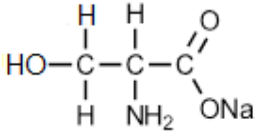
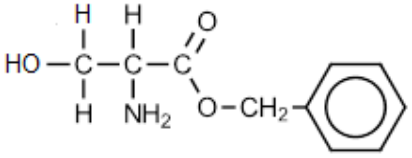
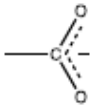
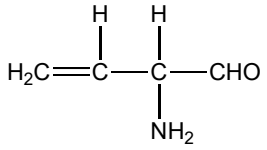
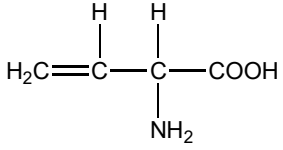
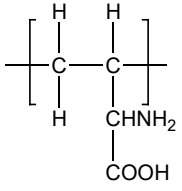
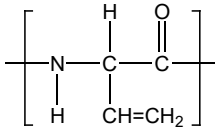
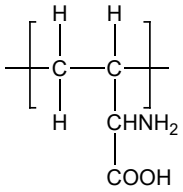
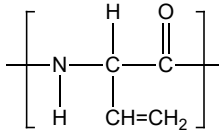
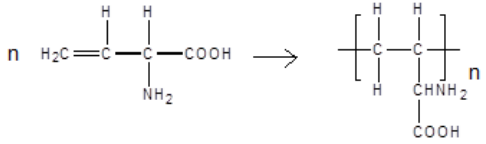
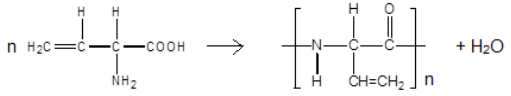
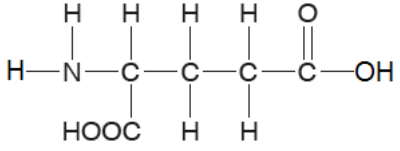
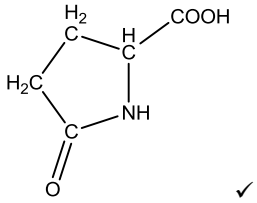
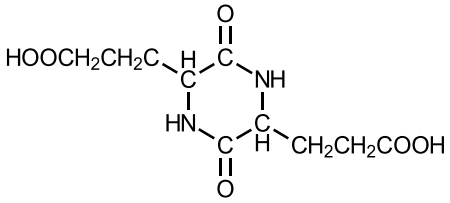
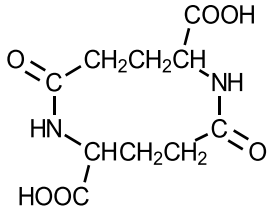
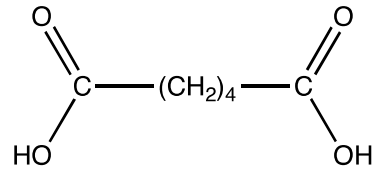
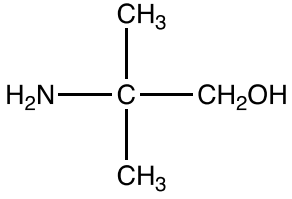
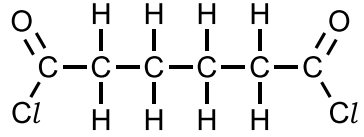
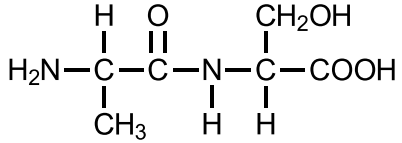
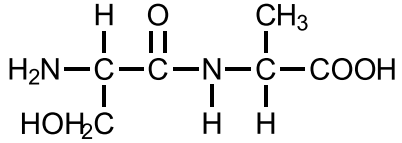
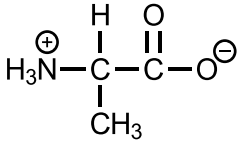
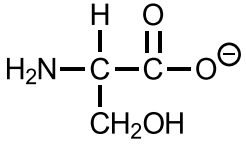
Question			Answer	Mark	Guidance
1	(a)	(i)	 ✓  ✓ $—NH_3^+$ in second product ✓	3	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW** $—O^-Na^+$ **OR** $—O^-$ (cation not required) **DO NOT ALLOW** —O—Na (covalent bond) **DO NOT ALLOW** –O (without the sodium) **ALLOW** delocalised carboxylate 
		(ii)	perfume/fragrance/flavouring ✓	1	**IGNORE** solvent **OR** food additive
		(iii)	Reaction 3: (hot) ethanolic ammonia ✓ Reaction 4: oxidation ✓ Reaction 5: hydrolysis ✓	3	**ALLOW** NH_3 (dissolved) in ethanol **IGNORE** other conditions **ALLOW** oxidisation/oxidised **DO NOT ALLOW** redox **ALLOW** nucleophilic addition-elimination **DO NOT ALLOW** nucleophilic substitution **IGNORE** acid/base

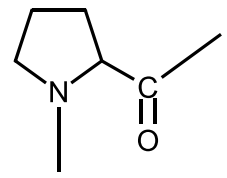
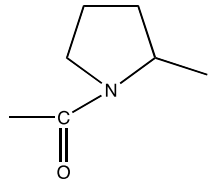
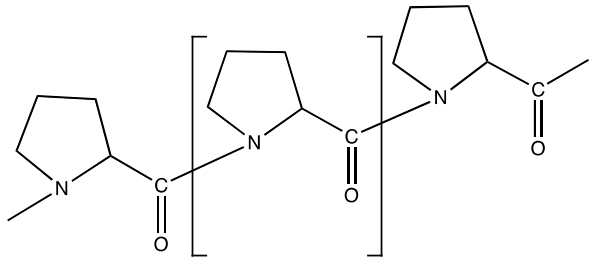
Question	Answer	Mark	Guidance
(b)	**M1** Compound **E**  ✓ **M2** Compound **F**  ✓ **M3** Compound **G**  ✓ **M4** Compound **H**  ✓	6	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous Labels are not required for compound E, F, G or H **IGNORE** labels for **M1**, **M2**, **M3** and **M4** CH_2=CH must be shown in **E** **ALLOW** C_2H_3 **OR** $CHCH_2$ for $CH=CH_2$ in **F** **ALLOW ECF** from error in structure of aldehyde E **ALLOW** multiple repeat units but must be full repeat units **ALLOW** end bonds shown as ..... **DO NOT ALLOW** if structures have no end bonds **IGNORE** brackets unless they are used to pick out the repeat unit from a polymer chain **IGNORE** n **ALLOW** $C_2H_4NO_2$ for $CH(NH_2)COOH$ in polymer **G** **ALLOW** C_2H_3 **OR** $CHCH_2$ for $CH=CH_2$ in polymer **H** **ALLOW ECF** from $NH_2CH_2CH=CHCOOH$ for the formation of compound G or compound H

Question			Answer	Mark	Guidance
			M5 Compound **G** **OR**  Is an addition polymer ✓ **M6** Compound **H** **OR**  is a condensation polymer ✓		**ALLOW** alkene forms addition polymer/polymer with same empirical formula as monomer **ALLOW** equation for reaction  **ALLOW** amino acid forms condensation polymer **OR** (molecules of) compound **F** join/bond/add/react/form polymer and water/small molecule **ALLOW** equation for reaction 
	(c)	**(i)**	 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous

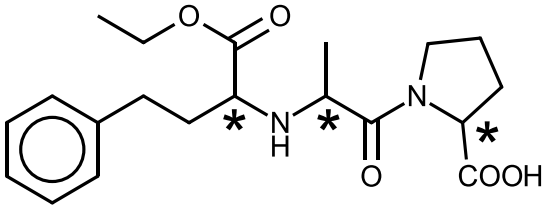
Question	Answer	Mark	Guidance
(ii)	 ✓  ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW** a cyclic amide with a 3 membered ring **ALLOW**  **OR** a structure obtained by condensation of a glutamic acid molecule with the first cyclic amide

Question			Answer	Mark	Guidance
	(d)	(i)	Ester **AND** amide ✓	1	**ALLOW** peptide for amide
		(ii)	 ✓  ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous Functional groups do not need to be fully displayed **ALLOW** structures as shown; the O-H bond and the N-H bonds in the functional groups **do not** need to be displayed **DO NOT ALLOW** -COOH **ALLOW**  Penalise incorrect connectivity to OH once in this question
		(iii)	(The molecule/amide/ester) can be hydrolysed ✓	1	**ALLOW** (the molecule/amide/ester) can form hydrogen/H-bonds with water **IGNORE** acid/base
			Total	**20**	

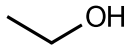
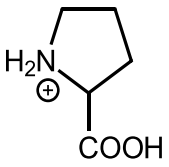
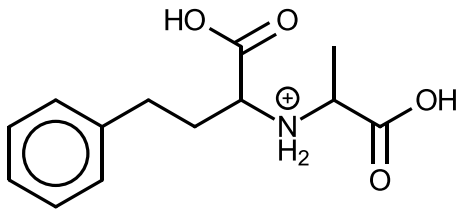
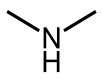
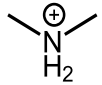
Question			Answer	Mark	Guidance
2	(a)	(i)	 ✓  ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous **DO NOT ALLOW** peptide chains
	(a)	(ii)	alanine at pH 6.0  ✓ serine at pH 10.0  ✓	2	**ALLOW** correct structural **OR** displayed **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

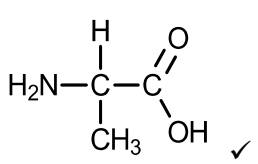
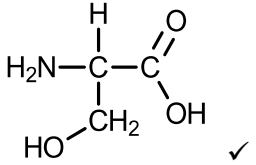
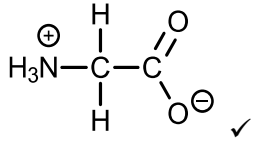
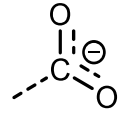
Question			Answer	Mark	Guidance
	(a)	(iii)	 ✓ **OR** 	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous **IGNORE** bond angles **DO NOT ALLOW** more than one repeat unit **ALLOW** end bonds shown as - - - - - **DO NOT ALLOW** if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

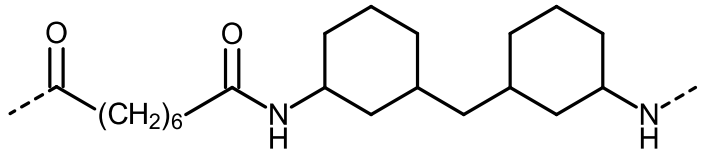
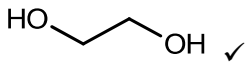
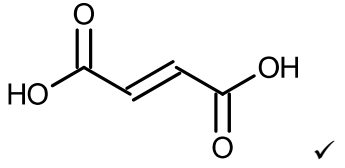
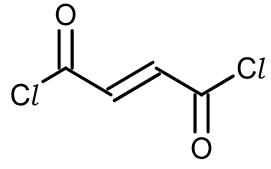
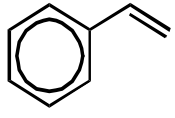
<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Mark</th><th>Guidance</th></tr>
<tr><td></td><td>(b)</td><td></td><td>
<table>
<tr><td colspan="3">^{1}H NMR spectrum for serine</td></tr>
<tr><td>chemical shift, δ /ppm</td><td>relative peak area</td><td>splitting pattern</td></tr>
<tr><td>2.0 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

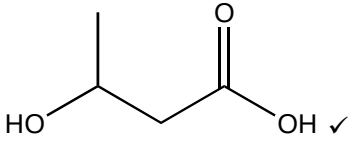
ALLOW a response that implies a splitting into three for a triplet/into two for a doublet</td></tr>
<tr><td></td><td>(c)</td><td>(i)</td><td> 

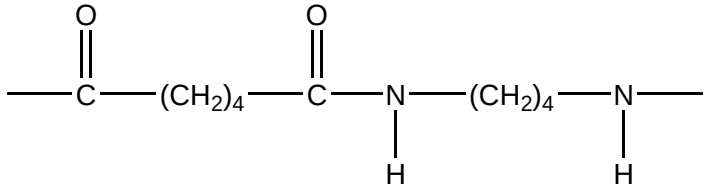
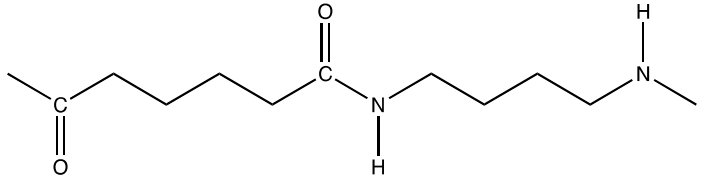
✓</td><td>1</td><td>ALL correct for one mark</td></tr>
<tr><td></td><td>(c)</td><td>(ii)</td><td>any two from:
no/fewer side effects
increases the (pharmacological) activity/effectiveness
Reduces/stops the need for/cost/difficulty in separating stereoisomers/optical isomers
✓✓</td><td>2</td><td>IGNORE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

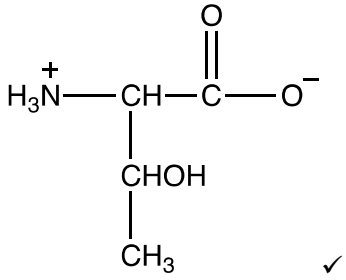
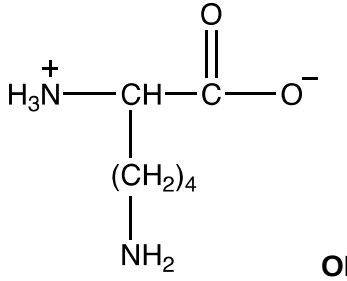
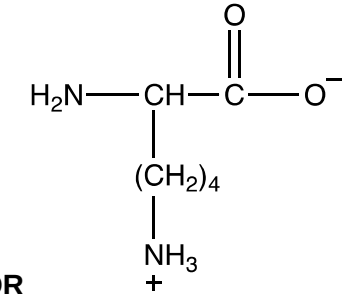
Question			Answer	Mark	Guidance
	(c)	(iii)	 ✓ one mark for ethanol  ✓ one mark for proline with NH **OR** NH_2^+  ✓ one mark for remaining fragment with  or  ✓ **Fourth** mark for structure of **both** ions shown correctly with NH_2^+	**4**	**ALLOW** correct structural **OR** displayed **OR** skeletal 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	Marks	Guidance
3	(a)	(i)	**monomers** join/bond/add/react/form polymer/form chain **AND** another product/small molecule *e.g.* H_2O/HC*l* ✓	1	**IGNORE** 'two' when referring to monomers, *i.e.* (two) monomers…
		(ii)	 ✓  ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous **ALLOW** zwitterions
		(iii)	The pH at which the zwitterion exists ✓  ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous **ALLOW** pH at which there is no **overall**/**net** charge **IGNORE** pH at which there is no charge/ neutral charge *ie overall/net is required* **ALLOW** pH at which contains COO^- **AND** NH_3^+  **ALLOW** delocalized carboxylate **ALLOW** + on N or H; - must be on O
	(b)	(i)	Adsorption ✓	1	**DO NOT ALLOW** absorption **ALLOW** partition **ALLOW** adsorbtion
		(ii)	R_f = 0.53 to 0.62 ✓ Amino acid is methionine ✓	2	Values vary if distance measured to middle or top of spot Independent marks. No need to show working as question asks for estimate of R_f

Question			Answer	Marks	Guidance
	(c)		 amide link ✓ correct structure ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous **ALLOW** 'terminal' —NH— at other end 'End bonds' **MUST** be shown (solid or dotted) **IGNORE** brackets and/or *n* **DO NOT ALLOW** aromatic rings in amine residue **ALLOW** CONH for amide link
	(d)	(i)	 ✓  Penalise connectivity once (i.e. not –HO)	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous For dicarboxylic acid: **ALLOW** dioyl chloride  **DO NOT ALLOW** the CIS monomer
		(ii)	 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous
			Total	**13**	

Question			er	Marks	Guidance
4	(a)	(	photodegradable **OR** light/sunlight/UV ✓	1	**IGNORE** IR/heat **IGNORE** bacteria **DO NOT ALLOW** burn/combustion
		(ii)	 ✓	1	**DO NOT ALLOW** structure with any C shown (especially as part of C=O) **DO NOT ALLOW** OH—
	(b)	(	ammonia/NH_3 **AND** ethanol **OR** ethanolic ammonia ✓	1	**ALLOW** ammonia in a sealed tube **IGNORE** heat **ALLOW** dilute ethanolic ammonia /NH_3 **DO NOT ALLOW** any reference to water or hydroxide ions, e.g. **DO NOT ALLOW** dilute ethanolic NH_3(**aq**) e.g. **DO NOT ALLOW** ethanolic NH_3 + NaOH
		(ii)	**Nitrogen** electron pair/lone pair accepts a proton/H^+ ✓ *Requires position of electron pair on N* $Cl^-H_3N^+(CH_2)_4N^+H_3\,Cl^-$ **OR** $ClH_3N(CH_2)_4NH_3Cl$ ✓	2	**DO NOT ALLOW** Nitrogen/N lone pair accepts hydrogen *proton/H^+ required* **ALLOW nitrogen** donates an electron pair **IGNORE** NH_2 group donates electron pair **ALLOW** + charge (if shown) on N or H of NH_3 e.g. $Cl^-H_3N^+(CH_2)_4NH_3^+Cl^-$ **DO NOT ALLOW** just $H_3N^+(CH_2)_4NH_3^+$ i.e. **2 x** Cl^- **MUST** be included

Question			er	Marks	Guidance
		(iii)	1 mark for amide/peptide link correctly displayed within an attempted repeat unit ✓ 1 mark for rest of structure correct including side links ✓ 	2	Minimum requirement is each end of a displayed amide group attached to a carbon atom (could be skeletal) Brackets **not** required **IF** more than one repeat unit has been drawn a single repeat unit **MUST** be identified by brackets or clear label **DO NOT ALLOW 2nd** mark if amide/peptide link wrong *1st mark requires amide group fully displayed* *For 2nd mark, **ALLOW** –CONH– in correct structure* **ALLOW** correct structural **OR** displayed **OR** skeletal formula **ALLOW** combination of formulae as long as unambiguous e. 

Question			er	Marks	Guidance
	(c)	(i)	One mark for each correct structure  ✓  **OR**  ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **ALLOW** combination of formulae as long as unambiguous **ALLOW** COO^- '–' charge must be on O of COO^- but **ALLOW** + sign shown as $^+NH_3$ **OR** NH_3^+ **BUT** only one NH_2 can be protonated in zwitterion
		(ii)	Zwitterion at pH 9.60/higher pH has **one** NH_2 group **OR** Zwitterion **OR** amino acid at pH 9.60/higher pH has a side chain with an NH_2 group ✓ **Note:** **ASSUME** that 'it' refers to zwitterion	1	**ALLOW** amino acid at 9.60/higher pH has **two** NH_2 groups **ALLOW** amino acid at 9.60/higher pH has more NH_2 groups **ALLOW** amine **OR** amino for NH_2 **IGNORE** CHOH slightly acidic
			Total	**10**	