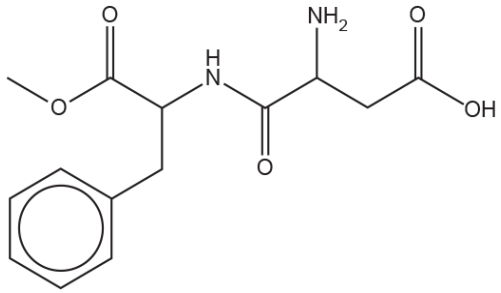
Polyesters and Polyamides

1. 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]**

2. 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.

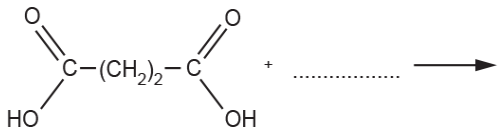
---

[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]

3. This question is about organic chemistry.

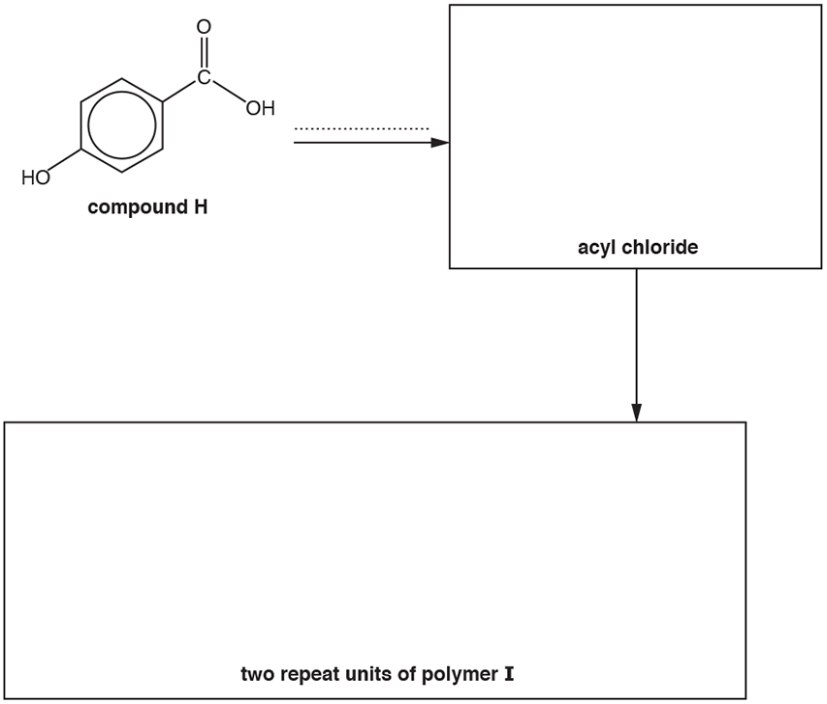
The amino acid Z−$H_2NCH=CHCOOH$ can react to form a cyclic compound with the molecular formula C_3H_3NO and one other product.

Complete the equation for this reaction.

[2]

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

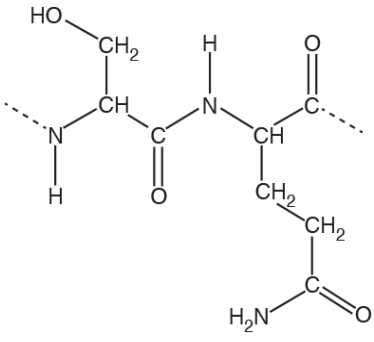
Complete the flowchart by drawing the structure of the acyl chloride and **two** repeat units of polymer **I**, and stating the **formula** of the reagent(s) required for the first stage on the dotted line.



[4]

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

A short section of a protein chain is shown below.

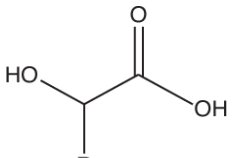


A student hydrolyses the protein with hot NaOH(aq).

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

[3]

6. 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

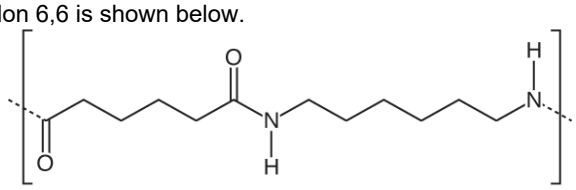
Type of reaction _____

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 _____

7(a). 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]**

(b). 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.

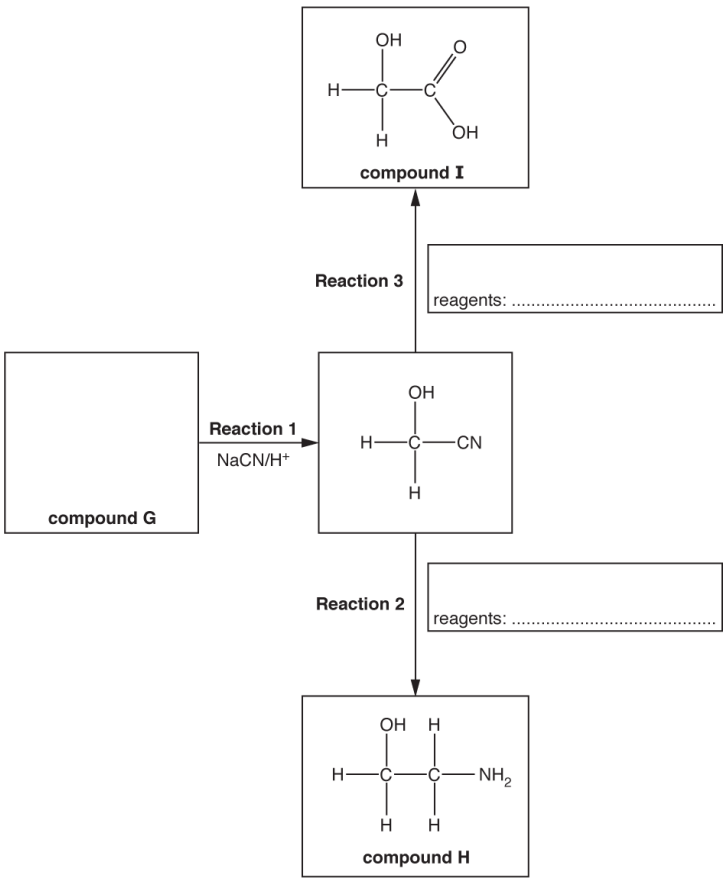
Outline the mechanism for this reaction.

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

[3]

ii. 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]

iii. 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]

iv. 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.

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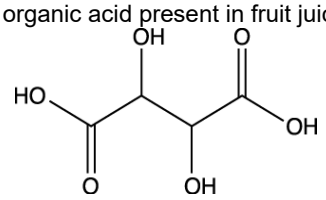
[3]

8. 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]

9. 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.

---

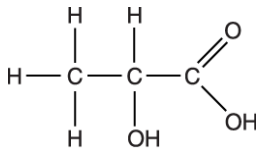
[3]

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]

10. 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.

---

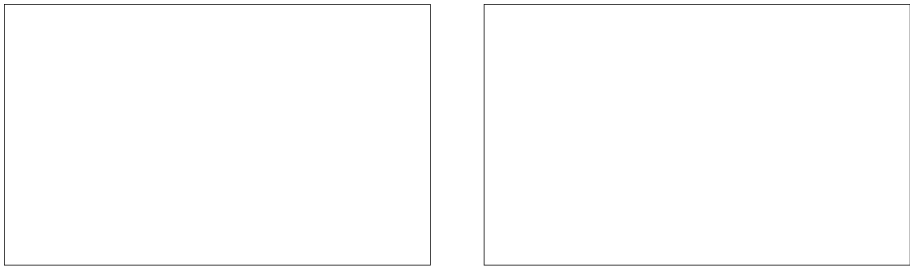
[3]

11 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]**

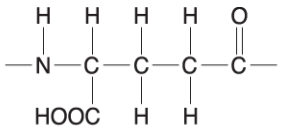
12(a). Compound **E**, C_4H_7NO, is one of two optical isomers. It can be oxidised by Tollens' reagent to an α-amino acid, **F**.

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]

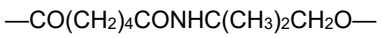
ii. A student tried to prepare poly(glutamic acid) from glutamic acid. No polymer was found in the product mixture.

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.



polymer J

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

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[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.

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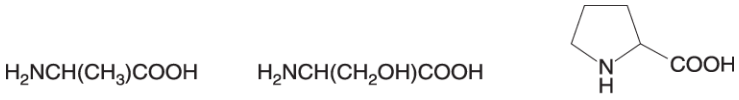
[1]

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



alanine **serine** **proline**

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**

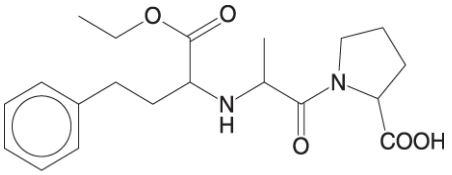
[2]

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.

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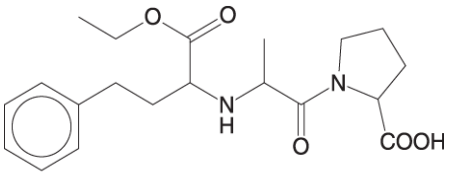
[2]

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–

Explain how GC– enables the products to be identified.

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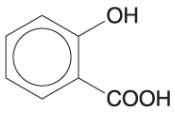
[1]

14. 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*.

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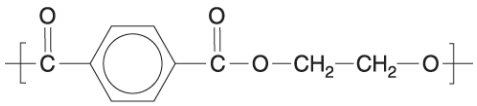
[1]

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.

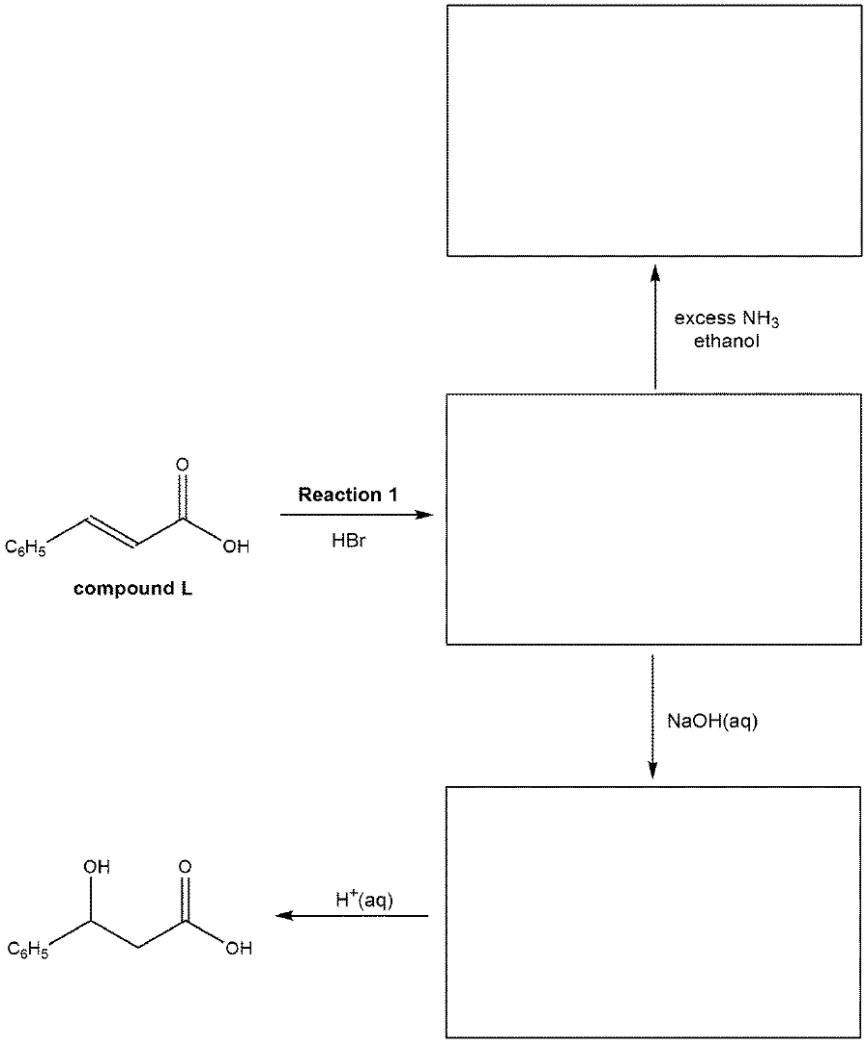
Draw the repeat unit of this polymer, displaying the link between the monomer units.

[1]

15(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.

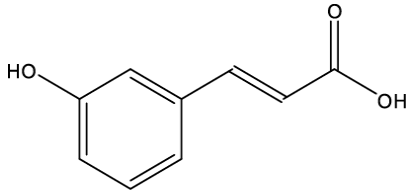


[3]

(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

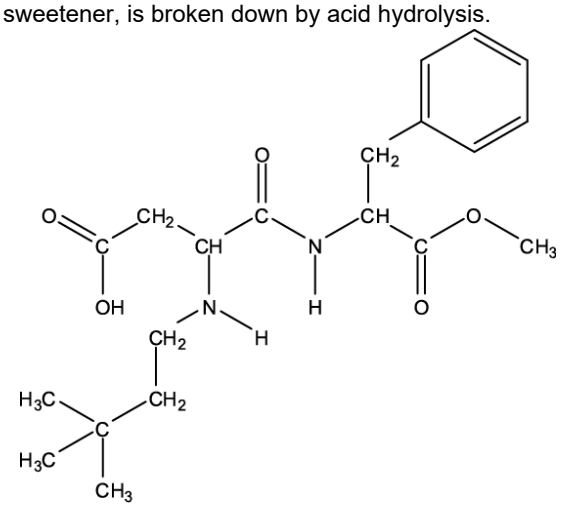
i. Draw the repeat unit of the **addition** polymer formed from compound **M**.

[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]

16(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.

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[4]

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

Use a diagram in your answer.

---

[3]

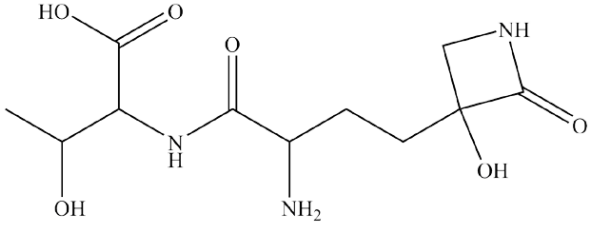
iii. Compound **D** reacts with propanedioic acid, $HOOCCH_2COOH$, to form a condensation polymer.

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]

END OF QUESTION PAPER