown precipitate/decolourised/pale pink
ALLOW Brady’s (reagent)
ALLOW orange/red/yellow for colour of the 2,4-DNP(H) precipitate
ALLOW solid/crystals in place of precipitate
IGNORE any reference to melting points
ALLOW PCl_5 as a test for the acid – observation would be ‘white fumes (of HCl)’

ALLOW detection of (carboxylic) acid by reacting with an alcohol to make an ester but no mark for the observation.

DO NOT ALLOW detection of (carboxylic) acid by pH or indicator

Please annotate, use ticks to show where marks are awarded</td></tr>
<tr><td></td><td></td><td></td><td>Tollens’ test AND ‘silver precipitate/mirror’ ✓
is the aldehyde ✓

react with 2,4-DNP(H) and ‘orange precipitate’ ✓

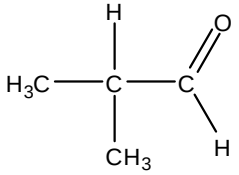
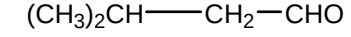
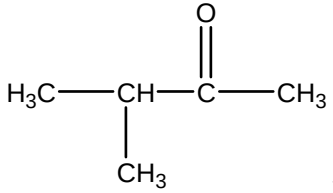
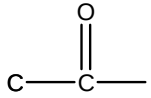
must be the ketone ✓</td><td>Tollens’ test AND ‘silver precipitate/mirror’ ✓
is the aldehyde ✓

react with carbonate/ hydrogencarbonate/ Na/Mg and ‘fizzes/ bubbles/ effervesces/ gas evolved ✓

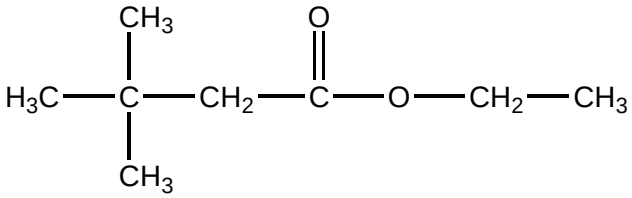
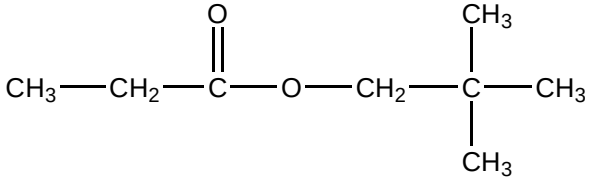
must be the (carboxylic) acid ✓</td></tr>
<tr><td></td><td></td><td></td><td>2,4-DNP(H) AND orange precipitate ✓
is either aldehyde OR ketone ALLOW carbonyl OR C=O✓

Tollens’ test & ‘silver ppt/mirror’ ✓
is the aldehyde ✓</td><td>2,4-DNP(H) and no orange precipitate ✓
is the (carboxylic) acid ✓

Tollens’ test & ‘silver ppt/mirror’ ✓
is the aldehyde ✓</td></tr>
<tr><td></td><td>b</td><td></td><td colspan="2">Peak in range 2500–3300 (cm^{-1}) or (around) 3000 shows O–H ✓
[need wavenumber (or range) <u>and</u> O–H bond]</td><td>1</td><td>DO NOT ALLOW single peak quoted within range 2500–3300 other than 3000 (cm^{-1}) for OH
DO NOT ALLOWrange 3200–3550 (cm^{-1})
IGNORE any reference to C-O or C=O</td></tr>
</table>

Question			Expected Answers		Marks	Additional Guidance
	c		**Alternative approaches depending on whether or not the aldehyde is correct**			**ALLOW** 3-methylbutanal , any correct unambiguous structure **ALLOW** two marks for correct aldehyde with no explanation **ALLOW** doublet/peak at 0.9ppm due to R–CH **ALLOW** the splitting shows adjacent to CH/environment that contains 1 H/proton **ALLOW** 6 Hs/ protons in same environment **DO NOT ALLOW** 6 Hs in same environment next to CHO e.g.  would score two marks if the doublet and the peak areas were correctly explained
			Doublet indicates adjacent C is bonded to only 1H **OR** (relative) peak area indicates 2 x CH_3 (in the same environment) ✓ If aldehyde is correct  ✓ ✓ *If aldehyde is correct **only** need to explain doublet **OR** peak areas*	Doublet indicates adjacent C is bonded to only 1H✓ **AND** (relative) peak area indicates 2 x CH_3 (in the same environment) ✓ If aldehyde identified is incorrect × *if aldehyde is incorrect **must** explain both doublet or peak areas*		
	d	i	 ✓ ketone **3**		1	**ALLOW** displayed/skeletal formulae
		ii	There are 4 (different C) environments ✓ (therefore) it is ketone **2 *I***  ✓ (C responsible for peak at δ = 210 ppm) is C=O/carbonyl carbon ✓		3	**ALLOW** 2 Cs are in same environment/equivalent **ALLOW** 3-methylbutan(-2-)one/ any correct unambiguous structure **ALLOW** 2-methylbutan-3-one **ALLOW** 
				Total	**12**	

Question			er	Mark	Guidance
4	(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			Answer	Mark	Guidance
4	(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			Answer	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**	