

OCR A-LEVEL CHEMISTRY A • H432

CHEMISTRY



EXAM QUESTION PACK

6.1 AROMATIC COMPOUNDS, CARBONYLS AND ACIDS

SCORE

/436

PERCENTAGE

%

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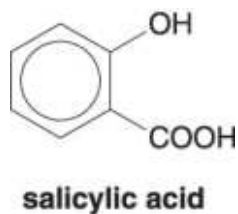
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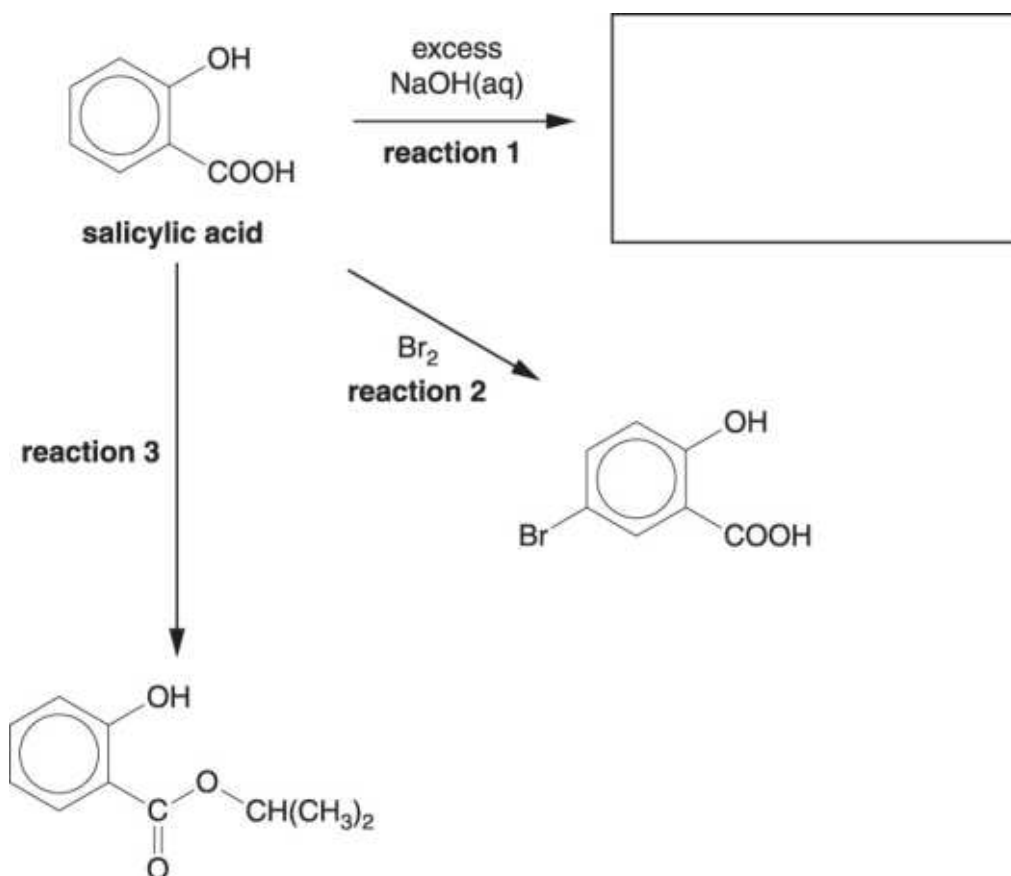
1(a) Salicylic acid is a naturally occurring carboxylic acid, widely used in organic synthesis.



The flowchart below shows some reactions of salicylic acid.

(i) In the box below, draw the structure of the organic compound formed by **reaction 1**.

[1]



(ii) Describe what would be **observed** during **reaction 2**.

----- [1]

(iii) Write a chemical equation to represent **reaction 2**.

[1]

(iv) State the reagents and conditions in **reaction 3**.

----- [1]

(b) Bromine reacts more readily with salicylic acid than with benzene.

(i) Outline the mechanism for the bromination of salicylic acid shown in **reaction 2** in the flowchart.

A halogen carrier is not required for this reaction.

The electrophile is Br₂.

[4]

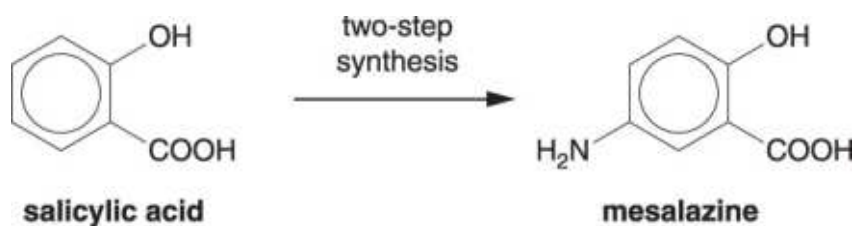
(ii) Explain why bromine reacts more readily with salicylic acid than with benzene.



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

[3]

(c) 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]

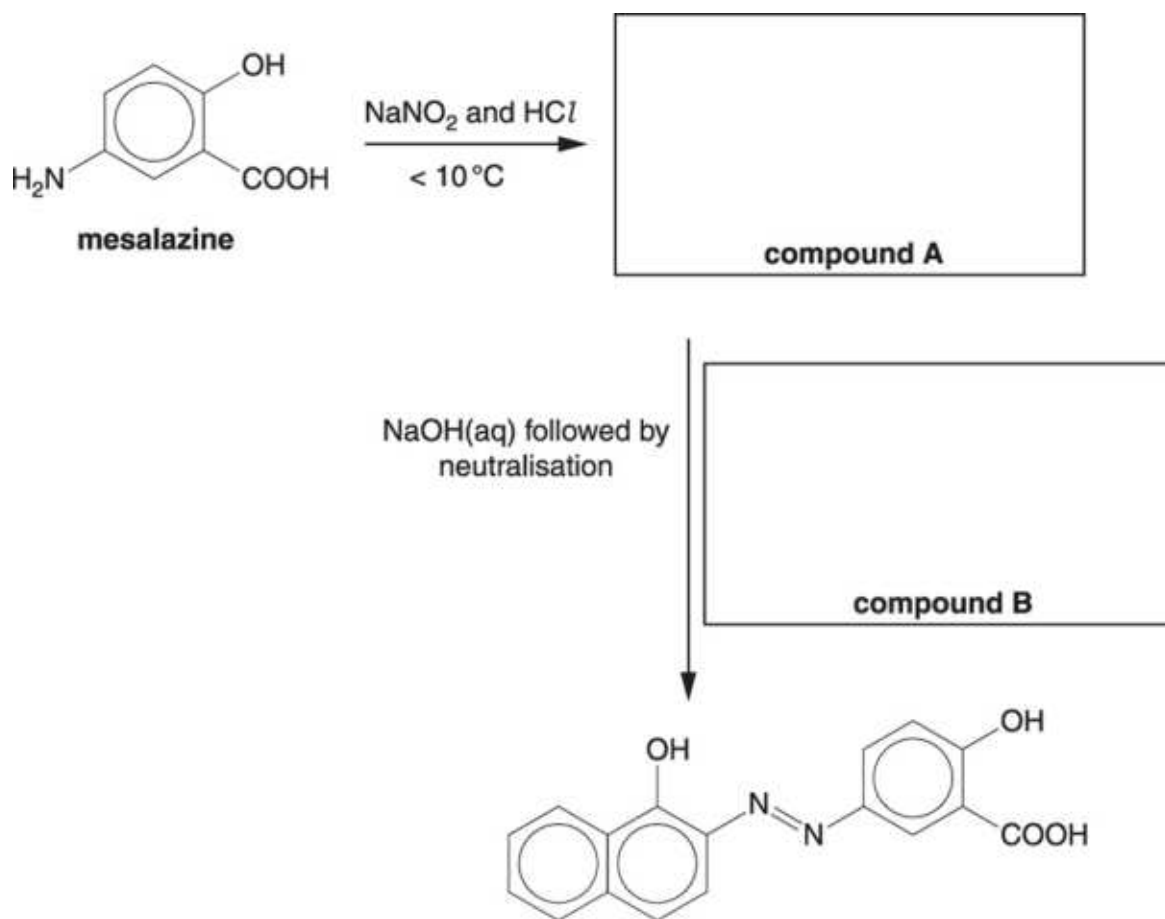
(ii) Mesalazine reacts with acids to form salts.

Explain how mesalazine is able to react with acids.

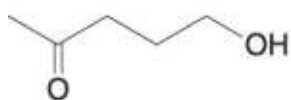
[1]

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

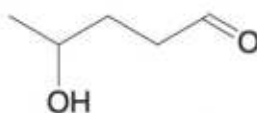
In the boxes, draw the structures of organic compounds **A** and **B**.



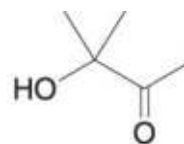
2 The following three carbonyl compounds are structural isomers of $C_5H_{10}O_2$.



compound C



compound D



compound E

Aldehydes and ketones are both reduced by $NaBH_4$. When used in the presence of a $CeCl_3$ catalyst, $NaBH_4$ only reduces ketones.

Compound F has the structural formula $CH_3COCH_2CH_2CHO$. It is reduced by $NaBH_4$ in the presence of a $CeCl_3$ catalyst to form one of the compounds C, D or E.

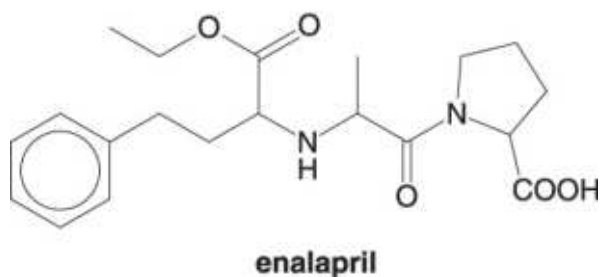
Show the mechanism for this reduction of compound F and identify the product that is formed.

Use curly arrows and show relevant dipoles.

You do not need to show the role of the $CeCl_3$ catalyst.

[4]

- 3 Enalapril is a drug used in the treatment of high blood pressure.



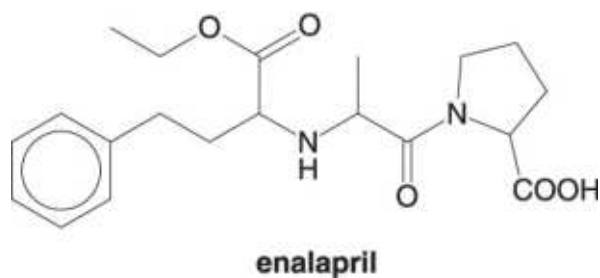
- (i) On the structure above, mark each chiral centre with an asterisk (*).

[1]

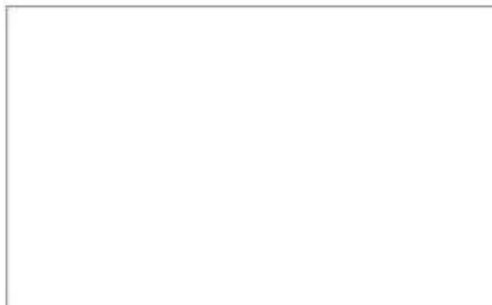
- (ii) Suggest **two** benefits of using single stereoisomers in the synthesis of drugs such as enalapril.

[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]

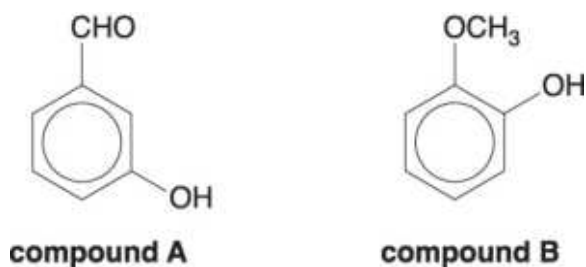
- (iv) A scientist hydrolysed enalapril in the laboratory. The scientist then analysed the mixture of products using GC–MS.

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

[1]

4(a) A student analysed a mixture of compounds found in red wine using gas chromatography followed by mass spectrometry (GC-MS).

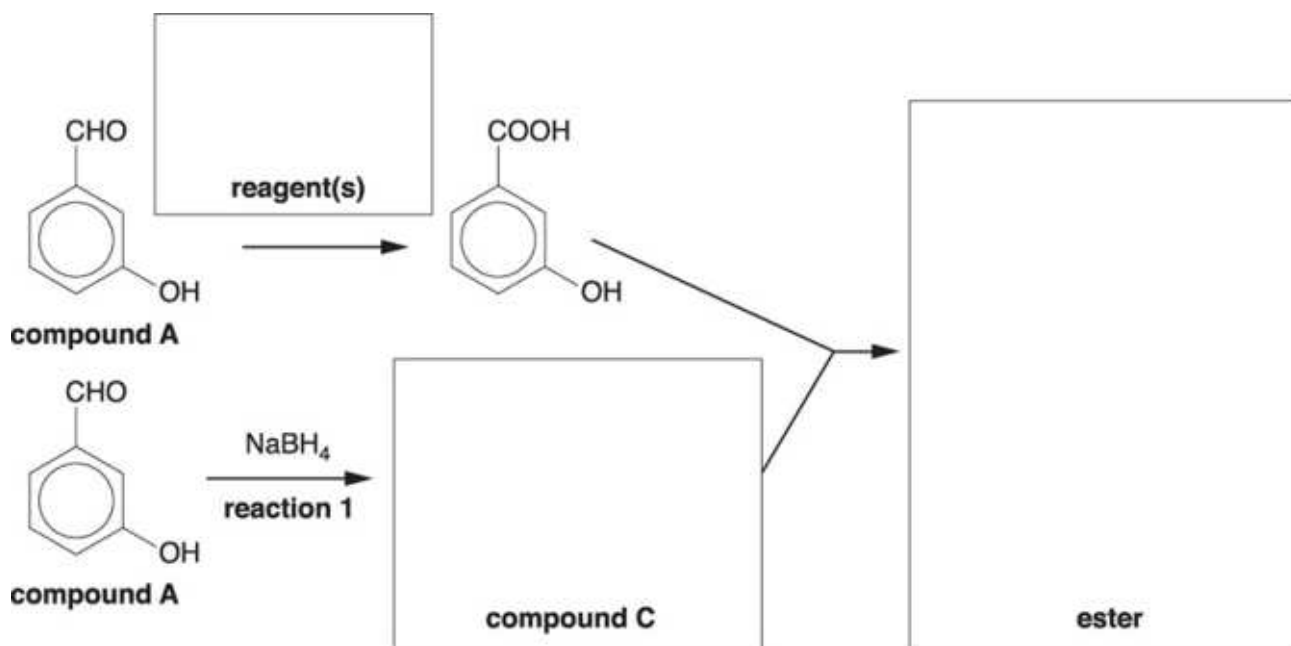
Two of the compounds found to be present in the mixture are shown below.



In red wine, compound A slowly forms an ester.

The formation of the ester can also be done in the laboratory, as shown in the flowchart below. Separate portions of compound A are used in the formation of the ester.

(i) Complete the boxes in the flowchart below.

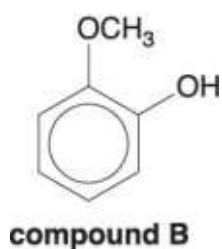


[3]

- (ii) Give the mechanism to show the formation of compound **C** in reaction 1.
Use curly arrows and relevant dipoles.

[3]

- (b) 1 mol of compound **B** reacts with 2 mol of bromine, Br₂ by electrophilic substitution.



Write a balanced equation for this reaction, showing clearly the structure of the organic compound.

[1]

5(a) Chemists often use two different structures to represent a molecule of benzene, as shown below.



- (i) Describe, with the aid of suitable diagrams showing orbital overlap, the difference in bonding between structure A and structure B.



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

[4]

- (ii) The table below shows the enthalpy changes for the reactions of cyclohexene, C_6H_{10} , and benzene, C_6H_6 , with hydrogen.

reaction	enthalpy change / kJ mol^{-1}
$C_6H_{10} + H_2 \rightarrow C_6H_{12}$	-119
$C_6H_6 + 3H_2 \rightarrow C_6H_{12}$	-208

Using this information, suggest and explain whether structure **A** or structure **B** is a better representation of benzene.

[2]

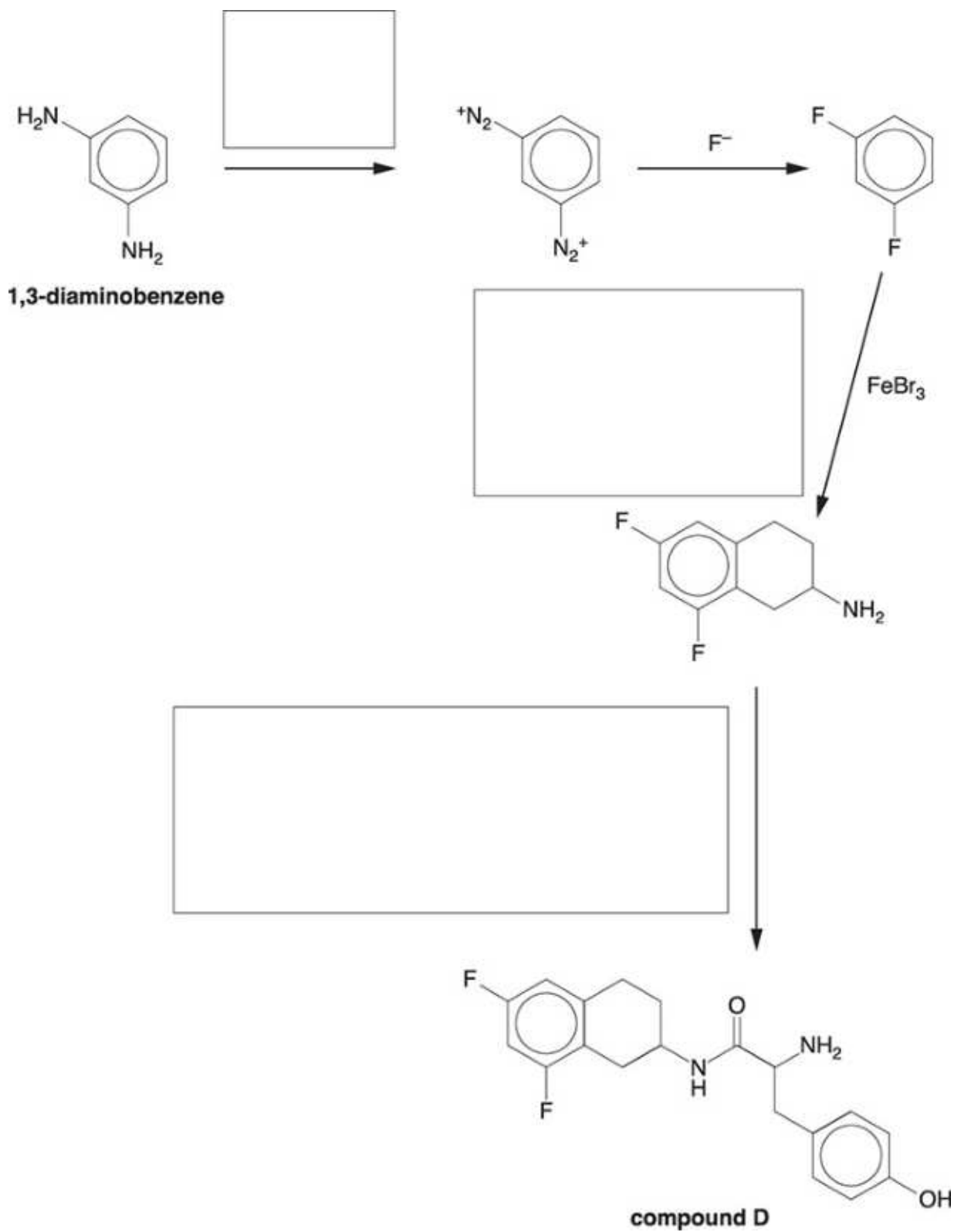
- (b) Benzene can react with halogenoalkanes in the same way as with bromine, as shown in **reaction 1** below.



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

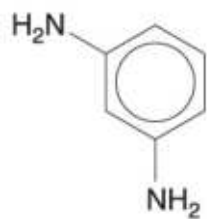
[1]

- (c) 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.

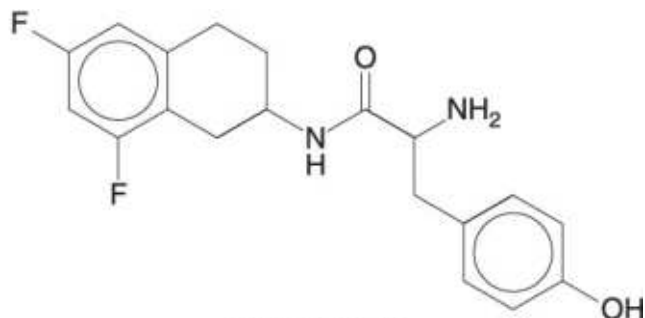


[3]

- (ii) In a synthesis of compound D from 1,3-diaminobenzene shown in the flowchart, 1.73 g of compound D was prepared. These structures have been repeated below:



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.

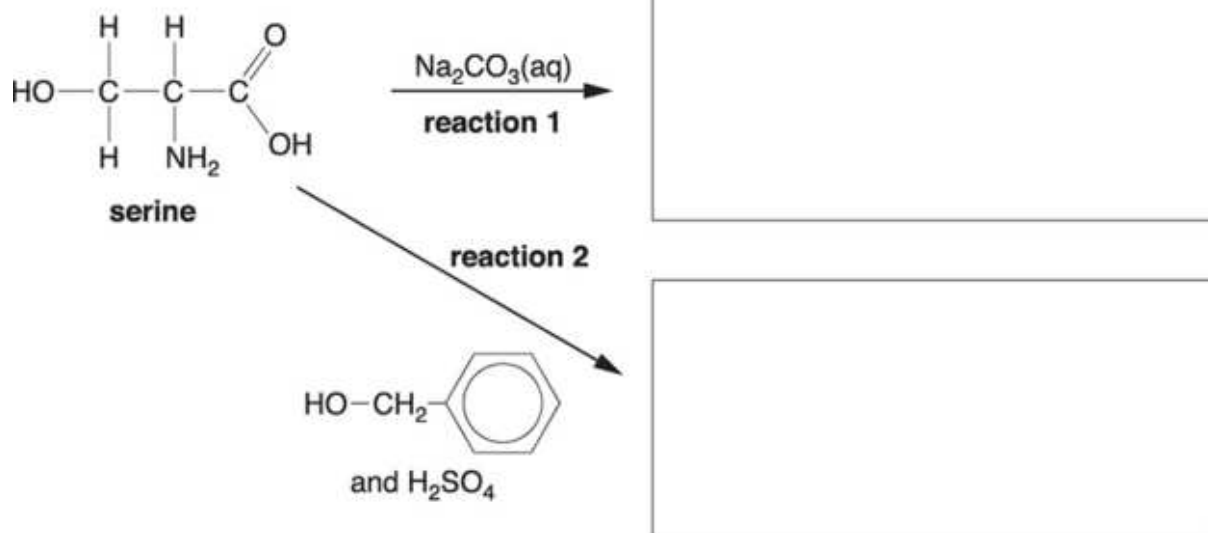
Explain why only 25% of the dose was effective. Suggest how the synthesis of compound **D** might be changed to make the dose more effective.

[3]

6 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.



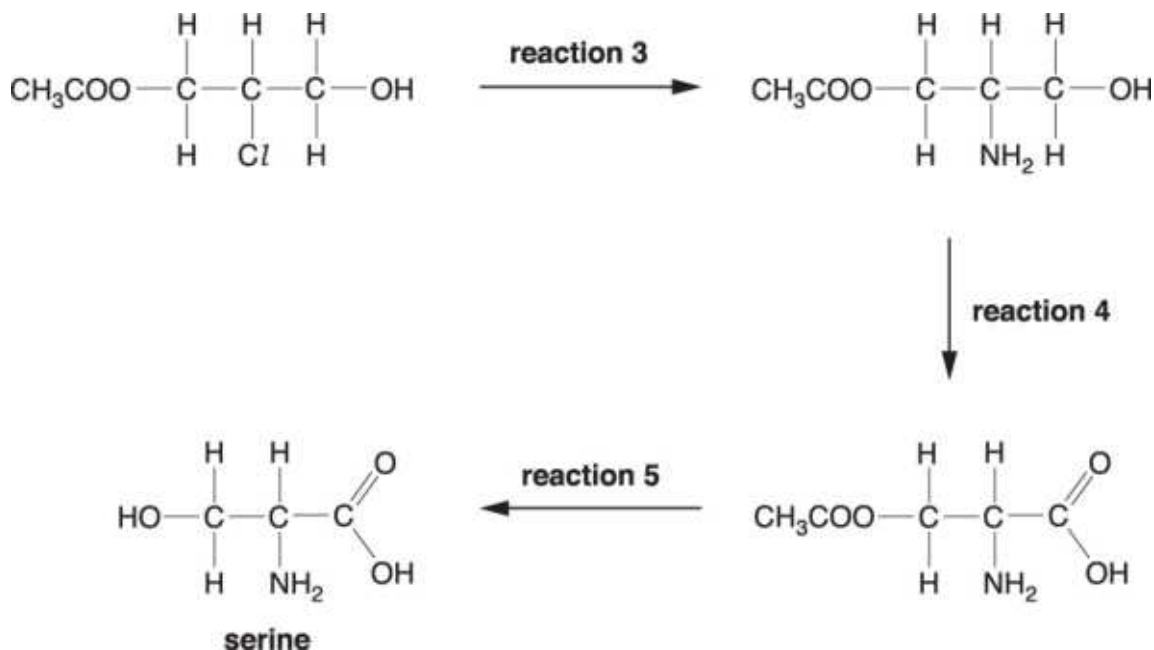
[3]

(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]

7 Aqueous propanoic acid, $\text{C}_2\text{H}_5\text{COOH}$, reacts with carbonates and alkalis.

(i) Write the full equation for the reaction of aqueous propanoic acid with sodium carbonate.

----- [1]

(ii) Write the ionic equation for the reaction of aqueous propanoic acid with aqueous potassium hydroxide.

----- [1]

- 8 The functional group in an organic compound, **W**, was identified by carrying out two chemical tests. The results of the tests are shown below.

Heating with acidified sodium dichromate(VI)(aq)	Addition of 2,4-dinitrophenylhydrazine(aq)
orange solution turns green	yellow / orange precipitate formed

Which compound could be **W**?

- A $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
B CH_3COCH_3
C $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$
D $\text{CH}_3\text{CH}_2\text{CHO}$

Your answer

[1]

- 9 Two chemical tests are carried out on an aqueous solution of an aromatic organic compound **Y**.

The results of the tests are shown below.

Test	$\text{Br}_2(\text{aq})$	$\text{Na}_2\text{CO}_3(\text{aq})$
Observation	decolourised	effervescence

What is the minimum number of C atoms in **Y**?

- A 6
B 7
C 8
D 9

Your answer

[1]

10 Bromine is reacted separately with nitrobenzene and phenylamine.

Which organic products are likely to form?

	Product from nitrobenzene	Product from phenylamine
A	2-bromonitrobenzene	2-bromophenylamine
B	2-bromonitrobenzene	3-bromophenylamine
C	3-bromonitrobenzene	2-bromophenylamine
D	3-bromonitrobenzene	3-bromophenylamine

Your answer

[1]

11 Which alcohol could be used to prepare $\text{HCOOCH}(\text{CH}_3)_2$?

- A Propan-1-ol
- B Propan-2-ol
- C 2-Methylpropan-2-ol
- D Methanol

Your answer

[1]

12 CN^- ions react with haloalkanes and with carbonyl compounds.

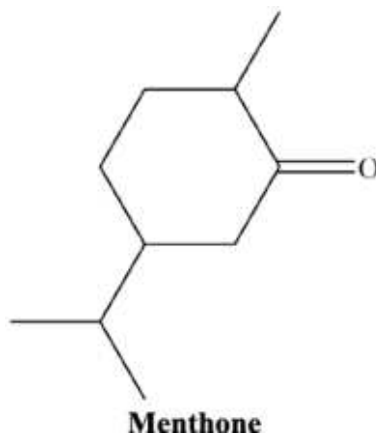
Which row gives the correct mechanisms for the reactions?

	Reaction of CN^- with haloalkanes	Reaction of CN^- with carbonyl compounds
A	Electrophilic substitution	Electrophilic addition
B	Electrophilic substitution	Nucleophilic addition
C	Nucleophilic substitution	Electrophilic addition
D	Nucleophilic substitution	Nucleophilic addition

Your answer

[1]

- 13 Carbonyl compounds have distinctive smells.
Menthone smells of peppermint.



Menthone is reacted in a two-step synthesis shown below.

Step 1: A sample of menthone is added to hot acidified aqueous dichromate(VI) ions.

Step 2: The resulting mixture from **Step 1** is added to NaBH_4 in water.

What happens to the smell of the reaction mixture during the process?

	Step 1	Step 2
A	Smell of peppermint remains	Smell of peppermint is lost
B	Smell of peppermint is lost	Smell of peppermint returns
C	Smell of peppermint remains	Smell of peppermint remains
D	Smell of peppermint is lost	Smell of peppermint does not return

Your answer

[1]

14 Which of the following support(s) the delocalised model for benzene rather than the Kekulé model?

- 1: Benzene is less reactive than cyclohexene
- 2: A benzene molecule has a planar, hexagonal structure
- 3: The enthalpy change of hydrogenation of benzene is more exothermic than predicted from the Kekulé structure

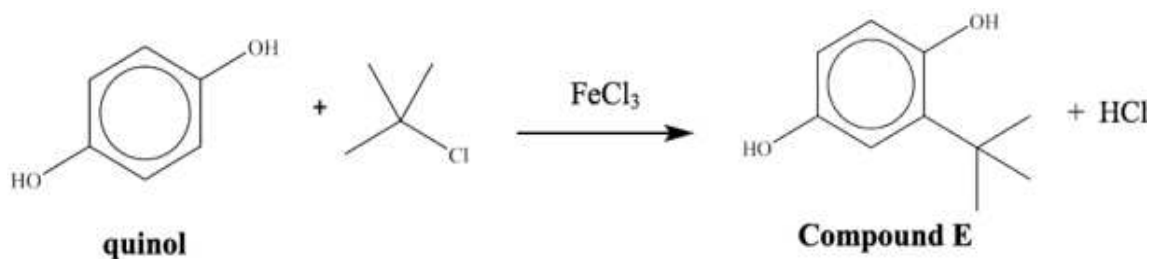
- A 1, 2 and 3
- B Only 1 and 2
- C Only 2 and 3
- D Only 1

Your answer

[1]

15(a) A student investigates reactions of aromatic compounds.

The student first carries out the reaction shown below.



- (i) The student obtains a very low yield of compound **E**.

The student obtains a much higher yield of a different organic product with molecular formula $C_{14}H_{22}O_2$.

Suggest an identity for the organic product $C_{14}H_{22}O_2$ and draw its structure below.

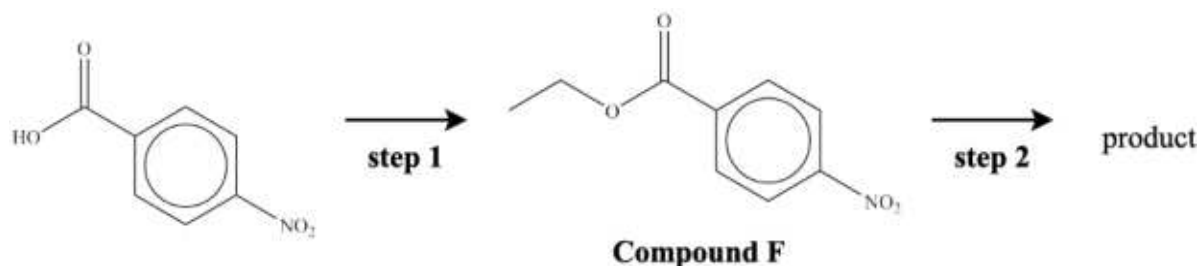
[1]

- (ii) The student is told by a friend that the $FeCl_3$ catalyst is not needed because quinol is more reactive than benzene.

Explain why the student's friend is correct.

You may draw a diagram to support your answer.

- (b) 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.

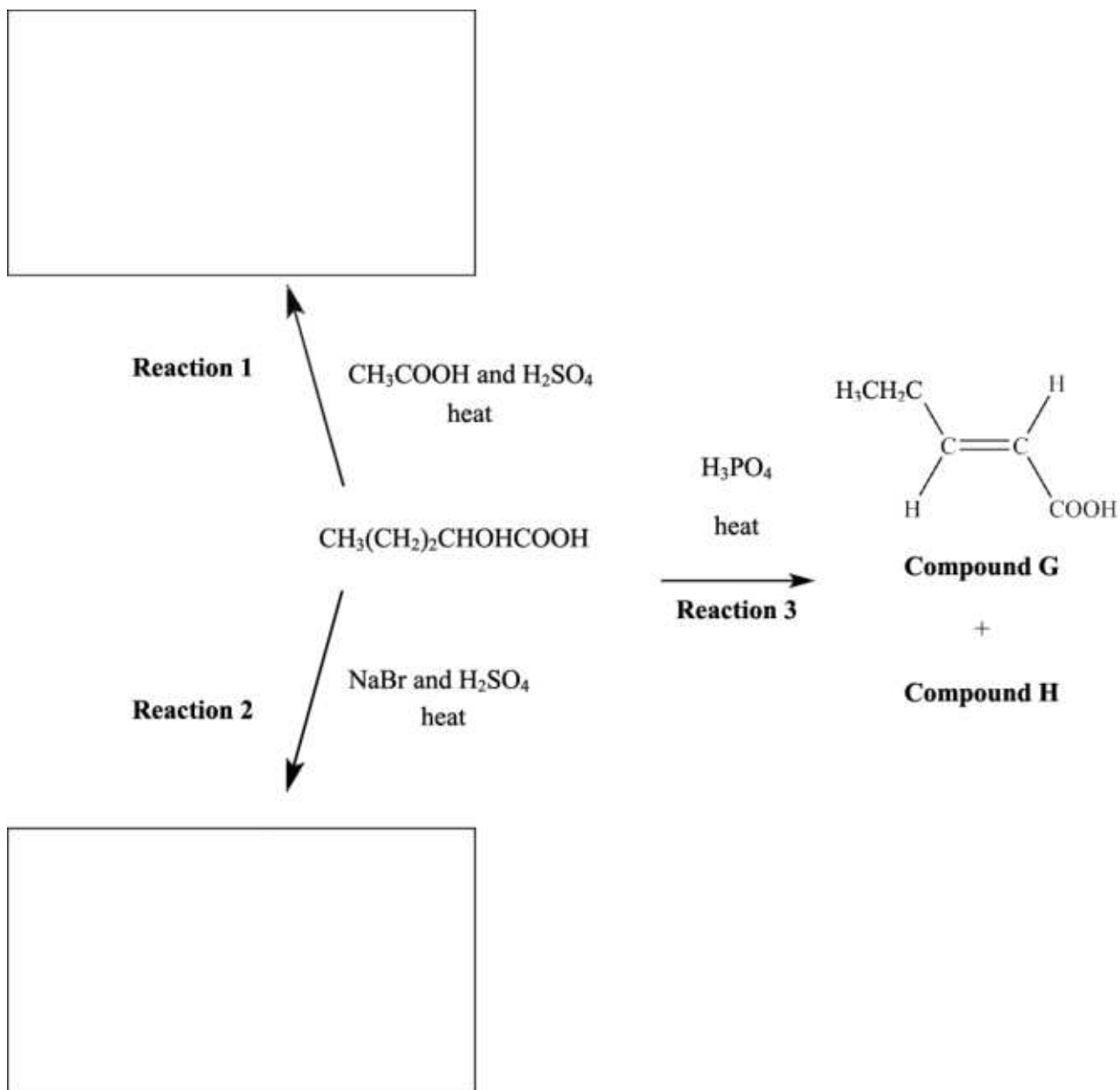
Show the structures of any organic compounds involved.

[2]

16(a) α -Hydroxy acids (AHAs) are naturally occurring acids often used as cosmetics.

The flowchart below shows some reactions of an AHA, $\text{CH}_3(\text{CH}_2)_2\text{CHOHCOOH}$.

- (i) Fill in the boxes to show the organic products of **Reactions 1** and 2, clearly showing the relevant functional groups.



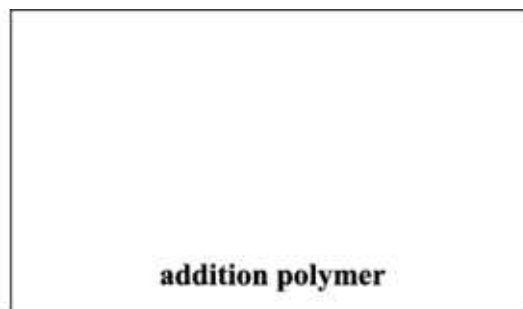
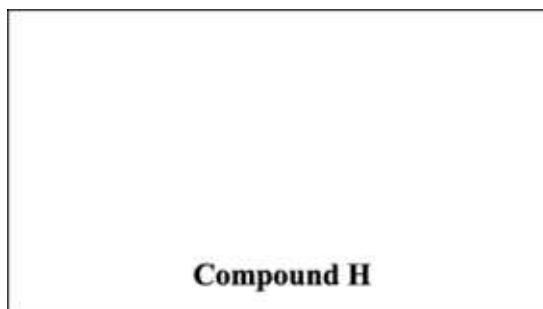
[2]

- (ii) Give the full systematic name for compound G.

----- [1]

(iii) Compound H is a stereoisomer of compound G.

- Suggest a structure for compound H.
- Draw the repeat unit of the addition polymer that can be formed from compound H.



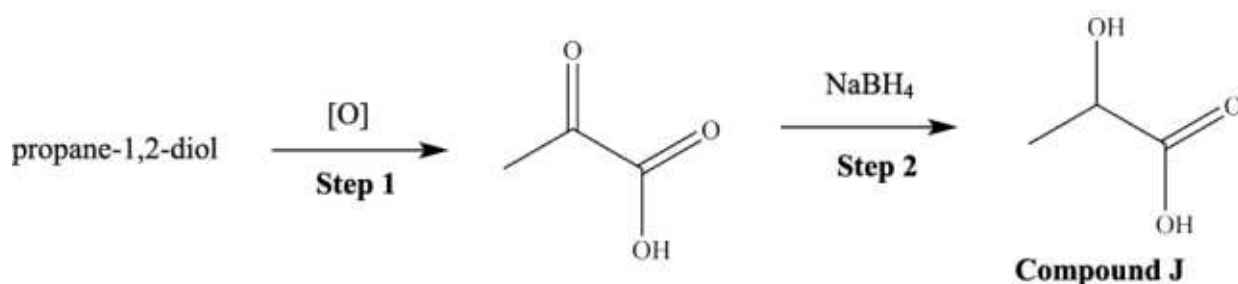
[2]

(iv) The addition polymer in (iii) is used widely in industry. Increasingly, waste polymers are being processed as a more sustainable option than disposal.

Apart from recycling, state **two** methods for usefully processing waste polymers.

----- [2]

(b) A student synthesises a sample of the AHA J using the following reaction scheme, starting from propane-1,2-diol.



(i) In the space below:

- state a suitable oxidising agent for **Step 1**
- write an equation for **Step 1**
- outline the mechanism for **Step 2**, showing curly arrows and relevant dipoles.

----- [5]

- (ii) The reagent used in **Step 2** of the synthesis in (i) was NaBH_4 . NaBH_4 contains the ions Na^+ and $[\text{BH}_4]^-$.

Draw a '*dot-and-cross*' diagram of NaBH_4 and give the **full** electron configuration of Na^+ .

Show outer shells of electrons only.

full electronic configuration of Na^+ : -----

[2]

17(a) Cyclohexanone can be prepared in the laboratory by reacting cyclohexanol with concentrated sulfuric acid and sodium dichromate.

Ethanedioic acid is added to the reaction mixture to react with any excess dichromate.

The mixture is then distilled. The impure distillate is a mixture of cyclohexanone and water.

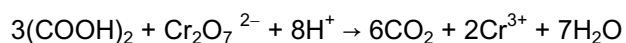
You will need to refer to some or all of the following data to answer these questions.

	Boiling point / °C	Density / g cm ⁻³	<i>M_r</i>
Cyclohexanol	161	0.962	100.0
Cyclohexanone	156	0.948	98.0

* Draw a labelled diagram to show how you would safely set up apparatus for distillation and describe a method to obtain a pure sample of cyclohexanone from the distillate.

[6]

- (b) Ethanedioic acid removes excess dichromate ions, $\text{Cr}_2\text{O}_7^{2-}$, as in the equation below.



Suggest how you could tell when the excess dichromate has completely reacted with the ethanedioic acid.

----- [1]

- (c) A student monitors the course of this reaction using thin-layer chromatography (TLC).

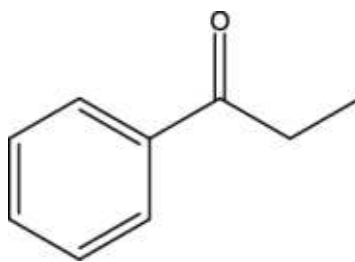
Outline how TLC could be used to monitor the course of the reaction.

----- [2]

- (d) Plan an experiment that would allow the student to confirm the identity of the pure organic product by means of a chemical test.

----- [3]

18 A chemist reacts the following molecule with sodium borohydride, NaBH_4 .



Which functional group is formed in the reaction?

- A Carboxylic acid
- B Secondary alcohol
- C Primary alcohol
- D Aldehyde

Your answer

[1]

19 What is the mechanism for the nitration of benzene?

- A Nucleophilic addition
- B Nucleophilic substitution
- C Electrophilic addition
- D Electrophilic substitution

Your answer

[1]

20 A student adds bromine water to a solution of phenol.

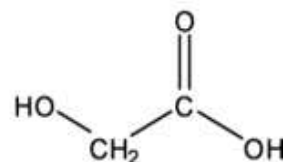
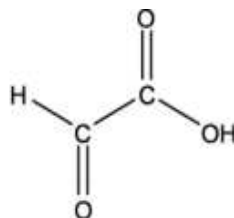
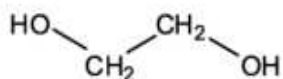
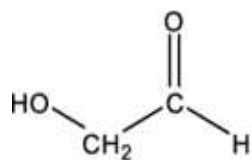
What would the student see during this reaction?

- A Bromine water goes from orange to green.
- B Bromine water goes from orange to colourless and a white precipitate is formed.
- C There is no reaction.
- D Bromine water goes from orange to colourless and the solution fizzes.

Your answer

[1]

21 Which molecule is the most soluble in water?

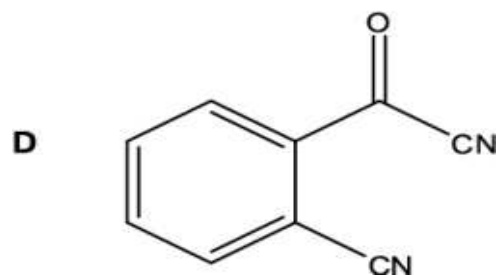
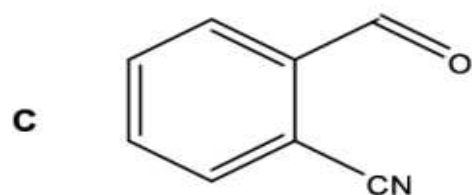
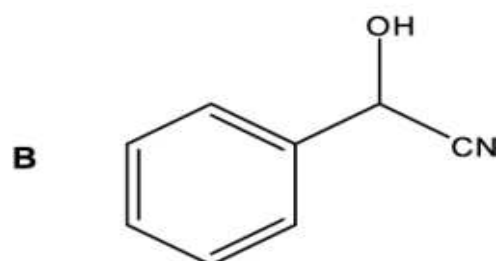
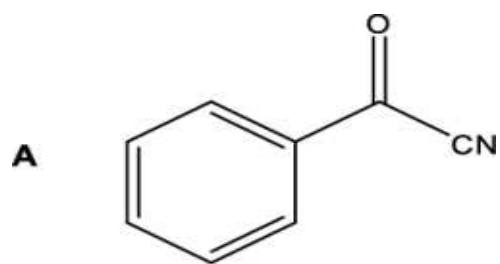


Your answer

[1]

22 Benzaldehyde, $\text{C}_6\text{H}_5\text{CHO}$, reacts with $\text{NaCN(aq)}/\text{H}^+(\text{aq})$.

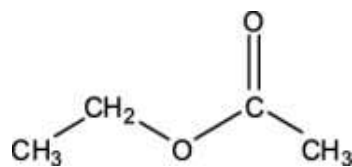
What is the organic product of this reaction?



Your answer

[1]

23 The structure of an ester is shown below.



Which statement is most likely to be true about the mass spectrum of the ester?

- A The peak at $m/z = 45$ is due to the fragment $[\text{C}_2\text{H}_5\text{O}]^+$.
- B The peak at $m/z = 44$ is due to the fragment $[\text{C}_3\text{H}_8]^+$.
- C The peak at $m/z = 88$ is the $M+1$ peak.
- D There is no peak at $m/z = 43$.

Your answer

[1]

24(a) This question is about the chemistry of benzene and substituted benzene compounds.

In 1865, the Kekulé model was suggested for the structure of benzene. Experimental evidence has led to the development of an updated model. Both models are shown below.



Kekulé model

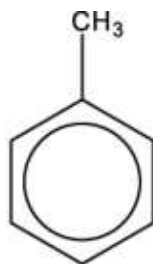


Updated model

- Explain the experimental evidence that led to the development of the updated model from the Kekulé model of benzene.
- Describe the bonding in the updated model of benzene.

[4]

- (b) A chemist investigates the chlorination of methylbenzene and finds that the methyl group has a 2- and 4-directing effect.



methylbenzene

4-Chloromethylbenzene is one of the products of the chlorination of methylbenzene.

Outline the mechanism for the formation of 4-chloromethylbenzene from methylbenzene and chlorine in the presence of the catalyst, AlCl_3 .

Show how AlCl_3 behaves as a catalyst.

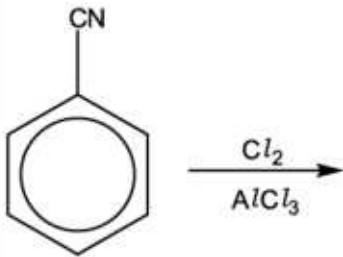
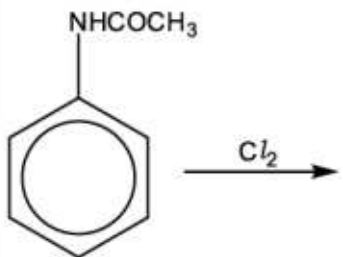
[5]

- (c) The chemist carries out further investigations into the reactions of substituted benzene compounds.

The table below shows the directing effects of different groups attached to a benzene ring.

Group	Position to which new substituent is directed
$-\text{NO}_2$	3
$-\text{OH}$	2, 4
$-\text{COCH}_3$	3
$-\text{N}(\text{CH}_3)_2$	2, 4
$-\text{NHCOCH}_3$	2, 4
$-\text{CN}$	3

- (i) Draw all of the organic products from monosubstitution reactions of the substituted benzene compounds shown below.

Reaction	Monosubstituted Product(s)
 Reaction of benzonitrile ($\text{C}_6\text{H}_5\text{CN}$) with Cl_2 and AlCl_3.	
 Reaction of N-methylacetanilide ($\text{C}_6\text{H}_5\text{NHCOCH}_3$) with Cl_2.	

[3]

- (ii) The reactions of $\text{C}_6\text{H}_5\text{N}(\text{CH}_3)_2$ are similar to the reactions of phenol.

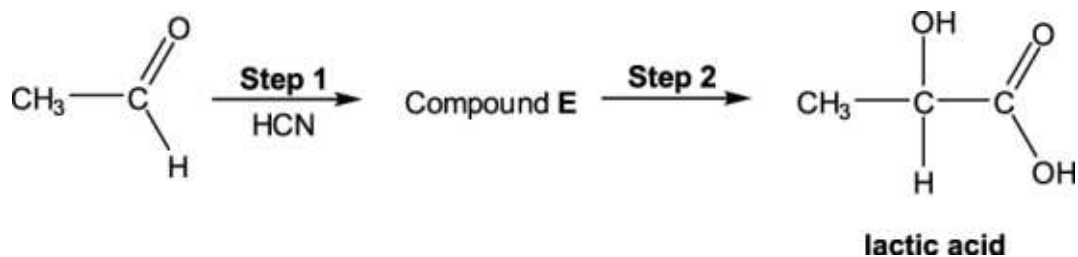
Draw the organic product that is formed from the tri-substitution of $\text{C}_6\text{H}_5\text{N}(\text{CH}_3)_2$ with chlorine.

[1]

(iii) Explain why chlorine reacts much more readily with $\text{C}_6\text{H}_5\text{N}(\text{CH}_3)_2$ than with benzene.

[3]

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



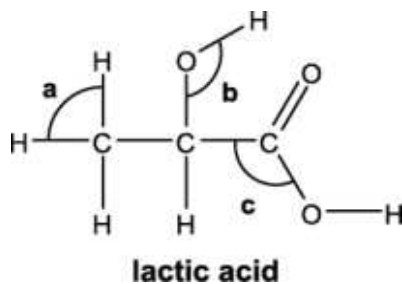
(i) Draw the structure for compound E.

[1]

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

[1]

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



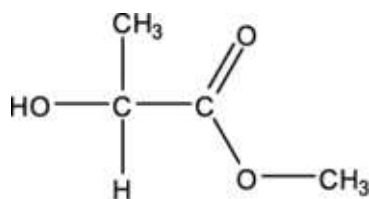
Suggest a value for each bond angle a-c.

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

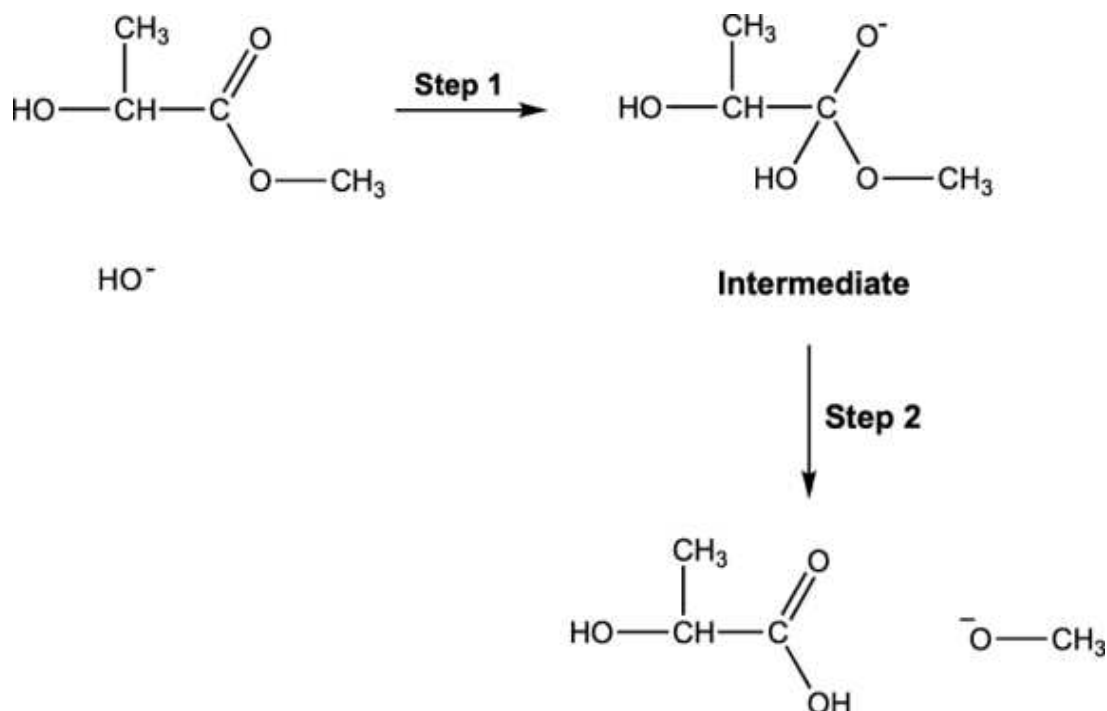
Methyl lactate can be hydrolysed by refluxing with sodium hydroxide solution.

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

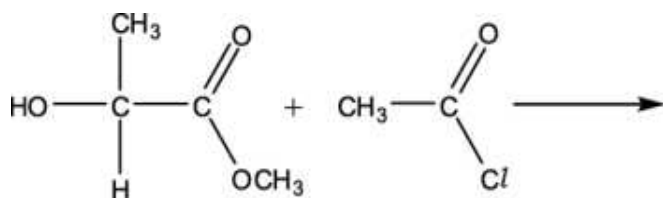
mechanism.

- Add curly arrows to show how the carboxylic acid and 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]

26(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.

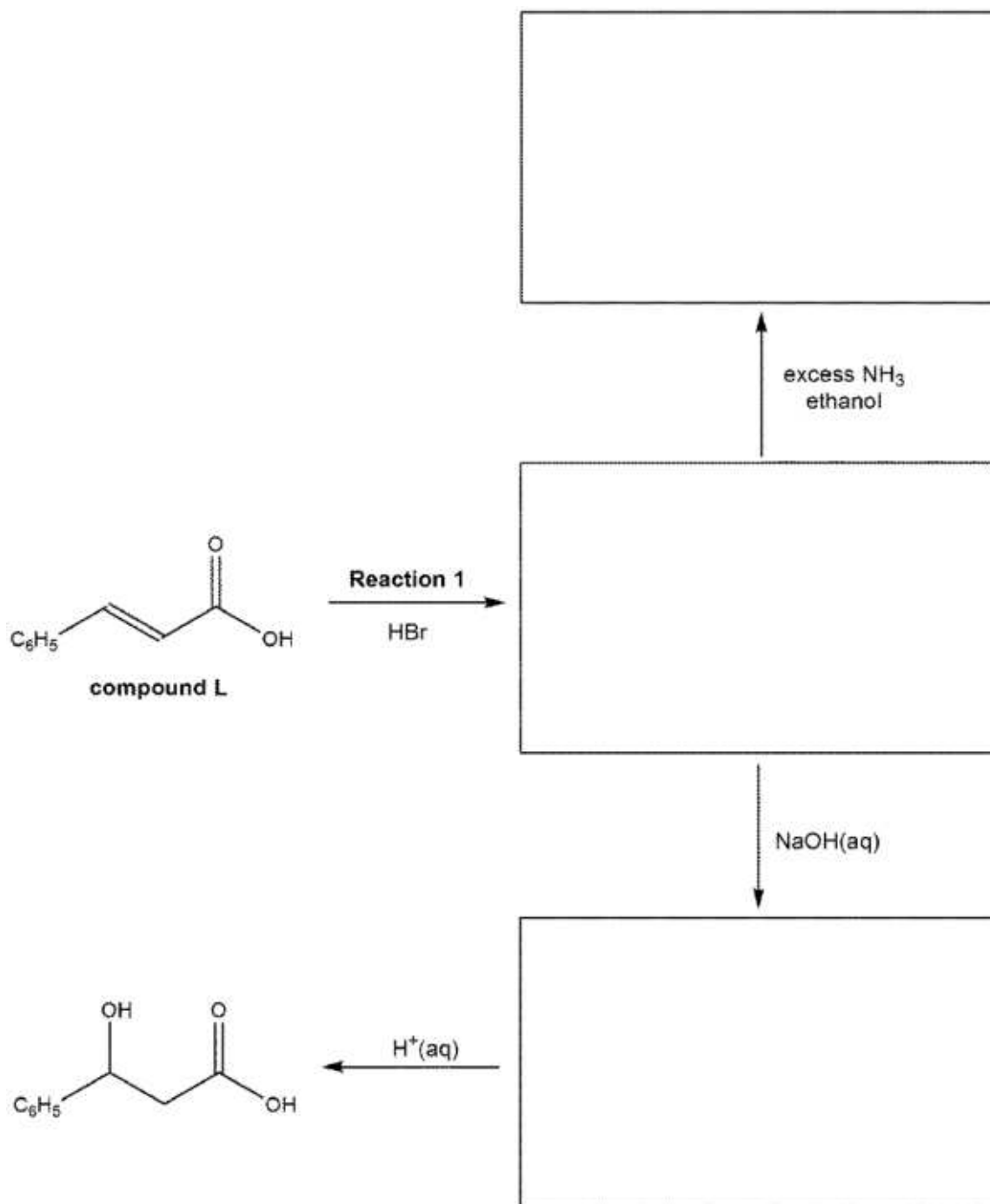
Your answer should not include spectroscopy.

[3]

27(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.



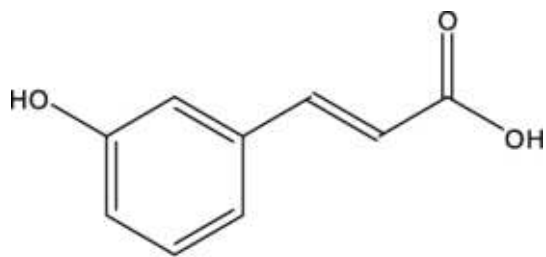
[3]

(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]

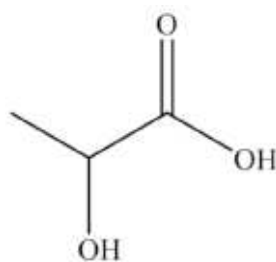
28 Give chemical explanations for the following statements.

The carbon–carbon bonds in benzene are all the same length.

[1]

29(a) This question is about organic acids.

Lactic acid, shown below, has two functional groups.



Lactic acid reacts with bases and with many metals.

- An aqueous solution containing 1.125 g of lactic acid is reacted with an excess of magnesium producing hydrogen gas.
- The excess magnesium is removed.
The water is evaporated, leaving a white solid, A.

(i) Name the type of reaction of lactic acid with bases and with metals.

reaction with bases: _____

reaction with metals: _____

[1]

(ii) Calculate the volume of $\text{H}_2(\text{g})$ produced, measured at room temperature and pressure.

volume of H_2 = _____ [2]

(i) What is the empirical formula of the white solid A?

-----[1]

(ii) Predict **two** reactions of lactic acid, each involving a different functional group.

Do **not** include reactions with bases or metals.

For each reaction,

- state the type of reaction, the reagents and conditions
- draw the structures of any organic products formed.

[4]

- D reacts by both electrophilic substitution and electrophilic addition.
- The molecular formula of D is $C_xH_yO_2$.
- The mass spectrum of D has a molecular ion peak at $m/z = 148$.
- The ^{13}C NMR spectrum of D contains seven peaks.

Explain your reasoning from the evidence provided.

[5]

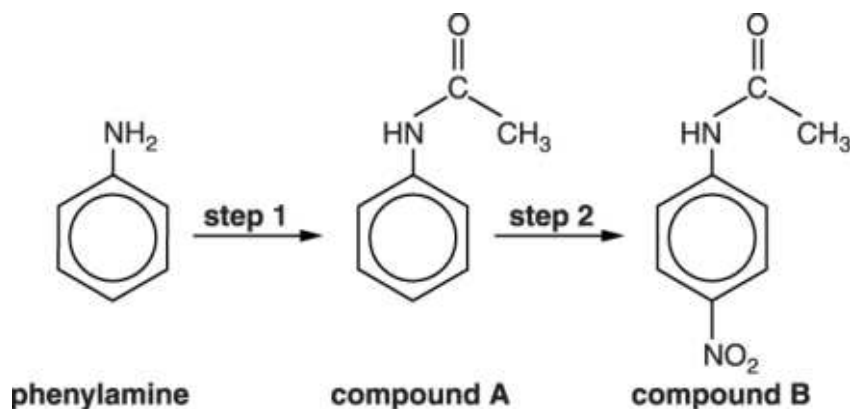
Traditional name	Structure	Systematic name
Stearic acid	$C_{17}H_{35}COOH$	Octadecanoic acid
Oleic acid	$C_{17}H_{33}COOH$	Octadec-9-enoic acid
Linoleic acid	$C_{17}H_{31}COOH$	Octadeca-9,12-dienoic acid

Write an equation for the formation of sodium stearate.

-----[1]

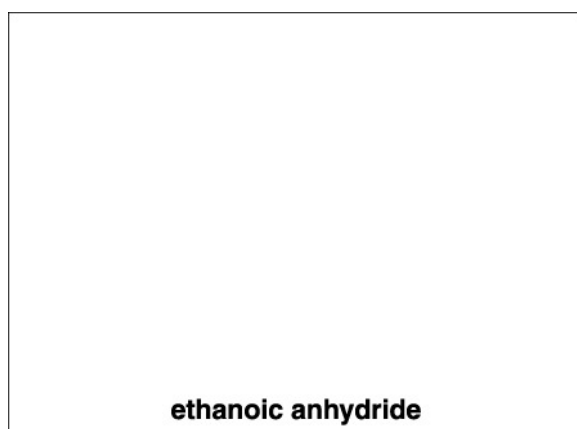
31 A student plans a two-step synthesis starting with phenylamine.

The steps of the synthesis are shown below.



- (i) In **step 1**, phenylamine reacts with ethanoic anhydride to make compound A and one other organic product.

Draw the structure of ethanoic anhydride, with the functional group displayed, and suggest the structure of the other organic product formed in **step 1**.



[2]

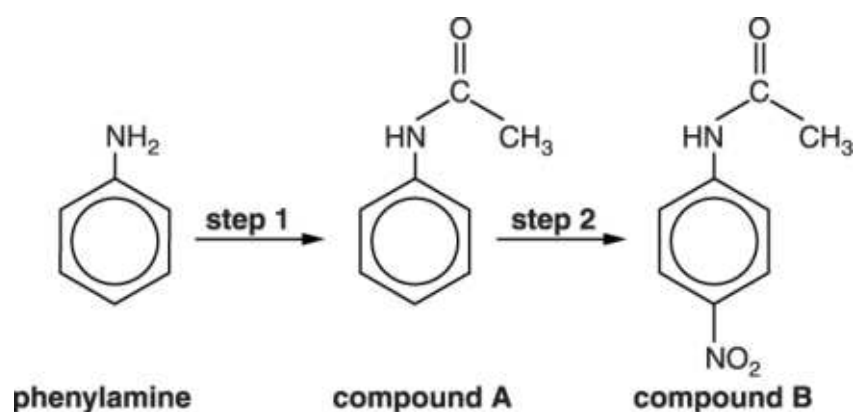
- (ii) Calculate the mass of compound A that can be synthesised from 3.00 g of phenylamine in **step 1**. The percentage yield of this reaction is 61.0%.

$$M_r(\text{phenylamine}) = 93.0$$

Give your answer to **three** significant figures.

mass of compound A = ... g [3]

The steps of the synthesis are shown again below.



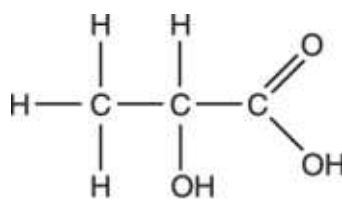
- (iii) In **step 2**, compound A is converted into compound B using a mixture of concentrated nitric acid and concentrated sulfuric acid.

Outline, with the aid of curly arrows, the mechanism for the conversion of compound A into compound B.

Use equations to explain how sulfuric acid acts as a catalyst in this reaction.

[5]

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



lactic acid

When heated strongly, lactic acid forms a cyclic 'diester'.

The diester has the molecular formula, $C_6H_8O_4$.

Draw the structure of the cyclic diester.

[1]

33(a) There are several isomeric alcohols with the formula $C_5H_{11}OH$.

Pentan-1-ol, $CH_3(CH_2)_3CH_2OH$, can be prepared in the laboratory by the reduction of an aldehyde.

State a suitable reducing agent for this reaction and write an equation to show the preparation of pentan-1-ol. Use $[H]$ to represent the reducing agent in the equation.

Reducing agent

Equation

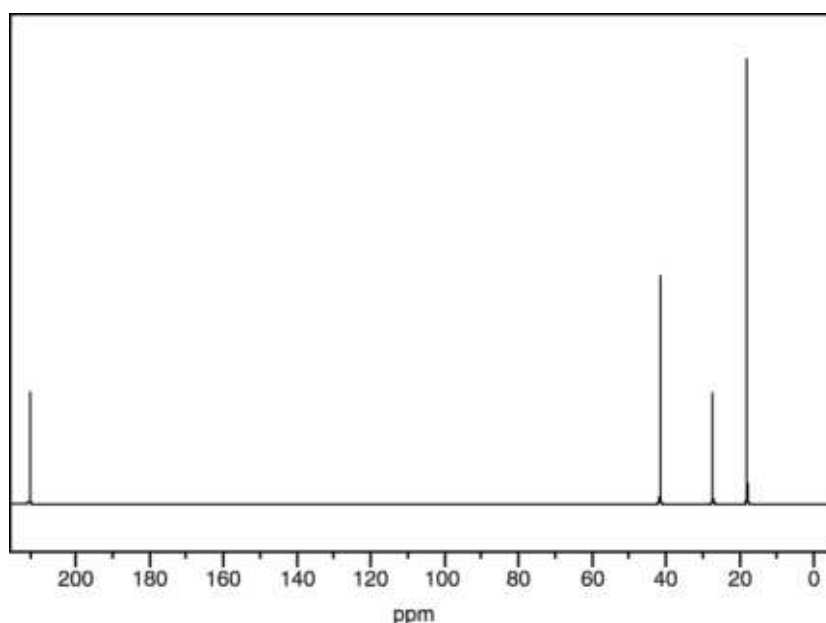
[2]

(b) Compound F is a structural isomer of $C_5H_{11}OH$.

Compound F is converted to compound G when heated under reflux with acidified potassium dichromate(VI) solution.

Compound G reacts with 2,4-dinitrophenylhydrazine to form an orange solid but compound G does not react with Tollens' reagent.

The ^{13}C NMR spectrum of compound G is shown below.

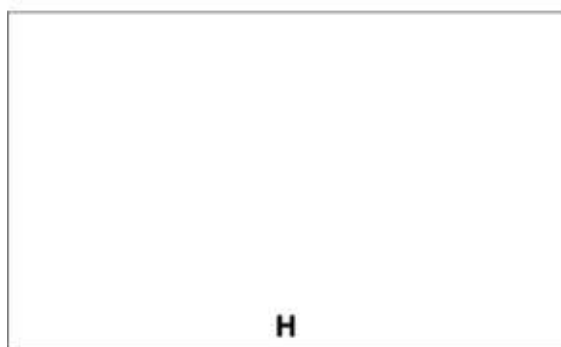
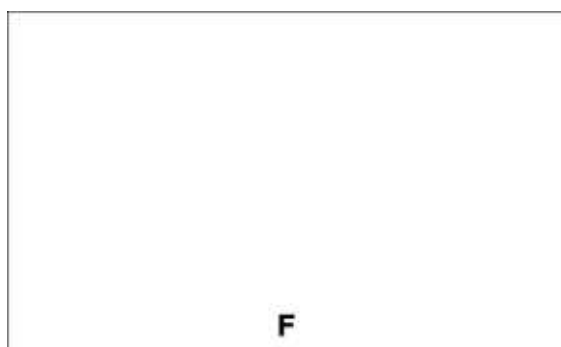


Compound H is a carboxylic acid. In a titration, 0.211 g of carboxylic acid H requires 22.8 cm^3 of 0.125 mol dm^{-3} NaOH for neutralisation.

Compound F reacts with compound H in the presence of concentrated sulfuric acid to form organic compound I.

Identify compounds F, G, H and I and draw their structures in the boxes below.

Show your working **only** for the identification of compound H.

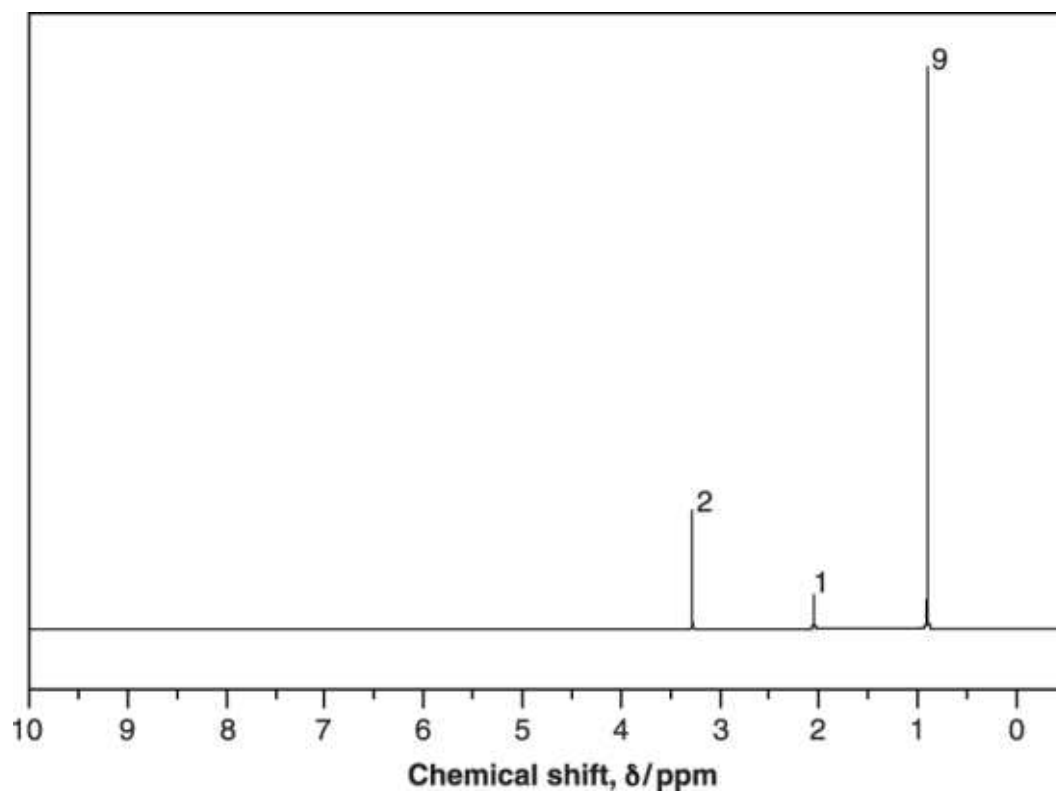


[7]

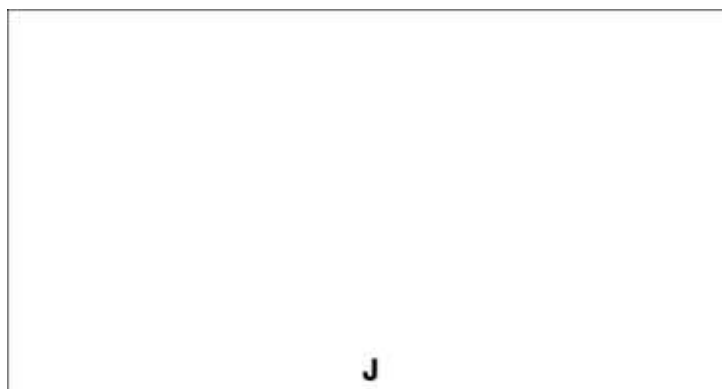
(c) Compound **J** is another structural isomer of $\text{C}_5\text{H}_{11}\text{OH}$.

The ^1H NMR spectrum of **J** is shown below.

The numbers next to each peak are the relative peak areas.



Identify compound **J** and draw its structure in the box below.



[1]

34 What is the number of sigma bonds in a benzene molecule?

- A 3
- B 6
- C 9
- D 12

Your answer

[1]

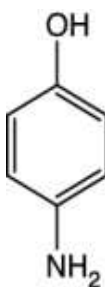
35 Which compound **cannot** be hydrolysed?

- 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]

36 The compound shown below can be prepared from phenol.



Which reagent(s) is/are required?

- A Concentrated NH₃
- B Dilute NH₃
- C Dilute HNO₃ and then concentrated HCl/Sn
- D Dilute HNO₃ and then NaBH₄

Your answer

[1]

37 Which reagent could be used to distinguish between CH₃CH₂OH and C₆H₅OH?

- A AgNO₃(aq) in ethanol
- B CH₃COC/
- C Na₂CO₃(aq)
- D Bromine water

Your answer

[1]

38(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 $\text{C}_5\text{H}_{10}\text{N}_2\text{O}_4$.

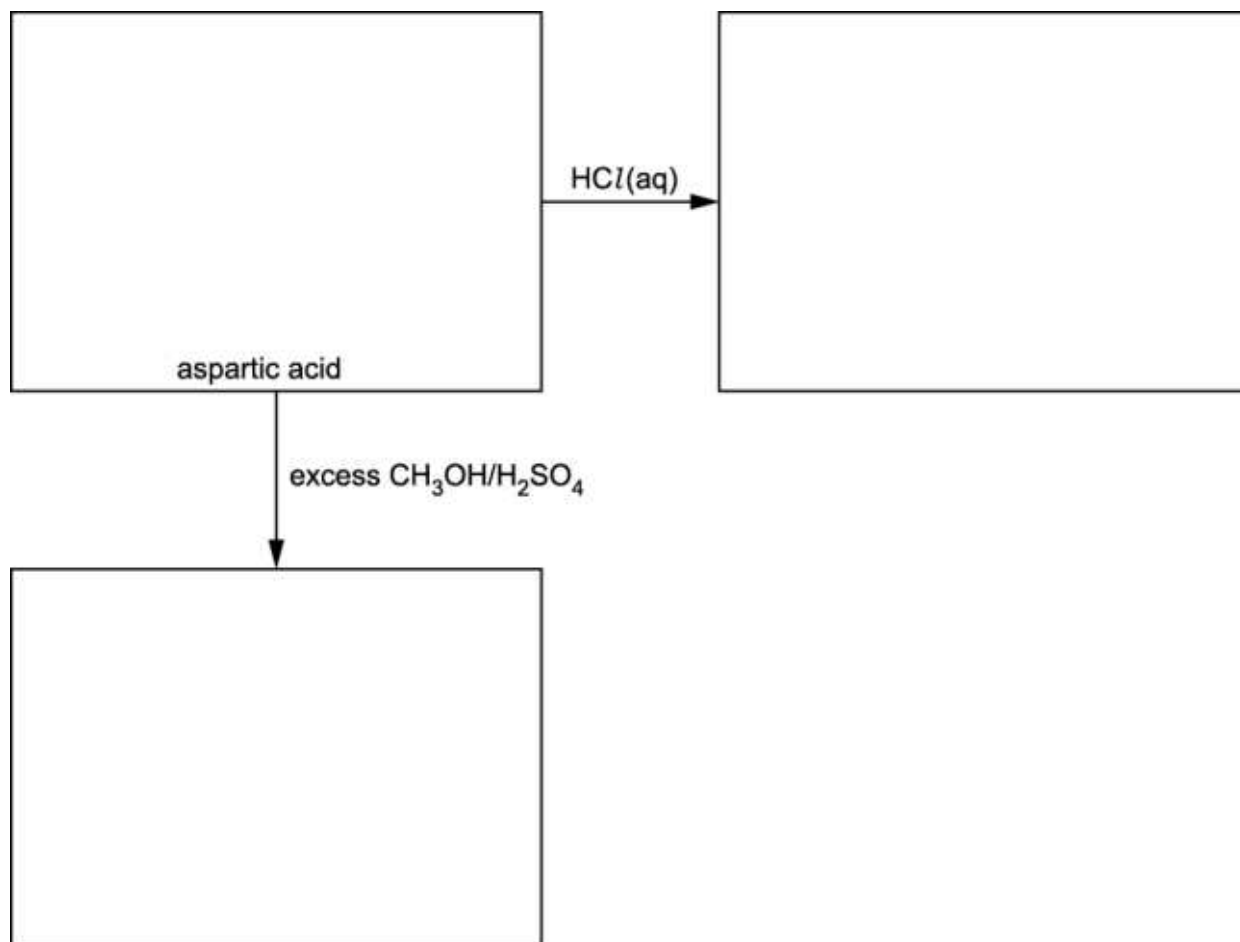
Draw the structures of the **three** organic products that can be formed by the reaction of serine with glycine.

[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.

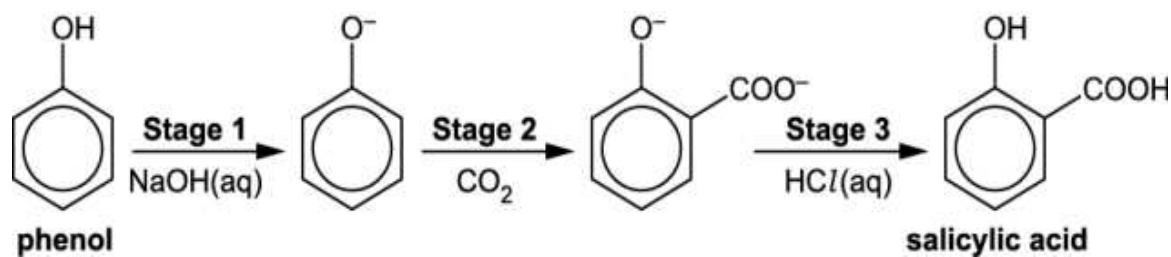
0.0300 mol of **G** has a mass of 3.51 g.

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

[2]

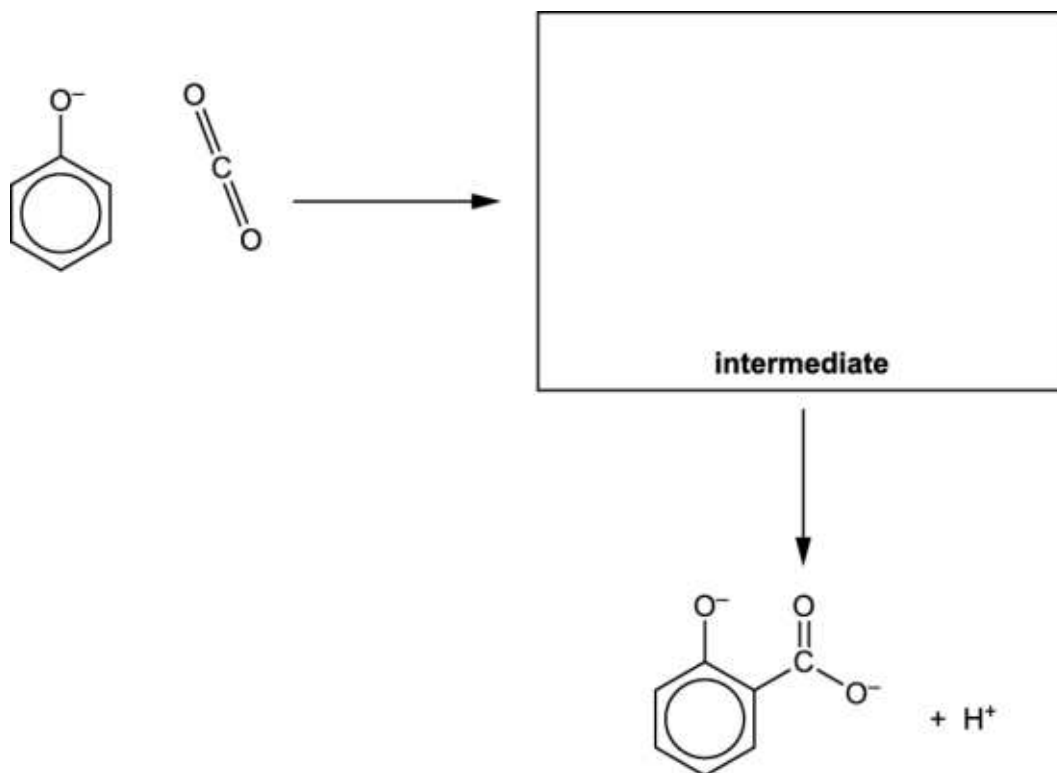
39(a) This question is about medical compounds made from salicylic acid.

Salicylic acid can be made from the reaction of phenol with carbon dioxide as shown below.



(i) **Stage 2** takes place by electrophilic substitution and part of the mechanism is shown below.

Complete the mechanism by showing relevant dipoles, curly arrows and the structure of the intermediate.



[3]

(ii) What type of reaction takes place during **Stage 1** and **Stage 3**?

Explain your answer.

Type of reaction _____

Explanation _____

_____ [2]

(iii) A chemist prepares 4.83 g of salicylic acid from phenol. The percentage yield of this reaction is 45.0%.

Calculate the mass of phenol that the chemist uses.

Give your answer to **three** significant figures.

mass of phenol = _____ g [3]

(b) Aspirin is an ester of salicylic acid.

Aspirin can be prepared by reacting salicylic acid with ethanoic anhydride, $(\text{CH}_3\text{CO})_2\text{O}$. One other organic compound also forms.

Draw **skeletal** formulae for the products of this reaction.

[2]

- (c) '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.

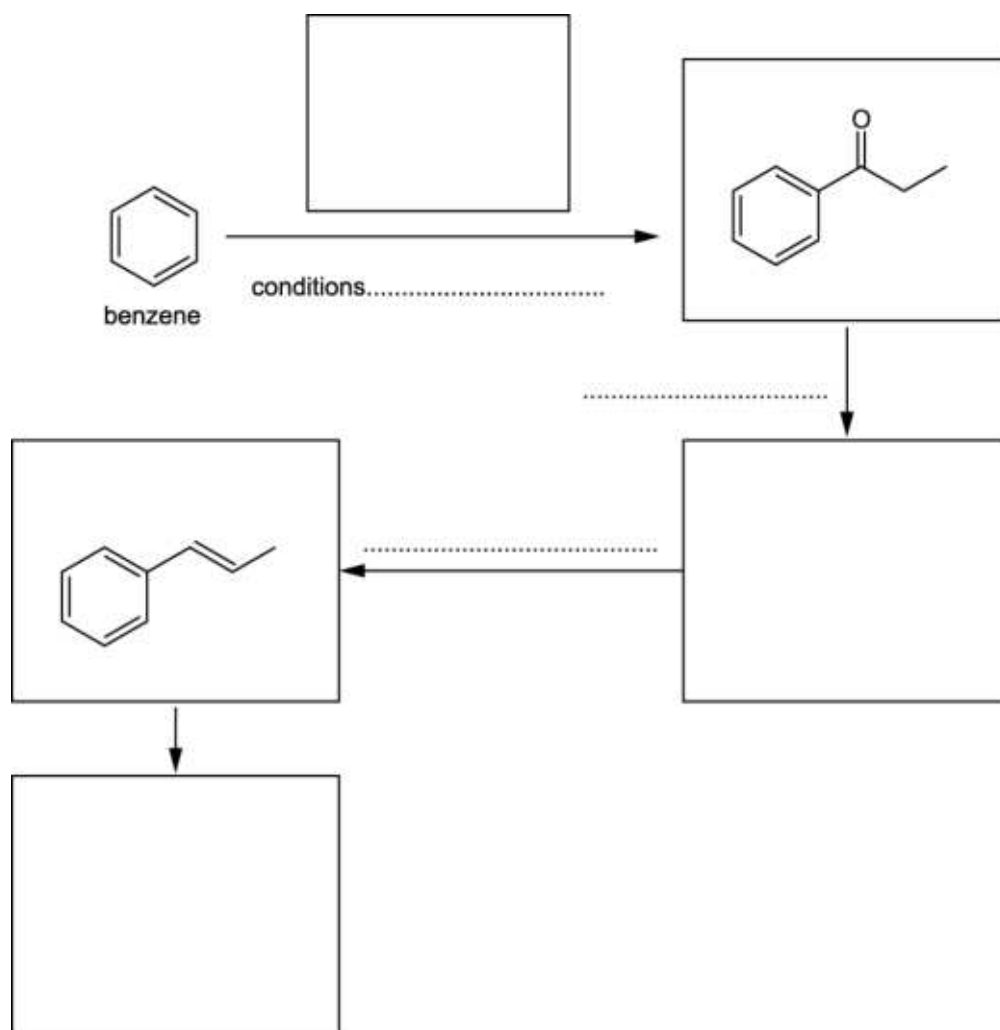
Draw a **labelled** diagram showing how the apparatus is set up for distillation.

[2]

40(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]

41(a) A student was provided with five compounds: an aldehyde, a ketone, a carboxylic acid and two esters. The student decides to identify the type of compound by carrying out some chemical tests.

Suggest chemical tests to identify the carboxylic acid and aldehyde.

For each test, include essential reagent(s), observation(s) and a balanced equation.

In your equations, use 'R' for the alkyl group.

(i) Test for carboxylic acid.

Reagent(s) _____

Observation(s) _____

Equation

[2]

(ii) Test for aldehyde.

Reagent(s) _____

Observation(s) _____

Equation

[2]

- (b) Suggest a chemical test to distinguish the ketone from the two esters.

Reagent(s) _____

Observation(s) _____

-----[1]

- (c) The student wants to confirm that the other two compounds are esters. Unfortunately there is no direct test for an ester group.

The esters are $\text{CH}_3\text{COOC}(\text{CH}_3)_3$ and $(\text{CH}_3)_3\text{CCOOCH}_3$.

The student plans the following:

- hydrolyse the two esters using aqueous sodium hydroxide.
- separate the hydrolysis products.
- carry out tests on the hydrolysis products.

- (i) Write an equation for the hydrolysis of one of the two esters with aqueous sodium hydroxide.

Show the structures for the organic compounds.

[2]

- (ii) Suggest a chemical test on the hydrolysis products that would allow the two esters to be identified.

Write an equation for one reaction that takes place.

Show the structures for the organic compounds.

Reagent(s) _____

Observation(s) _____

Equation

[2]

- (iii) The student thought that NMR spectroscopy could be used to identify the two esters without the need to carry out chemical tests.

The esters are $\text{CH}_3\text{COOC}(\text{CH}_3)_3$ and $(\text{CH}_3)_3\text{CCOOCH}_3$.

Explain whether the student is correct for ^{13}C and ^1H NMR spectroscopy. Your answer should also clearly state any differences between the spectra of the two esters.

[3]

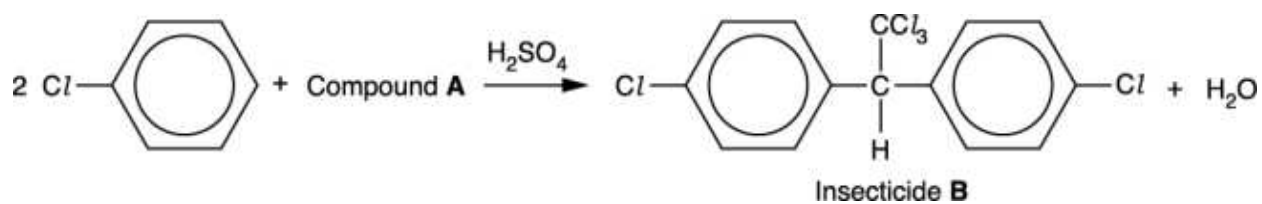
The ^1H NMR spectrum of the aldehyde contains two singlet peaks only: a large peak at $\delta = 1.2$ ppm and smaller peak at $\delta = 9.6$ ppm.

Show **all** your reasoning.

[5]

42 Concentrated sulfuric acid is often used to catalyse organic reactions.

An insecticide, **B**, can be made by the reaction below, using H_2SO_4 as a catalyst.



(i) Draw the structure for compound **A**.

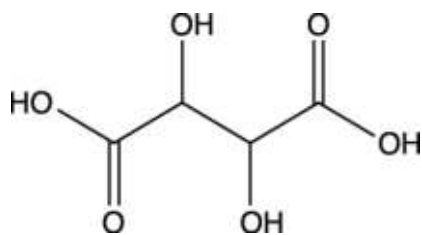
[1]

(ii) Sulfuric acid is a catalyst in many reactions.

State **one** other example of an organic reaction in which sulfuric acid is a catalyst.

-----[1]

(b) 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]

44 Equal amounts of the four compounds are added to the same volume of water.

Which compound would produce the most acidic solution?

- A CH_3CONH_2
- B CH_3COOH
- C $\text{CH}_3\text{COOCH}_3$
- D $\text{CH}_3\text{COC/}$

Your answer

[1]

45 0.1 mol of $\text{HOOCCH}_2\text{COOH}$ are reacted with 0.1 mol of aqueous NaOH.

How many molecules of water are formed?

- A 6.02×10^{22}
- B 3.01×10^{22}
- C 6.02×10^{23}
- D 3.01×10^{23}

Your answer

[1]

46(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]



(ii)

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 investigates the relative ease of nitration of phenol, benzene, and benzoic acid.



The student finds that the conditions required for the nitration of each compound are different, as shown in Table 17.1.

Compound	phenol	benzene	benzoic acid
Conditions required for nitration	Dilute HNO_3 20 °C No catalyst	Concentrated HNO_3 55 °C H_2SO_4 catalyst	Concentrated HNO_3 100 °C H_2SO_4 catalyst

Table 17.1

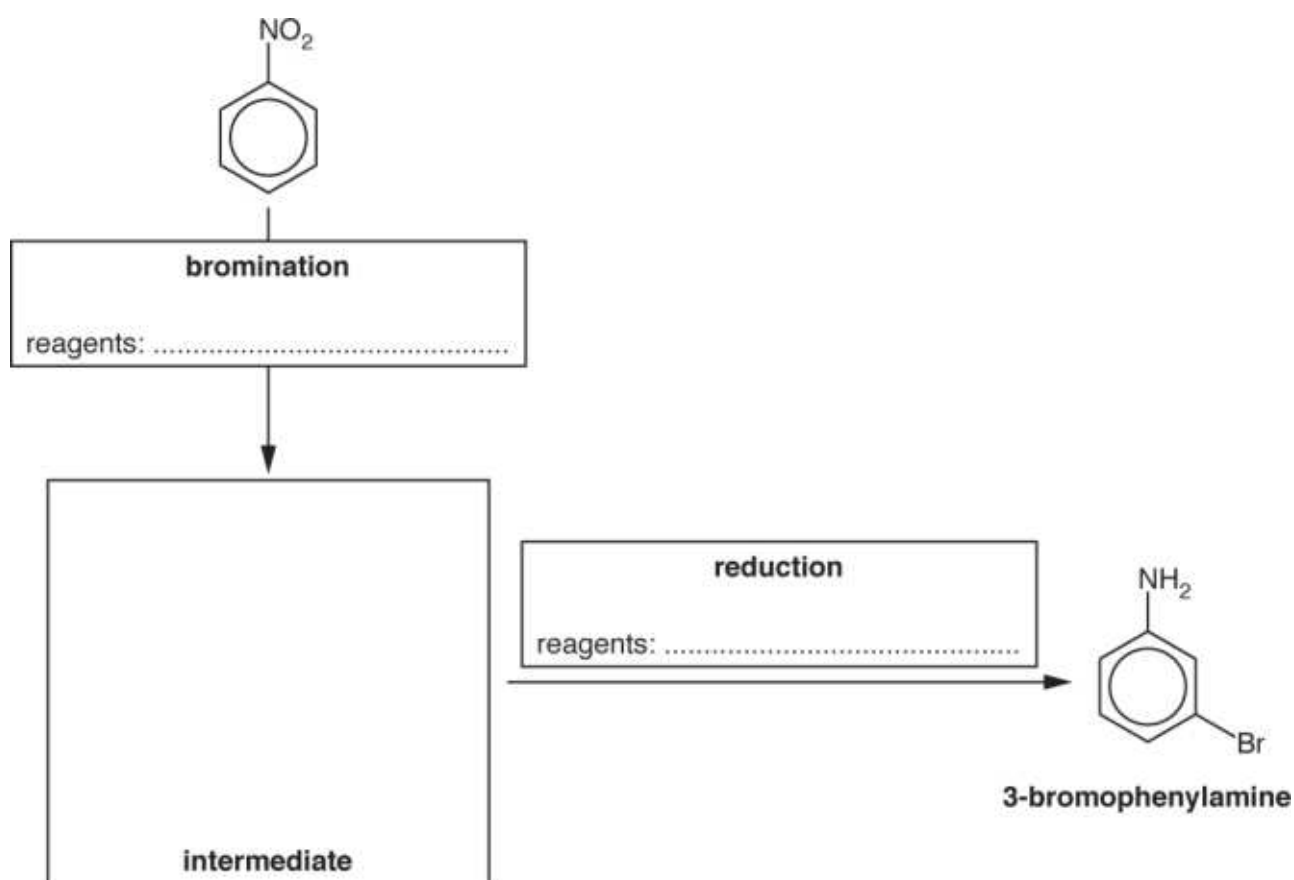
- (i) State the trend in the relative ease of nitration of phenol, benzene, and benzoic acid.

- (ii) Apply your knowledge of the bonding in arenes to explain the trend in part (b)(i).

[3]

(c) 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]

47 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.

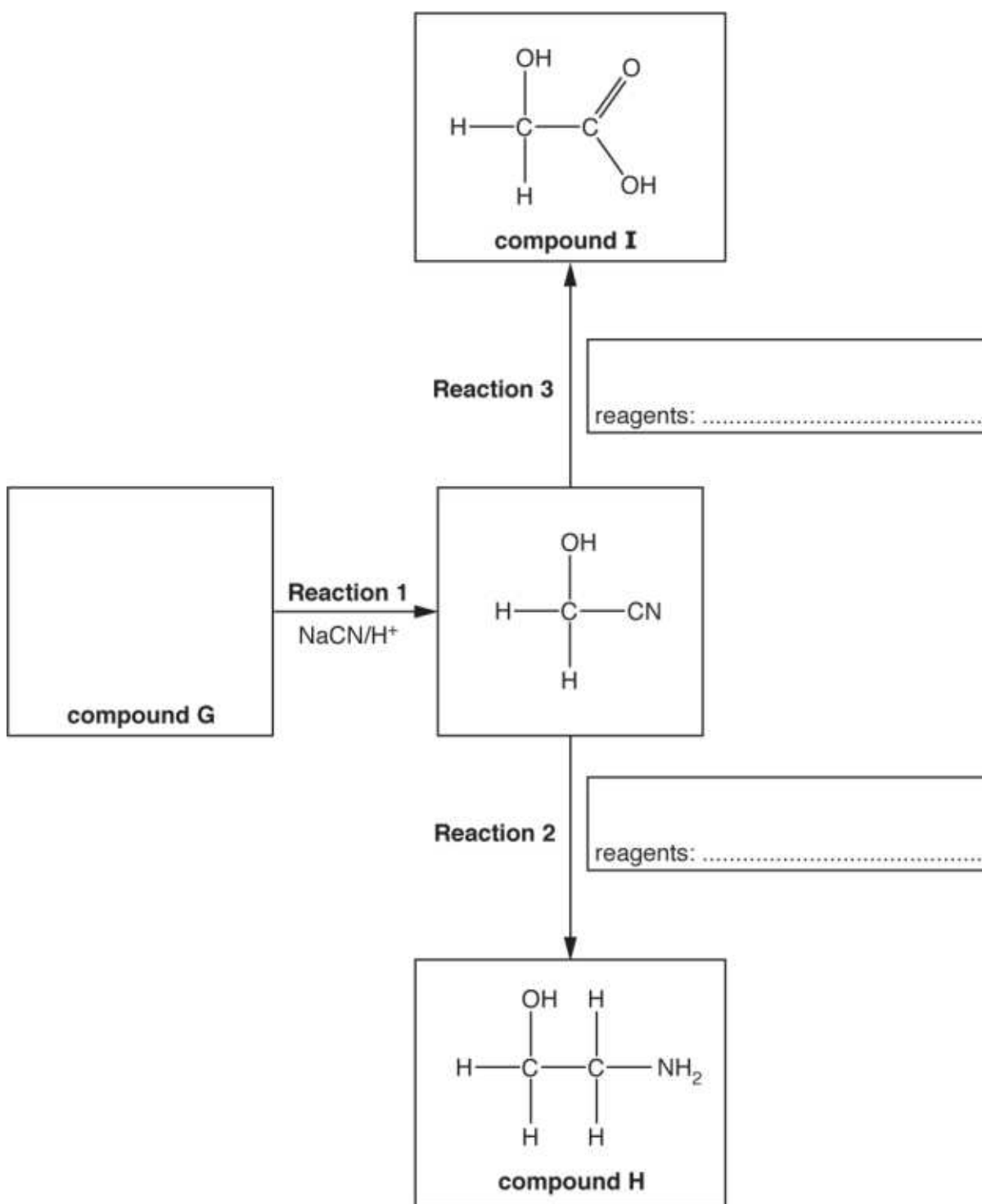
Outline the mechanism for this reaction.

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

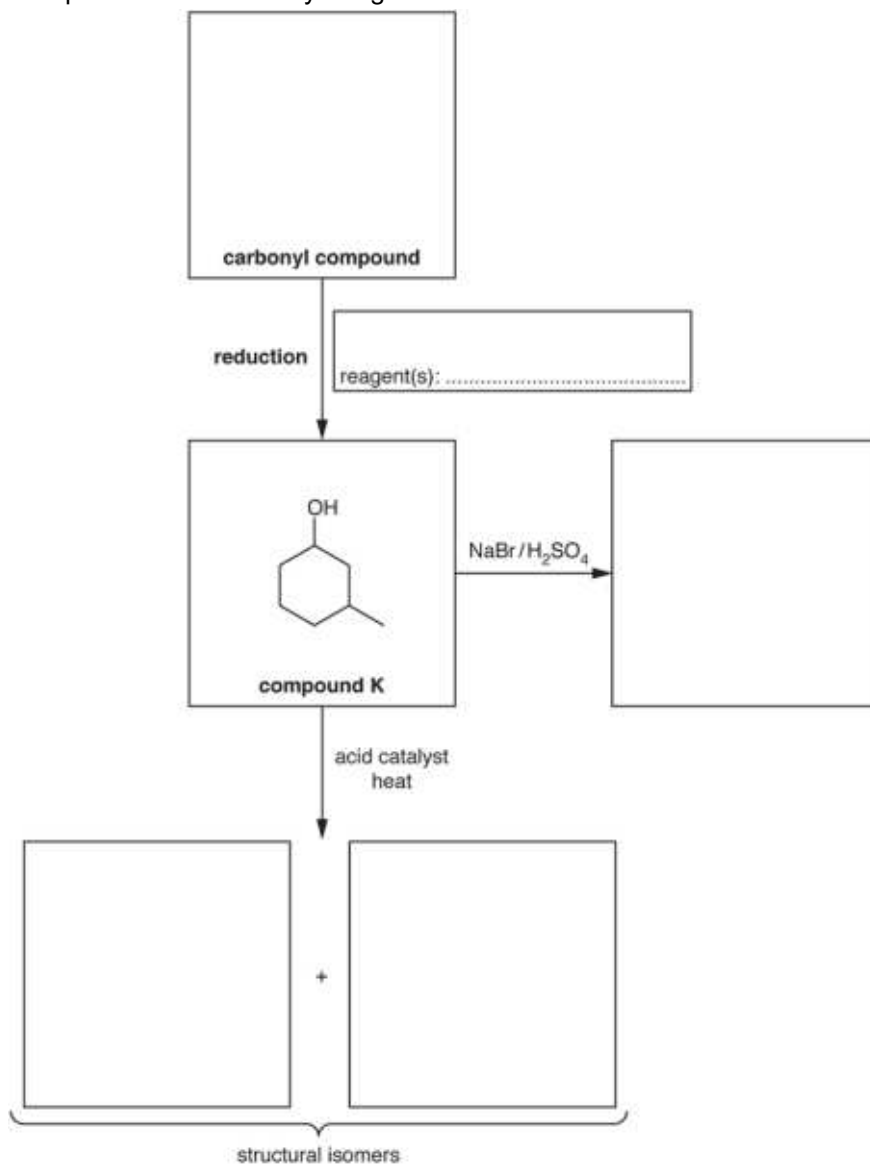
[2]

(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]

(i) Complete the flowchart by filling in each box.



[5]

(ii) What is the name of compound K?

-----[1]

49(a) This question is about weak acids.

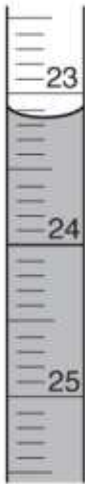
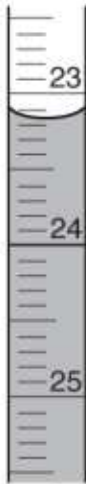
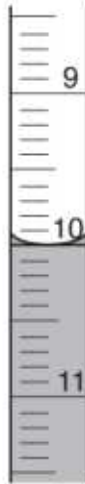
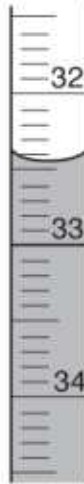
Compound **A** is a weak monobasic acid.

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 .

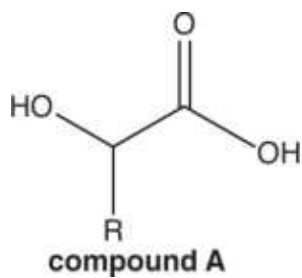
Titration 1		Titration 2		Titration 3	
Initial reading	Final reading	Initial reading	Final reading	Initial reading	Final reading
					

(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.

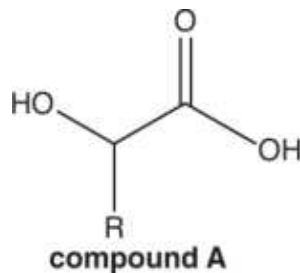
Using this information and the student's results, answer the following.

- 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.

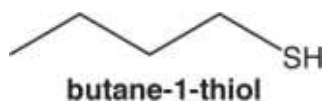
Equation

Type of reaction ----- [3]

50 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]

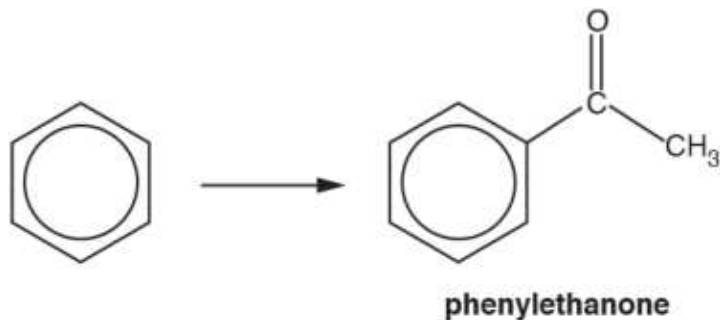
- (iv) Propane-1,3- dithiol reacts with carbonyl compounds in a condensation reaction to form a cyclic organic sulfur product.

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

Use structures for organic compounds.

[2]

51 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 $\text{CH}_3\text{COC/}$
- D CH_3COOH

Your answer

[1]

52 Which statement(s) support(s) the delocalised model for the structure of benzene?

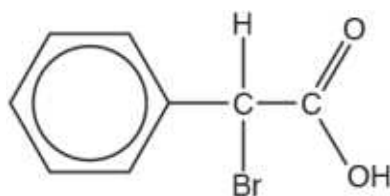
- 1 All carbon–carbon bonds have the same length.
- 2 The enthalpy change of hydrogenation of benzene is less exothermic than expected.
- 3 Bromine reacts with benzene less readily than with cyclohexene.

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

Your answer

[1]

53 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

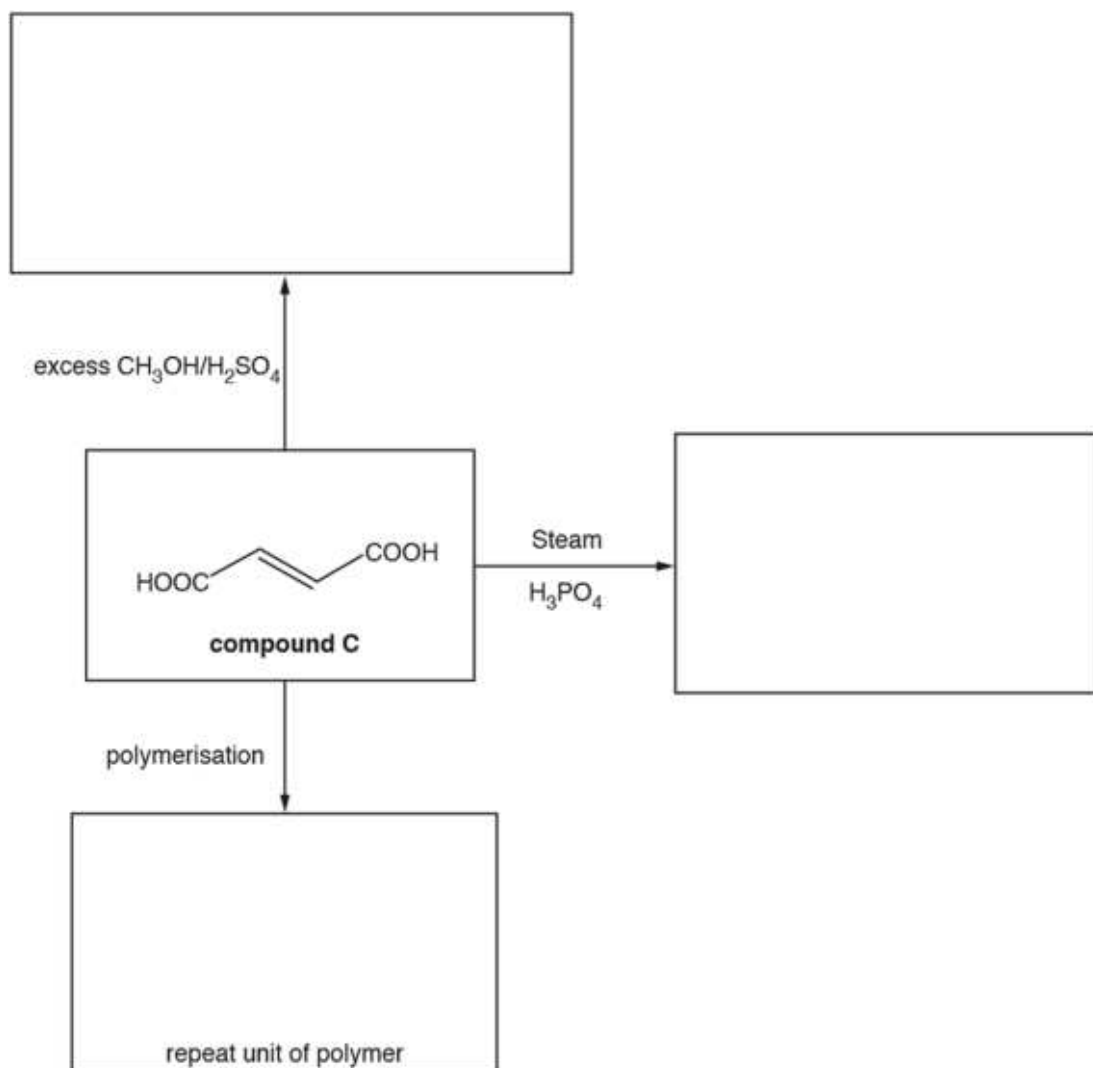
- A 1, 2 and 3
- B Only 1 and 2
- C Only 2 and 3
- D Only 1

Your answer

[1]

54 The flowchart below shows some reactions of compound C.

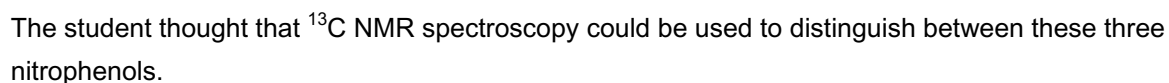
In the boxes, draw the organic products of these reactions.



[3]

Phenol undergoes nitration more readily than benzene.

A small amount of 3-nitrophenol is also produced.



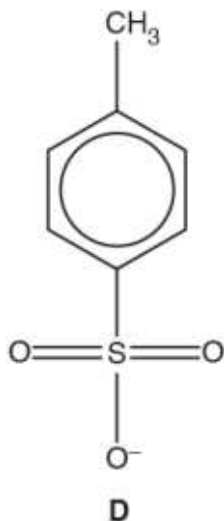
Explain whether the student is correct.

[3]

(ii) Explain why phenol is nitrated more readily than benzene.

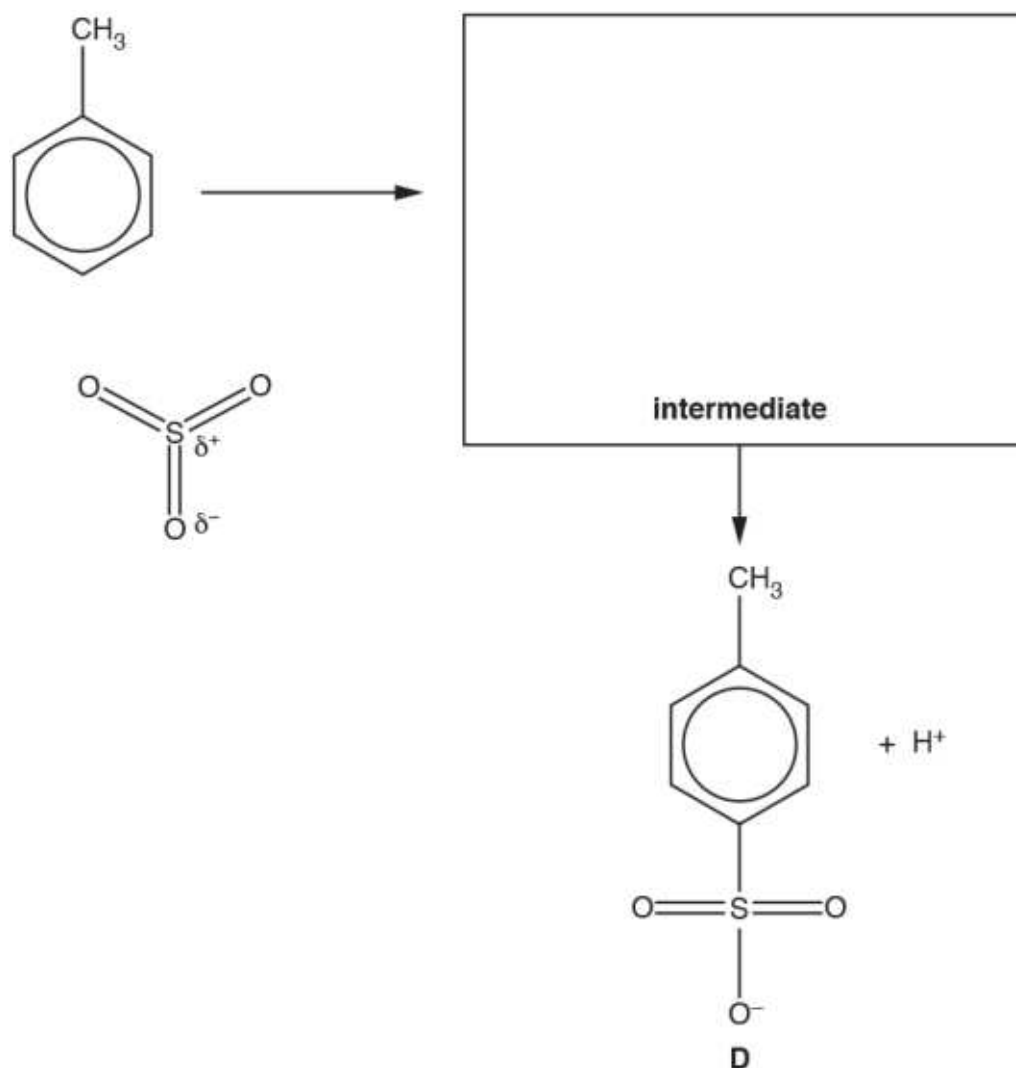
[3]

(b) Methylbenzene reacts with sulfur trioxide, SO_3 , to form D, shown below.



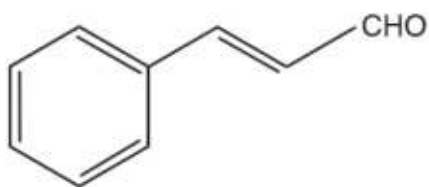
The electrophile in this reaction is SO_3 .

Complete the mechanism for the formation of D.
Show curly arrows and the structure of the intermediate.

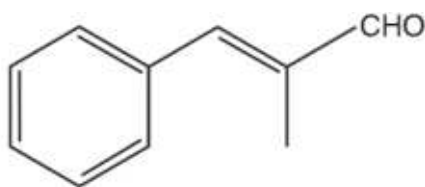


[3]

56(a) A student plans to carry out some chemical tests on both cinnamaldehyde and methylcinnamaldehyde.



cinnamaldehyde



methylcinnamaldehyde

- (i) Suggest a suitable chemical test to confirm that both compounds contain an unsaturated carbon chain.

Your answer should include the reagent and observations.

----- [1]

- (ii) Describe a chemical test to confirm that both compounds contain an aldehyde functional group.

Your answer should include the reagent and observations.

----- [1]

- (iii) Describe a chemical test to confirm that cinnamaldehyde and methylcinnamaldehyde contain a carbonyl group.

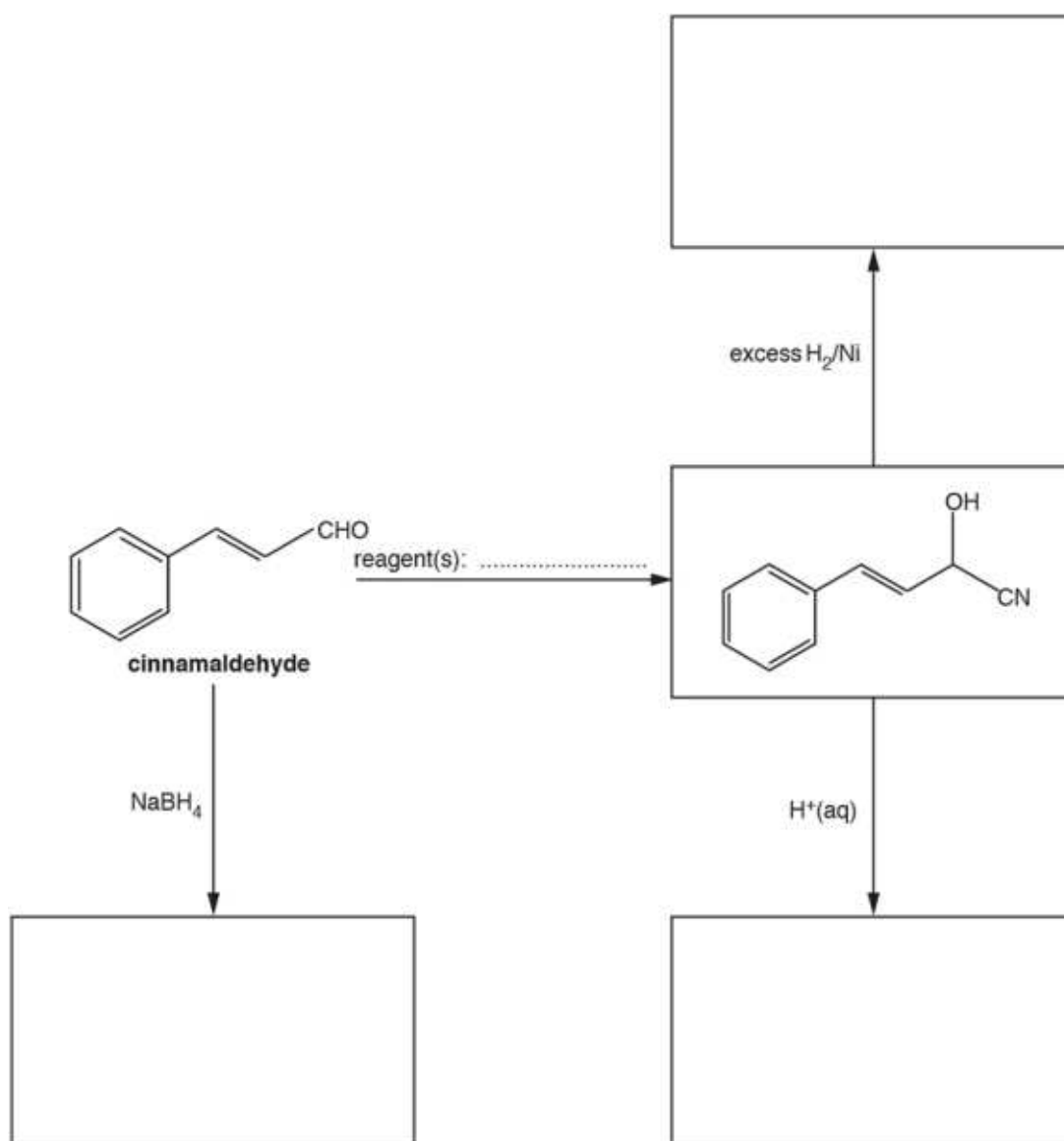
How could the products of this test be used to distinguish between the two compounds?

Your answer should **not** include spectroscopy.

[3]

(b) The flowchart below shows some reactions starting with cinnamaldehyde.

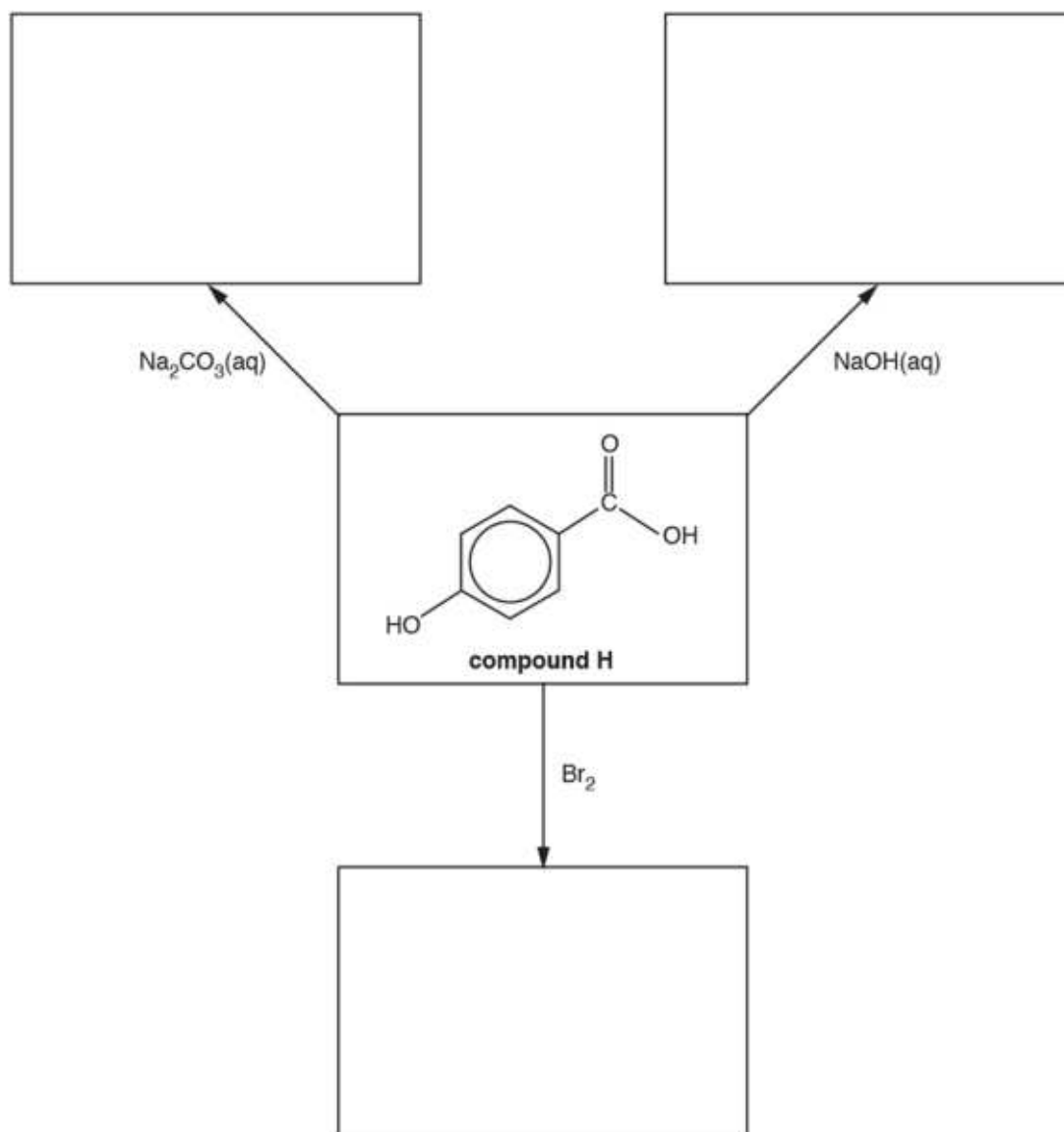
Draw the structures of the missing organic compounds in the boxes and add the missing reagent(s) on the dotted line.



[5]

57(a) This question is about aromatic carboxylic acids and their derivatives.

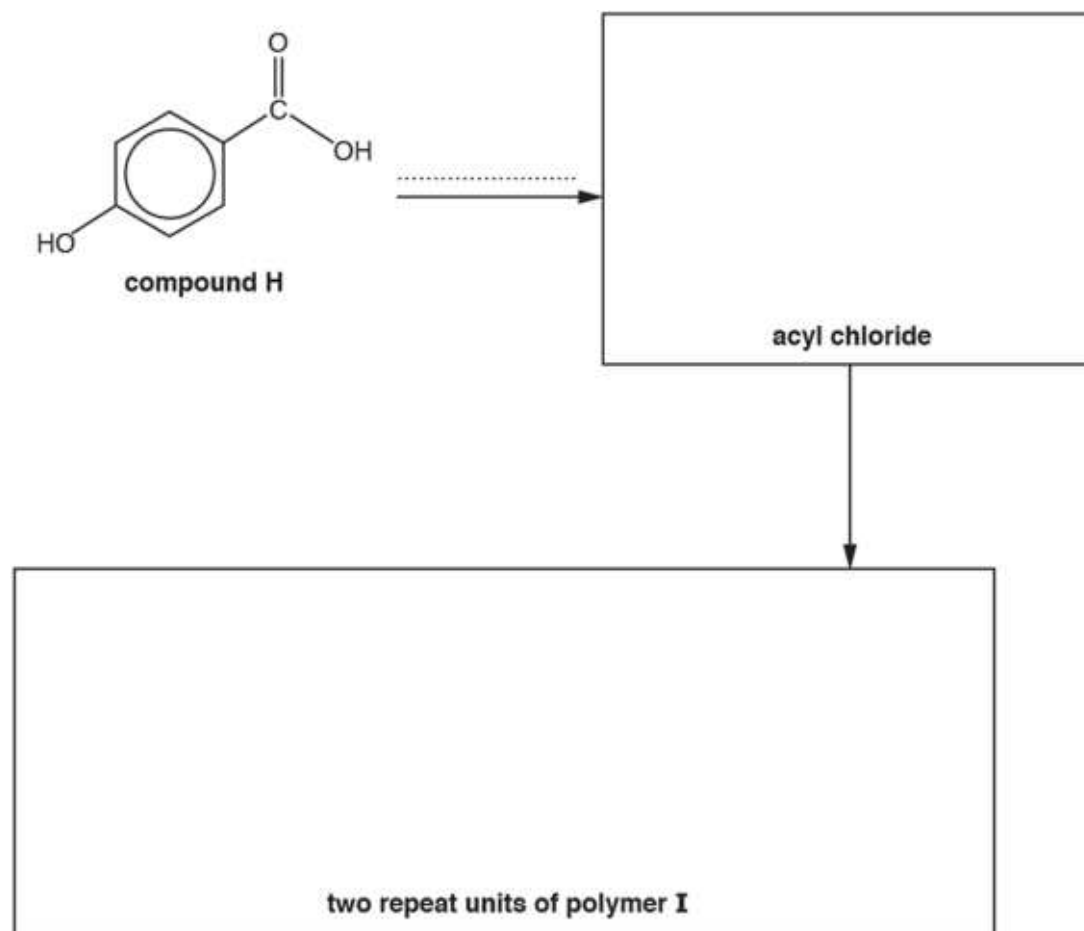
The flowchart below shows some reactions of compound H. In the boxes, draw the organic products of these reactions.



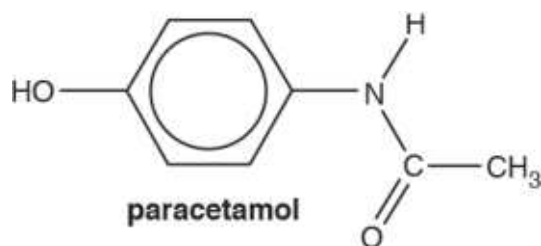
[3]

(b) 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]



(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]

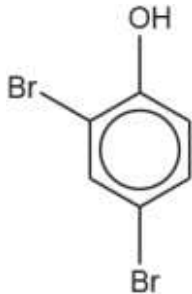
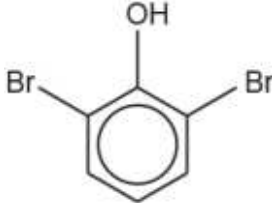
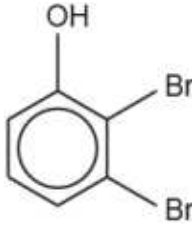
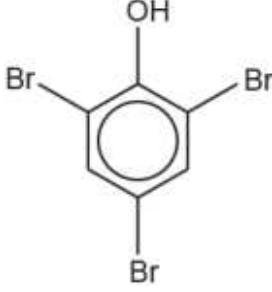
59 * Many organic reactions use electrophiles as reagents.

Explain the role of electrophiles in organic chemistry.

Your answer should include **one** reaction of an aliphatic compound and **one** reaction of an aromatic compound, including relevant mechanisms.

[6]

Which is the **least** likely organic product?

A	
B	
C	
D	

Your answer

[1]

61 A carbonyl compound is reacted with NaBH_4 .

Which compound(s) could be formed?

- 1 2-Methylpentan-2-ol
- 2 2-Methylpentan-1-ol
- 3 3-Methylpentan-2-ol

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

Your answer

[1]

62 Which chemical(s) can react with phenol?

- 1 Potassium hydroxide
- 2 Ethanoyl chloride
- 3 Nitric acid

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

Your answer

[1]

Over time, the Kekulé and delocalised models have been used to describe the bonding and structure of a benzene molecule.

- (i) Describe, in terms of orbital overlap, the similarities and differences between the bonding in the Kekulé model and the delocalised model of benzene.

[3]

- (ii) Experimental evidence led to the general acceptance of the delocalised model over the Kekulé model.

Describe **two** pieces of evidence to support the delocalised model of benzene.

[2]

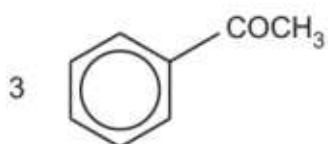
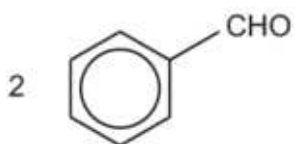
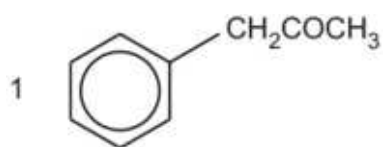
64 Which one of the following reacts with ethanoic acid **and** with phenol?

- A Aqueous potassium hydroxide
- B Bromine
- C Calcium carbonate
- D Methanol and an acid catalyst

Your answer

[1]

- 65 Which compound(s) could be prepared by reacting benzene with an acyl chloride in the presence of a halogen carrier?



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

Your answer

☐

[1]

- 66 Which of these reagent(s) will **not** react with $\text{HOCH}_2\text{CH}_2\text{CH}_2\text{COOH}$?

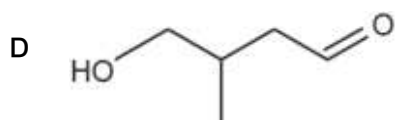
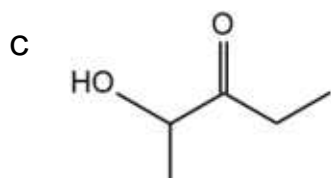
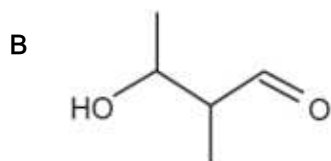
- A NaCN in ethanol
B $\text{C}_2\text{H}_5\text{OH}$ in the presence of an acid catalyst
C $(\text{CH}_3\text{CO})_2\text{O}$
D concentrated H_2SO_4

Your answer

☐

[1]

67 Which compound can be refluxed with acidified potassium dichromate (VI) to form an organic product with molecular formula $C_5H_8O_2$?



Your answer

☐

[1]

68 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.

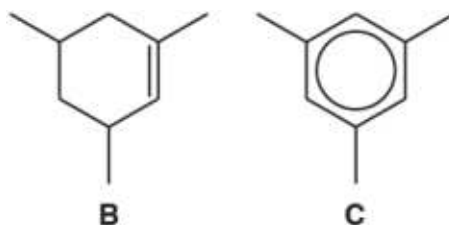
- A 1, 2 and 3
B Only 1 and 2
C Only 2 and 3
D Only 1

Your answer

☐

[1]

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



Compound **B** reacts with chlorine at room temperature, but compound **C** requires the presence of a halogen carrier.

In both reactions, the organic compound reacts with chlorine in a 1:1 molar ratio.

(i) Draw the structures of the organic product of each reaction.

Organic product with B	Organic product with C

[2]

(ii) Explain the relative resistance to chlorination of compound **C** compared with compound **B**.

----- [3]

(iii) Outline the mechanism for the reaction of compound **C** with chlorine.

Show the role of the halogen carrier.

[5]

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

$\text{HO}(\text{CH}_2)_4\text{OH}$ can be oxidised to form $\text{HOOC}(\text{CH}_2)_2\text{COOH}$.

(i) State the reagents and conditions and write an equation for this oxidation.

In the equation, use [O] for the oxidising agent.

Reagents and conditions:

Equation:

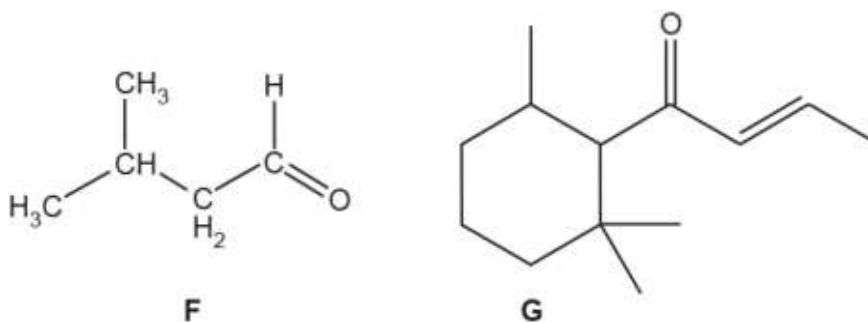
[3]

(ii) $\text{HOOC}(\text{CH}_2)_2\text{COOH}$ is soluble in water.

Explain, using a labelled diagram, why $\text{HOOC}(\text{CH}_2)_2\text{COOH}$ is soluble in water.

[2]

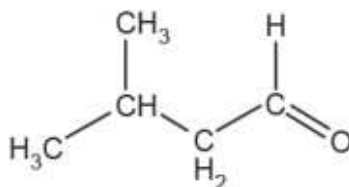
71 The carbonyl compounds, F and G, shown below, contribute to the flavour of coffee.



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]

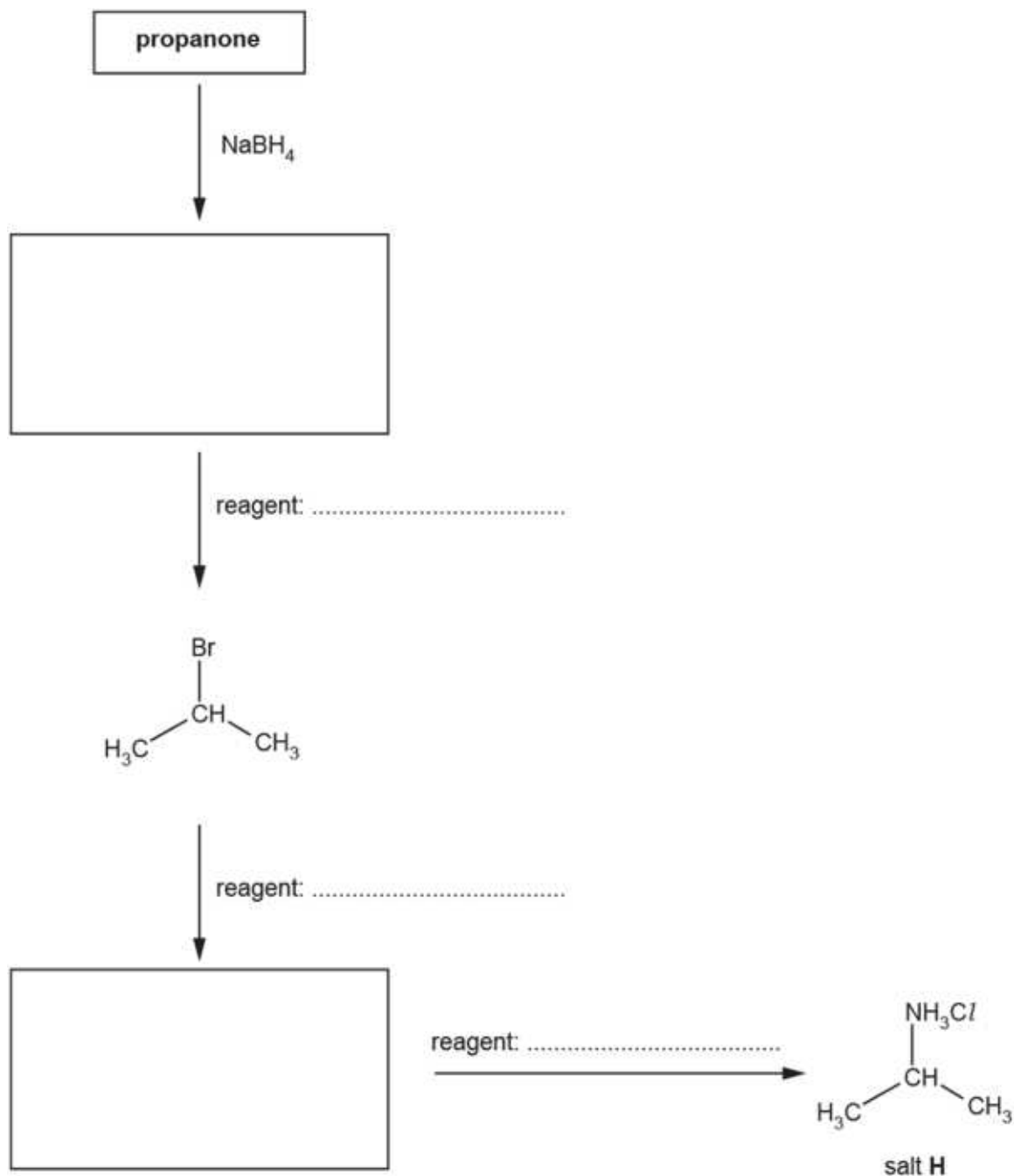
72(a) This question is about organic compounds containing nitrogen.

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.

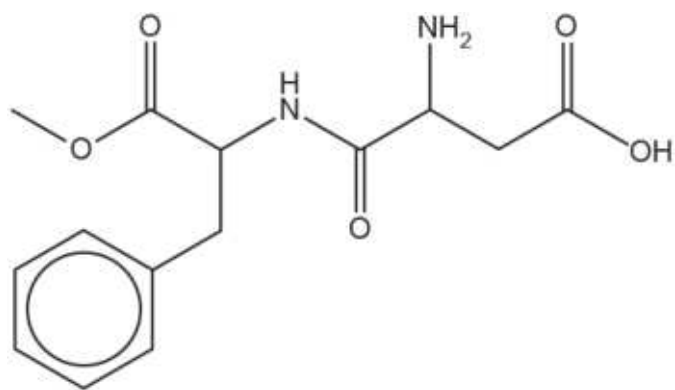
Complete the flowchart.

Show structures for organic compounds.



[5]

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



aspartame

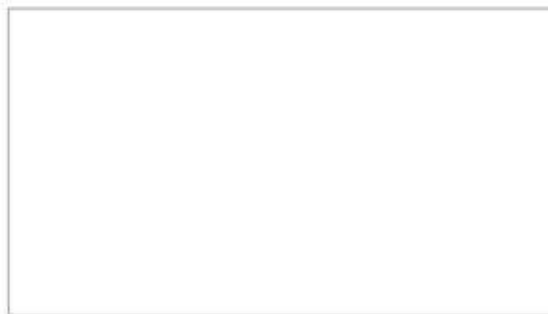
(i) Aspartame contains several functional groups.

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]

- 73 This question is about two different types of acid found in organic compounds, carboxylic acids and sulfonic acids, as shown in Fig. 6.1.

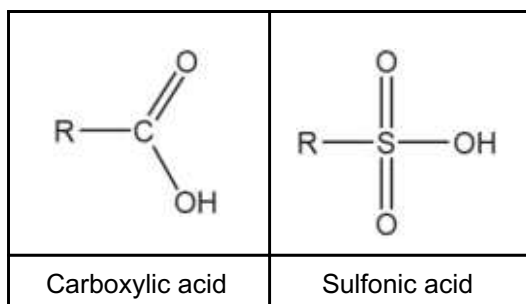
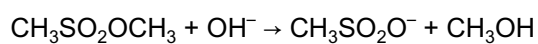


Fig. 6.1

Carboxylic acids and sulfonic acids both form esters.

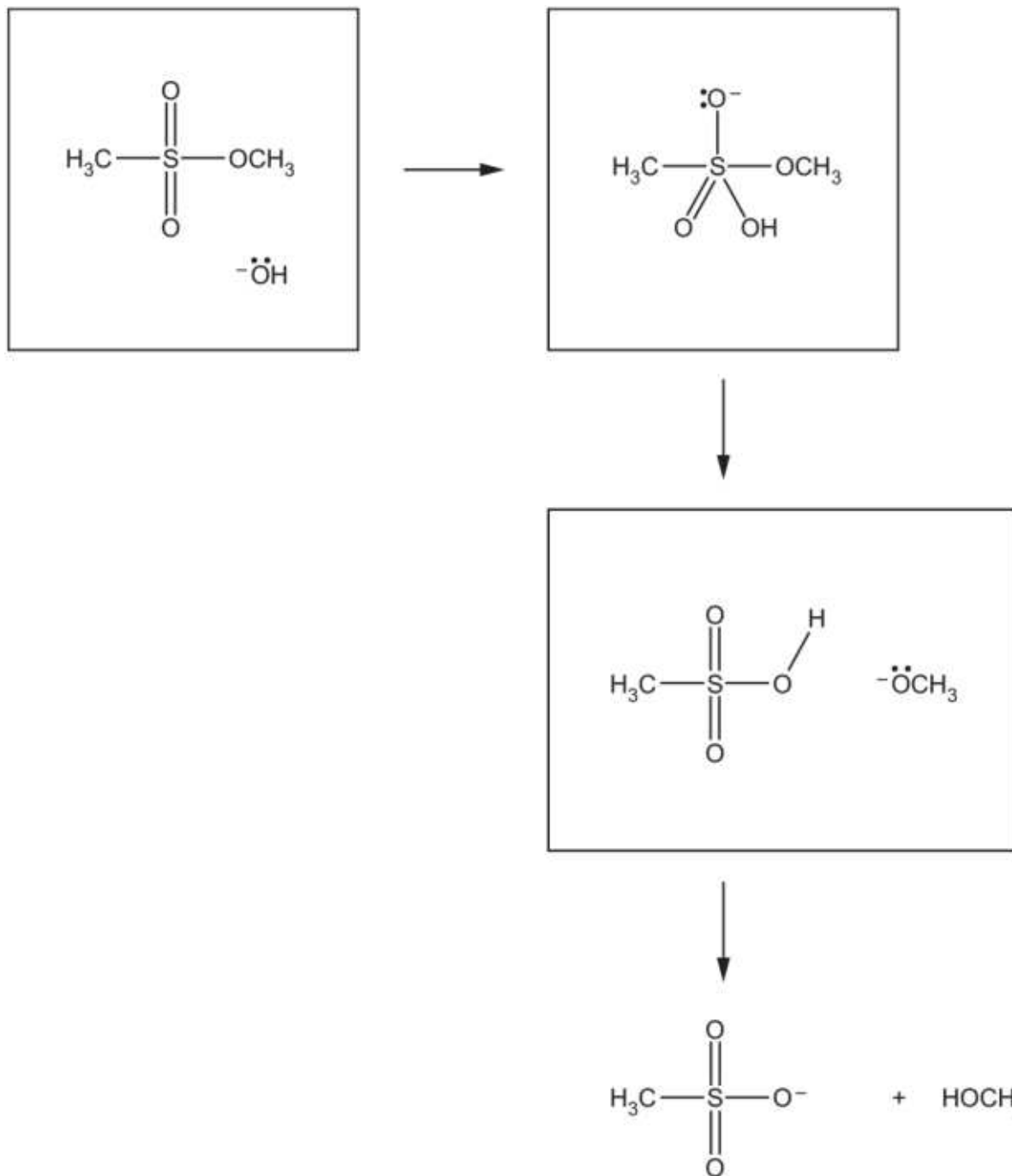
Sulfonic acid esters can be hydrolysed by aqueous alkali.

The equation shows the alkaline hydrolysis of a sulfonic acid ester.



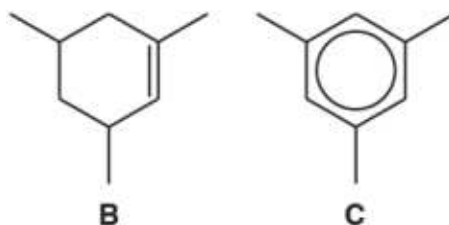
In the **3 boxes below**, add curly arrows to show the mechanism for this reaction.

In the first box, the hydroxide ion acts as a nucleophile.



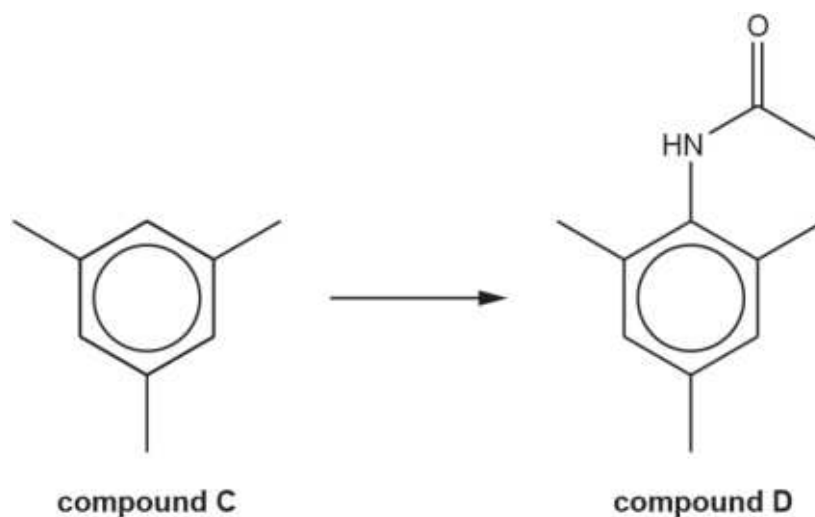
[2]

74 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**.

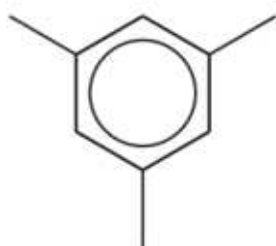
	Compound C	Compound D
Number of peaks		

[2]

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

Complete the flowchart.

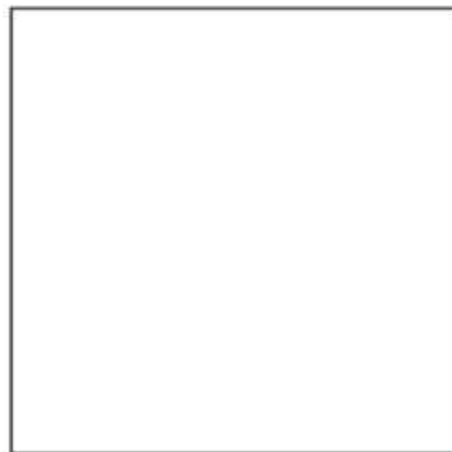
Show structures for organic compounds.



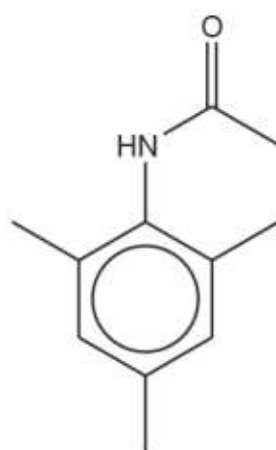
compound C

reagent:

catalyst:



1. Sn + HCl
2. Neutralise



compound D

reagent:



[5]

75 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.

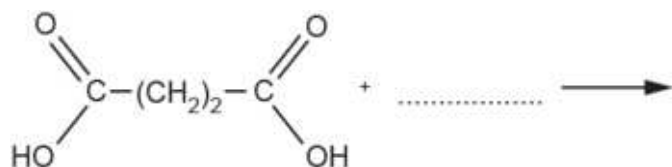
Suggest why polymer E is able to biodegrade.

[1]

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

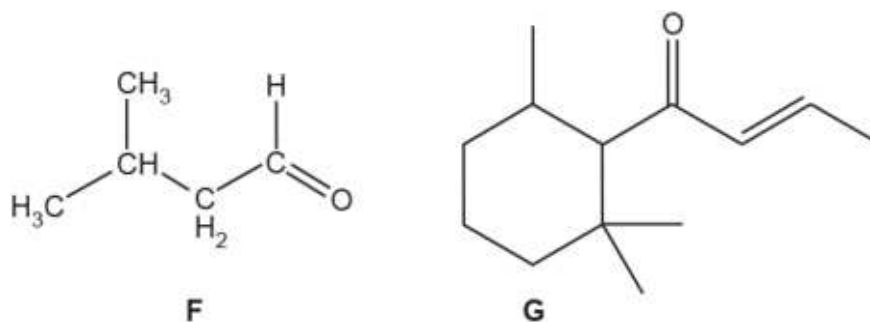
The diacyl dichloride is prepared from $\text{HOOC}(\text{CH}_2)_2\text{COOH}$.

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



[3]

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

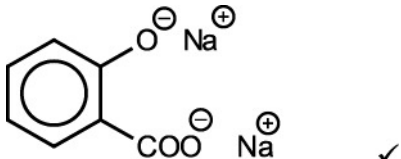
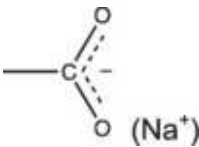


Describe suitable chemical tests, with observations, that would confirm the presence of the functional groups in F and G.

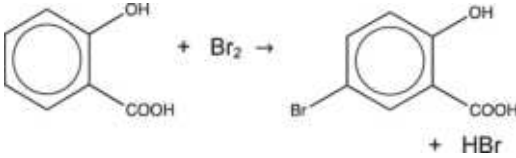
[4]

END OF QUESTION PAPER

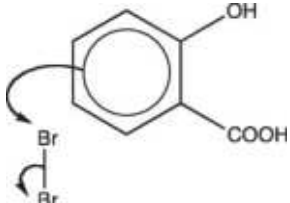
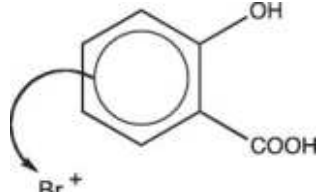
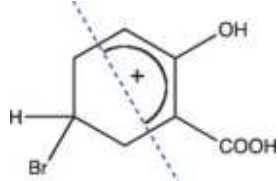
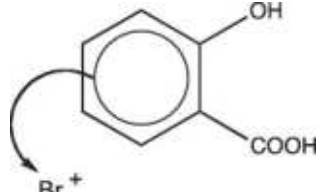
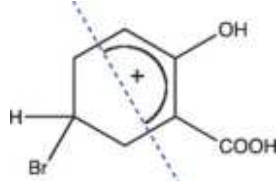
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
1	a	i		1	ALLOW correct structural OR displayed OR skeletal formulae OR combination of above as long as unambiguous DO NOT ALLOW —O—Na OR -COO-Na (covalent bond) ALLOW —O⁻ ALLOW —ONa ALLOW —COONa OR  OR  ALLOW delocalised carboxylate  Examiner's Comments The question asked for the product of the reaction with excess sodium hydroxide. Many answers included the product formed by the reaction of just one of the functional groups. Most commonly the phenol group was left unreacted. The mark scheme permitted the omission of the cation from the formula of the compound but this omission was rarely seen.

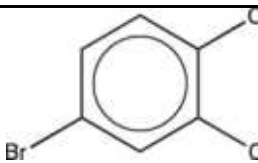
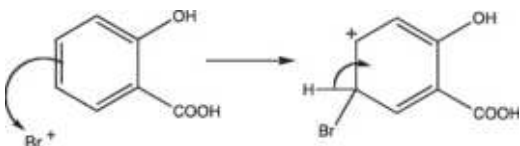
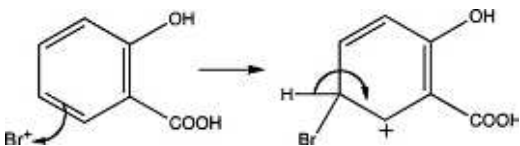
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	(Bromine) would be decolourised / turn (from orange / red / yellow / brown) to colourless OR white precipitate / solid / emulsion (formed) ✓	1	IGNORE goes clear DO NOT ALLOW other colours for bromine IGNORE cream precipitate DO NOT ALLOW salicylic acid turns colourless / decolourised IGNORE temperature / fumes Examiner's Comments The observation for the reaction of a phenol with bromine was very well known and many candidates offered two correct observations when only one was required to score the mark.
		iii	 ✓	1	ALLOW correct structural OR displayed OR skeletal formulae OR combination of above as long as unambiguous MUST be all correct to score mark ALLOW molecular formulae, i.e. $C_7H_6O_3 + Br_2 \rightarrow C_7H_5O_3Br + HBr$ Examiner's Comments A very well answered question. Most candidates copied the structural formulae given in the question. Some made errors when they unnecessarily converted the structures into molecular formulae. HBr was occasionally missing as a product.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	$(\text{CH}_3)_2\text{CHOH}$ / $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$ / propan(-)2(-)ol AND acid / H^+ / H_2SO_4 (catalyst) ✓	1	ALLOW correct structural OR displayed OR skeletal formulae OR combination of above as long as unambiguous ALLOW 2-propanol DO NOT ACCEPT incorrect name or incorrect formula of alcohol IGNORE reflux / concentrated (acid) Examiner's Comments Many candidates correctly gave the formula for propan-2-ol and included an acid catalyst. Common non-scoring answers omitted the acid or the alcohol or gave an incorrect name for the alcohol.
	b	i	 No Br_2 dipole needed Curly arrow to Br from ring OR from within the ring AND curly arrow Br-Br bond to Br ✓ -----  ----- BUT DO NOT ALLOW intermediate with π-system covering less than half of ring:  ALLOW + charge anywhere inside the 'horseshoe' Horseshoe must have open end towards Br	4	ALLOW mechanism with Br^+ electrophile (Maximum 3 marks)  IGNORE any equations involving a halogen carrier ----- BUT DO NOT ALLOW intermediate with π-system covering less than half of ring:  ALLOW + charge anywhere inside the 'horseshoe' Horseshoe must have open end towards Br

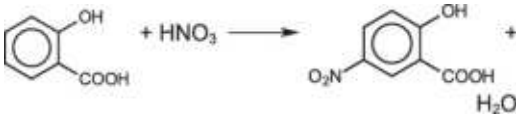
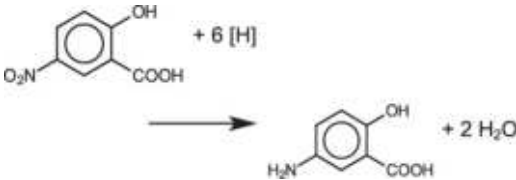
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
	 $\text{COOH} + \text{HBr} / \text{H}^+ + \text{Br}^-$ ✓ Correct products (Br⁻ may be shown in the first step)		Apply ecf to error in structure of intermediate (M2) ALLOW Kekulé mechanism as shown (Maximum 3 marks if Br⁺ is the electrophile)  ALLOW double bonds in alternate arrangement  Examiner's Comments Many fully correct and clearly structured mechanisms were seen. A proportion of candidates did not score full marks because they ignored the information in the question and based their mechanism on the Br⁺ electrophile and did not finish with HBr as a product. Relatively few candidates lost marks for incorrectly positioned curly arrows.

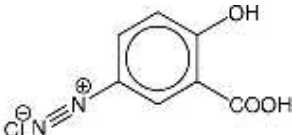
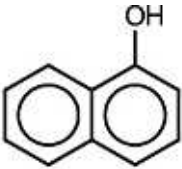
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	(In salicylic acid) lone pair / pair of electrons on O(H) / phenol is ~ (partially) delocalised into the ring ✓ electron density increases / is high ORA ✓ Br₂ / electrophile is (more) polarised ORA ✓  QWC: delocalised / delocalized / delocalise <i>etc.</i> must be spelled correctly in the correct context at least once	3	ALLOW diagram to show movement of lone pair into ring but delocalised ring must be mentioned ALLOW lone pair / pair of electrons on O(H) / phenol is (partially) drawn / attracted / pulled into delocalised ring IGNORE 'activates the ring' ALLOW more electron rich DO NOT ALLOW charge density or electronegativity ALLOW (salicylic acid) attracts electrophiles more/more susceptible to electrophilic attack ALLOW Br₂ is (more) attracted OR Br₂ is not polarised by benzene OR induces dipoles (in bromine / electrophile) Delocalise(d) needed to score the first marking point Examiner's Comments This question was very well answered with the majority of candidates scoring at least two marks. The most common errors were the omitting the words delocalised or lone pair or failure to use the word delocalised in the correct context.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	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.

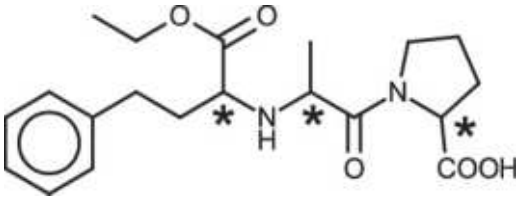
Mark Scheme

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.
			Total	18	

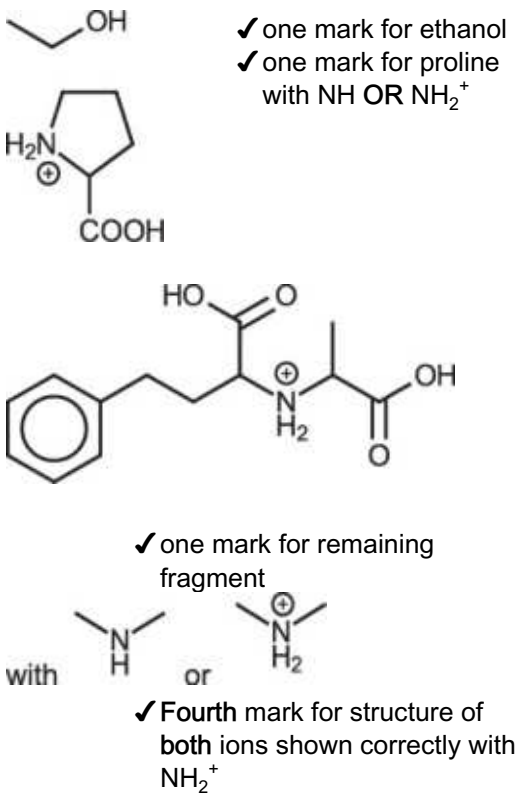
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
2	curly arrow from H^- to $\text{C}(\delta^+)$ of correct $\text{C}=\text{O}$ group ✓ dipole correct AND curly arrow from $\text{C}=\text{O}$ bond to $\text{O}(\delta^-)$ ✓ correct intermediate with negative charge on O ✓ correct product ✓	4	ALLOW correct structural OR displayed OR skeletal formulae OR combination of above as long as unambiguous First curly arrow must come from either a lone pair on H or negative charge on H IF aldehyde reduced OR both carbonyls reduced DO NOT AWARD first mark (second, third and fourth marks can be awarded ECF) IGNORE lack of $\text{C}-\text{H}$ if entirely skeletal IGNORE curly arrows in second stage Apply ecf to error in structure e.g. CH_2 missing from the chain or $-\text{COOH}$ / $-\text{COH}$ instead of $-\text{CHO}$ IGNORE other products Examiner's Comments Good candidates had no problem with this reaction mechanism. Some did not read the question carefully and reduced the wrong carbonyl group. Other errors included an incorrect starting position for the first curly arrow, the omission of a CH_2 unit from the carbon chain or changing the aldehyde functional group to a carboxyl group.
	Total	4	

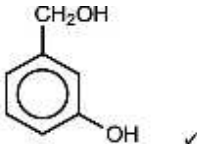
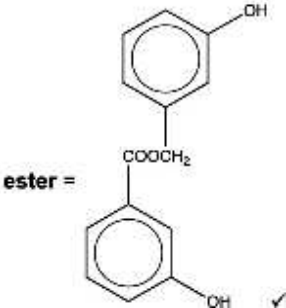
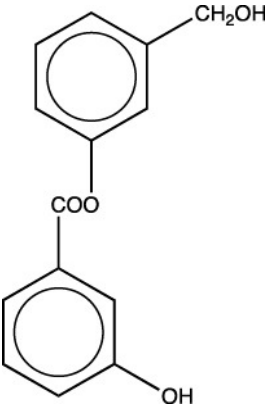
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
3		i		1	ALL correct for one mark Examiner's Comments This part was answered well by many candidates. Some missed the chiral centre on the proline moiety or added an asterisk to a carbonyl carbon.
		ii	any two from: no / fewer side effects increases the (pharmacological) activity / effectiveness 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.

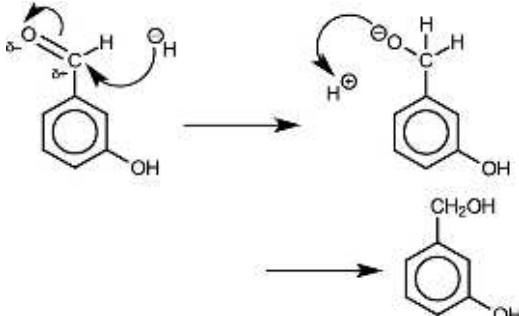
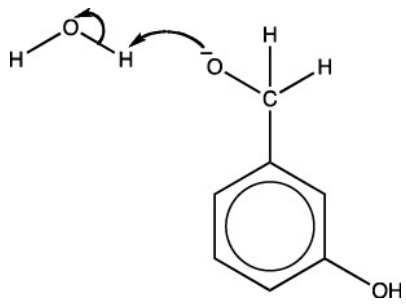
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
iii	 ✓ one mark for ethanol ✓ one mark for proline with NH OR NH₂⁺ ✓ one mark for remaining fragment with NH^+ or NH_2^+ ✓ 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.
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		8	

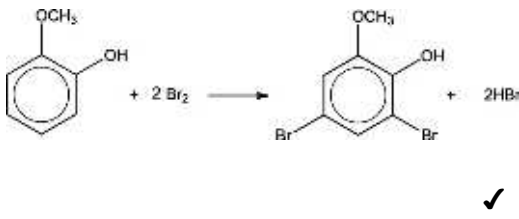
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
4 a i	reagent = $K_2Cr_2O_7$ AND H_2SO_4 ✓ compound C =  ester = 	3	ALLOW acidified dichromate ALLOW H^+ / any acid IGNORE concentration of acid ALLOW $Na_2Cr_2O_7$ / $Cr_2O_7^{2-}$ / (potassium OR sodium) dichromate(VI) ALLOW acidified MnO_4^- ALLOW Tollens' reagent / ammoniacal silver nitrate IGNORE conditions ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous ALLOW ECF from incorrect compound C Check positions of OH groups ALLOW esterification of phenol group  Examiner's Comments A well answered question. Most knew the correct reagents for the oxidation of the aldehyde and the majority were able to show the structure produced when the aldehyde is reduced using $NaBH_4$. Some chose to esterify the phenol group rather than the alcohol group in compound C and this was given credit.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
ii	curly arrow from H^- to $\text{C}^{\delta+}$ ✓ dipole AND curly arrow from $\text{C}=\text{O}$ bond to O ✓ correct intermediate AND curly arrow to H^+ ✓ 	3	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC curly arrow must come from lone pair on H or negative charge on H curly arrow must come from the bond, not the carbon atom curly arrow must come from lone pair on O or negative charge on O and go to H or positive charge on H Where circles have been placed round charges, this is for clarity only and does not indicate a requirement ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous ALLOW for second stage  IF H_2O is used it MUST show the curly arrow from the negative charge or lone pair on the oxygen atom of the intermediate to H in H_2O AND from the $\text{O}-\text{H}$ bond to the O in H_2O. Dipole not required on water molecule Penalise missing $-\text{OH}$ on intermediate only IGNORE product – already given credit in part (i) Examiner's Comments The full range of marks was seen.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					Common errors included missing charges, curly arrows beginning or ending in the wrong place and —OH groups missing or placed in the wrong position on the intermediate structure. Most candidates chose to show the reaction of the intermediate with water rather than with H ⁺ ions
	b			1	ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous ALLOW disubstitution at any positions on benzene ring Examiner's Comments Generally well answered. Some candidates reacted compound B with only one mole of bromine or three moles of bromine and this underlines the importance of paying careful attention to information given in the stem of the question. Hydrogen, not HBr, was occasionally formed as the other product.
			Total	7	

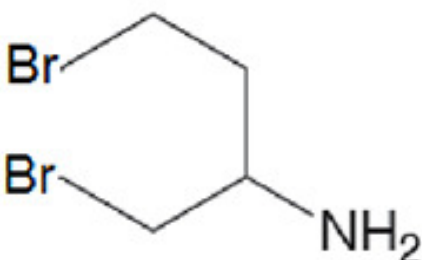
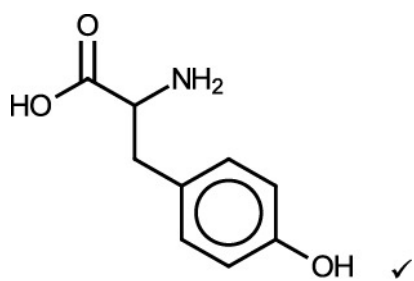
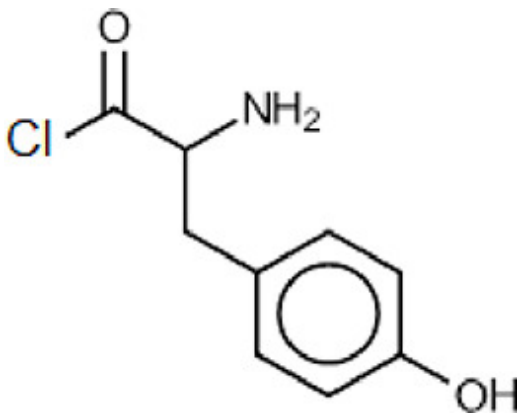
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
5	a	i	M1 p-orbitals overlap (to form pi / π-bonds) ✓ M2 π-bond(s) are delocalised in structure B ✓ M3 π-bonds are localised / between two carbons in structure A ✓ M4  Diagrams show correct position of delocalised and localised π-bonds / π-electrons OR correct position of p-orbital overlap ✓  QWC requires delocalised / delocalized spelled correctly and used in correct context	4	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC IGNORE p-orbitals overlap to form sigma bonds ALLOW electrons are delocalised in structure B IGNORE B has delocalised structure or ring (must be electrons or π-bonds) ALLOW π-electrons / p-orbital overlap localised / between two carbons in structure A ALLOW p-orbitals overlap with one other carbon IGNORE electrons are localised OR structure A has localised structure (must be π-bonds / π-electrons / p-orbital overlap) ALLOW labelled diagram showing overlap of p-orbitals between two carbon atoms DO NOT ALLOW C=C in this diagram Diagram for structure A must show the full ring for M4 IGNORE C=C in M4 diagram IGNORE charge density DO NOT ALLOW electronegativity Structures do not need to be labelled A and B if the description matches the structure Examiner's Comments Many excellent answers with clear diagrams and explanations were seen. Delocalised electrons in structure B and p-orbital overlap were the most accessible marking points.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	structure B / delocalised structure is (more) stable ✓ structure B is a better because (enthalpy change of hydrogenation for benzene is) less (exothermic) than (–) 357 (kJ mol^{–1}) ✓	2	ALLOW structure B is low in energy IGNORE structure B is less reactive ALLOW enthalpy change / hydrogenation for benzene is less (negative) than 3 × (–)119 IGNORE more positive than (–)357 kJ mol^{–1} ALLOW enthalpy change is less than 3x enthalpy change for cyclohexene ALLOW structure B is more stable by 149 kJ mol^{–1} (2 marks) DO NOT ALLOW more / less energy needed for the reaction Answer must refer to data given in the question and must be a comparison IGNORE 360 kJ mol^{–1} No marks can be awarded if structure A is selected Examiner's Comments Many used the data given in the question to compare the enthalpy of hydrogenation of structure A and structure B but relatively few candidates scored the other mark for stating that structure B is better representation of benzene because it is more stable. Some candidates confused cyclohexene with structure A and incorrectly concluded that the hydrogenation of benzene is more exothermic than structure A. Some incorrectly referred to enthalpy of hydration or stated that energy is required for the reaction. Others referred to data they had memorised rather than using the information in the question as instructed.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b		$(\text{CH}_3)_2\text{CHBr} + \text{FeBr}_3 \longrightarrow (\text{CH}_3)_2\text{CH}^+ + \text{FeBr}_4^-$	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.
	c	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 

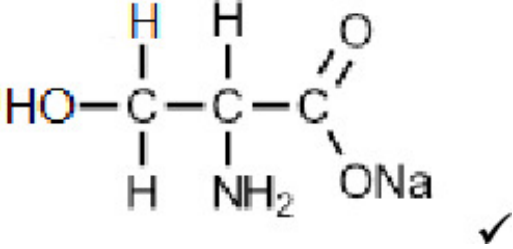
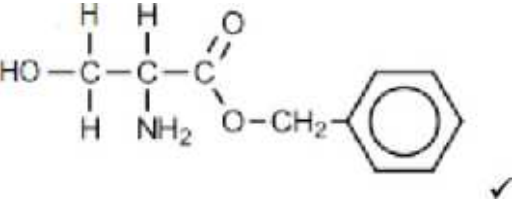
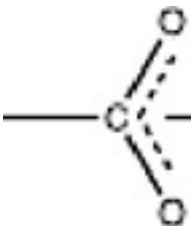
Mark Scheme

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 $108/346 \times 1.73 = 0.54 \text{ g}$ $0.54/40 \times 100 = 1.35 \text{ g}$ 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	16	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
6	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.
			Total	7	

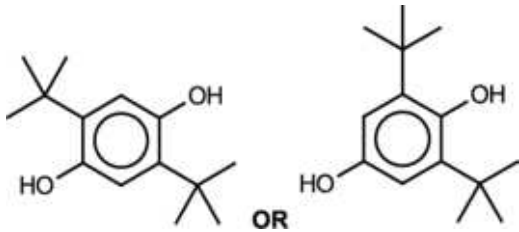
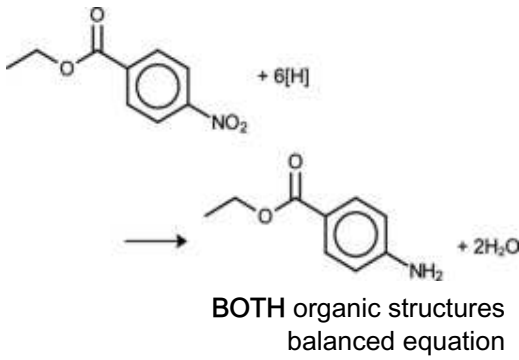
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
7		i	$2\text{C}_2\text{H}_5\text{COOH} + \text{Na}_2\text{CO}_3 \rightarrow 2\text{C}_2\text{H}_5\text{COONa} + \text{CO}_2 + \text{H}_2\text{O}$ ✓	1	IGNORE state symbols and use of equilibrium sign FOR $\text{CO}_2 + \text{H}_2\text{O}$ ALLOW H_2CO_3 ALLOW $\text{C}_2\text{H}_5\text{COO}^-\text{Na}^+$ OR $\text{C}_2\text{H}_5\text{COO}^- + \text{Na}^+$ BUT BOTH + and – charges must be shown ALLOW $\text{NaC}_2\text{H}_5\text{COO}$ Examiner's Comments Equations for reactions of weak acids continue to improve. Ionic signs within the formula of sodium propanoate were allowed but both were then needed. Common errors included an incorrect formula of sodium propanoate, usually $(\text{CH}_3\text{CH}_2\text{COO})_2\text{Na}$, sodium carbonate as NaCO_3 or an equation with correct species but unbalanced. Candidates are recommended to carefully check the formulae for missing atoms.
		ii	$\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}$ ✓	1	ALLOW $\text{C}_2\text{H}_5\text{COOH} + \text{OH}^- \rightarrow \text{C}_2\text{H}_5\text{COO}^- + \text{H}_2\text{O}$ IGNORE state symbols Examiner's Comments The required equation using $\text{H}^+(\text{aq})$ and $\text{OH}^-(\text{aq})$ was commonly seen but a significant number of candidates wrote an equation using $\text{H}^+(\text{aq})$ and $\text{CO}_3^{2-}(\text{aq})$, perhaps writing an ionic equation for the reaction in (i) rather than a different reaction.
			Total	2	
8			D	1	
			Total	1	
9			B	1	
			Total	1	
10			C	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
11			B	1	
			Total	1	
12			D	1	
			Total	1	
13			A	1	
			Total	1	
14			D	1	
			Total	1	

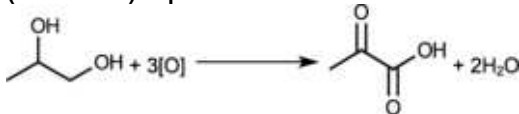
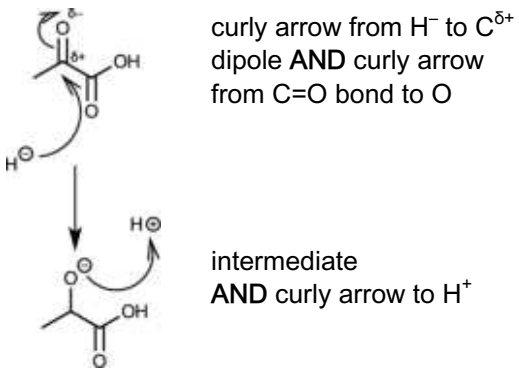
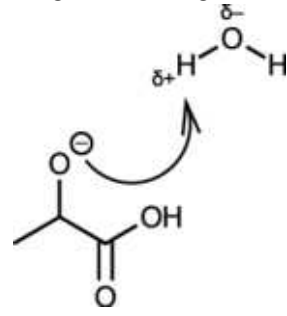
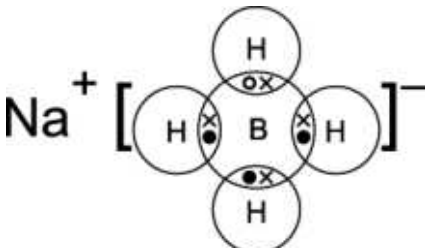
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
15	a	i		1	ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous ALLOW disubstituted compound with <i>tert</i>-butyl groups adjacent
		ii	(The student's friend is correct because) the lone pair of electrons on the oxygen atom(s) is donated to / partially delocalised into the π system making quinol more susceptible to electrophilic attack	3	ALLOW "the oxygen p-orbital overlaps with..." ALLOW diagrammatic answer for 1st and 2nd marks: 1st mark: π system OR 6 $\times$ p orbitals shown 2nd mark: O lone pair OR O p-orbital AND interaction ALLOW undergoes electrophilic substitution more easily if 1st and 2nd marks achieved through diagram, conclusion must refer to diagram for 3rd mark
	b	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	7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
16	a		Enter text here.		
		i	Product from reaction 1: $\begin{array}{c} \text{H} \\ \\ \text{CH}_3(\text{CH}_2)_2 - \text{C} - \text{COOH} \\ \\ \text{CH}_3\text{COO} \end{array}$ Product from reaction 2: $\begin{array}{c} \text{Br} \\ \\ \text{CH}_3(\text{CH}_2)_2 - \text{C} - \text{COOH} \\ \\ \text{H} \end{array}$	2	ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous.
		ii	(E)-pent-2-enoic acid	1	ALLOW "E" with or without brackets
		iii	compound H = $\begin{array}{c} \text{CH}_3\text{CH}_2 \quad \text{COOH} \\ \diagdown \quad \diagup \\ \text{C} = \text{C} \\ \diagup \quad \diagdown \\ \text{H} \quad \text{H} \end{array}$ $\begin{array}{c} \text{CH}_3\text{CH}_2 \quad \text{H} \\ \quad \\ -\text{C} - \text{C}- \\ \quad \\ \text{H} \quad \text{COOH} \end{array}$	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>
		iv	combustion for energy production use as an organic feedstock for the production of plastics and other organic chemicals	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b	i	Oxidising agent = acidified (potassium / sodium) dichromate(VI) (Oxidation) equation  (Reduction) mechanism  curly arrow from H^- to $\text{C}^{\delta+}$ dipole AND curly arrow from $\text{C}=\text{O}$ bond to O intermediate AND curly arrow to H^+	5	ALLOW $\text{Cr}_2\text{O}_7^{2-}$ OR $\text{K}_2\text{Cr}_2\text{O}_7$ OR $\text{Na}_2\text{Cr}_2\text{O}_7$ for dichromate ALLOW H^+ OR (conc.) sulfuric acid for "acidified" ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous  ALLOW for second stage IF H_2O is used it MUST show the curly arrow from the intermediate to $\text{H}^{\delta+}$ in H_2O AND from the $\text{O}-\text{H}$ bond to the O IGNORE product IGNORE stereochemistry of intermediate
		ii	 $\text{Na}^+ [\text{BH}_4]^-$ $1s^2 2s^2 2p^6$	2	IGNORE inner electron shells for both ions Three different symbols required to identify electrons from different elements DO NOT ALLOW $[\text{Ne}]$ OR $[\text{He}] 2s^2 2p^6$
Total				14	

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
17	a	<i>* Please refer to the marking instruction point 10 for guidance on how to mark this question.</i> Level 3 (5–6 marks) Correctly labelled diagram of apparatus that works, with no safety problems AND Full appreciation of further two steps required to gain pure sample <i>There is a well-developed diagram which is clear and structured. The information on further purification is detailed and relevant.</i> Level 2 (3–4 marks) Labelled diagram of apparatus but with safety / procedural problems OR clear diagram of functional apparatus without labelling AND Some details of further purification steps <i>The diagram presents apparatus that is in the most-part relevant with some correct labelling, and supported by some details of further purification steps.</i> Level 1 (1–2 marks) Diagram of apparatus drawn with no labelling OR labelled diagram with significant safety / procedural problems AND Few or imprecise details about further purification stages <i>The diagram is basic and unstructured. Any mention of purification steps is limited to generic term, e.g. 'drying', without relevant detail.</i> 0 marks No response or no response worthy of credit.	6	Indicative scientific points may include: Diagram Includes following components: distillation flask heat source thermometer at outlet (bulb level with outlet) still-head water condenser (correct direction of water flow) receiving vessel open system. Further purification Shake and leave to settle in a separating funnel Separate layers by tapping off Add (a small amount of) anhydrous magnesium sulfate / anhydrous calcium chloride to organic layer (in a dry conical flask) (Re)distil the organic layer Collect fraction distilling at (between 150 °C and) 156 °C.
	b	Lack of (further) effervescence	1	ALLOW fizzing / bubbling stops

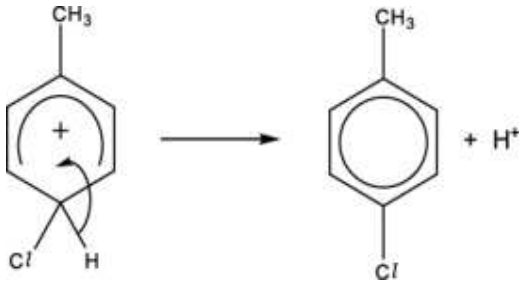
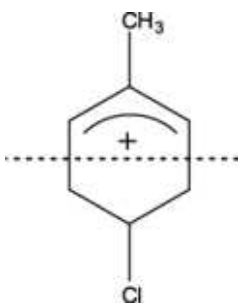
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c		Take samples from reaction mixture at regular intervals Spot / run on a TLC plate, alongside cyclohexanol (and cyclohexanone) controls	2	ALLOW "frequent" for "regular" ALLOW measure / compare R_f value to cyclohexanol IGNORE reference to solvent or visualising chemicals / UV
	d		React (sample of distillate) with 2,4-dinitrophenylhydrazine recrystallise AND determine the melting point Compare melting point to known / library value for cyclohexanone (derivative)	3	ALLOW (2,4-)DNPH / Brady's reagent
			Total	12	
18			B	1	
			Total	1	
19			D	1	
			Total	1	
20			B	1	
			Total	1	
21			D	1	
			Total	1	
22			B	1	
			Total	1	
23			A	1	
			Total	1	

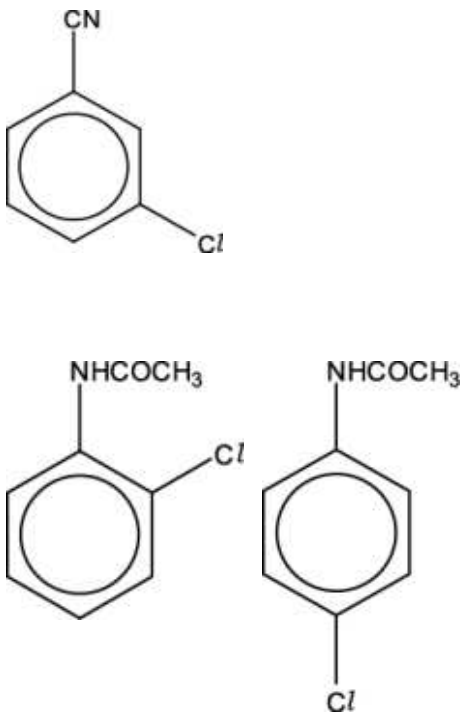
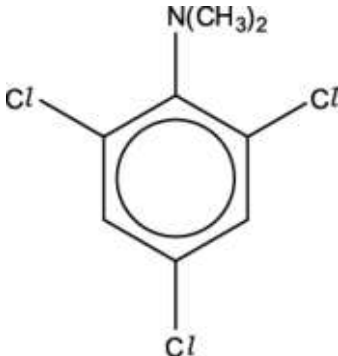
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
24	a		Experimental evidence – ANY TWO from carbon–carbon bond lengths are the same in benzene Enthalpy change of hydrogenation is less (exothermic) for benzene (than for Kekulé model) Discussion of named reaction to highlight greater stability, e.g. chlorination of benzene requires a catalyst whereas no catalyst is needed for alkenes Bonding in modern model p-orbitals overlap to form π bonds (π)–electrons are delocalised	4	ALLOW both marks for correctly labelled diagrams showing overlap of p-orbitals to form delocalised π–electrons

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
b	Generation of electrophile $\text{AlCl}_3 + \text{Cl}_2 \rightarrow \text{AlCl}_4^- + \text{Cl}^+$ Electrophilic substitution Curly arrow from π-bond to Cl^+  Correct intermediate Curly arrow back from C-H bond to reform π-ring AND H^+ as product  Regeneration of catalyst $\text{H}^+ + \text{AlCl}_4^- \rightarrow \text{AlCl}_3 + \text{HCl}$	5	ANNOTATE ANSWER WITH TICKS AND CROSSES DO NOT ALLOW the following intermediate:  π-ring must be more than 1/2 way down AND 'horseshoe' the right way, <i>i.e.</i> gap towards C with Cl ALLOW + sign anywhere inside the 'hexagon' of intermediate

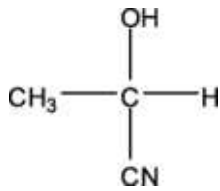
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	i	 3-chlorobenzonitrile N-(3-chlorophenyl)acetamide N-(4-chlorophenyl)acetamide	3	IGNORE names throughout DO NOT ALLOW poly-substituted products DO NOT ALLOW 2-chloro or 4-chloro products DO NOT ALLOW 3-chloro product
		ii	 1-(3,4,5-trichlorophenyl)N,N-dimethanimine	1	

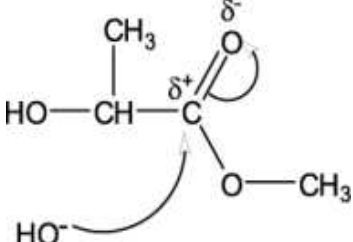
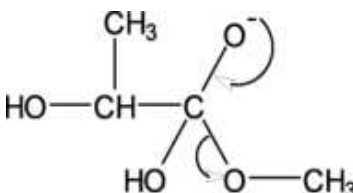
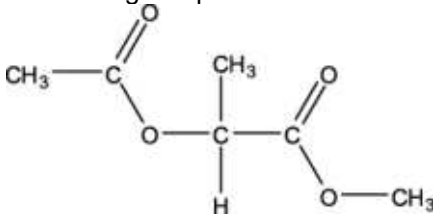
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	(In $\text{C}_6\text{H}_5\text{N}(\text{CH}_3)_2$) (lone) pair of electrons on N is (partially) delocalised into the ring electron density increases / is higher (than in benzene) ORA Cl_2 / electrophile is (more) polarised ORA	3	ALLOW diagram to show movement of lone pair into ring but delocalised ring must be mentioned ALLOW lone pair of electrons on N is (partially) drawn / attracted / pulled into delocalised ring DO NOT ALLOW charge density or electronegativity ALLOW Cl_2 is (more) attracted OR Cl_2 is not polarised by benzene OR induces dipoles (in chlorine / electrophile)
			Total	16	

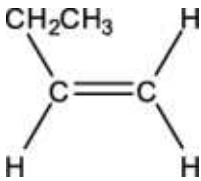
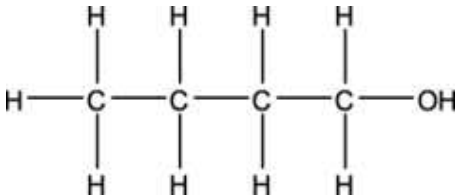
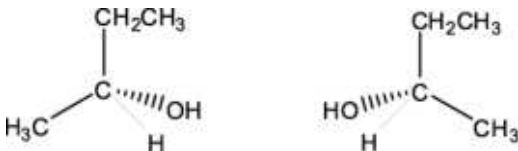
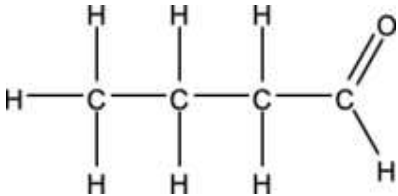
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
25	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	

Mark Scheme

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	

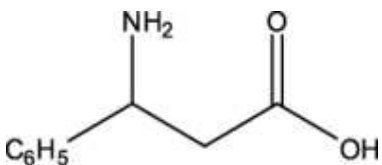
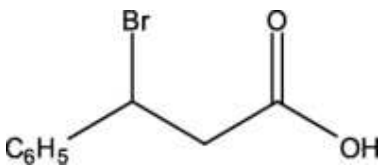
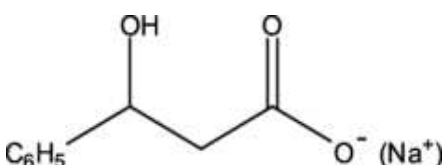
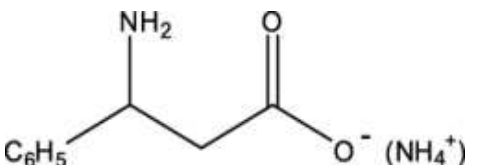
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
26 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

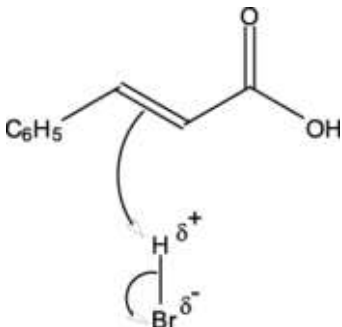
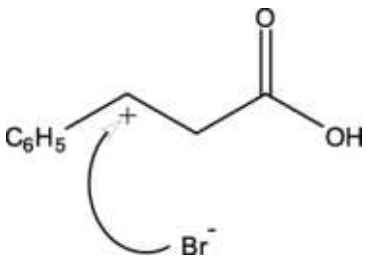
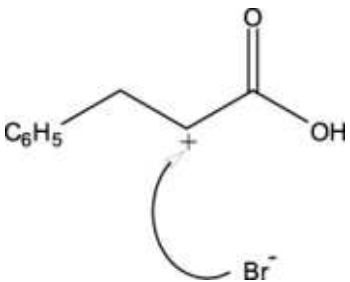
Mark Scheme

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	

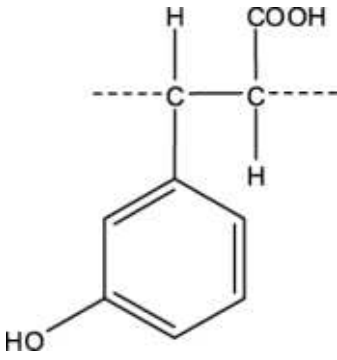
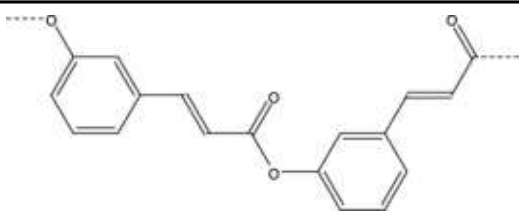
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
27	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 

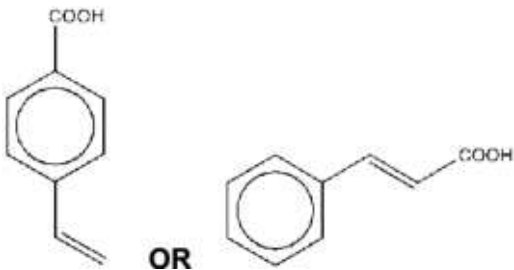
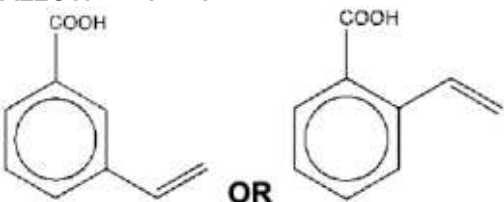
Mark Scheme

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)
			Total	10	
28			π bonds in benzene are delocalised	1	
			Total	1	

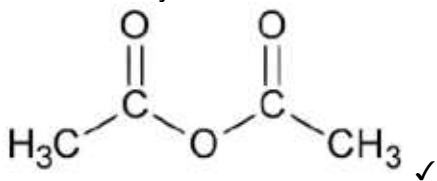
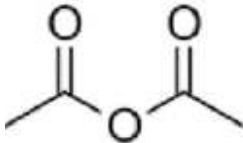
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
29	a	i	reaction with bases: neutralisation AND reaction with metals: redox	1	Enter text here.
		ii	correctly calculates $n(\text{A}) = \frac{1.125}{90} = 0.0125 \text{ (mol)}$ $\text{volume of H}_2 = \frac{0.0125}{2} \times 24,000 = 150 \text{ cm}^3$ units required	2	ALLOW 0.15 dm ³ ALLOW ECF from $n(\text{A})$
		iii	C ₆ H ₁₂ O ₆ Mg	1	DO NOT ALLOW (C ₃ H ₆ O ₃) ₂ Mg
		iv	Type of reaction of COOH: e.g. esterification AND reagents and conditions e.g. CH ₃ OH AND H ₂ SO ₄ Organic product of COOH reaction Type of reaction of –OH AND reagents and conditions Organic product of –OH reaction	4	ALLOW esterification with any stated alcohol e.g. product from CH ₃ OH/H ₂ SO ₄ → CH ₃ (CHOH)COOCH ₃ Many possible reactions of secondary alcohol possible, e.g. oxidation with K ₂ Cr ₂ O ₇ / H ₂ SO ₄ + heat → CH ₃ (CO)COOH elimination with H ₂ SO ₄ / H ₃ PO ₄ + heat → CH ₂ = CHCOOH esterification with CH ₃ COOH / H ₂ SO ₄ OR CH ₃ COC/ → CH ₃ (CHOOCCH ₃)COOH bromination with NaBr / H ₂ SO ₄ → CH ₃ (CHBr)COOH ALLOW self-polymerisation as reaction for either group (if another reaction example given) condensation polymerisation with H ₂ SO ₄ → [OCH(CH ₃)CO] _n

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b		Electrophilic substitution means benzene ring Electrophilic addition means alkene / C=C Isomer of C₉H₈O₂ containing C=C, benzene ring AND COOH Correct isomer:  justification in terms of number of carbon environments	5	Concluded using data provided and conclusions from 1st two marks. ALLOW 1 mark for:  (does not gain final justification mark)
			Total	13	
30			C₁₇H₃₅COOH + NaOH → C₁₇H₃₅COO⁻Na⁺ + H₂O ✓	1	ALLOW C₁₇H₃₅COONa IGNORE state symbols Examiner's Comments Very well answered. Most candidates could write the correct equation.
			Total	1	

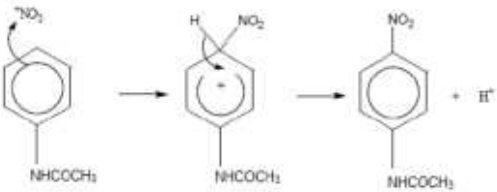
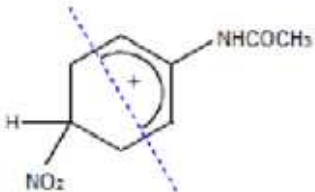
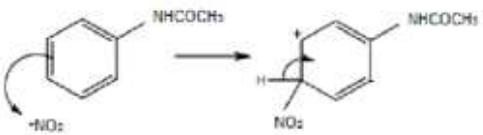
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
31		i	<u>Ethanoic anhydride</u>  <u>Other organic compound</u> CH₃COOH ✓	2	ALLOW skeletal formula  ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous IGNORE names Examiner's Comments The structure of ethanoic anhydride was well known and most candidates gave the correct structure for the other organic product of the reaction.

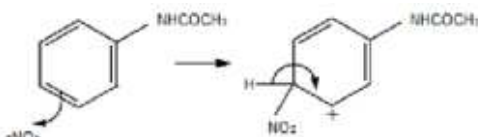
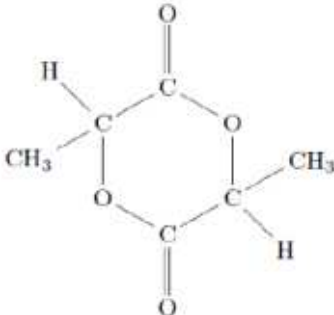
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = 2.66 (g) award 3 marks IF answer = 4.36 (g) award 2 marks (% yield not used) IF answer = 7.14 (g) award 2 marks (% yield used incorrectly) $n(\text{phenylamine}) = (3.00/93.0) = 0.0323 \text{ mol}$ ✓ $n(\text{compound A}) = (0.0323 \times 0.61) = 0.0197 \text{ mol}$ ✓ Mr (compound A) = 135 AND Mass of compound A = $(135)(0.0197) = 2.66 \text{ g}$ ✓ OR $n(\text{phenylamine}) = (3.00/93.0) = 0.0323 \text{ mol}$ ✓ Mr (compound A) = 135 AND Theoretical mass of compound A = $(0.0323 \times 135) = 4.36$ ✓ Actual mass of compound A = $(4.36 \times 0.61) = 2.66 \text{ g}$ ✓	3	ANNOTATE WITH TICKS AND CROSSES ETC. ALLOW 3 SF: 0.0323 up to calculator value of 0.032258064 correctly rounded ALLOW 3 SF up to calculator value Penalise rounding to 2 SF once ALLOW ECF on incorrectly rounded values Final answer must be expressed to 3 significant figures ALLOW ecf from incorrect Mr IF answer = 2.65 (g) award 2 marks unless this alternative method is used (3 marks) 93 g gives 135 g 3.00 g gives $135/93 \times 3.00 = 4.35 \text{ g}$ $4.35 \times 0.61 = 2.65 \text{ g}$ Examiner's Comments Once again it was clear that candidates had been well prepared for this type of percentage yield question. It was well answered with almost all candidates scoring some marks here and a high proportion gaining all three marks for the calculation.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
iii	M1 $\text{H}_2\text{SO}_4 + \text{HNO}_3 \rightarrow \text{HSO}_4^- + \text{H}_2\text{O} + \text{NO}_2^+ \checkmark$ M2 curly arrow from π ring OR from within the ring to $^+\text{NO}_2 \checkmark$  M3 correct intermediate (with charge) $\checkmark$ M4 curly arrow from C-H to reform ring AND correct products $\checkmark$	5	ANNOTATE WITH TICKS AND CROSSES ETC. Equation to show formation of the electrophile ALLOW $2\text{H}_2\text{SO}_4 + \text{HNO}_3 \rightleftharpoons \text{HSO}_4^- + \text{H}_3\text{O}^+ + \text{NO}_2^+$ ALLOW $\text{H}_2\text{SO}_4 + \text{HNO}_3 \rightleftharpoons \text{HSO}_4^- + \text{H}_2\text{NO}_3^+$ AND $\text{H}_2\text{NO}_3^+ \rightleftharpoons \text{H}_2\text{O} + \text{NO}_2^+$ Penalise missing or incorrect $-\text{NHCOCH}_3$ on intermediate only (M3) DO NOT ALLOW intermediate with the π-system covering less than half the ring  ALLOW + charge anywhere inside the 'horseshoe' Horseshoe must have open end towards NO_2 ALLOW Kekulé mechanism  OR

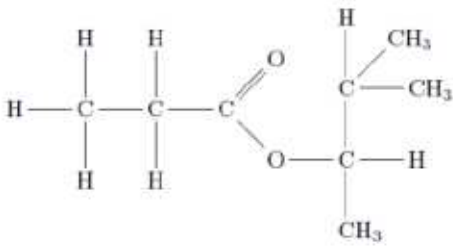
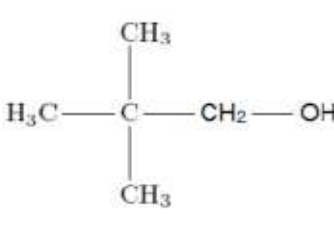
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			M5 Regeneration of the catalyst: $\text{H}^+ + \text{HSO}_4^- \rightleftharpoons \text{H}_2\text{SO}_4$ ✓		 ALLOW $\text{H}_3\text{O}^+ + \text{HSO}_4^-$ $\rightleftharpoons \text{H}_2\text{SO}_4 + \text{H}_2\text{O}$ Examiner's Comments Although some lost marks through minor errors on the details, most candidates scored well on this question
			Total	10	
32			 ✓	1	ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous Examiner's Comments A good discriminator. Many failed to produce the correct cyclic structure.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
33	a		<u>Reducing agent</u> NaBH_4 / sodium tetrahydridoborate(III) / sodium borohydride ✓ <u>Equation</u> $\text{CH}_3(\text{CH}_2)_3\text{CHO} + 2[\text{H}] \rightarrow \text{CH}_3(\text{CH}_2)_3\text{CH}_2\text{OH}$ ✓	1	ALLOW LiAlH_4/lithium tetrahydridoaluminate(III)/lithium aluminium hydride ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above ALLOW $\text{C}_4\text{H}_9\text{CHO} + 2[\text{H}] \rightarrow \text{C}_5\text{H}_{11}\text{OH}$ ALLOW molecular formulae: $\text{C}_5\text{H}_{10}\text{O} + 2[\text{H}] \rightarrow \text{C}_5\text{H}_{12}\text{O}$ DO NOT ALLOW $-\text{COH}$ for aldehyde Examiner's Comments Very well answered. The most common error was an incorrect formula for the aldehyde.
	b		M1 Compound F structure is a secondary alcohol with the formula $\text{C}_5\text{H}_{11}\text{OH}$ ✓ M2 Compound F $= \text{CH}_3\text{CH}(\text{OH})\text{CH}(\text{CH}_3)\text{CH}_3$ ✓ M3 Compound G = $\text{CH}_3\text{COCH}(\text{CH}_3)\text{CH}_3$ ✓ M4 $n(\text{NaOH}) = (0.125 \times 22.8/1000) =$	7	ANNOTATE WITH TICKS AND CROSSES ETC ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous IGNORE names if structures are given ALLOW 3-methylbutan-2-ol if structure not given ALLOW ECF from an incorrect secondary alcohol for M3 e.g. pentan-2-ol → pentan-2-one e.g. pentan-3-ol → pentan-3-one ALLOW (3-)methylbutanone if structure not given IGNORE any discussion of the reactions of compound G with 2,4-dinitrophenylhydrazine and/or Tollens' reagent. ALLOW 3 SF up to calculator value correctly rounded

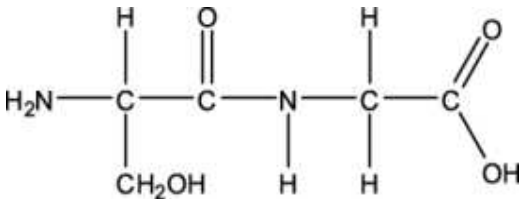
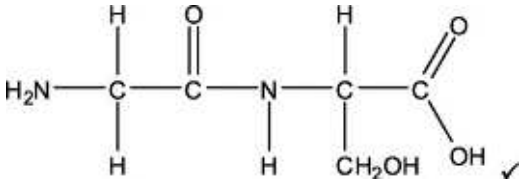
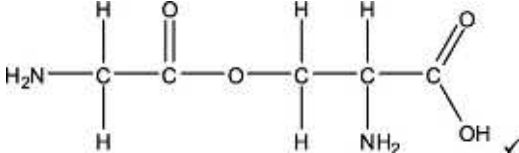
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			0.00285 (mol) ✓ M5 M(compound H) = (0.211/0.00285 =) 74(.0) (g mol⁻¹) ✓ M6 Compound H = / CH₃CH₂COOH ✓ M7 Compound I =  ✓		IF M(compound H) = 74 award 2 marks (M4 + M5) ALLOW ECF from incorrect calculation of amount of NaOH ALLOW propanoic acid if structure not given ALLOW ECF from incorrect compound F (alcohol) and/or incorrect compound H (carboxylic acid) to form compound I (ester). Compounds F, G, H and I must be placed in the correct box or correctly labelled for M2, M3, M6 and M7 Examiner's Comments A high scoring question with many candidates gaining full marks. Although most realised that Compound F was a secondary alcohol, fewer candidates combined this knowledge with the information provided by carbon-13 NMR to deduce the correct structure of the secondary alcohol.
	c		The structural isomer is:  ✓	1	ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous ALLOW 2,2-dimethylpropan-1-ol Examiner's Comments A good discriminator but many correct structures were seen.
			Total	10	
34			D	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
35			A	1	
			Total	1	
36			C	1	
			Total	1	
37			D	1	
			Total	1	

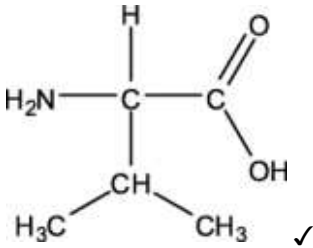
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
38	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

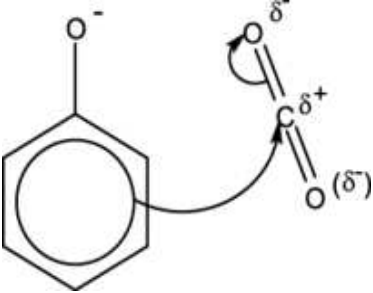
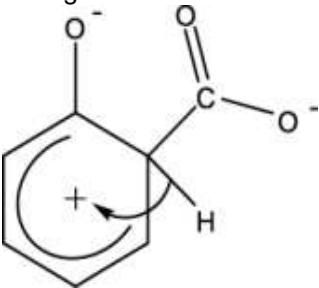
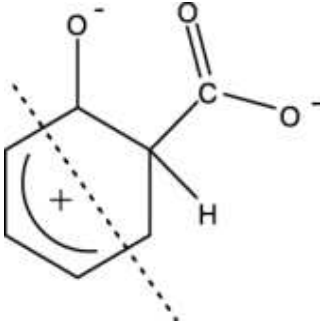
Mark Scheme

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} \\ \\ \text{COOH} \end{array} $ ✓ 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} \\ \\ \text{COOH} \end{array} $ ✓ 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 \quad \\ \text{COOCH}_3 \quad \text{OCH}_3 \end{array} $ ✓✓	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 \quad \\ \text{COOH} \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 \quad \\ \text{COOCH}_3 \quad \text{OH} \end{array} $

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Molar mass of G = $\frac{3.51}{0.0300} = 117(.0) \text{ (g mol}^{-1}\text{)}$ ✓ Structure of G 	6	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous ALLOW R (group of G) is $-\text{CH}(\text{CH}_3)_2$ if structure of amino acid is not given
			Total	12	

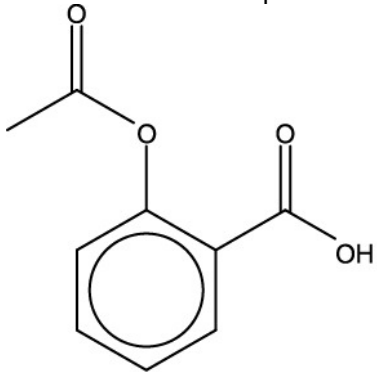
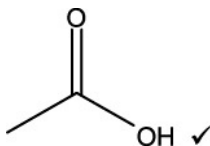
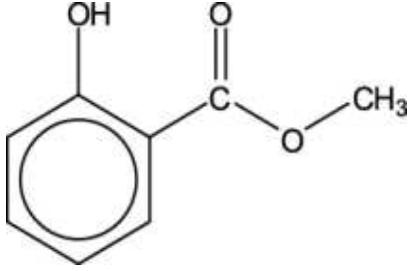
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
39 a i	Dipole shown on C=O bond, C^{δ+} and O^{δ-}, AND curly arrow from the C=O bond to the O^{δ-} atom AND Curly arrow from π-bond to C in CO₂ ✓  Correct intermediate ✓ Curly arrow back from C-H bond to reform π-ring ✓ 	3	ANNOTATE ANSWER WITH TICKS AND CROSSES DO NOT ALLOW the following intermediate:  π-ring must cover more than 1/2 of the ring AND 'horseshoe' in the correct orientation, <i>ie</i> gap towards C with COO⁻ ALLOW + sign anywhere inside the 'hexagon' of intermediate
	ii Neutralisation ✓ (In Stage 1) phenol loses H⁺ AND (In Stage 3) carboxylate ion gains H⁺ ✓	2	ALLOW acid-base ALLOW both Stage 1 AND Stage 3 involve proton transfer

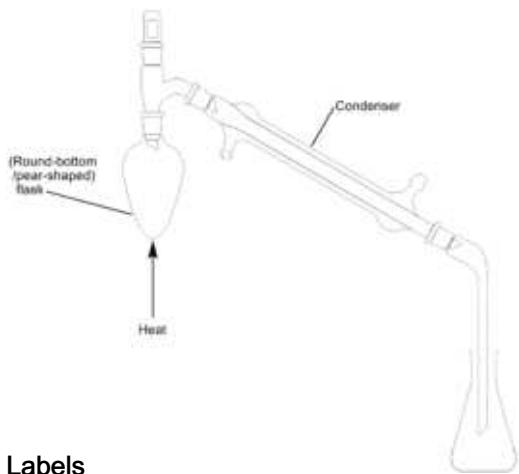
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	FIRST CHECK THE ANSWER ON THE ANSWER LINE IF answer = 7.31 (g) award 3 marks actual $n(\text{salicylic acid}) \text{ produced} = \frac{4.83}{138} = 0.035(0) \text{ (mol)} \checkmark$ theoretical $n(\text{phenol}) = n(\text{salicylic acid}) = 0.035(0) \times \frac{100}{45.0} = 0.0778 \text{ (mol)} \checkmark$ Mass of phenol = $0.0778 \times 94.0 = 7.31 \text{ (g)}$ ✓	3	ANNOTATE ANSWER WITH TICKS AND CROSSES ALLOW ECF at each stage ALLOW 3 SF up to calculator value correctly rounded for intermediate values 100 ALLOW expected mass compound E $= 4.83 \times \frac{100}{45.0} = 10.733 \text{ (g)}$ ALLOW Mass phenol reacted = $0.035 \times 94.0 = 3.29 \text{ (g)}$ ALLOW Mass of phenol used = $3.29 \times \frac{100}{45.0} = 7.31 \text{ (g)}$ Note: 1.48 g would get 2 marks <i>(use of 45.0/100 instead of 100/45.0)</i> 7.30 g would get 2 marks <i>(use of 0.0777 for moles phenol)</i>

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b		Skeletal formula of aspirin  Skeletal formula of ethanoic acid 	2	IF skeletal formulae are not used ALLOW one mark if both the structures of aspirin AND ethanoic acid are correct IGNORE names
	c	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

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		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	13	

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
40	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
41	a	i	Reagent and observation sodium carbonate AND Fizzing/effervescence/bubbling ✓ Equation Correctly balanced equation ✓ e.g. $2\text{RCOOH} + \text{Na}_2\text{CO}_3 \rightarrow 2\text{RCOONa} + \text{CO}_2 + \text{H}_2\text{O}$	2	Note: both reagent and observation are required for first mark ALLOW name or formula for any suitable carbonate e.g. NaHCO_3, potassium carbonate etc. ALLOW reagent from equation if not stated elsewhere
		ii	Reagent and observation Tollens' (reagent) AND Silver (mirror) ✓ Equation $\text{RCHO} + [\text{O}] \rightarrow \text{RCOOH}$ ✓	2	Note: both reagent and observation are required for first mark ALLOW ammoniacal silver nitrate OR Ag^+/NH_3 ALLOW $\text{H}^+/\text{Cr}_2\text{O}_7^{2-}$ OR acidified (potassium/sodium) dichromate AND Orange to green (<i>this would identify the aldehyde from the carboxylic acid, ketone and esters</i>)
	b		2,4-dinitrophenylhydrazine AND Orange/yellow/red precipitate ✓	1	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
	c	i	$\text{CH}_3\text{COOC}(\text{CH}_3)_3 + \text{NaOH} \rightarrow \text{CH}_3\text{COONa} + (\text{CH}_3)_3\text{COH}$ CH_3COONa ✓ Rest of equation correct ✓ OR $(\text{CH}_3)_3\text{CCOOCH}_3 + \text{NaOH} \rightarrow (\text{CH}_3)_3\text{CCOONa} + \text{CH}_3\text{OH}$ $(\text{CH}_3)_3\text{CCOONa}$ ✓ Rest of equation correct ✓	2	Note: the hydrolysis of either ester may be given ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous DO NOT ALLOW molecular formulae of products (<i>question requires structures of products to be shown</i>)

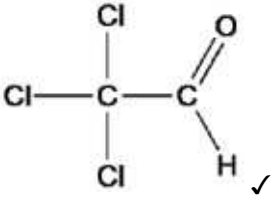
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Reagent and observation $\text{H}^+/\text{Cr}_2\text{O}_7^{2-}$ OR acidified (potassium/sodium) dichromate AND Orange to green (with CH_3OH) ✓ Equation $\text{CH}_3\text{OH} + [\text{O}] \rightarrow \text{HCHO} + \text{H}_2\text{O}$ OR $\text{CH}_3\text{OH} + 2[\text{O}] \rightarrow \text{HCOOH} + \text{H}_2\text{O}$ ✓	2	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous DO NOT ALLOW molecular formulae <i>(question requires structures of organic compounds to be shown)</i>
		iii	^{13}C NMR (1 mark) (It is) not possible to identify (the esters) with ^{13}C NMR AND (both) spectra would contain four peaks (with similar chemical shifts) ✓ ^1H NMR (2 marks) (It is) possible to identify (the esters) with ^1H NMR (^1H NMR spectrum of) $\text{CH}_3\text{COOC}(\text{CH}_3)_3$ has a singlet/peak between 2.0–3.0 (ppm) (^1H NMR spectrum of) $(\text{CH}_3)_3\text{CCOOCH}_3$ has a singlet/peak between 3.0–4.3 (ppm) All three correct statements ✓✓ Any two correct statements ✓	3	ALLOW 'same number of peaks' in place of 'four peaks' ALLOW any value or range of values within 2.0–3.0 ALLOW any value or range of values within 3.0–4.3

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d		<u>Possible structures for ketone (2 marks)</u> $\begin{array}{c} \text{O} \\ \parallel \\ \text{CH}_3 - \text{C} - \text{CH}_2\text{CH}_2\text{CH}_3 \end{array}$ $\begin{array}{c} \text{O} \\ \parallel \\ \text{CH}_3\text{CH}_2 - \text{C} - \text{CH}_2\text{CH}_3 \end{array}$ $\begin{array}{c} \text{O} \\ \parallel \\ \text{CH}_3 - \text{C} - \text{CH} - \text{CH}_3 \\ \\ \text{CH}_3 \end{array}$ All three correct ✓✓ Any two correct ✓ <u>Aldehyde (3 marks)</u> Peak at (δ) 1.2 shows HC–R AND No H on adjacent C atom as peak is singlet ✓ Peak at (δ) 9.6 shows H–C=O AND No H on adjacent C atom as peak is singlet ✓ $\begin{array}{c} \text{CH}_3 \quad \text{O} \\ \quad \parallel \\ \text{H}_3\text{C} - \text{C} - \text{C} - \text{H} \\ \\ \text{CH}_3 \end{array}$ OR (2,2-)dimethylpropanal ✓	5	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous IGNORE names of ketones
			Total	17	

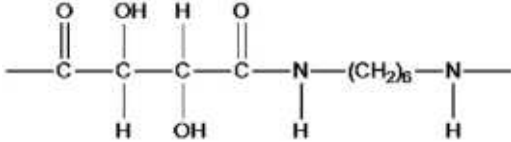
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
42		i		1	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous
		ii	Any organic reaction in which sulfuric acid is a catalyst e.g: Elimination of (H₂O from) alcohols Nitration of benzene Esterification Hydrolysis of esters/amides	1	The answer needs to refer to the reaction: i.e. 'Elimination', 'hydrolysis' are insufficient but 'Esterification' describes the reaction DO NOT ALLOW oxidation for alcohols/ aldehydes
			Total	2	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
43	a		<i>Please refer to marking instructions on page 4 of mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) A comprehensive analysis of the information available with through explanations linked to the evidence. Acid C identified as a tricarboxylic acid with a tertiary –OH group and the correct molecular formula of C₆H₈O₇. <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) Analysis of the information available but explanations may be incomplete or there may be mistakes in calculations, although the method may be sound. <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) A simple analysis of the information available and limited explanations which may or may not be explicitly linked to the evidence. <i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i> 0 marks – No response worthy of credit.	6	Indicative scientific points may include Identification of functional groups • Tribasic acid → three –COOH groups <i>From 1 mol C requires 3 mol NaOH</i> • Tertiary alcohol <i>From no colour change with hot acidified dichromate(VI)</i> Determination of molecular formula of C $M(C) = \frac{2.323}{1.21 \times 10^{-2}} = 192 \text{ (g mol}^{-1}\text{)}$ <i>From 1.21 × 10⁻² mol C has a mass of 2.323 g.</i> • 192 – 3 × 45 (3 × COOH) – 16 (O) = 41 41 → C₃H₅ (<i>or evidence of working</i>) • Molecular formula = C₆H₈O₇ Structure of citric acid • 4 peaks in ¹³C NMR → 4 types of carbon • Correct structure of C matching evidence. $\begin{array}{c} \text{COOH} \\ \\ \text{HOOC}-\text{CH}_2-\text{C}-\text{CH}_2-\text{COOH} \\ \\ \text{OH} \end{array}$ NOTE: Structure below match all evidence except for ¹³C NMR. See Level 3 criteria. $\begin{array}{c} \text{COOH} \\ \\ \text{HO}-\text{C}-\text{CH}_2-\text{CH}_2-\text{COOH} \\ \\ \text{COOH} \end{array} \quad \begin{array}{c} \text{COOH} \\ \\ \text{HOOC}-\text{C}-\text{CH}-\text{COOH} \\ \quad \\ \text{OH} \quad \text{CH}_3 \end{array}$
	b	i	C ₂ H ₃ O ₃ ✓	1	

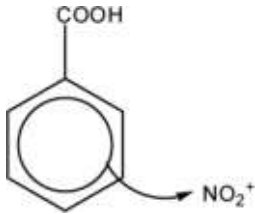
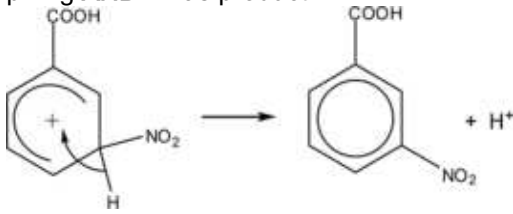
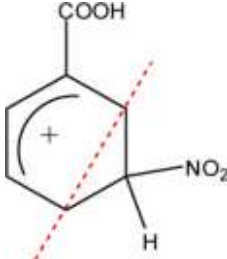
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		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 <i>n</i>
		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	12	
44			D	1	Examiner Comments In contrast to question 9, this proved to be the most difficult of the multiple choice questions for candidates who frequently gave B, ethanoic acid as their answer. The correct answer, D, an acyl chloride reacts with water to produce acidic fumes of HCl which are soluble in water and a carboxylic acid.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
45			A	1	Examiner Comments Candidates across the whole ability range appeared to find the question equally challenging. The common incorrect answer B, resulted from a failure to use the information that equal moles of acid were reacted with equal moles of alkali to produce an equal number of moles of water.
			Total	1	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
46 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

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	<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

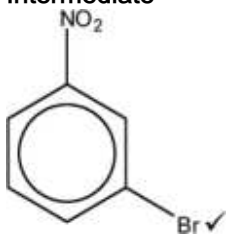
Mark Scheme

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					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	Phenol is the most easily nitrated/most reactive AND Benzoic acid is the least easily nitrated/least reactive ✓	1	Response must give rank order of reactivity e.g. nitration becomes more difficult from phenol (to benzene) to benzoic acid OR nitration becomes easier from right to left in the table Examiner Comments The vast majority of candidates gave a good answer to indicate that it was easier to carry out the nitration of phenol than benzene and that benzene would undergo nitration easier than benzoic acid.
		ii	Reactivity of phenol a (lone) pair of electrons on O is (partially) delocalised/donated into the p-system/ring Reactivity of benzoic acid The –COOH group on benzoic acid is an electron withdrawing group ✓ Links electron density in p-bond to reactivity In phenol electron density is higher AND The ring is more susceptible to attack OR In benzoic acid electron density is lower AND The ring is less susceptible to attack ✓	3	ANNOTATE ANSWER WITH TICKS AND CROSSES ALLOW the electron pair in the p orbitals of the O atom becomes part of the p-system / ring ALLOW diagram to show movement of lone pair into ring ALLOW lone pair of electrons on O is (partially) drawn/attracted/pulled into p-system / ring IGNORE activating and deactivating. ALLOW the following alternatives for susceptibility to attack: - phenol attracts electrophiles / NO_2^+ more - phenol polarises electrophiles / NO_2^+ more - benzoic acid attracts electrophiles / NO_2^+ less - benzoic acid polarises electrophiles / NO_2^+ less

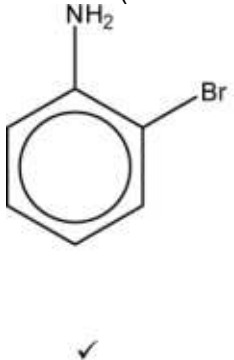
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					Examiner Comments The most able candidates scored well on what proved a difficult question for many. Although the vast majority of candidates knew about the reasons behind phenol's increased reactivity many were unable to express themselves clearly to gain credit. Often answers lacked the specific detail about the lone pair on the oxygen atom in the -OH group being delocalised into the ring. Weaker answers discussed electrons being supplied to the ring, the -OH group providing the electrons to the ring or just that -OH is an activator. Good answers expressed the increase in electron density and the subsequent increase in phenol's susceptibility to electrophilic attack. The most able candidates were able to interpret the information given in the question to establish that the -COOH group must be electron withdrawing leading to decreased electron density of the ring structure and reduced ability to react with electrophiles.

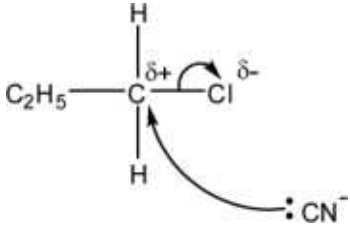
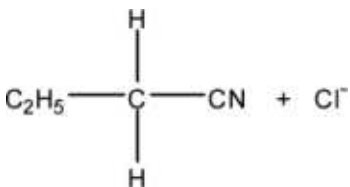
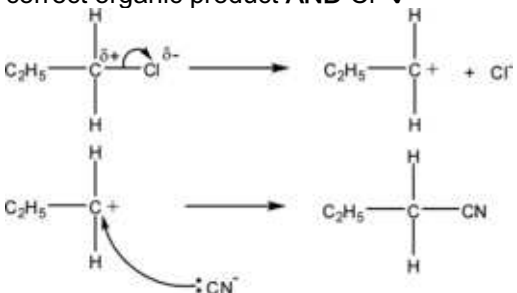
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	c	i	Bromination: Br₂ AND A/Br₃/FeBr₃/Fe ✓ Intermediate  Reduction: Sn AND (concentrated) HC/ ✓	3	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous ALLOW any suitable halogen carrier catalyst ALLOW Kekulé structure 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.

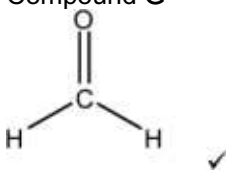
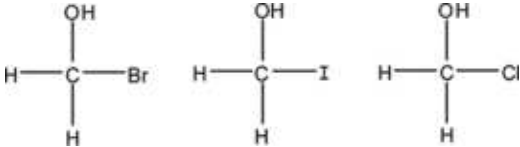
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		ii	NH₂ is 2,4 directing ✓ Products (1 mark for each):  	3	IGNORE references to electron donating/withdrawing groups ALLOW –NH₂ activates the ring causing the new group to join at positions 2 and 4. ALLOW ortho and para directing for 2,4 directing 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	21	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
47	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.

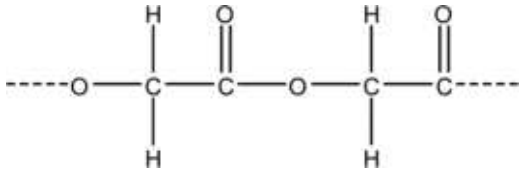
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		ii	Compound G  Reagents Reaction 2: H₂ AND Ni ✓ Reaction 3: Correct formula of an aqueous acid e.g. HCl(aq)/H₂SO₄(aq) ✓	3	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous IGNORE name(s) ALLOW  ALLOW any 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.

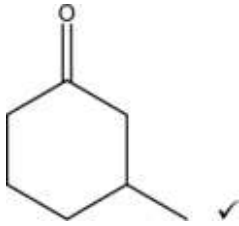
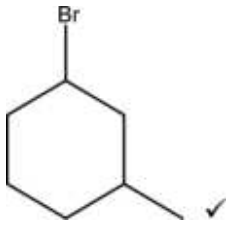
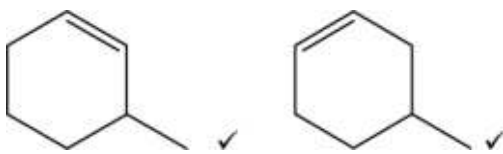
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	iii Explanation Nitrogen electron pair OR nitrogen lone pair AND accepts a proton / H^+ ✓ Structure of salt $ \begin{array}{c} \text{OH} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{NH}_3^+ \\ \quad \\ \text{H} \quad \text{H} \end{array} $ AND Cl^- ✓	2	IGNORE NH_2 group donates electron pair ALLOW nitrogen donates an electron pair to H^+ DO NOT ALLOW nitrogen donates lone pair to acid IGNORE comments about the O in the $-\text{OH}$ 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} $ <i>i.e. charges not required</i> 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.

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		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.
			Total	11	

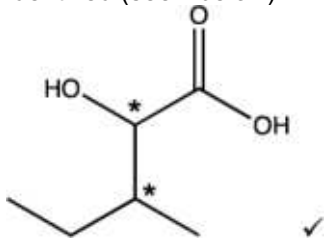
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48		i	Starting material from reduction reaction  Reagent for reduction NaBH₄ ✓ Product from reaction with NaBr/H₂SO₄  Structural isomers 	5	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous Watch for missing methyl groups IGNORE H⁺ / acid or H₂O or ethanol ALLOW sodium borohydride OR sodium tetrahydridoborate ALLOW LiAlH₄ ALLOW in either order Examiner Comments There were many good answers to this synthesis question with about 40% of the cohort scoring full marks. The structure of the carbonyl and the reagent needed for reduction were well known by a majority of candidates however some reacted the alcohol group with sodium bromide to obtain –O[–]Na⁺ for the second structure. Weaker candidates did not realise that an alcohol could be dehydrated and thus failed to be awarded the final two marks.
		ii	3-methylcyclohexanol ✓	1	ALLOW 3-methylcyclohexan-1-ol ALLOW 1-methylcyclohexan-3-ol IGNORE lack of hyphens, or addition of commas Examiner Comments Just over half of candidates managed to name the structure as 3-methylcyclohexanol. The most common errors included 3-methylphenol, 3-methylcyclichexanol and 3-methylhexanol.
			Total	6	

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Question			Answer/Indicative content	Marks	Guidance														
49	a	i	<i>Burette readings</i> <table><tr><td>Final (reading) /cm³</td><td>23.15</td><td>45.95</td><td>32.45</td><td rowspan="2">✓</td></tr><tr><td>Initial (reading) /cm³</td><td>0.60</td><td>23.15</td><td>10.00</td></tr></table> • Correct titration results recorded with initial and final readings, clearly labeled AND all readings recorded to two decimal places with last figure either 0 or 5 <i>Titres</i> <table><tr><td>Titre / cm³</td><td>22.55</td><td>22.80</td><td>22.45</td><td>✓</td></tr></table> • Correct subtractions to obtain final titres to 2 DP <i>Units</i> • Units of cm³ for initial, final and titres ✓ <i>Mean titre</i> • mean titre = $\frac{22.55 + 22.45}{2} = 22.50$ OR 22.5 cm³ ✓ <i>i.e. using concordant (consistent) titres</i>	Final (reading) /cm ³	23.15	45.95	32.45	✓	Initial (reading) /cm ³	0.60	23.15	10.00	Titre / cm ³	22.55	22.80	22.45	✓	4	Table not required ALLOW initial reading before final reading ALLOW ECF ALLOW units with each value ALLOW brackets for units, i.e. (cm³) ALLOW ECF from incorrect concordant titres Examiner’s Comment: This question should have been four straightforward marks, but it was actually found very challenging by candidates. Most read the scales correctly but then did not present their findings clearly, often scattering unlabelled numbers around, omitting units with absence of any heading linking them to the burettes. 0.60 was very often shown as 0.6 and 22.80 as 22.8. Candidates were expected to take the mean of their closest titres but a significant
Final (reading) /cm ³	23.15	45.95	32.45	✓															
Initial (reading) /cm ³	0.60	23.15	10.00																
Titre / cm ³	22.55	22.80	22.45	✓															

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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 $\times \frac{250}{22.50}$

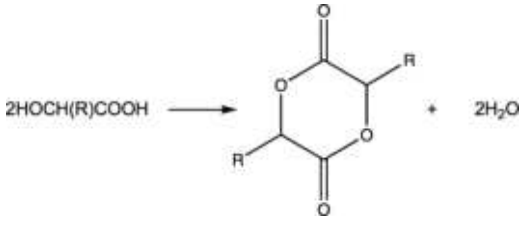
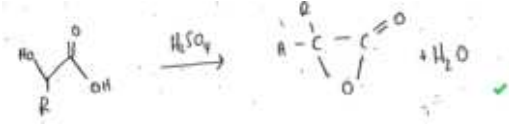
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					$2.10 \times 10^{-3} \rightarrow 2.33 \times 10^{-2} \checkmark$ $\rightarrow 106.93 \checkmark \rightarrow 31.93 \checkmark \rightarrow \text{C}_2\text{H}_5 \checkmark$ No structure with 2 chiral centres possible. Examiner's Comment: Most candidates 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.

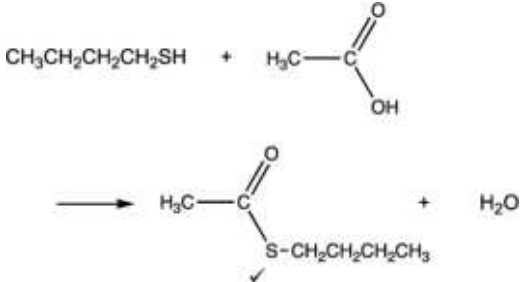
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	b	i	<i>Equation</i> $2\text{HOCH(R)COOH} + \text{Mg} \rightarrow (\text{HOCH(R)COO})_2\text{Mg} + \text{H}_2$ Organic product ✓ Balance ✓ <i>Type of reaction</i> Redox ✓	3	ALLOW correct structural OR skeletal OR displayed formula OR mixture of the 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.

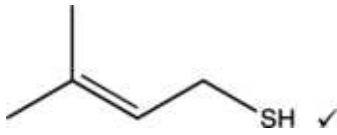
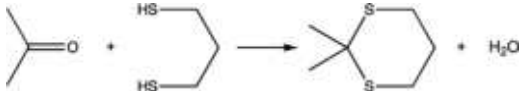
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		ii	Equation  Organic product ✓ Balance ✓ Type of reaction Condensation OR esterification ✓	3	ALLOW correct structural OR skeletal OR displayed formula OR mixture of the above as long as non-ambiguous ALLOW 1 mark of the 2 equation marks for formation 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	

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50	i $K_a = \frac{[H^+][C_4H_9S^-]}{[C_4H_9SH]} \checkmark$ 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 C₄H₉SH, 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 [C₄H₉S⁻] [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 C₄H₉SH ALLOW CH₃COOH Thioester functional group must be fully displayed, OR as a skeletal formula but allow SC₄H₉ 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 H₂S, 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.

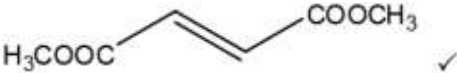
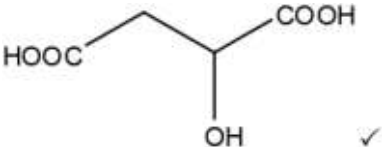
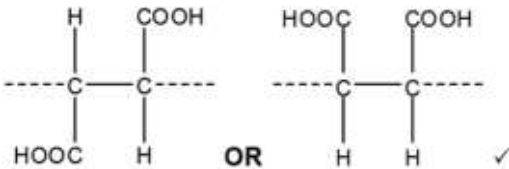
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		iii		1	IF correct skeletal formula is shown, IGNORE displayed formula in a second structure Examiner's Comment: Just over half the candidates drew the correct structure, displaying a good understanding of interpreting organic nomenclature when drawing 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	
51			C	1	<u>Examiner's Comments</u> Almost all candidates identified C (CH₃COCl) as the reagent required for this reaction.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
52			A	1	<u>Examiner's Comments</u> The bonding in benzene is well known by candidates at this level and most correctly selected A as their response.
			Total	1	
53			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	

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54	Product from excess $\text{CH}_3\text{OH}/\text{H}_2\text{SO}_4$  Product from steam, H_3PO_4  Repeat unit of polymer C 	3	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous e.g.  IGNORE connectivity in each product ALLOW the <i>E</i> or <i>Z</i> isomer as product from excess $\text{CH}_3\text{OH}/\text{H}_2\text{SO}_4$ 'End bonds' MUST be shown (do not have to be dotted) IGNORE brackets IGNORE <i>n</i> ALLOW more than one repeat unit but has to be a whole number of repeat units Examiner's Comments The majority of candidates were able to identify at least one product from the reactions of compound C. The polymerisation reaction appeared to be the most familiar, although some candidates attempted to draw a condensation polymer using the carboxylic acid groups rather than the alkene. The reaction of C with excess methanol was also well attempted. However, a significant number of candidates used chemical symbols to show their product. A proportion of these did not show the H atoms of the alkene group, showing only $\text{C}=\text{C}$ in the centre of the structure. Candidates are advised to use the type of formulae given in a question as this will reduce the potential for error or omissions. The product from the hydration of C appeared to be the hardest to deduce.

Mark Scheme

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					Many candidates recognised this reaction would produce an alcohol, but often included two OH groups – one on each C from the double bond – in their structure. Other candidates confused this reaction with hydrogenation and formed a saturated product from C.
			Total	3	

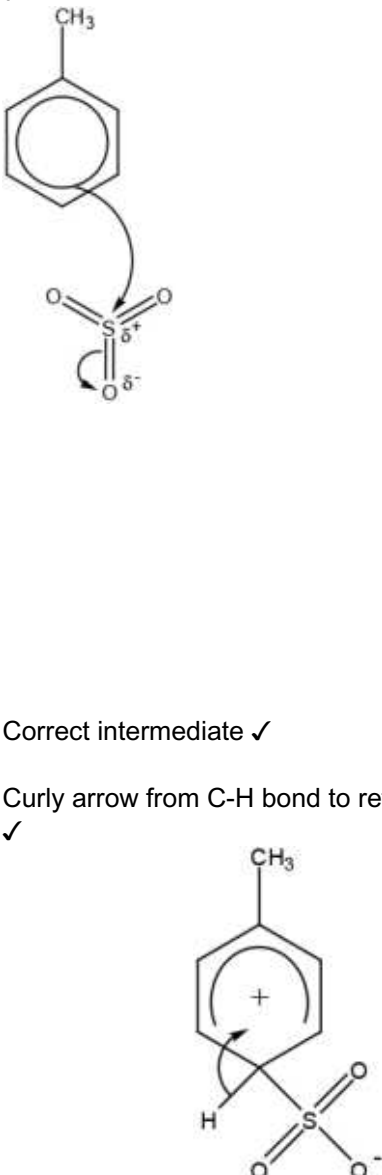
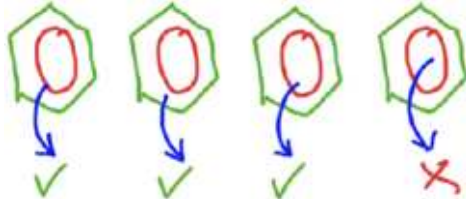
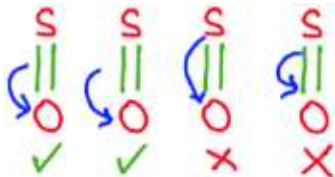
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
55	a	i	Number of peaks 2 marks 2-nitrophenol AND 3-nitrophenol have six peaks/environments/types of carbon ✓ 4-nitrophenol has four peaks/environments/types of carbon ✓ Statement 1 mark 4-nitrophenol can be distinguished OR 2-nitrophenol and 3-nitrophenol cannot be distinguished ✓	3	IGNORE any numbers shown on structures ALLOW 1 mark only IF a response identifies that all the compounds have 6 peaks/environments/types of C OR all the compounds have 4 peaks/environments/types of carbon IGNORE chemical shifts DO NOT ALLOW ECF from an incorrect number of peaks/environments/types of carbon <u>Examiner's Comments</u> This question required candidates to apply their knowledge of ^{13}C NMR spectroscopy to deduce the number of different carbon environments in each of the nitrophenols shown. The best responses were succinct, stating that it is possible to distinguish 4-nitrophenol from the other two after deducing the correct number of carbon environments for each compound. Lower ability candidates' responses did not identify the symmetry in 4-nitrophenol and suggested all three compounds would produce six peaks, therefore making it impossible to distinguish between them.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	(In phenol) a (lone) pair of electrons on O is (partially) delocalised/donated into the π-system / ring ✓ Electron density increases/is higher (than benzene) ✓ ORA (phenol) is more susceptible to electrophilic attack OR (phenol) attracts/accepts electrophile/HNO_3 more OR (phenol) polarises electrophile/HNO_3 more ✓ ORA	3	ALLOW the electron pair in the p-orbitals of the O atom becomes part of the π-system / ring ALLOW diagram to show movement of lone pair into ring ALLOW lone pair of electrons on O is (partially) drawn/attracted/pulled/ into π-system / ring IGNORE activating IGNORE charge density IGNORE electronegativity IGNORE phenol reacts more readily (<i>no reference to electrophile</i>) ALLOW NO_2^+ for electrophile Examiner's Comments The relative reactivity of phenol is well known by candidates at this level and the majority scored two or three marks. Candidates who did not score full marks gave imprecise or vague explanations. This included reference to 'higher charge density' or 'higher electronegativity' of the phenol ring, rather than 'higher electron density'.

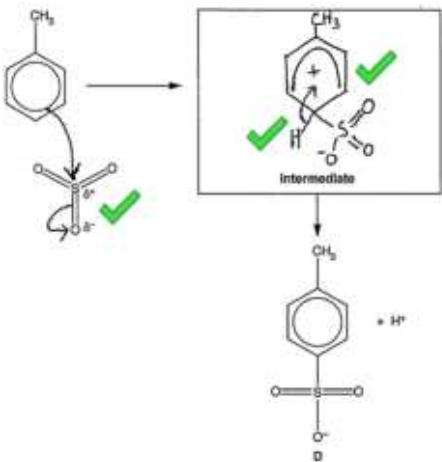
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
b	Curly arrow from π-bond to S in SO_3 AND curly arrow from the S=O bond to O atom ✓  Correct intermediate ✓ Curly arrow from C-H bond to reform π-ring ✓	3	ANNOTATE WITH TICKS AND CROSSES NOTE: curly arrows can be straight, snake-like, etc. but NOT double headed or half headed arrows 1st curly arrow must - go to the S of SO_3 AND - start from, OR close to circle of benzene ring  2nd curly arrow must start from, OR be traced back to, any part of S=O bond and go to O  ALLOW 2nd curly arrow from S=O to any O in SO_3 Intermediate must have correct SO_3^- structure fully displayed DO NOT ALLOW the following intermediate:

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			π-ring must cover more than half of the benzene ring structure AND the correct orientation, i.e. gap towards C with SO_3^- ALLOW + sign anywhere inside the 'hexagon' of the intermediate. DO NOT ALLOW mark for intermediate if CH_3 is missing curly arrow must start from, OR be traced back to, any part of C-H bond and go inside the 'hexagon' <u>Examiner's Comments</u> This question required candidates to apply their understanding of electrophilic substitution to the reaction of methylbenzene with sulfur trioxide. Examiners were encouraged by the quality of responses to this question. Most candidates secured full marks in this part. Some candidates did not show the curly arrow for the breaking of the $\text{S}=\text{O}$ bond, while others omitted the methyl group from the intermediate. Exemplar 4 shows an excellent response.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			Exemplar 4  [3] This response demonstrates an excellent example for candidates to follow. Curly arrows are drawn accurately, with each arrow touching the bond it starts from. The intermediate has been drawn clearly, using all the space provided. The 'horseshoe' has been drawn accurately over five of the carbon atoms with the positive charge shown neatly in the centre.
	Total	9	

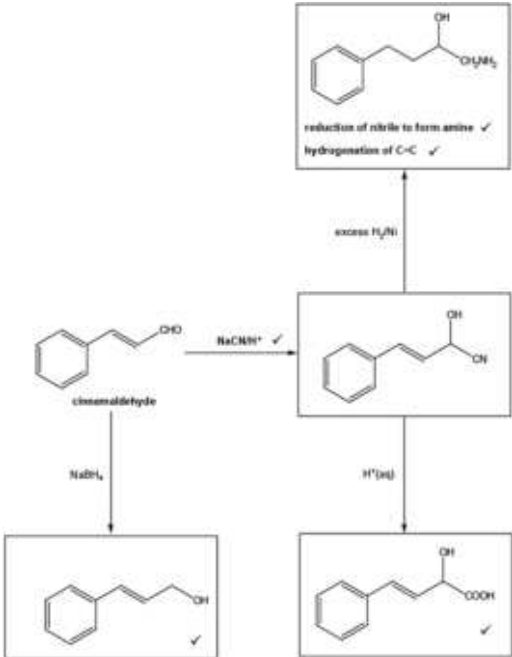
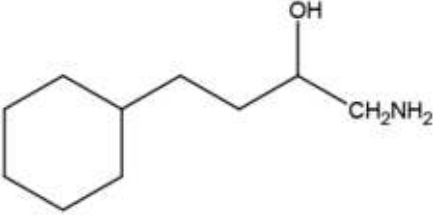
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
56	a	i	Bromine/ Br ₂ AND goes colourless/decolourised ✓	1	Note: both reagent and observation are required ALLOW bromine water/ Br₂(aq) <u>Examiner's Comments</u> Almost all candidates were able to correctly describe the use of bromine as a test for an unsaturated chain.
		ii	Tollens' (reagent) AND Silver (mirror/precipitate/ppt/solid) ✓	1	Note: both reagent and observation are required for the mark. ALLOW ammoniacal silver nitrate OR Ag⁺/NH₃ ALLOW black ppt OR grey ppt <u>Examiner's Comments</u> Almost all candidates were able to correctly describe the use of Tollens' reagent as a test for an aldehyde functional group.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	(Add) 2,4-dinitrophenylhydrazine AND orange/yellow/red precipitate ✓ Take melting point (of crystals) ✓ Compare to known values/database ✓	3	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 <u>Examiner's Comments</u> The use of 2,4-dinitrophenylhydrazine as a test for the carbonyl group is well known by candidates at this level. The majority of the cohort correctly identified this test and the subsequent analysis of the melting point of the products as a method of identifying each compound. Lower ability candidate responses made reference to analysis of the boiling points of the cinnamaldehyde and methylcinnamaldehyde as a means of identification.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
b	Marks for each correct structure/reagent shown below  reduction of nitrile to form amine ✓ hydrogenation of C=C ✓ excess H_2/Ni NaCNH_4 ✓ NaBH_4 $\text{H}^+(\text{aq})$	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.

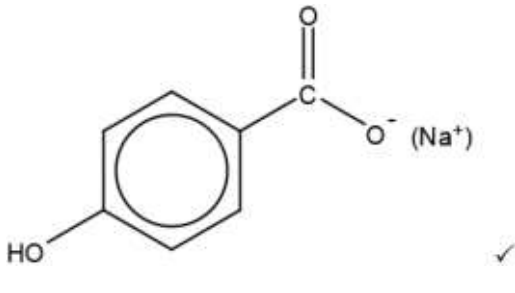
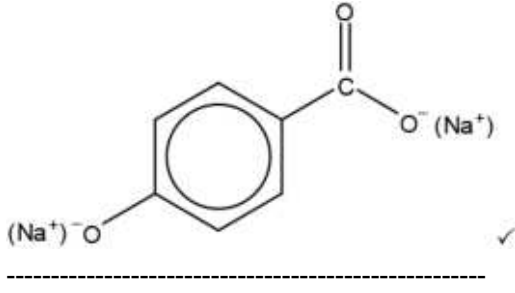
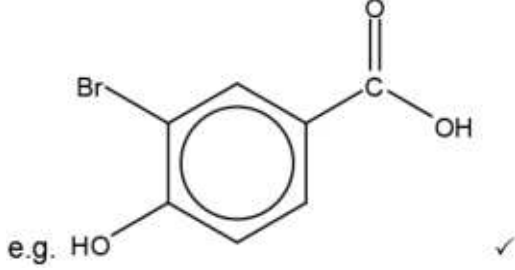
Mark Scheme

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 NaBH_4. 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	10	

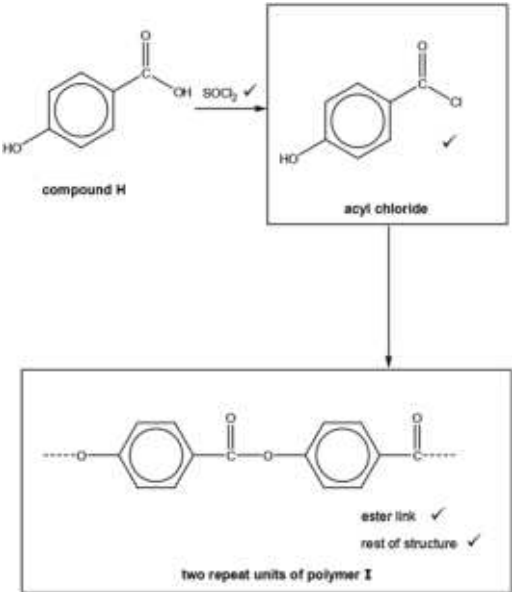
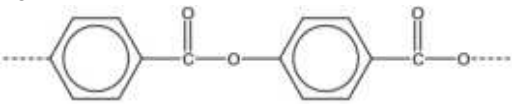
Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
57	a	Product from Na_2CO_3  Product from NaOH(aq)  Product from Br_2 	3	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous ALLOW -COO^- OR -COONa DO NOT ALLOW negative charge on C atom DO NOT ALLOW -COO-Na (covalent bond) IGNORE connectivity of phenol OH group (marks are for correct conversions) ALLOW 1 mark if top two structures are shown in wrong boxes ALLOW substitution of any H from benzene ring ALLOW multiple substitution, <i>i.e.</i> di-, tri- and tetrabromo products. IGNORE connectivity of phenol OH group (marks are for correct conversions) Examiner's Comments This question assessed different reactions of compound H, 4-hydroxybenzoic acid, and discriminated well. Two of the reactions focused on acid-base chemistry,

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					using the reagents Na_2CO_3 and NaOH. Many candidates recognised that the carboxylic acid group would react in both cases but only some managed to identify when the phenol group was involved correctly. A number of responses suggested that a phenoxide ion was formed with sodium carbonate but not with sodium hydroxide. The third reaction was substitution with bromine. This reaction appeared more familiar to all candidates with the majority scoring this mark. A small proportion of candidates substituted the phenol OH group or carboxylic acid group.

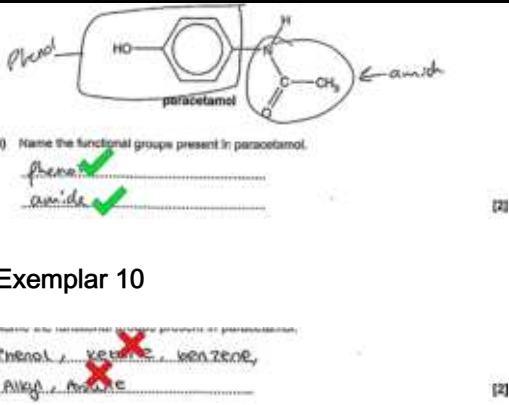
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
b	One mark for each correct structure/reagent as shown below  compound H acyl chloride ester link ✓ rest of structure ✓ two repeat units of polymer I	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	7	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
58		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

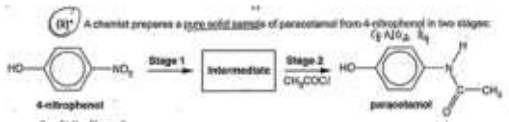
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			 Exemplar 10
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

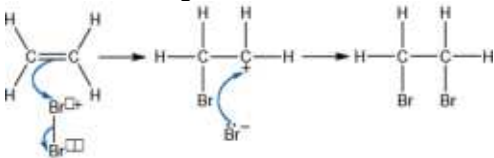
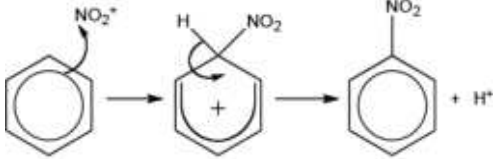
Mark Scheme

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: 4-nitrophenol $\text{C}_6\text{H}_5\text{NO}_2$ → Stage 1 → Intermediate → Stage 2 CH_3COCl → paracetamol 4-nitrophenol $\text{C}_6\text{H}_5\text{NO}_2$ + Sn + conc. HCl → 4-aminophenol $\text{C}_6\text{H}_5\text{NH}_2$ + $2\text{H}_2\text{O}$ 4-aminophenol $\text{C}_6\text{H}_5\text{NH}_2$ + CH_3COCl → paracetamol $\text{C}_8\text{H}_9\text{NO}_2$ + HCl Relative molar mass of paracetamol = 151 g mol⁻¹ moles in 5g = $\frac{5}{151} = 0.0331 \text{ mol}$ moles required = $0.0331 \times 0.4 = 0.01324 \text{ mol}$ moles of 4-nitrophenol required = 0.01324 mol 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. (3) 4-nitrophenol is reduced with reduced with (Sn) in presence of acid and forms 4-phenylhydrazide under high temperature <chem>Oc1ccc(N)cc1</chem> $\frac{100}{150} \times 5.00 = 12.5\text{g}$ 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	

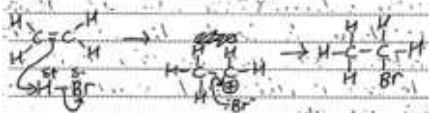
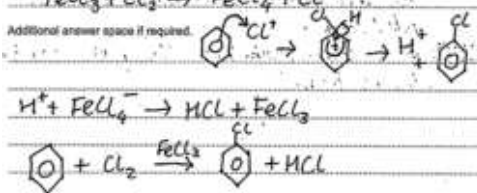
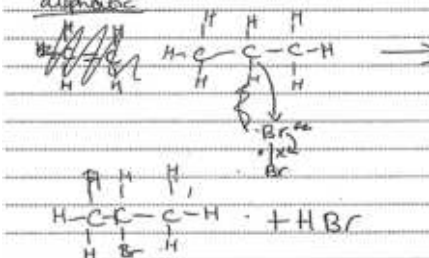
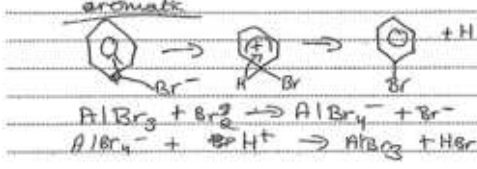
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
59	Refer to marking instructions on page 5 of mark scheme for guidance on marking this question. Level 3 (5–6 marks) Describes, in detail, electrophilic reactions and mechanisms of one aliphatic AND one aromatic compound. <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) Describes, in detail, an electrophilic reaction and mechanism of one aliphatic OR one aromatic compound. OR Describes electrophilic reactions and mechanisms of one aliphatic AND one aromatic compound, with few omissions/errors. <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) Selects suitable reagents for electrophilic reactions of one aliphatic AND one aromatic compound. OR Attempts to describe an electrophilic reaction and mechanism of one aliphatic OR one aromatic compound, with omissions/errors. <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.	6	Indicative scientific points may include: <u>Explanation of role of electrophiles in organic chemistry</u> <u>Reaction of aliphatic compound and mechanism</u> - Suitable reaction, e.g. ethene and Br₂ <i>May be shown within mechanism</i> - Mechanism, e.g.  <u>Reaction of aromatic compound and mechanism</u> - Suitable reaction, e.g. benzene + Cl₂ ; HNO₃ <i>May be shown within mechanism</i> - Mechanism, e.g.  Examples of a detailed description (NOT INCLUSIVE) - Electrophile as electron pair acceptor - Types and names of mechanisms - Equations for generation of electrophile and regeneration of catalyst - Accurately positioned and directed curly arrows and charges/ dipoles included - Explanation of major and minor product from electrophilic addition <u>Examiner's Comments</u> Overall, this part was answered well. Good answers were well organised, showing clear mechanisms with precisely positioned curly arrows. Most candidates included a clear definition of an electrophile and were able to select

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					appropriate reactions. Most candidates were familiar with the mechanisms for electrophilic addition and electrophilic substitution. Mechanisms of an alkene with HBr or Br₂ and benzene with NO₂⁺ or Br⁺ were the most commonly seen. Most candidates showed the role of a catalyst in electrophilic substitution. Common errors/omissions were the direction of the curly arrow from the aromatic ring to the electrophile, the position of the curly arrow when H⁺ is lost from an aromatic intermediate, and not showing the lone pair when Br₂ attacks a carbocation. Some answers lacked detail and gave only two mechanisms with minimal supporting words. Lower ability candidates described nucleophilic addition or substitution as one of their mechanisms or had curly arrows going in the wrong direction. A few candidates answered in prose without including equations or diagrams. Candidates are advised that mechanisms must always be communicated in the usual diagrammatic way. Exemplar 16 is a very clear and concise response showing all the key features of electrophilic addition and electrophilic substitution, including the role of the FeCl₃ catalyst. Curly arrows are precisely positioned, with correct use of lone pairs and charges. The candidate has demonstrated excellent knowledge and understanding. The response in Exemplar 17 is clearly at a different level. The candidate has chosen an alkane rather than an alkene and has used curly arrows and charges incorrectly. This candidate appears to have been poorly prepared.

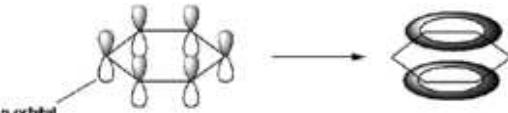
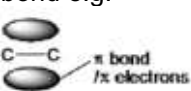
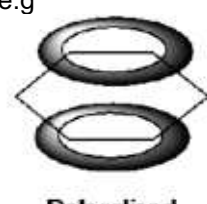
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			Exemplar 16 aromatic compound, including relevant mechanisms. [10] Electrophiles are electron pair acceptors and can accept a pair of electrons from an electron-rich area. Aliphatic Electrophilic addition:  $C_2H_4 + HBr \rightarrow C_2H_5Br$ Aromatic electrophilic substitution $FeCl_3 + Cl_2 \rightarrow FeCl_4 + Cl^+$ Additional answer space if required.  $H^+ + FeCl_4^- \rightarrow HCl + FeCl_3$ $C_6H_6 + Cl_2 \xrightarrow{FeCl_3} C_6H_5Cl + HCl$ Exemplar 17 Your answer should include one reaction of an aliphatic compound and one reaction of an aromatic compound, including relevant mechanisms. [11] Electrophiles accept a pair of electrons and attack an organic molecule. aliphatic  Additional answer space if required. aromatic  $AlBr_3 + Br_2 \rightleftharpoons AlBr_4^- + Br^-$ $AlBr_4^- + H^+ \rightarrow AlBr_3 + HBr$
	Total	6	

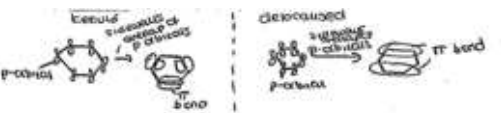
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
60			C	1 (AO 1.2)	
			Total	1	
61			C	1 (AO 1.2)	<u>Examiner's Comments</u> This question discriminated well, with the higher ability candidates correctly selecting C. The most common incorrect response was A.
			Total	1	
62			A	1 (AO 1.1)	<u>Examiner's Comments</u> This question proved difficult. Many candidates correctly deduced that all three chemicals would react with phenol and selected A. Some candidates did not recognise that phenol would react with HNO_3 without the need for a catalyst and selected B. Other candidates did not consider the weak acidity of phenol and selected C.
			Total	1	

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Question	Answer/Indicative content	Marks	Guidance
63	Similarities Orbital overlap (sideways) overlap of p orbitals ✓ π bond π bond/system/ring above and below (bonding (C) atoms/ring/plane) ✓ Difference Kekule has: alternating π bonds OR 3 π bonds / localised (π electrons) / overlap in one direction / 2 electrons in π bond AND Delocalised has: π ring (system) / all p orbitals overlap OR (π electrons) spread around ring / overlap in both directions / 6 electrons in π bond /	3(AO 1.1 × 3)	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC ALLOW diagram showing orbital overlap e.g.  OR  p orbital label is required for first mark IGNORE C=C in diagram showing π bond IGNORE reference to s orbital overlap/σ bonds ALLOW from labelled diagram showing π bond e.g.  OR  OR  π bond/π electrons label is required for second mark ALLOW diagram showing π bond in both Kekule AND delocalised models e.g  AND  π bond labels not required for third mark <u>Examiner's Comments</u> Candidates found this question difficult. The majority of the cohort referred to the overlap of p orbitals in either the Kekulé or delocalised model. The best responses

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			developed this idea further and made reference to π bonds above and below the bonding carbon atoms. Although some candidates were able describe the difference between the two models, the responses of others lacked detail. Describing conceptual ideas, such as orbital overlap and π bonds, is understandably tricky. Candidates are advised to draw diagrams. These serve as a good basis from which to construct a written response. Exemplar 5 shows how effective the use of diagrams can be. Exemplar 4  Similarities: Both models involve the sideways overlap of adjacent p-orbitals. Both are a π bond with a trigonal planar shape with bond angles of 120°. Same C-H. Differences: Delocalised π bonds overlap forms delocalised π electrons (6 electrons delocalised over 6 Carbons), whereas Kekulé leads to 3 π bonds of 2 electrons localised over 2 Carbons each. Delocalised structure gives more stability. This response starts with a diagram for both the Kekulé and delocalised models of benzene. Each diagram is clear and shows the p orbitals and π bonds separately. This is an excellent response for future candidates to follow. The candidate's written response is effectively a description of the diagrams they have drawn and describes the similarities and differences between these two models clearly. This response scored full marks and demonstrates the best style of response seen in this part.

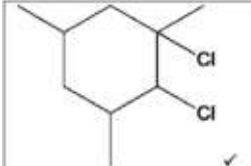
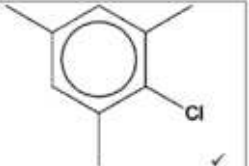
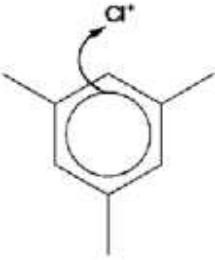
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Any 2 pieces of evidence from (✓ ✓) Bond length (C–C) bond length is between single (C–C) and double bond (C=C) OR all (C–C) bond lengths are the same ΔH hydrogenation ΔH hydrogenation less (exothermic) than expected Resistance to reaction Benzene is less reactive than alkenes OR bromination of benzene requires a catalyst/halogen carrier OR benzene does not react with/decolourise bromine (at room temperature) OR benzene reacts by substitution OR benzene does not (readily) react by addition	2(AO 1.1 ×2)	ALLOW (C–C) bond enthalpy is between single (C–C) and double bond (C=C) OR all (C–C) bond enthalpies are the same IGNORE enthalpy of hydration Benzene is unreactive is not sufficient (no comparison to alkene) For halogen carrier, ALLOW name or formula of suitable catalyst e.g. Fe, AlCl₃, FeBr₃ <u>Examiner's Comments</u> Candidates were well prepared for this question and the majority of the cohort scored two marks. The most common piece of evidence given was the lack of reactivity of benzene with bromine, with candidates citing the need for a catalyst for the reaction to occur. Responses also included reference to carbon-carbon bond lengths as well as the enthalpy of hydrogenation. A small but significant proportion of the cohort referred to hydration rather than hydrogenation.
			Total	5	
64			A	1 (AO1.1)	
			Total	1	
65			C	1 (AO1.2)	
			Total	1	
66			A	1 (AO1.1)	
			Total	1	
67			C	1 (AO2.3)	
			Total	1	

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Question			Answer/Indicative content	Marks	Guidance
68			B	1 (AO2.3)	
			Total	1	

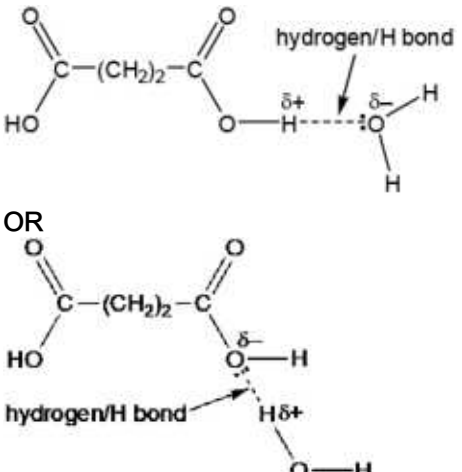
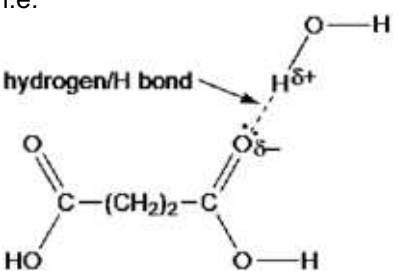
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
69	i   Organic product with B ✓ Organic product with C ✓	2 (AO2.5×2)	
	ii Reactivity of B in B electrons are localised OR in B π-bond is localised ✓ Reactivity of C in C electrons are delocalised OR In C π-system / ring is delocalised In B, electron density is higher AND B is more susceptible to electrophilic attack OR B attracts/accepts the electrophile/Cl₂ more OR B polarises the electrophile/Cl₂ more ✓ ORA	3 (AO1.1×3)	ALLOW labelled diagram to show delocalised system IGNORE charge density IGNORE electronegativity IGNORE B is more reactive/reacts more readily (no reference to electrophile) IGNORE references to electron density spread around the π-ring ALLOW chlorine <u>Examiner's Comments</u> Candidates answered this question well. Many were able to correctly use the terms delocalised and localised in their responses and were able to provide comparisons for both electron density and attack of an electrophile.
	iii Generation of electrophile $\text{AlCl}_3 + \text{Cl}_2 \rightarrow \text{AlCl}_4^- + \text{Cl}^+$ ✓ Attack of Cl⁺  Curly arrow from π-bond to Cl⁺ ✓ ----- Intermediate and organic product	5 (AO1.2) (AO1.2) (AO2.5) (AO1.2) (AO1.2)	ANNOTATE ANSWER WITH TICKS AND CROSSES ALLOW $\text{FeCl}_3 + \text{Cl}_2 \rightarrow \text{FeCl}_4^- + \text{Cl}^+$ ALLOW use of Fe NOTE: curly arrows can be straight, snake-like, etc. but NOT double-headed or half-headed arrows 1st curly arrow must • start from, OR close to, circle of benzene ring

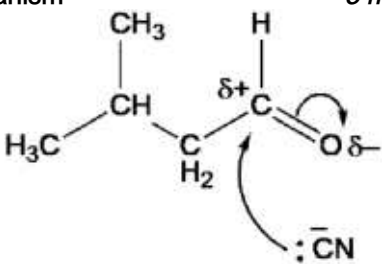
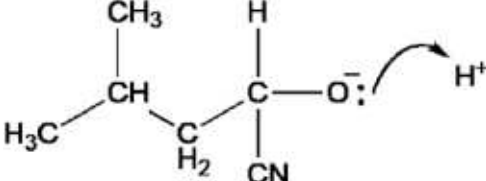
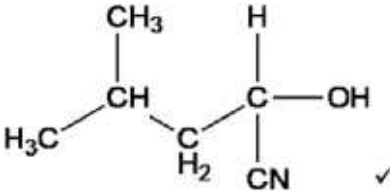
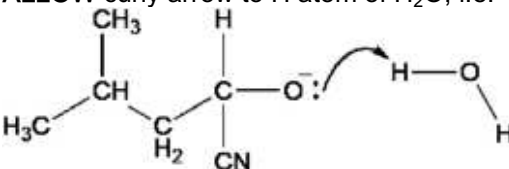
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
	Correct intermediate ✓ Curly arrow from C–H bond to reform π-ring ✓ ----- Regeneration of catalyst $\text{H}^+ + \text{AlCl}_4^- \rightarrow \text{AlCl}_3 + \text{HCl}$ ✓		DO NOT ALLOW following intermediate: π-ring must cover 4 of the 6 sides of the benzene ring AND correct orientation, <i>i.e.</i> gap towards C–Cl ALLOW + sign anywhere inside the 'hexagon' of the intermediate. IGNORE partial charges on the chlorine in the intermediate DO NOT ALLOW mark for intermediate if any CH_3 is missing Curly arrow must start from, OR be traced back to, any part of C–H bond and go inside the 'hexagon' ALLOW use of AlCl_4^- in the mechanism ALLOW ECF for regeneration of an incorrect metal chloride catalyst <i>e.g.</i> AgCl_3
	Total	10	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
70	i Reagents $\text{K}_2\text{Cr}_2\text{O}_7$ AND acid AND reflux ✓ Equation $\text{HO}(\text{CH}_2)_4\text{OH} + 4[\text{O}] \rightarrow$ $\text{HOOC}(\text{CH}_2)_2\text{COOH} + 2\text{H}_2\text{O}$ [O] AND H_2O ✓ Correctly balanced equation ✓	3 (AO1.1) (AO2.5) (AO2.6)	ALLOW $\text{Na}_2\text{Cr}_2\text{O}_7$ OR $\text{Cr}_2\text{O}_7^{2-}$ ALLOW H_2SO_4 OR HCl OR H^+ ALLOW words. e.g. 'acidified dichromate' ALLOW a small slip in formula for dichromate e.g KCr_2O_7, <u>Examiner's Comments</u> Many candidates did not correctly balance this equation or missed water as a product entirely.
	ii  Diagram showing correct dipole charges on each end of one hydrogen bond between a water molecule and a diacid ✓ Hydrogen bond between one lone pair on O atom in one of the molecules and the H atom of another AND Hydrogen bonding stated or labelled on diagram	2 (AO2.1×2)	ALLOW any combination of skeletal OR structural OR displayed formula as long as unambiguous DO NOT ALLOW δ^+ on H atoms of CH_2 group ALLOW H-bond for hydrogen bond ALLOW H bond between $\text{C}=\text{O}$ and H_2O, i.e.  IF diagram is not labelled, ALLOW hydrogen bond/H bond from text <u>Examiner's Comments</u> Candidates who answered this question well had clear, labelled diagrams. Too often, labels, dipoles and lone pairs were missing.
	Total	5	

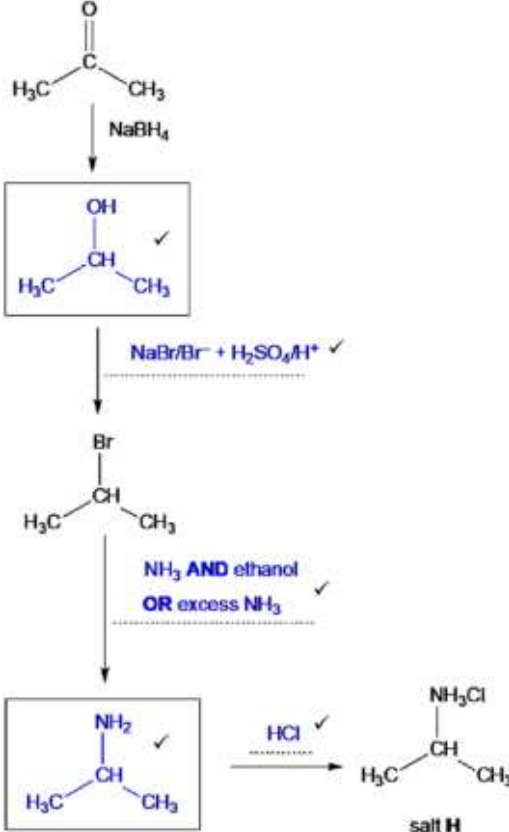
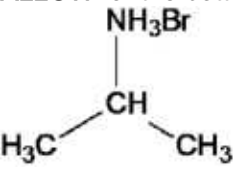
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
71	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^- (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

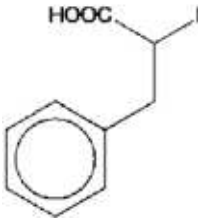
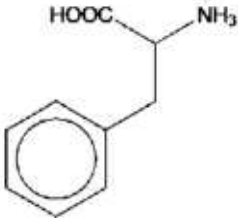
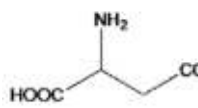
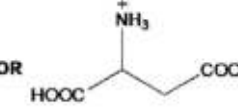
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		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

Question	Answer/Indicative content	Marks	Guidance
72 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
73	6 curly arrows correct ✓✓✓✓ 5 curly arrows correct ✓✓✓ 4 curly arrows correct ✓✓ 3 curly arrows correct ✓	4 (AO 3.1×4)	IGNORE any added charges OR dipoles. <i>Marks solely for curly arrows</i> IGNORE any curly arrows on bottom structures (not in boxes): <u>Examiner's Comments</u> Most candidates showed a good understanding and appreciation of drawing curly arrows. It must be stressed that curly arrows that do not start from a lone pair, negative charge or a bond cannot be credited. Lower-attaining candidates often drew imprecisely positioned curly arrows, curly arrows in the wrong direction or to the wrong atoms. For their response to be credited with marks, candidates should position curly arrows to ensure credit when outlining reaction mechanisms.
	Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance						
74		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	reagent: HNO_3 ✓ catalyst: H_2SO_4 ✓ 1. Sn + HCl 2. Neutralise reagent: CH_3COCl ✓	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 $\text{AlCl}_3/\text{FeCl}_3/\text{Fe4}$						
Total				7							

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
75	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
	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
	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	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
76			F/aldehyde AND Tollens' (reagent) AND Silver (mirror/precipitate/ppt/solid) ✓ G/alkene/C=C AND Bromine/Br₂ AND goes colourless/decolourised ✓ G/ketone AND 2,4-dinitrophenylhydrazine AND orange/yellow/red precipitate ✓ G/ketone AND Tollens' (reagent) AND no silver mirror/no change/no reaction ✓	4 (AO2.3) (AO3.3) (AO3.3) (AO3.3)	IGNORE use of 2,4-DNP with F ALLOW ammoniacal silver nitrate OR Ag⁺/NH₃ ALLOW black ppt OR grey ppt ALLOW bromine water/ Br₂(aq) ALLOW errors in spelling for 2,4-DNP 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 ALLOW ammoniacal silver nitrate OR Ag⁺/NH₃ ALLOW black ppt OR grey ppt ALLOW alternative approach using acidified potassium dichromate for tests with F and/or G, with correct observations, alongside use of 2,4-DNP Examiner's Comments Candidates who found this question difficult often did not give a response that would identify all three of the functional groups (aldehyde, ketone and alkene). The use of Tollens' in identifying aldehydes was well demonstrated, however no reaction with Tollens' was less well demonstrated as a result for ketones.
			Total	4	