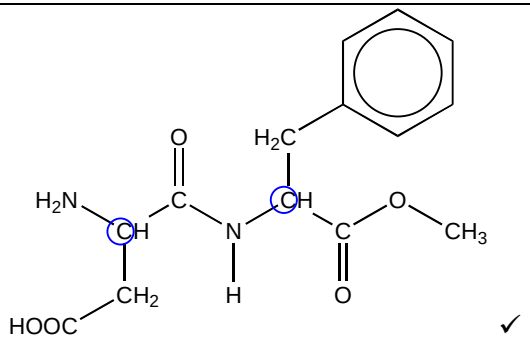
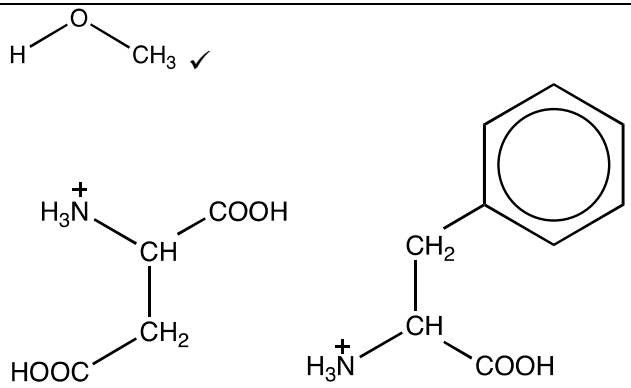
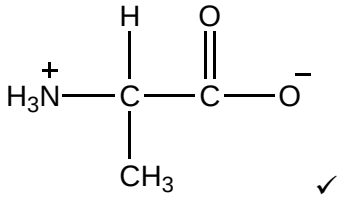
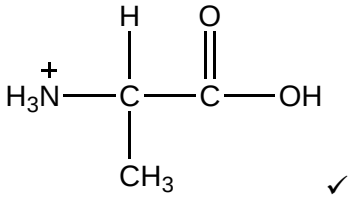
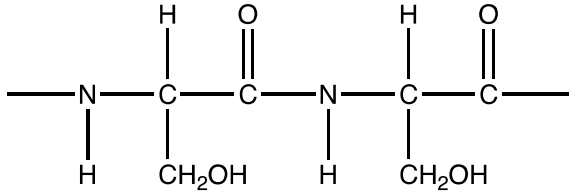
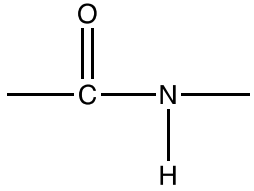
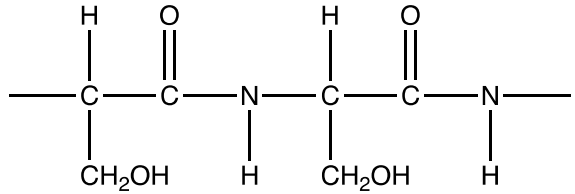
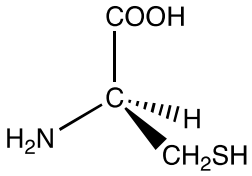
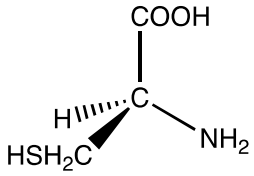
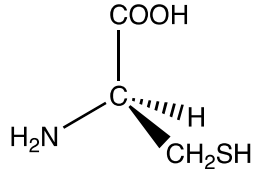
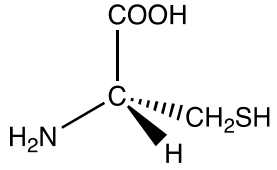
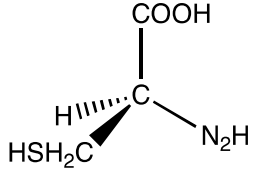
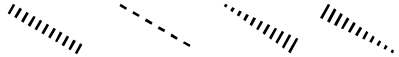
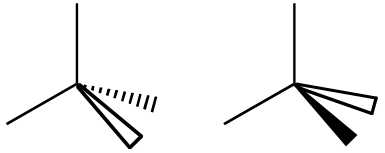
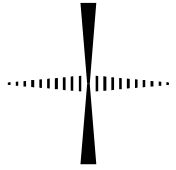
Question			Answer	Mark	Guidance
1	(a)	(i)	 ✓	1	Circles can be around C **OR** CH atoms but must **not** include other atoms **ALLOW** any suitable way of highlighting chiral carbons, e.g. asterisk, * **Note**: Mark the circles and ignore other working on diagram
		(ii)	carboxyl **OR** carboxylic acid, amine, amide, ester must be **names** 2 marks for 4 correct functional groups ✓✓ 1 mark for 3 correct functional groups ✓	2	**ALLOW** peptide for amide
	(b)		 ✓ 1 mark for left-hand amino acid with NH_3^+ **OR** NH_2 ✓ 1 mark for right-hand amino acid with NH_3^+ **OR** NH_2 ✓ 1 mark for **both** amino acids shown with NH_3^+ ✓	4	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** + charge on H of NH_3 groups, ie NH_3^+ **Note**: If there are more than three structures shown, credit any correct structures and ignore incorrect structures

Question			Answer	Mark	Guidance
	(c)		(adverse) side effects **OR** toxicity **OR** irritation ✓	**1**	**ALLOW** a stated adverse side effect, *eg* allergy, carcinogenic, hyperactivity etc **IGNORE** references to optical isomers, chirality, etc **IGNORE** vague statements such as harmful to body, dangerous to body **DO NOT ALLOW** obesity, corrosive to body **ALLOW** company liable to litigation/damages **Note**: Scroll down to bottom of page to check for any further writing
			Total	**8**	

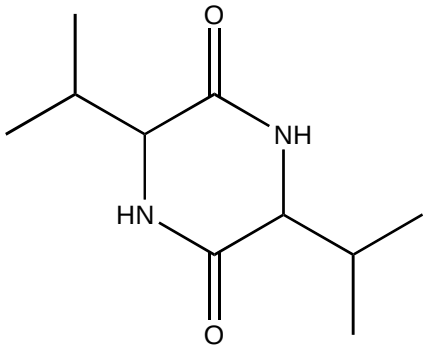
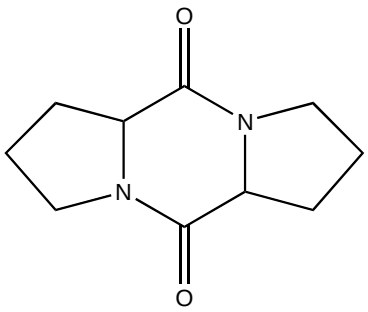
Question			er	Mark	Guidance
2	(a)	(	The pH **OR** point at which the zwitterion exists ✓	1	**ALLOW** pH/point at which there is no **overall/net** charge **IGNORE** pH/point at which there is no charge/ neutral charge *ie overall/net is required* **ALLOW** pH/point at which contains COO^- **AND** NH_3^+
		(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

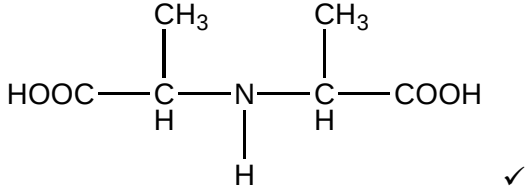
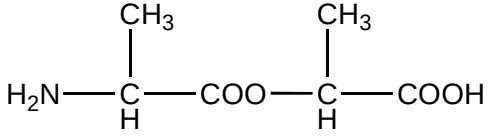
Question			er	Mark	Guidance
	(a)	(iii)	pH < 3: COOH ✓ pH > 10: NH_2 ✓	2	**ALLOW** carboxyl group **OR** carboxylic acid **DO NOT ALLOW** 'acid' **OR** just 'carboxylic' (without 'acid') **ALLOW** amino group **OR** amine **DO NOT ALLOW** if give correct formula but wrong name or correct name and wrong 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

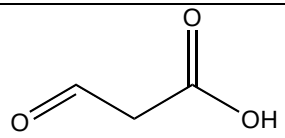
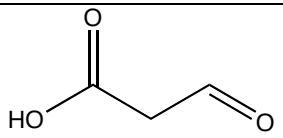
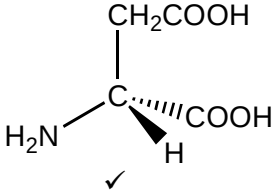
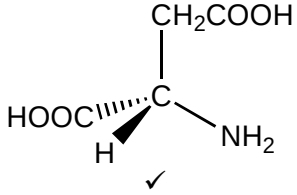
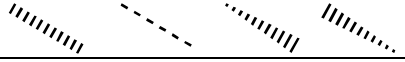
Question			er	Mark	Guidance
	(c)	(	There is **no** chiral carbon **OR** there is no asymmetry in the molecule ✓	1	**ALLOW** there is **no** asymmetric carbon **OR** it has **no** non-superimposable mirror image **OR** there are **not** four different atoms/groups of atoms (attached to carbon) **OR** 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.   **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**

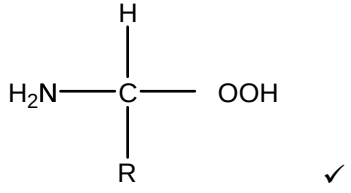
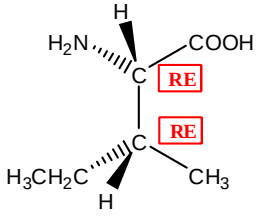
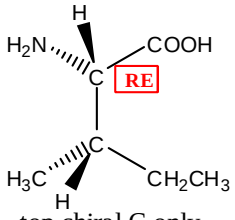
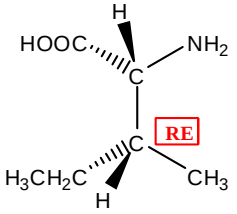
Question			er	Mark	Guidance
					--- For bond into plane of paper, **ALLOW**:  For bond out of plane of paper, a solid wedge is expected, either way around:  **ALLOW** a hollow wedge for 'in bond' **OR** an 'out bond', provided it is different from the other in or out wedge eg:  **ALLOW** examples of 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

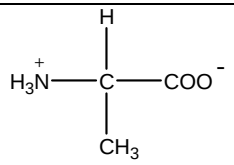
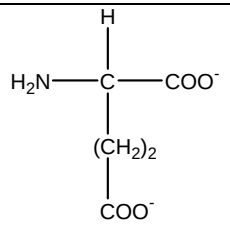
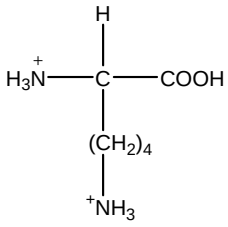
Question			Answer	Mark	Guidance
	(c)	(iii)	***Disadvantages***: *any **two** from:* • (one stereoisomer might have harmful/adverse) side effects✓ • reduces the (pharmacological) activity/effectiveness ✓ • **cost** of separating stereoisomers **OR** difficulty in separating stereoisomers ✓ ***Synthesis 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

Question			er	Mark	Guidance
	(d)		<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>	3	1 mark for each number
	(e)		 ✓ **valine anhydride**  ✓ **proline anhydride**	2	**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
			Total	**19**	

Question			Answer	Mark	Guidance
3	(a)	(i)	$ClCH(CH_3)COOH + 3NH_3 \rightarrow H_2NCH(CH_3)COO^- + NH_4^+ + NH_4Cl$ ✓	1	**ALLOW** use of **two** NH_3: $ClCH(CH_3)COOH + 2NH_3 \rightarrow H_2NCH(CH_3)COO^- + NH_4^+ + HCl$ **ALLOW** products as above **OR** $H_2NCH(CH_3)COOH + NH_4Cl$ **ALLOW** use of **one** NH_3: $ClCH(CH_3)COOH + NH_3 \rightarrow H_2NCH(CH_3)COO^- + H^+ + HCl$ **ALLOW** products as above **OR** $H_2NCH(CH_3)COOH + HCl$ For alternatives below, for NH_4Cl, **ALLOW** $NH_4^+Cl^-$ **OR** $NH_4^+ + Cl^-$ for HCl, **ALLOW** H^+Cl^- **OR** $H^+ + Cl^-$ for $H_2NCH(CH_3)COO^- + NH_4^+$ **ALLOW** $H_2NCH(CH_3)COO^-NH_4^+$ **OR** $H_2NCH(CH_3)COONH_4$ **ALLOW** R in equation in place of CH_3 (either or both sides) **ALLOW** correct structural **OR** displayed **OR** skeletal formula **ALLOW** combination of formulae as long as unambiguous **DO NOT ALLOW** molecular formulae
	(a)	(ii)	 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **ALLOW** combination of formulae as long as unambiguous **ALLOW** product from carboxylate ion as nucleophile: 

Question			er	Mark	Guidance
	(b)	(i)	 **OR**  ✓	1	**DO NOT ALLOW** any structure containing C **OR** H (except in OH)
	(b)	(ii)	 ✓  ✓	2	**ALL** bond linkages must be correct, eg the chiral C must be linked to the C of the COOH, the C of the CH_2COOH and the N of the NH_2 (connectivity is being tested) The 2nd mark is for the mirror image of an amino acid. This could be any amino acid **EXCEPT** glycine **DO NOT** penalise connectivity more than once **ALLOW** R in equation in place of CH_2COOH (either or both sides) Each structure **must** have four central bonds, with at least two wedges, one in; one out For bond into paper, accept: 
	(c)		***Disadvantages*** *Any **two** from:* • (one stereoisomer might have harmful) side effects✓ • reduces the (pharmacological) activity/effectiveness ✓ • cost **OR** difficulty in separating stereoisomers ✓ ***Synthesis of a single optical isomer*** *Any **two** from:* • using enzymes or bacteria ✓ • using a chiral catalyst **OR** transition metal complex/transition metal catalyst ✓ • using chiral synthesis **OR** chiral starting material **OR** natural amino acid ✓	2 max 2 max	***ANNOTATIONS MUST BE USED*** **ALLOW** optical isomer **OR** enantiomers as alternative for stereoisomers **ALLOW** a response that implies an increased dose **ALLOW** biological catalyst **ALLOW** 'chiral pool' **OR** L-amino acids **OR** D-sugars
			Total	**8**	

Question			Expected Answers	Marks	Additional Guidance
4	(a)	(i)	adsorption ✓	1	**ALLOW** partition **OR** adsorbtion **IGNORE** solubility **OR** desorption **DO NOT ALLOW** absorption
		(ii)	measure how far each spot travels relative to the solvent front or calculate the R_f value ✓ compare R_f values to those for known amino acids ✓	2	**ALLOW** compare R_f values to database **ALLOW** compare to known amino acids **DO NOT ALLOW** retention times for first mark, but the 2nd mark would be available as ✓ ECF **ALLOW** alternative approach: on the same plate compare position of spots ✓ with known amino acids ✓
		(iii)	(amino acids won't separate because) similar compounds have similar R_f (values) ✓	1	**ALLOW** spots often overlap **OR** don't (fully) separate **ALLOW** they have similar R_f (values) or similar adsoptions or similar retention times ECF to **a(ii)**
	(b)	(i)	 ✓	1	**ALLOW** $RCH(NH_2)COOH$ any order for R, NH_2 and COOH but C must be next to H 'CH' must be shown **ALLOW** CO_2H brackets around NH_2 are **not** essential **ALLOW** structure
		(ii)	must attempt 3D use RE symbol in the "tools" to denote whether or not each chiral C is a reflection of the one given in the question  both chiral Cs are mirror images  top chiral C only is a mirror image  bottom chiral C only is a mirror image	3	each chiral C must have 2 — bonds, 1 wedge bond (**IGNORE** shading) & 1 dash bond (**IGNORE** wedge) check the clockwise orientation of each C. For each C start with the H and if on the: • top C the H is followed by COOH it is not a mirror image. If it is a mirror image annotate using RE. • bottom C the H is followed by CH_3 it is not a mirror image. If it is a mirror image annotate using RE. the four groups can be attached in any order. If the molecule is drawn upside down – clockwise becomes anti-clockwise. **MUST** check that the drawn structure is non-superimposable irrespective of the orientation or the way it has been drawn. **IGNORE** bond linkage for all groups

	(c)		 alanine at pH = 6.0 ✓  glutamic acid at pH =10 ✓  lysine at pH = 2.0 ✓		**ALLOW** CO_2^- **ALLOW** NH_3^+ If NH_3 fully displayed **ALLOW** + charge on N or H If COO fully displayed **ALLOW** $^-$ charge on O only
	(d)		valine–glycine–leucine ✓	**1**	**ALLOW** val–gly–leu **DO NOT ALLOW** structures
	(e)		$H_2N(CH_2)_6NH_2$ ✓ $HOOC(CH_2)_8COOH$ ✓	**2**	**ALLOW** $H_2NCH_2CH_2CH_2CH_2CH_2CH_2NH_2$ **ALLOW** $HOOCCH_2CH_2CH_2CH_2CH_2CH_2CH_2CH_2COOH$ **ALLOW** CO_2H for COOH **ALLOW** acid chloride, $ClOC(CH_2)_8COCl$ **ALLOW** displayed formulae or skeletal formulae
			Total	**14**	