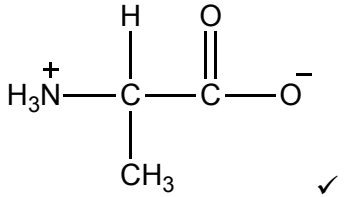
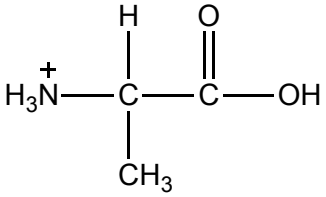
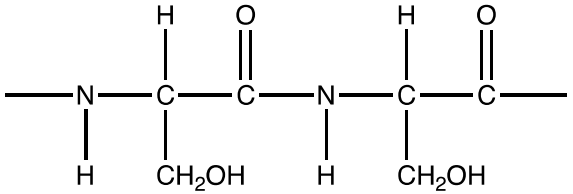
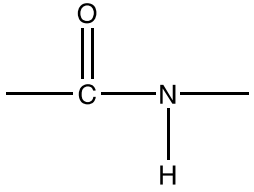
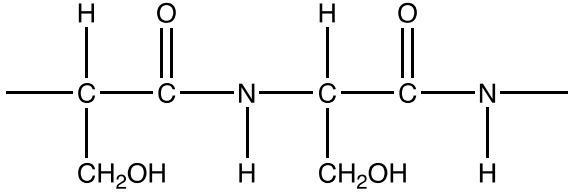
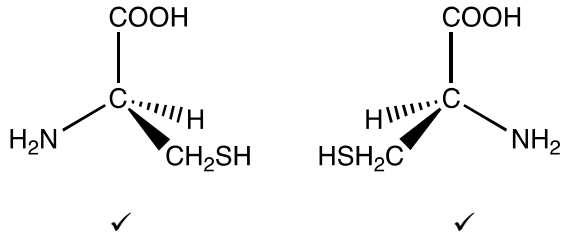
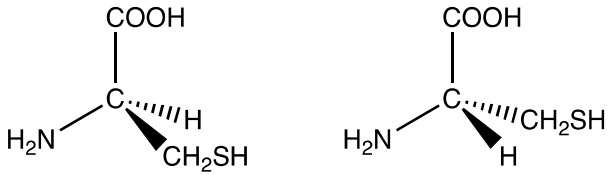
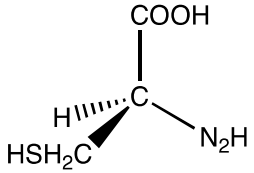
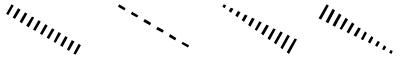
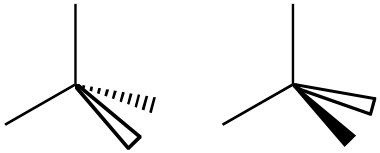
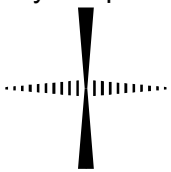
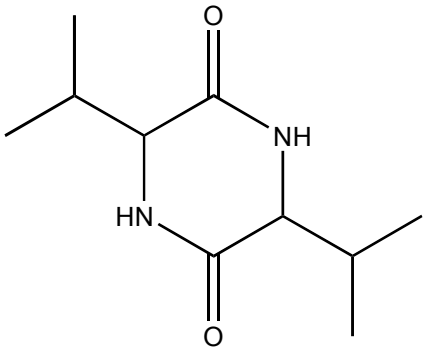
Question			Answer	Mark	Guidance
1	(a)	(i)	The pH **OR** point at which the zwitterion exists ✓	1	**ALLOW** pH/point at which there is no **overall**/**net** charge **IGNORE** pH/point at which there is no charge/ neutral charge *ie overall/net is required* **ALLOW** pH/point at which contains COO^- **AND** NH_3^+
		(ii)	 ✓  ✓	2	**ALLOW** $CH_3CH(NH_3)^+COO^-$ **ALLOW** $CH_3CH(NH_3)^+COOH$ **ALLOW** CO_2^- and CO_2H **ALLOW** + charge on N or H: ie $^+NH_3$ or NH_3^+ **DO NOT ALLOW '–'** charge on C: ie ^-COO **DO NOT ALLOW** H or CH_3 missing **ALLOW** correct structural **OR** displayed **OR** skeletal formula **ALLOW** combination of formulae as long as unambiguous

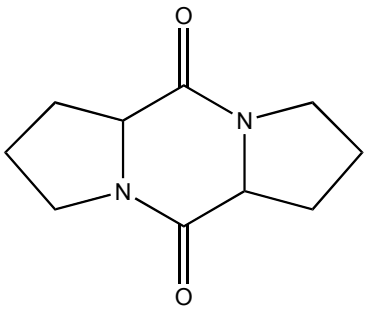
Question			Answer	Mark	Guidance
1	(a)	(iii)	pH < 3: COOH ✓ pH > 10: NH_2 ✓	2	**ALLOW** carboxyl group **OR** carboxylic acid **DO NOT ALLOW** 'acid' **OR** just 'carboxylic' (without 'acid') **ALLOW** amino group **OR** amine **DO NOT ALLOW** if give correct formula but wrong name or correct name and wrong formula eg NH_2 and amide **IF** any carbon chain is shown attached to **BOTH** functional groups **ALLOW** 1 mark eg CH_2COOH **AND** CH_2NH_2 for 1 mark CH_3COOH **AND** CH_3NH_2 for 1 mark RCOOH **AND** RNH_2 for 1 mark **IF** functional groups are shown the wrong way round, **ALLOW** 1 mark i.e. NH_2 COOH
	(b)		 peptide link **must** be fully displayed, i.e.  **TWO** repeat units shown correctly ✓	2	**DO NOT ALLOW** more repeat units **IGNORE** brackets and '*n*' **ALLOW** end bonds shown as ----- **DO NOT ALLOW** if end bonds are missing **ALLOW** terminal N–H on right (OR C=O on left), *ie*  **IF** peptide bond is shown not displayed, i.e. CONH, **2nd mark** can still be awarded

Question			Answer	Mark	Guidance
1	(c)	(i)	There is **no** chiral carbon **OR** there is no asymmetry in the molecule ✓	1	**ALLOW** there is **no** asymmetric carbon **OR** it has **no** non-superimposable mirror image **OR** there are **not** four different atoms/groups of atoms (attached to carbon) **OR** there are only three different atoms/groups of atoms (attached to carbon) **OR** because there are two hydrogen atoms on the carbon
		(ii)	 ✓ ✓	2	**ALLOW** Add the same 3-D structure repeated but with 2 groups 'swapped' as after rotation the 2nd isomer is a mirror image of the first, i.e.  **Connectivity:** Chiral C must be linked to the C of the COOH, the C of the CH_2SH and the N of the NH_2 (ie **connectivity is being tested**) ie, **ALLOW** as in the example but **DO NOT ALLOW** an attempted NH_2 shown as below:  The 2nd mark is for the mirror image of **CORRECT** optical isomer only **CARE**: may be orientated differently **DO NOT** penalise connectivity more than once **Each structure must have four central bonds, with at least one wedge in AND one wedge out**

Question			Answer	Mark	Guidance
					--- For bond into plane of paper, **ALLOW**:  For bond out of plane of paper, a solid wedge is expected, either way around:  **ALLOW** a hollow wedge for 'in bond' **OR** an 'out bond', provided it is different from the other in or out wedge eg:  **ALLOW** examples of other 3-D representations provided they are possible: i.e.  **CARE**: This is a 3-D representation so this is possible and the bonds are clearly not 90º to one another

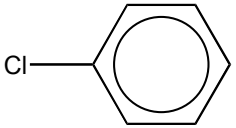
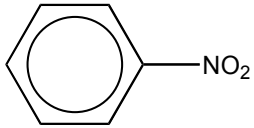
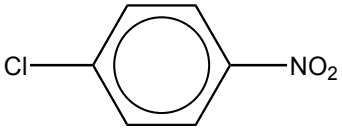
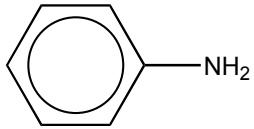
Question			Answer	Mark	Guidance
1	(c)	(iii)	***Disadvantages***: *any **two** from:* • (one stereoisomer might have harmful/adverse) side effects✓ • reduces the (pharmacological) activity/effectiveness ✓ • **cost** of separating stereoisomers **OR** difficulty in separating stereoisomers ✓ ***Synthesis of a single optical isomer*** *any **two** from:* • using enzymes or bacteria ✓ • using (chemical) **chiral** synthesis **OR** using **chiral** catalysts ✓ • using (natural) **chiral** molecules/compounds ✓ ***Quality of Written Communication*** For full marks to be awarded for this question chiral **OR** enzyme **OR** bacteria **OR** catalyst must be spelled correctly at least once in the correct context	2 2	***ANNOTATIONS MUST BE USED*** **IGNORE** harmful/adverse effects only **ALLOW** a response that implies an increased dose **IGNORE** it takes time to separate **ALLOW** biological catalysts **ALLOW chiral** transition metal complex/catalyst **OR stereoselective** transition metal complex/catalyst **ALLOW 'chiral** pool' **OR** L-amino acids / D-sugars

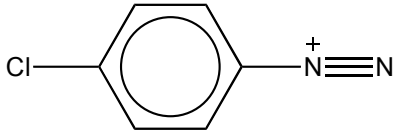
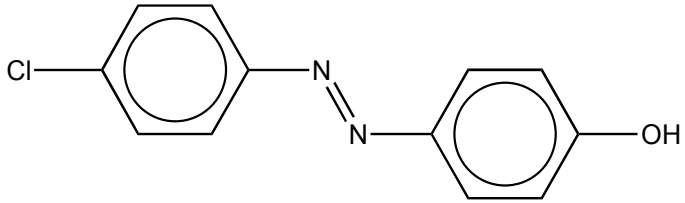
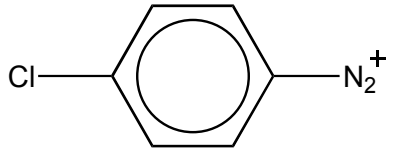
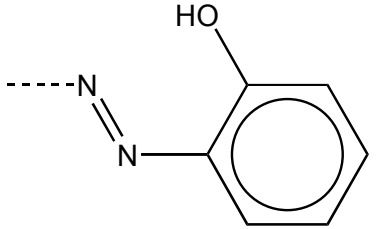
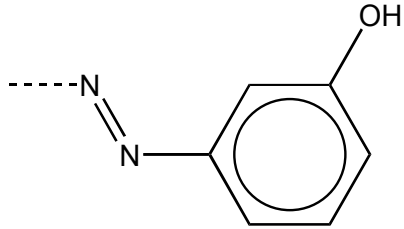
<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Mark</th><th>Guidance</th></tr>
<tr><td>1</td><td>(d)</td><td></td><td>
<table>
<tr><td>amino acid</td><td>isoleucine</td><td>leucine</td><td>tyrosine</td></tr>
<tr><td>number of peaks</td><td>6 ✓</td><td>5 ✓</td><td>7 ✓</td></tr>
</table>
</td><td>3</td><td>1 mark for each number</td></tr>
<tr><td></td><td>(e)</td><td></td><td>


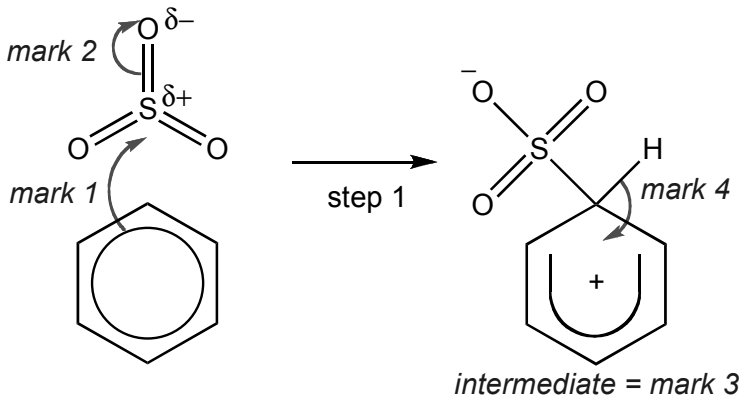
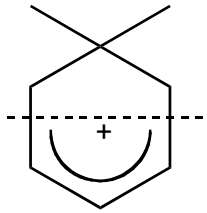


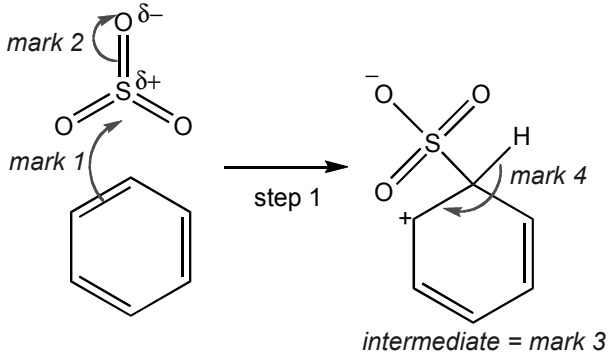
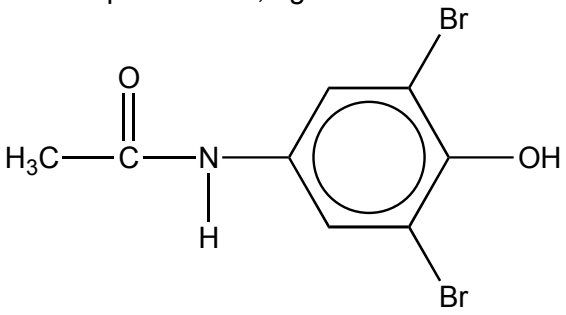
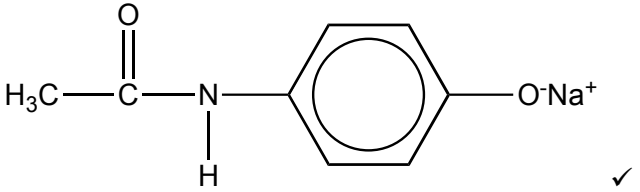
✓ valine anhydride
✓ proline anhydride
</td><td>2</td><td>ALLOW correct structural OR displayed OR skeletal formula
ALLOW combination of formulae as long as unambiguous

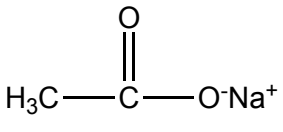
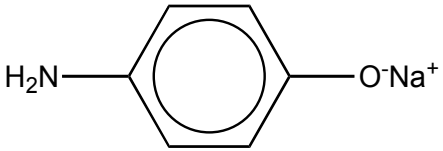
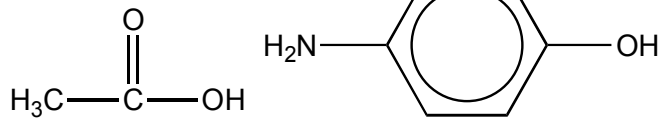
Common errors:
Look for NH_2 on first structure and NH on second structure</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>19</td><td></td></tr>
</table>

Question			Answer	Mark	Guidance
2	(a)	(i)	Response requires three stages • chlorination • nitration • reduction Reduction must be **a later stage** than nitration **Mark according to which sequence chosen.** **Stage 1** **organic product:**  **OR**  ✓ **chemicals:** Cl_2 **AND** $AlCl_3$ **OR** HNO_3 **AND** H_2SO_4 ✓ **Stage 2** **organic product:**  **OR**  ✓ **chemicals:** HNO_3 **AND** H_2SO_4 **OR** Sn **AND** HCl ✓ **Stage 3** **chemicals:** Cl_2 **AND** $AlCl_3$ **OR** Sn **AND** HCl ✓	5	Acceptable sequence of stages are: • nitration, reduction, chlorination • nitration, chlorination, reduction, • chlorination, nitration, reduction For organic products, **ALLOW** $C_6H_5NO_2$ **OR** C_6H_5Cl **OR** $C_6H_5NH_2$ **ALLOW** NO_2– **AND** NH_2– **DO NOT ALLOW** $ClC_6H_4NO_2$ (formula ambiguous) **DO NOT ALLOW** molecular formulae **IGNORE** any **additional** structures shown eg 2- (*ortho*) and 3- (*meta*) substituted isomers In chemicals boxes, **IGNORE** temperatures **IGNORE '**catalyst' For **chlorination** chemicals, **ALLOW** Cl_2 **AND** $FeCl_3$ **OR** Cl_2 **AND** Fe **OR** Cl_2 **AND** halogen carrier For **nitration** chemicals, 'concentrated' **not** required for HNO_3 OR H_2SO_4 **BUT** ... **DO NOT ALLOW** 'dilute' For **reduction** chemicals, 'concentrated' HCl **not** required but **DO NOT ALLOW** 'dilute' For Sn/HCl **ALLOW** addition of NaOH also **IF** it is clear that it is a second step **BUT** ……. **DO NOT ALLOW** Sn **AND** HCl **AND** NaOH **IGNORE** catalyst

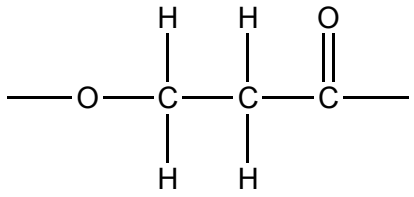
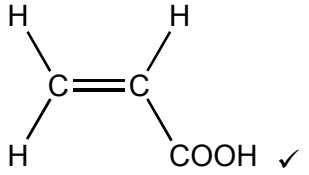
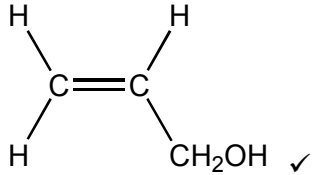
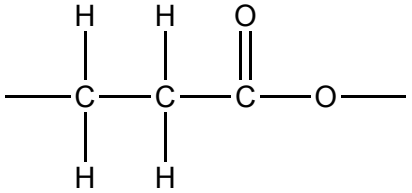
Question			Answer	Mark	Guidance
2	(a)	(ii)	**diazonium ion**  ✓ –N≡N group **MUST** be displayed **azo dye**  ✓ –N=N– group **MUST** be displayed	2	**ALLOW** '+' sign up to halfway along triple bond from left-hand N **IGNORE** presence of Cl^- **DO NOT ALLOW** Cl^- – substituent on benzene ring **DO NOT ALLOW:**  **In azo dye,** **ALLOW** as alternative to phenol OH group: O^- **OR** O^-Na^+ **OR** ONa **ALLOW** phenol part substituted at any carbon (ie 2,3 or 4 position for –OH) i.e.   **IGNORE** geometry/shape, i.e. **ALLOW** —N=N— **Mark independently** **DO NOT ALLOW** if Cl– is missing from benzene ring in **EITHER** structure

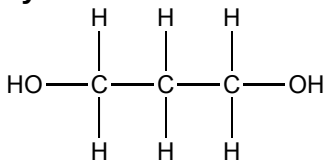
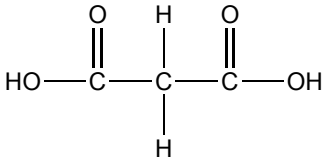
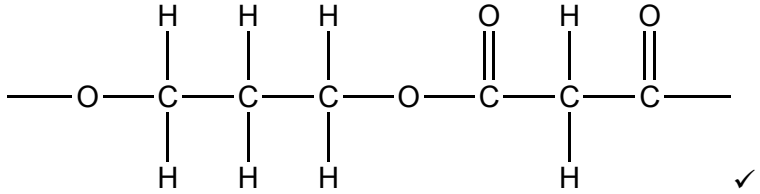
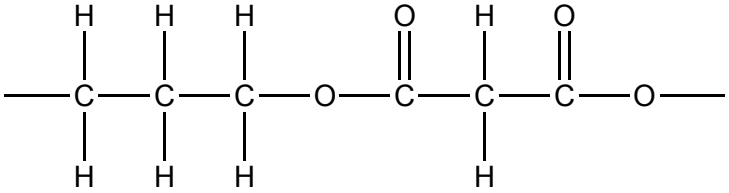
Question			Answer	Mark	Guidance
2	(b)			4	***ANNOTATIONS MUST BE USED*** **mark 1** – curly arrow from π-delocalised ring in benzene to $S^{\delta+}$ in SO_3 ✓ **ALLOW** curly arrow from the ring **OR** from within the ring **mark 2** – curly arrow from **one** S=O double bond to the O (to produce a S–O^-) ✓ **ALLOW** curly arrow to any O in SO_3 **mark 3** – intermediate showing delocalisation over 5 carbons ✓ Intermediate must have correct SO_3^- structure **FULLY** displayed **DO NOT ALLOW** intermediate with broken ring less than halfway up in correct orientation:  **mark 4** – curly arrow from C–H bond reforming π- delocalised ring in benzene ✓ **Stand alone mark** **IGNORE** responses after **STEP 2**

Question			Answer	Mark	Guidance
					ALLOW Kekulé mechanism  **ALLOW** double bonds shown in other Kekulé arrangement
2	(c)	(i)	Various possibilities, eg:  ✓		**ALLOW** 1, 2, 3 or 4 Br atoms substituted on phenol ring at carbon atoms 2, 3, 5 or 6 **BUT** –OH must be in correct position shown **DO NOT ALLOW** O^- or ONa **ALLOW** for side chain: CH_3CONH but aromatic part of structure must be shown **IGNORE** any additional inorganic products in boxes (even if incorrect
			Reaction with Na  ✓	2	**ALLOW** ONa **OR** O^- as alternative to O^-Na^+ **DO NOT ALLOW** O–Na **OR** O^-Na (i.e. Na without charge) –ONa must be in correct position shown **ALLOW** for side chain: CH_3CONH but aromatic part of structure must be shown **IGNORE** any additional inorganic products in boxes (even if incorrect)

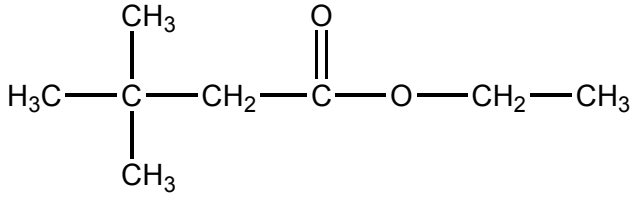
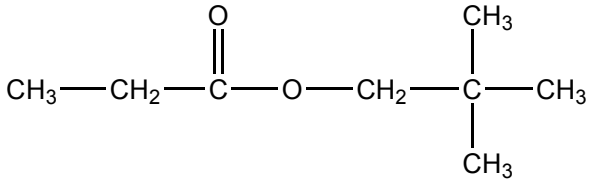
Question			Answer	Mark	Guidance
2	(c)	(ii)	**Hydrolysis with NaOH(aq)**  ✓  ✓ **Mark independently**	2	On **BOTH** structures, **ALLOW** ONa **OR** O^- as alternative to O^-Na^+ **DO NOT ALLOW** O–Na **OR** O^-Na (i.e. Na without charge) –ONa must be in correct position shown on 2nd structure **ALLOW** CH_3COONa/ CH_3CO_2Na **OR** CH_3COO^-/ $CH_3CO_2^-$ **ALLOW** one mark for carboxylic acid **AND** phenol, rather than sodium salts:  **ALLOW** NH_2–, CH_3– **IGNORE** any additional inorganic products in boxes (even if incorrect)
			Total	**15**	

Question			Answer	Mark	Guidance
3	(a)	(i)	One mark is for positive carbonyl test (Add) 2,4-dinitrophenylhydrazine **AND** orange/yellow/red precipitate ✓ One mark is for negative aldehyde test **EITHER** (Add) Tollens' reagent/Tollens' test **AND** **no** change **OR no** reaction **OR no** silver (mirror) **OR** (Add) H_2SO_4 **AND** $K_2Cr_2O_7$ **AND** **no** change **OR no** reaction **OR no** green colour ✓	2	**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 **ALLOW** $AgNO_3/NH_3$ (Formulae must be correct) **OR** ammoniacal silver nitrate **ALLOW** Fehling's solution **OR** Benedict's solution **AND no** (brick-red) precipitate **ALLOW** any response that implies that nothing happens **ie no** change **OR no** reaction **OR no** silver (mirror) **ALLOW** 'the aldehyde/pentanal gives a silver mirror' **ALLOW** H^+ **AND** $Cr_2O_7^{2-}$ (Formulae must be correct) **ALLOW** any response that implies that nothing happens **IGNORE** responses using $NaBH_4$ (as no observations)
		(ii)	**1st mark** Take melting point of orange crystals/derivative/product from 2,4-DNP ✓ **2nd mark** Compare melting point with known values **OR** compare melting point with value in database/reference book ✓	2	**NOTE**: **a(ii)** is marked completely independently of **a(i)** **Mark independently of response for 1st mark** **DO NOT ALLOW** 1st or 2nd marks for taking and comparing boiling points **OR** chromatograms

Question			Answer	Mark	Guidance
3	(b)	(i)	**Synthesis 1**  ✓ Ester linkage **must** be fully displayed **Synthesis 2**  ✓  ✓	6	**NOTE: ALL** Structures **MUST** have Hs shown **IGNORE** bond angles **DO NOT ALLOW** more than one repeat unit **IGNORE** brackets and '*n*' **ALLOW** terminal O— on right (**OR** C=O on left), i.e.  **ALLOW** end bonds shown as ----- **DO NOT ALLOW** if structure has **no** end bonds

Question			Answer	Mark	Guidance
			Synthesis 3  ✓  ✓  ✓		**Mark each structure independently** HO– **must** be connected correctly on **BOTH** structures **DO NOT ALLOW** more repeat units **IGNORE** brackets and '*n*' **ALLOW** terminal O— on right (**OR** C=O on left), i.e.  **ALLOW** end bonds shown as ----- **DO NOT ALLOW** if structure has **no** end bonds **DO NOT ALLOW ECF** from wrong structure in previous boxes
3	(b)	(ii)	**Synthesis 1**: condensation **AND** **Synthesis 2**: addition **AND** **Synthesis 3**: condensation ✓	1	**All** three correct responses required for the mark
			Total	**11**	

Question			Answer	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**	