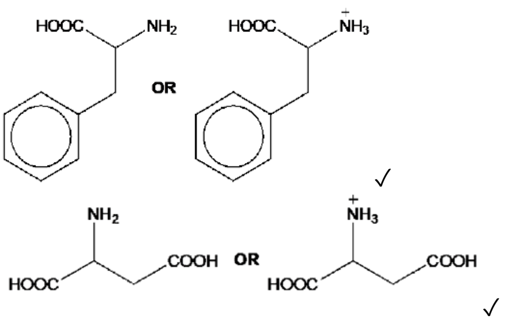
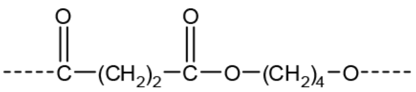
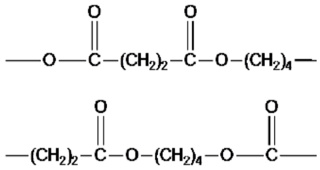
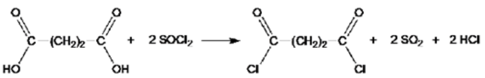
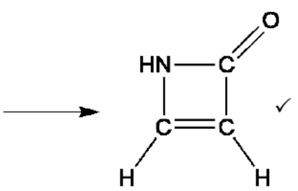
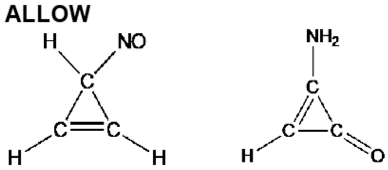
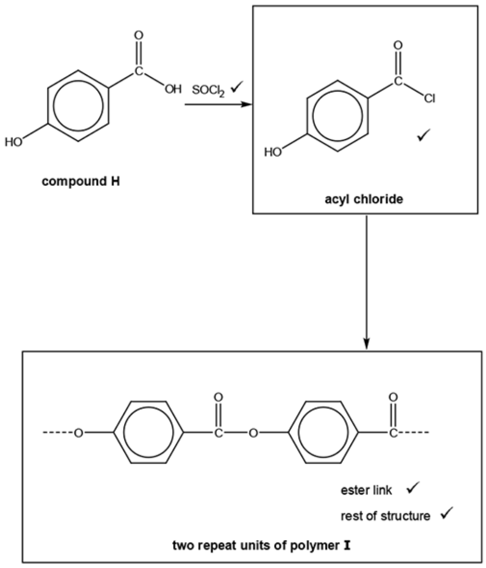
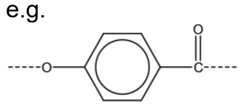
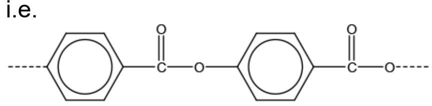
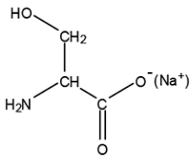
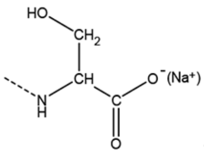
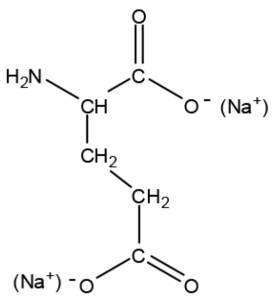
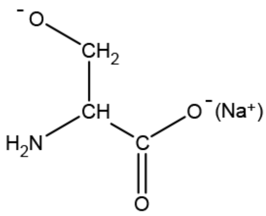
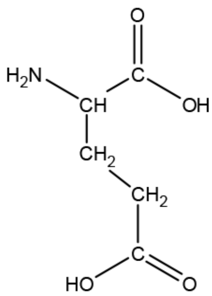
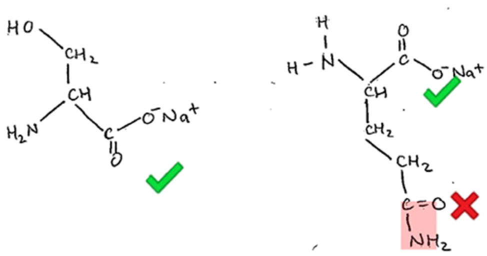
Mark scheme – Polyesters and Polyamides

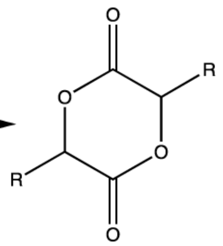
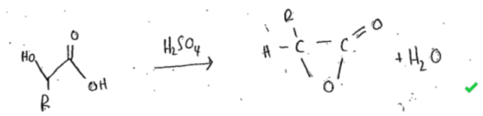
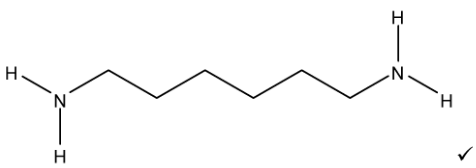
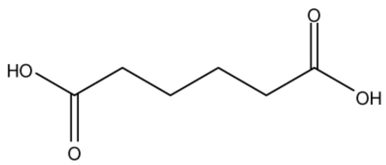
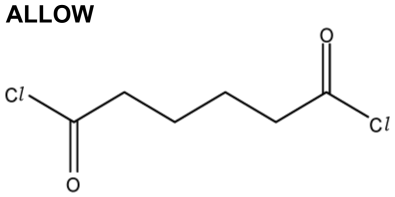
Question			Answer/Indicative content	Marks	Guidance
1		i	Ester Amide Amine Carboxylic acid 4 groups correct ✓ ✓ ✓ 3 groups correct ✓ ✓ 2 groups correct ✓	3 (AO1.2×3)	**IGNORE** amino acid **ALLOW** carboxyl **IGNORE** attempt to classify amide, e.g. secondary **IGNORE** formulae (question asks for names) **IF > 4** functional groups are shown, • Count 4 groups max but incorrect groups **first** **IGNORE** aryl **OR** alkyl group e.g. benzene, phenyl, aryl, arene, methyl
		ii	**Methanol** **1 mark** $H_3C — OH$ ✓  Both amino acids shown with NH_3^+ ✓	4 (AO2.5×4)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** + charge on H of NH_3 group, i.e.NH_3^+ If **BOTH** amino acids are shown with NH_3 groups (without the + charge) **OR** as NH_2^+ groups, award 2 of the 3 marks for the amino acids If **BOTH** amino acids are shown as correctly balanced salts, e.g NH_3Cl, all marks can be awarded.
		iii	**FIRST CHECK ANSWER ON THE ANSWER LINE** **If answer = 22.4 OR 22 OR 23 award 3 marks** n(aspartame) in 1 can = 0.167 / 294 = 5.68×10^{-4} (mol) ✓ n(aspartame) limit per day = $1.7 \times 10^{-4} \times 75$ = 0.01275 (mol) ✓ number of cans = 0.01275 / 5.68×10^{-4} = 22.4 ✓	3 (AO2.2×3)	**If there is an alternative answer, apply ECF and look for alternative methods** **Alternative methods** n(aspartame) in 1 can = 0.167 / 294 = 5.68×10^{-4} (mol) ✓ n(aspartame) per kg = 5.68×10^{-4} / 75 = 7.57×10^{-6} (mol) ✓ number of cans = 1.7×10^{-4} / 7.57×10^{-6} = 22.4✓ **OR** n(aspartame) limit per day = $1.7 \times 10^{-4} \times 75$ =0.01275 (mol) ✓ mass(aspartame) limit per day =0.01275 x 294 = 3.7485 (g) ✓

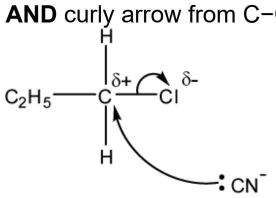
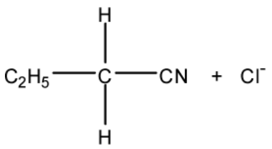
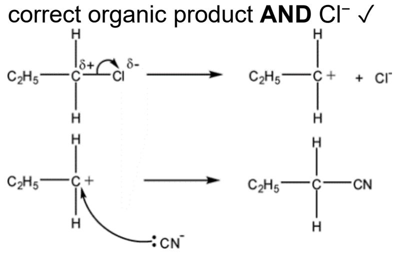
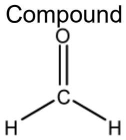
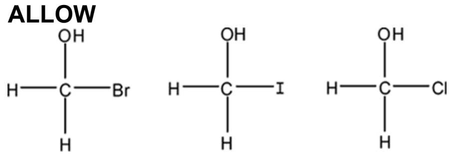
					number of cans = 3.7485 / 0.167 = 22.4 ✓
			Total	**10**	
2	i		 Ester link (must be displayed) ✓ Rest of structure ✓	2 (AO1.2) (AO2.5)	**ALLOW** the 'O' or C=O at either end, e.g.  **IGNORE** brackets **IGNORE** *n* End bonds' **MUST** be shown (solid or dotted) **DO NOT ALLOW** more than one repeat unit
	ii		the ester/ ester bond/ ester group /polyester can be broken down ✓ **OR** It can be hydrolysed ✓	1 (AO3.2)	**IGNORE** references to photodegradable 'Bond breaks' is not sufficient – no reference to ester bond
	iii		 $SOCl_2$ in equation ✓ Structure of diacyl dichloride ✓ Complete balanced equation ✓	3 (AO1.1) (AO1.2) (AO2.6)	**ALLOW** alternative approach using PCl_5 or PCl_3
			Total	**6**	
3			 ✓ + H_2O ✓ **Organic product** and **water** marked **independently**. *1st mark* correct organic product **OR** water **IGNORE** balancing numbers *2nd mark* **BOTH** products **AND** correctly balanced.	2 (AO3.2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW**  **NOTE**: For **ECF**, any structure must have correct number of bonds to C, H, O and N **DO NOT ALLOW** structure of dimer *Question states molecular formula =* C_3H_3NO **<u>Examiner's Comments</u>** Candidates were supplied with information about an unfamiliar reaction of an amino acid and asked to predict a possible equation. Many candidates suggested H_2O as one product, being the

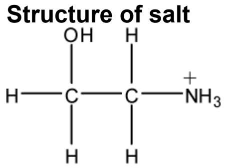
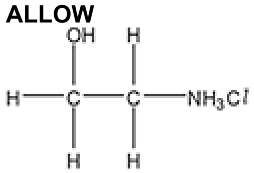
					difference in the formula of the amino acid and the C_3H_3NO cyclic organic product. Any cyclic structure of C_3H_3NO that met the bonding rules for C, H, N and O was credited. Examples included a 4-membered ring lactam and substituted cyclopropenes. A significant number of candidates showed an equation for the reaction of two molecules of the amino acid to form 2 H_2O and a cyclic dipeptide. Although chemically feasible, the dipeptide could not be credited because the molecular formula was C_3H_3NO in the question. This error could have been avoided if the information in the question had been used.
			Total	**2**	
4			One mark for each correct structure/reagent as shown below 	**4**	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** PCl_5 **OR** PCl_3 for reagent mark. **IGNORE** references to temperature for reagent mark **IGNORE** additional reagents shown with $SOCl_2$/PCl_5/PCl_3 e.g. H_2O, $AlCl_3$, HCl etc. **IGNORE** names *(question asks for structures of organic compounds and formula of reagent)* **DO NOT ALLOW** more than two repeat units **ALLOW** 1 mark for one correct repeat unit e.g.  'End bonds' **MUST** be shown (do not have to be dotted) **ALLOW** the 'O' at either end i.e.  **IGNORE** brackets **IGNORE** *n* **<u>Examiner's Comments</u>** Compound **H** was also the focus for this question. Most candidates were able to provide the structure of the acyl chloride obtained from **H** but only some identified $SOCl_2$ as the correct reagent. Common incorrect reagents included HCl and $AlCl_3$. Most candidates recognised that polymer **I** was a polyester but only some were able to draw two repeat units correctly. Candidates are advised to

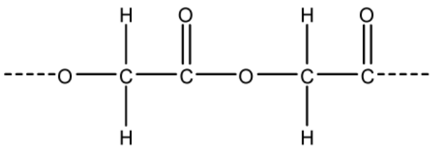
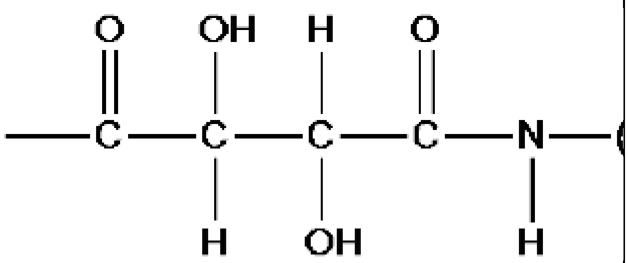
					practice drawing different polymers, taking care to ensure the correct number of repeat units are present when a specific number is required.
			Total	**4**	
5			 OR  ✓  ✓✓ i.e. one mark for each group hydrolysed	**3**	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** NH_3 *(question asks for organic products)* **ALLOW** $–COO^–$ **OR** –COONa **DO NOT ALLOW** negative charge on C atom **DO NOT ALLOW** –COO–Na (covalent bond) **BUT ALLOW ECF** if seen in subsequent structures **DO NOT ALLOW** COOH in this structure **DO NOT ALLOW** (sodium) salt of alcohol group i.e.  **ALLOW** COOH groups in this structure i.e. award 2 marks for  **IGNORE** small slip in carbon chain <u>**Examiner's Comments**</u> This question required candidates to apply their knowledge of amide hydrolysis to a section of protein. Many candidates correctly recognised that two amino acids would be produced but not all took account of the alkaline conditions and showed COOH groups rather than carboxylates. Candidates found this question difficult and although many gained some credit only the highest ability candidates, who recognised the amide in the side-chain would also react, scored

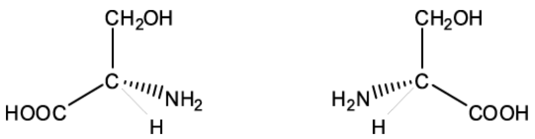
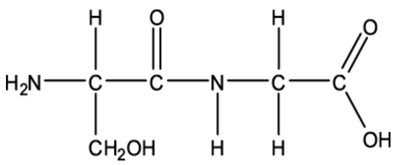
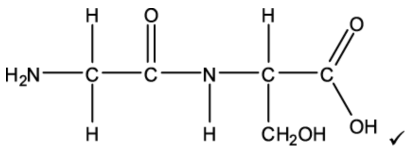
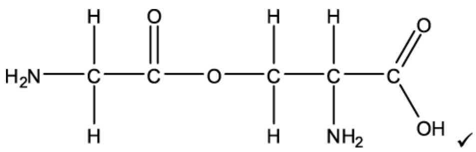
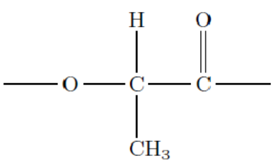
					full marks after. Exemplar 3 shows a good response. **Exemplar 3**  This response has correctly identified the amino acid on the left hand side of the amide link and also shown this as a carboxylate. Consequently the first mark has been achieved. The right hand amino acid has also been identified correctly. However, the amide in the R group has not been hydrolysed so this response only scores one of the two marks available for this product. Notice the candidate has presented their structures clearly with the atoms drawn in a similar arrangement to the protein shown in the question. This is a good strategy to avoid errors and omissions when drawing organic structures.
			Total	**3**	
6		i	***Equation*** 2HOCH(R)COOH + Mg → (HOCH(R)COO)$_2$Mg + H_2 Organic product ✓ Balance ✓ ***Type of reaction*** Redox ✓	**3**	**ALLOW** correct structural **OR** skeletal **OR** displayed formula **OR** mixture of the above as long as non- ambiguous **ALLOW** 2HOCH(R)COOH + Mg → 2HOCH(R)COO$^-$ + Mg^{2+} + H_2 **ALLOW** multiples **IGNORE** poor connectivity to OH groups *Given in question* **Examiner's Comment:** Candidates found this part difficult and the problem presented many opportunities for errors. Many candidates tried to show charges for the salt formed but often the 2+ charge was missing on Mg^{2+} or Mg^+ was shown. The balanced equation required a balancing 2 before compound A but this was often omitted. Candidates using skeletal formulae fared better than attempts to show

					structural formulae such as HOCHRCOOH, with many omitting the H atom from CHR. Few candidates identified the reaction as redox, with many giving neutralisation instead.
		ii	***Equation*** 2HOCH(R)COOH ⟶  + $2H_2O$ Organic product ✓ Balance ✓ ***Type of reaction*** Condensation **OR** esterification ✓	**3**	**ALLOW** correct structural **OR** skeletal **OR** displayed formula **OR** mixture of the above as long as non- ambiguous **ALLOW** 1 mark of the 2 equation marks for formation of '3 ring' with balanced equation:  **ALLOW** condensation polymerisation **ALLOW** addition–elimination **IGNORE** elimination **IGNORE** dehydration **Examiner's Comment:** As with 4(b)(ii), candidates found this question difficult. It was not often that the dimer was seen but, when it was, the structure was usually correct. Balancing required $2H_2O$ and the balancing 2 was often omitted. In contrast with 4(b)(i), many more candidates identified the type of reaction, here condensation or esterification.
			Total	**6**	
7	a	i	 ✓  ✓	**2**	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW**  **Examiner Comments** All but the weakest candidates scored two marks for the two monomers that could be used to produce Nylon 6,6.
		ii	$(n = \frac{21500}{226} =)$ 95 (repeat units) ✓	**1**	**MUST** be a whole number. **DO NOT ALLOW** an answer that uses an incorrect molar mass in the working. **ALLOW** 96 **Examiner Comments** This was a fairly simple calculation where candidates were expected to divide the relative molecular mass of the polymer by the relative

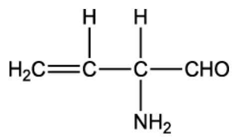
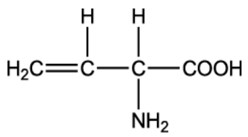
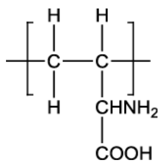
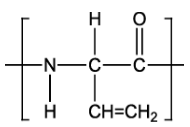
			Answer	Marks	Guidance
					molecular mass of a single repeat unit (226) to establish the number of repeat units present in the polymer. Many candidates obtained the correct answer. Those that did not gain credit made a simple error in their calculation of the relative molecular mass of the repeat unit. Answer 95
	b	i	curly arrow from ^{-}CN to carbon atom of C−C*l* bond ✓ Dipole shown on C–C*l* bond, $C^{\delta+}$ and $Cl^{\delta-}$, **AND** curly arrow from C−C*l* bond to C*l* atom ✓  correct organic product **AND** Cl^{-}✓ 	2	**ANNOTATE ANSWER WITH TICKS AND CROSSES** Curly arrow must come from lone pair on C of ^{-}CN OR CN^{-} **OR** from minus sign on C of ^{-}CN ion (then lone pair on CN^{-} does not need to be shown) **IGNORE** NaCl **ALLOW** S_N1 mechanism: Dipole shown on C–Cl bond, $C^{\delta+}$ and $Cl^{\delta-}$, **AND** curly arrow from C–C*l* bond to C*l* atom ✓ Correct carbocation **AND** curly arrow from ^{-}CN to carbocation. Curly arrow must come from lone pair on C of ^{-}CN **OR** CN^{-} **OR** from minus sign on C of ^{-}CN ion (then lone pair on CN^{-} does not need to be shown) ✓ correct organic product **AND** Cl^{-} ✓  **Examiner Comments** The mechanism for the reaction of 1-chloropropane was well done with the majority of candidates scoring two or three of the marks. Marks were not awarded when candidates used a negative charge or a lone pair sited on the nitrogen as the starting point for a curly arrow in the first stage of the reaction mechanism. The final marking point was awarded for the production of a Cl^{-} ion. The placing of curly arrows, dipoles and lone pairs of electrons are important when communicating by mechanisms.
		ii	Compound **G**  ✓	3	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** name(s) **ALLOW** 

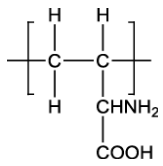
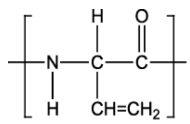
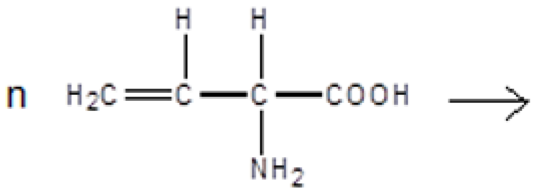
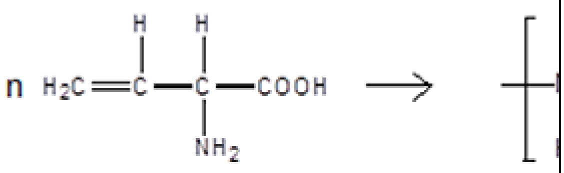
			Reagents **Reaction 2:** H_2 **AND** Ni ✓ **Reaction 3:** Correct formula of an aqueous acid e.g. $HCl(aq)/H_2SO_4(aq)$ ✓		**ALLOW** any suitable metal catalyst e.g. Pt **ALLOW** $LiAlH_4$ for reagent in reaction 2 **DO NOT ALLOW** $NaBH_4$ for reagent in reaction 2 **IGNORE** names *(question asks for formulae)* **IGNORE** references to temperature and/or pressure **ALLOW** $H^+(aq)$ **IGNORE** dilute **ALLOW** formula of an acid **AND** water e.g. HCl **AND** H_2O H_2SO_4 **AND** H_2O **Examiner Comments** Although many candidates were able to provide the structure of methanal as the starting material for this synthesis, the structures of chloromethanol, bromomethanol and iodomethanol were accepted as suitable alternatives. It should be noted that hydrolysis is carried out using aqueous acid and that dilute acid is not a suitable alternative.
		iii	**Explanation** Nitrogen electron pair **OR** nitrogen lone pair **AND** accepts a proton / H^+✓ **Structure of salt**  **AND** Cl^- ✓	**2**	**IGNORE** NH_2 group donates electron pair **ALLOW** nitrogen donates an electron pair to $\mathbf{H^+}$ **DO NOT ALLOW** nitrogen donates lone pair to acid **IGNORE** comments about the O in the –OH group Compound **H** is a base is **not sufficient** *(role of lone pair required)* **DO NOT ALLOW** nitrogen/N lone pair accepts hydrogen (*proton/H⁺ required*) **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW**  *i.e.* charges **not** required **IF** charges are shown **both** need to be present **ALLOW** charge either on **N** atom or NH_3^+ **IF** displayed then + charge must be on the nitrogen **Examiner Comments** Only 20% of candidates were awarded both marks for this question. The commonest error was a failure to state that the N atom has a lone pair of electrons that can gain a proton. Answers stating

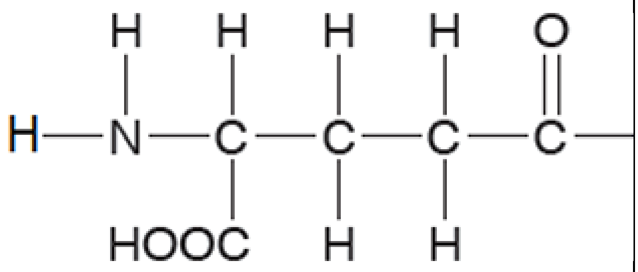
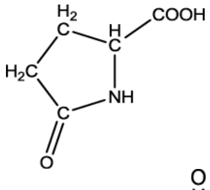
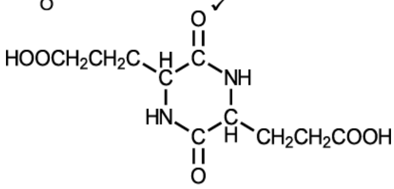
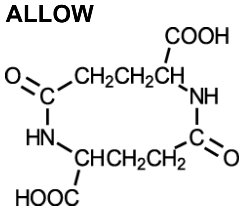
					that amines accept protons or that a salt is produced when an acid reacts with a base were not credited. Where a full displayed structure is given the positive charge must be shown on the nitrogen atom, although $-NH_3^+$ is acceptable. As the question required the formula of the salt, the Cl^- had to be included.
		iv	 Ester link ✓ Rest of structure✓ (polymer **J** is biodegradable because) the ester / ester bond / ester group / polyester can be hydrolysed✓	**3**	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW** more than two repeat units for second marking point. 'End bonds' **MUST** be shown (do not have to be dotted) **IGNORE** brackets **IGNORE** *n* Broken down by water is **not** sufficient **IGNORE** references to photodegradable **Examiner Comments** The most common mark for this question was two out of the three marks available, with candidates giving a correct structure of the polymer but failing to express that the polymer was biodegradable due the ability of the ester functional group to undergo hydrolysis.
			Total	**14**	
8		i	$C_2H_3O_3$ ✓	1	
		ii	2,3− dihydroxybutanedioic acid ✓	1	**ALLOW** 2,3−dihydroxybutane−1,4−dioic acid **ALLOW** absence of hyphens or extra hyphen or space, e.g. 2,3−dihydroxy butanedioic acid **ALLOW** full stops or spaces between numbers e.g. 2.3 dihydroxybutanedioic acid
		iii	 Correct amide link ✓ Rest of structure ✓	2	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous 'End bonds' **MUST** be shown **IGNORE** brackets **IGNORE** *n*

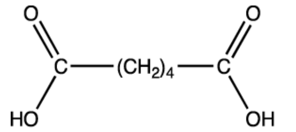
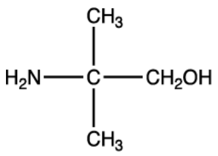
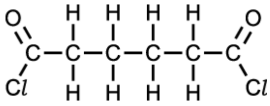
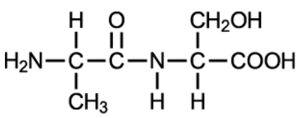
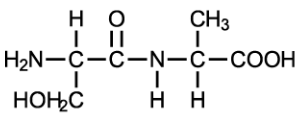
		iv	$[H_3N^+(CH_2)_6NH_3^+]$ $[^-OOC(CHOH)_2COO^-]$ **OR** $[H_3N(CH_2)_6NH_3]^{2+}$ $[OOC(CHOH)_2COO]^{2-}$ Positive ion correct ✓ Negative ion correct ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW** charge either on N atom or NH_3^+ Negative charge must be on COO^- **ALLOW**$[H_2N(CH_2)_6NH_3^+]$ $[^-OOC(CHOH)_2COOH]$
			Total	**6**	
9		i	(optical isomers are) non-super imposable mirror images ✓ Two 3D structures of serine that are mirror images irrespective of connectivity ✓  Correct connectivity in both structures ✓	3	
		ii	Dipeptide Ser-Gly  Dipeptide Gly-Ser  Esterification of OH on Ser 	3	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** structures in any order
			Total	**6**	
10		i	 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **DO NOT ALLOW** more than one repeat unit **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 **Examiner's Comments**

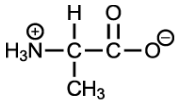
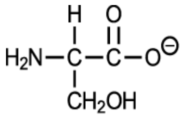
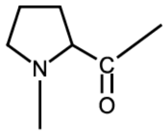
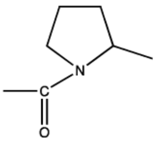
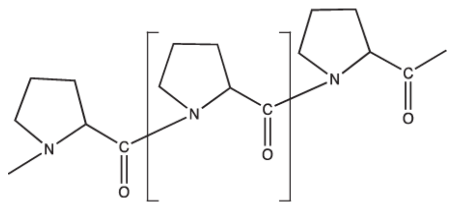
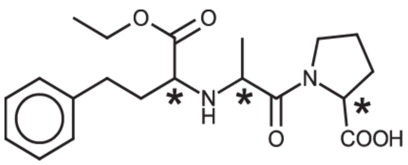
					Although many incorrect structures and structures with two repeat units were seen, this question was well answered by the majority of candidates.
		ii	(Ester links in PLA are) **hydrolysed** ✓ Any two from: • Ester (links in the polymer) **OR** (PLA is a) polyester • Monomer/lactic acid/product (is soluble because it) forms hydrogen bonds to water • polymer is photodegradable • the C=O bond absorbs radiation/uv/light ✓✓ ✎ **QWC**: **hydrolysed/hydrolysis/hydrolyses** spelled correctly in the correct context	3	**ANNOTATE WITH TICKS AND CROSSES ETC.** **ALLOW** (ester) **hydrolysis**/(ester) **hydrolyses** **IGNORE** acid/alkaline (hydrolysis) **IGNORE** PLA forms hydrogen bonds to water **IGNORE** biodegradable **IGNORE** infrared radiation Maximum of 2 marks if hydrolysed/hydrolysis/hydrolyses does not appear inthe answer **ALLOW** (ester) hydrolyzed **Examiner's Comments** The question discriminated well and relatively few candidates were able to score full marks despite there being several alternative scoring points listed in the mark scheme. Many based their answer on an explanation of the polymer dissolving in water rather than the dissolving process taking place after hydrolysis of the polymer chain.
			Total	**4**	
11		i	$H_2N(CH_2)_6NH_2$ ✓ $HOOC(CH_2)_4COOH$ ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW** acid chloride, $ClOC(CH_2)_4COCl$ **Examiner's Comments** Very well answered. The vast majority of candidates scored full marks on this question.
		ii		1	Both answers required for one mark

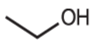
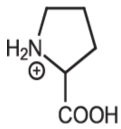
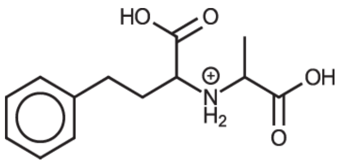
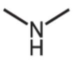
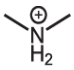
			<u>Type of condensation polymer</u> Polyamide **AND** <u>Use of condensation polymer</u> Fibres in clothing ✓		**ALLOW** nylon **IGNORE** numbers **IGNORE** polypeptide **DO NOT ALLOW** kevlar **ALLOW** any common use for nylon e.g. fibre, clothing, rope, fishing net, bristles, brushes,bags, cable ties etc. **DO NOT ALLOW** distinctive uses associated with kevlar or other polymers e.g. bullet-proof vests, crash helmets, bottles, cups **IGNORE** Plastic **Examiner's Comments** Generally well answered but many incorrect answers referred to Kevlar or the uses of Kevlar.
			Total	**3**	
12	a		**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**

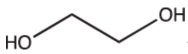
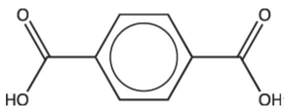
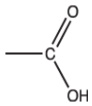
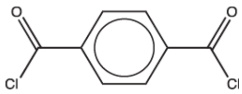
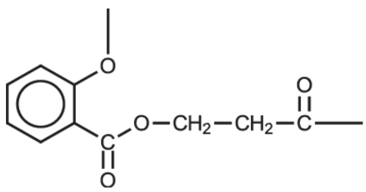
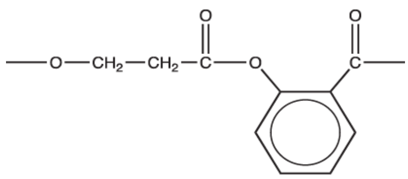
			M5 Compound **G** **OR**  Is an addition polymer ✓ **M6** Compound **H** **OR**  is a condensation polymer ✓		**ALLOW ECF** from $NH_2CH_2CH{=}CHCOOH$ for the formation of compound G or compound H **ALLOW** alkene forms addition polymer / polymer with same empirical formula as monomer **ALLOW** equation 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  **Examiner's Comments** This question discriminated well and many well organised and well-presented answers were seen. Candidates were usually able to identify the aldehyde structure in compound **E** and those who failed to include a chiral centre in compound **E** had possibly missed essential information in the stem of the question. However, they could still score marks for the polymer structures by the application of error carried forward. Some candidates correctly identified the four structures but then missed the last two marks for a description of how the polymers are formed. Although labels were not required to score marks for the four structures, the description of the formation of the polymers had to be linked to the correct structure or the correctly labelled compound and some candidates lost marks here because their description was linked to the wrong polymer.

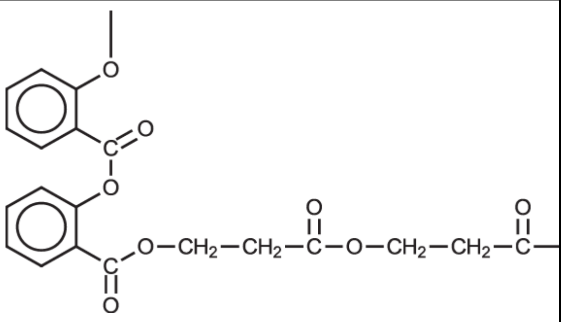
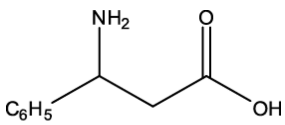
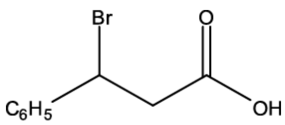
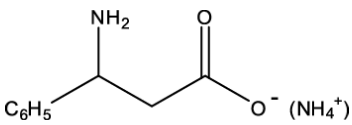
	b	i	 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **Examiner's Comments** The majority scored this mark for the structure of glutamic acid.
		ii	 ✓ ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **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 **Examiner's Comments** Marks were awarded for a variety of structures and although few candidates scored both marks here, examiners were impressed by the excellent attempts to produce workable cyclic structures.
	c	i	Ester **AND** amide ✓	1	**ALLOW** peptide for amide **Examiner's Comments** Identification of functional groups in polymers seemed to be an area of weakness. Many candidates correctly named one of the functional groups but both were required for the mark. Examples of incorrect responses included amine, carboxylic acid, alcohol and ketone.

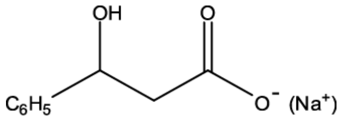
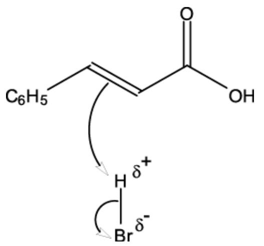
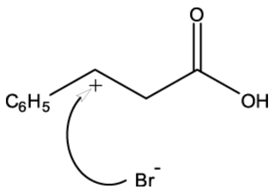
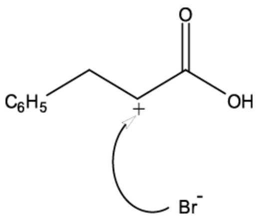
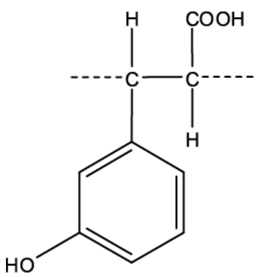
		ii	 ✓  ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous Functional groups do not need to be fully displayed **ALLOW** structures as shown; the O–H bond and the N–H bonds in the functional groups **do not** need to be displayed **DO NOT ALLOW** -COOH **ALLOW**  Penalise incorrect connectivity to OH once in this question **Examiner's Comments** The question asked for the functional groups to be displayed in the structures of the monomers. Most candidates scored well here but this was only possible because the mark scheme did not require the functional groups to be fully displayed.
		iii	(The molecule / amide / ester) can be hydrolysed ✓	1	**ALLOW** (the molecule / amide / ester) can form hydrogen / Hbonds with water **IGNORE** acid / base **Examiner's Comments** A well answered question with marks equally divided between answers that either suggested that the polymer can be hydrolysed or that the polymer can form hydrogen bonds with water. A statement that the polymer is soluble in water was not sufficient to score the mark.
			Total	**13**	
13	a	i	 ✓  ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous **DO NOT ALLOW** peptide chains **Examiner's Comments** Many correct dipeptide structures were seen. Common errors included peptide chains and including extra oxygen atoms in the amide link.
		ii	alanine at pH 6.0	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous

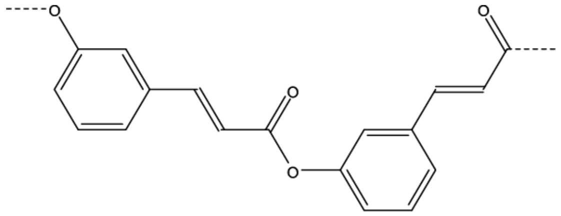
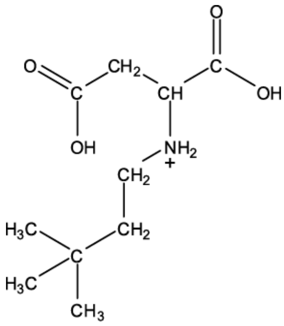
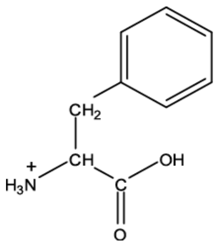
			 ✓ serine at pH 10.0  ✓		**ALLOW** + charge on N or H: *i.e.* $^+NH_3$ or NH_3^+ **DO NOT ALLOW** '—' charge on C *i.e.* ^-COO **DO NOT ALLOW** if structure is incomplete **Examiner's Comments** Most candidates gave the correct structure for the alanine zwitterion. Common errors include the protonation of the amine group and the ionisation of the alcohol group in serine.
		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*  **Examiner's Comments** This question proved to be a difficult challenge for many. Extra oxygen atoms or two repeat units were occasionally seen.
	b	i		1	**ALL** correct for one mark **Examiner's Comments** This part was answered well by many candidates. Some missed the chiral centre on the proline moiety or added an asterisk to a carbonyl carbon.
		ii	*any **two** from:* no / fewer side effects	2	**IGNORE** toxic / harmful

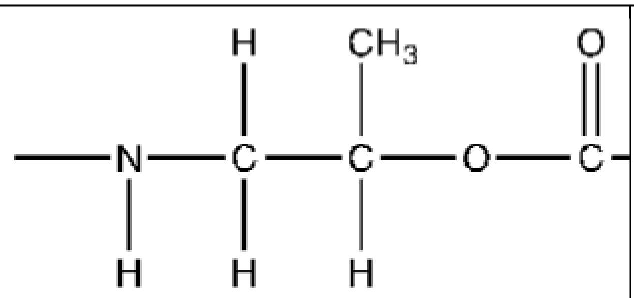
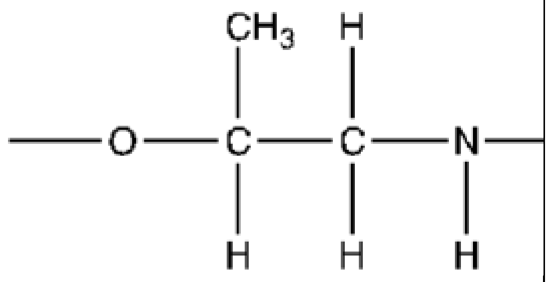
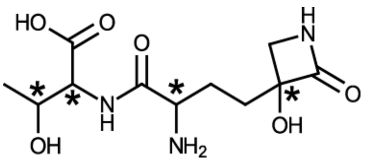
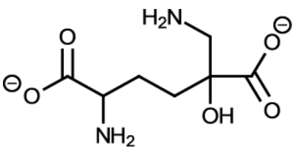
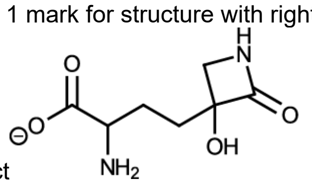
			increases the (pharmacological) activity / effectiveness Reduces / stops the need for / cost / difficulty in separating stereoisomers / optical isomers ✓✓		**IGNORE** a response that implies a reduced dose **IGNORE** “it takes (less) time to separate” **Examiner's Comments** Most candidates gained this mark by stating that the use of a single stereoisomer results in fewer side effects and increased pharmacological activity. Vague answers and comments about a reduced dose did not score marks.
		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 **Examiner's Comments** This question discriminated well. Most candidates were able to score one mark for the formula of ethanol. Only a small number of able candidates scored full marks for including the correct formulae for the protonated amine groups formed during acid hydrolysis.
		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 **Examiner's Comments** To get the mark for this question candidates had to include points about the separation of the mixture and identification of the compounds. Answers based on identification using retention times or measurement of molar mass did not score the mark.
			Total	**13**	
14		i	**monomers** join / bond / add / react / form polymer / form chain **AND** another product / small molecule / H_2O / HCl ✓	1	**IGNORE** specific reference to number of molecules **Examiner's Comments** Most candidates knew this definition and the

					majority of those who failed to score this mark omitted to the word *monomer*.
		ii	 ✓  ✓ Connectivity is penalised only in this question	2	**DO NOT ALLOW** —HO (penalise connectivity once only) Both structures must be skeletal **DO NOT ALLOW** stray sticks (skeletal means CH_3 attached) **DO NOT ALLOW** structure with a C shown, e.g.  **ALLOW**  **Examiner's Comments** Skeletal formulae were often very well drawn with incorrect connectivity being penalised very rarely. Some candidates knew the structure of the monomers but did not present them as skeletal formulae. If a structural formula is used for working it should be crossed out and not left as an alternative answer to the skeletal formula.
		iii	 ester link **MUST** be fully displayed ✓ **OR** 	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** combination of above as long as unambiguous **ALLOW**

					 **IGNORE** bond angles **DO NOT ALLOW** more than one repeat unit unless correct repeat unit is indicated **IGNORE** brackets with *n* **ALLOW** any correct repeat unit **ALLOW** end bonds shown as - - - - - **DO NOT ALLOW** if structure has no end bonds **Examiner's Comments** Many correct repeat units were seen. Common errors included missing off hydrogen atoms, adding extra oxygen atoms and connecting to the wrong position of the aromatic ring.
			Total	**4**	
15	a		**Product from NH_3/ethanol**  .... **Product from Reaction 1** 	3	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW**  **ALLOW ECF** from 2-bromo compound as product from Reaction 1 .... **DO NOT ALLOW** 2-bromo compound *(inconsistent with final product shown)* ....

			Answer	Marks	Guidance
			Product from NaOH(aq)		**DO NOT ALLOW ECF** from 2-bromo compound as product from Reaction 1 *(inconsistent with final product shown)*
					
	b				**ANNOTATE ANSWER WITH TICKS AND CROSSES**
			Curly arrow from C=C bond to H of H-Br		
					ALLOW any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous
			Correct dipole shown on H–Br **AND** curly arrow showing the breaking of H-Br bond		
					**DO NOT ALLOW** partial charges shown on C=C double bond
			....		**DO NOT ALLOW** δ+ on C of carbocation
			Correct carbocation **AND** curly arrow from Br^- to C^+ of carbocation		**ALLOW** formation of the 2-bromo isomer
					
			.... Electrophilic addition		Curly arrow must come from a lone pair on Br^- **OR** from the negative sign of Br^- ion (then lone pair on Br^- ion does not need to be shown)
	c	i		1	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous 'End bonds' **MUST** be shown (do not have to be dotted) **IGNORE** brackets **IGNORE** *n*

		ii	 Ester link Rest of structure	2	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous 'End bonds' **MUST** be shown (do not have to be dotted)
	d		 **OR** structure with NH rather than NH_2^+  **OR** structure with NH_2 rather than NH_3^+ $CH_3–OH$ Correct charge and number of protons on both nitrogen atoms	4	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous
			Total	**14**	
16	a	i	**Step 1**: add HCN **OR** H_2SO_4/KCN $CH_3CHO + HCN \rightarrow CH_3CH(OH)CN$ **Step 2**: react with H_2/Ni $CH_3CH(OH)CN + 2H_2 \rightarrow CH_3CH(OH)CH_2NH_2$	4	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous first mark can be implicit from equation. third mark can be implicit from equation if Ni shown as catalyst (*e.g.* above the reaction arrow) **ALLOW** $CH_3CH(OH)CN + 4[H] \rightarrow CH_3CH(OH)CH_2NH_2$
		ii	because (compound **D**) forms hydrogen bonds form **with** water demonstrated through diagram showing: - dashed line between —OH and (:)OH_2 - dashed line between —NH_2 and (:)OH_2	3	dipole and lone pair are **not** required **IGNORE** bond angles Diagram does **not** need to show all of Compound **D** (and **IGNORE** if wrong)

		iii	 **OR**  ester **AND** amide link rest of structure	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous 'End bonds' **MUST** be shown (solid or dotted) **IGNORE** brackets and / or *n*
	b	i	 for all four	1	
		ii	***Left-hand fragment***  **OR** structure with COOH rather than COO^- ***Right-hand fragment***  **OR** structure with COOH rather than COO^- Two **OR** three COO^- shown	4	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **ALLOW** 1 mark for structure with right-hand ring still intact 
			Total	**14**	