

OCR A-LEVEL CHEMISTRY A • H432

CHEMISTRY



EXAM QUESTION PACK

6.2 NITROGEN COMPOUNDS, POLYMERS AND SYNTHESIS

SCORE

/381

PERCENTAGE

%

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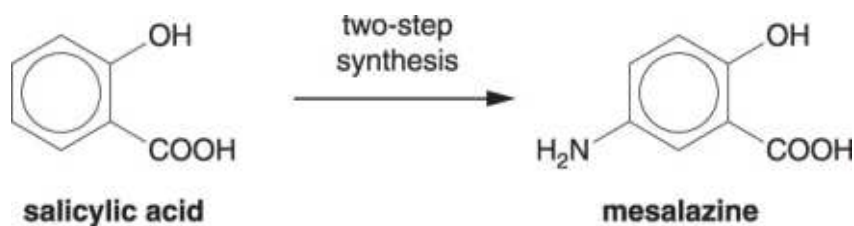
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1(a) Mesalazine is a drug that can be synthesised from salicylic acid in two steps.



(i) Suggest a **two-step** synthesis to prepare mesalazine from salicylic acid.

For each step

- state the reagents used,
- write a chemical equation.

[4]

(ii) Mesalazine reacts with acids to form salts.

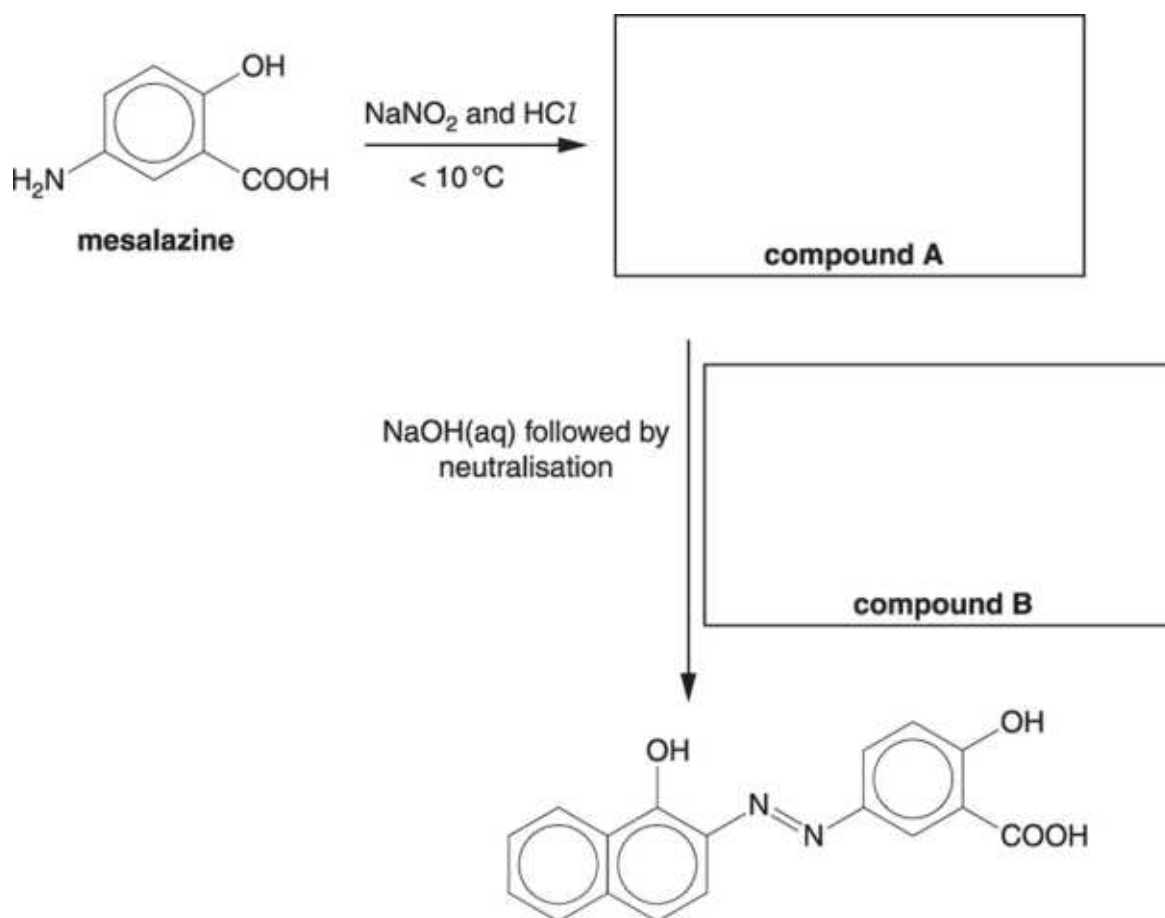
Explain how mesalazine is able to react with acids.

[1]

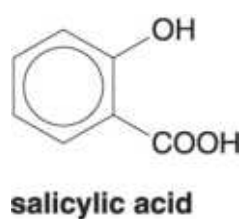
(iii) Mesalazine reacts in another two-stage process as shown below.

In the boxes, draw the structures of organic compounds **A** and **B**.

[2]



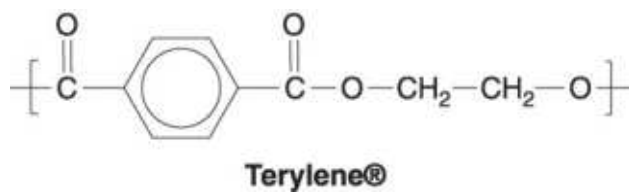
(b) Salicylic acid can be used to form a condensation polymer similar to Terylene®.



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

[1]

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



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.

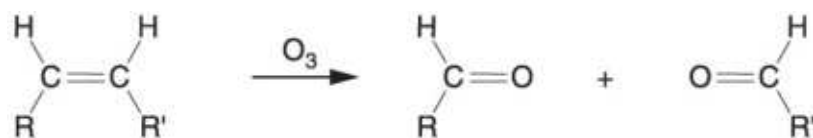
To form one polymer, the two monomers react in equal quantities.

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

[1]

2 'Ozonolysis' is a technique used in organic chemistry to break open a C=C double bond.

During ozonolysis, an alkene reacts with ozone, O₃. The products are carbonyl compounds, as shown below.



(i) Draw the structures of the products you would expect from the complete ozonolysis of the following alkenes.

◦ pent-2-ene

◦ hexa-2,4-diene

[3]

(ii) In another ozonolysis reaction, organic compound **G** reacted to form **only** hexane-1,6-dial.

Compound **G** has six carbon atoms.

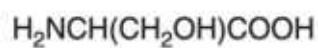
Draw the structure of compound **G**.

[1]

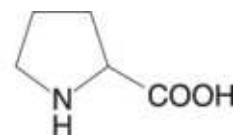
3(a) Alanine, serine and proline are α -amino acids.



alanine



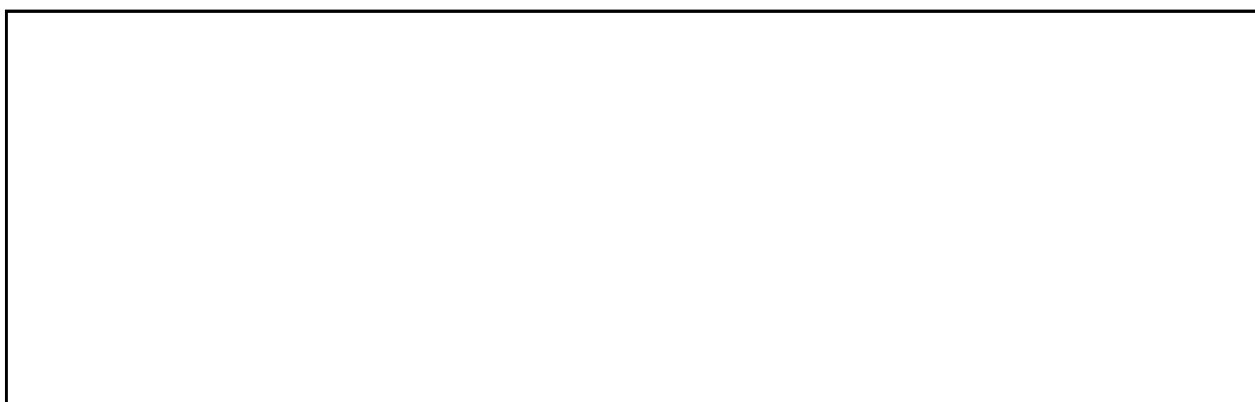
serine



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, $\text{pH} = 6.0$

serine, $\text{pH} = 5.6$

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**



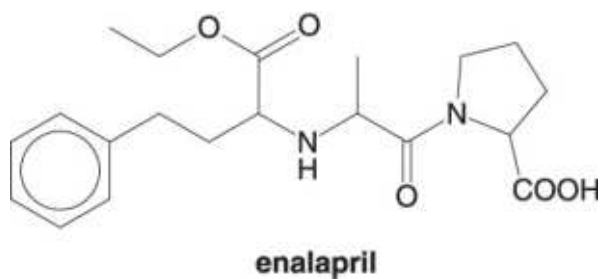
[2]

(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.



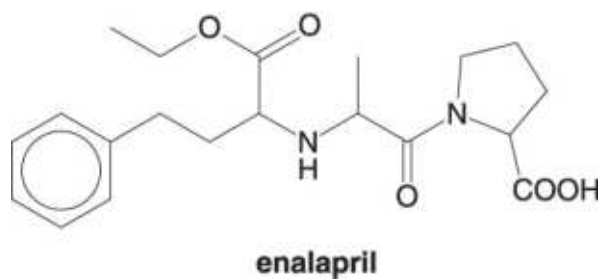
(i) On the structure above, mark each chiral centre with an asterisk (*).

[1]

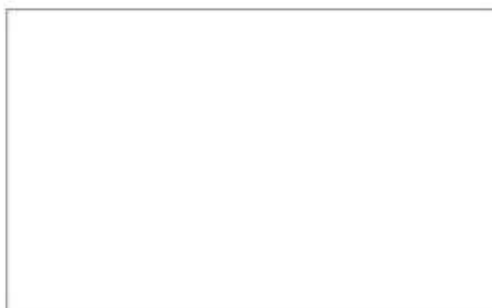
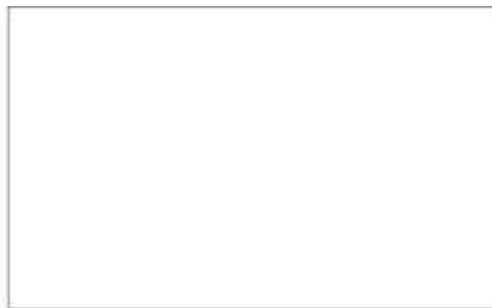
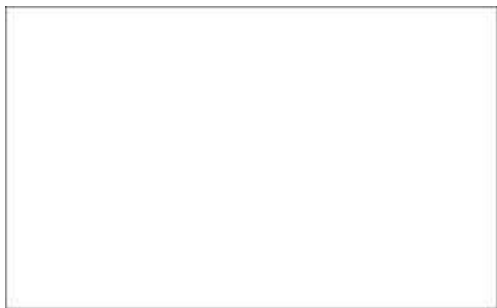
(ii) Suggest **two** benefits of using single stereoisomers in the synthesis of drugs such as enalapril.

[2]

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



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]

4(a) Benzene can react with halogenoalkanes in the same way as with bromine, as shown in **reaction 1** below.

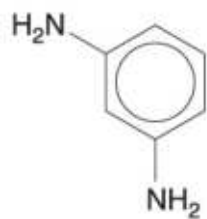


Write an equation to show the formation of the electrophile that reacts with benzene in **reaction 1**.

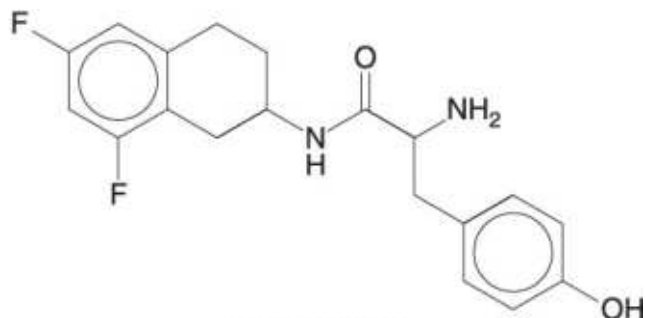
[1]

(b) The types of reaction shown in the previous questions can be used to synthesise compound **D**, as shown in the flowchart below.

(i) Complete the boxes below to suggest formulae for the reactants involved in the synthesis of compound **D**.
Give structures for organic compounds.



1,3-diaminobenzene



compound D

The overall percentage yield of compound **D** was 40.0%.

M_r of compound **D** = 346.0

Calculate the mass of 1,3-diaminobenzene needed for this synthesis.

mass = _____ g [3]

- (iii) Compound **D** has been developed for possible use as a drug to treat heart conditions. When compound **D**, prepared in this synthesis, was given to patients, only 25% of the dose was effective in treating their heart conditions.

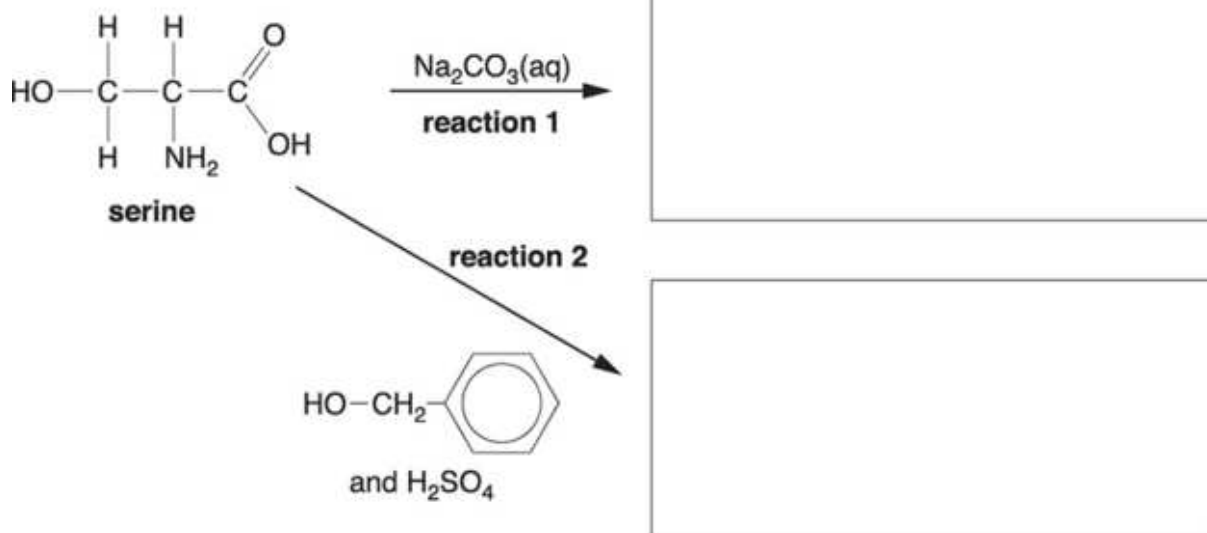
Explain why only 25% of the dose was effective. Suggest how the synthesis of compound **D** might be changed to make the dose more effective.

[3]

5(a) Many α -amino acids have several functional groups.

Serine, shown below, is a naturally occurring α -amino acid.

(i) In the boxes below, draw the structure of the organic compounds formed by each reaction.



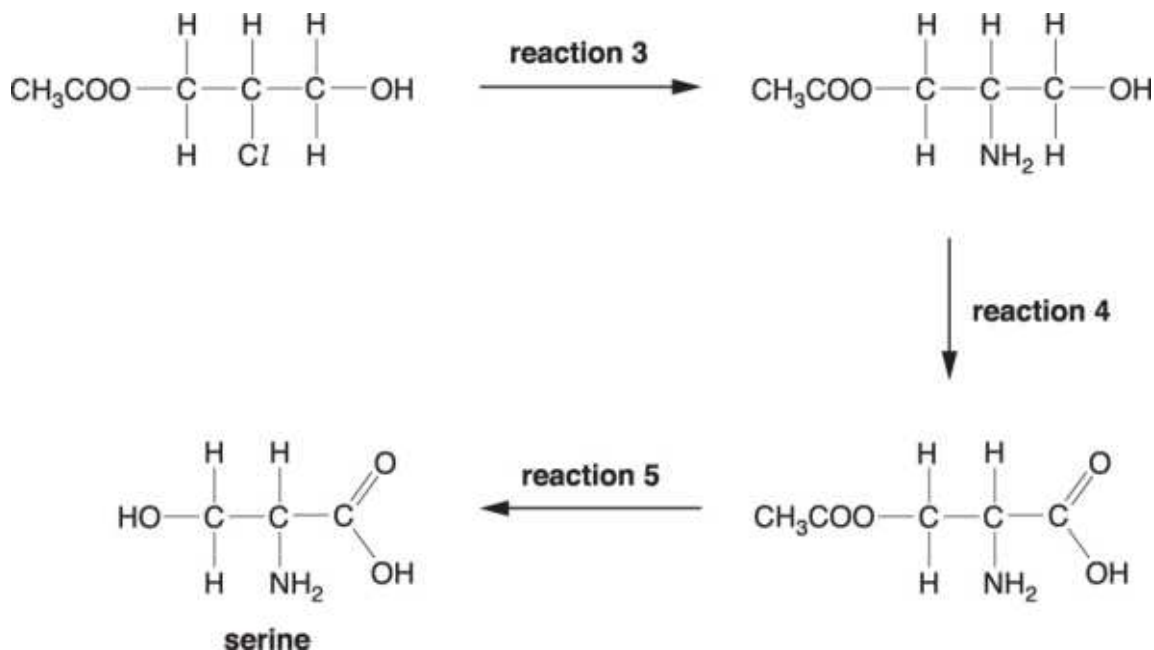
[3]

(ii) Suggest a use for the organic compound formed by reaction 2.

-----[1]

(iii) Serine is commonly used in organic synthesis.

One possible method of synthesising serine is shown below.



Complete the following:

Reagent and conditions used for **reaction 3**.

Type of reaction for:

reaction 4 -----

reaction 5 -----

[3]

- (b) Compound **E**, $\text{C}_4\text{H}_7\text{NO}$, 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**.

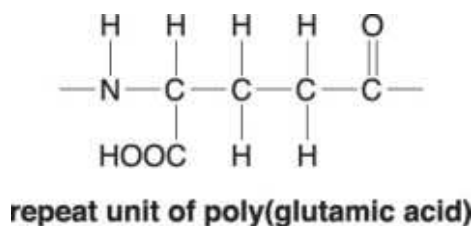
Polymer **G** has the empirical formula $\text{C}_4\text{H}_7\text{NO}_2$.

Polymer **H** has the empirical formula $\text{C}_4\text{H}_5\text{NO}$.

- 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]

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



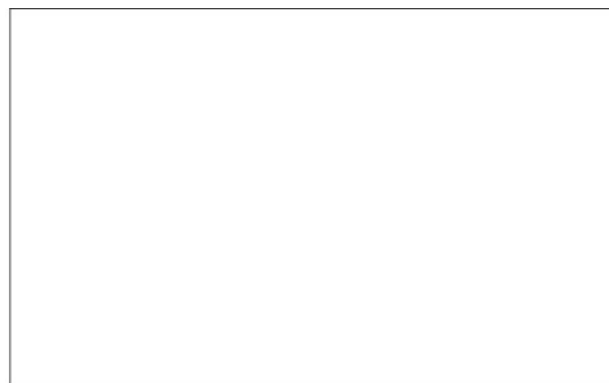
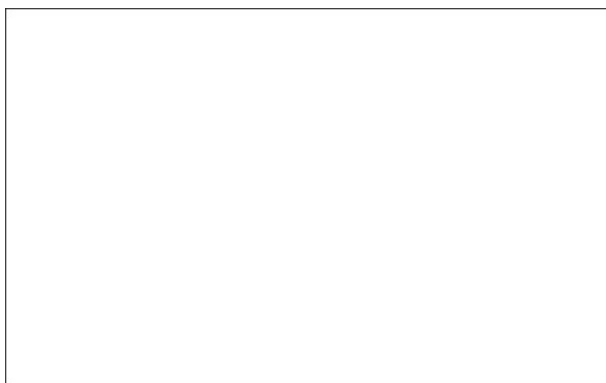
(i) Draw the structure of glutamic acid.

[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]

(d) 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?

-----[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.

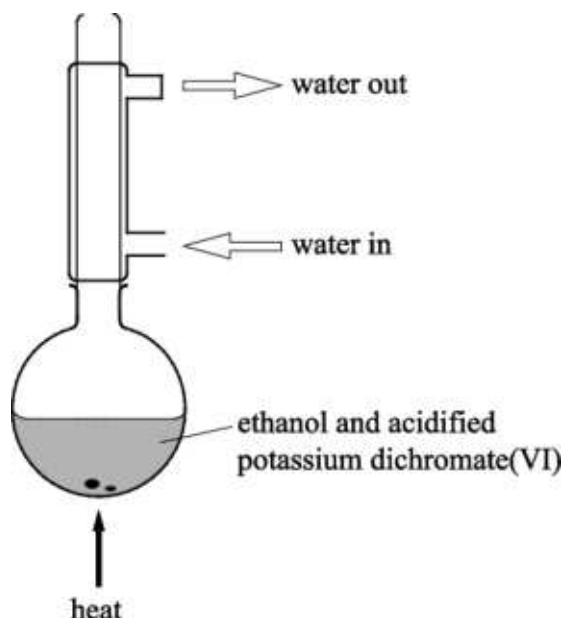
[2]

(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]

- 6 Ethanol is oxidised to ethanoic acid using acidified potassium dichromate(IV) solution. The reaction is heated under reflux using the equipment shown in the diagram below.



What is the reason for heating under reflux?

- A to ensure even heating
- B to prevent any substances escaping
- C to boil the mixture at a higher temperature
- D to allow efficient mixing

Your answer

[1]

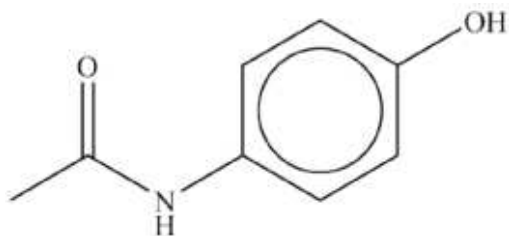
- 7 How many stereoisomers are there of $\text{CH}_3\text{CH}=\text{CHCH}(\text{OH})\text{CH}_2\text{CH}=\text{CH}_2$?

- A 2
- B 4
- C 6
- D 8

Your answer

[1]

8 The structure of a molecule that is used as a pain reliever is shown below.



Which statement about this molecule is **not** true?

- A It has the molecular formula $C_8H_9NO_2$.
- B It reacts with bases to form salts.
- C It has a ketone functional group.
- D It can be hydrolysed with aqueous acid.

Your answer

☐

[1]

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

Compound **D**, $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{NH}_2$, 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, $\text{HOOCCH}_2\text{COOH}$, to form a condensation polymer.

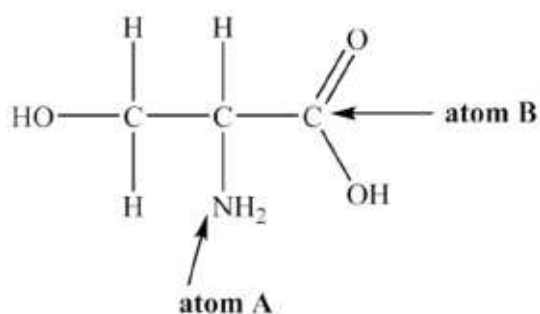
Draw a possible repeat unit of this condensation polymer.

Show clearly any functional group present in the repeat unit.

[2]

(b) Serine, shown below, is an amino acid.

(i)



Use electron repulsion theory to predict the shape of the bonds around atoms **A** and **B**.

Give relevant bond angles around atoms **A** and **B**.

Give reasons for your answers.

[4]

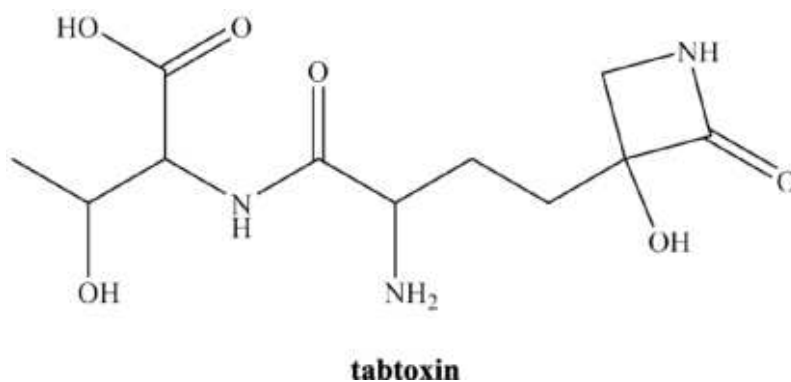
(ii) A student adds an excess of aqueous sodium hydroxide to a sample of solid serine.

The student then purifies the resulting reaction mixture to obtain a pure sample of an ionic organic product.

- Draw the structure of the ionic organic compound obtained.
- Outline the steps that the student could carry out to obtain a pure sample of the organic product from the reaction mixture.

[3]

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



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

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

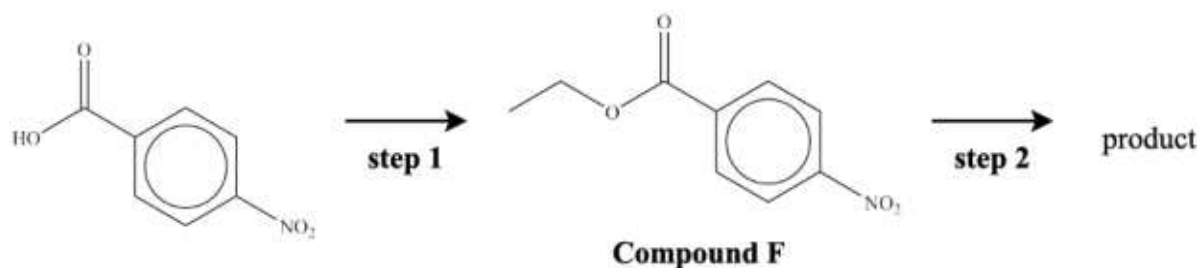
[1]

(ii) Tabtoxin can be broken down by alkaline hydrolysis.

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

[4]

- 10 4-Nitrobenzoic acid is an important compound in chemical synthesis. The flowchart below shows a synthesis involving 4-nitrobenzoic acid.



- (i) State suitable reactant(s) and conditions for **step 1**.

[1]

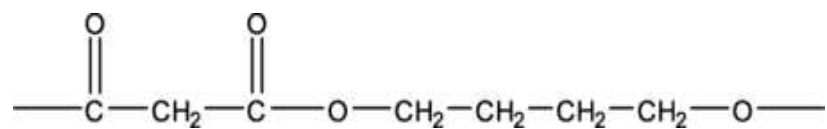
- (ii) In **step 2**, the -NO_2 group in compound **F** is reduced by tin and concentrated hydrochloric acid.

Write an equation for the reduction of compound **F**.

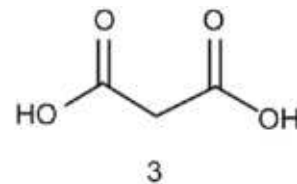
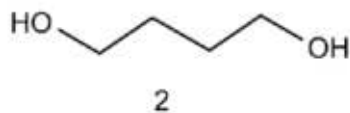
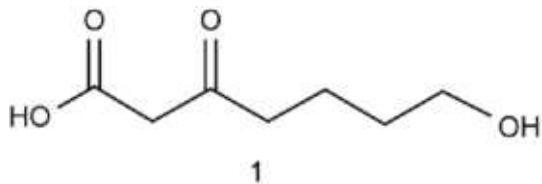
Show the structures of any organic compounds involved.

[2]

11 A chemist synthesises the following polymer.



Which monomers could be used?

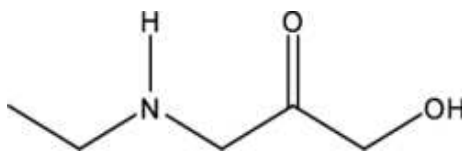


- A 1, 2 and 3
- B Only 1 and 2
- C Only 2 and 3
- D Only 1

Your answer

[1]

12 The skeletal formula of an organic molecule is shown below.



Which of the following statements is / are correct?

- 1: The molecule contains an amine group.
- 2: The molecule contains a carboxylic acid group.
- 3: The molecule contains an amide group.

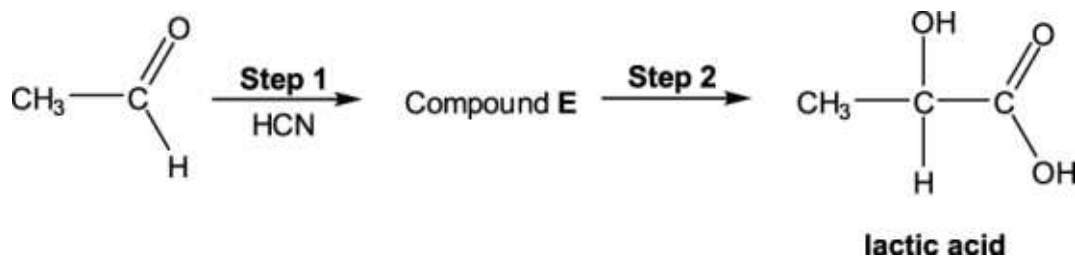
- A 1, 2 and 3
- B Only 1 and 2
- C Only 2 and 3
- D Only 1

Your answer

☐

[1]

13(a) Lactic acid is a naturally occurring chemical, which can be synthesised from ethanal, CH_3CHO , as shown in the steps below.



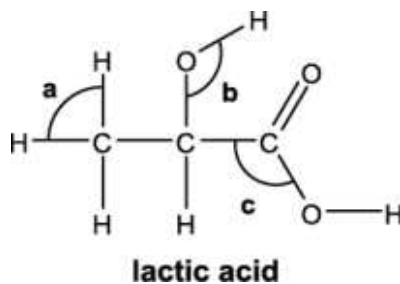
(i) Draw the structure for compound E.

[1]

(ii) Suggest a reagent that could be used for Step 2.

[1]

(iii) The displayed formula of lactic acid is shown below.



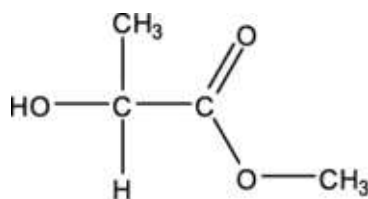
Suggest a value for each bond angle a–c.

Bond angle a: _____

Bond angle b: _____

Bond angle c: _____

(b) Methyl lactate is an ester of lactic acid which is used as a solvent.



methyl lactate

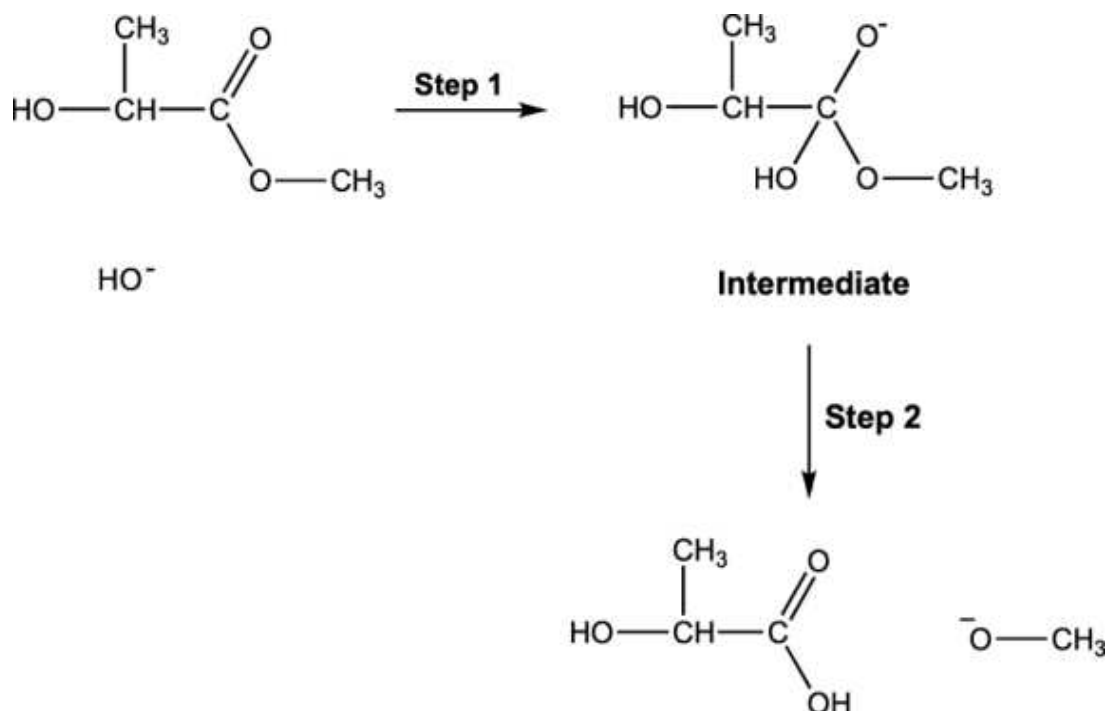
Methyl lactate can be hydrolysed by refluxing with sodium hydroxide solution.

In this reaction the hydroxide ion acts as a nucleophile.

(i) Suggest how the hydroxide ion can act as a nucleophile.

-----[1]

(ii) Part of the mechanism for the hydrolysis is shown below.



◦ Add relevant dipoles and curly arrows to show how the intermediate is formed in **Step 1** of the

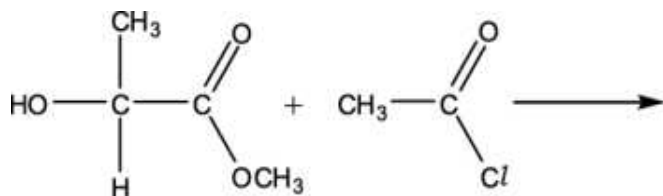
mechanism.

- Add curly arrows to show how the carboxylic acid and $^-\text{OCH}_3$ ion are formed from the intermediate in **Step 2** of the mechanism.

[4]

(iii) Methyl lactate can also react with ethanoyl chloride.

Complete the equation for this reaction.



[2]

14(a) Compound F has the molecular formula C_4H_8 .

Compound F is reacted with steam in the presence of an acid catalyst, to form a mixture of three alcohols, G, H and I.

Compound G is oxidised with acidified potassium dichromate(VI) to form compound J.

Compound J reacts with Tollens' reagent to form compound K.

Compounds H and I are optical isomers.

Draw the structures of the compounds F, G, H, I, J and K.

[6]

(b) Explain, with reference to a suitable chemical test, how compound J could be identified.

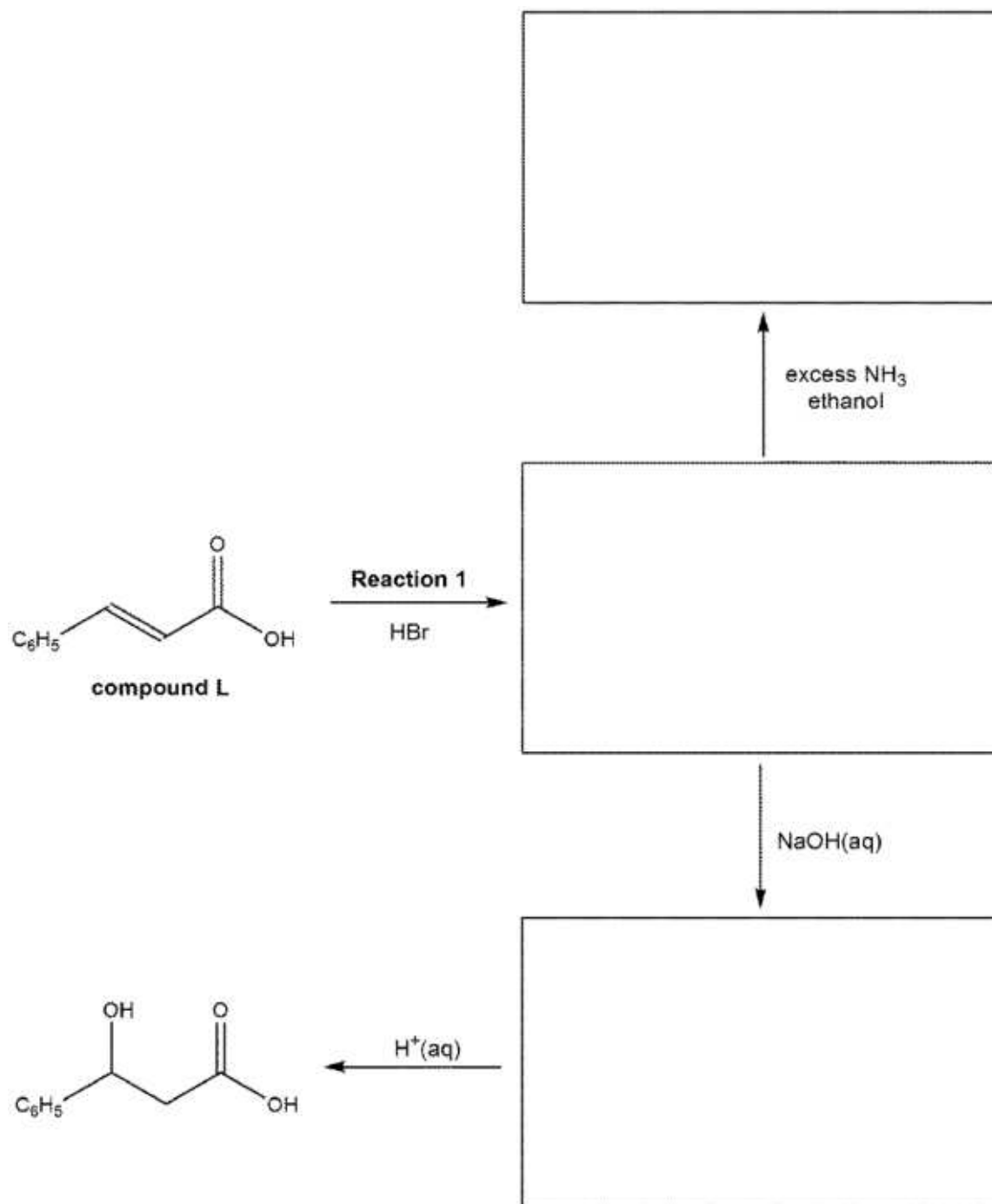
Your answer should not include spectroscopy.

[3]

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.



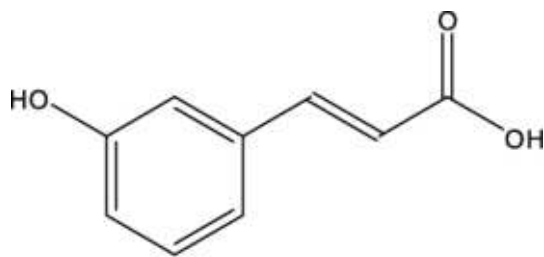
[3]

(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

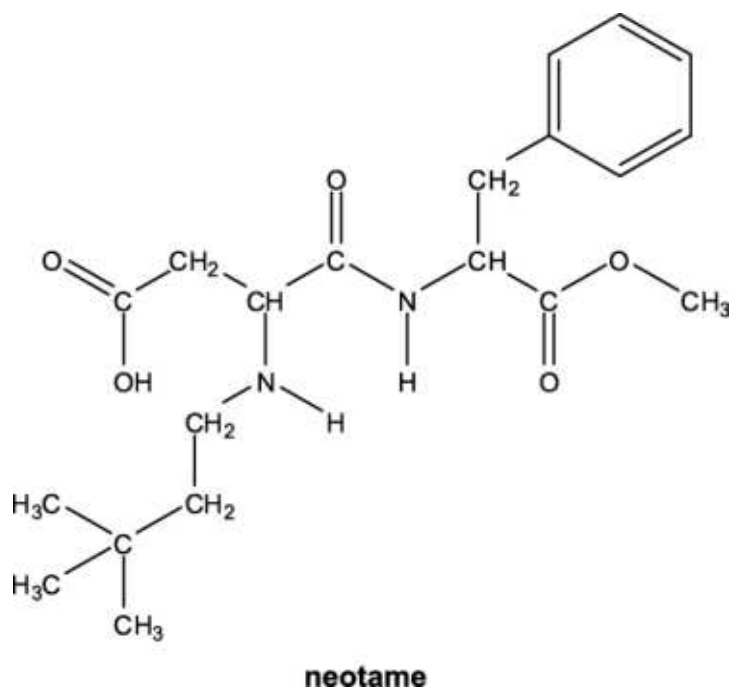
(i) Draw the repeat unit of the **addition** polymer formed from compound **M**.

[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.



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

[4]

- 16 In basic conditions, α -amino acids form anions with the general formula, $\text{RCH}(\text{NH}_2)\text{COO}^-$. These anions can act as bidentate ligands.

Copper(II) ions can form a square planar complex with anions of the amino acid glycine ($\text{R} = \text{H}$). There are two stereoisomers of this complex, **B** and **C**.

- (i) Draw the **skeletal** formula of the anion of glycine.

[1]

- (ii) Draw diagrams of stereoisomers **B** and **C**.

In your structures, show the ligands as skeletal formulae.

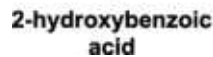
[2]

- (iii) Anion ligands of the amino acid alanine ($\text{R} = \text{CH}_3$) would be expected to form more than two square planar stereoisomers with copper(II) ions.

Explain this statement.

----- [1]

of a concentrated acid catalyst.



- The percentage yield of aspirin from this method is 90.0%.

Outline a plan to prepare 8.10 g of pure aspirin.

In your answer, include the mass of 2-hydroxybenzoic acid needed and the purification steps from the hot reaction mixture.

[6]

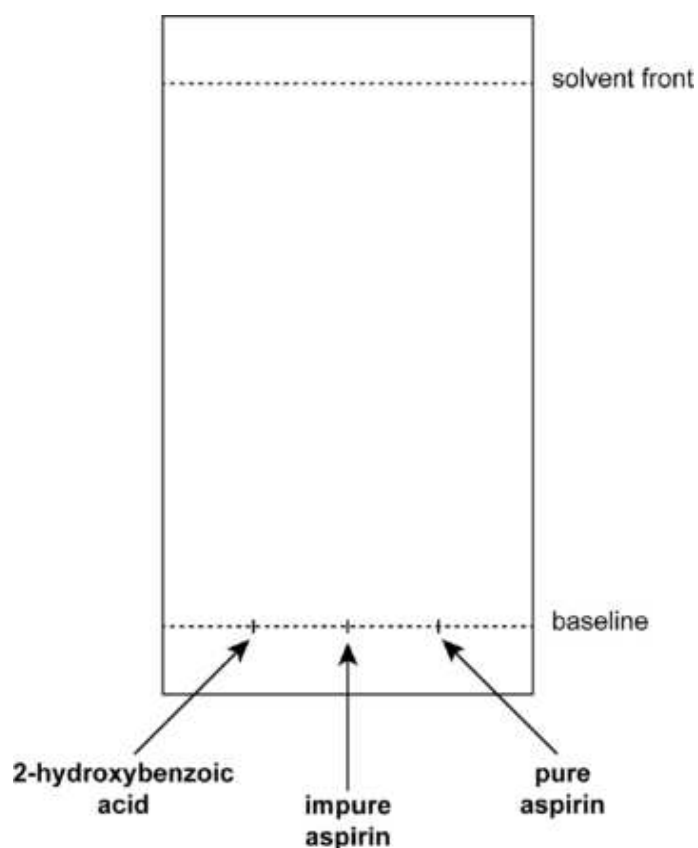
(b) The R_f values and melting point ranges of 2-hydroxybenzoic acid and pure aspirin are shown in the table.

Compound	R_f	Melting point range / °C
2-Hydroxybenzoic acid	0.30	158–161
Pure aspirin	0.75	138–140

(i) A student analyses the purity of their impure aspirin by thin-layer chromatography (TLC).

From the results the student concludes that the impure aspirin is contaminated with a small amount of unreacted 2-hydroxybenzoic acid.

Draw spots on the chromatogram below to show how the student arrived at this conclusion.



[2]

(ii) Predict the melting point range of the impure aspirin.

[1]

18(a) Ethers are a homologous series of organic compounds containing the R–O–R functional group.

The structures and names of two ethers are shown in Fig. 4.1.



Fig. 4.1

Draw the **skeletal** formula of the ether, 2-ethoxy-3-methylbutane.

[1]

(b) Ethers can be prepared by nucleophilic substitution of haloalkanes with alkoxide ions, RO^- .

(i) Alkoxide ions can be prepared by reacting sodium with an alcohol. A gas is also formed.

Write an equation for the formation of methoxide ions from sodium and an alcohol.

-----[1]

(ii) Methoxyethane, shown in Fig. 4.1, can be prepared by reacting bromoethane, $\text{CH}_3\text{CH}_2\text{Br}$, with methoxide ions, CH_3O^- .

Suggest the mechanism for the nucleophilic substitution of $\text{CH}_3\text{CH}_2\text{Br}$ with CH_3O^- .

Show curly arrows, charges, relevant dipoles, and products.

[3]

(iii) In this mechanism, explain how CH_3O^- ions have acted as a nucleophile.

State the type of bond fission that takes place.

-----[1]

(c) 2-Ethoxypropane, shown in Fig. 4.1, is analysed by ^1H NMR spectroscopy.

Complete the table to predict the ^1H NMR spectrum of 2-ethoxypropane.

You may **not** need to use all the rows.

Chemical shift, δ/ppm	Relative peak area	Splitting pattern

[4]

(d) In organic reactions, alkoxide ions can also act as a base.

The diagram below shows an incomplete mechanism for the reaction of a diester with methoxide ions, CH_3O^- (**Step 1**), followed by reaction of the intermediate with bromoethane (**Step 2**).

- (i) For **Step 1**, add curly arrows to show how CH_3O^- reacts with the diester to form the intermediate.
In the box, draw the structure of the organic product formed in **Step 2**.



[3]

- (ii) Explain how CH_3O^- ions have acted as a base in this mechanism.

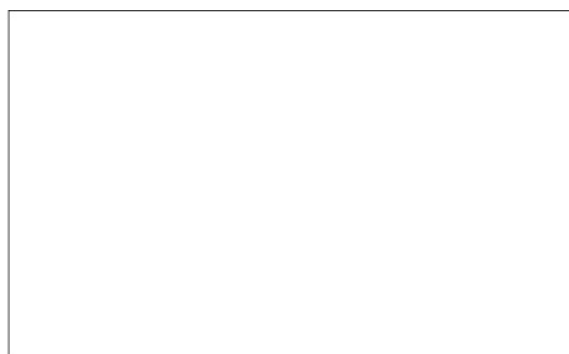
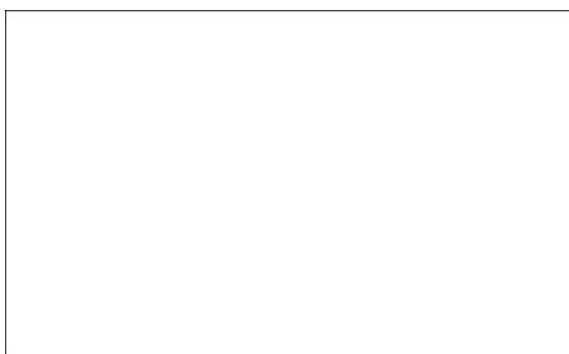
----- [1]

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

A section of a condensation polymer is shown below.



(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

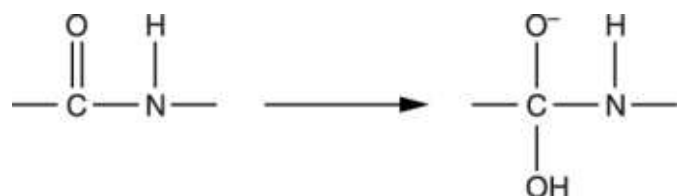
Use [1]

20(a) The building blocks of peptides and proteins are α -amino acids.

A tripeptide is hydrolysed to form a mixture of three different α -amino acids.

The first step of an incomplete mechanism for the alkaline hydrolysis of the tripeptide is shown below.

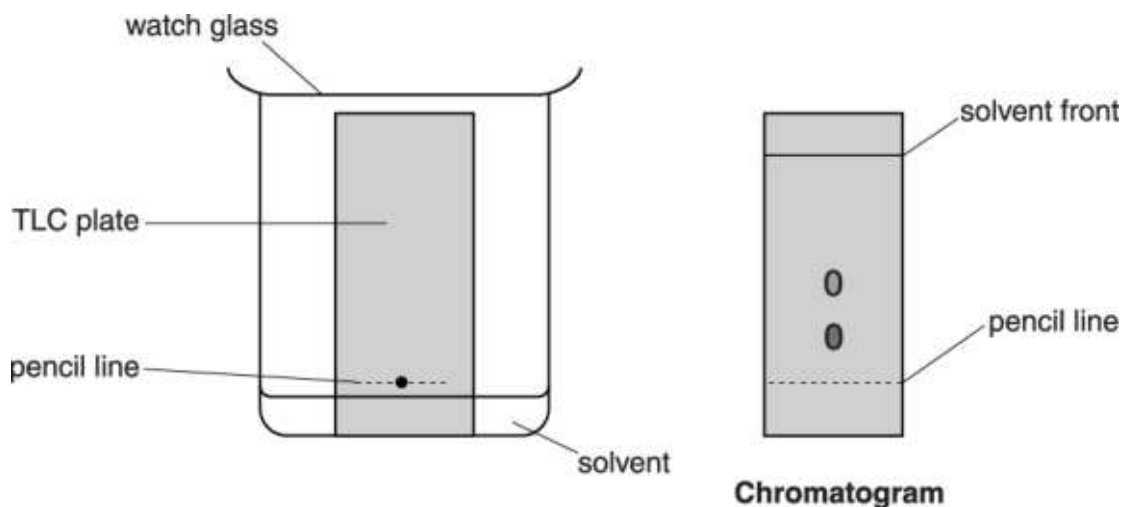
Add curly arrows and relevant dipoles to the diagram to suggest how the hydroxide ion takes part in the first step of this mechanism.



[2]

- (b) The tripeptide is hydrolysed and the resulting mixture containing the three amino acids is neutralised.

A student tries to separate and identify the three amino acids in the mixture using thin-layer chromatography (TLC). The diagram below shows the apparatus for the experiment and the chromatogram produced.



Explain how the chromatogram can be used to identify amino acids.

The student thinks that there should be three spots on the chromatogram.

Suggest why there are only two spots.

[3]

- (c) The three α -amino acids in the tripeptide are aspartic acid, glycine and isoleucine.

The general formula for an α -amino acid is $\text{RCH}(\text{NH}_2)\text{COOH}$.

α -amino acid	R-group
aspartic acid	$-\text{CH}_2\text{COOH}$
glycine	$-\text{H}$
isoleucine	$-\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_3$

- (i) Aspartic acid has an isoelectric point of 2.77.

What is meant by the term *isoelectric point*?



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

----- [1]

- (ii) Draw the structure of aspartic acid when it is dissolved in a solution with a high pH.

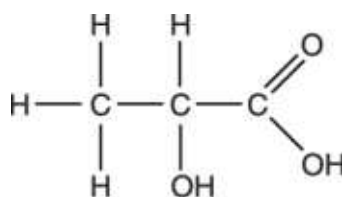
[1]

- (iii) Suggest a structure for the tripeptide.

On your structure, mark each chiral centre with an asterisk (*).

[2]

21 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]

22(a) A chemistry teacher carries out an experiment to synthesise 2-aminopropan-1-ol, $\text{CH}_3\text{CH}(\text{NH}_2)\text{CH}_2\text{OH}$.

The teacher asks a university chemistry department to test the 2-aminopropan-1-ol using proton NMR spectroscopy and mass spectrometry.

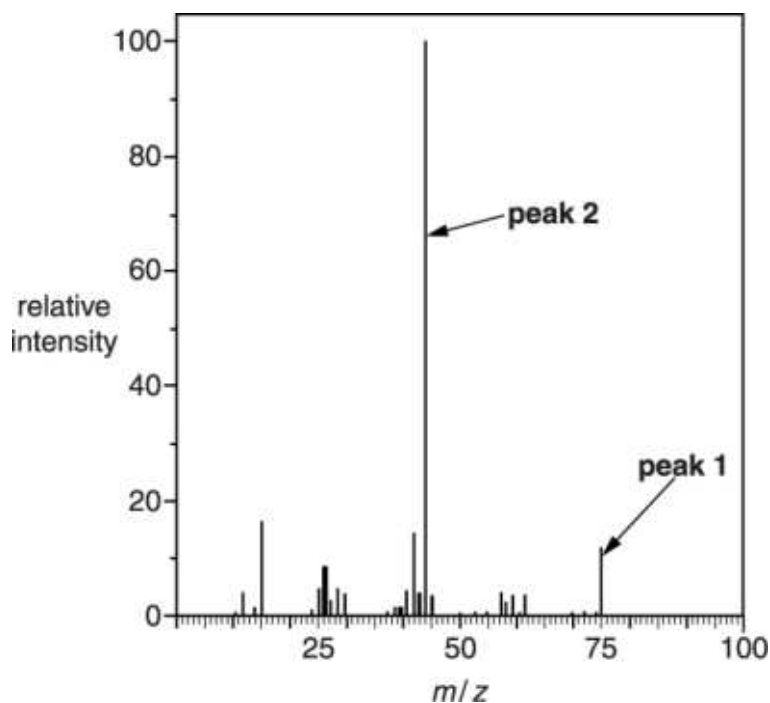
(i) For the ^1H NMR analysis, the sample was dissolved in D_2O .

Complete the table to predict the ^1H NMR spectrum of $\text{CH}_3\text{CH}(\text{NH}_2)\text{CH}_2\text{OH}$ after dissolving in D_2O .

^1H NMR spectrum for $\text{CH}_3\text{CH}(\text{NH}_2)\text{CH}_2\text{OH}$, dissolved in D_2O		
Chemical shift, δ / ppm	Relative peak area	Splitting pattern

[3]

(ii) The mass spectrum for $\text{CH}_3\text{CH}(\text{NH}_2)\text{CH}_2\text{OH}$ is shown below.



Give the formulae for the species responsible for **peak 1** and **peak 2** in the mass spectrum.

peak 1

peak 2

[2]

(b) The teacher synthesises 2-aminopropan-1-ol, $\text{CH}_3\text{CH}(\text{NH}_2)\text{CH}_2\text{OH}$, from 2-chloropropan-1-ol, $\text{CH}_3\text{CHClCH}_2\text{OH}$.

(i) State the reagents and conditions required for this synthesis.

----- [1]

(ii) The sample prepared by the teacher from 2-chloropropan-1-ol is not pure. It also contains compound D.

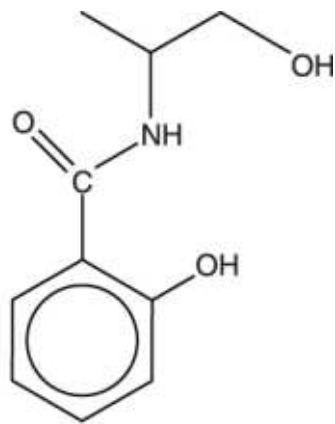
Compound D has a molecular formula of $\text{C}_6\text{H}_{15}\text{NO}_2$.

Suggest the structure of compound D.

Compound D

[1]

(c) In a separate experiment, the chemistry teacher prepares compound E from 2-aminopropan-1-ol.



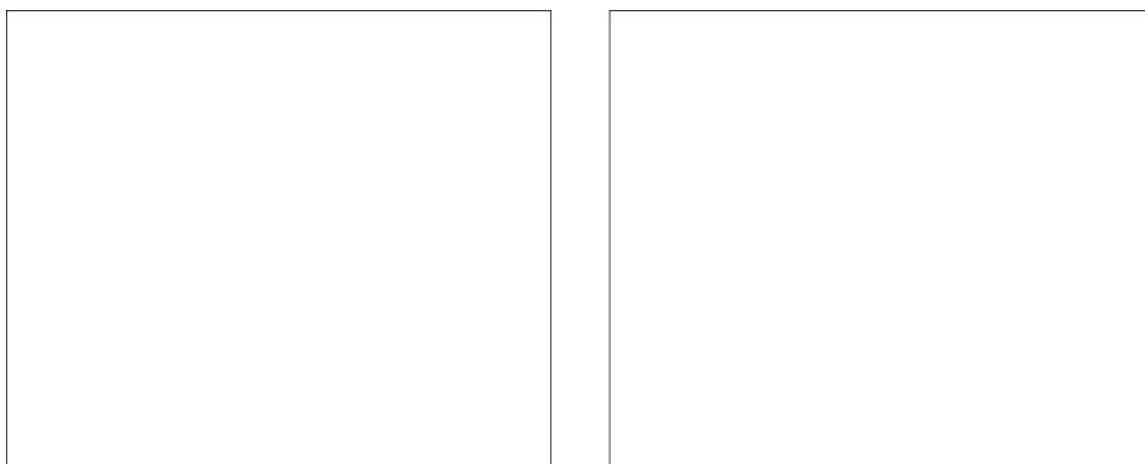
compound E

- (i) One of the functional groups in compound **E** is a phenol.

Name the other functional groups in compound **E**.

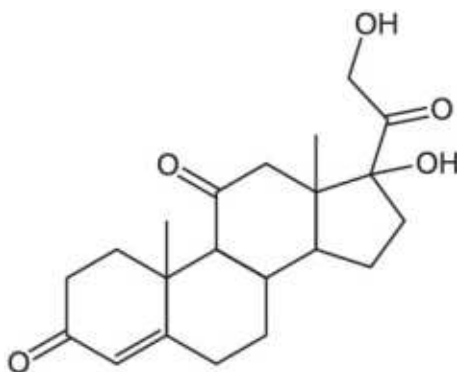
 ----- [1]

- (ii) Draw the structures of the **two** organic products formed when compound **E** is heated under reflux with dilute hydrochloric acid.



[2]

23 What is the number of chiral centres in the molecule below?



- A 4
- B 5
- C 6
- D 7

Your answer

[1]

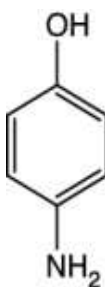
24 Which compound **cannot** be hydrolysed?

- A CH_3COOH
- B $\text{CH}_3\text{COC/}$
- C $\text{CH}_3\text{CONHCH}_3$
- D $\text{CH}_3\text{COOCH}_3$

Your answer

[1]

25 The compound shown below can be prepared from phenol.



Which reagent(s) is/are required?

- A Concentrated NH_3
- B Dilute NH_3
- C Dilute HNO_3 and then concentrated HCl/Sn
- D Dilute HNO_3 and then NaBH_4

Your answer

[1]

26 $\text{CH}_3\text{CH}_2\text{Cl}$ reacts with an excess of ethanolic NH_3 .

Which compound is the main organic product?

- A $\text{CH}_3\text{CH}_2\text{NH}_2$
- B $(\text{CH}_3\text{CH}_2)_2\text{NH}$
- C $(\text{CH}_3\text{CH}_2)_3\text{N}$
- D $(\text{CH}_3\text{CH}_2)_4\text{N}^+$

Your answer

[1]

27(a) This question is about α -amino acids.

Serine, $\text{H}_2\text{NCH}(\text{CH}_2\text{OH})\text{COOH}$, 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, $\text{H}_2\text{NCH}_2\text{COOH}$, to form **three** different organic products, each with the molecular formula $\text{C}_5\text{H}_{10}\text{N}_2\text{O}_4$.

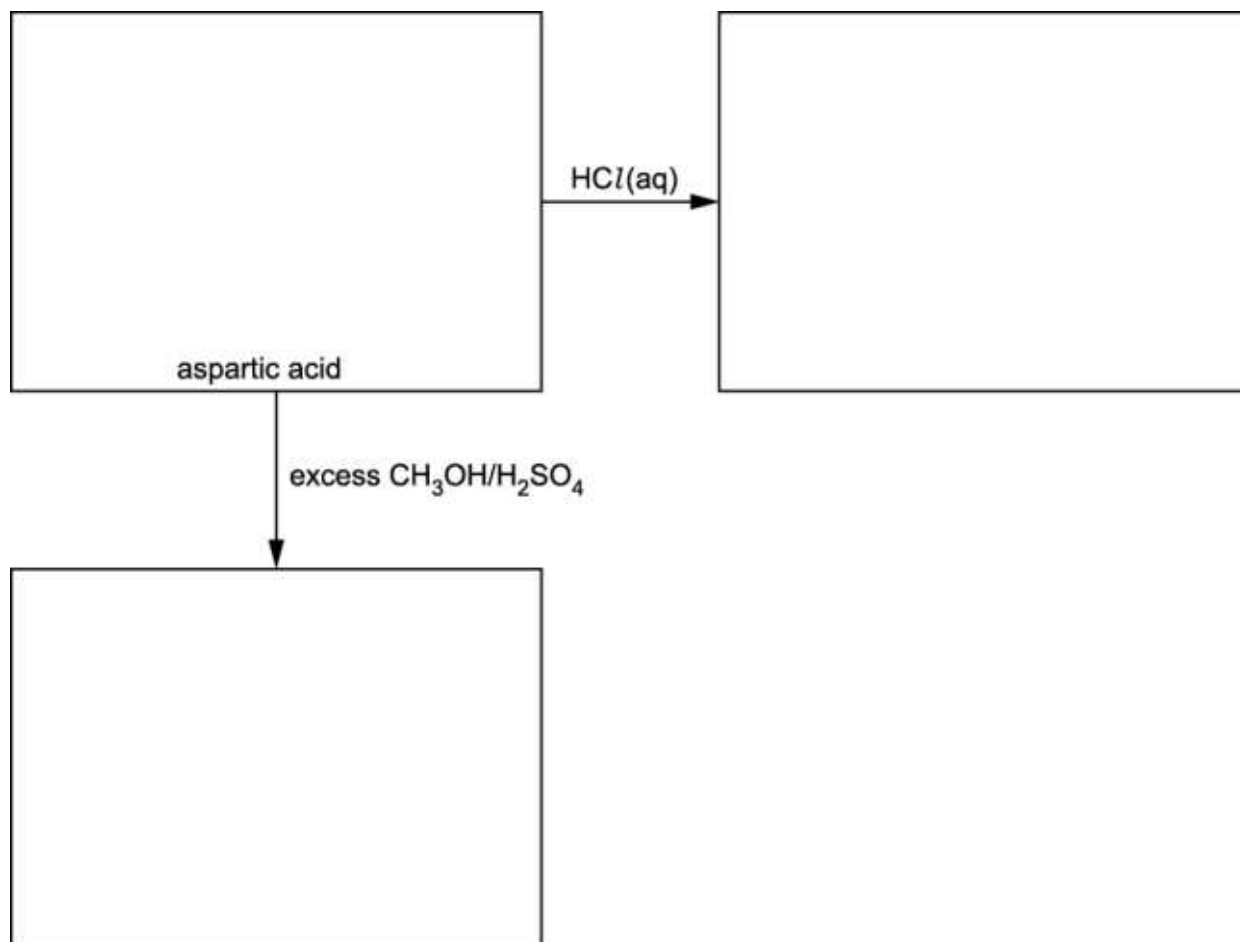
Draw the structures of the **three** organic products that can be formed by the reaction of serine with glycine.

[3]

(b) The general formula of an α -amino acid is $\text{RCH}(\text{NH}_2)\text{COOH}$.

(i) Aspartic acid ($\text{R} = \text{CH}_2\text{COOH}$) is reacted as shown in the flowchart below.

Draw the structures of aspartic acid and the missing organic products in the boxes.



[4]

(ii) Compound **G** is an α -amino acid with a **branched** R group.

0.0300 mol of **G** has a mass of 3.51 g.

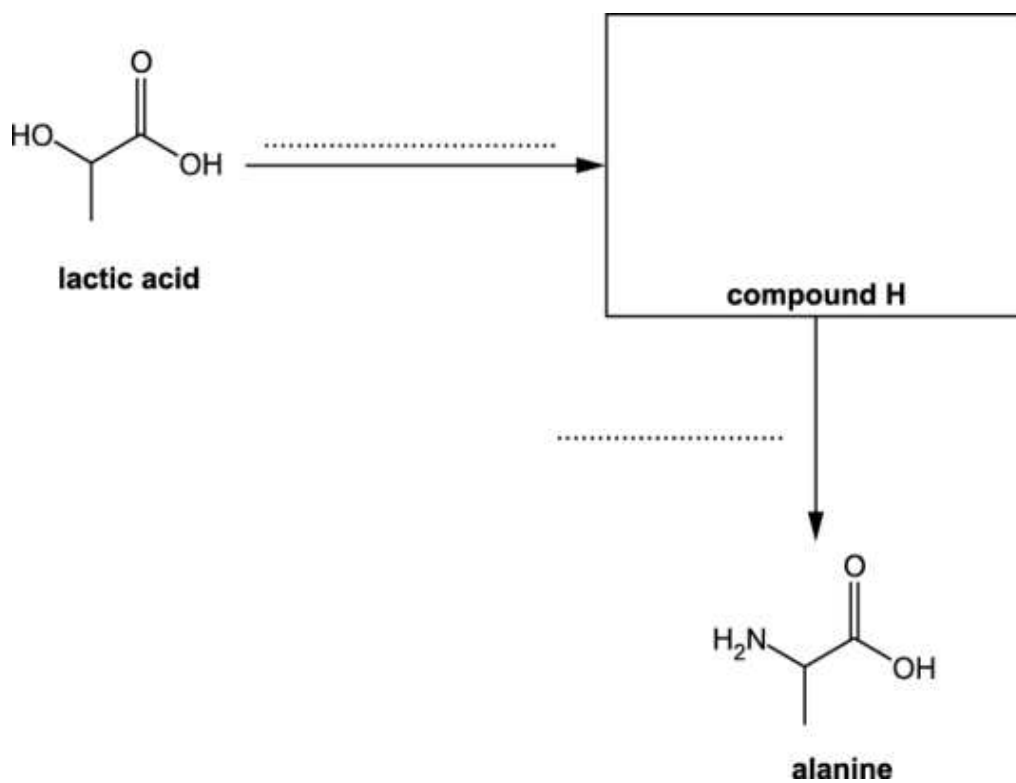
Determine the molar mass of α -amino acid **G** and suggest its structure.

[2]

(c) A student plans a two-stage synthesis of alanine from lactic acid, $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$.

The synthesis first prepared compound H, as shown in the flowchart.

Draw the structure of compound H in the box and add the formulae of the reagents for each stage on the dotted lines.



[3]

- 28 'Oil of wintergreen' is used to relieve aching muscles and can be prepared by reacting salicylic acid with methanol.



- (i) Suggest the structure of oil of wintergreen and the conditions needed to prepare oil of wintergreen from salicylic acid.

Structure

Conditions [1]

- (ii) After its preparation, oil of wintergreen can be purified by distillation.

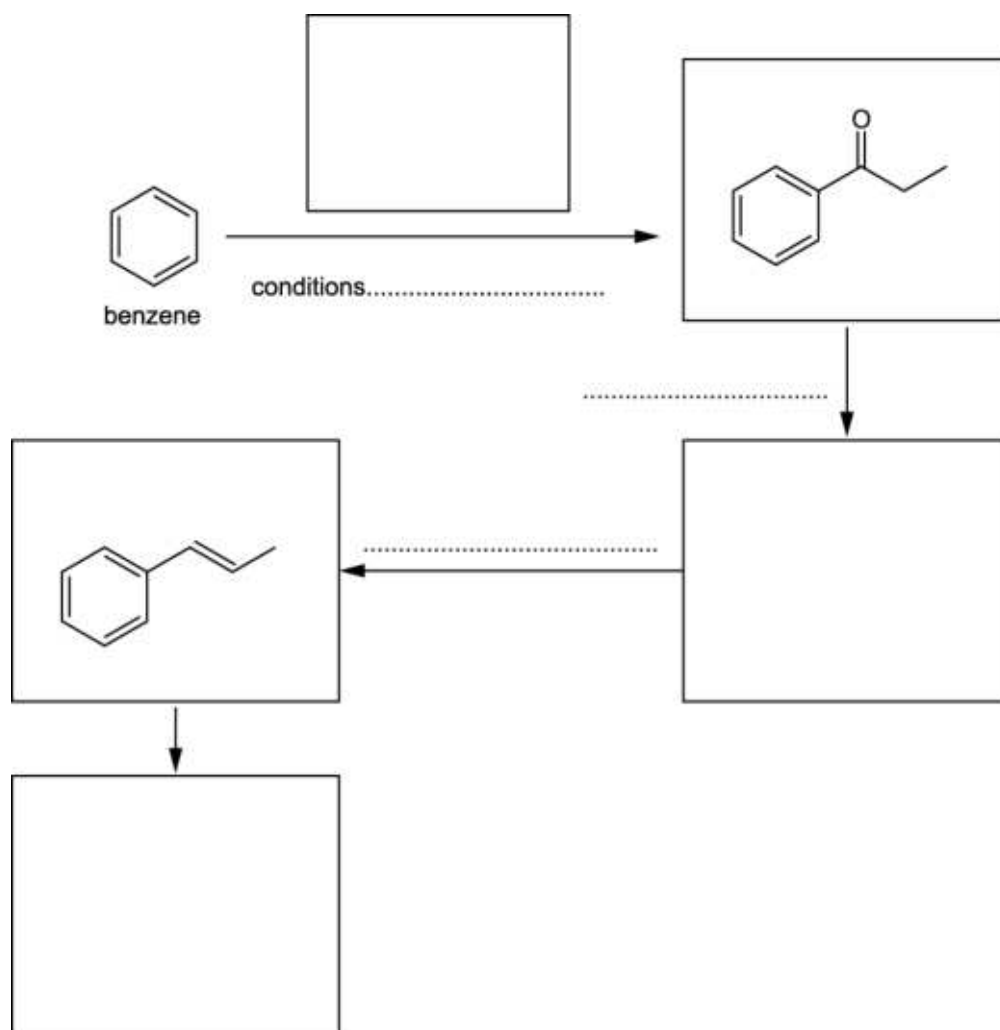
Draw a **labelled** diagram showing how the apparatus is set up for distillation.

[2]

29(a) This question is about the synthesis of a polymer.

The flowchart below shows the synthesis of polymer I starting from benzene.

Draw the structures of the missing compounds in the boxes and add the missing reagents on the dotted lines.



repeat unit of polymer I

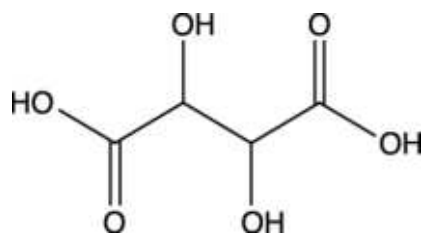
[6]

(b) Polymer I cannot be disposed of in landfill sites as it is not biodegradable.

Suggest **one** way of processing waste polymer I other than landfill and recycling.

[1]

30 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, $\text{H}_2\text{N}(\text{CH}_2)_6\text{NH}_2$, to form a polymer.

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

[2]

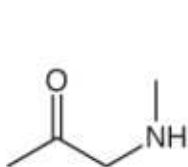
(iv) The polymerisation in (iii) takes place in two steps.

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

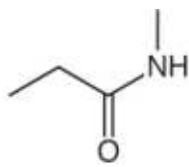
Draw the structure of this salt, showing the ions present.

[2]

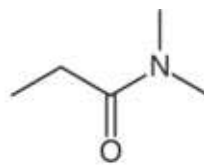
31 Which molecule is a secondary amine?



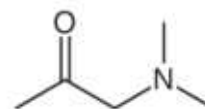
A



B



C

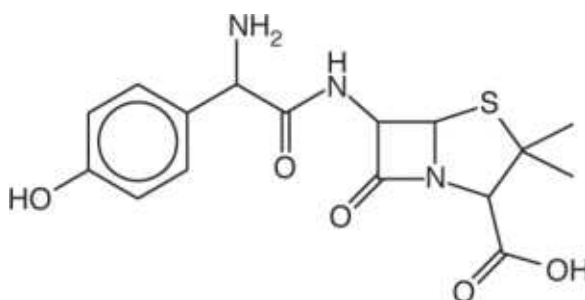


D

Your answer

[1]

32 What is the number of chiral centres in the molecule below?



A 2

B 3

C 4

D 5

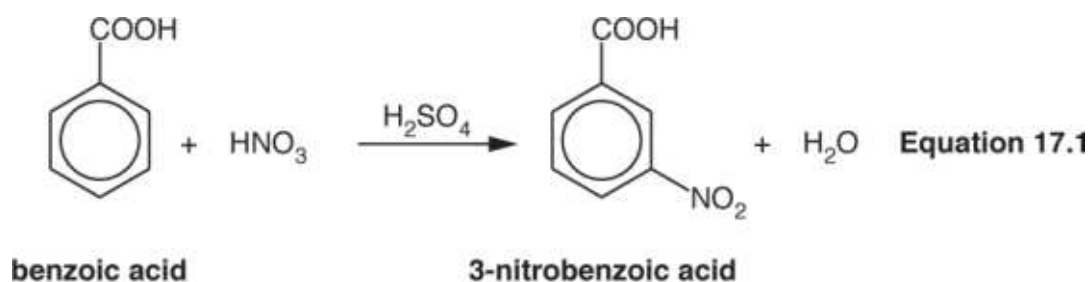
Your answer

[1]

33(a) This question is about the chemistry of aromatic compounds.

Benzoic acid can be nitrated by concentrated nitric acid in the presence of concentrated sulfuric acid as a catalyst, as shown in **Equation 17.1**.

The organic product of this reaction is 3-nitrobenzoic acid.



(i) Outline the mechanism for this nitration of benzoic acid.

Show how H_2SO_4 behaves as a catalyst.

[5]



A chemist carries out the reaction in **Equation 17.1** using 4.97 g of benzoic acid.

The chemist obtains 3-nitrobenzoic acid as an impure solid.

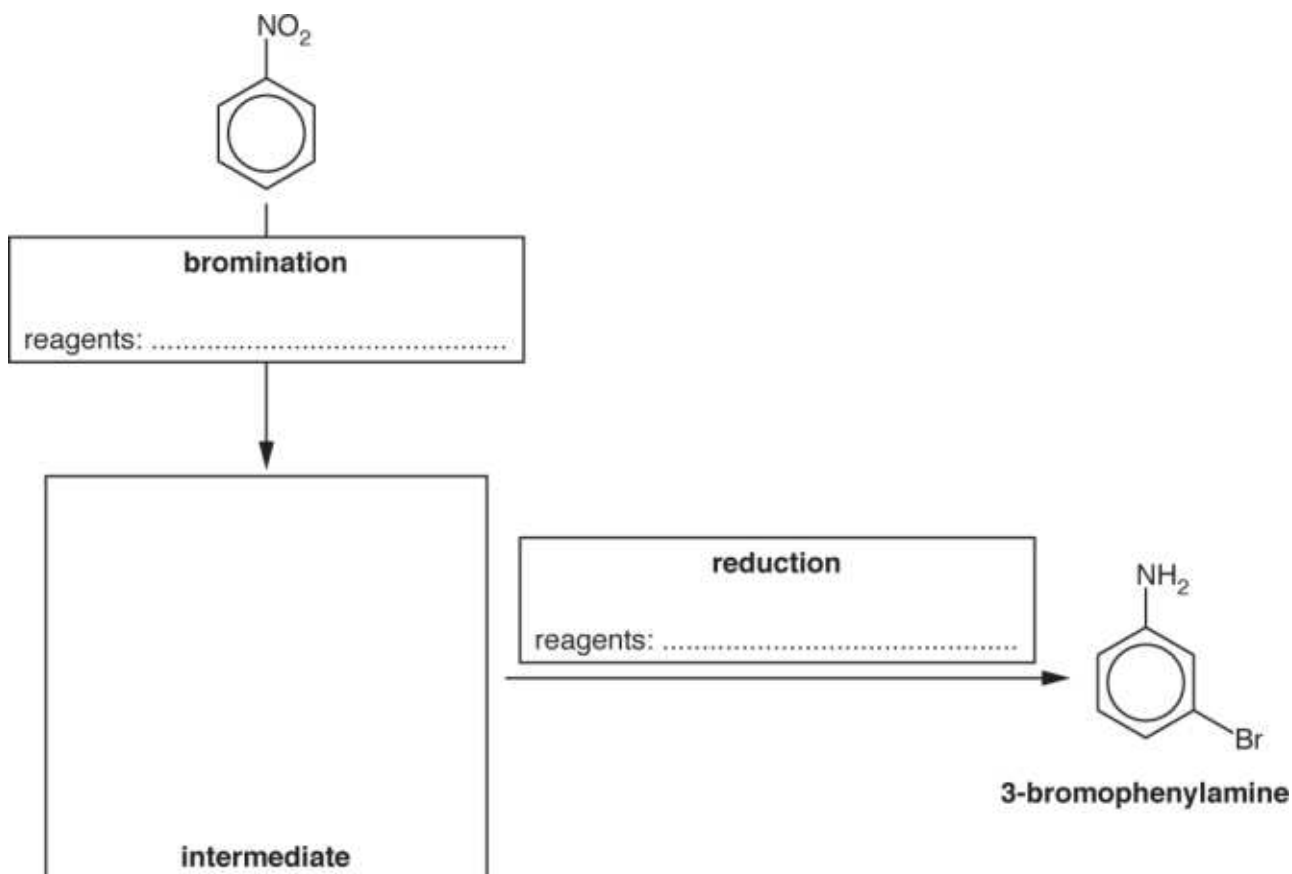
The chemist purifies the solid to obtain 4.85 g of 3-nitrobenzoic acid.

Describe a method to obtain a pure sample of 3-nitrobenzoic acid from the impure solid, determine the percentage yield and check its purity.

This image shows a blank sheet of white paper with horizontal dashed lines. The lines are evenly spaced and run across the width of the page, providing a guide for handwriting practice. There are no other markings or text on the page.

(b) A student synthesises 3-bromophenylamine, shown below, starting from nitrobenzene.

- (i) Complete the flowchart showing the structure of the intermediate and the formulae of the reagents for each stage.



[3]

- (ii) Another student attempts the same synthesis but carries out reduction **before** bromination. The student was surprised to find that two structural isomers of 3-bromophenylamine had been formed instead of the desired organic product.

Explain this result and suggest the structures of the two isomers that formed.

Explanation

Structures

[3]

34(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, $\text{CH}_3\text{CH}_2\text{CH}_2\text{Cl}$, reacts with ethanolic sodium cyanide by nucleophilic substitution.

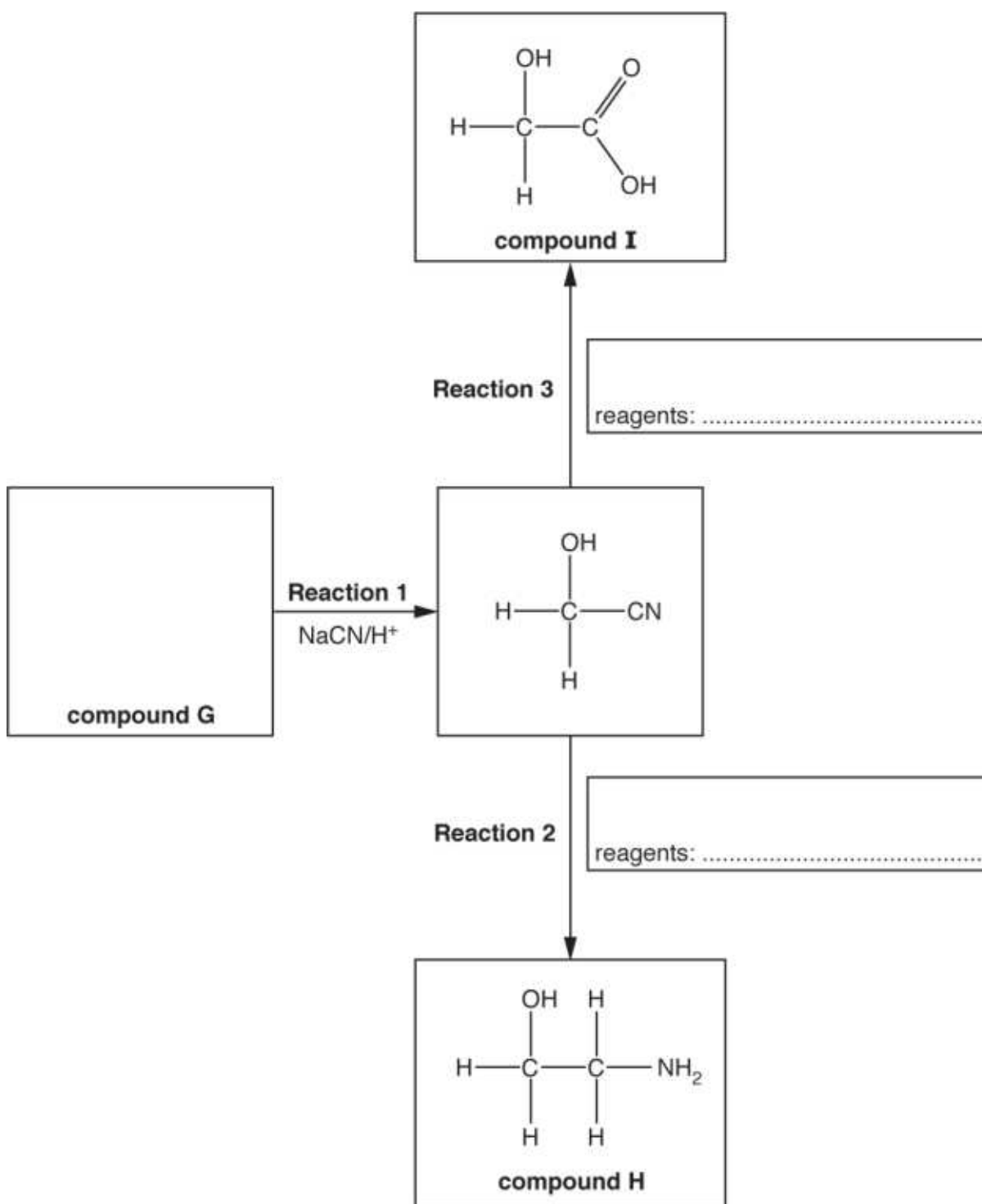
Outline the mechanism for this reaction.

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.

[3]

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



(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]

35(a) This question is about weak acids.

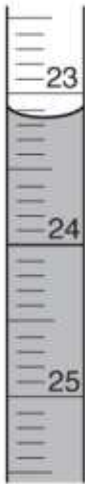
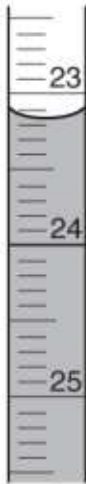
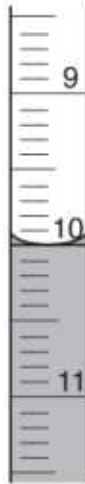
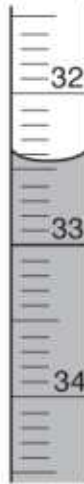
Compound A is a weak monobasic acid.

A student is supplied with a 250.0 cm^3 solution prepared from 2.495 g of A.

The student titrates 25.0 cm^3 samples of this solution with $0.0840\text{ mol dm}^{-3}$ NaOH in the burette.

The student carries out a trial, followed by the three further titrations. The diagrams show the initial burette readings and the final burette readings for the student's three **further** titrations.

All burette readings are measured to the nearest 0.05 cm^3 .

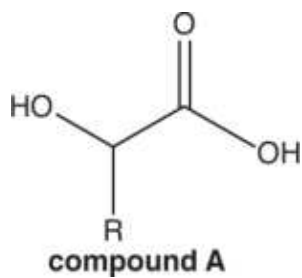
Titration 1		Titration 2		Titration 3	
Initial reading	Final reading	Initial reading	Final reading	Initial reading	Final reading
					

(i) Record the student's readings and the titres in an appropriate format.

Calculate the mean titre that the student should use for analysing the results.

mean titre = _____ cm^3 [4]

(ii) The structure of compound **A** is shown below.



Compound **A** has four optical isomers.

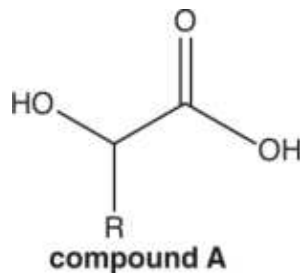
Using this information and the student's results, answer the following.

- Determine the molar mass of **A** and the formula of the alkyl group **R**.
- Draw the structure of compound **A** and label any chiral carbon atoms with an asterisk*.

Show all your working.

[6]

(b) The structural formula of compound **A** is repeated below.



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.

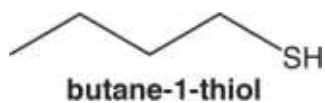
Equation

Type of reaction ----- [3]

36 This question is about organic molecules that have a strong smell.

Thiols are foul-smelling, organic sulfur compounds with the functional group –SH.

Butane-1-thiol, shown below, contributes to the strong smell of skunks.



(i) Thiols are weak acids.

Write the expression for the acid dissociation constant, K_a , for butane-1- thiol.

[1]

(ii) Thiols react with carboxylic acids to form thioesters.

Write an equation for the reaction of butane-1-thiol with ethanoic acid.

Use structures for all organic compounds with the functional groups clearly displayed.

[2]

(iii) When beer is exposed to light, 3-methylbut-2-ene-1-thiol is formed, which gives an unpleasant smell and flavour to the beer.

Draw the **skeletal** formula for 3-methylbut-2-ene-1-thiol.

[1]

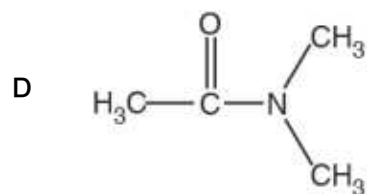
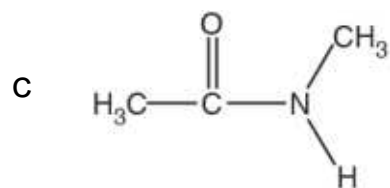
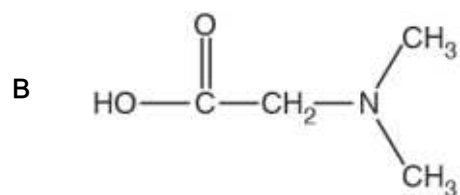
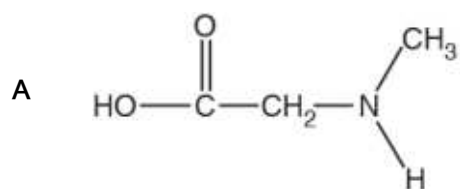
- (iv) Propane-1,3- dithiol reacts with carbonyl compounds in a condensation reaction to form a cyclic organic sulfur product.

Write an equation for the reaction of propane-1,3-dithiol with propanone.

Use structures for organic compounds.

[2]

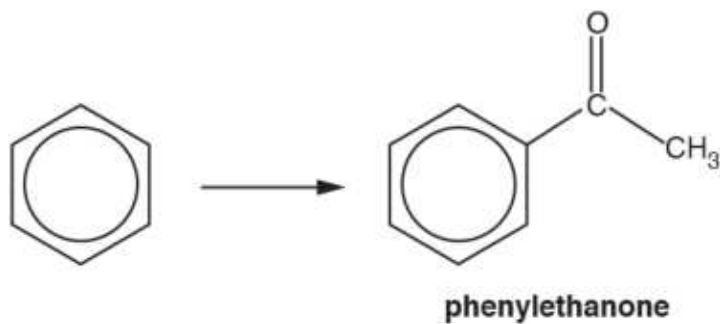
37 Which compound is a secondary amide?



Your answer

[1]

38 Benzene reacts with an organic reagent in the presence of a halogen carrier to form phenylethanone.



Which organic reagent is required?

- A $\text{CH}_3\text{CH}_2\text{OH}$
- B CH_3CHO
- C CH_3COCl
- D CH_3COOH

Your answer

[1]

39 How many straight-chain structural isomers of $\text{C}_7\text{H}_{15}\text{Cl}$ contain a chiral carbon atom?

- A 1
- B 2
- C 3
- D 4

Your answer

[1]

40 A solid organic compound can be purified by recrystallisation.

Which statement(s) about recrystallisation is/are true?

- 1 The organic compound is more soluble in hot solvent.
- 2 The hot solution is cooled before the purified organic compound is collected.
- 3 The melting point of the purified organic compound is lower than the impure compound.

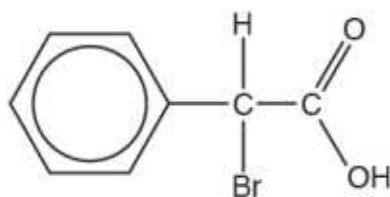
- A 1, 2 and 3
- B Only 1 and 2
- C Only 2 and 3
- D Only 1

Your answer

☐

[1]

41 Which of the following could react with the compound below to form a carbon-carbon bond?



- 1 CH_3Cl and AlCl_3
- 2 KCN in ethanol
- 3 CH_3OH and H_2SO_4

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

Your answer

☐

[1]

42(a) The general formula of an α -amino acid is $\text{RCH}(\text{NH}_2)\text{COOH}$.

The α -amino acid cysteine ($\text{R} = \text{CH}_2\text{SH}$) shows optical isomerism.

Draw 3-D diagrams to show the optical isomers of cysteine.

[2]

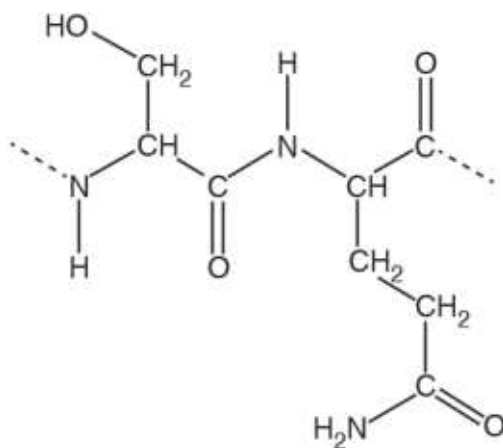
(b) The α -amino acid lysine ($\text{R} = (\text{CH}_2)_4\text{NH}_2$) reacts with an excess of dilute hydrochloric acid to form a salt.

Draw the structure of the salt formed in this reaction.

[2]

(c) α -Amino acids can react to form proteins.

A short section of a protein chain is shown below.



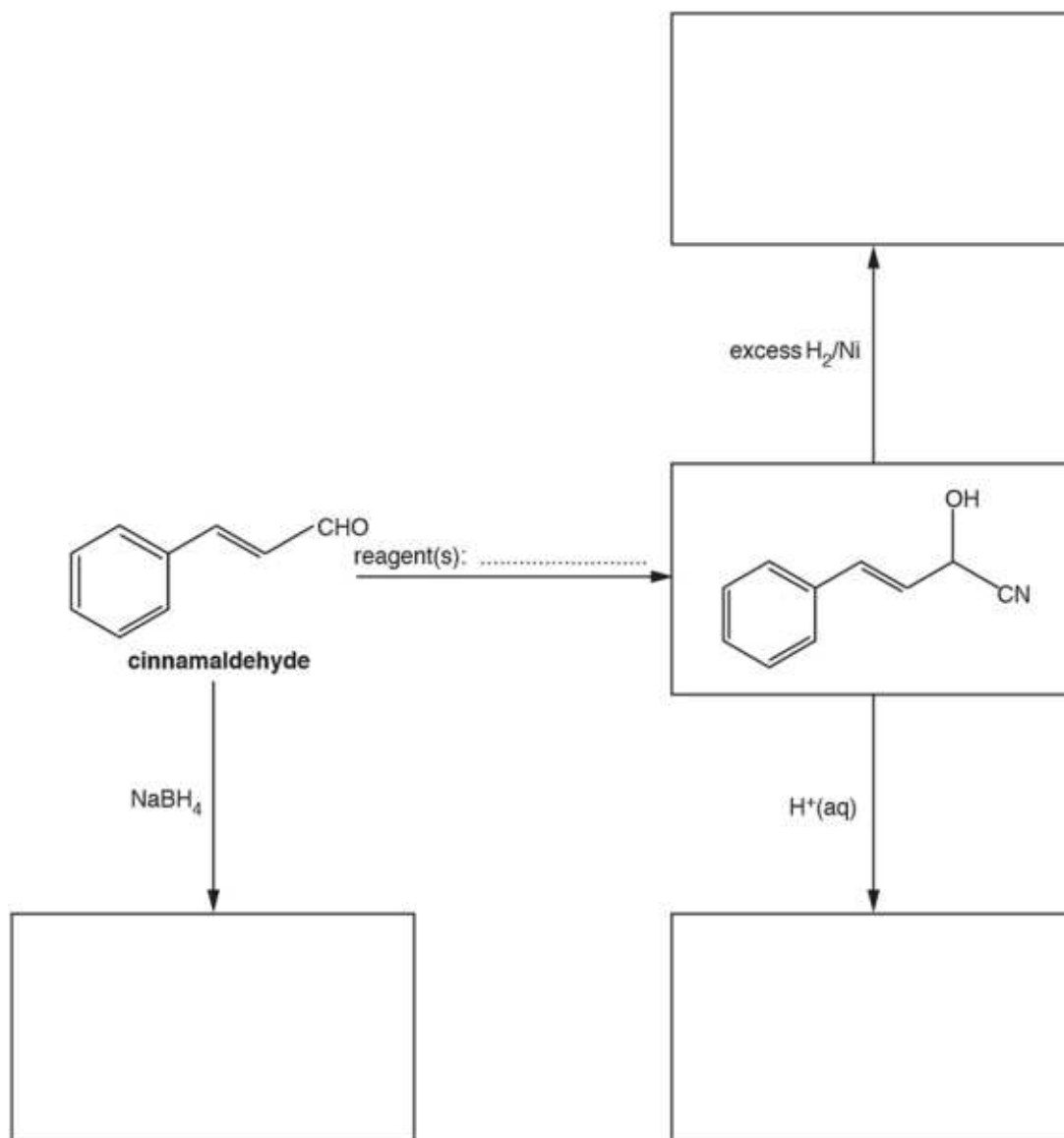
A student hydrolyses the protein with hot NaOH(aq).

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

[3]

43 The flowchart below shows some reactions starting with cinnamaldehyde.

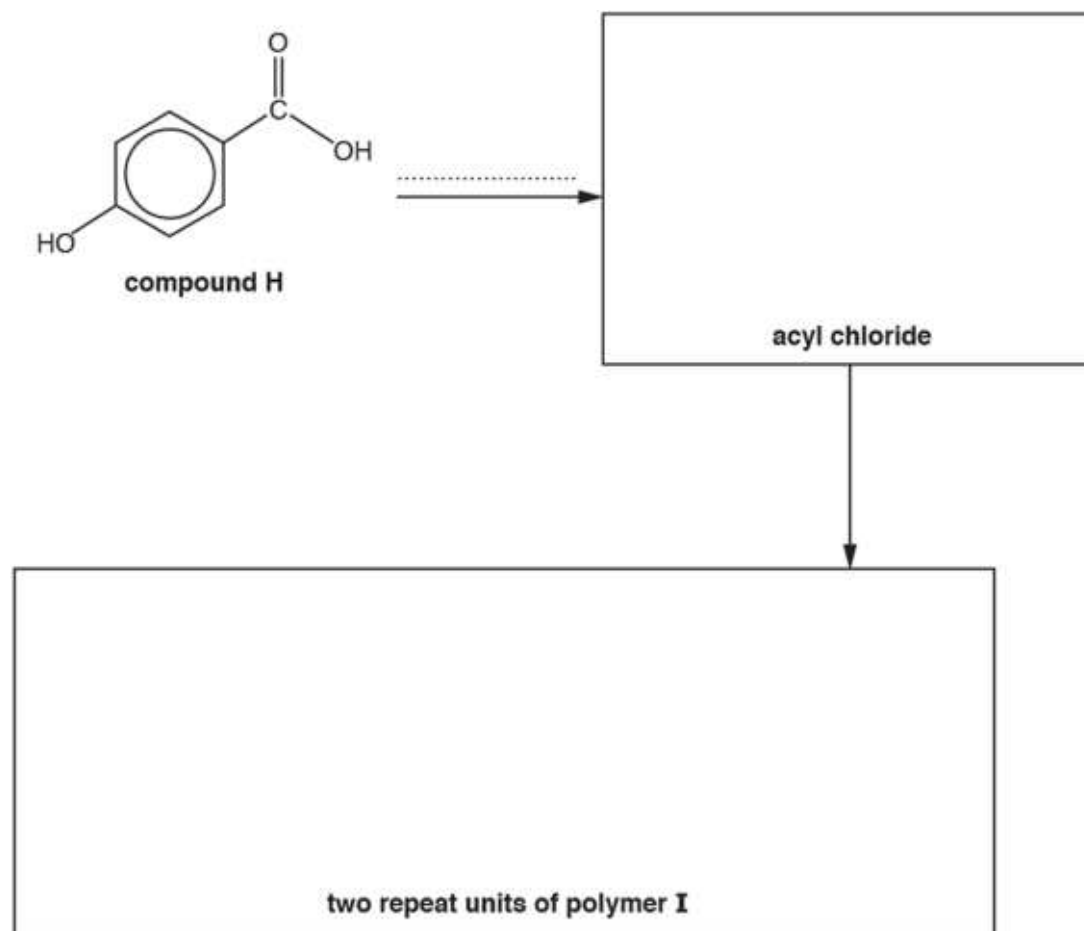
Draw the structures of the missing organic compounds in the boxes and add the missing reagent(s) on the dotted line.



[5]

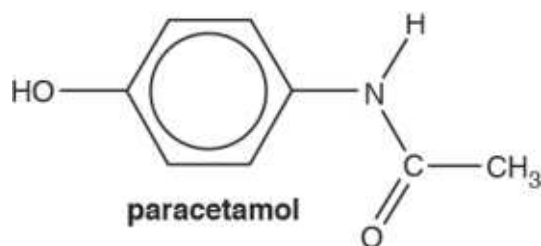
44 Compound H is used in the synthesis of polymer I, as shown in the flowchart below.

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]

45 Paracetamol is a solid organic compound used in tablets as a painkiller.



(i) Name the functional groups present in paracetamol.

[2]

(ii) * A chemist prepares a pure solid sample of paracetamol from 4-nitrophenol in two stages:



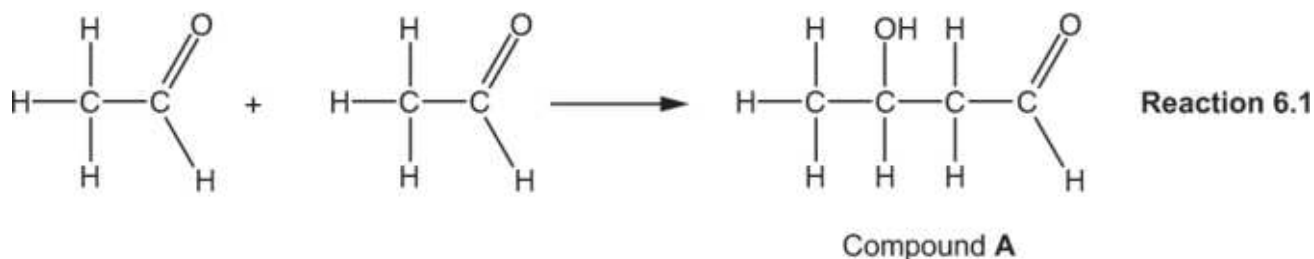
Describe a two-stage synthesis of 5.00 g of pure paracetamol from 4-nitrophenol. The overall percentage yield of paracetamol from 4-nitrophenol is 40.0%.

In your answer, include the mass of 4-nitrophenol required, the reagents and intermediate, and details of the purification of paracetamol.

[6]

Compound A is formed when ethanal is mixed with $\text{OH}^-(\text{aq})$ ions, which act as a catalyst.

The balanced equation is shown in **reaction 6.1** below.



(i) Give the systematic name for compound A.

----- [1]

(ii) What type of reaction has taken place?

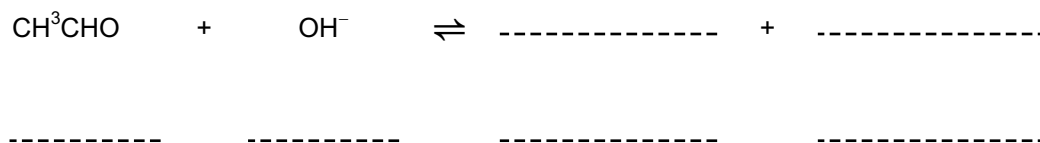
----- [1]

(iii) **Reaction 6.1** takes place in two steps. OH^- ions act as a catalyst.

In **step 1**, ethanal reacts with OH^- ions to set up an acid–base equilibrium.

In **step 2**, compound A is formed.

- Complete the equilibrium for **step 1** and label the conjugate acid–base pairs as: A1, B1 and A2, B2.



- Suggest the equation for **step 2**.

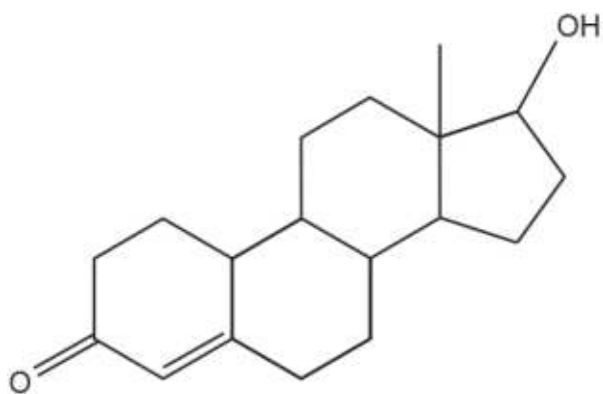
[3]

(iv) A similar reaction takes place when propanone, $(\text{CH}_3)_2\text{CO}$, is mixed with $\text{OH}^-(\text{aq})$ ions.

Draw the structure of the organic product of this reaction.

[1]

47 What is the number of chiral carbon atoms in the steroid molecule below?



- A 5
- B 6
- C 7
- D 8

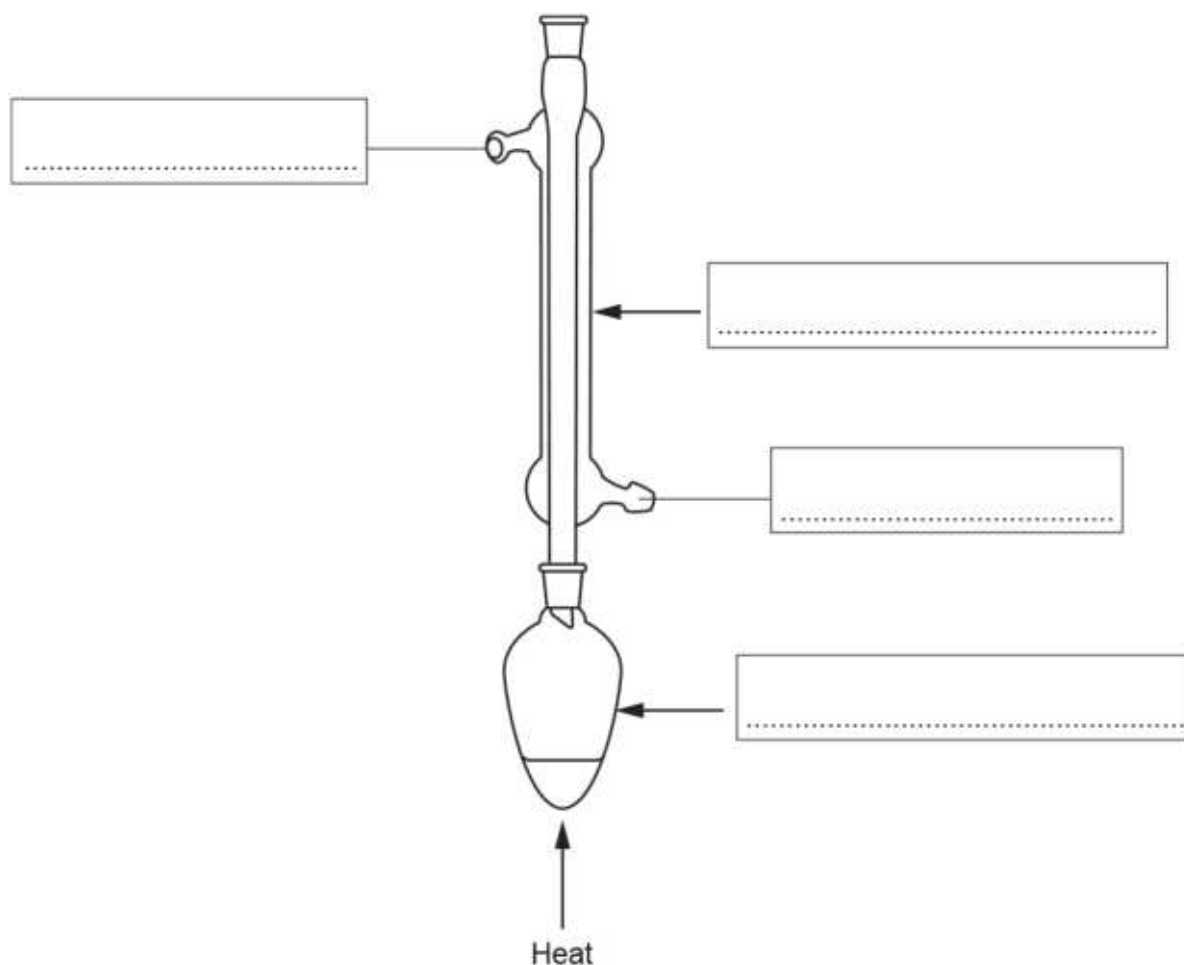
Your answer

[1]

48 This question is about organic chemistry.

This part is about two practical techniques used in organic preparations.

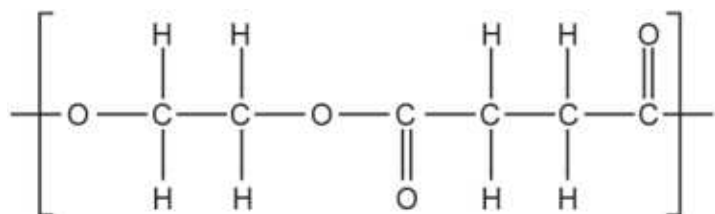
(i) Complete the missing labels on the diagram and name the technique.



Name of technique: _____ [2]

(ii) Draw a labelled diagram to show apparatus set up for filtration under reduced pressure (vacuum filtration).

49 The repeat unit of a polymer is shown below.



Which monomers could form this polymer?

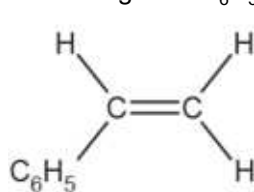
A		
B		
C		
D		

Your answer

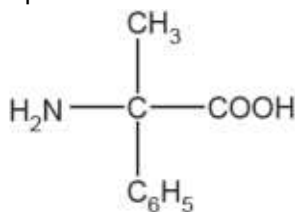
[1]

50 Benzene can be used as the starting material for the synthesis of compounds **D** and **E**, shown below.

In the diagrams C_6H_5 is a phenyl group.



compound D



compound E

Compounds **D** and **E** can be converted into polymers.

(i) Draw **two** repeat units of these polymers.

Two repeat units of polymer formed from **D**

Two repeat units of polymer formed from E

[3]

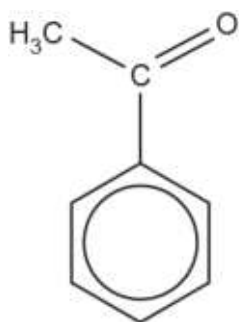
(ii) State the **type** of polymer formed from compounds D and E.

From compound D

From compound E

[1]

(iii) In the synthesis of compounds D and E, benzene is first reacted with ethanoyl chloride, CH_3COCl , to form phenylethanone, shown below.



phenylethanone

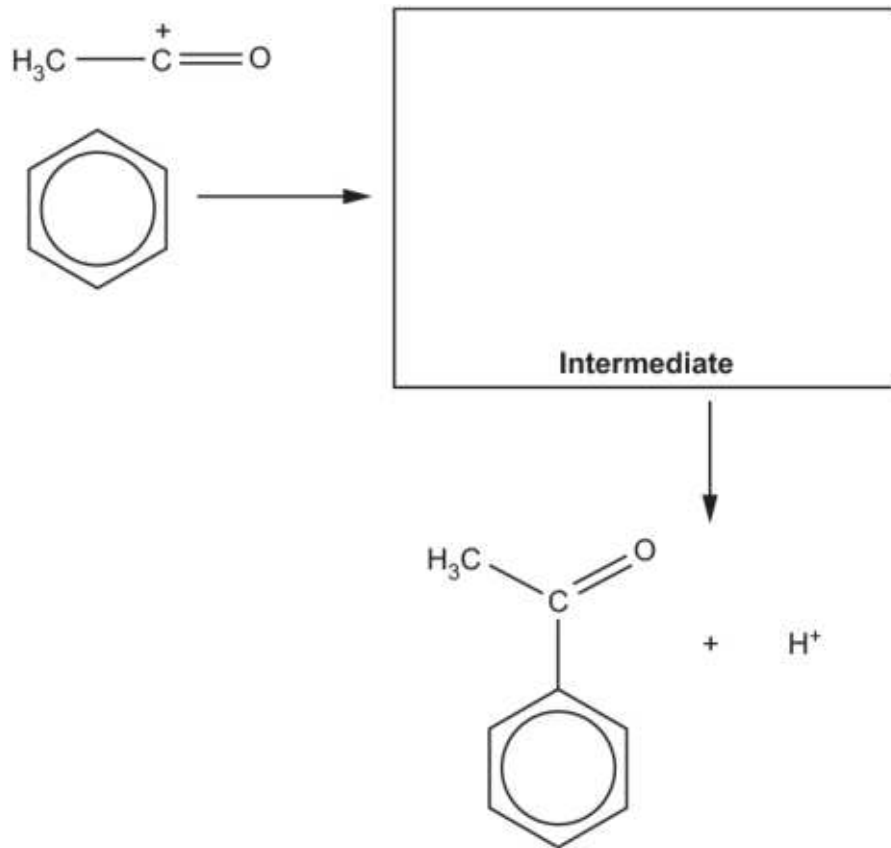
The reaction takes place in the presence of aluminium chloride, AlCl_3 , which acts as a catalyst.
In the mechanism for this reaction,

- ethanoyl chloride first reacts with aluminium chloride to form the $\text{CH}_3\text{-C}^+=\text{O}$ cation
- the $\text{CH}_3\text{-C}^+=\text{O}$ cation then behaves as an electrophile.

Complete the mechanism for the reaction.

Include equations to show the role of the AlCl_3 catalyst, relevant curly arrows and the structure of the intermediate.

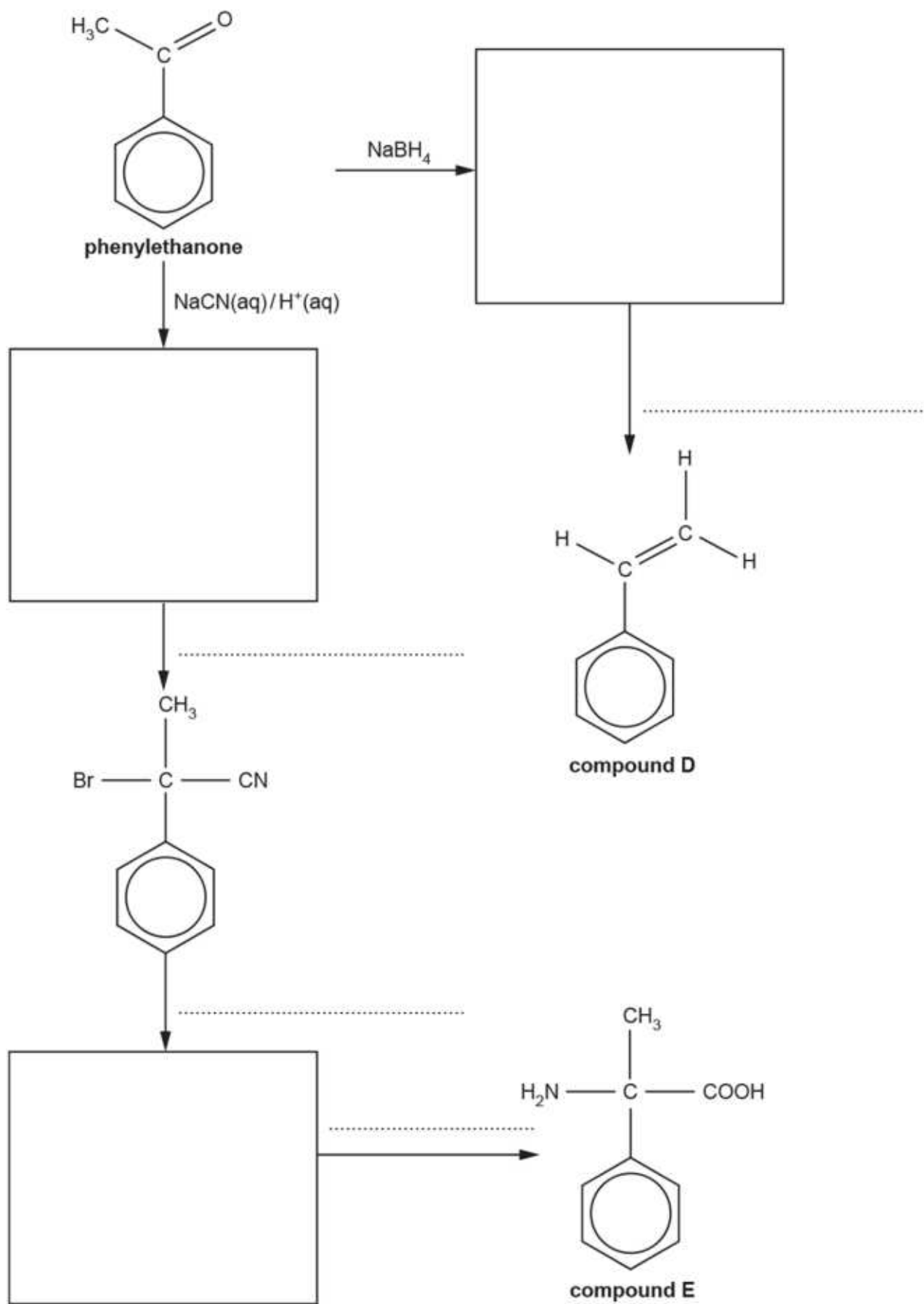
Formation of electrophile



Regeneration of catalyst

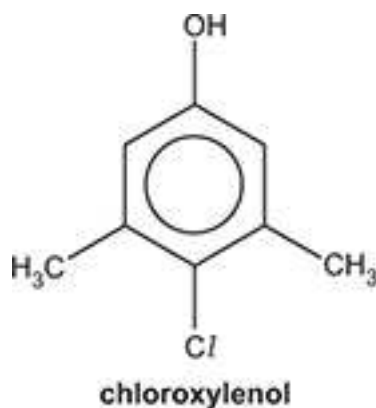
[5]

(iv) Complete the flowchart for the synthesis of compounds D and E from phenylethanone.



[7]

51 Dettol[®] is a disinfectant containing the antiseptic chloroxylenol, shown below.



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 cm³ of Dettol[®] contains 4.80 g of chloroxylenol.

Assume the following:

- Chloroxylenol is the only acidic component in Dettol[®].

- Chloroxylonol 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 chloroxylonol.

Calculate the acid dissociation constant, K_a , for chloroxylonol.

$K_a = \dots\dots\dots \text{mol dm}^{-3}$ [5]

52 Which of these reagent(s) will **not** react with HOCH₂CH₂CH₂COOH?

- A NaCN in ethanol
- B C₂H₅OH in the presence of an acid catalyst
- C (CH₃CO)₂O
- D concentrated H₂SO₄

Your answer

☐

[1]

53 Which of the following reactions produce propan-1-ol?

- 1 The alkaline hydrolysis of 1-chloropropane.
- 2 The acid hydrolysis of propyl methanoate.
- 3 The acid hydrolysis of propanenitrile.

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

Your answer

[1]

54 $(\text{CH}_3)_3\text{CCHBrCH}_3$ has stereoisomers.

(i) Explain the term stereoisomers and name this type of stereoisomerism.

Explanation:

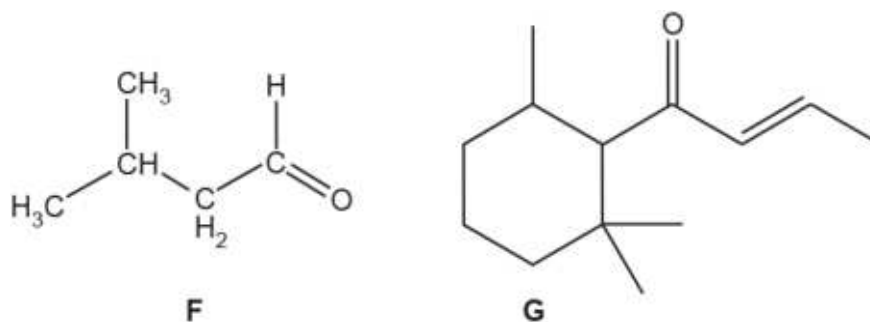
Type of stereoisomerism:

[1]

(ii) Draw 3D diagrams for the stereoisomers of $(\text{CH}_3)_3\text{CCHBrCH}_3$.

[2]

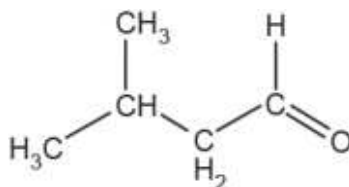
55 The carbonyl compounds, F and G, shown below, contribute to the flavour of coffee.



Compound F reacts with HCN using NaCN(aq) and H₊(aq).

- (i) Outline the mechanism for the reaction of F with NaCN(aq) and H⁺(aq) and state the name of the mechanism. The structure of F has been provided.

Include relevant dipoles, lone pairs and the structure of the organic product.



Name of mechanism: _____ [5]

- (ii) Explain why the mechanism in (i) involves heterolytic fission.

----- [2]

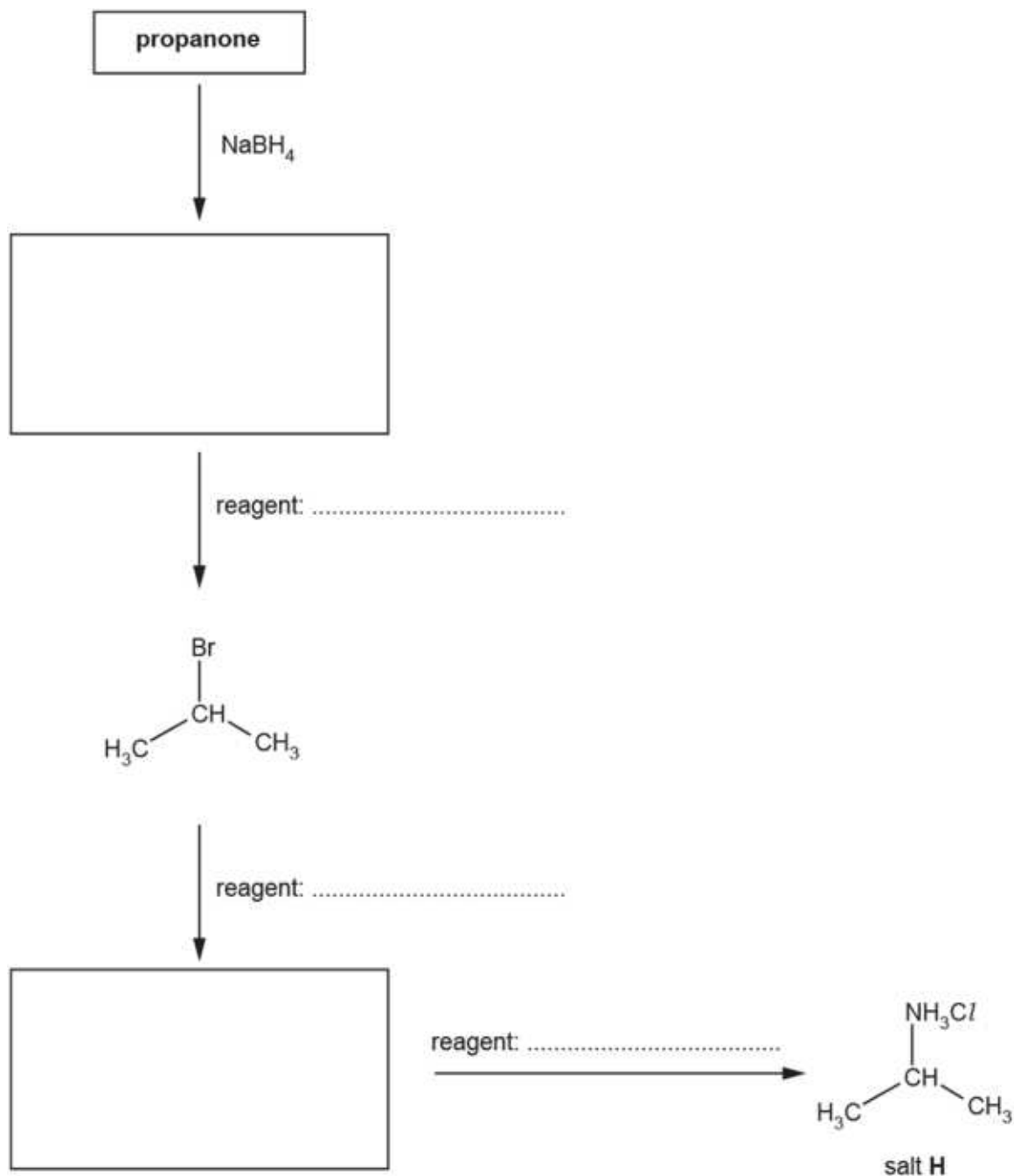
56(a) This question is about organic compounds containing nitrogen.

Salt H, $(\text{CH}_3)_2\text{CHNH}_3\text{Cl}$, is used in the manufacture of garden weedkillers.

The flowchart shows the synthesis of the salt H from propanone.

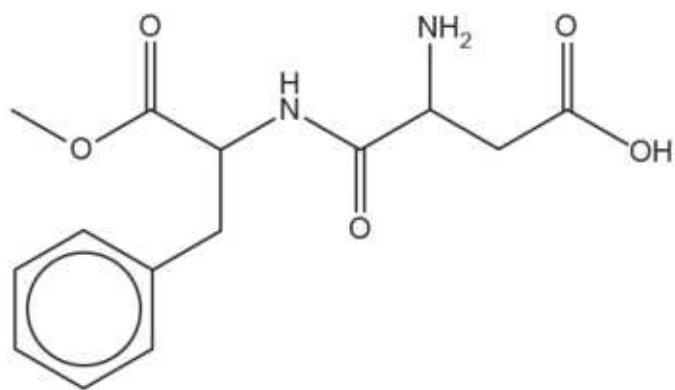
Complete the flowchart.

Show structures for organic compounds.



[5]

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



aspartame

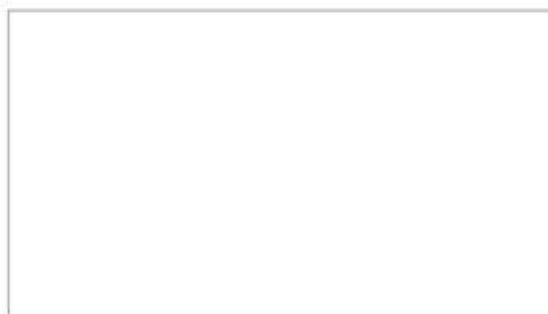
(i) Aspartame contains several functional groups.

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 $1.7 \times 10^{-4} \text{ mol kg}^{-1}$.

- 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]

57 This question is about organic chemistry.

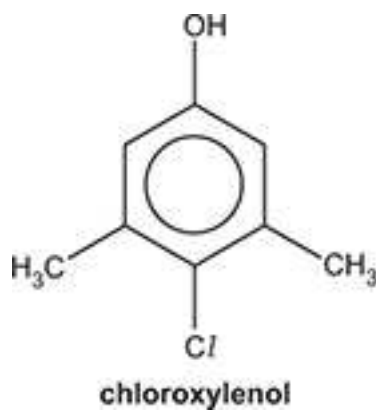
The amino acid Z-H₂NCH=CHCOOH can react to form a cyclic compound with the molecular formula C₃H₃NO and one other product.

Complete the equation for this reaction.



[2]

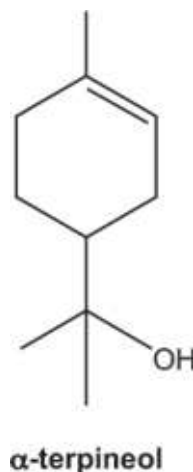
58 Dettol[®] is a disinfectant containing the antiseptic chloroxylenol, shown below.



Dettol[®] contains other chemicals including α -terpineol, shown below.

(i) α -Terpineol is a chiral compound.

Show with an asterisk, (*), the chiral centre(s) in the structure of α -terpineol.



[1]

(ii) α -Terpineol meets the requirements for *E* / *Z* isomerism.
However, only one *E* / *Z* isomer of α -terpineol exists.

Explain

- why α -terpineol meets the requirements for *E* / *Z* isomerism
 - whether α -terpineol is an *E*- or *Z*- isomer
 - why only one *E* / *Z* isomer of α -terpineol exists.
-

[4]

For each functional group, choose a reagent that reacts with that group **only**. Draw the structures for the organic products of the reactions.

Reagent(s)	-----
Name of functional group that reacts	-----
Structure of organic product	

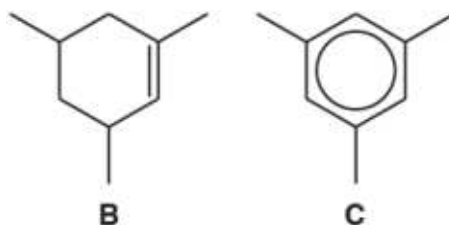
Reagent(s)	-----
Name of functional group that reacts	-----



Structure of organic product

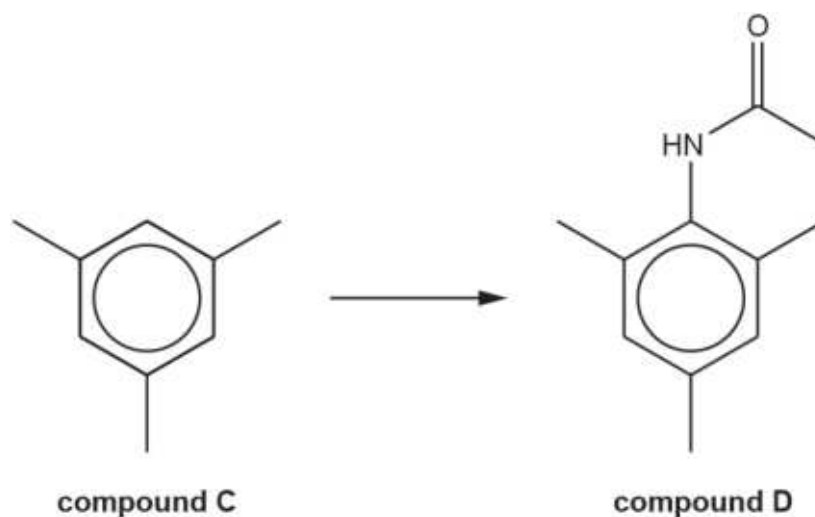
[4]

59 Compounds **B** and **C**, shown below, are unsaturated hydrocarbons containing nine carbon atoms.



An organic chemist is investigating compound **D** for possible use as a medicine.

The chemist proposes a synthesis of compound **D** from compound **C**.



(i) Predict the number of peaks in the ^{13}C NMR spectra of compounds **C** and **D**.

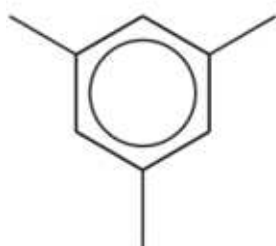
	Compound C	Compound D
Number of peaks		

[2]

(ii) The chemist develops a three-stage synthesis of compound **D** from compound **C**.

Complete the flowchart.

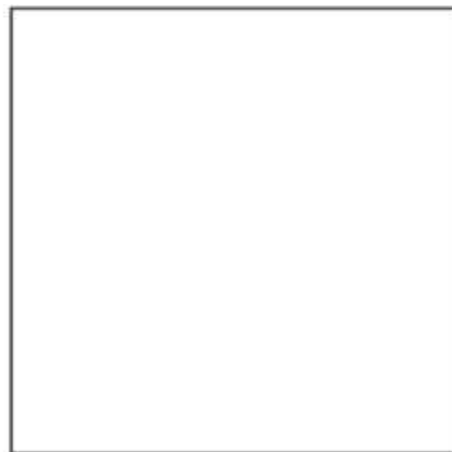
Show structures for organic compounds.



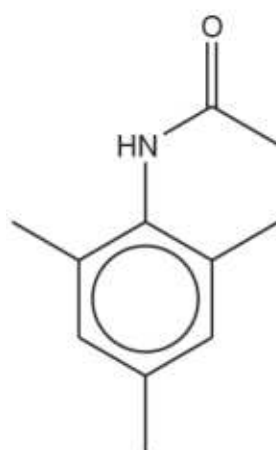
compound C

reagent:

catalyst:



1. Sn + HCl
2. Neutralise



compound D

reagent:



[5]

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

$\text{HOOC}(\text{CH}_2)_2\text{COOH}$ and $\text{HO}(\text{CH}_2)_4\text{OH}$ 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.

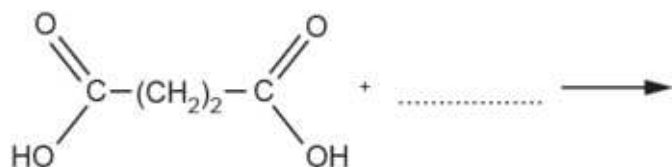
Suggest why polymer E is able to biodegrade.

[1]

(iii) A large yield of polymer E can be obtained by reacting a diacyl dichloride with $\text{HO}(\text{CH}_2)_4\text{OH}$.

The diacyl dichloride is prepared from $\text{HOOC}(\text{CH}_2)_2\text{COOH}$.

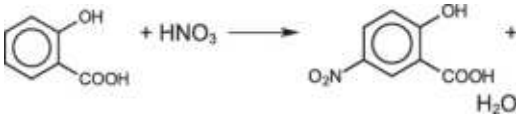
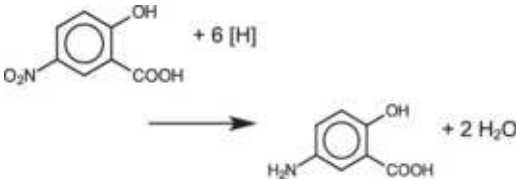
Complete the equation for the formation of a diacyl dichloride from $\text{HOOC}(\text{CH}_2)_2\text{COOH}$.



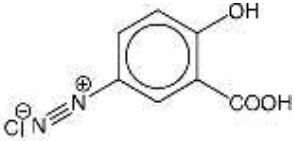
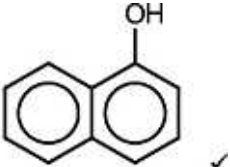
[3]

END OF QUESTION PAPER

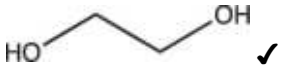
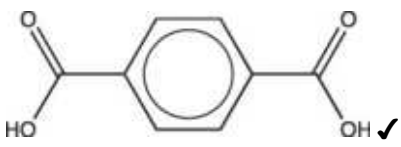
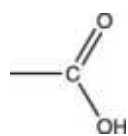
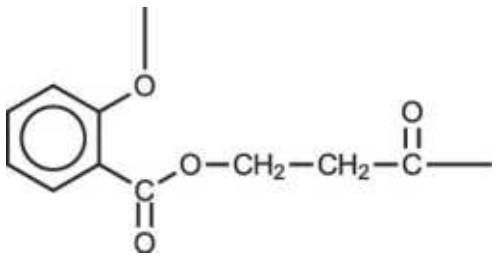
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
1	a	i	Step 1 Add HNO_3 ✓  Step 2 Tin AND concentrated HCl ✓ 	4	ALLOW reagent mark if HNO_3 in equation IGNORE H_2SO_4 (NOTE: H_2SO_4 not required with phenols) IGNORE concentrations of acids / temperature ALLOW correct structural OR displayed OR skeletal formulae OR combination of above as long as unambiguous Equations MUST be completely correct for one mark each DO NOT ALLOW 3H_2 Examiner's Comments This question discriminated well. Most candidates knew that nitric acid was involved in the first reaction but some also included sulfuric acid and tried to construct a mechanism involving the nitronium ion, rather than write the expected equation for the reaction. The omission of water as a product was an occasional error. Many correct equations were seen for Step 2, but tin and <i>concentrated</i> hydrochloric acid was required to score the reagent mark.
		ii	Nitrogen electron pair OR nitrogen lone pair accepts a proton / H^+ ✓	1	DO NOT ALLOW nitrogen / N lone pair accepts hydrogen (proton/H^+ required) ALLOW nitrogen donates an electron pair / lone pair to H^+ IGNORE NH_2 group donates electron pair Examiner's Comments Candidates needed to mention the electron pair on the nitrogen atom to score this mark.

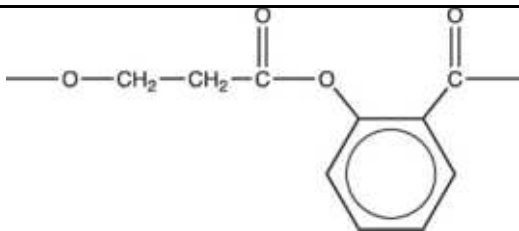
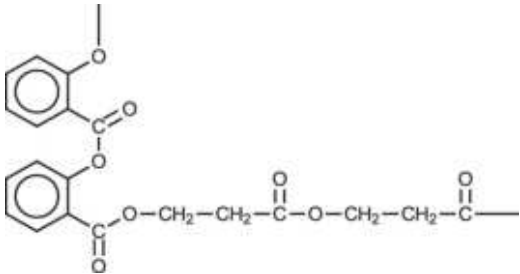
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	compound A ✓  compound B 	2	ALLOW correct structural OR displayed OR skeletal formulae OR combination of above as long as unambiguous ALLOW $\text{—N}_2\text{Cl}$ OR $\text{—N}_2^+ \text{Cl}^-$ DO NOT ALLOW $\text{—N}\equiv\text{N}^+$ OR $\text{—N}\equiv\text{N}^+ \text{Cl}$ DO NOT ALLOW $\text{—N}_2\text{—Cl}$ (covalent bond) Examiner's Comments The vast majority of candidates gave the correct structure for compound B, but common errors were the omission of the chloride ion in the formulae of the diazonium salt, or placing the positive charge on the wrong nitrogen atom.
	b	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 <i>monomer</i>.

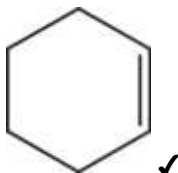
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	  Connectivity is penalised only in this question	2	DO NOT ALLOW —HO (penalise connectivity once only) Both structures must be skeletal DO NOT ALLOW stray sticks (skeletal means CH₃ attached) DO NOT ALLOW structure with a C shown, e.g.  ALLOW  Examiner's Comments Skeletal formulae were often very well drawn with incorrect connectivity being penalised very rarely. Some candidates knew the structure of the monomers but did not present them as skeletal formulae. If a structural formula is used for working it should be crossed out and not left as an alternative answer to the skeletal formula.
		iii	 ester link MUST be fully displayed ✓ OR	1	ALLOW correct structural OR displayed OR skeletal formulae OR combination of above as long as unambiguous

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					ALLOW  IGNORE bond angles DO NOT ALLOW more than one repeat unit unless correct repeat unit is indicated IGNORE brackets with <i>n</i> 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	11	

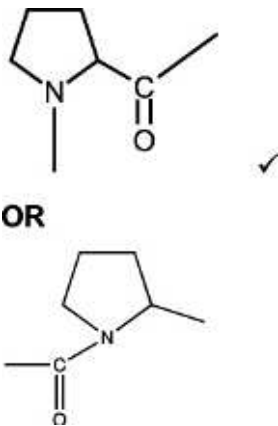
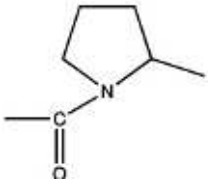
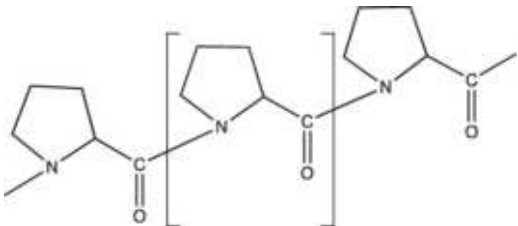
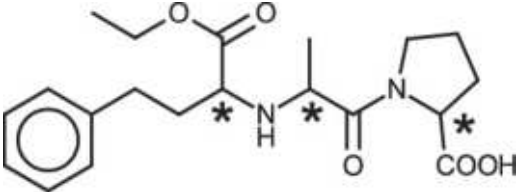
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
2		i	- pent-2-ene $\begin{array}{c} \text{H}_3\text{C} \\ \diagdown \\ \text{C}=\text{O} \\ \diagup \\ \text{H} \end{array} \quad \text{AND} \quad \begin{array}{c} \text{O}=\text{C} \\ \diagup \quad \diagdown \\ \text{H} \quad \text{CH}_2\text{CH}_3 \end{array} \quad \checkmark$ - hexa-2,4-diene $\begin{array}{c} \text{H}_3\text{C} \\ \diagdown \\ \text{C}=\text{O} \\ \diagup \\ \text{H} \end{array} \quad \checkmark \quad \text{O}=\text{C}-\text{C}=\text{O} \quad \begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H} \quad \text{H} \end{array} \quad \checkmark$	3	ALLOW correct structural OR displayed OR skeletal formulae OR combination of above as long as unambiguous ALLOW C₂H₅CHO and CH₃CHO Examiner's Comments Many candidates responded well when asked to apply information in a unfamiliar situation. The question discriminated well but a high proportion scored all three marks. Some candidates lost marks in the second part by providing a list of three or more different structures, some of them being incorrect.
		ii		1	ALLOW correct structural OR displayed OR skeletal formulae OR combination of above as long as unambiguous Examiner's Comments This was a challenging question. Only more able candidates predicted the correct cyclic structure.
			Total	4	

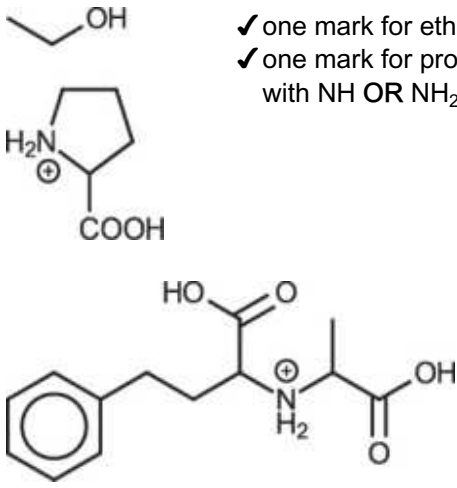
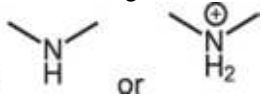
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
3	a	i	$\begin{array}{c} \text{H} \quad \text{O} \quad \text{CH}_2\text{OH} \\ \quad \quad \\ \text{H}_2\text{N}-\text{C}-\text{C}-\text{N}-\text{C}-\text{COOH} \\ \quad \quad \\ \text{CH}_3 \quad \text{H} \quad \text{H} \end{array}$ $\begin{array}{c} \text{H} \quad \text{O} \quad \text{CH}_3 \\ \quad \quad \\ \text{H}_2\text{N}-\text{C}-\text{C}-\text{N}-\text{C}-\text{COOH} \\ \quad \quad \\ \text{HOCH}_2 \quad \text{H} \quad \text{H} \end{array}$	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 $\begin{array}{c} \text{H} \quad \text{O} \\ \quad \\ \text{H}_3\text{N}^+-\text{C}-\text{C}-\text{O}^- \\ \\ \text{CH}_3 \end{array}$ serine at pH 10.0 $\begin{array}{c} \text{H} \quad \text{O} \\ \quad \\ \text{H}_2\text{N}-\text{C}-\text{C}-\text{O}^- \\ \\ \text{CH}_2\text{OH} \end{array}$	2	ALLOW correct structural OR displayed OR skeletal formulae OR combination of above as long as unambiguous ALLOW + charge on N or H: <i>i.e.</i> $^+\text{NH}_3$ or NH_3^+ DO NOT ALLOW '—' charge on C <i>i.e.</i> ^-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.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
iii	 OR 	1	ALLOW correct structural OR displayed OR skeletal formulae OR combination of above as long as unambiguous IGNORE bond angles DO NOT ALLOW more than one repeat unit ALLOW end bonds shown as - - - - - DO NOT ALLOW if structure has no end bonds IGNORE brackets unless they are used to pick out the repeat unit from a polymer chain IGNORE <i>n</i>  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.

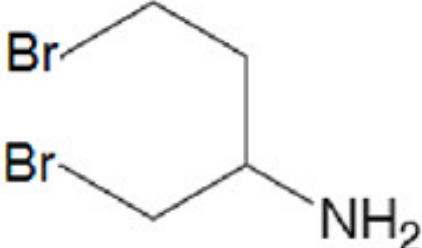
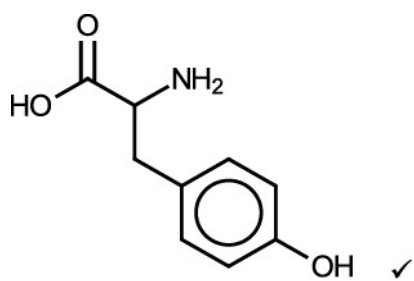
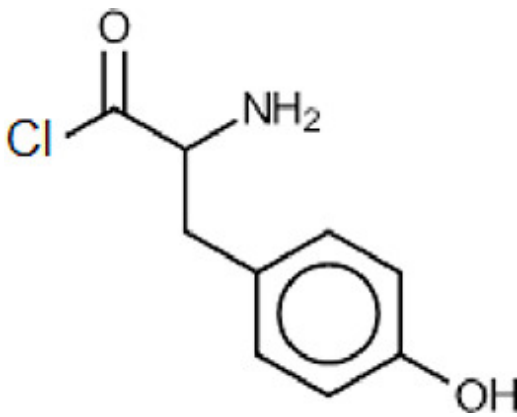
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	any <i>two</i> from: no / fewer side effects increases the (pharmacological) activity / effectiveness Reduces / stops the need for / cost / difficulty in separating stereoisomers / optical isomers ✓✓	2	IGNORE toxic / harmful IGNORE a response that implies a reduced dose IGNORE “it takes (less) time to separate” Examiner's Comments Most candidates gained this mark by stating that the use of a single stereoisomer results in fewer side effects and increased pharmacological activity. Vague answers and comments about a reduced dose did not score marks.
		iii	 ✓ one mark for ethanol ✓ one mark for proline with NH OR NH₂⁺ ✓ one mark for remaining fragment with  or ✓ Fourth mark for structure of both ions shown correctly with NH₂⁺	4	ALLOW correct structural OR displayed OR skeletal formulae OR combination of above as long as unambiguous ALLOW + charge on H of NH₂ groups, <i>i.e.</i> NH₂⁺ 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.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		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	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
4	a		$(\text{CH}_3)_2\text{CHBr} + \text{FeBr}_3 \longrightarrow (\text{CH}_3)_2\text{CH}^+ + \text{FeBr}_4^-$	1	ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous ALLOW positive charge anywhere on the electrophile IGNORE AlCl_3 OR AlBr_3 Examiner's Comments Well answered by those candidates who could apply their knowledge and understanding to new situations. It was a step too far for some who stuck to the more familiar equation for the generation of the Br^+ electrophile instead. Others made a good attempt but made errors with the charges.
	b	i	First reactant = HNO_2 ✓ Second reactant =  ✓ Third reactant =  ✓	3	ALLOW $\text{NaNO}_2 + \text{HCl}$ OR $\text{HNO}_2 + \text{HCl}$ IGNORE conditions / concentration ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous ALLOW 

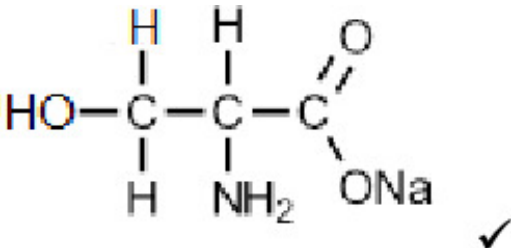
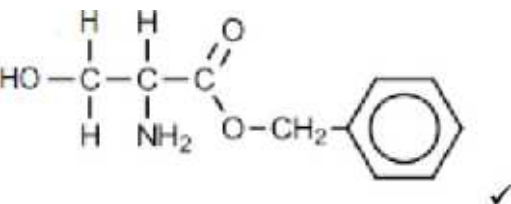
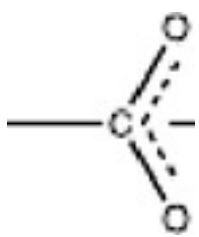
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					Examiner's Comments This question required candidates to recognise changes in chemical structure. The first reaction (the formation of a diazonium ion) and the third reaction (the formation of an amide linkage) should be familiar to candidates. The reagents for the first reaction were very well known and although the conditions for the reaction were often quoted they were not required for the mark. The correct structure of the second reactant was rarely seen with the most common incorrect responses being based on cyclic structures. Most candidates were able to deduce the structure of the third reactant.
		ii	FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = 1.35 (g) award 3 marks IF answer = 0.54 (g) award 2 marks (no scale-up) IF answer = 0.216 (g) award 2 marks (incorrect scale-up) $n(\text{compound D}) = 1.73/346 = 0.00500 \text{ mol}$ ✓ $n(1,3\text{-diaminobenzene}) \text{ required} = 100/40 \times 0.005$ $= 0.0125 \text{ mol}$ ✓ Molar mass of 1,3-diaminobenzene = 108 (g mol⁻¹) AND Mass of 1,3-diaminobenzene = (108)(0.0125) = 1.35 g ✓	3	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC If there is an alternative answer, check to see if there is any ECF credit possible ALLOW ECF from incorrect amount, scale-up or molar mass Alternative 1 $n(\text{compound D}) = 1.73/346 = 0.00500 \text{ mol}$ Molar mass of 1,3-diaminobenzene = 108 (g mol⁻¹) AND Mass of 1,3-diaminobenzene = (0.00500)(108) = 0.540 g Mass of 1,3-diaminobenzene required = (0.540)(100/40) = 1.35 g Alternative 2 346 g gives 108 g 1.73 g gives $108/364 \times 1.73 = 0.54 \text{ g}$ $0.54/40 \times 100 = 1.35 \text{ g}$ Examiner's Comments Candidates had been well prepared for this type of percentage yield question and it was very well answered with almost all candidates scoring marks here and a high proportion gaining all three marks for the calculation.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	(compound D has) two chiral centres ✓ Four optical isomers exist ✓ (Synthesis could) use enzymes OR bacteria OR use (chemical) chiral synthesis OR chiral catalysts OR use natural chiral molecules OR single isomers (as starting materials) ✓	3	ALLOW (Compound D) has two asymmetric carbons OR has two stereocentres ALLOW four enantiomers OR two pairs of enantiomers INDEPENDENT MARK ALLOW biological catalysts ALLOW chiral transition metal complex / catalyst OR stereoselective transition metal complex / catalyst ALLOW 'chiral pool' / chiral auxiliary Examiner's Comments Two chiral centres and four optical isomers was required in the mark scheme and less specific answers did not score the first two marks. Two pairs of enantiomers was an accurate description worthy of the mark and a reference to there being four enantiomers was also given credit. The majority of candidates scored only the third mark with their suggestion of how to improve the synthesis. Some candidates missed the point here and instead described techniques required to separate the optical isomers.
			Total	10	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
5	a	i	  —NH₃⁺ in second product ✓	3	ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous ALLOW —O⁻Na⁺ OR —O⁻ (cation not required) DO NOT ALLOW —O—Na (covalent bond) DO NOT ALLOW —O (without the sodium) ALLOW delocalised carboxylate  Examiner's Comments The majority scored two marks here. The question had a three mark total for drawing two structures and this may have prompted some candidates to incorrectly form a salt with the alcohol group in reaction 1. Many were able to draw a correct structure for the ester formed in reaction 2, but very few protonated the amine group in acidic conditions. The protonation of hydrolysis products has been well represented in recent papers.
		ii	perfume / fragrance / flavouring ✓	1	IGNORE solvent OR food additive Examiner's Comments Well answered with most of the correct responses referring to perfumes and flavourings which are the uses listed in the specification. Common responses marked as incorrect were suggestions that this ester could be used for making dyes, polymers or textiles.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	Reaction 3: (hot) ethanolic ammonia ✓ Reaction 4: oxidation ✓ Reaction 5: hydrolysis ✓	3	ALLOW NH₃ (dissolved) in ethanol IGNORE other conditions ALLOW oxidation / oxidised DO NOT ALLOW redox ALLOW nucleophilic addition-elimination DO NOT ALLOW nucleophilic substitution IGNORE acid / base Examiner's Comments Most candidates were able to score at least one mark here, usually for correctly identifying reaction 4 as an oxidation reaction. Although the use of excess reagent was not required for reaction 3, some missed ethanol as an essential solvent and reaction 5 was occasionally described as a reduction.

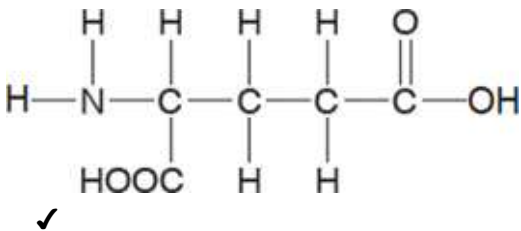
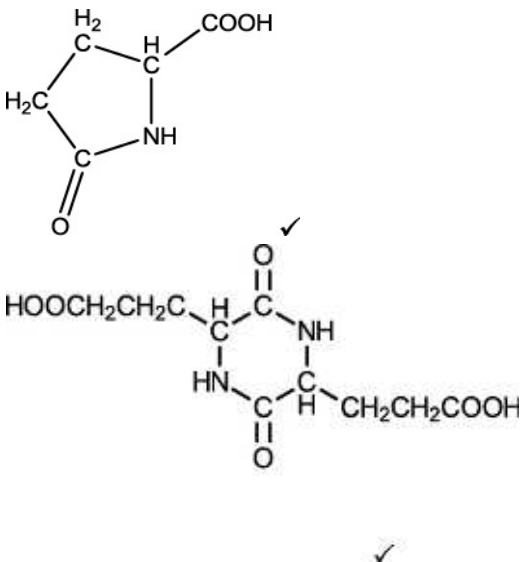
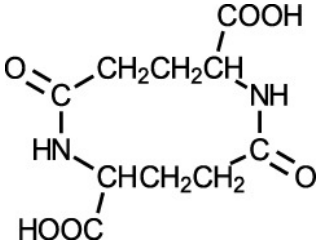
Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
b	M1 Compound E	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}_2\text{C}=\text{C}-\text{C}-\text{CHO} \\ \\ \text{NH}_2 \end{array}$	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 CH₂=CH must be shown in E ALLOW C₂H₃ OR CHCH₂ for CH=CH₂ in F
	M2 Compound F	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}_2\text{C}=\text{C}-\text{C}-\text{COOH} \\ \\ \text{NH}_2 \end{array}$		ALLOW ECF from error in structure of aldehyde E
	M3 Compound G	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \left[\text{C}-\text{C} \right] \\ \quad \\ \text{H} \quad \text{CHNH}_2 \\ \quad \\ \quad \text{COOH} \end{array}$		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 C₂H₄NO₂ for CH(NH₂)COOH in polymer G
	M4 Compound H	$\begin{array}{c} \text{H} \quad \text{O} \\ \quad \\ \left[\text{N}-\text{C}-\text{C} \right] \\ \quad \\ \text{H} \quad \text{CH}=\text{CH}_2 \end{array}$		ALLOW C₂H₃ OR CHCH₂ for CH=CH₂ in polymer H ALLOW ECF from NH₂CH₂CH=CHCOOH for the formation of compound G or compound H

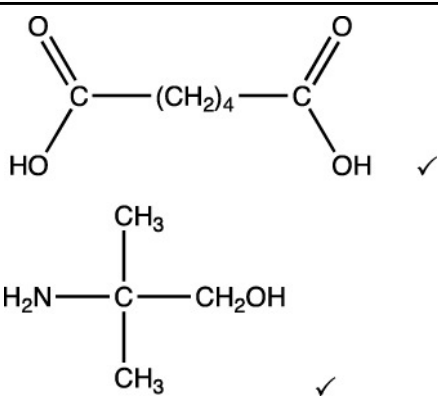
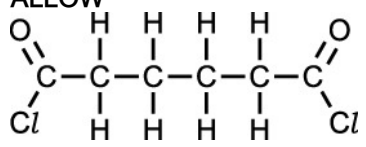
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
	M5 Compound G OR $\left[\begin{array}{cc} \text{H} & \text{H} \\ & \\ -\text{C} & -\text{C}- \\ & \\ \text{H} & \text{CHNH}_2 \\ & \\ & \text{COOH} \end{array} \right]_n$ Is an addition polymer ✓ M6 Compound H OR $\left[\begin{array}{ccc} & \text{H} & \text{O} \\ & & \\ -\text{N} & -\text{C} & -\text{C}- \\ & & \\ \text{H} & \text{CH=CH}_2 & \end{array} \right]_n$ is a condensation polymer ✓		monomer ALLOW equation for reaction $n \text{ H}_2\text{C}=\text{C}(\text{H})-\text{C}(\text{H})(\text{NH}_2)-\text{COOH} \rightarrow \left[\begin{array}{cc} \text{H} & \text{H} \\ & \\ -\text{C} & -\text{C}- \\ & \\ \text{H} & \text{CHNH}_2 \\ & \\ & \text{COOH} \end{array} \right]_n$ 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 $n \text{ H}_2\text{C}=\text{C}(\text{H})-\text{C}(\text{H})(\text{NH}_2)-\text{COOH} \rightarrow \left[\begin{array}{ccc} & \text{H} & \text{O} \\ & & \\ -\text{N} & -\text{C} & -\text{C}- \\ & & \\ \text{H} & \text{CH=CH}_2 & \end{array} \right]_n + \text{H}_2\text{O}$ 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.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	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.

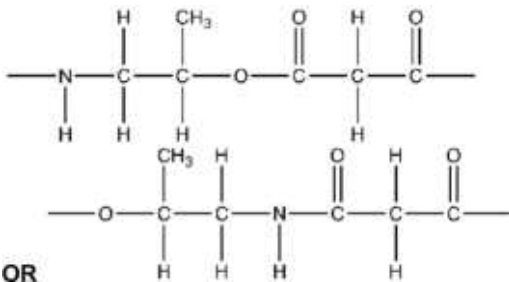
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d	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.

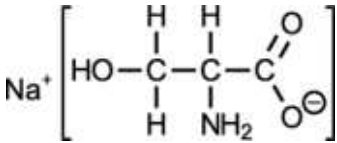
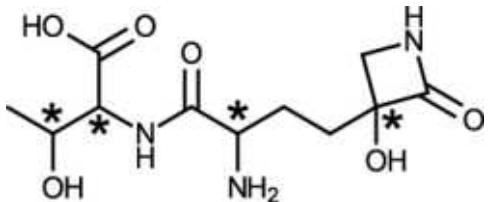
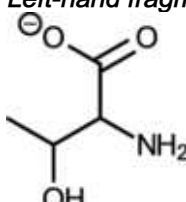
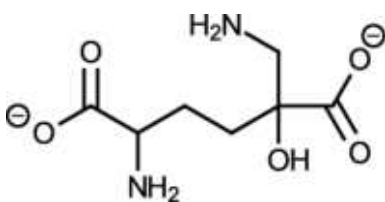
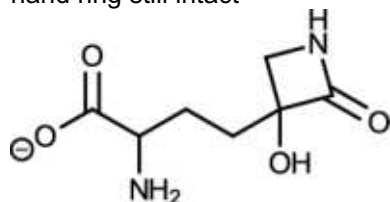
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	(The molecule / amide / ester) can be hydrolysed ✓	1	ALLOW (the molecule / amide / ester) can form hydrogen / Hbonds with water IGNORE acid / base Examiner's Comments A well answered question with marks equally divided between answers that either suggested that the polymer can be hydrolysed or that the polymer can form hydrogen bonds with water. A statement that the polymer is soluble in water was not sufficient to score the mark.
			Total	20	
6			B	1	
			Total	1	
7			B	1	
			Total	1	
8			C	1	
			Total	1	

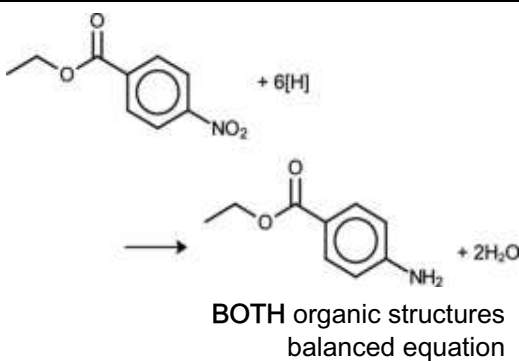
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
9	a	i	Step 1: add HCN OR $\text{H}_2\text{SO}_4/\text{KCN}$ $\text{CH}_3\text{CHO} + \text{HCN} \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{CN}$ Step 2: react with H_2/Ni $\text{CH}_3\text{CH}(\text{OH})\text{CN} + 2\text{H}_2 \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{NH}_2$	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 $\text{CH}_3\text{CH}(\text{OH})\text{CN} + 4[\text{H}] \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{NH}_2$
		ii	because (compound D) forms hydrogen bonds form with water demonstrated through diagram showing: - dashed line between —OH and $(\text{:})\text{OH}_2$ - dashed line between —NH_2 and $(\text{:})\text{OH}_2$	3	dipole and lone pair are not required IGNORE bond angles Diagram does not need to show all of Compound D (and IGNORE if wrong)
		iii	 OR ester AND amide link rest of structure	2	ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous 'End bonds' MUST be shown (solid or dotted) IGNORE brackets and / or <i>n</i>
	b	i	Atom A: 3 bonding pairs AND 1 lone pair (therefore) pyramidal AND 107° Atom B: 3 bonding centres (and 0 lone pairs) (therefore) trigonal planar AND 120°	4	ALLOW $106\text{--}108^\circ$ ALLOW 4 bonding pairs but with 1 double / π- bond (therefore 3 bonding centres)

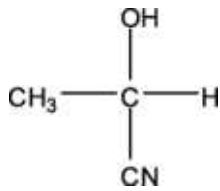
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	 filter solution recrystallise	3	ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous.
c	i		 for all four	1	
		ii	<i>Left-hand fragment</i>  OR structure with COOH rather than COO⁻ <i>Right-hand fragment</i>  OR structure with COOH rather than COO⁻ Two OR three COO⁻ shown	4	ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous ALLOW 1 mark for structure with right-hand ring still intact 
			Total	21	

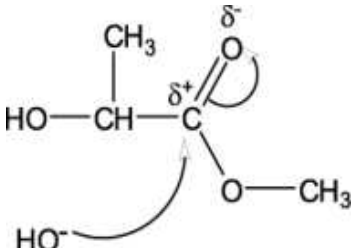
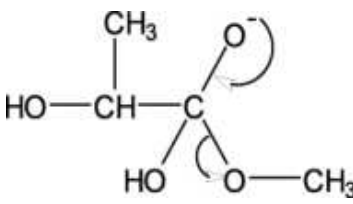
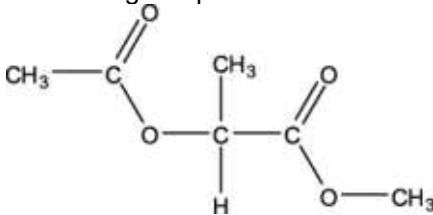
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Question			Answer/Indicative content	Marks	Guidance
10		i	step 1 = (conc.) H_2SO_4 AND $\text{CH}_3\text{CH}_2\text{OH}$	1	ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous.
		ii	 BOTH organic structures balanced equation	2	ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous.
			Total	3	
11			C	1	
			Total	1	
12			D	1	
			Total	1	

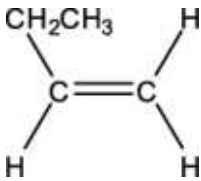
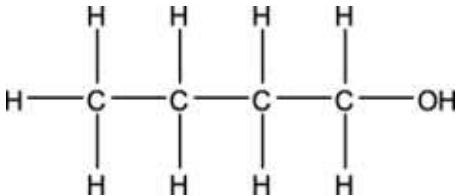
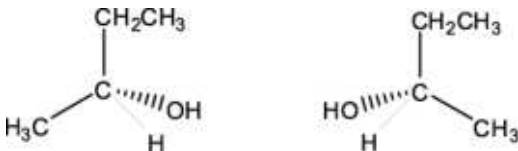
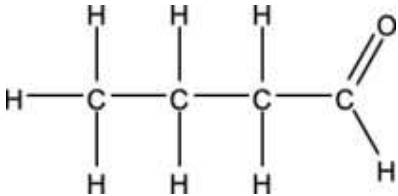
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13	a	i		1	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous
		ii	aqueous acid OR H^+ / H_2O	1	ALLOW $\text{H}^+(\text{aq})$ / $\text{H}_2\text{SO}_4(\text{aq})$ / $\text{HCl}(\text{aq})$
		iii	Angle a = 109.5° Angle b = 104.5° Angle c = 120° Two correct All three correct	2	ALLOW $109\text{--}110^\circ$ ALLOW $104\text{--}105^\circ$
	b	i	It is an electron pair donor OR donates a lone pair	1	

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Question	Answer/Indicative content	Marks	Guidance
ii	 Curly arrow from HO⁻ to carbon atom of C=O bond Correct dipole AND curly arrow from C=O bond to O^{δ-}  Curly arrow from negative charge on oxygen to C-O bond (to reform carbonyl π-bond) Curly arrow from C-O single bond to oxygen atom (to form methoxide ion)	4	Curly arrow must come from lone pair on O of HO⁻ OR OH⁻ OR from minus sign on HO⁻ ion (No need to show lone pair if curly arrow came from negative charge on O) IGNORE dipole on C-O single bond Curly arrow must come from lone pair on O OR from minus sign on O⁻ ion (No need to show lone pair if curly arrow came from negative charge on O)
iii	Correct organic product:  HC/	2	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous
	Total	11	

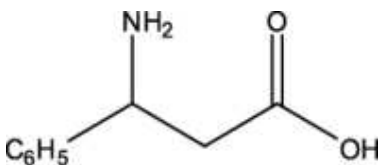
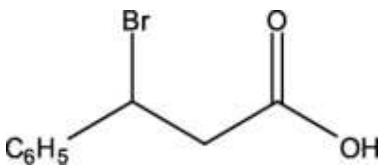
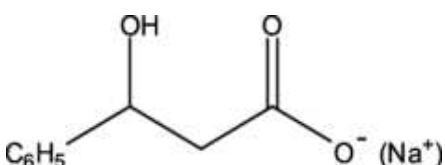
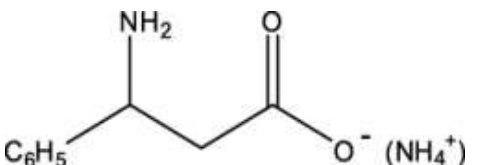
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Question		Answer/Indicative content	Marks	Guidance
14	a	F–K clearly identified Compound F:  Compound G:  Compounds H and I:  Compound J:  Compound K:	6	ANNOTATE ANSWER WITH TICKS AND CROSSES ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous IGNORE names H and I can be identified either way round

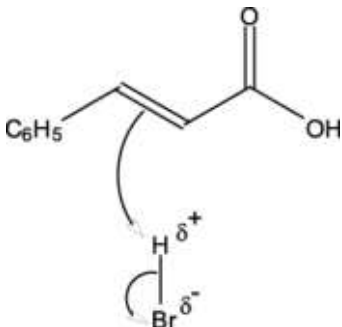
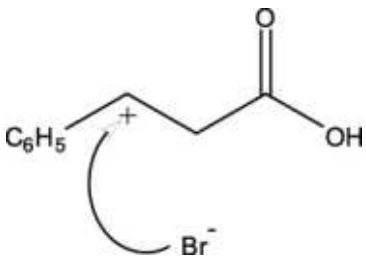
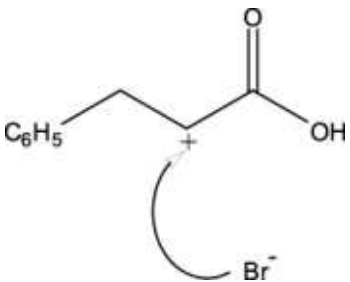
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Question			Answer/Indicative content	Marks	Guidance
			$ \begin{array}{ccccccc} & \text{H} & & \text{H} & & \text{H} & & \text{O} \\ & & & & & & & // \\ \text{H} & - \text{C} & - & \text{C} & - & \text{C} & - & \text{C} \\ & & & & & & & \backslash \\ & \text{H} & & \text{H} & & \text{H} & & \text{OH} \end{array} $		
	b		(Add) 2,4-dinitrophenylhydrazine AND orange/yellow/red precipitate Take melting point of crystals Compare to known values	3	NOTE: (b) ☐ is marked completely independently of (a) ALLOW errors in spelling ALLOW 2,4(-)DNP OR 2,4(-)DNPH ALLOW Brady's reagent or Brady's Test ALLOW solid OR crystals OR ppt as alternatives for precipitate Mark second and third points independently of response for first marking point DO NOT ALLOW 2nd and 3rd marks for taking and comparing boiling points OR chromatograms
			Total	9	

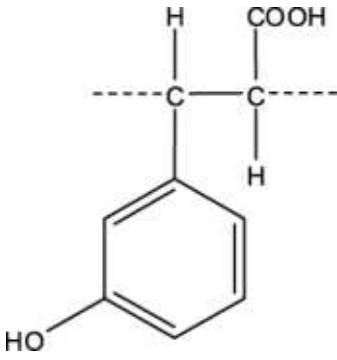
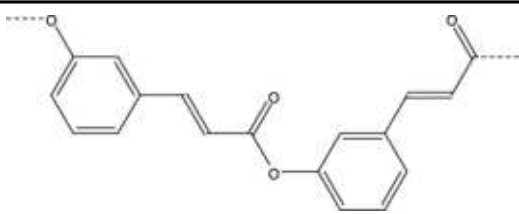
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
15	a		Product from NH_3/ethanol  ----- Product from Reaction 1  ----- Product from NaOH(aq) 	3	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous ALLOW  ALLOW ECF from 2-bromo compound as product from Reaction 1 ----- DO NOT ALLOW 2-bromo compound (<i>inconsistent with final product shown</i>) ----- DO NOT ALLOW ECF from 2-bromo compound as product from Reaction 1 (<i>inconsistent with final product shown</i>)
	b				ANNOTATE ANSWER WITH TICKS AND CROSSES

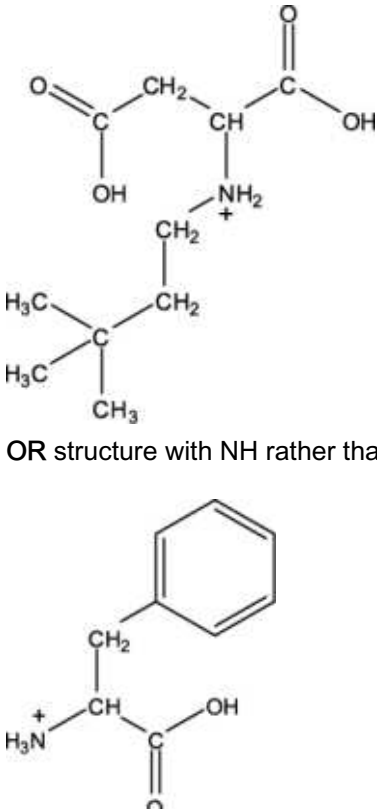
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
	Curly arrow from C=C bond to H of H-Br Correct dipole shown on H-Br AND curly arrow showing the breaking of H-Br bond  ----- Correct carbocation AND curly arrow from Br⁻ to C⁺ of carbocation 		ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous DO NOT ALLOW partial charges shown on C=C double bond DO NOT ALLOW δ^+ on C of carbocation ALLOW formation of the 2-bromo isomer 

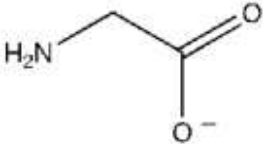
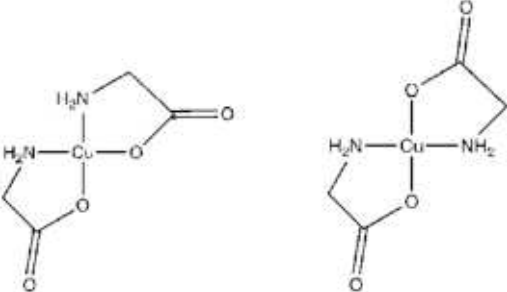
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			----- 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 <i>n</i>
		ii	 Ester link Rest of structure	2	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous 'End bonds' MUST be shown (do not have to be dotted)

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d		 OR structure with NH rather than NH₂⁺ OR structure with NH₂ rather than NH₃⁺ CH₃-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	

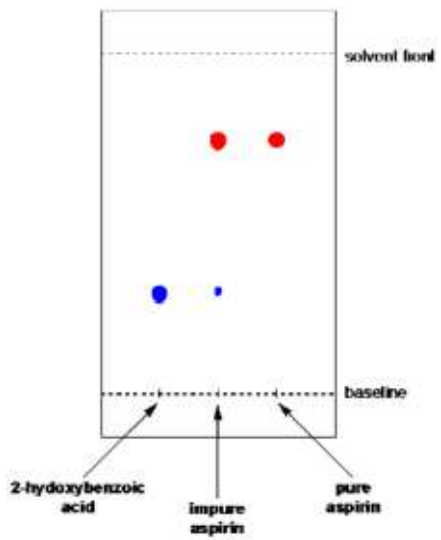
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
16		i		1	Must be skeletal formula
		ii		2	IGNORE charges ALLOW Cs and Hs labelled on structures <i>Marks are for correct connectivity</i>
		iii	Alanine has a chiral C atom / centre	1	
			Total	4	

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
17	a	<i>Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Correctly calculates mass of 2-hydroxybenzoic acid. AND Outlines full details of the two steps to obtain a pure sample of aspirin from the hot reaction mixture <i>Calculation shows all relevant steps.</i> <i>Purification steps are detailed and clear, in the correct order, using appropriate scientific terms, e.g. filter under reduced pressure / using a Buchner flask; dissolve in the minimum volume of solvent.</i> Level 2 (3–4 marks) Attempts a calculation which is mostly correct AND Some details of steps to obtain impure aspirin from the hot reaction mixture and recrystallisation <i>Calculation can be followed but lacks clarity.</i> <i>Purification steps lack detail, e.g. filter without reduced pressure; dissolve without minimum volume of solvent.</i> Level 1 (1–2 marks) Attempts to calculate the mass of B using mole approach but makes little progress with only 1 step correct. AND Few or imprecise details about steps to obtain impure aspirin from hot reaction mixture and recrystallisation <i>Calculation is difficult to follow and lacks clarity</i> <i>Purification steps are unclear with few scientific terms and little detail, e.g. just 'filter and crystallise'.</i>	6	Indicative scientific points, with bulleted elements, may include: 1. Mass of 2-hydroxybenzoic acid $n(\text{aspirin}) \text{ needed} = \frac{8.10}{180} = 0.0450 \text{ (mol)}$ $n(2\text{-hydroxybenzoic acid}) \text{ needed} = 0.0450 \times \frac{100}{90} = 0.0500 \text{ (mol)}$ - Mass = $0.0500 \times 138 = 6.9(0) \text{ g}$ 2. Purification Impure aspirin from hot reaction mixture - Cool reaction mixture - Filter product under reduced pressure Recrystallisation of impure aspirin: - Dissolve impure solid in minimum volume of hot water / solvent - Cool solution and filter solid - Wash with cold water / solvent and dry NOTE Filtration of hot solution to remove solid particles is not required.

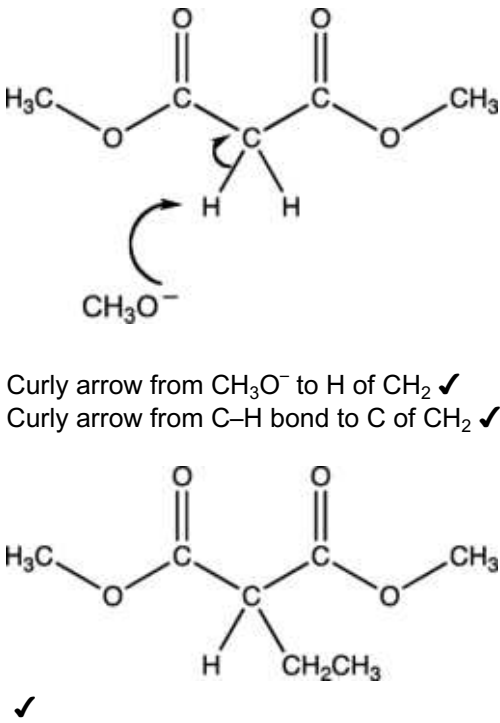
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			0 marks: No response or no response worthy of credit.		
	b	i	 Pure aspirin and 2-hydroxybenzoic acid correct Impure aspirin with 2 spots in line with aspirin and 2-hydroxybenzoic acid spots AND 2-hydroxybenzoic acid spot fainter than aspirin spot	2	Check measurements on diagram using online measuring tool. Distance from baseline to top of spot for aspirin = 70–80% of baseline → solvent front Distance from baseline to top of spot for aspirin = 25–35% of baseline → solvent front
		ii	Melting point range between 130–140°C AND Range $\geq 2^{\circ}\text{C}$	1	Range that starts <138 and finishes ≤ 140
			Total	9	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance																				
18	a		✓	1																					
	b	i	$2\text{Na} + 2\text{CH}_3\text{OH} \rightarrow 2\text{Na}^+ + 2\text{CH}_3\text{O}^- + \text{H}_2$ ✓	1	ALLOW $2\text{Na} + 2\text{CH}_3\text{OH} \rightarrow 2\text{CH}_3\text{ONa} + \text{H}_2$																				
		ii	 Curly arrow from CH_3O^- to carbon atom of C-Br bond ✓ Dipole shown on C-Br bond, $\text{C}^{\delta+}$ and $\text{Br}^{\delta-}$ AND curly arrow from C-Br bond to the Br atom ✓ Products of reaction (must not be ambiguous) ✓	3	ALLOW correct structural OR skeletal OR displayed formula OR mixture of the above as long as non-ambiguous. The curly arrow must start from O atom of CH_3O^- AND must start either from a lone pair or from the negative charge. No need to show lone pair if curly arrow comes from negative charge. ALLOW $\text{S}_{\text{N}}1$ Dipole shown on C-Br bond, $\text{C}^{\delta+}$ and $\text{Br}^{\delta-}$, and curly arrow from C-Br bond to the Br atom. Correct carbocation drawn. AND curly arrow from CH_3O^- to carbocation. The curly arrow must start from the oxygen atom of the CH_3O^-, and must start either from a lone pair or from the negative charge.																				
		iii	CH_3O^- donates an electron pair AND heterolytic fission ✓	1	ASSUME 'it' refers to CH_3O^-																				
	c		<table><tr><th>Chemical shift, δ/ppm</th><th>Relative peak area</th><th>Splitting pattern</th><th></th></tr><tr><td>0.5–1.9</td><td>3</td><td>Triplet</td><td>✓</td></tr><tr><td>3.0–4.3</td><td>2</td><td>Quartet</td><td>✓</td></tr><tr><td>0.5–1.9</td><td>6</td><td>Doublet</td><td>✓</td></tr><tr><td>3.0–4.3</td><td>1</td><td>Heptet</td><td>✓</td></tr></table>	Chemical shift, δ/ppm	Relative peak area	Splitting pattern		0.5–1.9	3	Triplet	✓	3.0–4.3	2	Quartet	✓	0.5–1.9	6	Doublet	✓	3.0–4.3	1	Heptet	✓	4	ALLOW δ values ± 0.2 ppm, as a range or a value within the range ALLOW multiplet for heptet
Chemical shift, δ/ppm	Relative peak area	Splitting pattern																							
0.5–1.9	3	Triplet	✓																						
3.0–4.3	2	Quartet	✓																						
0.5–1.9	6	Doublet	✓																						
3.0–4.3	1	Heptet	✓																						

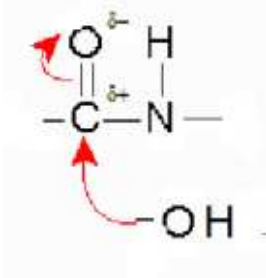
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d	i	 Curly arrow from CH_3O^- to H of CH_2 ✓ Curly arrow from C-H bond to C of CH_2 ✓	3	The curly arrow must start from O atom of CH_3O^- AND must start either from a lone pair or from the negative charge. No need to show lone pair if curly arrow comes from negative charge. ALLOW any unambiguous structure, skeletal, displayed, structural or combination.
		ii	CH_3O^- accepted a proton ✓	1	ASSUME 'it' refers to CH_3O^-
			Total	14	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
19		i	$\text{H}_2\text{N}(\text{CH}_2)_6\text{NH}_2$ ✓ $\text{HOOC}(\text{CH}_2)_4\text{COOH}$ ✓	2	ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous ALLOW acid chloride, $\text{ClOC}(\text{CH}_2)_4\text{COCl}$ 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	

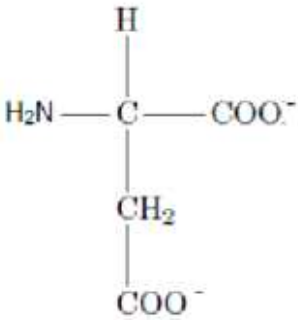
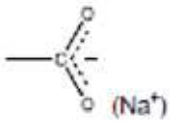
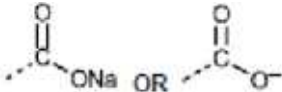
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
20	a		 Curly arrow from OH⁻ to C(δ^+) ✓ Dipole correct AND curly arrow from C=O bond to O(δ^-) ✓	2	First curly arrow must come from either a lone pair on O or negative charge on O Examiner's Comments Some candidates lost a mark for the incorrect positioning of the curly arrow from the hydroxide ion. The mark scheme specifies that it should start at either the lone pair on the oxygen atom or the negative charge on the oxygen atom.
	b		Measure distance moved by spot/distance moved by solvent ✓	2	ALLOW attempt at calculation of R_f value using distances measured on the chromatogram IGNORE explanation of how chromatography works

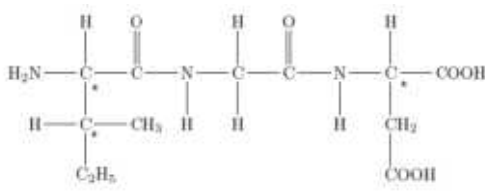
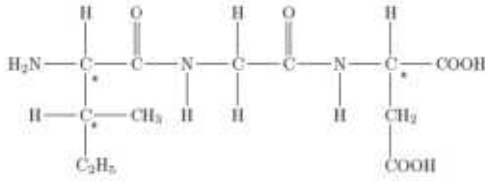
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Compare (R_f) value with data book values/known values ✓ Two amino acids have the same/similar R_f value OR similar adsorption OR move the same/similar distance ✓	1	ALLOW One spot contains two amino acids ALLOW Two amino acids have not separated IGNORE relative solubility ALLOW two of the amino acids have similar structures Examiner's Comments This question discriminated well with relatively few candidates able to score all three marks. Some candidates attempted to explain how the technique separates components between a mobile phase and a stationary phase which was not required by the question. There was some confusion with gas chromatography and retention times. Vague answers about all amino acids having similar structures did not score the final marking point to explain why only two spots appeared on the chromatogram.
	c	i	The pH at which the amino acid exists as a <u>zwitterion</u> ✓  QWC: zwitterion spelled correctly in the correct context	1	DO NOT ALLOW PH/ph ALLOW zwitter ion Examiner's Comments This definition had been learned by the majority of candidates.

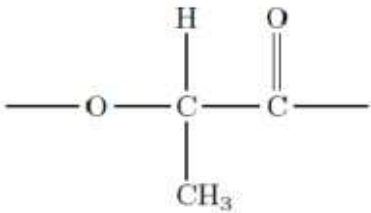
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
ii		1	ALLOW correct structural OR displayed OR skeletal formulae OR combination of above as long as unambiguous Two COO⁻ groups are required in the structure ALLOW –COO⁻Na⁺ OR –COONa  ALLOW delocalised carboxylate ALLOW  DO NOT ALLOW -COO-Na OR -O-Na (covalent bond) Examiner's Comments Generally well answered but structures with only one carboxylate group were quite common and some candidates showed aspartic acid being protonated at high pH.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	M1 structure  ✓ M2 correct structure has three chiral centres  ✓	2	ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous ALLOW tripeptide with the 3 amino acids in any order ALLOW cyclic tripeptide Isoleucine has two chiral centres, aspartic acid has one chiral centre and glycine has none. ALL three correct for one mark ALLOW chiral centres correctly identified if the three amino acids are part of a polypeptide chain Examiner's Comments A more challenging question with relatively few candidates able to show the position of all three chiral centres on a correct tripeptide structure. Most candidates identified the chiral centres in the amino acid backbone of aspartic acid and isoleucine and realised that glycine was not chiral, but many missed the second chiral centre in isoleucine.
			Total	9	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
21		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.

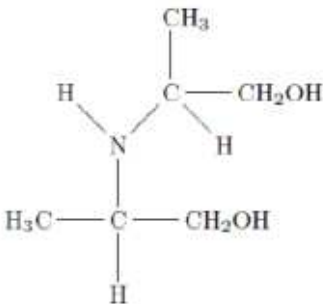
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	(Ester links in PLA are) hydrolysed ✓ Any two from: - Ester (links in the polymer) OR (PLA is a) polyester - Monomer/lactic acid/product (is soluble because it) forms hydrogen bonds to water - polymer is photodegradable - the C=O bond absorbs radiation/uv/light ✓✓  QWC: hydrolysed/hydrolysis/hydrolyses spelled correctly in the correct context	3	ANNOTATE WITH TICKS AND CROSSES ETC. ALLOW (ester) hydrolysis/(ester) hydrolyses IGNORE acid/alkaline (hydrolysis) IGNORE PLA forms hydrogen bonds to water IGNORE biodegradable IGNORE infrared radiation Maximum of 2 marks if hydrolysed/hydrolysis/hydrolyses does not appear in the 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	

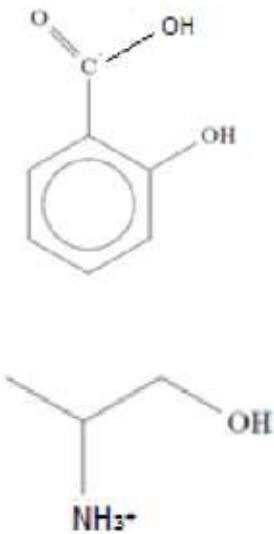
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance															
22	a	i	<table><tr><th colspan="3">¹H NMR spectrum for 2-aminopropan-1-ol</th></tr><tr><th>Chemical shift, δ/ppm</th><th>Relative peak area</th><th>Splitting pattern</th></tr><tr><td>0.8 – 2.0</td><td>3</td><td>doublet</td></tr><tr><td>2.3 – 3.0</td><td>1</td><td>multiplet</td></tr><tr><td>3.3 – 4.2</td><td>2</td><td>doublet</td></tr></table> ✓✓✓	¹ H NMR spectrum for 2-aminopropan-1-ol			Chemical shift, δ /ppm	Relative peak area	Splitting pattern	0.8 – 2.0	3	doublet	2.3 – 3.0	1	multiplet	3.3 – 4.2	2	doublet	3	One mark for each correct row ALLOW δ values as a range or a value within the specified range. ALLOW δ values +/- 0.2 ppm. ALLOW a response that implies a splitting into two for a doublet etc. ALLOW sextet/hextet/six (or more than 5) as alternative to multiplet Relative peak area = CH /3H etc. penalise once Examiner's Comments Although it could be argued that this question tested the same skill three times, the full range of marks was awarded and errors were seen in the chemical shift, relative peak area and splitting pattern. Fully correct responses included either a chemical shift value within the range specified on the data sheet or a range that matched the one given on the data sheet.
¹ H NMR spectrum for 2-aminopropan-1-ol																				
Chemical shift, δ /ppm	Relative peak area	Splitting pattern																		
0.8 – 2.0	3	doublet																		
2.3 – 3.0	1	multiplet																		
3.3 – 4.2	2	doublet																		
		ii	M⁺ peak at 75 (peak 1) CH₃CH(NH₂)CH₂OH⁺/C₃H₉NO⁺ ✓ Fragment peak at 44 (peak 2) CH₃CH(NH₂)⁺/C₂H₆N⁺ ✓	2	ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous Positive charge is essential but ALLOW maximum of one mark if both formulae are correct AND neither species has a positive charge Examiner's Comments Although peak 2 was often correct, the species responsible for the M⁺ peak was often missing a positive charge. Possibly students have learned that the particles become charged as part of the fragmentation process and don't realise that only charged particles can be detected by a mass spectrometer.															

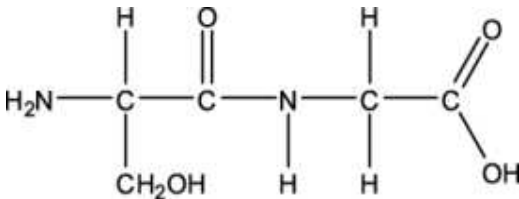
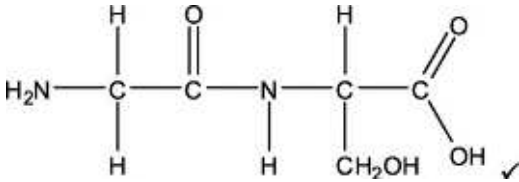
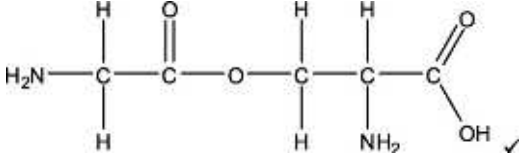
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b	i	Ethanolic ammonia OR ammonia/NH ₃ AND ethanol ✓	1	ALLOW ammonia in a sealed tube ALLOW dilute ethanolic ammonia/NH₃ IGNORE heat ALLOW alcohol for ethanol DO NOT ALLOW any reference to water or hydroxide ions Examiner's Comments A well answered question. Some candidates forgot to use a solvent or suggested the use of aqueous ammonia.
		ii	(compound D) 	1	ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous Examiner's Comments This question discriminated well. Although there were very few blank pages, many incorrect structures were seen.
	c	i	Alcohol AND Amide/peptide ✓	1	IGNORE phenol IGNORE hydroxyl/hydroxy IGNORE attempts to classify alcohol or amide as primary, secondary or tertiary DO NOT ALLOW hydroxide Examiner's Comments Generally well answered but incorrect functional groups included carbonyl and amine.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii		2	ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above ALLOW correct structural OR displayed OR skeletal formulae OR combination of above as long as unambiguous ALLOW + on N or H i.e. NH_3^+ or NH_3^+ ALLOW NH_3^+Cl^- Examiner's Comments Many candidates were able to score one mark for this question but the amine group was often not protonated and it was surprisingly common to see the amine group as NH_2^+.
			Total	10	
23			C	1	
			Total	1	
24			A	1	
			Total	1	
25			C	1	
			Total	1	
26			A	1	
			Total	1	

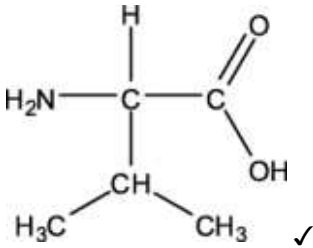
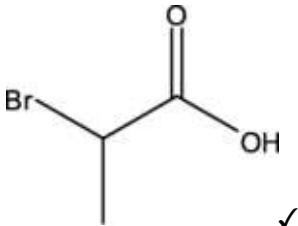
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
27	a	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

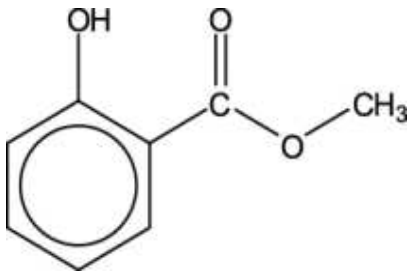
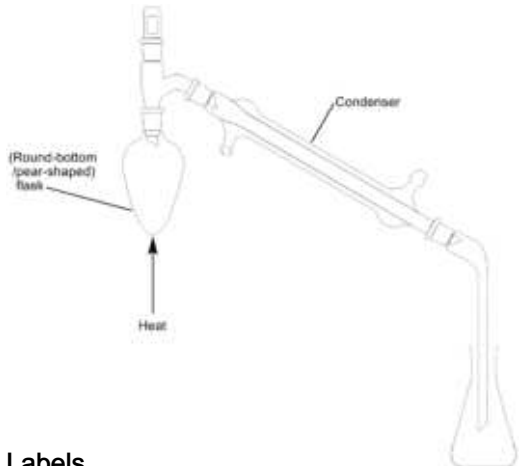
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b	i	Structure of aspartic acid $ \begin{array}{c} \text{H} \\ \\ \text{H}_2\text{N}-\text{C}-\text{C} \\ \quad \quad // \\ \text{CH}_2 \quad \quad \text{O} \\ \quad \quad \backslash \\ \text{COOH} \quad \quad \text{OH} \end{array} \quad \checkmark $ Product from HCl(aq) $ \begin{array}{c} \text{H} \\ \\ (\text{Cl}^-) \text{H}_3\text{N}^+-\text{C}-\text{C} \\ \quad \quad // \\ \text{CH}_2 \quad \quad \text{O} \\ \quad \quad \backslash \\ \text{COOH} \quad \quad \text{OH} \end{array} \quad \checkmark $ Product from excess $\text{CH}_3\text{OH}/\text{H}_2\text{SO}_4$ $ \begin{array}{c} \text{H} \\ \\ \text{H}_2\text{N}-\text{C}-\text{C} \\ \quad \quad // \\ \text{CH}_2 \quad \quad \text{O} \\ \quad \quad \backslash \\ \text{COOCH}_3 \quad \quad \text{OCH}_3 \end{array} \quad \checkmark\checkmark $	4	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous Note: the amine group could be shown as either NH_2 or NH_3^+ (acidic conditions) ALLOW one mark for $ \begin{array}{c} \text{H} \\ \\ \text{H}_2\text{N}-\text{C}-\text{C} \\ \quad \quad // \\ \text{CH}_2 \quad \quad \text{O} \\ \quad \quad \backslash \\ \text{COOH} \quad \quad \text{OCH}_3 \end{array} $ OR $ \begin{array}{c} \text{H} \\ \\ \text{H}_2\text{N}-\text{C}-\text{C} \\ \quad \quad // \\ \text{CH}_2 \quad \quad \text{O} \\ \quad \quad \backslash \\ \text{COOCH}_3 \quad \quad \text{OH} \end{array} $

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Molar mass of G = $\frac{3.51}{0.0300} = 117(.0)$ (g mol⁻¹) ✓ Structure of G  ✓	6	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous ALLOW R (group of G) is -CH(CH₃)₂ if structure of amino acid is not given
	c		Reagents for first stage NaBr/H₂SO₄ ✓ Compound H  ✓ Reagent for second stage (excess ethanolic) NH₃ ✓	3	ALLOW any suitable halide salt/sulfuric acid combination ALLOW HC/ OR HBr OR HI ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous Note: the halogen in compound H can be Cl, Br or I, but must be consistent with halide salt used
			Total	15	

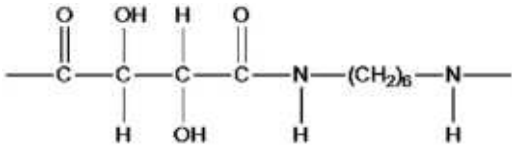
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
28		i	 AND Acid (catalyst) ✓	1	Note: both the structure and condition are required for the mark ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous ALLOW H⁺ / H₂SO₄ / H₃PO₄ / named mineral acid
		ii	Diagram Diagram showing correct apparatus for distillation ✓ <i>i.e.</i> • Round-bottom/pear-shaped flask • Condenser (correctly orientated) • Stopper/thermometer • Delivery tube and suitable collection vessel  Labels (Round-bottom/pear-shaped) flask AND condenser AND heat (source) ✓	2	DO NOT ALLOW conical flask, volumetric flask, beaker in place of round bottomed/pear shaped flask DO NOT ALLOW diagram mark if top of distillation head not closed Note: suitable collection vessels include: conical flask, boiling tube, test-tube, beaker etc.
			Total	3	

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
29	a	One mark for each correct structure/reagent/condition as shown below	6	ANNOTATE ANSWER WITH TICKS AND CROSSES ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous IGNORE names of organic compounds (<i>question asks for structures</i>) ALLOW aluminium(III) chloride OR aluminium trichloride ALLOW FeCl₃ OR Fe as halogen carrier in first step. ALLOW sodium borohydride OR sodium tetrahydridoborate IGNORE [H] for reducing agent in second step ALLOW H⁺ / H₂SO₄ / H₃PO₄ / named mineral acid for reagent in third step
	b	Use as an organic feedstock ✓ OR Combustion for energy production ✓	1	ALLOW the production of plastics or monomers or new polymers Combustion alone is not sufficient
Total			7	

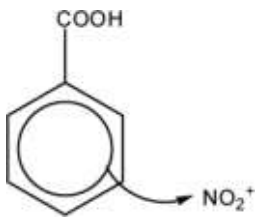
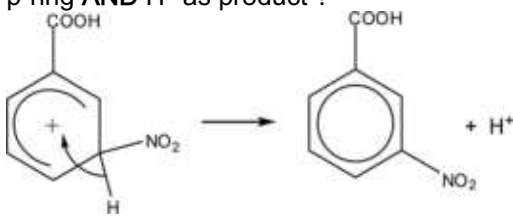
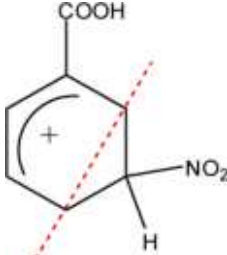
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
30		i	$C_2H_3O_3$ ✓	1	
		ii	2,3– dihydroxybutanedioic acid ✓	1	ALLOW 2,3–dihydroxybutane–1,4–dioic acid ALLOW absence of hyphens or extra hyphen or space, e.g. 2,3–dihydroxy butanedioic acid ALLOW full stops or spaces between numbers e.g. 2.3 dihydroxybutanedioic acid
		iii	 Correct amide link ✓ Rest of structure ✓	2	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous ‘End bonds’ MUST be shown IGNORE brackets IGNORE n
		iv	$[H_3N^+(CH_2)_6NH_3^+]$ $[^-OOC(CHOH)_2COO^-]$ OR $[H_3N(CH_2)_6NH_3]^{2+}$ $[OOC(CHOH)_2COO]^{2-}$ Positive ion correct ✓ Negative ion correct ✓	2	ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous ALLOW charge either on N atom or NH_3^+ Negative charge must be on COO^- ALLOW $[H_2N(CH_2)_6NH_3^+]$ $[^-OOC(CHOH)_2COOH]$
			Total	6	
31			A	1	Examiner Comments This question was answered correctly by over 80% of the candidates. The main distractor appeared to be B which was an amide rather than an amine.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
32			C	1	ALLOW 4 (This is the number of chiral centres) Examiner Comments This question was answered well. The correct answer C, was provided by just over 60% of candidates. Where incorrect responses were seen, it was frequently due to the candidate missing one of the chiral centres, typically the one nearest to the sulfur atom within the ring.
			Total	1	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
33 a i	Generation of electrophile $\text{HNO}_3 + \text{H}_2\text{SO}_4 \longrightarrow \text{H}_2\text{O} + \text{HSO}_4^- + \text{NO}_2^+ \checkmark$ Electrophilic substitution Curly arrow from p-bond to NO_2^+ ?  Correct intermediate ? Curly arrow back from C-H bond to reform p-ring AND H^+ as product ?  Regeneration of catalyst $\text{H}^+ + \text{HSO}_4^- \longrightarrow \text{H}_2\text{SO}_4 \checkmark$	5	ANNOTATE ANSWER WITH TICKS AND CROSSES ALLOW $\text{HNO}_3 + 2\text{H}_2\text{SO}_4 \rightarrow \text{H}_3\text{O}^+ + 2\text{HSO}_4^- + \text{NO}_2^+$ ALLOW $\text{HNO}_3 + \text{H}_2\text{SO}_4 \rightarrow \text{H}_2\text{NO}_3^+ + \text{HSO}_4^-$ Then $\text{H}_2\text{NO}_3^+ \rightarrow \text{H}_2\text{O} + \text{NO}_2^+$ ALLOW $^+\text{NO}_2$ OR NO_2^+ First curly arrow must come from the ring to NO_2^+ DO NOT ALLOW the following intermediate:  p-ring should cover approximately 4 of the 6 sides of the benzene ring structure AND the correct orientation, <i>i.e.</i> gap towards C with NO_2 ALLOW + sign anywhere inside the 'hexagon' of intermediate Examiner Comments The majority of candidates were well prepared for this standard mechanism and frequently scored marks of four or five. Most were able to show equations to generate the electrophile and regenerate the catalyst. Candidates should note the importance of the correct placement of curly arrows and the horseshoe in the intermediate to show the remaining electrons present in the ring structure. These were often poorly represented, leading to marks not being awarded.

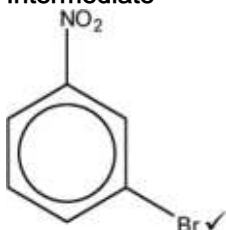
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	<i>Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Outlines the main steps of recrystallisation to produce a pure sample of 3-nitrobenzoic acid from the impure solid. AND Calculates correct percentage yield of 3-nitrobenzoic acid. AND Method of checking purity to include comparison to relevant data. <i>A well-structured response with the steps for recrystallisation and the determination of purity being given in the correct order. Correct use of terminology throughout.</i> Level 2 (3–4 marks) Attempts all three scientific points but explanations may be incomplete. OR Explains two scientific points thoroughly with very few omissions. <i>The description of checking for purity or recrystallisation is clear and any calculations structured. Key terminology used appropriately.</i> Level 1 (1–2 marks) A simple explanation based on at least two of the main scientific points. OR Explains one scientific point thoroughly with few omissions. <i>There is an attempt at a logical structure. The description of the practical techniques provides some detail but may not be in the correct order.</i> <i>Purification step is unclear with few scientific terms and little detail, e.g. just 'recrystallise'.</i> <i>Calculation is difficult to follow, may just include a calculation of moles of reactants and/or products.</i>	6	Indicative scientific points, with bulleted elements, may include: 1. Purification - Recrystallisation - Dissolve impure solid in minimum volume of hot water/solvent - Cool solution and filter solid - Wash with cold water/solvent and dry 2. Percentage yield $n(\text{benzoic acid}) \text{ used} = \frac{4.97}{122} = 0.0407 \text{ (mol)}$ $n(3\text{-nitrobenzoic acid}) \text{ made} = \frac{4.85}{167} = 0.0290 \text{ (mol)}$ $\text{percentage yield} = \frac{0.0290}{0.0407} \times 100 = 71.3 \text{ (\%)}$ ALLOW 71 to calculator value of 71.29001554 correctly rounded. CHECK for extent of errors by ECF Alternative correct calculation may calculate theoretical mass of 3-nitrobenzoic acid that can be produced as $0.0407 \times 167 = 6.80 \text{ (g)}$ followed by: $\text{percentage yield} = \frac{4.85}{6.80} \times 100 = 71.3 \text{ (\%)}$ Calculation must attempt to calculate n (benzoic acid) in mol. 3. Checking purity - Obtain melting point - Compare to known values - Pure sample will have a (sharp) melting point very close to data book value ALLOW alternative approach based on spectroscopy or TLC Spectroscopy - Run an NMR/IR spectrum - Compare to (spectral) database - Spectrum of pure sample will contain

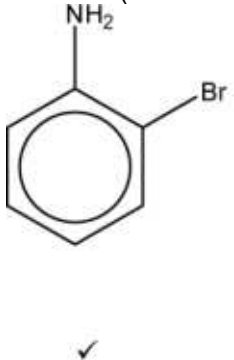
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
	<i>Purity check specifies a method but this is unclear with little detail, e.g. take melting point.</i> 0 marks No response or no response worthy of credit.		same peaks and not others TLC - Run a TLC - Compare (R_f value) to known data - Pure sample will have a very similar R_f Examiner Comments This question tested some of the practical techniques covered as part of the practical endorsement as well as requiring candidates to calculate a percentage yield for the reaction. This proved to be quite a challenging question with some candidates giving little detail of how to carry out a recrystallisation. Common answers included a statement that the solid should be allowed to dissolve in a solvent and then filtered to obtain crystals. This did not gain credit for the scientific content as there was no indication of the solid dissolving in a hot solvent and then being allowed to cool before carrying out filtration. High quality answers often went above and beyond the requirements of the marking scheme with some candidates discussing the importance of dissolving in the minimum amount of hot solvent to obtain a saturated solution, the need to wash and dry the crystals and provided detail of the apparatus and or method required. Most candidates discussed that purity could be determined by taking the melting point of the product and comparing this to a value obtained from data book. The most comprehensive answers gave an indicated of the apparatus required to carry out the melting point determination and discussed how the melting point becomes higher and sharper as impurities are removed. Common errors included comments about carrying out a boiling point determination. When carrying out a percentage yield calculation, it is important to round answers only at the last stage of the calculation. Early rounding frequently led candidates to

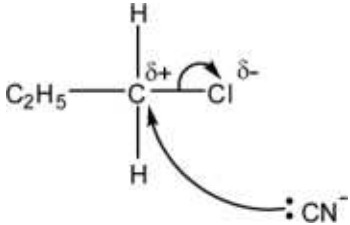
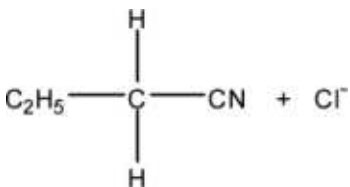
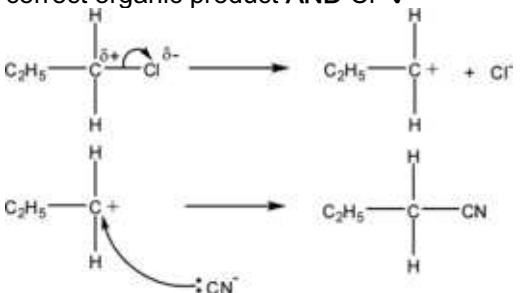
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					obtain answers, which did not gain credit. Weaker Candidates divided the mass of 3-nitrobenzoic acid by the mass of benzoic acid and obtained an answer of 97.6%. Answer = 71.3%
	b	i	Bromination: Br₂ AND A/Br₃/FeBr₃/Fe ✓ Intermediate  Reduction: Sn AND (concentrated) HC/✓	3	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous ALLOW any suitable halogen carrier catalyst ALLOW Kekulé structure IGNORE names (<i>question asks for formulae</i>) IGNORE reaction conditions even if incorrect IGNORE 'dilute' for HC/ IGNORE H₂ IGNORE NaOH if seen as a reagent to convert nitro group into amine e.g 'Sn/(concentrated) HC/ then NaOH' scores the mark Examiner Comments Candidates were able, in the main, to provide the reagents for bromination and reduction. The structure of the intermediate compound in the preparation of 3-bromophenylamine proved to be straightforward, however common errors involved the omission of the halogen carrier catalyst for bromination or stating names rather than formulae as indicated in the question.

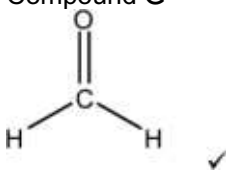
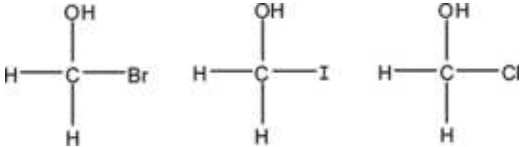
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	NH₂ is 2,4 directing ✓ Products (1 mark for each):  	3	IGNORE references to electron donating/withdrawing groups ALLOW –NH₂ activates the ring causing the new group to join at positions 2 and 4. ALLOW ortho and para directing for 2,4 directing IGNORE 6-directing ALLOW Kekulé structure IGNORE names Examiner Comments The most able candidates completed this question with a clear statement that the –NH₂ group was 2,4 directing and provided two clearly drawn structures of 2-bromophenylamine and 4-bromophenylamine. The most common errors observed included drawing two structures that were identical and explaining the two structures in terms of electron donation from the –NH₂ without any indication of positioning. Candidates using the terms ortho and para directing were awarded full marks for their answers.
			Total	17	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
34 a i	curly arrow from CN^- to carbon atom of C–Cl bond ✓ Dipole shown on C–Cl bond, $\text{C}^{\delta+}$ and $\text{Cl}^{\delta-}$, AND curly arrow from C–Cl bond to Cl 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 $\text{S}_{\text{N}}1$ mechanism: Dipole shown on C–Cl bond, $\text{C}^{\delta+}$ and $\text{Cl}^{\delta-}$, AND curly arrow from C–Cl bond to Cl 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.

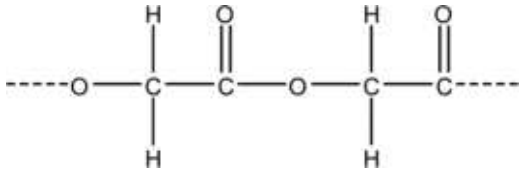
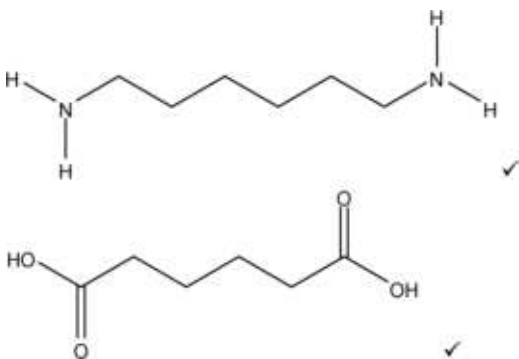
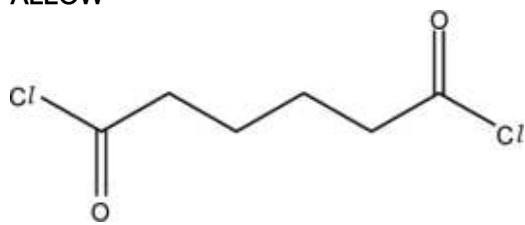
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Compound G  Reagents Reaction 2: H₂ AND Ni ✓ Reaction 3: Correct formula of an aqueous acid e.g. HCl(aq)/H₂SO₄(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 LiAlH₄ for reagent in reaction 2 DO NOT ALLOW NaBH₄ for reagent in reaction 2 IGNORE names (<i>question asks for formulae</i>) IGNORE references to temperature and/or pressure ALLOW H⁺(aq) IGNORE dilute ALLOW formula of an acid AND water e.g. HCl AND H₂O H₂SO₄ AND H₂O 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.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
	iii Explanation Nitrogen electron pair OR nitrogen lone pair AND accepts a proton / H^+ ✓ Structure of salt $\begin{array}{c} \text{OH} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{NH}_3^+ \\ \quad \\ \text{H} \quad \text{H} \end{array} \quad \text{AND } \text{Cl}^- \quad \checkmark$	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 $-\text{OH}$ group Compound H is a base is not sufficient (<i>role of lone pair required</i>) DO NOT ALLOW nitrogen/N lone pair accepts hydrogen (<i>proton/H^+ required</i>) ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous ALLOW $\begin{array}{c} \text{OH} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{NH}_3\text{Cl} \\ \quad \\ \text{H} \quad \text{H} \end{array} \quad \text{i.e. charges not required}$ 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 $-\text{NH}_3^+$ is acceptable. As the question required the formula of the salt, the Cl^- had to be included.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	 Ester link ✓ Rest of structure ✓ (polymer J is biodegradable because) the ester / ester bond / ester group / polyester can be hydrolysed ✓	3	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous DO NOT ALLOW more than two repeat units for second marking point. 'End bonds' MUST be shown (do not have to be dotted) IGNORE brackets IGNORE <i>n</i> 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.

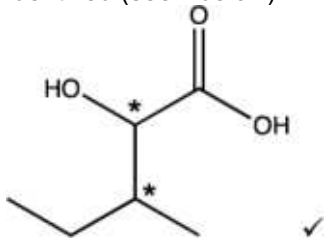
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	$(n = \frac{21500}{226} =) 95 \text{ (repeat units)}$	✓ 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	

Mark Scheme

Question			Answer/Indicative content					Marks	Guidance
35	a	i	<i>Burette readings</i>					4	Table not required ALLOW initial reading before final reading ALLOW ECF ALLOW units with each value ALLOW brackets for units, i.e. (cm ³) ALLOW ECF from incorrect concordant titres

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					number took an average of all three titres instead. The mark scheme allowed for a mean titre obtained from incorrect titres. Candidates need to appreciate the importance of communicating their results in a clear and comprehensive way with headings and units, and showing numerical values to the accuracy of the apparatus used.
		ii	ALLOW 3SF or more throughout IGNORE trailing zeroes, e.g. ALLOW 0.084 for 0.0840 $n(\text{NaOH}) = 0.0840 \times \frac{22.50}{1000} = 1.89 \times 10^{-3} \text{ (mol)} \checkmark$ $n(\text{A}) \text{ in } 250 \text{ cm}^3 = 10 \times 1.89 \times 10^{-3} = 1.89 \times 10^{-2} \text{ (mol)} \checkmark$ $M(\text{A}) = \frac{2.495}{1.89 \times 10^{-2}} = 132 \text{ (g mol}^{-1}\text{)} \checkmark$ $M(\text{alkyl group}) (= 132 - 75) = 57 \checkmark$ R = C₄H₉ ✓ ALLOW alkyl group in drawn structure with straight chain or branch (es) in wrong position, e.g. for R = C₄H₉, CH₃CH₂CH₂CH₂ OR (CH₃)₃C Structure with chiral carbon atoms identified (see * below) 	6	ALLOW ECF from incorrect mean titre in 4a(i) e.g. From 22.60 cm³ (mean of all 3 titres in (i)), $n(\text{NaOH}) = 1.8984 \times 10^{-3} \text{ (mol)}$ ALLOW ECF from incorrect $n(\text{NaOH})$ ALLOW ECF from incorrect $n(\text{A})$ ALLOW ECF from incorrect $M(\text{A}) - 75$ ALLOW ECF for alkyl group closest to calculated $M(\text{alkyl group})$, e.g. for $M = 45$, ALLOW C₃H₇ (43) ALLOW correct structural OR skeletal OR displayed formula OR mixture of the above as long as non-ambiguous IGNORE poor connectivity to OH groups <i>Given in question</i> Common error for 4 marks max 25.00 instead of 22.50 and scaling by $\times 10$ $2.10 \times 10^{-3} \rightarrow 2.10 \times 10^{-2} \checkmark$ $\rightarrow 118.81 \checkmark \rightarrow 43.81 \checkmark \rightarrow \text{C}_3\text{H}_7 \checkmark$ 25.00 instead of 22.50 and scaling by $\times \frac{250}{22.50}$

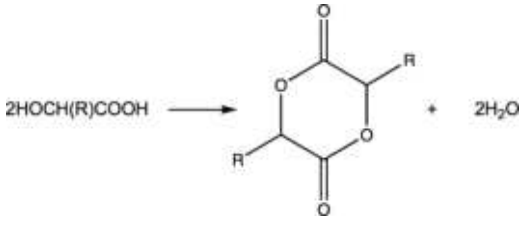
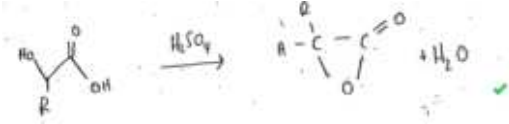
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					$2.10 \times 10^{-3} \rightarrow 2.33 \times 10^{-2} \checkmark$ $\rightarrow 106.93 \checkmark \rightarrow 31.93 \checkmark \rightarrow \text{C}_2\text{H}_5 \checkmark$ No structure with 2 chiral centres possible. Examiner's Comment: Most candidates made some headway with this problem. Candidates were expected to process their mean titre from 4(a)(i) in a conventional titration calculation to arrive at a molar mass of 132 g mol^{-1}. From there, candidates could determine a C_4H_9 alkyl group and draw the structure of compound A with two chiral carbon atoms. Most candidates scored some marks but processing beyond the molar mass proved to be difficult for weaker candidates. Some candidates showed a structure with a linear C_4H_9 group which contains one chiral carbon atom. A common error was use of 25.0 cm^3, instead of the titre, as the volume of NaOH, obtaining an initial value of $2.10 \times 10^{-3} \text{ mol}$. The mark scheme allowed processing of this value to be credited using error carried forwards. Some candidates omitted to scale their initial value by a factor of $\times 10$, obtaining a molar mass of over 1000 g mol^{-1}, e.g. 1320 instead of 132. A large range of marks was seen and the question discriminated extremely well.

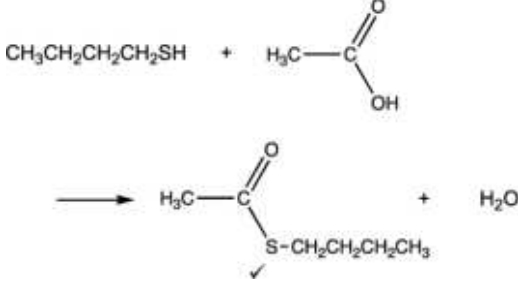
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b	i	<i>Equation</i> $2\text{HOCH(R)COOH} + \text{Mg} \rightarrow (\text{HOCH(R)COO})_2\text{Mg} + \text{H}_2$ Organic product ✓ Balance ✓ <i>Type of reaction</i> Redox ✓	3	ALLOW correct structural OR skeletal OR displayed formula OR mixture of the above as long as non- ambiguous ALLOW $2\text{HOCH(R)COOH} + \text{Mg} \rightarrow 2\text{HOCH(R)COO}^- + \text{Mg}^{2+} + \text{H}_2$ ALLOW multiples IGNORE poor connectivity to OH groups <i>Given in question</i> 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.

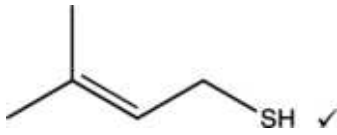
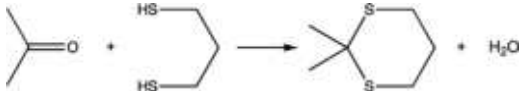
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		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 2H₂O 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	16	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
36	i $K_a = \frac{[H^+][C_4H_9S^-]}{[C_4H_9SH]} \quad \checkmark$ Square brackets required	1	ALLOW correct structural OR skeletal OR displayed formula OR mixture of the above as long as non- ambiguous Examiner's Comment: This part was very well answered. Candidates responded with either near molecular formulae, such as C_4H_9SH, structural formulae or with skeletal formulae. Some candidates made careless errors such as omitting the negative charge or showing $[H^+]^2$ as numerator rather than $[C_4H_9S^-][H^+]$.
	ii  Structure of thioester ✓ Complete equation ✓	2	ALLOW correct skeletal OR displayed formula OR mixture of the above as long as non-ambiguous ALLOW C_4H_9SH ALLOW CH_3COOH Thioester functional group must be fully displayed, OR as a skeletal formula but allow SC_4H_9 in thioester Examiner's Comment: In this part, candidates were expected to apply their knowledge and understanding of esterification to thiols and thioesters. Over half the candidates obtained a correct structure of the thioester. Most of these candidates constructed a balanced equation although some omitted the water product. Common errors included formation of a conventional ester and H_2S, and retaining the O atom from the OH in the carboxyl group to form $-COOS-$. As with 4(b)(i), structural and skeletal formulae were used. Candidates are less likely to omit H atoms if the skeletal formula is used.

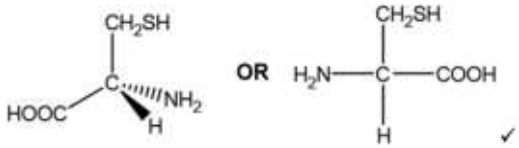
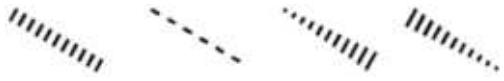
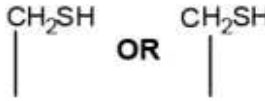
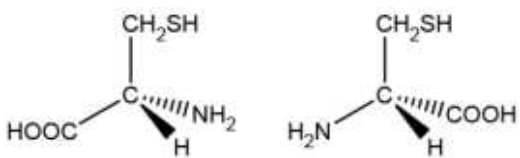
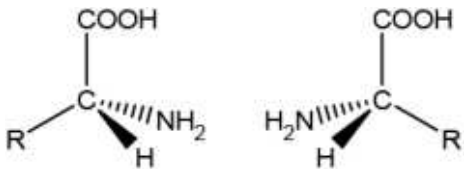
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii		1	IF correct skeletal formula is shown, IGNORE displayed formula in a second structure Examiner's Comment: Just over half the candidates drew the correct structure, displaying a good understanding of interpreting organic nomenclature when drawing a structure. Common errors included omission of the CH₂ adjacent to the terminal –SH group and placing the branch or double bond in wrong positions. Some candidates spoilt an otherwise good response by showing a structural formula or a mixture of skeletal and structural formulae.
		iv	 Reactants ✓ Products AND balanced equation ✓	2	ALLOW correct structural OR skeletal OR displayed formula OR mixture of the above as long as non- ambiguous Examiner's Comment: In this part, candidates were expected to apply their knowledge and understanding of condensation to an entirely new context. One mark was allocated for the reactants and this was usually scored. The second mark for the novel cyclic compound and water was much more difficult, aimed at stretch and challenge. A significant number of candidates interpreted the information to obtain a correct cyclic structure but this mark was the domain of the most able candidates.
			Total	6	
37			C	1	<u>Examiner's Comments</u> The majority of candidates identified C as the secondary amide.
			Total	1	

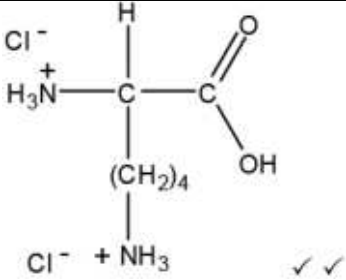
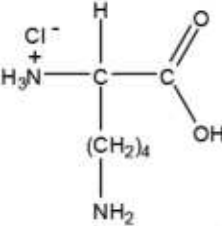
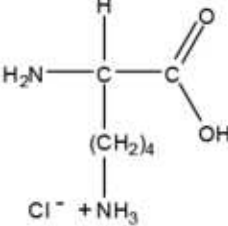
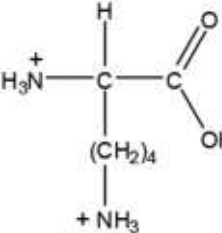
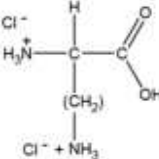
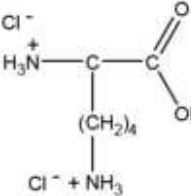
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
38			C	1	<u>Examiner's Comments</u> Almost all candidates identified C (CH_3COCl) as the reagent required for this reaction.
			Total	1	
39			B	1	ALLOW 2 (This is the number of straight chain isomers with a chiral C atom) <u>Examiner's Comments</u> This question proved difficult. Candidates who drew out the different isomers of chloroheptane were able to identify B as the correct response.
			Total	1	
40			B	1	<u>Examiner's Comments</u> Many candidates correctly selected B. Option A proved a good distractor, presumably as candidates linked melting point to recrystallisation without fully interpreting statement 3.
			Total	1	
41			B	1	<u>Examiner's Comments</u> Candidates found this question difficult, presumably as it involved reactions of different functional groups within the same compound. Many candidates identified B as the correct response. The most common incorrect responses were C and D.
			Total	1	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
42 a	Correct groups attached to chiral C of cysteine seen once e.g.  Two 3D structures of cysteine that are mirror images with correct connectivity in both ✓ 	2	Each structure must have four central bonds with at least two wedges. For bond into paper accept:  ALLOW bond to any part of the CH₂ of the CH₂SH group e.g. ALLOW  ALLOW two 3D structures with 2 groups swapped e.g.  IF CH₂SH is shown as 'R' ALLOW 1 mark for two 3D structures with correct connectivity that are mirror images e.g.  Examiner's Comments Candidates were well prepared to tackle this question and consequently most candidates scored both marks.
b	Correct salt of lysine with both amine groups protonated	2	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous Note: <i>Cl</i> is required (<i>question asks for salt</i>)

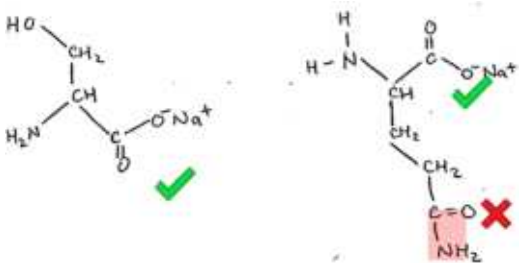
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			ALLOW NH_3Cl / <i>i.e</i> charges not required ALLOW 1 mark for   OR  <i>i.e. no Cl-</i> IF there is a small slip in the structure ALLOW 1 mark for diammonium salt e.g  (incorrect number of CH_2 in R group) OR  (H missing from a C atom) Examiner's Comments In contrast to part (a) this question proved difficult and discriminated well. The higher ability candidates correctly identified the dichloride salt produced by the reaction of lysine with excess acid. Some candidates formed ammonium ions on both nitrogen atoms but omitted the chloride ions. Others only formed a monochloride salt, leaving the R group unchanged. These two approaches scored one mark.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
c	i.e. one mark for each group hydrolysed	3	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous IGNORE NH₃ (<i>question asks for organic products</i>) 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

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					Examiner's Comments 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	7	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
43	Marks for each correct structure/reagent shown below	5	ANNOTATE WITH TICKS AND CROSSES ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous For reaction with excess H_2/Ni IGNORE hydrogenation of benzene ring i.e. the following structure scores two marks ALLOW KCN/H^+ ALLOW HCN ALLOW H_2SO_4 or HNO_3 or $\text{HC}/\text{for } \text{H}^+$ <u>Examiner's Comments</u> This question proved difficult and although the majority of candidates scored in some parts, only the very best responses secured all five marks. More detailed feedback is discussed with Exemplar 8.

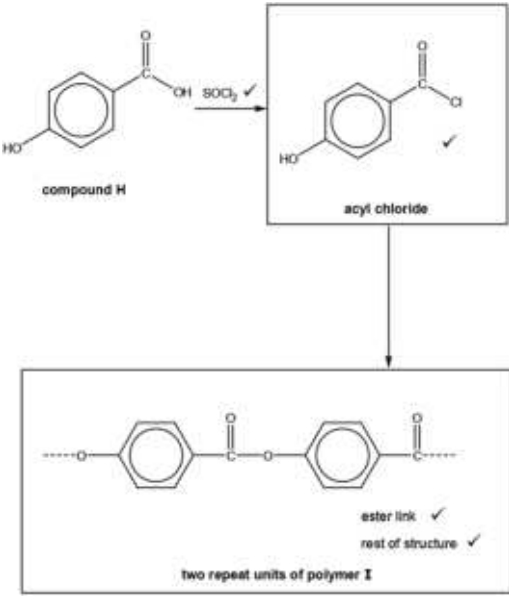
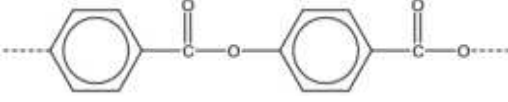
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			Exemplar 8 Cinnamaldehyde was the starting point for this flowchart of reactions. The most frequently scored mark was correct identification of the reagents required for the formation of the hydroxynitrile. This response uses NaCN/H⁺. Other candidates used HCN which was also acceptable. The flowchart shows two different reactions of this hydroxynitrile. The first is the reaction with excess hydrogen in the presence of Ni. Most candidates scored one mark for their product. As in this exemplar, the double bond was often reacted to form a saturated chain. Some candidates identified that the CN group would also react but instead of writing CH₂NH₂ they replaced the CN group with just NH₂, effectivity removing a carbon atom from the chain. The second reaction of the hydroxynitrile is acid hydrolysis of the CN group. This response identifies the correct carboxylic acid. However, this reaction seemed unfamiliar to many candidates and a range of incorrect

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					responses were frequently seen. The final reaction is the reduction of cinnamaldehyde with NaBH₄. Many candidates recognised this reaction, but as can be seen in this response the alcohol group is shown on the incorrect carbon atom. This was a common error. Candidates are advised to number carbon atoms present if provided with a complex structure, such as cinnamaldehyde. Numbering will ensure that each carbon is considered when drawing reaction products and would minimise errors, such as those demonstrated in the reduction product.
			Total	5	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
44	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 $\text{SOCl}_2/\text{PCl}_5/\text{PCl}_3$ e.g. H_2O, AlCl_3, HCl etc. IGNORE names (<i>question asks for structures of organic compounds and formula of reagent</i>) 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	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
45		i	Phenol ✓ Amide ✓ • IGNORE attempt to classify amide, e.g. secondary	2	IF > 2 functional groups are shown, • Mark 2 groups ONLY • Mark incorrect groups first Treat carbonyl with aldehyde OR with ketone as one functional group, i.e. • carbonyl, aldehyde • carbonyl, ketone • carbonyl IGNORE aryl OR alkyl group e.g. benzene, phenyl, aryl, arene, methyl IGNORE hydroxyl/hydroxy <u>Examiner's Comments</u> This part assessed knowledge of functional groups and proved to be a very good discriminator. Able candidates usually identified the phenol and amide functional groups, with 'secondary amide' also seen. In Exemplar 9, the candidate has identified the correct functional groups. The candidate's working by circling the functional groups in the structure shows good examination technique, helping the candidate to arrive at the correct conclusion. The phenol group was often incorrectly identified as an alcohol and the amide group as a combination of 'amine', 'ketone', 'keytone' or 'carbonyl'. Neutral responses such as 'hydroxyl' and 'benzene' were ignored. Candidates need to be careful that they do not present an extensive list of many functional groups in the hope that the correct groups are amongst them, as shown in Exemplar 10. Incorrect groups are marked first. Exemplar 9

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			 (i) Name the functional groups present in paracetamol. phenol ✓ amide ✓ Exemplar 10 phenol, ketone, benzene, amide, amine
ii	Refer to marking instructions on page 5 of mark scheme for guidance on marking this question. Level 3 (5-6 marks) A correct calculation of the mass of 4-nitrophenol. AND Identifies the reagents AND intermediate. AND A detailed description of most purification steps. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3-4 marks) Calculates the mass of 4-nitrophenol with some errors AND suggests reagents and intermediate with some omissions. OR Calculates the mass of 4-nitrophenol with some errors AND describes some purification steps, with some detail. OR Suggests reagents and intermediate with some omissions AND describes some purification steps, with some detail. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1-2 marks)	6	Indicative scientific points may include: Calculation of mass of 4-nitrophenol Using moles $n(\text{paracetamol}) = \frac{5.00}{151} = 0.0331 \text{ (mol)}$ $n(4\text{-nitrophenol}) = 0.0331 \times \frac{100}{40} = 0.0828 \text{ (mol)}$ - Mass of 4-nitrophenol = $139 \times 0.0828 = 11.5 \text{ g}$ ALLOW 11.4–11.6 for small slip/rounding Using mass - Theoretical mass paracetamol = $5.00 \times \frac{100}{40} = 12.5 \text{ g}$ - Theoretical $n(4\text{-nitrophenol}) = \frac{12.5}{151} = 0.0828 \text{ (mol)}$ - Mass of 4-nitrophenol = $139 \times 0.0828 = 11.5 \text{ g}$ NOTE: Incorrect inverse ratio of $\frac{100}{40}$ gives: $0.0331 \times \frac{40}{100} = 0.0132 \text{ (mol)}$ - Mass = $139 \times 0.0132 = 1.84 \text{ g}$ Reagents and intermediate Reagents: Sn + (conc) HCl (then NaOH) Intermediate: 4-aminophenol or structure Purification - Dissolve impure solid in minimum volume of hot solvent Cool solution and filter solid Scratch with glass rod

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
	Attempts to calculate the mass of 4-nitrophenol OR Suggests reagents OR intermediate but may be incomplete OR Describes few purification steps. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.		• Wash with cold solvent/solvent and dry Examples of detail in bold (NOT INCLUSIVE) NOTE: 'Recrystallisation' on its own is NOT a detailed description <u>Examiner's Comments</u> This part assessed practical aspects of a two-stage organic synthesis. Overall, candidates responded well, and this part was discriminating. Many candidates produced well-structured responses although lower ability candidates do have problems with constructing a cohesive response. Most candidates identified the correct reagents (Sn and concentrated HCl) and the intermediate (4-aminophenol), which was usually shown as its structure. Able candidates usually showed that 11.5 g of 4-nitrophenol is needed for the synthesis. A common error used the 'inverse percentage' ratio of 40/100, resulting in an incorrect mass of 1.84 g. Candidates are recommended to check whether a calculated answer looks sensible. Looking at the structures and with a percentage yield of 40%, 1.84 g does not look to be enough of the starting chemical. Some lower ability candidate responses assumed that 5.00 g was 40% of the required mass and responded with $5.00 \times 100/40 = 12.5$ g. There were some good descriptions of purification, although finer details such as using a minimum volume of hot solvent, washing with cold solvent, and drying) were often omitted. Candidates needed to respond with more than just 'recrystallisation'. In the purification, common errors were showing the correct steps but in the wrong

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			order and use of a drying agent such as CaCl_2 (confusion with part of the purification of an organic liquid). These candidates seemed unaware that adding a solid drying agent to an organic solid would result in impure paracetamol rather than purifying. Exemplar 11 shows an excellent response that addresses all aspects of the problem. In comparison, Exemplar 12 is much less detailed: concentrated HCl has not been shown as a reagent for step 1, the candidate has not shown that they know how to carry out a percentage yield calculation, and the purification is confused, and lacks detail. Exemplar 11  Describe a two-stage synthesis of 5.00g of pure paracetamol from 4-nitrophenol. The overall percentage yield of paracetamol from 4-nitrophenol is 40.0%. In your answer, include the mass of 4-nitrophenol required, the reagents and intermediate, and details of the purification of paracetamol. Handwritten Answer: $\text{HO-C}_6\text{H}_4\text{-NO}_2 + \text{H}_2\text{O} \xrightarrow{\text{conc. HCl}}$ (Intermediate) $\xrightarrow{\text{CH}_3\text{COCl}}$ $\text{HO-C}_6\text{H}_4\text{-NH-CO-CH}_3 + 2\text{H}_2\text{O}$ molar mass of paracetamol = 151 g mol⁻¹ moles in 5g = $\frac{5}{151} = 0.0331 \text{ mol}$ moles required = $0.0331 \times 0.4 = 0.01324 \text{ mol}$ molar mass of 4-nitrophenol required = 123 g mol⁻¹ mass of 4-nitrophenol required = $0.01324 \times 123 = 1.63 \text{ g}$ To purify the paracetamol, filter the remaining solution under reduced pressure using Buchner apparatus. Dissolve the remaining solid in the minimum amount of hot solvent and filter again. Cool the remaining solution and filter with a glass filter. Wash the remaining solid with cold solvent and leave to dry. Exemplar 12

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					In your answer, include the mass of 4-nitrophenol required, the reagents and intermediate, and details of the purification of paracetamol. 4-nitrophenol is reduced with reduced with (Sn) in presence of acid and forms 4-phenylhydrazide under high temperature <chem>Nc1ccc(O)cc1</chem> $\frac{100}{140} \times 5.00 = 12.5\text{g}$ from the beginning is required A pure sample of paracetamol was obtained by crystallisation. The impure solution was heated with a Bunsen burner and stirred until crystals start forming, and after formation it was left to cool and even was used to evaporate any water left
			Total	8	

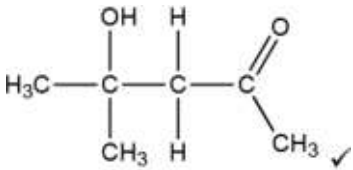
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Question			Answer/Indicative content	Marks	Guidance
46		i	3-hydroxybutanal ✓	1	ALLOW 3-hydroxybutan-1-al IGNORE lack of hyphens or addition of commas ALLOW 4-oxobutan-2-ol OR 1-oxobutan-3-ol DO NOT ALLOW • 3-hydroxybutal • 3-hydroxylbutanal <u>Examiner's Comments</u> Most candidates made good attempts at the name, the difficulty being that hydroxyl group needed to be shown as a hydroxy-prefix, rather than the suffix -ol. Common errors included 2-hydroxybutanal (counting the carbon chain from the wrong end) and 2- or 3-hydroxybutanoic acid (reading the aldehyde group as a carboxylic acid).
		ii	Addition ✓	1	IGNORE nucleophilic OR electrophilic OR radical DO NOT ALLOW addition–elimination, condensation, polymerisation <u>Examiner's Comments</u> This part was answered well with most choosing nucleophilic addition. Credit was given just for 'addition'.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
iii	ALLOW any formula provided that number and type of atoms and charge are correct, e.g. For CH₃CHO, ALLOW CH₃COH, C₂H₄O, etc. Step 1: • Correct equation ✓ • One correct acid–base pair ✓ i.e. A1 and B1 OR A2 and B2 CH₃CHO + OH[−] ⇌ [−]CH₂CHO + H₂O OR CH₃CHO + OH[−] ⇌ CH₃CO[−] + H₂O ✓ A1 B2 B1 A2 OR A2 B1 B2 A1 Step 2: CH₃CHO + [−]CH₂CHO + H₂O → CH₃CHOHCH₂CHO + OH[−] ✓ For [−]CH₂CHO: ALLOW CH₂CHO[−]; CH₃CO[−]; C₂H₃O[−] For CH₃CHOHCH₂CHO, ALLOW C₄H₈O₂	3	Throughout, IGNORE ‘connectivity in any formula or structures shown. Examples in Answer column and in 6a(iv) guidance below Step 1: ALLOW H⁺ transfer from OH[−], i.e. CH₃CHO + OH[−] ⇌ CH₃CH₂O⁺ + O^{2−} ✓ B2 A1 A2 B1 OR B1 A2 A1 B2 Step 2: CH₃CHO + CH₃CH₂O⁺ + O^{2−} → CH₃CHOHCH₂CHO + OH[−] ✓ For CH₃CH₂O⁺: ALLOW CH₃CHOH⁺, C₂H₅O⁺ Examiner’s Comments This novel question linked together acid–base equilibria with a multi-step process. Many candidates completed an equation to generate acid–base pairs, which were then usually assigned correctly. The final equation was challenging but the highest ability candidates were able to combine together all the information with their earlier responses to arrive at the correct equation. See Exemplar 15. Exemplar 15 CH₃CHO + OH[−] ⇌ CH₃CO[−] + H₂O ✓ acid 1 base 2 base 1 acid 2 ✓ • Suggest the equation for step 2. CH₃CHO + CH₃CO[−] + H₂O → CH₃CHOHCH₂CHO + OH[−] ✓

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv		1	ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous For connectivity, ALLOW $\begin{array}{c} \\ \text{OH} \end{array}$ $\begin{array}{c} \\ \text{CH}_3 \end{array}$ CH_3- $\text{C}_3\text{H}-$ $\text{OH}-$ (Connectivity not being assessed) <u>Examiner's Comments</u> This part was one of the most challenging on the paper. Candidates needed to link the earlier information for combining two ethanal molecules to derive the product for combining two propanone molecules. Despite the challenge, the highest ability candidates were able to come up with the correct structure.
			Total	6	
47			B	1 (AO 1.2)	ALLOW 6 (This is the number of chiral centres)
			Total	1	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
48	Water flow AND condenser Water in at bottom and out at top AND condenser ✓ Flask and technique Pear-shaped/round-bottom flask AND reflux ✓	2 (AO 1.2x2)	DO NOT ALLOW conical flask, volumetric flask, beaker in place of round bottom/pear shaped flask <u>Examiner's Comments</u> Most candidates labelled some of the apparatus correctly and identified the reflux technique. A significant number showed water flowing in the wrong direction and 'distillation' was given as the name of the technique. The 'condenser' was sometimes labelled incorrectly, e.g. 'condensation tube', 'distillation tube' and 'water jacket'. Only just over half the candidates were given both marks.  OCR support Candidates are advised to learn the names of chemical apparatus and the practical techniques involved. Diagrams of distillation and reflux apparatus are provided in our Practical Activities Support Guide: https://www.ocr.org.uk/Images/598371-practical-activities-support-guide.pdf

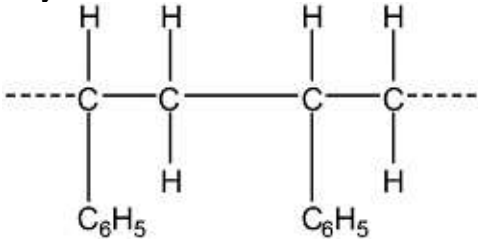
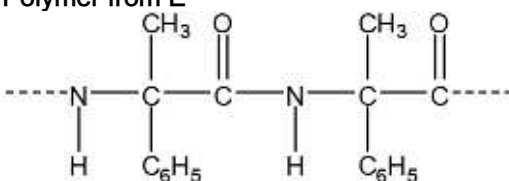
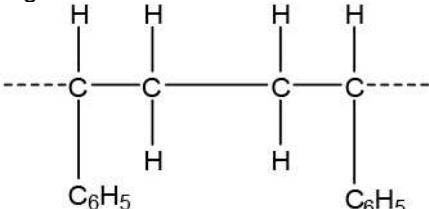
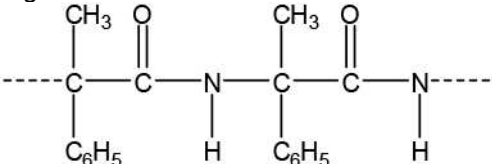
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Question			Answer/Indicative content	Marks	Guidance
		ii	Diagram showing knowledge of filtration under reduced pressure Diagram showing Buchner flask <i>must have <u>ONE</u> side arm</i> AND Buchner/Hirsh funnel on top of flask ✓ <i>Labels not required</i> ----- Further details: • Funnel sealed or stoppered to flask AND • Apparatus capable of filtering under reduced pressure AND • Label for setup from side arm to indicate reduced pressure AND • Label for Buchner flask OR Buchner/Hirsh funnel ✓ <i>ALLOW slips in spelling of 'Buchner'</i>	2 (AO 2.3) (AO 2.7)	Labels NOT required for diagram ALLOW diagram of a conical flask with a filtering setup above AND Side arm either in conical flask OR between flask and filter paper of funnel IGNORE absence of seals ----- MUST imply some type of seal between filter setup and flask. ALLOW <u>small</u> gaps Examples of suitable labels (may have arrow from side arm or tube attached) • to pump • to vacuum • air out • suction • reduced pressure • etc. For Buchner flask and Buchner funnel DO NOT ALLOW just 'flask OR 'funnel' <i>Flask and funnel used in normal filtration</i> <u>Examiner's Comments</u> Many diagrams were incomplete and it was comparatively rare for both of the two available marks to be given. Important labels were often missing. Some candidates drew diagrams of other techniques, such as distillation. Many responses were not credited with marks and this question was often omitted. Candidates need practice in recognising practical techniques and in drawing acceptable diagrams.
			Total	4	

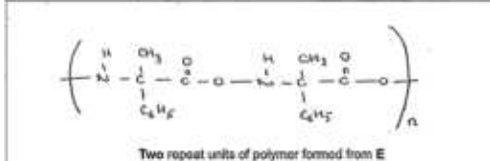
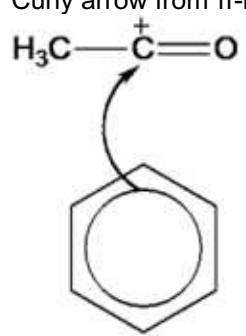
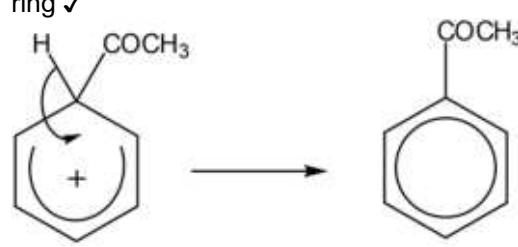
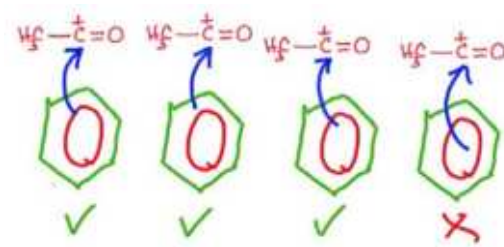
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Question			Answer/Indicative content	Marks	Guidance
49			A	1 (AO 2.5)	
			Total	1	

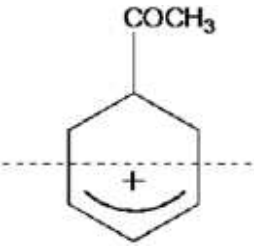
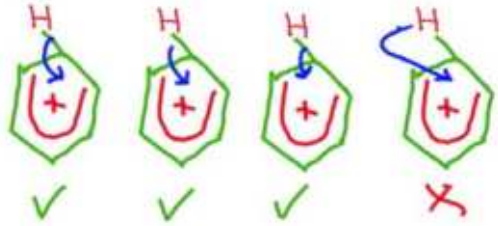
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
50	i Polymer from D  Polymer from E  Amide link ✓ 2 repeat units of correct polymer ✓	3 (AO 2.5) (AO 1.2) (AO 2.5)	----- For BOTH structures, ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous 'End bonds' MUST be shown 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 C₆H₅ ----- CARE: ALLOW any consistent repeat unit: C₆H₅ and H groups can alternate or be on opposite sides of chain e.g.  end -NH- may be at either side e.g.  IGNORE brackets IGNORE <i>n</i> <u>Examiner's Comments</u> The majority of candidates were able to draw two repeats units of the polymer formed from D and scored at least one mark. While most candidates drew the polymer from E correctly, securing full marks, some candidates were unable to show the amide link correctly. This common error is demonstrated in Exemplar 6. Exemplar 5

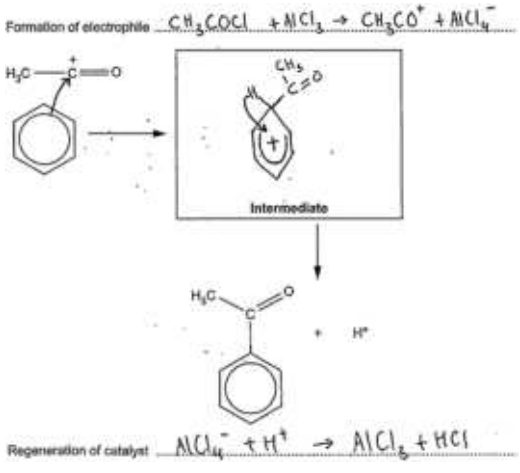
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					 Two repeat units of polymer formed from E This response demonstrates a common error seen by examiners. The candidate has included an O atom as part of the amide link. So they have also included an O atom before the 'end bond'. This is a costly error as the candidate is unable to be given either of the marks available for this polymer.
		ii	D Addition / polyalkene AND E: Condensation / polyamide ✓	1(AO 1.1)	DO NOT ALLOW 'additional'
		iii	Formation of electrophile $\text{CH}_3\text{COCl} + \text{AlCl}_3 \rightarrow \text{CH}_3\text{-C}^+=\text{O} + \text{AlCl}_4^-$ ✓ Mechanism Curly arrow from π -bond to $\text{CH}_3\text{C}^+=\text{O}$ ✓  ----- Correct intermediate ✓ Curly arrow from C-H bond to reform π -ring ✓ 	5 (AO 2.5) (AO 2.5) (AO 3.1) (AO 2.5) (AO 1.2)	ANNOTATE ANSWER WITH TICKS AND CROSSES ALLOW '+' charge anywhere on $\text{CH}_3\text{C}^+\text{O}$ i.e. CH_3CO^+ NOTE: curly arrows can be straight, snake-like, etc. but NOT double headed or half headed arrows 1st curly arrow must - go to the C of $\text{C}=\text{O}$ AND - start from, OR close to circle of benzene ring  IGNORE curly arrow shown on $\text{C}=\text{O}$ DO NOT ALLOW the following

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			intermediate:  π-ring should cover approximately 4 of the 6 sides of the benzene ring structure AND the correct orientation, i.e. gap towards C with COCH_3 ALLOW + sign anywhere inside the 'hexagon' of intermediate curly arrow must start from, OR be traced back to, any part of C-H bond and go inside the 'hexagon'  Examiner's Comments This question required candidates to apply their knowledge of the mechanism of electrophilic substitution to the formation of phenylethanone from benzene. Examiners were encouraged by the number of excellent responses to this question, with the majority of candidates securing four out of five marks. Common errors included accuracy of curly arrows (Exemplar 7 below) and omission of HCl as product from the regeneration of the catalyst. The responses of lower ability candidates also contained errors in the equation for the formation of the electrophile. Such responses used chlorine rather than ethanoyl chloride. Exemplar 6

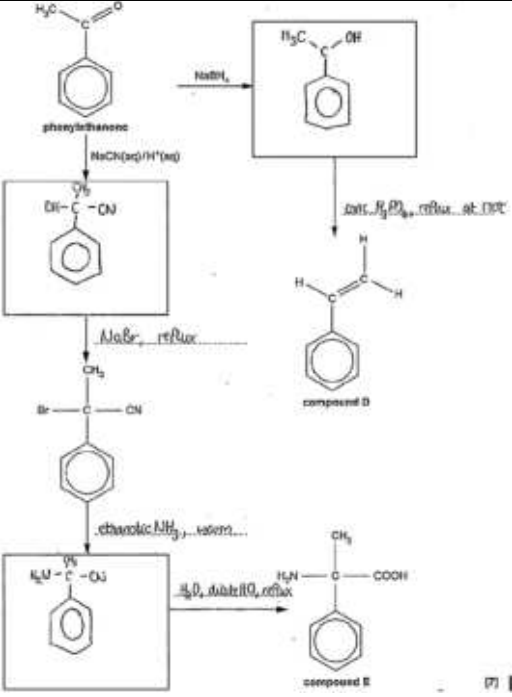
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			Formation of electrophile $\text{CH}_3\text{COCl} + \text{AlCl}_3 \rightarrow \text{CH}_3\text{CO}^+ + \text{AlCl}_4^-$  Regeneration of catalyst $\text{AlCl}_4^- + \text{H}^+ \rightarrow \text{AlCl}_3 + \text{HCl}$ This response demonstrates a near perfect attempt at this question. The equations for the formation of the electrophile and regeneration of the catalyst are correct. The first curly arrow is drawn accurately from the circle of the benzene ring to the correct carbon atom of the electrophile. The intermediate is correct, with the π ring over the five carbon atoms and in the correct orientation. Unfortunately the curly arrow drawn to reform the π bond starts at the H atom rather than from the bond. This small error has prevented this candidate from being given full marks.
iv	one mark for each correct structure/reagent	7(AO 2.5 ×7)	ALLOW any vertical bond to the OH OR NH₂ groups e.g. ALLOW $\begin{array}{c} \\ \text{OH} \end{array}$ OR $\begin{array}{c} \\ \text{HO} \end{array}$ AND $\begin{array}{c} \\ \text{NH}_2 \end{array}$ OR $\begin{array}{c} \\ \text{H}_2\text{N} \end{array}$ DO NOT ALLOW OH⁻, OR NH₂⁻ but ALLOW ECF for subsequent use in this part For elimination, IGNORE 'concentrated', 'dilute' with acids BUT DO NOT ALLOW H₂O/steam/(aq) ALLOW HBr for NaBr/H₂SO₄ For hydrolysis. IGNORE missing (aq)

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
	Reaction scheme showing the synthesis of 1-phenylethanol from 2-phenylpropanenitrile: 2-phenylpropanenitrile ($\text{CH}_3\text{-CH(OH)-CN}$) is converted to 2-bromo-2-phenylpropanenitrile ($\text{CH}_3\text{-CH(Br)-CN}$) using NaBr/Br^- AND $\text{H}_2\text{SO}_4/\text{H}^+$ ✓. 2-bromo-2-phenylpropanenitrile is converted to 2-bromo-2-phenylpropanoic acid ($\text{CH}_3\text{-CH(Br)-COOH}$) using $\text{H}^+/\text{H}_2\text{SO}_4/\text{HCl}$ ✓. 2-bromo-2-phenylpropanoic acid is converted to 1-phenylethanol ($\text{CH}_3\text{-CH(OH)-H}$) using NH_3 AND ethanol OR excess NH_3 ✓. Alternatively, 2-phenylpropanenitrile can be converted to 1-phenylethanol using $\text{acid/H}^+/\text{H}_3\text{PO}_4/\text{H}_2\text{SO}_4$ ✓.		ALLOW HNO_3 for hydrolysis but DO NOT ALLOW 'HNO₃ and H₂SO₄' ALLOW final 2 stages in opposite order i.e. NH_3 before acid hydrolysis Reaction scheme showing the synthesis of 1-phenylethanol from 2-phenylpropanenitrile: 2-phenylpropanenitrile ($\text{CH}_3\text{-CH(OH)-CN}$) is converted to 2-phenylpropan-2-amine ($\text{CH}_3\text{-CH(NH}_2\text{)-CN}$) using NH_3 AND ethanol OR excess NH_3. 2-phenylpropan-2-amine is converted to 1-phenylethanol ($\text{CH}_3\text{-CH(OH)-H}$) using $\text{H}^+/\text{H}_2\text{SO}_4/\text{HCl}$. Examiner's Comments This question required candidates to apply knowledge of organic reactions from across the specification and discriminated well. Candidates with a good knowledge of reagents and conditions frequently scored over five marks. More detailed feedback is discussed with Exemplar 7, below. Exemplar 7

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			 Phenylethanone is the starting point of this flowchart which shows the synthesis of compounds D and E. Synthesis of D The first step in the synthesis of D is the reduction of the ketone group. This response demonstrates a common error seen by examiners. The candidate has correctly deduced that an alcohol is formed but has omitted a hydrogen atom. Candidates are advised to take care when drawing structures. If a carbon atom is displayed it should be shown to be making four bonds. The final step of the synthesis is the dehydration of the alcohol with an acid. This candidate has used H_3PO_4. H_2SO_4 was also frequently seen. Lower ability responses included reference to water or steam and this was not credited. Synthesis of E The first step of the synthesis of E from phenylethanone is the reaction with $\text{NaCN(aq)/H}^+(\text{aq})$. This candidate identifies that the product of the reaction is a

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					hydroxynitrile but unfortunately this cannot be credited due to the incorrect linking of the OH group via the H atom. Candidates should be aware that, when drawing structures, groups must be bonded via the correct atoms. The next step of the synthesis is the substitution of the OH group. The candidate correctly recognises that NaBr is a suitable reagent but omits an acid, e.g. H_2SO_4, which is also required for this reaction. This error was seen frequently by examiners. The final two steps involve the substitution of the Br atom and acid hydrolysis of the nitrile group. In this case the candidate chooses the reaction with excess NH_3. The structure of the correct product of this reaction is shown and the synthesis is completed by identifying a suitable reagent for the final step. Other candidates opted to perform these steps in the reverse order and the mark scheme allowed full credit for either approach. Common errors in the final steps were omissions. Some candidates simply stated NH_3 without mentioning ethanol. Others identified water as important for the hydrolysis but did not include reference to an acid.
			Total	16	

Mark Scheme

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51		i	4-chloro-3,5-dimethylphenol ✓ CARE: Look for dimethyl	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 <u>Examiner's Comments</u> 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	<u>Examiner's Comments</u> 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.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	Functional group Phenol ✓ Test Indicator/pH paper turns red / orange OR pH < 7 OR pH meter < 7 AND No reaction with Na₂CO₃/CO₃²⁻/ carbonate ✓	2 AO 1.2 AO 2.3	DO NOT ALLOW alcohol OR hydroxide IGNORE hydroxyl OR hydroxy IGNORE OH (<i>name asked for</i>) ALLOW Add bromine AND white precipitate ALLOW FeCl₃ AND violet/blue colour <u>Examiner's Comments</u> 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.
		iv	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) $C_8H_9ClO \rightleftharpoons H^+ + C_8H_8ClO^-$ ✓ <i>Molecular formulae required (atoms in any order)</i> [C₈H₉ClO] calculation (2 marks) Molar mass C₈H₉ClO = 156.5 (g mol⁻¹) ✓ ONLY correct answer OR 0.3067.....	5 AO1.2×1 AO2.8×4	ALLOW → for ⇌ DO NOT ALLOW C₈H₈ClOH in equation i.e. C₈H₈ClOH ⇌ H⁺ + C₈H₈ClO⁻ If equation is omitted, ALLOW equation mark for a correct K_a expression with molecular formula i.e. $\frac{[H^+][C_8H_8ClO^-]}{[C_8H_9ClO]}$

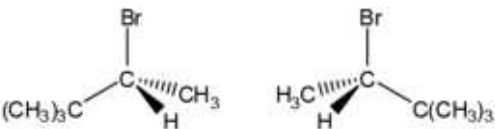
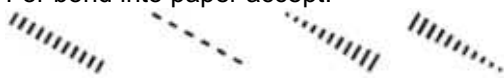
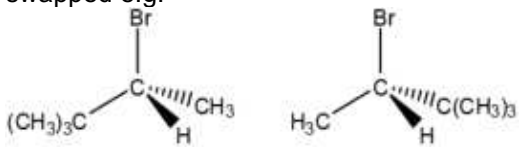
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
	$[\text{C}_8\text{H}_8\text{ClO}] = \frac{4.8 \times 10}{156.5} (\text{mol dm}^{-3}) \checkmark$ <i>Subsumes mark for molar mass = 156.5</i> K_a calculation (2 marks) $[\text{H}^+] = 10^{-5.14} = 7.244 \dots \times 10^{-6} (\text{mol dm}^{-3}) \checkmark$ $K_a = \frac{(7.244 \dots \times 10^{-6})^2}{0.3067 \dots} = 1.71 \times 10^{-10} (\text{mol dm}^{-3}) \checkmark$		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: $7.244359601 \times 10^{-6}$ correctly rounded ALLOW 2 SF ($1.7 \dots \times 10^{-10}$) up to calculator value, correctly rounded (but take care from acceptable intermediate rounding) COMMON ERRORS $2.36 \dots \times 10^{-5}$ 3/4 calculation marks <i>No squaring of 7.24×10^{-6}</i> <u>Examiner's Comments</u> Candidates produced some very good calculations. It was common for candidates to determine the correct K_a value of $1.71 \times 10^{-10} \text{ mol dm}^{-3}$, after first calculating the hydrogen ion and weak acid concentrations. The initial calculation of the hydrogen ion concentration from $10^{-\text{pH}}$ 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 $\times 10$ was not always successful. Some candidates used the mole equations that they had learnt to obtain the $\times 10$ 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

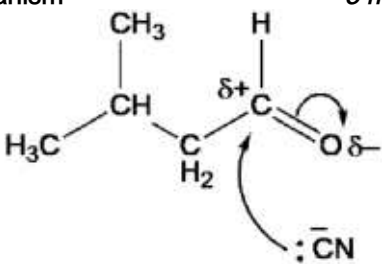
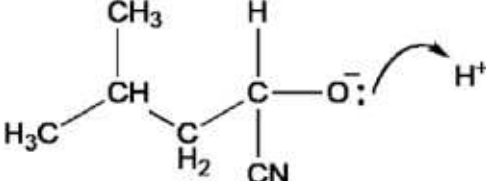
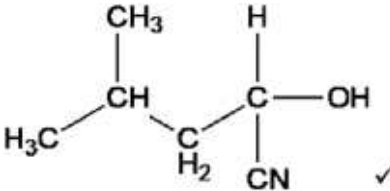
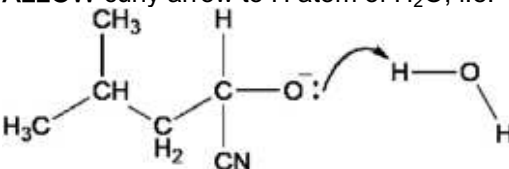
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					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 $7.244 \times 10^{-6} \text{ mol dm}^{-3}$ before carrying out the final K_a calculation. This candidate had combined these stages. Exemplar 3 $C_8H_9ClO \rightarrow C_8H_8ClO^- + H^+$ $K_a = \frac{[H^+][C_8H_8ClO^-]}{[C_8H_9ClO]}$ $[H^+] = 10^{-5.14}$ $[H^+] = [C_8H_8ClO^-]$ $\therefore K_a = \frac{(10^{-5.14})^2}{0.3067} = 1.71 \times 10^{-10}$ $n = CV$ $C = \frac{n}{V}$ $[C_8H_9ClO]: M_r = 156.5$ $M = 4.88$ $n = 0.03067$ $[] = \frac{0.03067}{0.1} = 0.3067$
			Total	9	
52			A	1 (AO1.1)	
			Total	1	
53			B	1 (AO2.3)	
			Total	1	

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Question			Answer/Indicative content	Marks	Guidance
54		i	Stereoisomers Same structural formula AND Different arrangement (of atoms) in space OR different spatial arrangement (of atoms) AND Type: Optical ✓	1 (AO1.2)	ALLOW structure/displayed/skeletal formula DO NOT ALLOW same empirical formula OR same general formula IGNORE same molecular formula IGNORE references to chiral molecules/compounds
		ii	One 3D structure with correct groups attached to the chiral C ✓ Two 3D structures of $(\text{CH}_3)_3\text{CCHBrCH}_3$ that are mirror images AND correct connectivity in both ✓ 	2 (AO2.5) (AO1.2)	ALLOW small slip in one of the groups OR use of C_4H_9 3D structures must have four central bonds with at least two wedges. For bond into paper accept:  ALLOW two 3D structures with 2 groups swapped e.g. 
			Total	3	

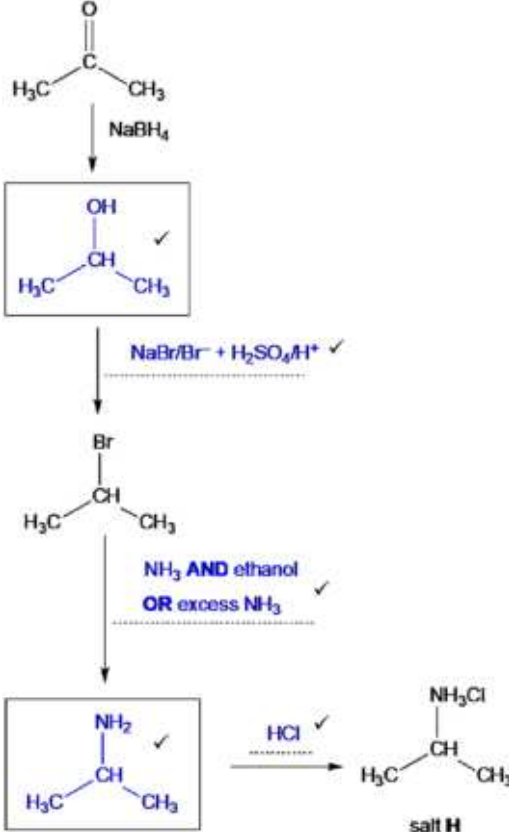
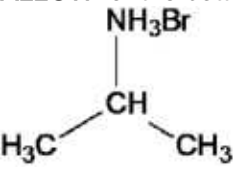
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55	i Mechanism 3 marks  Curly arrow from CN^- to C atom of $\text{C}=\text{O}$ ✓ Dipole shown on $\text{C}=\text{O}$ bond, $\text{C}^{\delta+}$ and $\text{O}^{\delta-}$, AND curly arrow from $\text{C}=\text{O}$ bond to O atom ✓  Curly arrow from lone pair OR – charge on O^- of correct intermediate to H^+ ✓ Product 1 mark  Name of mechanism 1 mark Nucleophilic addition ✓	5 (AO1.2) (AO1.2) (AO2.5) (AO2.5) (AO2.5) (AO1.1)	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) Curly arrow from $\text{C}=\text{O}$ bond must start from, OR be traced back to, any part of $\text{C}=\text{O}$ bond and go to O  ALLOW curly arrow to H atom of H_2O, i.e.  IGNORE attempt to draw curly arrow showing breaking of $\text{H}-\text{O}$ in H_2O IGNORE lack of dipole on H_2O

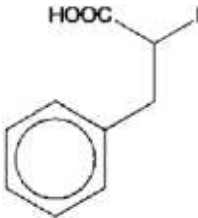
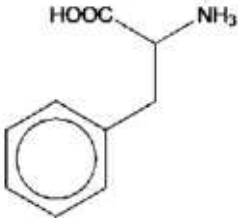
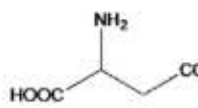
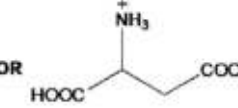
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		ii	Heterolytic One (bonded) atom/O receives both/2 electrons ✓ Fission Breaking of a covalent bond ✓	2 (AO1.2)	ALLOW 2 electrons go to one (bonded) atom/O DO NOT ALLOW both pairs of electrons go to O IGNORE formation of ions/radicals For O atom, ALLOW species DO NOT ALLOW element or molecule ALLOW π bond in C=O breaks IGNORE breaking of C=O bond (no reference to only one bond breaking) 'Bond breaking' is not sufficient (no reference to covalent) <u>Examiner's Comments</u> Candidates often referred to NaCN and HCN in their responses. Candidates who identified the correct bond breaking often then incorrectly wrote that the oxygen atom gained the lone pair of electrons.
			Total	7	

Mark Scheme

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56 a		5 (AO2.5×5)	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous ALLOW HBr ALLOW for the bottom left structure 
b 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

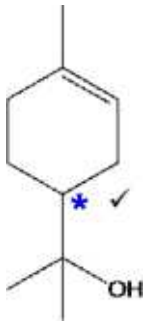
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Methanol 1 mark $\text{H}_3\text{C} - \text{OH}$ ✓  ✓ OR   ✓ OR  Both amino acids shown with NH_3^+ ✓	4 (AO2.5×4)	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous ALLOW + charge on H of NH_3 group, i.e. NH_3^+ If BOTH amino acids are shown with NH_3 groups (without the + charge) OR as NH_2^+ groups, award 2 of the 3 marks for the amino acids If BOTH amino acids are shown as correctly balanced salts, e.g. NH_3Cl, all marks can be awarded.
		iii	FIRST CHECK ANSWER ON THE ANSWER LINE If answer = 22.4 OR 22 OR 23 award 3 marks $n(\text{aspartame})$ in 1 can = $0.167 / 294 = 5.68 \times 10^{-4}$ (mol) ✓ $n(\text{aspartame})$ limit per day = $1.7 \times 10^{-4} \times 75 = 0.01275$ (mol) ✓ number of cans = $0.01275 / 5.68 \times 10^{-4} = 22.4$ ✓	3 (AO2.2×3)	If there is an alternative answer, apply ECF and look for alternative methods Alternative methods $n(\text{aspartame})$ in 1 can = $0.167 / 294 = 5.68 \times 10^{-4}$ (mol) ✓ $n(\text{aspartame})$ per kg = $5.68 \times 10^{-4} / 75 = 7.57 \times 10^{-6}$ (mol) ✓ number of cans = $1.7 \times 10^{-4} / 7.57 \times 10^{-6} = 22.4$ ✓ OR $n(\text{aspartame})$ limit per day = $1.7 \times 10^{-4} \times 75 = 0.01275$ (mol) ✓ mass(aspartame) limit per day = $0.01275 \times 294 = 3.7485$ (g) ✓ number of cans = $3.7485 / 0.167 = 22.4$ ✓
			Total	15	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
57	Organic product and water marked independently. <i>1st mark</i> correct organic product OR water IGNORE balancing numbers <i>2nd mark</i> 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 <i>Question states molecular formula = C₃H₃NO</i> <u>Examiner's Comments</u> Candidates were supplied with information about an unfamiliar reaction of an amino acid and asked to predict a possible equation. Many candidates suggested H₂O as one product, being the difference in the formula of the amino acid and the C₃H₃NO cyclic organic product. Any cyclic structure of C₃H₃NO 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 H₂O and a cyclic dipeptide. Although chemically feasible, the dipeptide could not be credited because the molecular formula was C₃H₃NO in the question. This error could have been avoided if the information in the question had been used.
	Total	2	

Mark Scheme

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58		i		1 AO 2.5	DO NOT ALLOW more than one * ALLOW a circle for * <u>Examiner's Comments</u> Most candidates showed one asterisk at the base of the cyclic part of the structure. The most common error was to show two asterisks, the second being on $^*\text{C}(\text{CH}_3)_2\text{OH}$, despite this carbon not being connected to four different groups.

Mark Scheme

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		ii	MAXIMUM OF 4 MARKS FROM 5 MARKING POINTS Requirement for <i>E/Z</i> isomerism 2 marks C=C/double bond ✓ Each C (in C=C) is attached to (two) different groups/atoms ✓ Identification as <i>E</i>- or <i>Z</i>- isomer 2 marks <i>E/Z</i> isomerism linked to (high) priority groups ✓ <i>Z</i>- isomer AND groups are on same side OR the ring carbons ✓ Reason why other <i>E/Z</i> isomer does not exist 1 mark ring would be strained OR ring would break/deform OR Cannot form ring if high priority groups are on opposite sides OR ring locks groups on one side of C=C bond ✓	4 AO1.2 x2 AO2.5x2	IGNORE no H attached to C=C IGNORE functional', i.e. ALLOW different functional groups ALLOW in context of groups with largest atomic number ORA Award BOTH identification marks for: <i>Z</i>- isomer AND (high) priority groups on same side Mark independently of previous part Response MUST be linked to the ring/cyclic structure IGNORE just '<i>E</i> isomer is impossible' IGNORE C=C bond cannot rotate IGNORE Groups can't swap sides Examiner's Comments Candidates displayed a good knowledge of the requirements for <i>E/Z</i> isomerism in terms of a C=C double bond and different groups on the carbon atoms of the C=C bond. Many assigned terpineol as the <i>Z</i> isomer explained in terms of the priority groups being on the same side of the C=C bond. Candidates found it difficult to explain why terpineol has only one <i>E/Z</i> isomer. Many candidates thought that the C=C bond could not rotate because it was part of the ring. however, a C=C bond cannot rotate whether it is in a ring or not. Few candidates considered the strain put on the ring if the priority groups (being part of the ring) were to be placed in an <i>E</i> conformation.

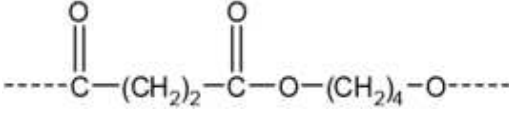
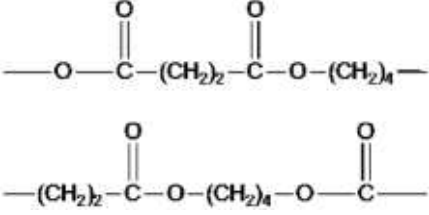
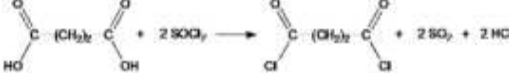
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	First group: Reagent AND Functional group: Alkene OR cycloalkene ✓ <i>Examples of reagents</i> Br₂ or other halogen, HBr, H₂ AND Ni (catalyst), H₂O(g)/steam AND H⁺ (catalyst) Organic product for reagent with C=C in α-terpineol ✓ ALLOW product from H₂ or H₂O if H⁺ catalyst has been omitted from reagent. ----- Second group Reagent AND Functional group: (Tertiary) alcohol ✓ <i>Examples of reagents</i> NaBr/KBr/Br⁻ AND acid/H⁺ (substitution), OR HBr Acid/H⁺ (catalyst) (elimination), CH₃COOH AND acid/H⁺ (esterification) (catalyst) CH₃COOCOCH₃ (esterification) CH₃COCl (esterification) Organic product for reagent with OH in α-terpineol ✓ ALLOW product if catalyst omitted from reagent	4 AO3.2×4	CONTACT TEAM LEADER FOR OTHER REACTIONS ----- ALLOW GROUPS EITHER WAY ROUND IN BOXES Functional group MUST be named DO NOT ALLOW UV with halogens ALLOW H₂SO₄/H₃PO₄/acid for H⁺ ALLOW addition of HBr/ H₂O either way across C=C ALLOW ANY HALIDE, i.e. Cl⁻, Br⁻, I⁻ ALLOW H₂SO₄/H₃PO₄/acid for H⁺ ALLOW HBr for H⁺ and Br⁻ ALLOW name or formula of any carboxylic acid or acyl chloride for esterification ALLOW Na → product with -ONa OR -O⁻ DO NOT ALLOW Cr₂O₇²⁻/H⁺ (tertiary alcohol) Examiner's Comments In this question, candidates were given the opportunity to demonstrate some knowledge of organic reaction in a new context. The choice of reaction was up to the candidate. Most candidates were able to identify the alkene group in terpineol and to suggest a reagent that would react with this functional group. A correct structure for the organic product then usually followed. Although most candidates identified the alcohol group, many struggled with a reagent and resulting product. Although the alcohol -OH group has many reactions, (e.g. elimination, substitution, esterification)

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					many candidates were fixated on oxidation with acidified dichromate despite a tertiary alcohol not being capable of oxidation with this reagent. Some candidates quoted acidified dichromate but then copied the structure of terpineol, stating that there was no reaction, despite the question directing them to select a reagent that would react with their chosen group.						
			Total	9							
59		i	<table><tr><td></td><td>Compound C</td><td>Compound D</td></tr><tr><td>Number of peaks</td><td>3 ✓</td><td>8 ✓</td></tr></table>		Compound C	Compound D	Number of peaks	3 ✓	8 ✓	2 (AO3.2)	
	Compound C	Compound D									
Number of peaks	3 ✓	8 ✓									
		ii	Reaction scheme for question 59(ii): Compound C (1,3,5-trimethylbenzene) reacts with reagent: HNO_3 and catalyst: H_2SO_4 to form 3,5-dimethylbenzoic acid. 3,5-dimethylbenzoic acid is then reduced using 1. Sn + HCl / 2. Neutralisation to form 3,5-dimethylaniline. 3,5-dimethylaniline reacts with reagent: CH_3COCl to form compound D (N-(3,5-dimethylphenyl)acetamide).	5 (AO3.2×5)	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous IGNORE names for organic intermediates (question asks for structures) ALLOW names of reagents and catalyst Around top arrow, ALLOW 1 of 2 marks if HNO_3 and H_2SO_4 swapped. i.e. reagent: H_2SO_4 catalyst: HNO_3 IGNORE references to concentration ALLOW $(\text{CH}_3\text{CO})_2\text{O}$ for left arrow IGNORE CH_3COOH IGNORE acyl chloride DO NOT ALLOW $\text{AlCl}_3/\text{FeCl}_3/\text{FeCl}_4$						
			Total	7							

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60	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  SOCl₂ in equation ✓ Structure of diacyl dichloride ✓ Complete balanced equation ✓	3 (AO1.1) (AO1.2) (AO2.6)	ALLOW alternative approach using PCl₅ or PCl₃
	Total	6	