1(a). Molecules with more than one functional group are useful chemical 'building blocks'.

Compound **D**, $CH_3CH(OH)CH_2NH_2$, is an intermediate in the synthesis of a variety of drugs.

i. Compound **D** can be synthesised from ethanal, CH_3CHO.

Devise a **two-step** synthesis of compound **D** from ethanal.

- Give details of appropriate reagents and relevant conditions.
- Write an equation for each step, showing clearly all organic compounds.

[4]

ii. Explain why compound **D** is very soluble in water.

Use a diagram in your answer.

[3]

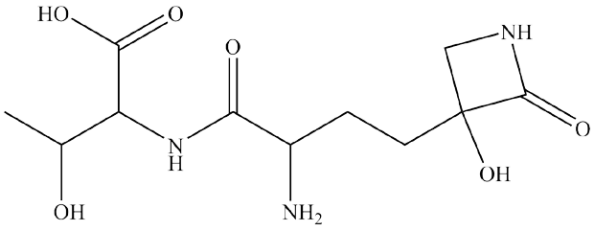
iii. Compound **D** reacts with propanedioic acid, $HOOCCH_2COOH$, to form a condensation polymer.

Draw a possible repeat unit of this condensation polymer.

Show clearly any functional group present in the repeat unit.

[2]

(b). Tabtoxin is a poisonous substance produced by bacteria found in lilac trees.



tabtoxin

i. Identify the chiral centres present in a molecule of tabtoxin.

On the structure above, mark each chiral centre with an asterisk, *.

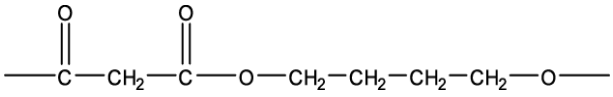
[1]

ii. Tabtoxin can be broken down by alkaline hydrolysis.

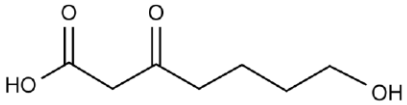
Draw the structures of **all** the organic products of the alkaline hydrolysis of tabtoxin.

[4]

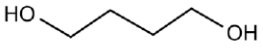
2. A chemist synthesises the following polymer.



Which monomers could be used?



1



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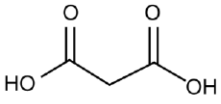


3

A. 1, 2 and 3
B. Only 1 and 2
C. Only 2 and 3
D. Only 1

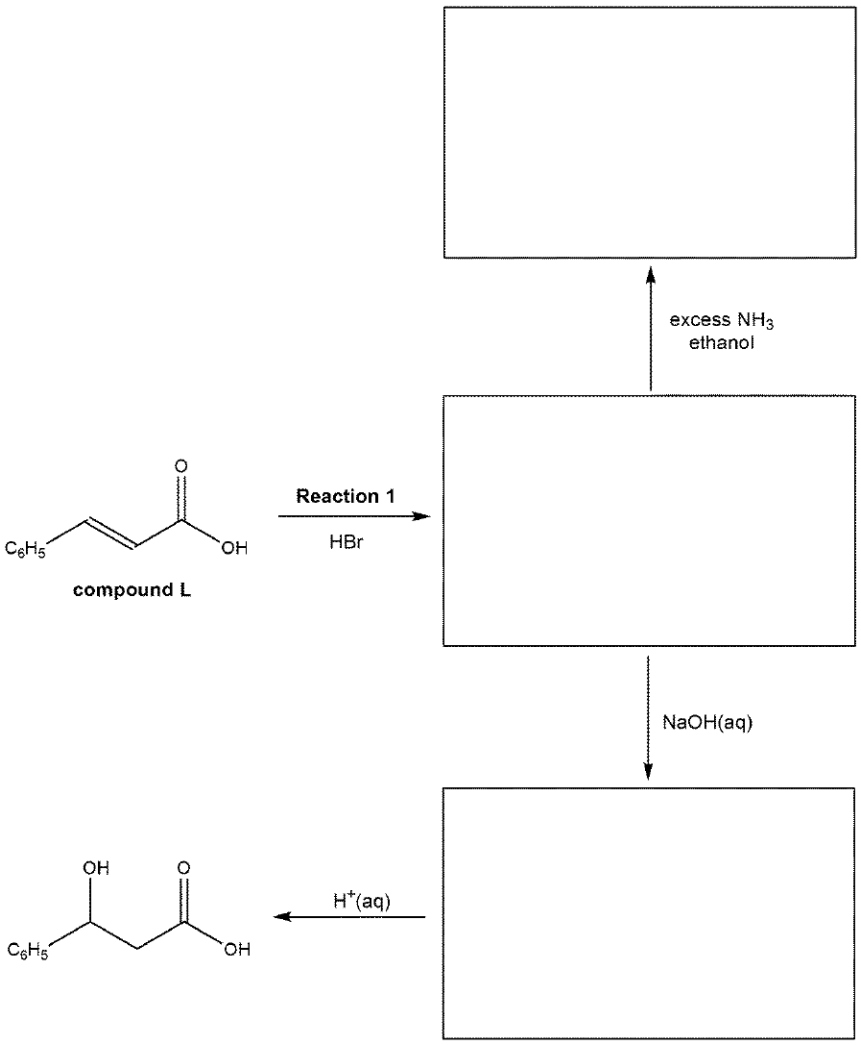
Your answer ☐

[1]

3(a). This question is about the reactions of compounds with more than one functional group.

A chemist investigates some reactions of compound **L**, as shown in the flowchart below.

Complete the flowchart by showing the missing organic structures in the boxes.



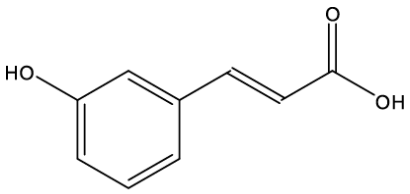
[3]

(b). Outline the mechanism that occurs in **Reaction 1**.

Include curly arrows, relevant dipoles and the name of the mechanism.

name of mechanism ..... **[4]**

(c). The chemist synthesises compound **M**, which can undergo both addition and condensation polymerisation.



compound M

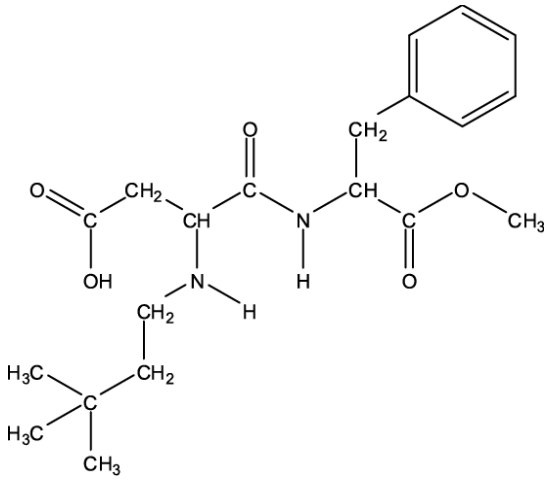
i. Draw the repeat unit of the **addition** polymer formed from compound **M**.

[1]

ii. Draw **two** repeat units of the **condensation** polymer formed from compound **M**.

[2]

(d). Neotame, an artificial sweetener, is broken down by acid hydrolysis.

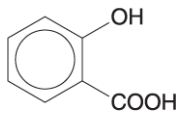


neotame

Draw the structures of **all** the organic compounds formed.

[4]

4. Salicylic acid can be used to form a condensation polymer similar to Terylene®.

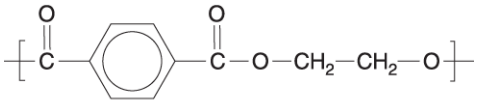


salicylic acid

i. Explain what is meant by the term *condensation polymer*.

[1]

ii. The repeat unit of Terylene® is shown below.



Terylene®

Draw the skeletal formulae of **two** monomers that can be used to form Terylene®.

[2]

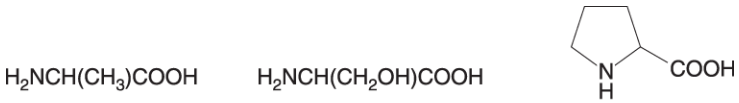
iii. Salicylic acid reacts with 3-hydroxypropanoic acid to form a mixture of condensation polymers.

To form one polymer, the two monomers react in equal quantities.

Draw the repeat unit of this polymer, displaying the link between the monomer units.

[1]

5(a). Alanine, serine and proline are α-amino acids.



i. Alanine and serine react together to form two different dipeptides.

Draw the structures of the **two** dipeptides that can form when alanine and serine react together.

[2]

ii. The isoelectric points of alanine and serine are shown below.

alanine, pH = 6.0

serine, pH = 5.6

Draw the structures of the ions formed at the following pH values.

structure of **alanine** ion at **pH 6.0**

structure of **serine** ion at **pH 10.0**

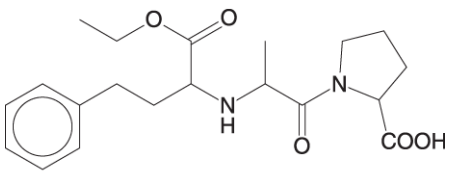
[2]

iii. Proline can polymerise to form poly(proline).

Draw the structure of the repeat unit in poly(proline).

[1]

(b). Enalapril is a drug used in the treatment of high blood pressure.



enalapril

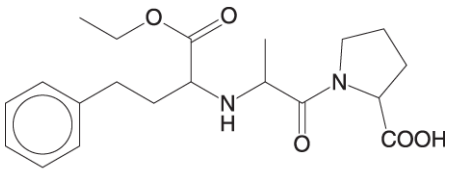
i. **On the structure above**, mark each chiral centre with an asterisk (*).

[1]

ii. Suggest **two** benefits of using single stereoisomers in the synthesis of drugs such as enalapril.

[2]

iii. Enalapril is broken down in the body by acid hydrolysis.



enalapril

Draw the structures of the **three** organic products of the **acid hydrolysis** of enalapril.

[4]

iv. A scientist hydrolysed enalapril in the laboratory. The scientist then analysed the mixture of products using GC–MS.

Explain how GC–MS enables the products to be identified.

[1]

6(a). Compound **E**, C_4H_7NO, is one of two optical isomers. It can be oxidised by Tollens' reagent to an α-amino acid, **F**.

The α-amino acid **F** forms two different polymers, **G** and **H**.

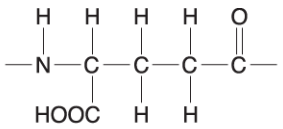
Polymer **G** has the empirical formula $C_4H_7NO_2$.

Polymer **H** has the empirical formula C_4H_5NO.

- Suggest structures for compound **E** and compound **F**.
- Draw repeat units of polymer **G** and polymer **H**.
- Describe how **F** forms **G** and **H**.

[6]

(b). Poly(glutamic acid) is a polymer of the amino acid, glutamic acid.



repeat unit of poly(glutamic acid)

i. Draw the structure of glutamic acid.

[1]

ii. A student tried to prepare poly(glutamic acid) from glutamic acid. No polymer was found in the product mixture.

The student isolated the two major compounds in the mixture. The mass spectra of these two compounds showed molecular ion (M^+) peaks at m / z = 129 and m / z = 258.

Suggest structures for these two compounds.

[2]

(c). Polymer **J** has been recently developed by scientists. The repeat unit of polymer **J** is shown below.

—$CO(CH_2)_4CONHC(CH_3)_2CH_2O$—

polymer J

i. What are the functional groups in polymer **J**?

[1]

ii. Two different monomers react to form polymer **J**.

Draw the structures of the two monomers in the boxes below.

Display the functional groups in each monomer.

[2]

iii. Polymer **J** is used in hair spray. It can be washed away easily with hot water.

Suggest why polymer **J** is able to be washed away easily with hot water.

[1]

7. Some organic compounds contain nitrogen atoms. Examples include condensation polymers and azo dyes.

A section of a condensation polymer is shown below.

$$–CO(CH_2)_4CONH(CH_2)_6NHCO(CH_2)_4CONH(CH_2)_6NH–$$

i. In the boxes below, draw the structures of the two monomers that form this condensation polymer.

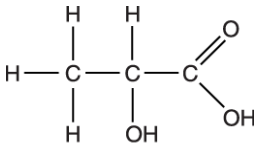
[2]

ii. Name the type of condensation polymer and give a use for this polymer.

Type .....

Use .....**[1]**

8. This question is about the preparation, properties and uses of lactic acid.



lactic acid

Poly(lactic acid), PLA, is used to make 'dissolvable' stitches (for holding wounds together).
PLA breaks down into smaller molecules after one or two weeks.

i. Draw the structure of **one** repeat unit in PLA.

[1]

ii. Explain how PLA breaks down and why the stitches 'dissolve'.

In your answer you should use the appropriate technical terms spelled correctly.

[3]

9. Which compound **cannot** be hydrolysed?

A CH_3COOH

B CH_3COCl

C $CH_3CONHCH_3$

D CH_3COOCH_3

Your answer ☐

[1]

10. This question is about α-amino acids.

Serine, $H_2NCH(CH_2OH)COOH$, is a naturally occurring α-amino acid.

i. Serine has two optical isomers.

Explain what is meant by the term *optical isomers*, and draw the two optical isomers of serine.

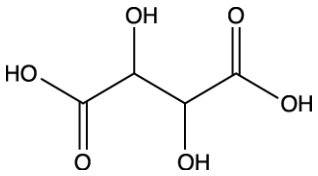
[3]

ii. Serine can react with the α-amino acid glycine, H_2NCH_2COOH, to form **three** different organic products, each with the molecular formula $C_5H_{10}N_2O_4$.

Draw the structures of the **three** organic products that can be formed by the reaction of serine with glycine.

[3]

11. Tartaric acid, shown below, is an organic acid present in fruit juice.



i. What is the empirical formula of tartaric acid?

[1]

ii. Write the systematic name for tartaric acid.

[1]

iii. Tartaric acid reacts with 1,6-diaminohexane, $H_2N(CH_2)_6NH_2$, to form a polymer.

Draw the structure of **one** repeat unit of this polymer.

[2]

iv. The polymerisation in **(iii)** takes place in two steps.

In the first step, tartaric acid and 1,6-diaminohexane react to form a salt.

Draw the structure of this salt, showing the ions present.

[2]

12(a). This question is about organic compounds containing nitrogen.

Sodium cyanide, NaCN, can be reacted with many organic compounds to increase the length of a carbon chain.

i. 1-Chloropropane, $CH_3CH_2CH_2Cl$, reacts with ethanolic sodium cyanide by nucleophilic substitution.

Outline the mechanism for this reaction.

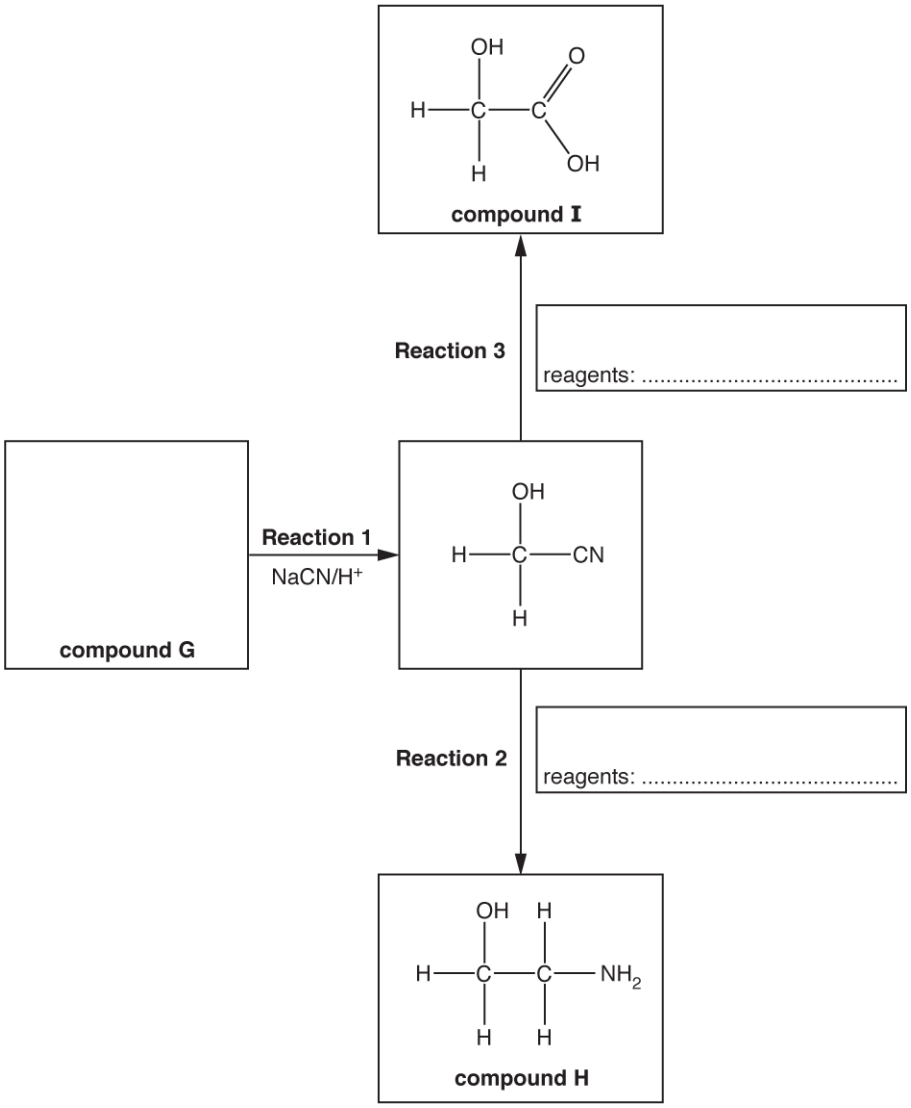
Include curly arrows, relevant dipoles and the structure of the organic product.

[3]

ii.

iii. Compound **G** is used to synthesise compounds **H** and **I** as shown in the flowchart below.

Complete the flowchart showing the structure of compound **G** and the **formulae** of the reagents for **Reaction 2** and **Reaction 3**.



[3]

iv. Compound **H** reacts with dilute hydrochloric acid to form a salt.

Explain why compound **H** can react with dilute hydrochloric acid and suggest a structure for the salt formed.

Explanation

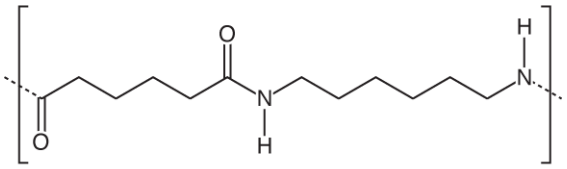
Structure

[2]

v. Compound **I** is the monomer for the biodegradable polymer **J**.
Draw **two** repeat units of polymer **J** and suggest a reason why it is biodegradable.

[3]

(b). The repeat unit of Nylon 6,6 is shown below.



Nylon 6,6

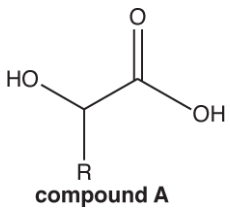
i. Draw the structures of **two** monomers that can be used to form Nylon 6,6.

[2]

ii. A sample of Nylon 6,6 has a relative molecular mass of 21500.
Estimate the number of repeat units in the sample.
Give your answer as a **whole** number.

number of repeat units = ... **[1]**

13. The structural formula of compound **A** is shown below.



compound A

Two reactions of compound **A** are carried out.

Suggest an equation for each reaction and state the type of reaction.

In your equations, draw structures for organic compounds.

You can use R for the alkyl group.

i. Magnesium ribbon is added to a solution of compound **A**.
Gas bubbles are seen and the magnesium slowly dissolves.

Equation

Type of reaction

[3]

ii. Compound **A** is heated with a few drops of concentrated sulfuric acid as a catalyst.
A cyclic 'dimer' of compound **A** forms.

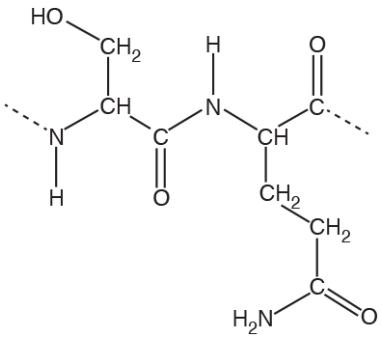
Equation

Type of reaction

[3]

14. α-Amino acids can react to form proteins.

A short section of a protein chain is shown below.



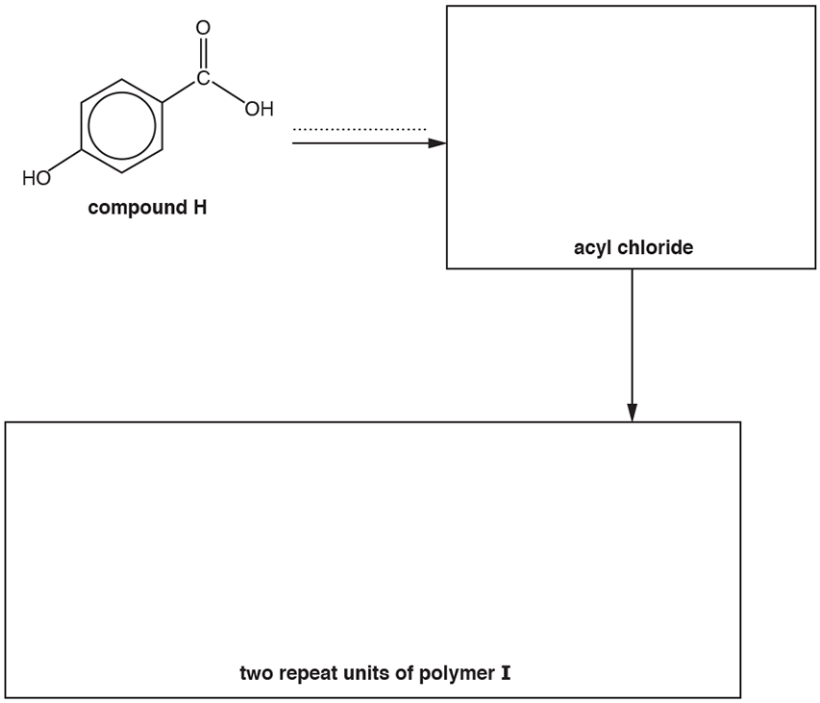
A student hydrolyses the protein with hot NaOH(aq).

Draw the structures of the organic products formed from this section of the protein.

[3]

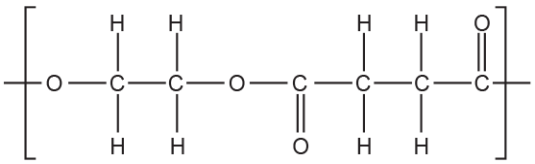
15. Compound **H** is used in the synthesis of polymer **I**, as shown in the flowchart below.

Complete the flowchart by drawing the structure of the acyl chloride and **two** repeat units of polymer **I**, and stating the **formula** of the reagent(s) required for the first stage on the dotted line.

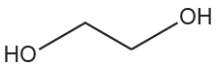
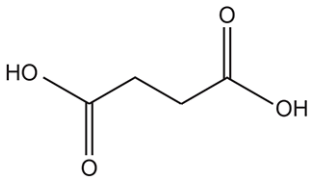
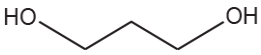
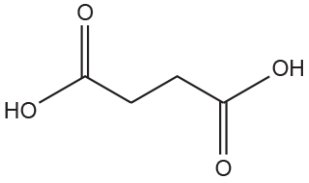
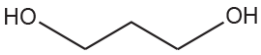
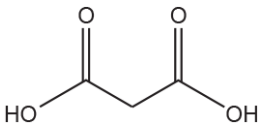
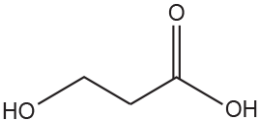
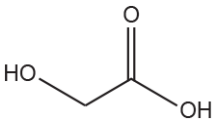


[4]

16. The repeat unit of a polymer is shown below.

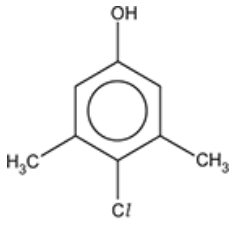


Which monomers could form this polymer?

A		
B		
C		
D		

Your answer ☐ **[1]**

17. Dettol® is a disinfectant containing the antiseptic chloroxylenol, shown below.



chloroxylenol

Chloroxylenol is a weak Brønsted–Lowry acid.

i. What is the systematic name of chloroxylenol?

[1]

ii. Predict the number of peaks in a ^{13}C NMR spectrum of chloroxylenol.

[1]

iii. Name the functional group responsible for the acidity of chloroxylenol and describe a simple test which would confirm the presence of this group.

Functional group

Test

[2]

iv. A student measures the pH of the contents in a bottle of Dettol® as 5.14.

The label on the bottle shows the percentage of chloroxylenol in Dettol® as 4.80% i.e. 100 cm^3 of Dettol® contains 4.80 g of chloroxylenol.

Assume the following:

- Chloroxylenol is the only acidic component in Dettol®.
- Chloroxylenol is a weak monobasic acid.
- The density of Dettol® is 1.00 g cm^{-3}.

Write the equation, using molecular formulae, for the acid dissociation of chloroxylenol.

Calculate the acid dissociation constant, K_a, for chloroxylenol.

K_a = ... mol dm^{-3} **[5]**

18. This question is about organic chemistry.

The amino acid Z−H_2NCH=CHCOOH can react to form a cyclic compound with the molecular formula C_3H_3NO and one other product.

Complete the equation for this reaction.

[2]

19. Alcohols can be used to prepare organic compounds with different functional groups.

$HOOC(CH_2)_2COOH$ and $HO(CH_2)_4OH$ react together to form polymer **E**.

i. Draw **one** repeat unit of polymer **E**.

The functional groups should be clearly displayed.

[2]

ii. Governments are encouraging the development of biodegradable polymers to reduce dependency on persistent plastic waste derived from fossil fuels.

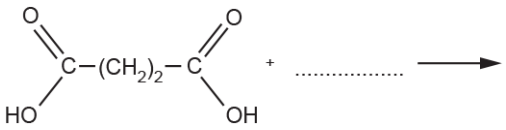
Polymer **E** is a biodegradable polymer.
Suggest why polymer **E** is able to biodegrade.

[1]

iii. A large yield of polymer **E** can be obtained by reacting a diacyl dichloride with $HO(CH_2)_4OH$.

The diacyl dichloride is prepared from $HOOC(CH_2)_2COOH$.

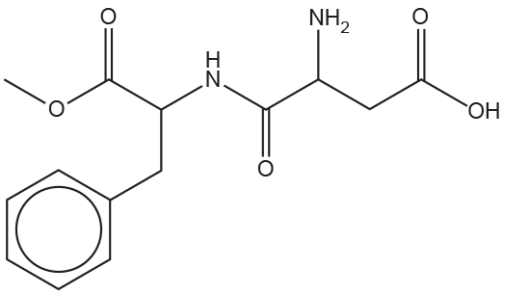
Complete the equation for the formation of a diacyl dichloride from $HOOC(CH_2)_2COOH$.



[3]

20. This question is about organic compounds containing nitrogen.

Aspartame, shown below, is an artificial sweetener commonly used as a sugar substitute.



aspartame

i. Aspartame contains several functional groups.

Apart from the benzene ring, name the functional groups in aspartame.

[3]

ii. A sample of aspartame is hydrolysed with aqueous acid.

Draw the structures of the **three** organic products of the complete **acid hydrolysis** of aspartame.

[4]

iii. Some people are concerned that aspartame, $C_{14}H_{18}N_2O_5$, may have adverse health effects. Research shows that the safe maximum daily intake of aspartame is 1.7×10^{-4} mol kg^{-1}.

• A typical UK adult has a mass of 75 kg.
• A can of a diet drink contains 167 mg of aspartame.

How many cans of this diet drink is it safe for a typical adult to drink in one day?

Number of cans = ... **[3]**

21. This question is about haloalkanes and polymers.

A polymer can be made from the monomers:

- 1,4-diaminobutane
- benzene-1,4-diacyl dichloride.

Draw the structures of these monomers and **one** repeat unit of the polymer.

1,4-diaminobutane	**benzene-1,4-diacyl dichloride**
one repeat unit of polymer	

[4]

22. Butyl propanoate is hydrolysed by aqueous sodium hydroxide.

Which compound is one of the products of this hydrolysis?

A C_3H_7ONa

B $C_3H_5O_2Na$

C C_4H_9ONa

D $C_4H_7O_2Na$

Your answer ☐ **[1]**

23(a). This question is about polymers derived from carboxylic acid monomers.

i. Poly(pent-3-enoic acid) is an addition polymer.

Draw the structure of pent-3-enoic acid and **two** repeat units of this polymer.

Pent-3-enoic acid	
Two repeat units of poly(pent-3-enoic acid)	

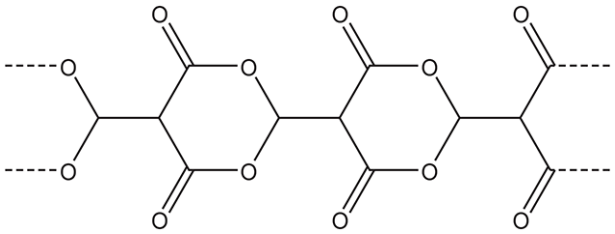
[2]

ii. Butanedicarboxylic acid and 1,4-dihydroxy-2-methylbenzene react to form a condensation polymer.

Draw **one** repeat unit of this condensation polymer.

[2]

iii. Three repeat units of a condensation polymer are shown below.



Draw the structure of the monomer required to form this polymer.

[1]

(b). This question is about compounds that contain the carboxylic acid functional group.

A polymer is formed from 400 molecules of 2-aminopropanoic acid.

i. Draw **one** repeat unit of this polymer.

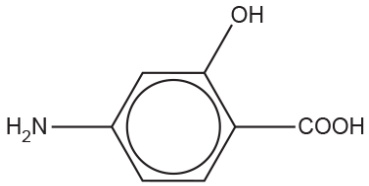
[1]

ii. What is the relative molecular mass, M_r, of the polymer?

M_r = ... **[2]**

24. This question is about aromatic compounds containing the –COOH and –OH functional groups.

PAS, shown below, is an antibiotic used to treat several diseases including tuberculosis (TB).



PAS

i. A student predicts that PAS could polymerise to form a polymer containing **both** ester and amide linkages.

Draw a section of this polymer.

The section should contain **one** amide and **one** ester linkage, which should be displayed.

[3]

ii. For the treatment of TB, the maximum daily dosage of PAS that should be prescribed is 300 mg per kg of body mass.

A child weighs 20.0 kg.

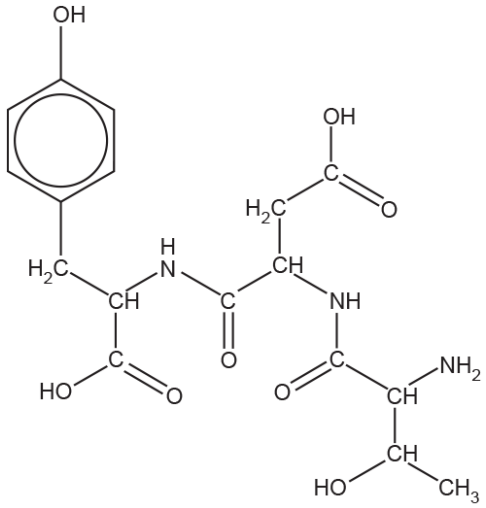
Calculate the number of PAS molecules in the maximum daily dosage of PAS for this child.

number of PAS molecules = ...

[3]

25. This question is about α-amino acids.

Three α-amino acids can react together to form compound **E**, shown below.



Compound E

i. How many optical isomers are possible for compound **E**?

[1]

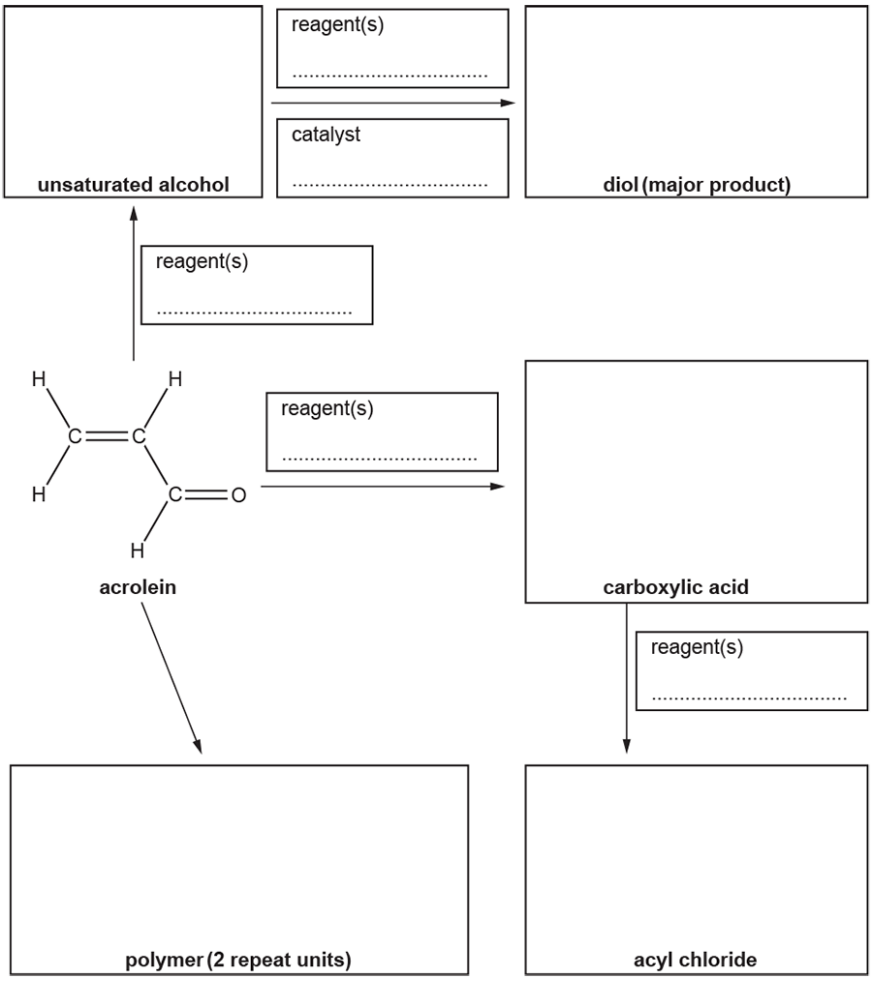
ii. A student hydrolyses compound **E** with dilute hydrochloric acid, HCl (aq).

Draw the structures of the organic products formed by this hydrolysis.

[4]

26. This question is about reactions of acrolein, $H_2C=CHCHO$.

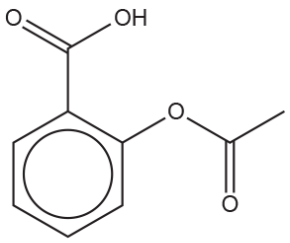
Complete the flowchart by filling in each box.



[9]

27. Aspirin tablets are used for pain relief.

The structure of aspirin is shown below.



Aspirin

Aspirin reacts with hot NaOH(aq), under reflux.

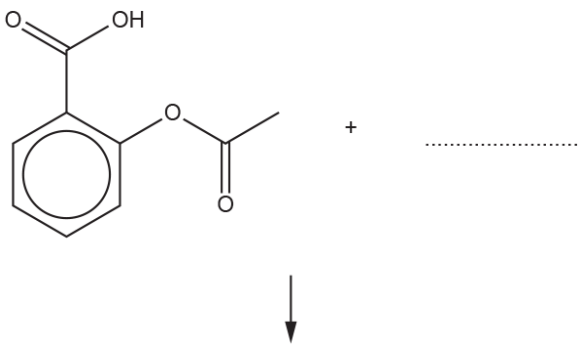
i. Draw a labelled diagram of suitable apparatus for reflux.

[2]

ii. In this reaction, 1 mol of aspirin reacts with 3 mol of hot NaOH(aq).

Complete the equation for the reaction of aspirin with an excess of hot NaOH(aq).

Show structures for organic compounds.



[3]

28. 1,6-Diaminohexane, $H_2N(CH_2)_6NH_2$, reacts with hexanedioyl dichloride, $ClOC(CH_2)_4COCl$ to form a polyamide and one other product.

What is the other product formed in this reaction?

A HCl

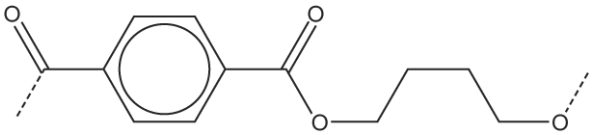
B H_2O

C CO

D NH_3

Your answer ☐ **[1]**

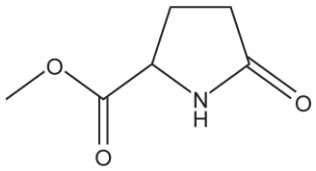
29(a). The repeat unit of a polyester is shown below.



Draw the structures of monomers required to form this polyester.

[2]

(b). The compound below contains an ester and an amide group.



Draw the structures of the organic products formed by the complete **alkaline** hydrolysis of this compound using NaOH(aq).

[4]

30(a). α-Amino acids have the general formula $RCH(NH_2)COOH$.

The R group in an α-amino acid contains C and H only.

This R group has a molar mass of 91 g mol^{-1}.

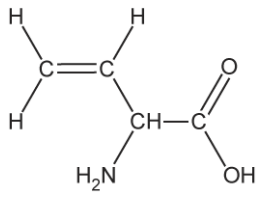
A polymer is formed from 500 molecules of this α-amino acid.

Determine the molar mass of this polymer.

Give your answer to the nearest whole number.

molar mass of polymer = ... g mol^{-1} **[3]**

(b). The amino acid below can form addition and condensation polymers.



Draw **2** repeat units of these polymers.

Display the sections linking the monomers together.

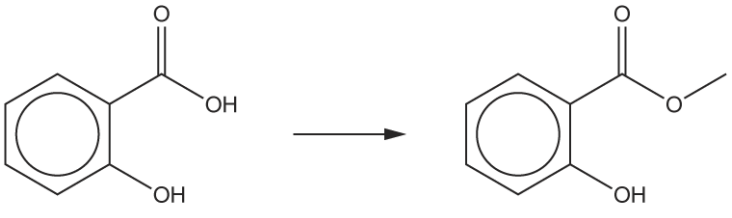
addition polymer (2 repeat units)

condensation polymer (2 repeat units)

[3]

31. Oil of wintergreen is a liquid used in medicine to relieve muscle pain.

Compound **H** is a component in oil of wintergreen and can be synthesised from compound **G**, as shown below. The boiling point and density of compound **H** are stated.



Compound G

Compound H

boiling point = 222 °C
density = 1.174 g cm^{-3}

A student prepares a sample of compound **H** by the method below.

Step 1	Reflux 8.97 g of compound **G** for 30 minutes with an excess of methanol in the presence of a small amount of sulfuric acid as a catalyst.
Step 2	Add an excess of aqueous sodium carbonate, $Na_2CO_3(aq)$. Two layers are obtained.
Step 3	Purify the impure compound **H** that forms from the resulting mixture.

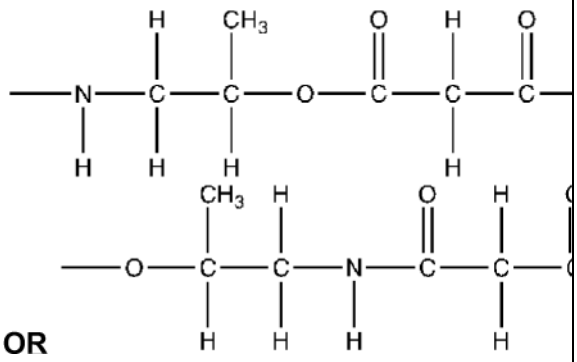
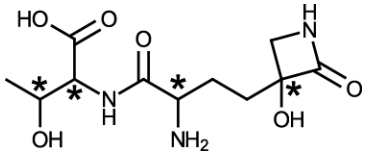
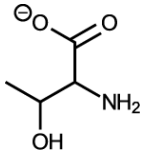
The student follows this method and obtains 5.32 g of pure compound **H**.

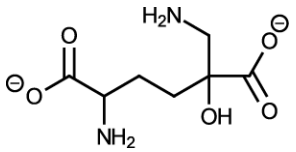
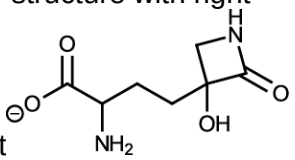
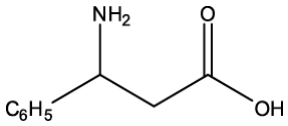
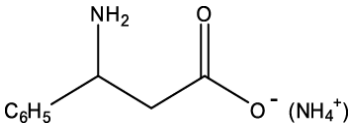
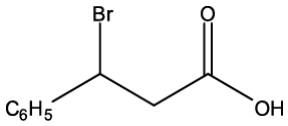
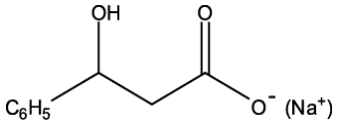
Why does the student use reflux in **Step 1**?

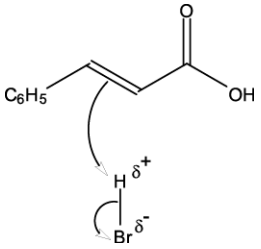
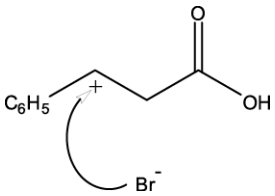
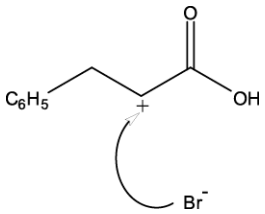
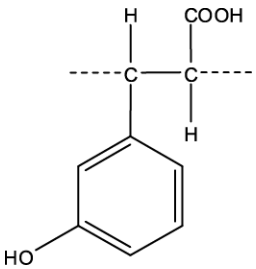
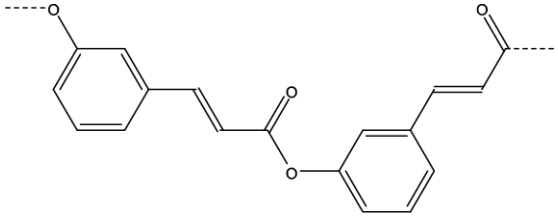
[1]

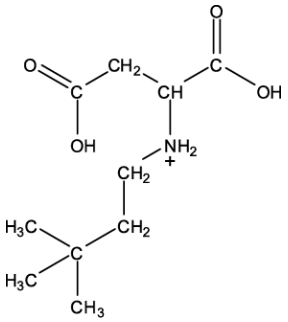
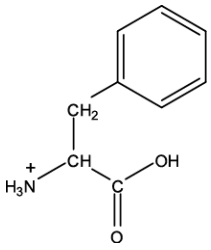
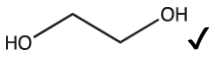
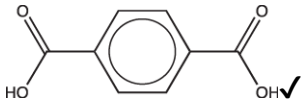
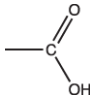
END OF QUESTION PAPER

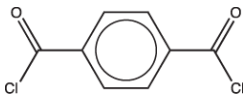
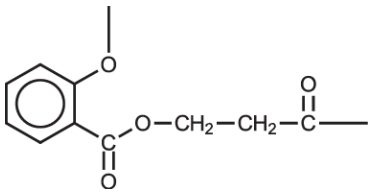
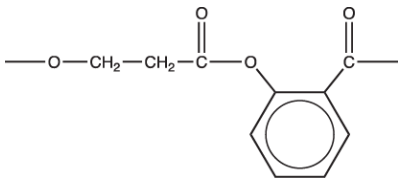
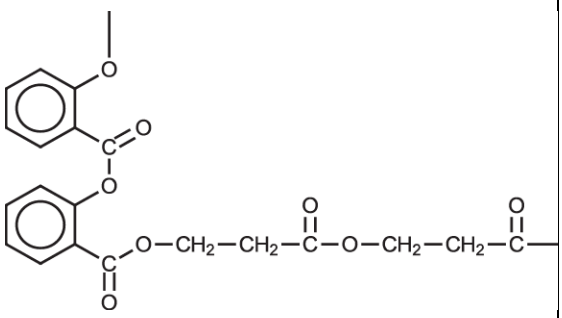
Mark scheme

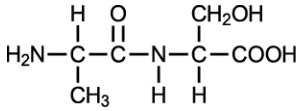
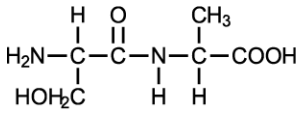
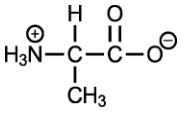
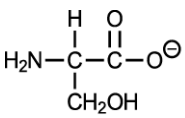
Question			Answer/Indicative content	Marks	Guidance
1	a	i	**Step 1**: add HCN **OR** H_2SO_4/KCN $CH_3CHO + HCN \rightarrow CH_3CH(OH)CN$ **Step 2**: react with H_2/Ni $CH_3CH(OH)CN + 2H_2 \rightarrow CH_3CH(OH)CH_2NH_2$	4	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** 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)
		ii i	 **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***	4	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous

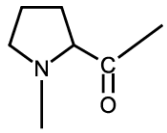
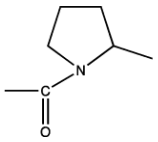
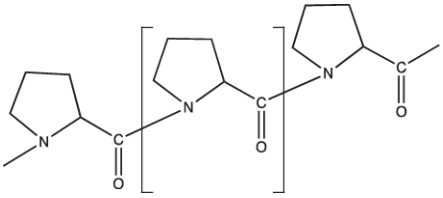
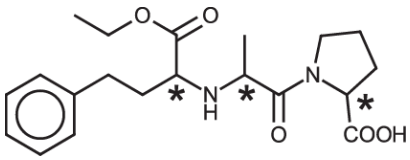
			 **OR** structure with COOH rather than COO^- Two **OR** three COO^- shown		**ALLOW** 1 mark for structure with right-hand ring still intact 
			Total	**14**	
2			C	1	
			Total	**1**	
3	a		**Product from NH_3/ethanol** 	3	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW**  **ALLOW ECF** from 2-bromo compound as product from Reaction 1 .....
			Product from Reaction 1 		**DO NOT ALLOW** 2-bromo compound *(inconsistent with final product shown)* .....
			Product from NaOH(aq) 		**DO NOT ALLOW ECF** from 2-bromo compound as product from Reaction 1 *(inconsistent with final product shown)*
	b		Curly arrow from C=C bond to H of H-Br		**ANNOTATE ANSWER WITH TICKS AND CROSSES**

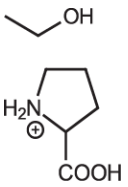
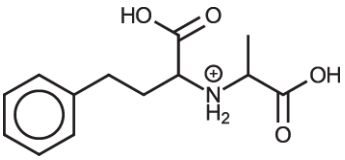
					ALLOW any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous
			Correct dipole shown on H–Br **AND** curly arrow showing the breaking of H-Br bond  		
			.....		**DO NOT ALLOW** partial charges shown on C=C double bond
			Correct carbocation **AND** curly arrow from Br^- to C^+ of carbocation  		**DO NOT ALLOW** δ+ on 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	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)

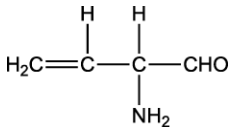
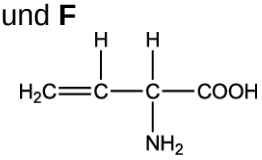
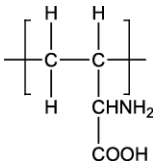
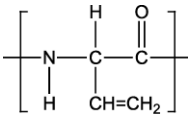
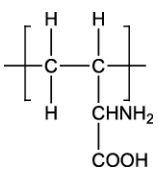
			Rest of structure		
	d		 **OR** structure with NH rather than NH_2^+  **OR** structure with NH_2 rather than NH_3^+ $CH_3{-}OH$ Correct charge and number of protons on both nitrogen atoms	4	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous
			Total	**14**	
4		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	 ✓  ✓	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**

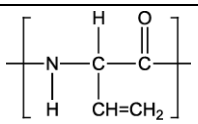
			Connectivity is penalised only in this question		 **Examiner's Comments** Skeletal formulae were often very well drawn with incorrect connectivity being penalised very rarely. Some candidates knew the structure of the monomers but did not present them as skeletal formulae. If a structural formula is used for working it should be crossed out and not left as an alternative answer to the skeletal formula.
		ii i	 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**	
5	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  ✓ 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 **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.
		ii i	 ✓ **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 increases the (pharmacological) activity / effectiveness	2	**IGNORE** toxic / harmful **IGNORE** a response that implies a

			Reduces / stops the need for / cost / difficulty in separating stereoisomers / optical isomers ✓✓		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

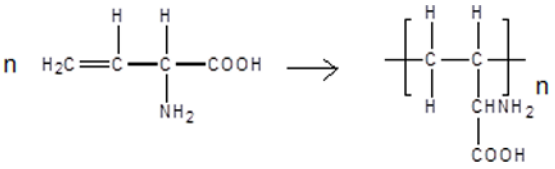
					times or measurement of molar mass did not score the mark.
			Total	**13**	
6	a		**M1** Compound **E**  ✓ **M2** Compound **F**  ✓ **M3** Compound **G**  ✓ **M4** Compound **H**  ✓ **M5** Compound **G** **OR**  Is an addition polymer ✓ **M6** Compound **H** **OR**	6	**ANNOTATE ANSWER WITH TICKS AND CROSSES 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



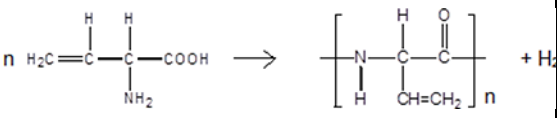
is a condensation polymer ✓

ALLOW alkene forms addition polymer / polymer with same empirical formula as monomer

ALLOW equation for reaction

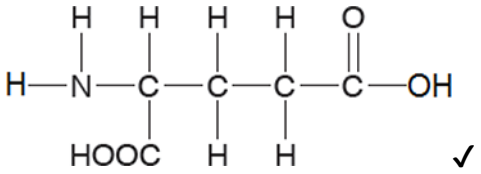
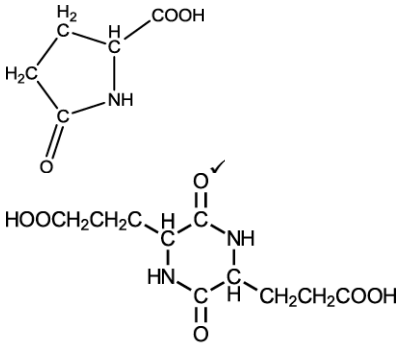
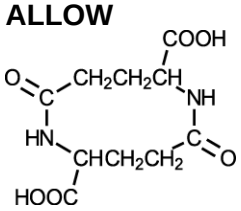


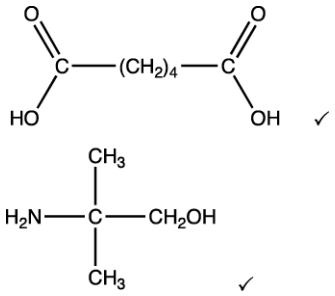
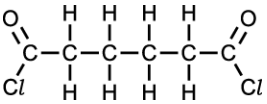
ALLOW amino acid forms condensation polymer
OR (molecules of) compound **F** join / bond / add / react / form polymer and water / small molecule
ALLOW equation for reaction

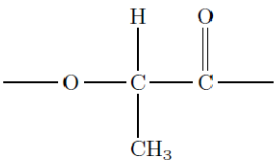


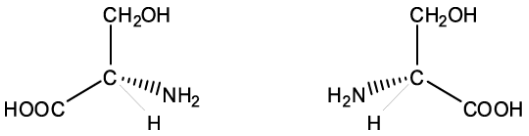
Examiner's Comments

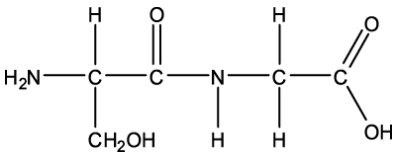
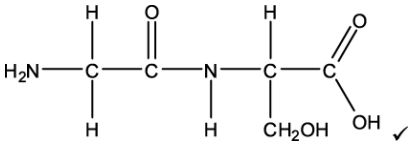
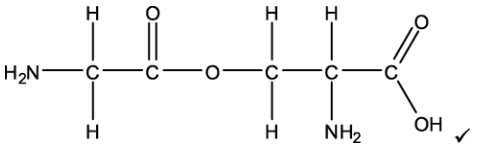
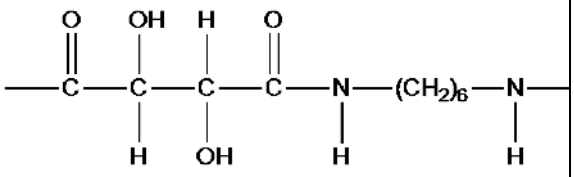
This question discriminated well and many well organised and well-presented answers were seen. Candidates were usually able to identify the aldehyde structure in compound **E** and those who failed to include a chiral centre in compound **E** had possibly missed essential information in the stem of the 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.

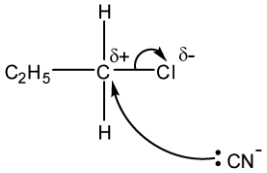
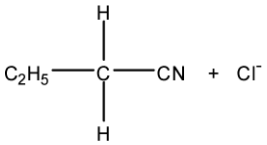
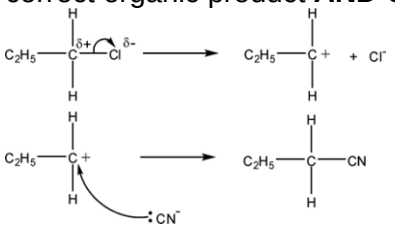
	b	i	 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous **Examiner's Comments** The majority scored this mark for the structure of glutamic acid.
		ii	 ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **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.

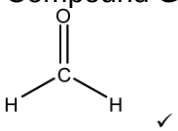
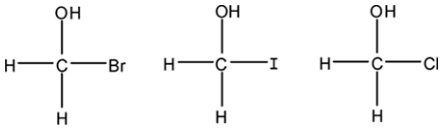
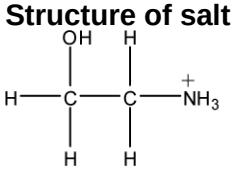
		ii	 ✓ ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous Functional groups do not need to be fully displayed **ALLOW** structures as shown; the O–H bond and the N–H bonds in the functional groups **do not** need to be displayed **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.
		ii i	(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**	
7		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**

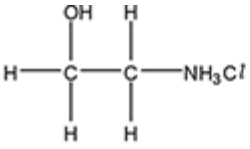
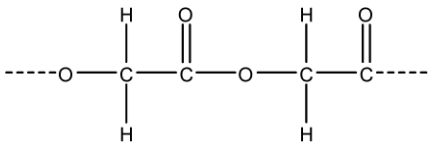
					Very well answered. The vast majority of candidates scored full marks on this question.
		ii	<u>Type of condensation polymer</u> Polyamide **AND** <u>Use of condensation polymer</u> Fibres in clothing ✓	1	Both answers required for one mark **ALLOW** nylon **IGNORE** numbers **IGNORE** polypeptide **DO 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**	
8		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** ✓	3	**ANNOTATE WITH TICKS AND CROSSES ETC.** **ALLOW** (ester) **hydrolysis**/(ester) **hydrolyses**

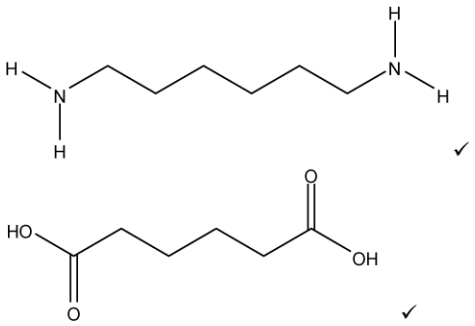
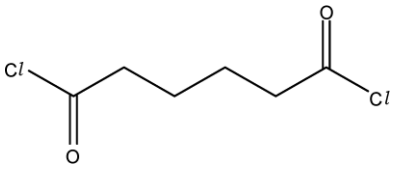
			Any two from: • Ester (links in the polymer) **OR** (PLA is a) polyester • Monomer/lactic acid/product (is soluble because it) forms hydrogen bonds to water • polymer is photodegradable • the C=O bond absorbs radiation/uv/light ✓✓ **QWC**: **hydrolysed/hydrolysis/hydrolyses** spelled correctly in the correct context		**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**	
9			**A**	1	
			Total	**1**	
10		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	

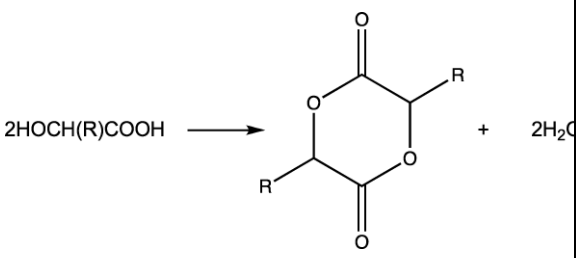
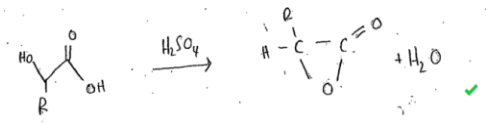
		ii	Dipeptide Ser-Gly  Dipeptide Gly-Ser  Esterification of OH on Ser 	3	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** structures in any order
			Total	**6**	
11		i	$C_2H_3O_3$ ✓	1	
		ii	2,3− dihydroxybutanedioic acid ✓	1	**ALLOW** 2,3−dihydroxybutane−1,4−dioic 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 ✓	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^-

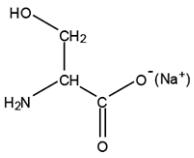
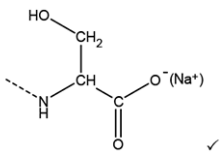
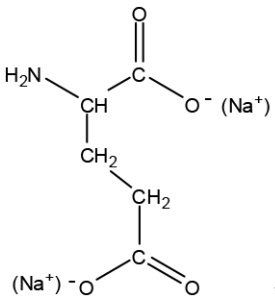
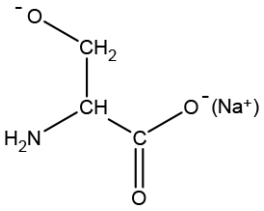
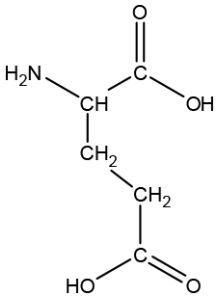
			Negative ion correct ✓		**ALLOW**[$H_2N(CH_2)_6NH_3^+$] [$^-OOC(CHOH)_2COOH$]
			Total	**6**	
12	a	i	curly arrow from $^-$CN to carbon atom of C−C*l* bond ✓ Dipole shown on C–C*l* bond, $C^{\delta+}$ and $Cl^{\delta-}$, **AND** curly arrow from C−C*l* bond to C*l* atom ✓  correct organic product **AND** 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.

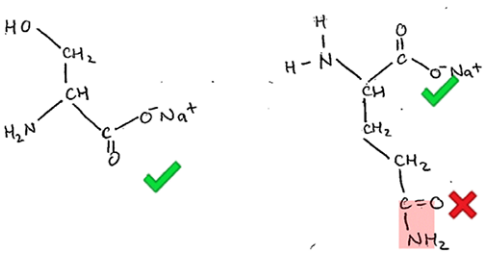
		ii	Compound **G**  ✓ **Reagents** **Reaction 2:** H_2 **AND** Ni ✓ **Reaction 3:** Correct formula of an aqueous acid e.g. HCl(aq)/H_2SO_4(aq) ✓	**3**	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** name(s) **ALLOW**  **ALLOW** any suitable 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 **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)*

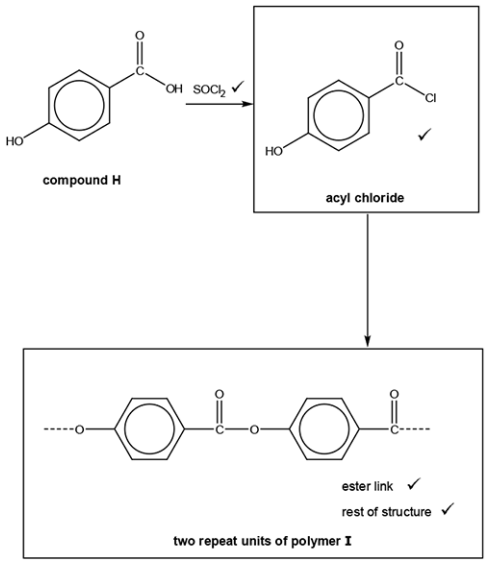
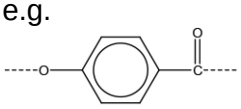
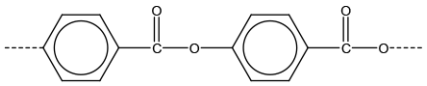
					DO NOT ALLOW nitrogen/N lone pair accepts hydrogen (*proton/H^+ required*) **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW**  *i.e.* charges **not** required **IF** charges are shown **both** need to be present **ALLOW** charge either on **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.
		i v	 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.
	b	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 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
			Total	**14**	
13		i	***Equation*** $2HOCH(R)COOH + Mg \rightarrow (HOCH(R)COO)_2Mg + H_2$	**3**	**ALLOW** correct structural **OR** skeletal **OR** displayed formula **OR** mixture of the above as long as non- ambiguous **ALLOW** $2HOCH(R)COOH + Mg \rightarrow 2HOCH(R)COO^- + Mg^{2+} + H_2$ **ALLOW** multiples

			Organic product ✓ Balance ✓ ***Type of reaction*** Redox ✓		**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***  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**	
14			 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

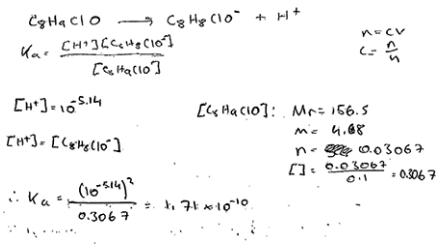
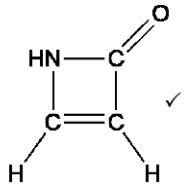
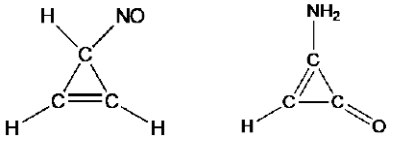
					correctly recognised that two amino acids would be produced but not all took account of the alkaline conditions and showed COOH groups rather than carboxylates. Candidates found this question difficult and although many gained some credit only the highest ability candidates, who recognised the amide 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**	
15			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*

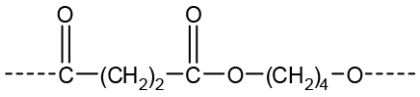
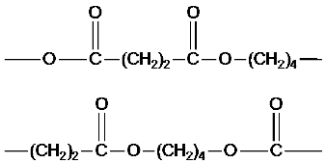
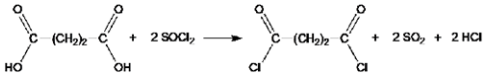
					*formula of reagent)* **DO NOT ALLOW** more than two repeat units **ALLOW** 1 mark for one correct repeat unit e.g.  'End bonds' **MUST** be shown (do not have to be dotted) **ALLOW** the 'O' at either end i.e.  **IGNORE** brackets **IGNORE** *n* **Examiner's Comments** Compound **H** was also the focus 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**	
16			**A**	1 (AO 2.5)	
			Total	**1**	
17		i	4-chloro-3,5-dimethylphenol ✓ **CARE**: Look for **di**methyl	1 AO 1.2	**ALLOW** 3,5-dimethyl-4-chlorophenol **ALLOW** absence of hyphens or extra hyphen or space, e.g. 4 chloro 3,5 dimethylphenol **ALLOW** full stops or spaces between numbers e.g. 4-chloro-3.5-dimethylphenol **ALLOW** name based on benzene, if

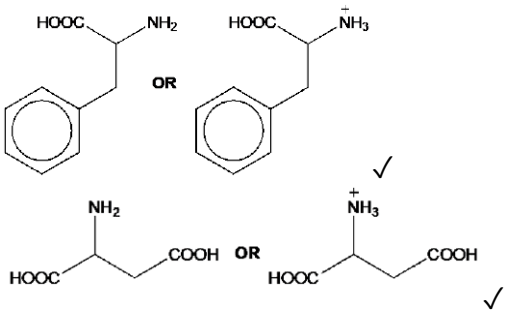
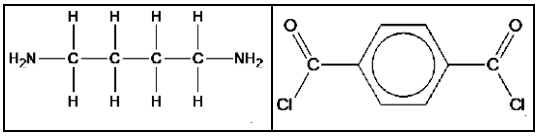
					unambiguous e.g.1-chloro-4-hydroxy-2,6-dimethylbenzene **DO NOT ALLOW** meth **OR** methy **Examiner's Comments** Most candidates correctly named the organic compound as 4-chloro-3,5-dimethylphenol. The numbers caused candidates less issues than the need for the 'di' prefix to signify two methyl groups in the name.
		ii	5 ✓	1 AO 2.5	**Examiner's Comments** Most candidates predicted that there would be 5 peaks in the ^{13}C NMR spectrum. The common incorrect responses were 3 or 4 peaks, presumably from omitting the C–OH or C–Cl carbon atoms.
		ii i	**Functional group** Phenol ✓ **Test** Indicator/pH paper turns red / orange **OR** pH < 7 **OR** pH meter < 7 **AND** No reaction with Na_2CO_3/CO_3^{2-}/ carbonate ✓	2 AO 1.2 AO 2.3	**DO NOT ALLOW** alcohol **OR** hydroxide **IGNORE** hydroxyl **OR** hydroxy **IGNORE** OH (*name asked for*) **ALLOW** Add bromine **AND** white precipitate **ALLOW** $FeCl_3$ **AND** violet/blue colour **Examiner's Comments** Most candidates identified the phenol functional group but a satisfactory test proved to be far more difficult. Many candidates identified that there would be no effervescence with sodium carbonate but it was common that the pH being less than 7 was often not seen. Neutralisation with sodium hydroxide was often seen but with no observation. Although not in the specification, the reaction with bromine to produce a white precipitate was often seen as an

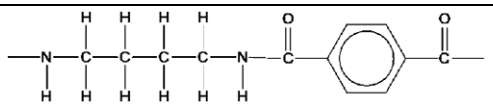
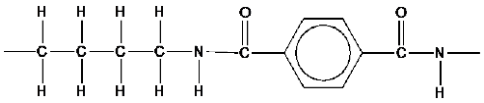
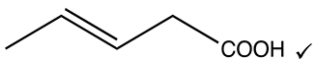
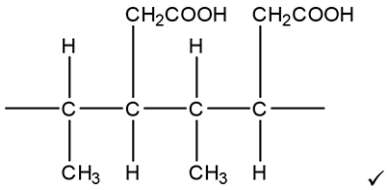
					acceptable alternative test for the phenol group.
		i v	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = 1.71 × 10^{-10},** **award FOUR calculation marks** **CARE Separate mark for equation** --- **Equation (1 mark)** $C_8H_9ClO \rightleftharpoons H^+ + C_8H_8ClO^-$ ✓ *Molecular formulae required (atoms in any order)* **[C_8H_9ClO] calculation (2 marks)** Molar mass C_8H_9ClO = 156.5 (g mol^{-1}) ✓ **ONLY** correct answer $[C_8H_9ClO] = \frac{4.8 \times 10}{156.5}$ **OR** 0.3067….. (mol dm^{-3}) ✓ *Subsumes mark for molar mass = 156.5* **K_a calculation (2 marks)** $[H^+] = 10^{-5.14}$ = 7.244….. × 10^{-6} (mol dm^{-3}) ✓ $K_a = \frac{(7.244\ldots. \times 10^{-6})^2}{0.3067\ldots..}$ = 1.71 × 10^{-10} (mol dm^{-3}) ✓	5 AO1.2×1 AO2.8×4	**ALLOW** → for ⇌ **DO NOT ALLOW** C_8H_8ClOH in equation i.e. $C_8H_8ClOH \rightleftharpoons H^+ + C_8H_8ClO^-$ If equation is omitted, **ALLOW** equation mark for a correct K_a expression with molecular formula i.e. $\frac{[H^+][C_8H_8ClO^-]}{[C_8H_9ClO]}$ **NO ECF** from an incorrect formula in equation **ALLOW ECF** from incorrect molar mass **ALLOW** 0.307 up to calculator value: 0.306709265 correctly rounded **ALLOW** 7.24 × 10^{-6} up to calculator value: 7.244359601 × 10^{-6} correctly rounded **ALLOW 2 SF** (1.7…. × 10^{-10}) up to calculator value, correctly rounded (but take care from acceptable intermediate rounding) **COMMON ERRORS** 2.36….. × 10^{-5} 3/4 calculation marks *No squaring of 7.24 × 10^{-6}* **Examiner's Comments** Candidates produced some very good calculations. It was common for candidates to determine the correct K_a value of 1.71 × 10^{-10} mol dm^{-3}, after first calculating the hydrogen ion and weak acid concentrations. The initial calculation of the hydrogen ion concentration from

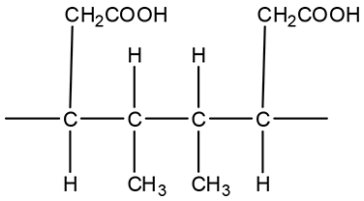
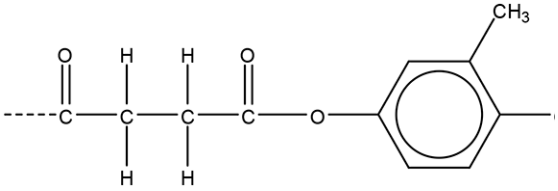
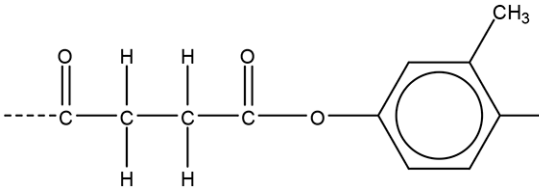
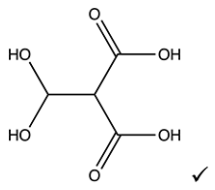
					10^{-pH} proved to be the easiest mark. The weak acid concentration proved to be more difficult with a significant number unable to determine the correct molar mass of chloroxylenol as 156.5. Most candidates recognised that the molar concentration in mol dm^{-3} was required from the mass of chloroxylenol in 100 cm^3. Almost all candidates divided the mass of 4.80 by their molar mass but the scaling by ×10 was not always successful. Some candidates used the mole equations that they had learnt to obtain the ×10 scaling in a very roundabout way. The final mark was often given by ECF (error carried forward) from an incorrect concentration. The question did also ask for an equation, using molecular formulae, for the acid dissociation. This was sometimes omitted or written using C_8H_8ClOH as the molecular formula of chloroxylenol, instead of C_8H_9ClO. Even if the equation had been omitted, the mark could still given from a correct K_a expression using molecular formulae. The usual advice of 'read and answer the question' still holds. Exemplar 3 shows a clear and concise response to the question and was given all 5 marks. The equation has been written using molecular formulae and all stages of the calculation are clear to see. Most candidates worked out the hydrogen ion concentration as 7.244×10^{-6} mol dm^{-3} before carrying out the final K_a calculation. This candidate had combined these stages. **Exemplar 3**

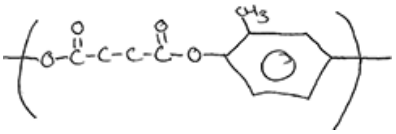
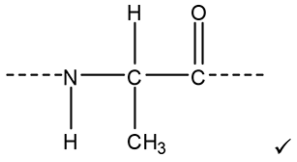
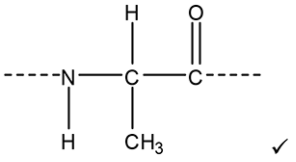
					
			Total	**9**	
18			→  ✓ + H_2O ✓ **Organic product** and **water** marked **independently**. *1st mark* correct organic product **OR** water **IGNORE** balancing numbers *2nd mark* **BOTH** products **AND** correctly balanced.	2 (AO 3.2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed 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* **Examiner's Comments** 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.

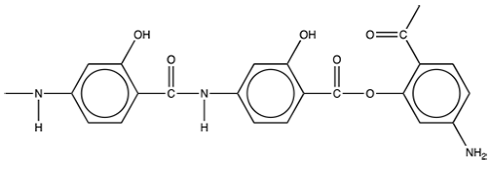
			Total	**2**	
19		i	 Ester link (must be displayed) ✓ Rest of structure ✓	2 (AO1.2) (AO2.5)	**ALLOW** the 'O' or C=O at either end, e.g.  **IGNORE** brackets **IGNORE** *n* End bonds' **MUST** be shown (solid or dotted) **DO NOT ALLOW** more than one repeat unit
		ii	the ester/ ester bond/ ester group /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**	
20		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.
		ii i	**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 x 10^{-4} (mol) ✓ n(aspartame) limit per day = 1.7x10^{-4} x 75 = 0.01275 (mol) ✓ number of cans = 0.01275 / 5.68 x 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 x 10^{-4} (mol) ✓ n(aspartame) per kg = 5.68 x 10^{-4} / 75 = 7.57 x 10^{-6} (mol) ✓ number of cans = 1.7 x 10^{-4} / 7.57 x 10^{-6} = 22.4✓ **OR** n(aspartame) limit per day = 1.7x10^{-4} x 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 1			 	4 (AO2.5× 2) (AO1.2) (AO2.5)	**For polymer, DO NOT ALLOW > 1** repeat unit 'End bonds' **MUST** be shown (do not have to be dotted) **ALLOW** –NH– at either end i.e.

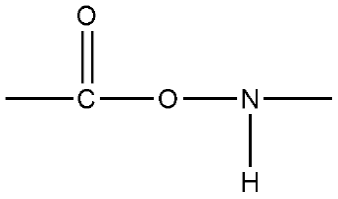
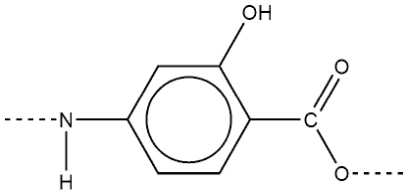
			 Amide link: ✓ 1 repeat unit of correct polymer: ✓		 **IGNORE** brackets **IGNORE** *n*
			Total	**4**	
22			B	1 (AO1.2)	**Examiner's Comments** Most candidates correctly identified B as one of the products. These candidates often drew out the structures of butyl propanoate and the product options to aid in their selection.
			Total	**1**	
23	a	i	**Pent-3-enoic acid**  **2 repeat units of polymer** 	2 (AO1.2) (AO2.5)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** either the *E* or *Z* isomer **ALLOW ECF** from pent-2-enoic acid **OR** pent-4-enoic acid **ONLY** **For repeat unit,** • 'side bonds' required on either side of repeat unit from C atoms • **2** repeat units required **IGNORE** connectivity of CH_2COOH in polymer **IGNORE** brackets **IGNORE** *n* --- **ALLOW** any consistent repeat unit: CH_2COOH and CH_3 groups can alternate or be on opposite sides of chain e.g.

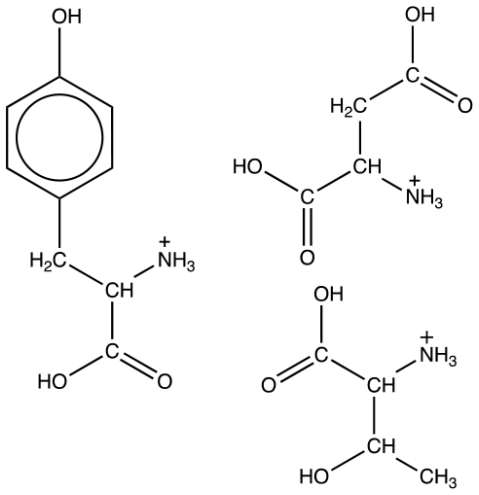
					
		ii	 ester link ✓ **ONE** repeat units of correct polymer ✓	2 (AO1.2) (AO2.5)	end –O– may be at either side e.g.  **ALLOW** CH_3 to be on position 2 or 3 of the aromatic ring 'End bonds' **MUST** be shown (do not have to be dotted) **IGNORE** brackets **IGNORE** *n*
		ii i	 ✓	1 (AO3.2)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **Examiner's Comments** Most candidates were given at least 1 mark with many correctly drawing the structure of pent-3-enoic acid. Common errors included drawing pent-2-enoic acid or propenoic acid, suggesting a lack of knowledge of prefixes. The second mark required candidates to draw two repeat units, frequently candidates tried to draw repeat units linking the carboxylic acid groups rather than identifying that it is the carbon-carbon double bond that breaks. This question differentiated well. Candidates who scored 1 mark had often

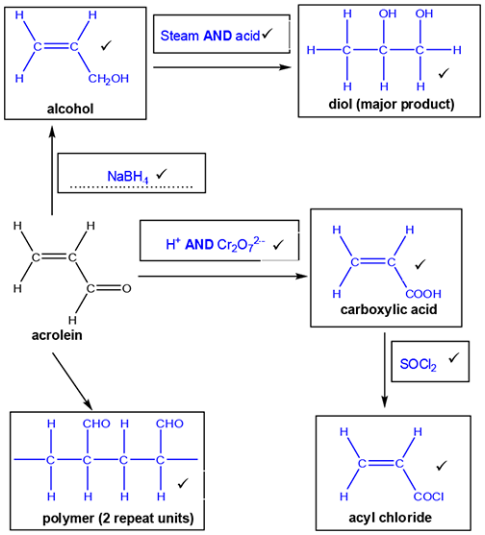
					shown an ester link but their structure was missing hydrogen atoms from the carbon chain (as shown in exemplar 1) or the methyl group was missing from the ring. **Exemplar 1**  This type of response was seen frequently by examiners. The candidate has correctly drawn the ester link but has omitted the hydrogen atoms from the carbon chain. This question proved difficult for candidates with the majority of candidates not scoring the mark. A significant proportion of candidate had identified the monomer but drew structures that combined skeletal and displayed formulae. This resulted in ambiguous structures being given that had missing hydrogen atoms on the carbons. **Drawing of organic structures** Candidates need practice at drawing structures that are not ambiguous. They should check the number of bonds on each atom and make sure the appropriate number of hydrogen atoms are drawn.
	b	i	 ✓ **ONE** repeat unit **ONLY**	1 (AO2.5)	end –N– may be at either side e.g.  ✓ 'End bonds' **MUST** be shown (do not have to be dotted) **IGNORE** brackets **IGNORE** *n*
		ii	**IF** answer on answer line = 28418, **AWARD** 2 marks **IF** answer on answer line = 28400, **AWARD** 1 mark	2 (AO2.2× 2)	

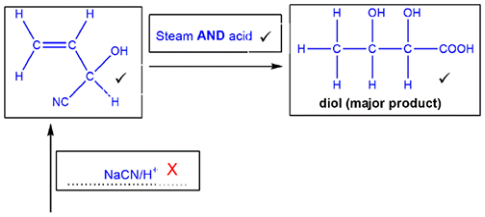
			---------- M_r of 400 molecules = 400 × 89 = 35600 ✓ M_r of polymer = 35600 − (399 × 18) = 28418 ✓		**ALLOW ECF** from incorrect repeat unit in 19di **ALLOW ECF** from incorrect M_r of 400 repeat units Alternative method based on repeat unit: M_r of 400 repeat units = 400 × 71 = 28400 ✓ M_r of polymer = 28400 + 1 + 17 = 28418 ✓ **Examiner's Comments** Few candidates were given the mark for this question. Frequently candidates drew structures with two repeat units or the did not remove the oxygen atom from the OH group. A variety of responses were seen in this demanding question. In general candidates adopted one of two approaches. The most common was to multiply the Mr of the repeat unit by 200 and then add the mass of H and OH at each end of the polymer. The other approach used the Mr of the monomer by 200 and then subtract the mass of the 199 water molecules removed in the polymerisation. Many candidates were successful with the first step of their approach, but the best responses included the second step taking into account the Mr of water. A significant number of candidates used an incorrect value for the Mr.
			Total	**8**	
24		i		3 (AO1.2 ×2) (AO3.2)	

			Section contains A displayed amide linkage between 2 benzene rings ✓ A displayed ester linkage between 2 benzene rings ✓ Section with at least **one** 'end bond' and correct positioning of all 3 groups on **each** benzene ✓		**Marking point 3 is dependent on first 2 marks** Check bonding around **each** benzene so C=O position 1, C-O position 2 and C-NH position 4. **ALLOW** 'end bonds' (with either a solid or dashed line') **OR** terminal ends e.g. -O- or -OH **ALLOW** any combination of 'end bonds' as showing a section not a repeat unit **IGNORE** connectivity of OH and NH_2 groups to benzene **Examiner's Comments** This was a demanding question with just over a third of candidates not scoring marks. However, many candidates were able to gain a mark for either showing the displayed ester or amide link between two benzene rings. Some candidates recognised that at least 3 PAS units would be needed to show both the amide and ester links appropriately. Few responses were able to show a section of polymer that contained correct amide and ester linkages, the correct substituent groups and at least one end bond. The most common reason why candidates did not secure all 3 marks was omission of the OH group on one or more benzene rings of PAS. This question was more challenging as candidates needed to show a polymer section. Many gave 2 'end bonds' as they would for a repeat unit but this was not sufficient here due to the many different possible combinations, we could not make assumptions about what would be next. A common incorrect response was:

					 Furthermore, many candidates just gave 1 benzene ring, like this: 
		ii	**FIRST CHECK ANSWER ON THE ANSWER LINE** **If answer = 2.36×10^{22} award 3 marks** **Calculate moles of PAS:** 300 mg of PAS contains $\frac{300 \times 10^{-3}}{153}$ **OR** $1.96.... \times 10^{-3}$ (mol) ✓ **Daily dose of PAS:** *n*(PAS) for 20.0 kg child = $20 \times 1.96.... \times 10^{-3}$ (mol) **OR** 0.0392..... (mol) ✓ **Use of Avogadro's constant:** Number of PAS molecules = 0.0392..... × 6.02×10^{23} = 2.36×10^{22} ✓	3 (AO3.1 ×2) (AO3.2 ×1)	**ALLOW 3SF** up to calculator value throughout **IGNORE** rounding errors past **3SF** **If there is an alternative answer, apply ECF throughout. Steps can be carried out in any order.** **Calculator values:** $1.960784314 \times 10^{-3}$ 0.03921568627 **Common alternative method:** m(PAS) for 20.0 kg child = 0.3 x 20 **OR** 6.0 (g) ✓ n(PAS) for 20.0 kg child = 6/153 **OR** 0.0392…(mol**)** ✓ **<u>Examiner's Comments</u>** Nearly half the candidates were able to correctly calculate the number of PAS molecules in the maximum daily dosage.

					Some struggled with conversion from mg to g. Some made errors calculating the molar masses or did not calculate moles at all. Most were confident to multiply by N_A at the end. As with other calculations some lost marks for significant figures and rounding errors.
			Total	**6**	
25		i	16 ✓	1 (AO2.6)	**Examiner's Comments** This question was challenging for even the most able candidates with very few obtaining the correct answer of 16. Many identified the four chiral centres in compound E, often labelling these with an asterisk. However, only a small proportion were able to predict that there would be 16 possible optical isomers. Most provided an answer of four corresponding to the number of chiral centres or eight considering that each chiral centre would result in two optical isomers. They struggled to see that they needed 2^n in this case where n represents the number of chiral centres. Candidates have probably seen very few, if any, examples of chiral compounds with more than two chiral centres.
		ii	 **1 mark** for each **correct** structure with • **Either** NH_3^+ **OR** NH_2 ✓✓✓ **1 mark** for	4 (AO2.5 ×4)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** connectivity **ALLOW** + charge on H of NH_3 group, i.e. NH_3^+ If structures are shown with NH_3 groups (without the + charge) **OR** as NH_2^+ groups allow **ECF** for subsequent use. **ALLOW** structures shown as correctly balanced salts, e.g NH_3Cl **OR** $NH_3^+Cl^-$ all marks can be awarded.

			• **all 3 correct** structures with NH_3^+ ✓		**Examiner's Comments** A significant number of candidates did not attempt this question despite similar questions appearing in previous exam series. However, approximately a quarter of candidates scored all 4 marks. Some lost the final mark for not protonating the amine groups as required as under acidic conditions. A very common error was to hydrolyse the amides to give acyl chlorides or even aldehydes rather than carboxylic acids. Lower scoring candidates often had incomplete hydrolysis or no hydrolysis at all with just changes to acid/amine/phenol functional groups, e.g. protonation of amine to form salts or swapping or OH groups for Cl. Candidates need to check their answers carefully for missing or extra Hs as this lost marks. It was much easier to mark candidates' work presented with structures with a similar arrangement to compound E.
			Total	**5**	
26			 **Only possible alternative that can gain credit:** Reaction with NaCN/H^+	9 (AO1.2 ×4) (AO2.5 ×5)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** Correct names instead of formula for all reagents throughout e.g. For H^+ and $Cr_2O_7^{2-}$, **ALLOW** acidified dichromate For Steam and acid • For steam, **ALLOW** $H_2O(g)$ **OR** H_2O with T ≥ 100°C • For acid, **ALLOW** H^+ **OR** H_2SO_4 **OR** H_3PO_4 • Note both needed for 1 mark. **ALLOW** either way round. For $NaBH_4$ • **IGNORE** water / aqueous /acid • **ALLOW** $LiAlH_4$ For $SOCl_2$, **ALLOW** PCl_5 **OR** $COCl_2$



- **IGNORE** H^+ OR HCl

For H^+ and $Cr_2O_7^{2-}$, **ALLOW** H_2SO_4 **AND** $K_2Cr_2O_7$ **OR** $Na_2Cr_2O_7$
ALLOW Tollens' reagent

IGNORE connectivity except
DO NOT ALLOW -COH for aldehyde

For polymer **ALLOW** alternating side chains.
IGNORE brackets and use of 'n'
'End bonds' **MUST** be shown (solid or dotted)

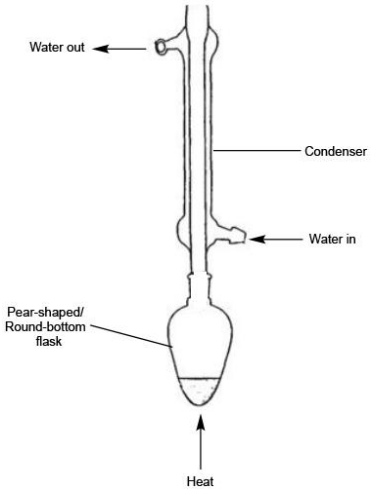
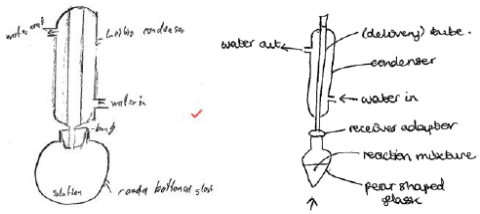
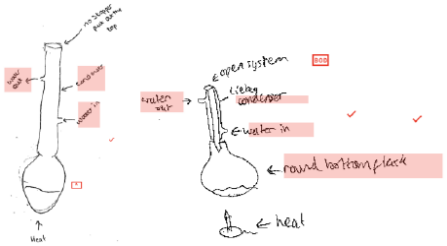
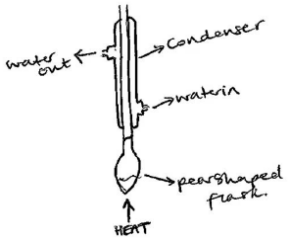
IF NaCN/H^+ reacted with acrolein instead of $NaBH_4$

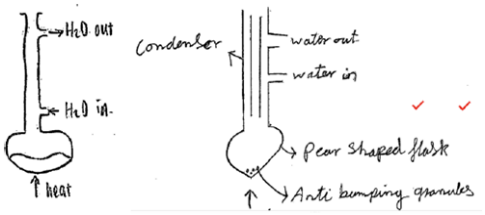
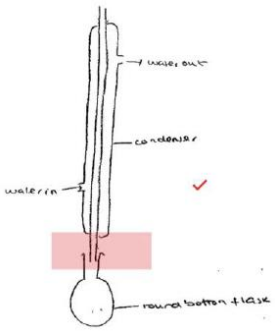
- No mark for NaCN/H+ **OR** HCN
- Unsaturated alcohol award mark for product as shown
- Final product must have CN hydrolysed as shown

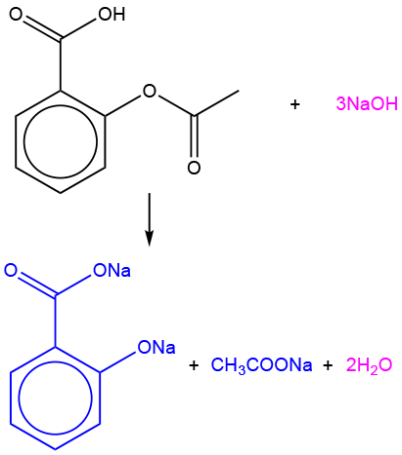
Examiner's Comments

This question discriminated well. Many candidates were able to demonstrate an excellent knowledge of organic reactions and it was not uncommon to see scores of at least 7 marks. This question identified which candidates had learned their synthetic routes including necessary reagents and conditions. Marks were often lost for small details such as missing Hs (check all Cs have four bonds) or not specifying that steam is required for hydration of alkenes or missing the acid needed for oxidation. Many suggested the use of NaOH or just a mixture of acids to product the diol. The minor 1,3-diol or 1,1-diol product was often seen.

The sequence leading to an acyl chloride from acrolein was usually the most well answered. However, quite a few tried to use HCl to make the acyl chloride. Many lost marks for the polymer for incorrect

					connectivity on the aldehyde, e.g. -COH or attempting to make a polymer via connection of the aldehyde group. **OCR support** This topic guide provides a summary of synthetic routes. Copies of the summary posters without the conditions can be found on Teach Cambridge. This should be used in conjunction with the organic synthesis topic exploration pack.
			Total	**9**	
27		i	 **Reaction apparatus (Labels NOT required)** flask **AND** upright condenser **AND** open system at top ✓ *(Could be labelled)* **Labels AND direction of water flow** Pear-shaped/round-bottom flask **AND** condenser	2 (AO 3.3 ×2)	For open system, **DO NOT ALLOW**  **For open system, ALLOW** label. e.g. 'open at top'  **ALLOW** line across flask 

			AND water in at bottom and out at top ✓ Heat **NOT** required **DO NOT ALLOW** flask, conical flask, volumetric flask **DO NOT ALLOW** thermometer **DO NOT ALLOW** condensing tube as label		 **ALLOW small** gap between flask and condenser **BOD**, e.g.  **If in doubt, ask Team Leader** **<u>Examiner's Comments</u>** Most candidates drew a diagram that looked like a vertical condenser above a flask. The quality of the diagrams was not very good. Candidates then needed to label their diagram. Errors included a bung or thermometer inserted at the top of the condenser and water flowing the wrong way in the condenser. For labelling, candidates were expected to use scientific terminology. Responses such as 'condensation tube' and vague terms such as 'flask' were not credited. These labels were often omitted. A significant number drew a set up for distillation instead of reflux.
		ii		3 (AO 2.6 ×3)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **IGNORE** annotations of provided structure of aspirin at top left

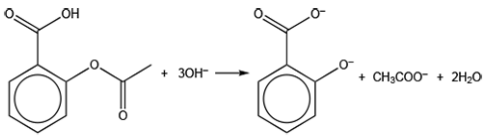


Organic products	✓	✓ ***2 marks***
3NaOH AND $2H_2O$	✓	***1 mark***

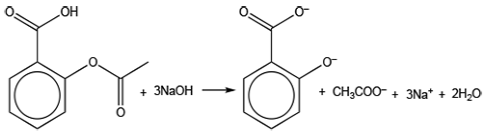
NOTE: ALLOW O^-Na^+ for ONa throughout

SCROLL DOWN FOR PRODUCTS

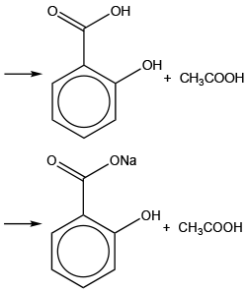
ALLOW equation with 3OH– **OR** 3NaOH giving anions for organic products, i.e.



OR



ALLOW 1 of the 2 organic products mark for BOTH structures as COOH and OH (or mixture) e.g



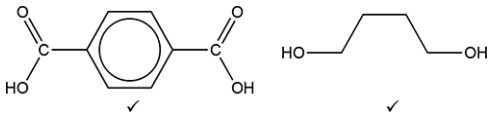
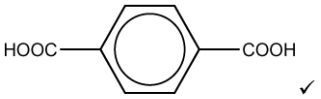
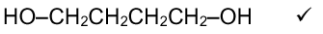
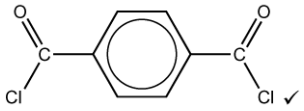
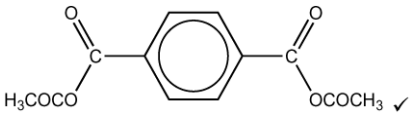
Examiner's Comments

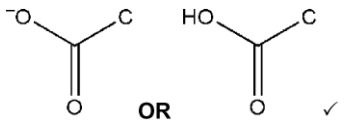
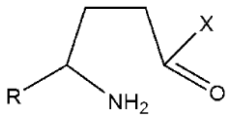
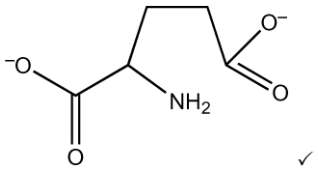
This question was the hardest part of Question 5 and about half the candidates were not given any marks. Some drew the sodium carboxylate salt of aspirin structure, leaving the ester link intact.

A large number of candidates realised that the ester would be hydrolysed. Sometimes the sodium salts were often not shown and, even they were shown, the phenol group was often shown intact.

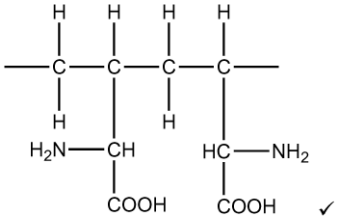
The hardest mark was the formation of $2H_2O$ and a large number of candidates showed the more intuitive but incorrect '$3H_2O$' instead.

Total	**5**	

28			**A**	1	**ALLOW** HC*l* **Examiner's Comments** The vast majority of candidates gave the correct option A, HC*l*. The most common incorrect response was B i.e. H_2O.
			Total	**1**	
29	a			2	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous e.g. **ALLOW**   **ALLOW** Diacyl chloride:  **ALLOW** a diacid anhydride of benzene-1,4-dicarboxylic acid, e.g.  **DO NOT ALLOW** incorrect connectivity on OH **BUT ALLOW ECF** on subsequent structures **ALLOW** correct Kekulé representation of benzene **Examiner's Comments** The majority scored both marks here. A few drew the diacyl dichloride, but these were in the minority. A small minority only lost one mark, usually for incorrect connectivity on -OH groups. Some other errors seen included missing a carbon

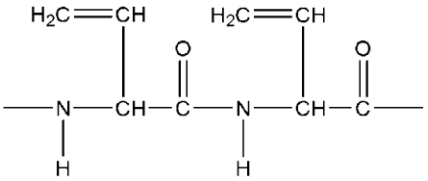
					from alcohol, missing hydrogens on carbon if not drawn skeletally, carboxylic acid groups added directly on to the benzene ring with a pentavalent carbon atom or omitting the circle in the benzene ring.
	b		**Hydrolysis of ester:** Methanol / CH_3OH ✓ **Formation of carboxylate / carboxylic acid from hydrolysis of ester or amide:**  **OR** ✓ *C=O of Carboxylate or carboxylic acid group must be attached to a C But ignore rest of molecule* **Hydrolysis of amide:** Breaks amide bond in ring to give: ✓  *Where R can be H or any other structure* *For X, ignore group attached to C=O* **Correct hydrolysis product:**  ✓	4	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **DO NOT ALLOW** incorrect connectivity on OH **…BUT ALLOW ECF** on subsequent structures **DO NOT ALLOW** CH_3O^- (Na^+) **OR** sodium methoxide **ALLOW** $-COO^-Na^+$ **OR** −COONa **DO NOT ALLOW** esters or amides **ALLOW** NH_3^+**IGNORE** missing Hs on carbon chain Must be completely correct structure **ALLOW** $-COO^-Na^+$ **OR** −COONa **Examiner's Comments** Just over a quarter of candidates were able to gain all 4 marks. The successful candidates clearly identified where theester and amide would be hydrolysed on the structure provided, helping them draw out the correct products. This question differentiated well. Most were able to gain some credit for hydrolysing the ester to give methanol and a carboxylate or carboxylic acid, leaving the amide bond and ring intact. However, some lost the first mark for giving the methoxide ion, assuming that the alkaline conditions are capable of deprotonating the alcohol group. Lower attaining candidates often broke other C-C bonds in the ring forming a range of products. A few displayed the structure as $C=O^-Na^+$ and some also

					protonated the amine group either with the ring intact or broken.
			Total	**6**	
3 0	a		**IF** answer on answer line = 73518 **AWARD** 3 marks **IF** answer on answer line = 73500 **AWARD** 2 marks --- M_r of amino acid = 165 ✓ M_r of 500 molecules = 500 × 165 = 82500 ✓ M_r of polymer = 82500 – (499 × 18) = 73518 ✓ *(final answer must be given to nearest whole number)*	3	**ALLOW ECF** from incorrect M_r of amino acid **Alternative method:** Mr of repeat unit = 147 ✓ 147 x 500 = 73500 ✓ 73500 + 18 = 73518 ✓ **Common error for 2 marks** 36518 Use of Mr 91 82500 Not shown 165 in working **Common error for 1 mark** 45500 Use of Mr 91 **Examiner's Comments** Most candidates managed to score at least one mark here, either for correctly determining the molar mass of the monomer, the repeat unit in the polymer or alternatively they multiplied a molar mass by500. Many candidates gained 2 marks for either 73500 or 82500 but then struggled to account for thewater lost. Some candidates lost marks due to errors in calculating the molar mass of the monomer or some tried toincorporate the use of Avogadro's constant into the calculation. Many misunderstood what atoms wouldbe lost during polymerisation. For example, a common incorrect response seen was found by subtracting2 from the correct molar mass giving 163, followed by multiplication by 500 to give 81500 and finallyadding of 2 to give 81502. Some struggled to understand what was meant by nearest whole number,e.g. rounding 73518 to 74000 or 82500 to 80000.
	b		**Addition polymer**	3	For **BOTH** structures, **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous 'End bonds' **MUST** be shown (with either



✓

Condensation polymer



Amide link ✓

2 repeat units of correct polymer ✓

a solid or dashed line)
BUT ALLOW ECF IF end bonds omitted in both structures

DO NOT ALLOW more than 2 repeat units
BUT ALLOW ECF in subsequent structure

IGNORE connectivity of side groups in both diagrams

CARE: ALLOW any consistent repeat unit: side groups can alternate or be on opposite sides of chain

ALLOW NH in amide link i.e. without bond shown
ALLOW −NH− at either end

IGNORE brackets **IGNORE** *n* or subscript numbers

ALLOW C_2H_3 as side chain for condensation polymer
ALLOW 1 mark if correct structures given by wrong way round

Examiner's Comments

In general, candidates found it easier to give the correct addition polymer rather than the condensation polymer. Some lost the mark for using molecular formula on side chains rather than displaying thesection correctly. The condensation polymer was generally less well answered, with candidates oftenstruggling to give a correct amide bond – many had an oxygen atom retained between the carbonylcarbon and the amine group's nitrogen atom, giving C–O–N. Another common error was the omission ofhydrogen atoms from nitrogen or from the carbon attached to C_2H_3. Just over a quarter of candidates didnot score any marks. Some candidates drew ester linkages instead of amide linkages and struggled toinclude the side chains i.e. trying to incorporate the alkene into the main polymer chain.

			Total	**6**	
3 1			Idea that reflux is used to prevent loss by evaporation ✓ e.g. prevents reaction mixture boiling dry e.g. prevents loss of (volatile) compounds / products / reactants e.g. prevent methanol escaping	1	**IGNORE** responses related to rate of reaction **IGNORE** responses related to ensuring complete reaction **DO NOT ALLOW** reference to incorrect reaction e.g. oxidation, combustion (flammability) **Examiner's Comments** An unfamiliar question that proved challenging with only around a fifth of candidates obtaining the mark for correctly suggesting that reflux would prevent loss of volatile compounds. Many candidatessuggested that reflux ensures the reaction goes to completion but here this was insufficient asesterification is an equilibrium reaction and additional information in (b)(i) indicates that there isunreacted compound **G** present. It was necessary to focus on the purpose for reflux rather than other ways of heating a reaction, such asthe energy needed to break bonds or speed up the rate of reaction. Some less successful responseslinked to oxidation reactions, presumably as they understand the importance of either reflux or distillationin this context. For example, 'reflux is required for complete oxidation' or 'if distillation had been used analdehyde would have been formed'.
			Total	**1**	