Oxford Cambridge and RSA

# A Level Chemistry A
## H432/02 Synthesis and analytical techniques
Sample Question Paper

## Date – Morning/Afternoon
Time allowed: 2 hours 15 minutes

**You must have:**
- the Data Sheet for Chemistry A

**You may use:**
- a scientific calculator



| First name | |
|---|---|
| Last name | |

| Centre number | | | | | | Candidate number | | | | |
|---|---|---|---|---|---|---|---|---|---|---|

**INSTRUCTIONS**
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions.
- Write your answer to each question in the space provided.
- Additional paper may be used if required but you must clearly show your candidate number, centre number and question number(s).
- Do **not** write in the bar codes.

**INFORMATION**
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*).
- This document consists of **36** pages.



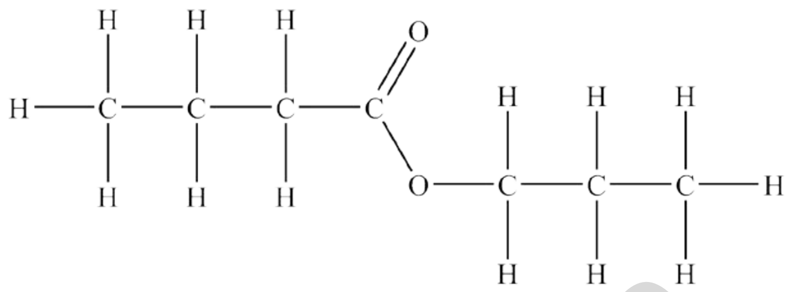
[601/5255/2] DC ( )

## SECTION A

**You should spend a maximum of 20 minutes on this section.**

Answer **all** the questions.

**1** The displayed formula of an organic compound is shown below.



What is the systematic name of this organic compound?

**A** Propyl propanoate

**B** Propyl butanoate

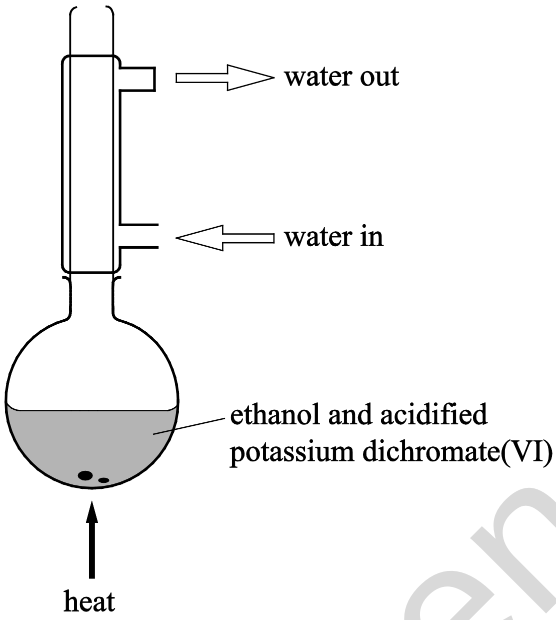
**C** Butyl propanoate

**D** Butyl butanoate

Your answer

**[1]**

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




What is the reason for heating under reflux?

**A** to ensure even heating

**B** to prevent any substances escaping

**C** to boil the mixture at a higher temperature

**D** to allow efficient mixing

Your answer ☐

**[1]**



**3** How many stereoisomers are there of $CH_3CH{=}CHCH(OH)CH_2CH{=}CH_2$?

**A** 2

**B** 4

**C** 6

**D** 8

Your answer ☐

**[1]**

**4** 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** $CH_3CH_2CH_2OH$

**B** $CH_3COCH_3$

**C** $CH_3CH(OH)CH_3$

**D** $CH_3CH_2CHO$

Your answer ☐

**[1]**

**5** Complete combustion of 40 $cm^3$ of a gaseous hydrocarbon **X** requires 240 $cm^3$ of oxygen. 160 $cm^3$ of carbon dioxide forms. All gas volumes are at room temperature and pressure.

What is the formula of **X**?

**A** $C_4H_8$

**B** $C_4H_{10}$

**C** $C_6H_{12}$

**D** $C_6H_{14}$

Your answer ☐

**[1]**

**6** The boiling point of butan-1-ol is 118 °C. The boiling point of 2-methylpropan-2-ol is 82 °C.

Why is the boiling point of butan-1-ol higher than that of 2-methylpropan-2-ol?

**A** butan-1-ol has stronger induced dipole–dipole interactions because it has more electrons

**B** butan-1-ol has stronger induced dipole–dipole interactions because it has a straight-chain structure

**C** butan-1-ol can form hydrogen bonds while 2-methylpropan-2-ol cannot

**D** butan-1-ol is more stable because it is a primary alcohol

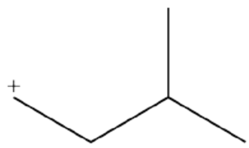
Your answer

**[1]**

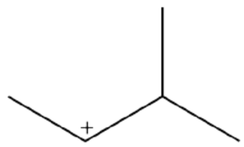
**7** Hydrogen bromide reacts with 3-methylbut-1-ene.

What is the structure of the major intermediate formed in the mechanism?

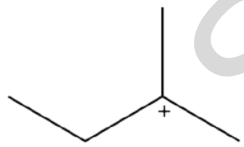
**A**



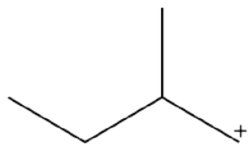
**B**



**C**



**D**



Your answer

**[1]**

**8** 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** | $Br_2(aq)$ | $Na_2CO_3(aq)$ |
|---|---|---|
| **Observation** | decolourised | effervescence |

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

**A** 6

**B** 7

**C** 8

**D** 9

Your answer

**[1]**

**9** 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]**

**10** Which alcohol could be used to prepare $HCOOCH(CH_3)_2$?

**A** Propan-1-ol

**B** Propan-2-ol

**C** 2-Methylpropan-2-ol

**D** Methanol

Your answer

**[1]**

**11** $CN^-$ ions react with haloalkanes and with carbonyl compounds.

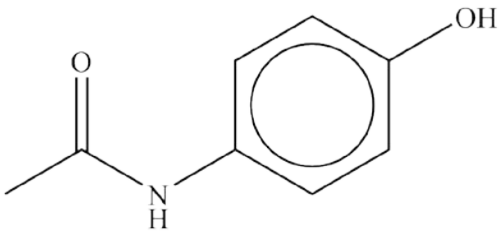
Which row gives the correct mechanisms for the reactions?

| | **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]**

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




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

**A** It has the molecular formula $C_8H_9NO_2$.

**B** It reacts with bases to form salts.

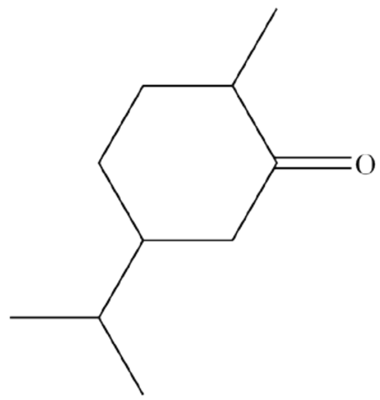
**C** It has a ketone functional group.

**D** It can be hydrolysed with aqueous acid.

Your answer

**[1]**

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



**Menthone**

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

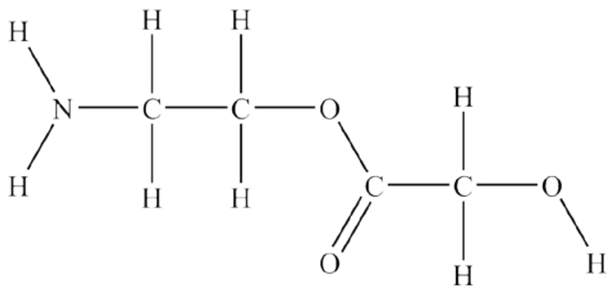
**C** Only 2 and 3

**D** Only 1

Your answer

**[1]**

**15** The structure of molecule **Z** is shown below.



Which of the following statements is/are true?

**1:** The carbon-13 NMR spectrum of **Z** shows four peaks

**2:** The proton NMR spectrum of **Z** shows five peaks

**3:** The proton NMR spectrum of **Z** run in $D_2O$ shows three peaks

**A** 1, 2 and 3

**B** Only 1 and 2

**C** Only 2 and 3

**D** Only 1

Your answer

**[1]**

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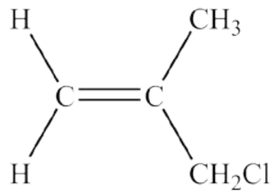
## SECTION B

Answer **all** the questions.

**16** Methyl allyl chloride, MAC, is a chemical used in the production of insecticides. The structure of MAC is shown below.




**MAC**

**(a)** **(i)** Give the **molecular** formula of MAC.

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

**(ii)** Draw the **skeletal** formula of MAC.

**[1]**

**(iii)** MAC has several structural isomers.

State what is meant by *structural isomers*.

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

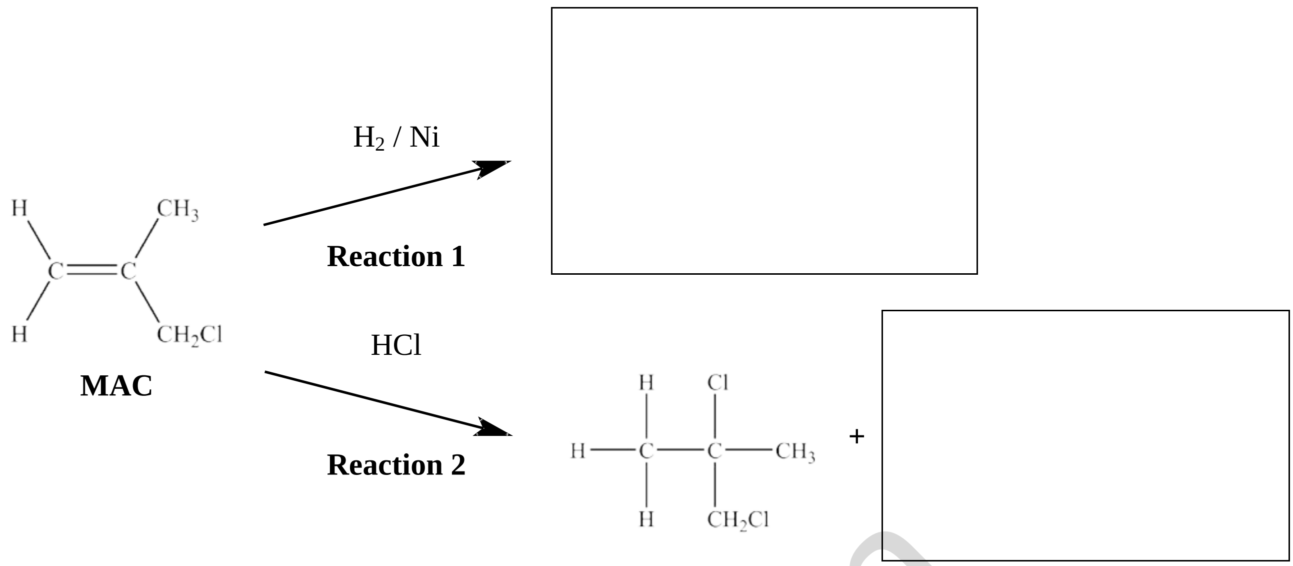
**(b)** MAC is highly flammable. When MAC burns, one of the products formed is a toxic gas.

1.321 g of this gas occupies 1.053 $dm^3$ at 100 kPa and 350 K.

Use the information provided to suggest the identity of the gas.

gas = ........................ **[4]**

**(c)** The flowchart below shows some reactions of MAC.




**Compound A** (major product) **Compound B** (minor product)

**(i)** Complete the flowchart above.

- Draw the structure of the product of **Reaction 1**.
- Draw the structure of the minor organic product of **Reaction 2** (Compound **B**).

**[2]**

**(ii)** **Reaction 2** creates a mixture of compounds. Compound **A** is the major product.

Draw the mechanism for the formation of compound **A**.

Use curly arrows and show relevant dipoles.

**[3]**

**(iii)** Explain why compound **B** is the minor product of **Reaction 2**.

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……………………………………………………………………………………………… **[1]**

**(iv)** **MAC** reacts with water in the presence of $AgNO_3(aq)$ and ethanol.

Draw the structure of the organic product of this reaction.

State what you would **observe** in this reaction and identify the compound responsible for the observation.

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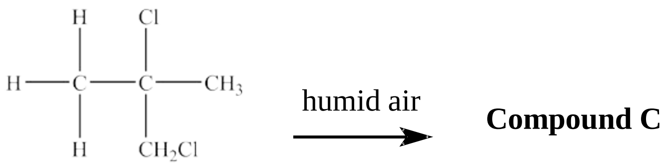
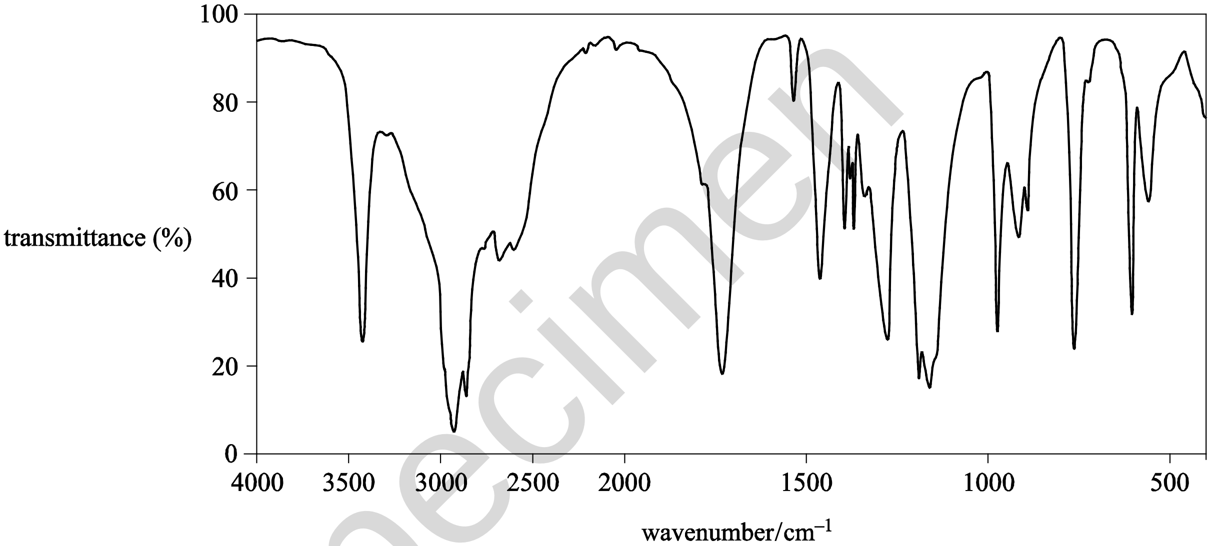
**(d)** Compound **A** reacts slowly in humid conditions to form compound **C**.




**Compound A**

Compound **C** contained the following percentage composition by mass:
C, 46.1%; H, 7.7%; O, 46.2%

The infrared spectrum of compound **C** is shown below.



Using the information on the previous page, deduce the structure of compound **C**.

Give your reasoning.

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structure = **[5]**

**17** Molecules with more than one functional group are useful chemical 'building blocks'.

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

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

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

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

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................................................................................................................ **[4]**

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

Use a diagram in your answer.

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................................................................................................................ **[3]**

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

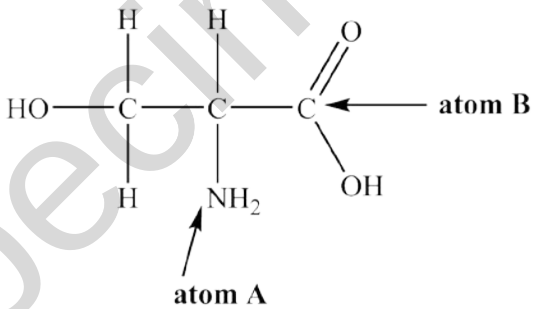
Draw a possible repeat unit of this condensation polymer.

Show clearly any functional group present in the repeat unit.

**[2]**

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

**(i)**




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

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

Give reasons for your answers.

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.............................................................................................. **[4]**

**(ii)** A student adds an excess of aqueous sodium hydroxide to a sample of solid serine.
The student then purifies the resulting reaction mixture to obtain a pure sample of an ionic organic product.

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

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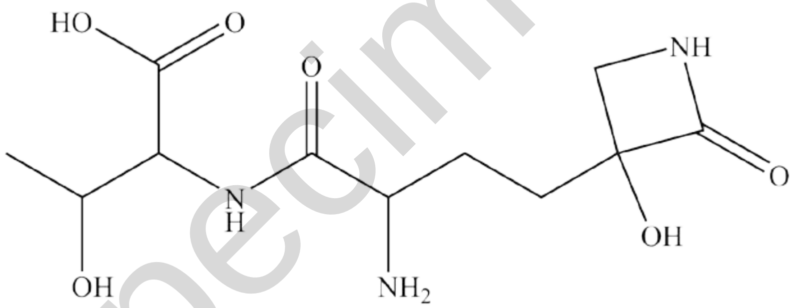
.......................................................................................................... **[3]**

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




**tabtoxin**

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

On the structure above, mark each chiral centre with an asterisk, *. **[1]**

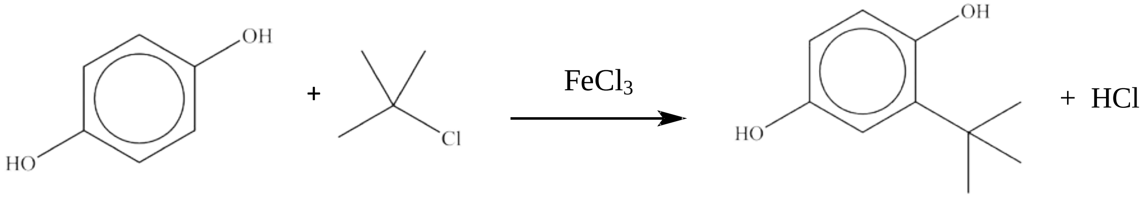
**(ii)** Tabtoxin can be broken down by alkaline hydrolysis.

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

**[4]**

**18** A student investigates reactions of aromatic compounds.

**(a)** The student first carries out the reaction shown below.




**quinol** **Compound E**

**(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.

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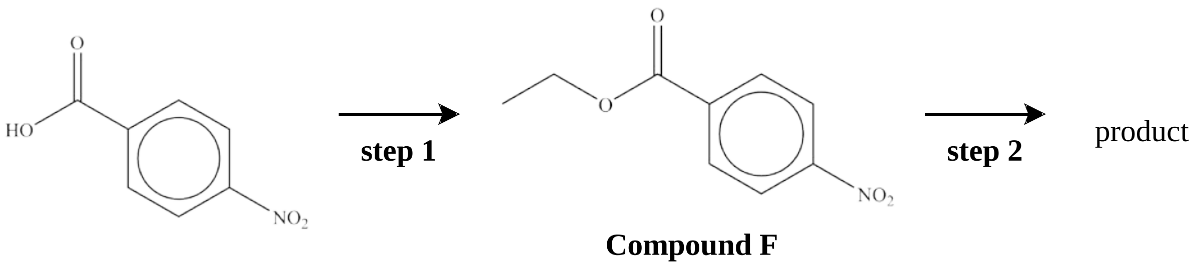
**(b)** 4-Nitrobenzoic acid is an important compound in chemical synthesis. The flowchart below shows a synthesis involving 4-nitrobenzoic acid.



**(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]**

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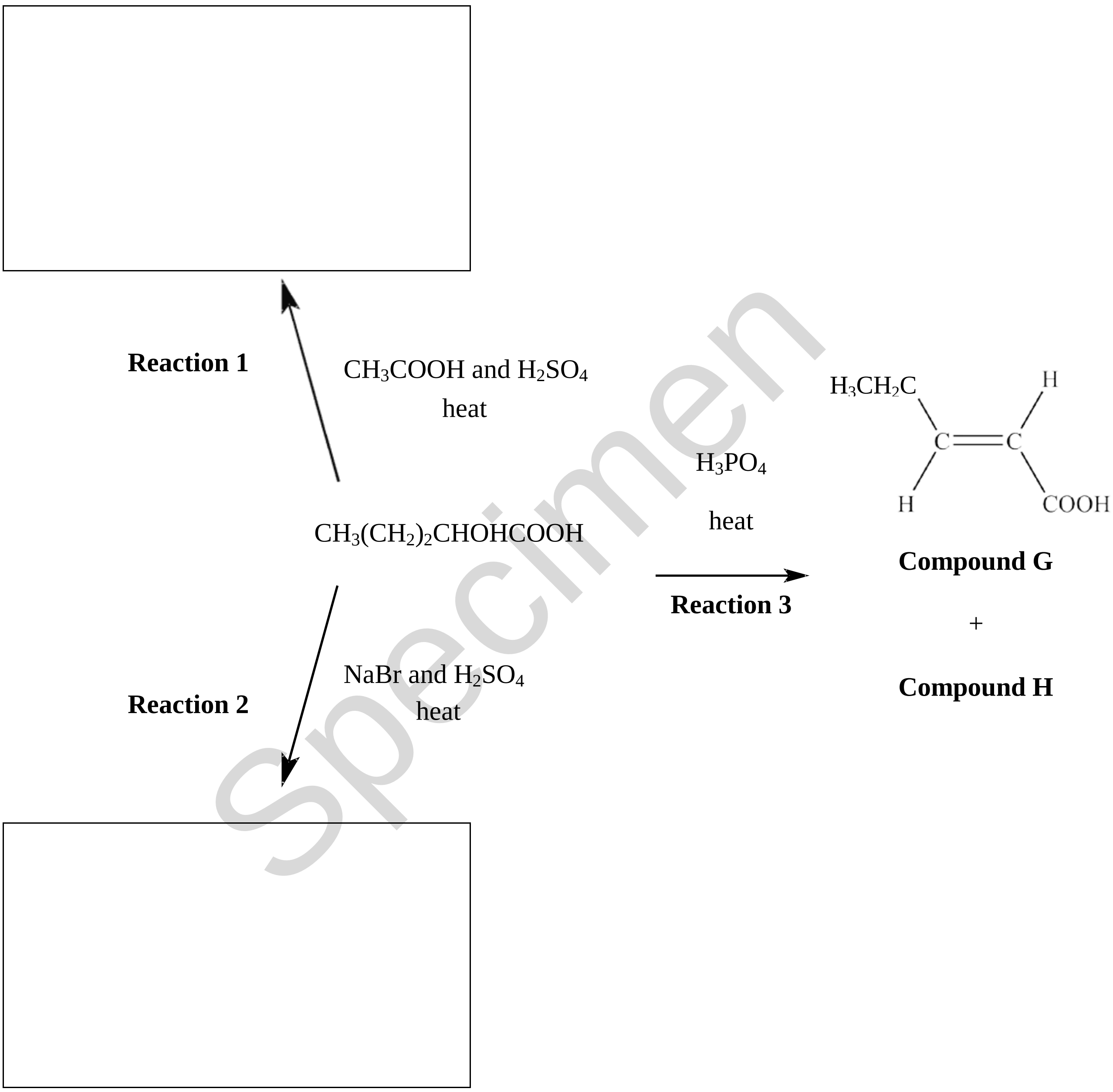
**19** α-Hydroxy acids (AHAs) are naturally occurring acids often used as cosmetics.

**(a)** The flowchart below shows some reactions of an AHA, $CH_3(CH_2)_2CHOHCOOH$.

**(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**.

| **Compound H** | **addition polymer** |
|---|---|

**[2]**

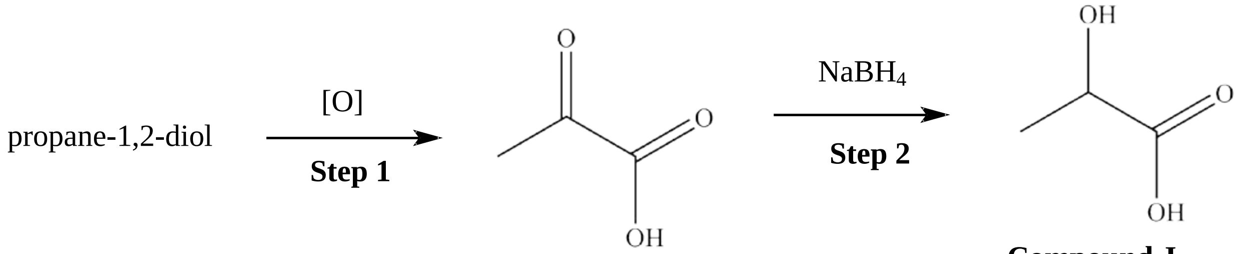
**(iv)** The addition polymer in **(iii)** is used widely in industry. Increasingly, waste polymers are being processed as a more sustainable option than disposal.

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.




**Compound J**

**(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 $[BH_4]^-$.

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]**

**(c)** Compound **K** is an AHA that is often used in 'chemical face peels'.

A student wishes to identify compound **K** from the list of compounds below.

| | |
|---|---|
| glycolic acid | $HOCH_2COOH$ |
| malic acid | $HOOCCH_2CHOHCOOH$ |
| mandelic acid | $C_6H_5CHOHCOOH$ |
| pantoic acid | $HOCH_2C(CH_3)_2CHOHCOOH$ |

The student isolates compound **K** and analyses a sample of the compound by titration.

The student dissolves 1.89 g of compound **K** in water and makes the solution up to 250.0 $cm^3$ in a volumetric flask. The student titrates 25.0 $cm^3$ of this solution with 0.150 mol $dm^{-3}$ NaOH(aq).

18.80 $cm^3$ of NaOH(aq) were required for complete neutralisation.

Use the results of the student's analysis to identify compound **K** from the list above.

Show **all** of your working.



**K** = ................................................ **[5]**

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**20** 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$^{-3}$** | $M_r$ |
|---|---|---|---|
| **Cyclohexanol** | 161 | 0.962 | 100.0 |
| **Cyclohexanone** | 156 | 0.948 | 98.0 |

**(a)*** 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.



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**(b)** Ethanedioic acid removes excess dichromate ions, $Cr_2O_7^{2-}$, as in the equation below.

$$3(COOH)_2 + Cr_2O_7^{2-} + 8H^+ \rightarrow 6CO_2 + 2Cr^{3+} + 7H_2O$$

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

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................................................................................................................... **[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.

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

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**21*** A chemist isolates compound **L**, with empirical formula $C_3H_6O$, and sends a sample for analysis. The analytical laboratory sends back the following spectra.

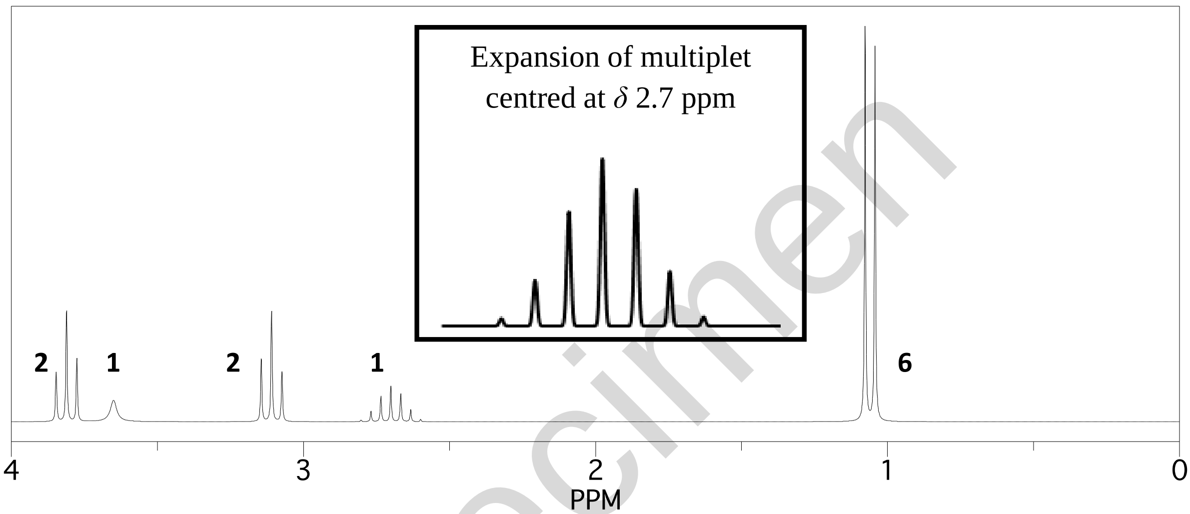
**Mass spectrum**

Molecular ion peak at $m/z$ = 116.0.

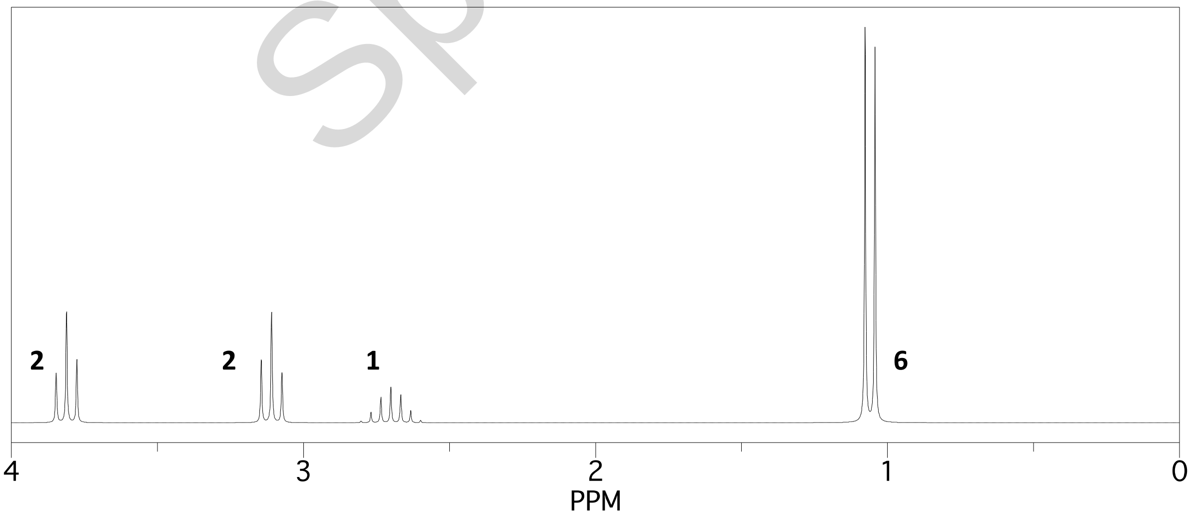
**$^1$H NMR spectra**

The numbers next to each signal represent the number of $^1$H responsible for that signal.
Two $^1$H NMR spectra were obtained: one without $D_2O$ and one with $D_2O$ added.

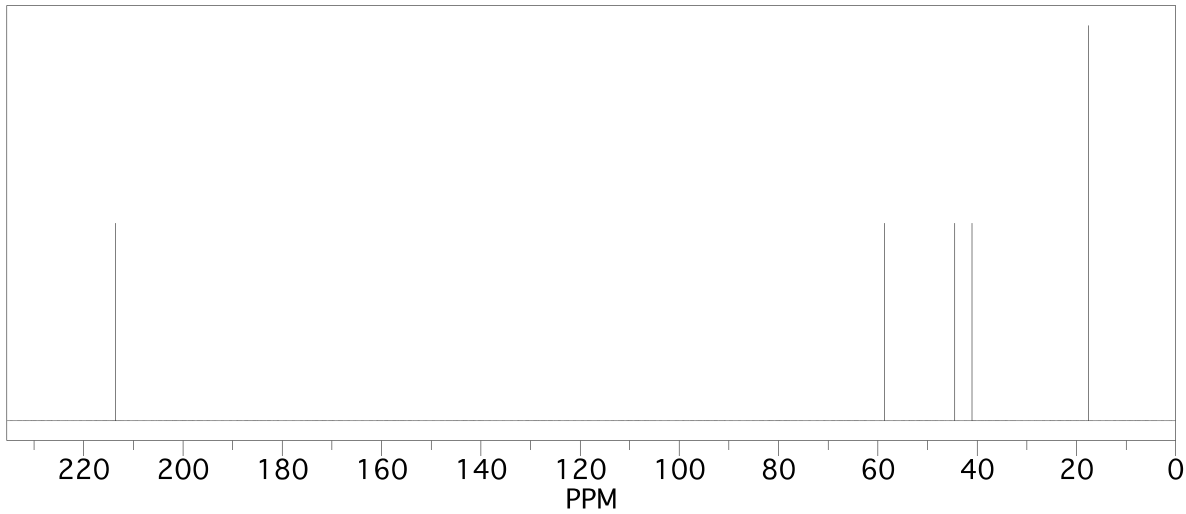
$^1$H NMR spectrum with no $D_2O$:




$^1$H NMR spectrum with $D_2O$ added:



$^{13}C$ NMR spectrum:




Use the information provided to suggest a structure for compound **L**.

Give your reasoning.



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**END OF QUESTION PAPER**

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