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

## Date – Morning/Afternoon
Version 2.0

Time allowed: 2 hours 15 minutes

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

**You may use:**
- a scientific or graphical 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.
- Where appropriate, your answers should be supported with working. Marks may be given for a correct method even if the answer is incorrect.
- 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.

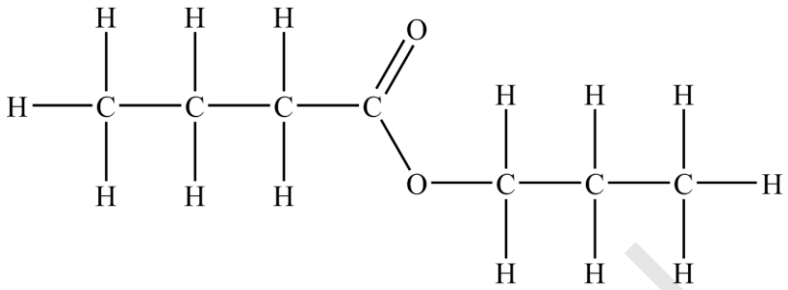
**INFORMATION**
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended responses will be assessed in questions marked with an asterisk (*).
- This document consists of **36** pages.

## 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

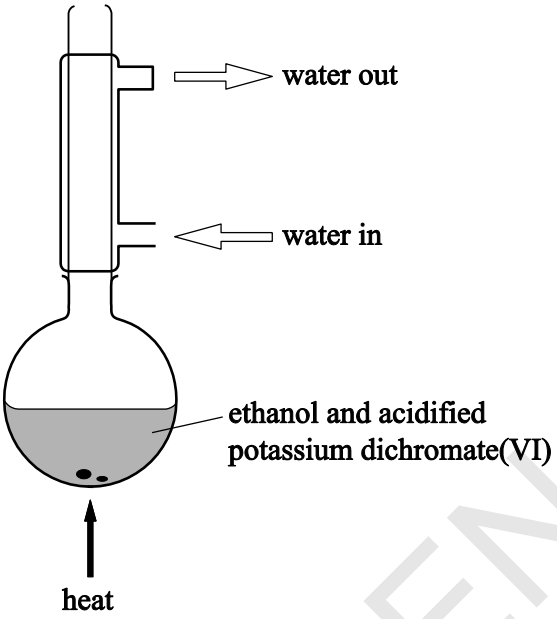
**C** Butyl propanoate

**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

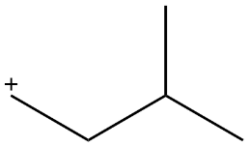
Your answer ☐

**[1]**

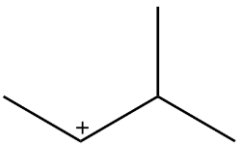
**7** Hydrogen bromide reacts with 3-methylbut-1-ene.

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

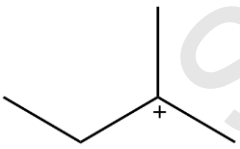
**A**



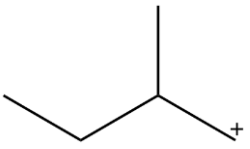

**B**




**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.

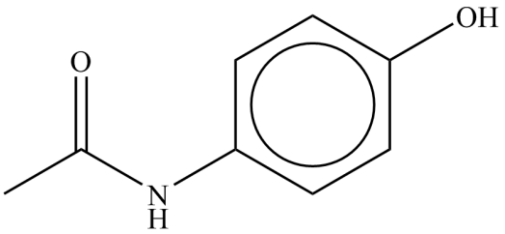
Which row gives the correct mechanisms for the reactions?

| | **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.

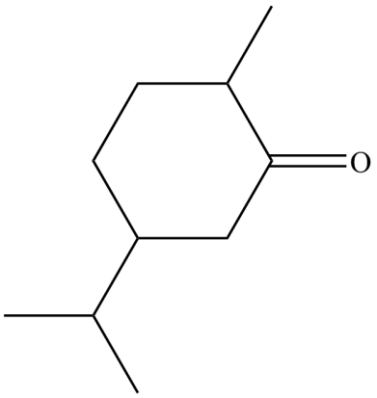
**C** It has a ketone functional group.

**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

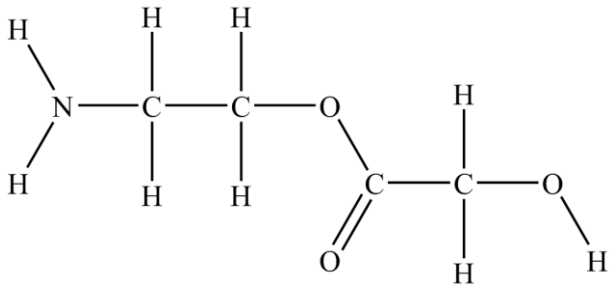
**C** Only 2 and 3

**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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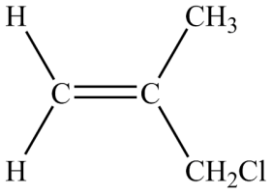
## SECTION B

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*.

……

…… **[1]**

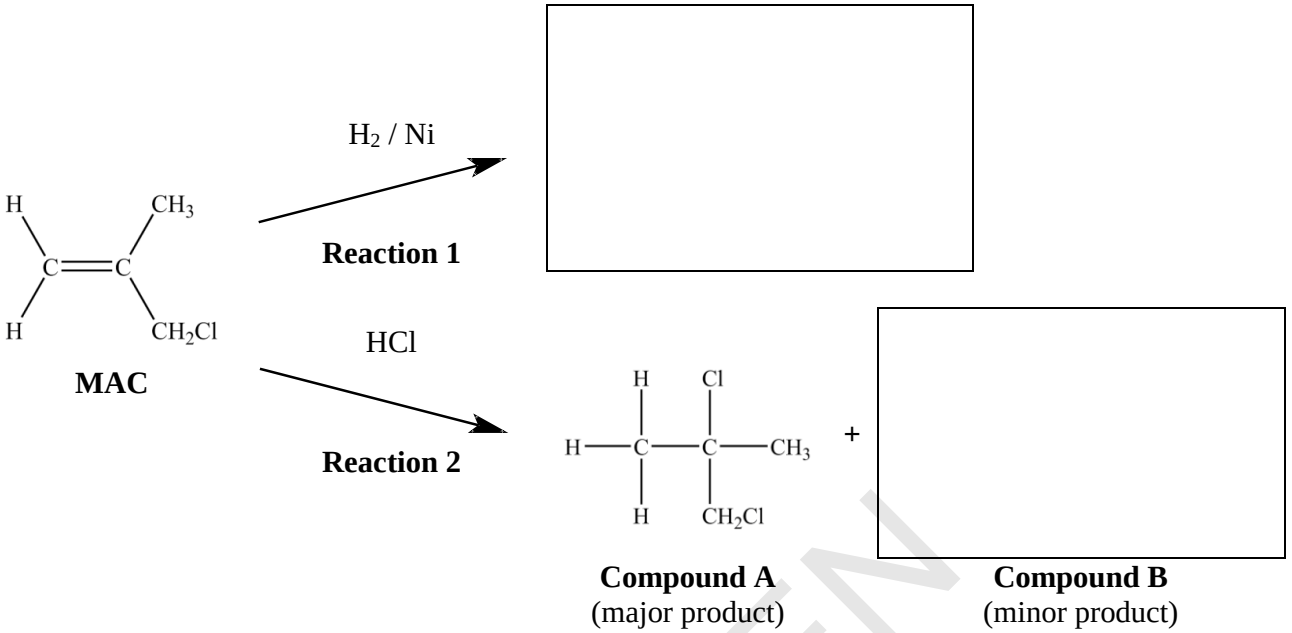
**(b)** MAC is highly flammable. When MAC burns, one of the products formed is a toxic gas.

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.




**(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**.

……

…… **[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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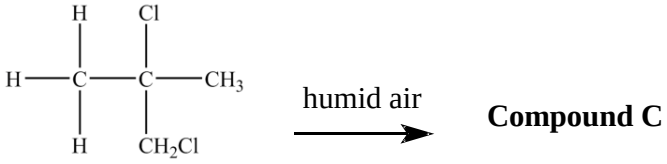
…… **[2]**

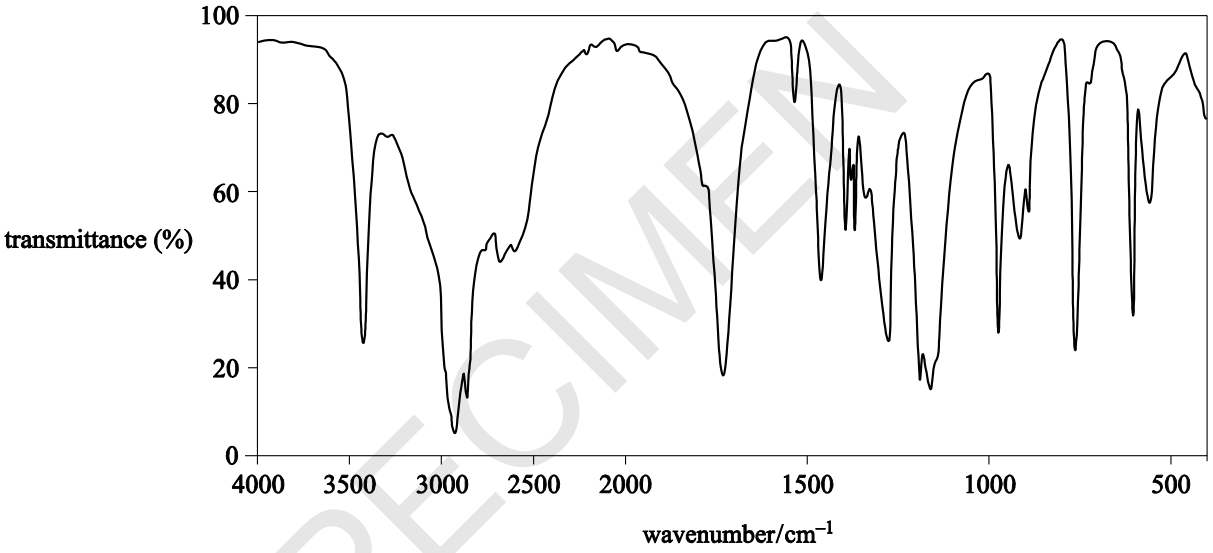
**(d)** Compound **A** reacts slowly in humid conditions to form compound **C**.




**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.

……

…… **[3]**

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

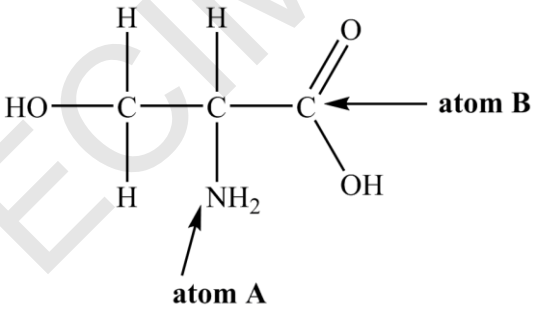
Draw a possible repeat unit of this condensation polymer.

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]**

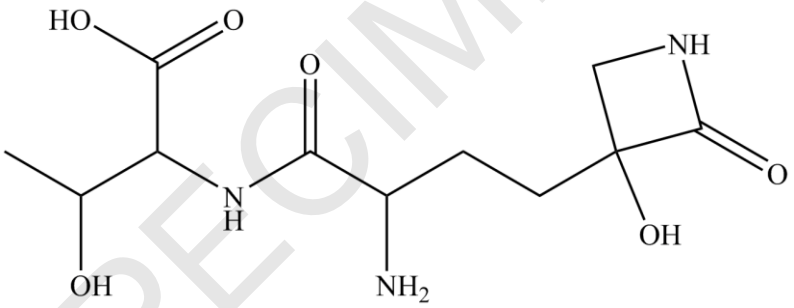
**(ii)** A student adds an excess of aqueous sodium hydroxide to a sample of solid serine.
The student then purifies the resulting reaction mixture to obtain a pure sample of an ionic organic product.

- 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.

……

…… **[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]**

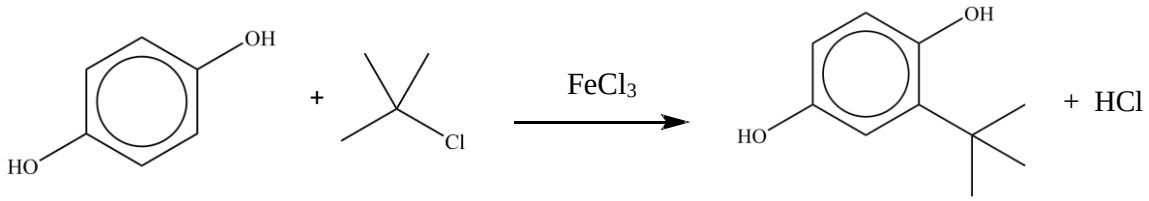
**(ii)** Tabtoxin can be broken down by alkaline hydrolysis.

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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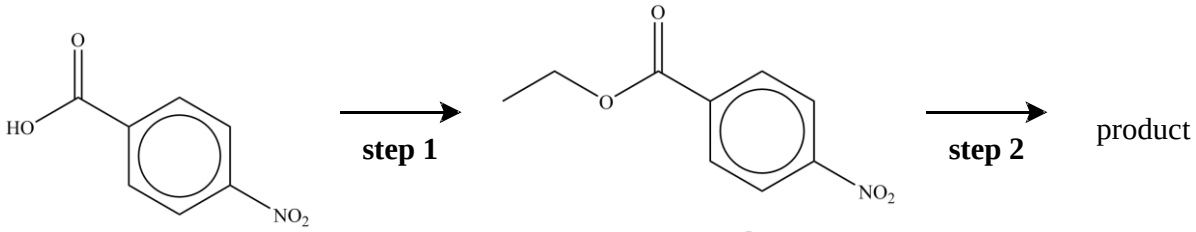
…… **[3]**

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




**Compound F**

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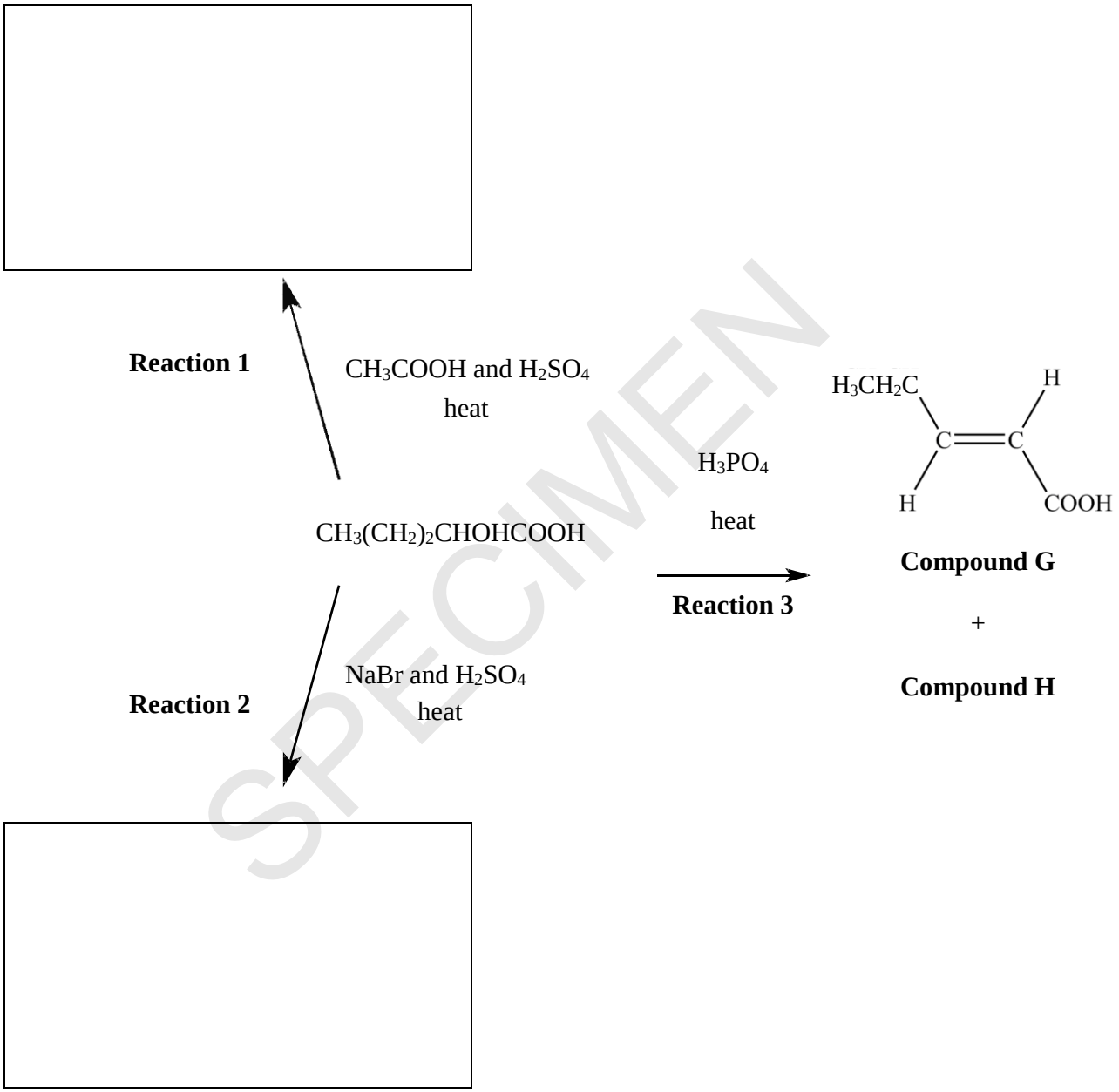
**19** α-Hydroxy acids (AHAs) are naturally occurring acids often used as cosmetics.

**(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]**

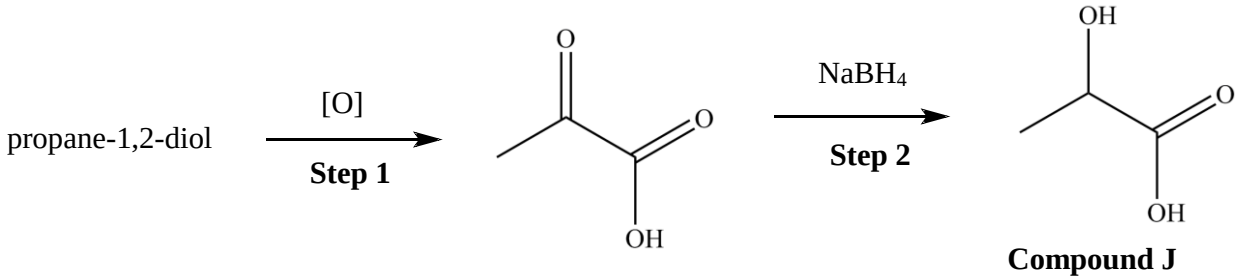
**(iv)** The addition polymer in **(iii)** is used widely in industry. Increasingly, waste polymers are being processed as a more sustainable option than disposal.

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.



**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. **[6]**



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Additional answer space if required.

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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.

……

…… **[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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…… **[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.

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…… **[3]**

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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.

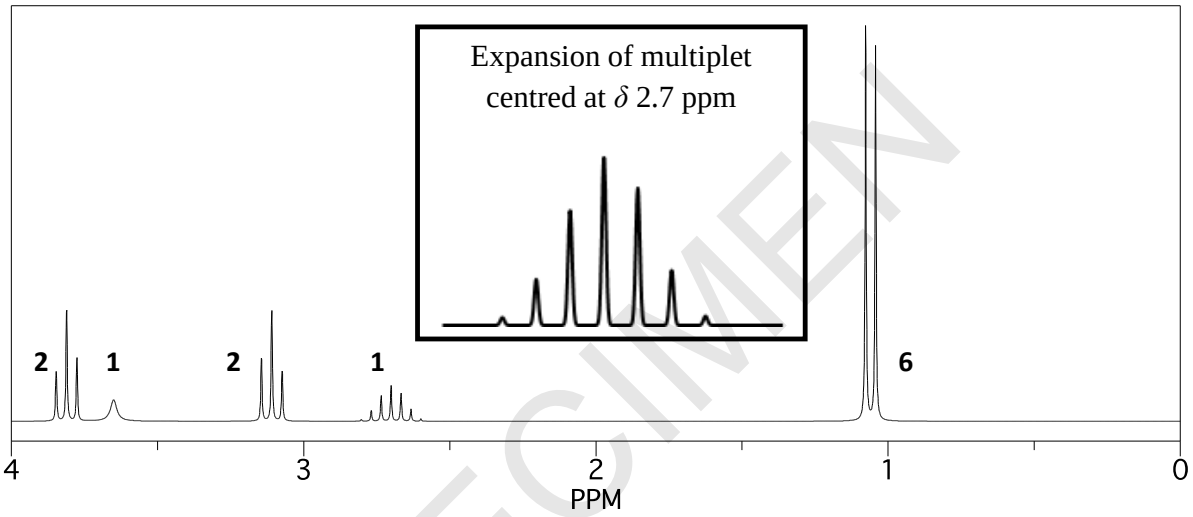
**Mass spectrum**

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

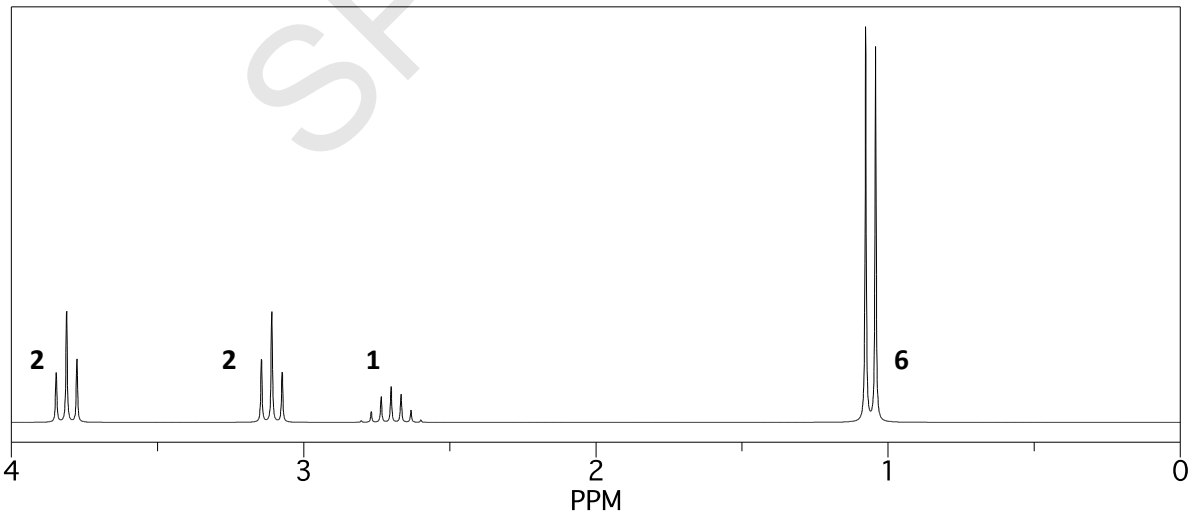
**$^1$H NMR spectra**

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.

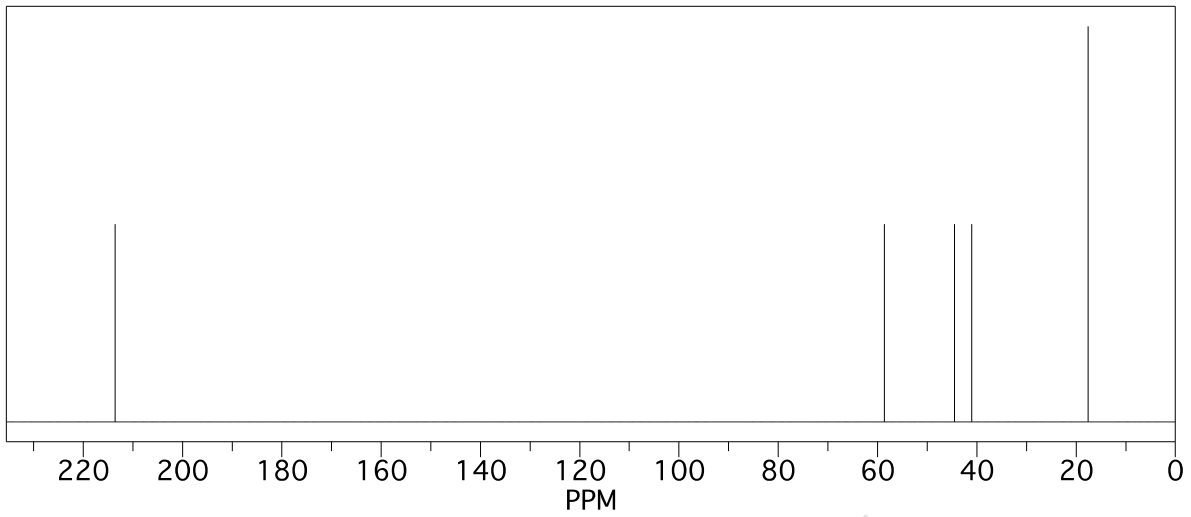
$^1$H NMR spectrum with no $D_2O$:




$^1$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. **[6]**



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Additional answer space if required.

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**END OF QUESTION PAPER**

OCR
Oxford Cambridge and RSA

**…day June 20XX – Morning/Afternoon**

**A Level Chemistry A**

**H432/02 Synthesis and analytical techniques**

**SAMPLE MARK SCHEME**

**Duration:** 2 hours 15 minutes

**MAXIMUM MARK 100**



**This document consists of 24 pages**

## MARKING INSTRUCTIONS

### PREPARATION FOR MARKING

### SCORIS

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: *scoris assessor Online Training*; *OCR Essential Guide to Marking*.

2. Make sure that you have read and understood the mark scheme and the question paper for this unit. These are posted on the RM Cambridge Assessment Support Portal http://www.rm.com/support/ca

3. Log-in to scoris and mark the **required number** of practice responses ("scripts") and the **required number** of standardisation responses.

   YOU MUST MARK 10 PRACTICE AND 10 STANDARDISATION RESPONSES BEFORE YOU CAN BE APPROVED TO MARK LIVE SCRIPTS.

### MARKING

1. Mark strictly to the mark scheme.

2. Marks awarded must relate directly to the marking criteria.

3. The schedule of dates is very important. It is essential that you meet the scoris 50% and 100% (traditional 50% Batch 1 and 100% Batch 2) deadlines. If you experience problems, you must contact your Team Leader (Supervisor) without delay.

4. If you are in any doubt about applying the mark scheme, consult your Team Leader by telephone, email or via the scoris messaging system.

5. Work crossed out:

   a. where a candidate crosses out an answer and provides an alternative response, the crossed out response is not marked and gains no marks

   b. if a candidate crosses out an answer to a whole question and makes no second attempt, and if the inclusion of the answer does not cause a rubric infringement, the assessor should attempt to mark the crossed out answer and award marks appropriately.

6. Always check the pages (and additional objects if present) at the end of the response in case any answers have been continued there. If the candidate has continued an answer there then add a tick to confirm that the work has been seen.

7. There is a NR (No Response) option. Award NR (No Response)

   - if there is nothing written at all in the answer space
   - OR if there is a comment which does not in any way relate to the question (e.g. 'can't do', 'don't know')
   - OR if there is a mark (e.g. a dash, a question mark) which isn't an attempt at the question.

   Note: Award 0 marks – for an attempt that earns no credit (including copying out the question).

8. The scoris **comments box** is used by your Team Leader to explain the marking of the practice responses. Please refer to these comments when checking your practice responses. **Do not use the comments box for any other reason.**

   If you have any questions or comments for your Team Leader, use the phone, the scoris messaging system, or email.

9. Assistant Examiners will send a brief report on the performance of candidates to their Team Leader (Supervisor) via email by the end of the marking period. The report should contain notes on particular strengths displayed as well as common errors or weaknesses. Constructive criticism of the question paper/mark scheme is also appreciated.

10. For answers marked by levels of response:

Read through the whole answer from start to finish, concentrating on features that make it a stronger or weaker answer using the indicative scientific content as guidance. The indicative scientific content indicates the expected parameters for candidates' answers, but be prepared to recognise and credit unexpected approaches where they show relevance.

Using a 'best-fit' approach based on the science content of the answer, first decide which set of level descriptors, Level 1, Level 2 or Level 3, **best** describes the overall quality of the answer using the guidelines described in the level descriptors in the mark scheme.

Once the level is located, award the higher or lower mark.

**The higher mark** should be awarded where the level descriptor has been evidenced and all aspects of the communication statement (in italics) have been met.

**The lower mark** should be awarded where the level descriptor has been evidenced but aspects of the communication statement (in italics) are missing.

**In summary:**

- **The science content determines the level.**
- **The communication statement determines the mark within a level.**

Level of response questions on this paper are **20(a)** and **21**.

11. **Annotations**

| Annotation | Meaning |
|---|---|
| **DO NOT ALLOW** | Answers which are not worthy of credit |
| **IGNORE** | Statements which are irrelevant |
| **ALLOW** | Answers that can be accepted |
| ( ) | Words which are not essential to gain credit |
| __ | Underlined words must be present in answer to score a mark |
| **ECF** | Error carried forward |
| **AW** | Alternative wording |
| **ORA** | Or reverse argument |

## 12. Subject-specific Marking Instructions

### INTRODUCTION

Your first task as an Examiner is to become thoroughly familiar with the material on which the examination depends. This material includes:

- the specification, especially the assessment objectives
- the question paper
- the mark scheme.

You should ensure that you have copies of these materials.

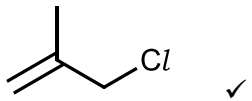
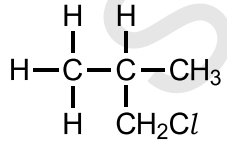
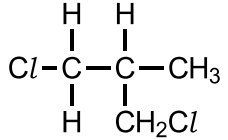
You should ensure also that you are familiar with the administrative procedures related to the marking process. These are set out in the OCR booklet **Instructions for Examiners**. If you are examining for the first time, please read carefully **Appendix 5 Introduction to Script Marking: Notes for New Examiners**.

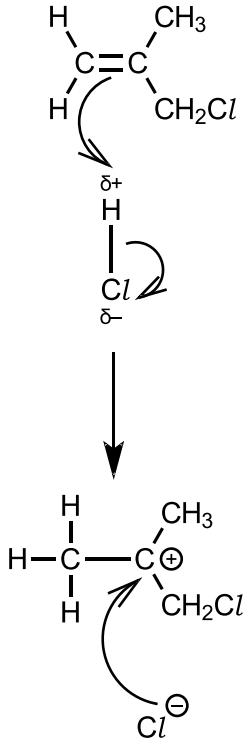
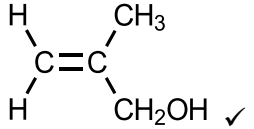
Please ask for help or guidance whenever you need it. Your first point of contact is your Team Leader.

## SECTION A

| Question | Key | Marks | Guidance |
|---|---|---|---|
| 1 | B | 1 | |
| 2 | B | 1 | |
| 3 | B | 1 | |
| 4 | D | 1 | |
| 5 | A | 1 | |
| 6 | B | 1 | |
| 7 | B | 1 | |
| 8 | B | 1 | |
| 9 | C | 1 | |
| 10 | B | 1 | |
| 11 | D | 1 | |
| 12 | C | 1 | |
| 13 | A | 1 | |
| 14 | D | 1 | |
| 15 | A | 1 | |
| | **Total** | 15 | |

## SECTION B

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 16 | (a) | (i) | $C_4H_7Cl$ ✓ | 1 | |
| | | (ii) |  ✓ | 1 | **DO NOT ALLOW** non-skeletal formulae |
| | | (iii) | (compounds with) the same (molecular) formula<br><br>**AND** different structures / structural formulae / arrangement of atoms / displayed formulae ✓ | 1 | **ALLOW** same number of atoms of each element<br>**ALLOW** different carbon backbone<br>**DO NOT ALLOW** different spatial arrangement (of atoms) |
| | (b) | | $n = \frac{pV}{RT} = \frac{(100 \times 10^3) \times (1.053 \times 10^{-3})}{8.314 \times 350}$ ✓<br><br>$n$ = 0.0362 mol ✓<br><br>$M = \frac{m}{n} = \frac{1.321}{0.0362}$ = 36.5 (g mol$^{-1}$) ✓<br><br>*Identity*<br>$HCl$ ✓ | 4 | |
| | (c) | (i) | From **Reaction 1** =  ✓<br><br>compound **B** =  ✓ | 2 | **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| | | (ii) |  <br>Curly arrow from C=C to attack the H atom ✓<br>Correct dipole on H—C*l*<br>**AND** curly arrow from bond to C*l* ✓<br>Correct carbocation/carbonium ion with full positive charge shown<br>**AND** correct curly arrow from negative charge of C*l*$^-$ to correct carbon atom<br>**OR** correct curly arrow from lone pair of C*l*$^-$ to correct carbon atom ✓ | **3** | **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous<br>Curly arrow must start from covalent bonds and not atoms<br>**DO NOT ALLOW** any other partial charges *e.g.* shown on double bond<br>**DO NOT ALLOW** $C^{\delta+}$ for charge on carbonium ion.<br>Curly arrow from C*l*$^-$ can start from the negative charge or the lone pair<br>**DO NOT ALLOW** delta negative, *i.e.* C*l*$^{\delta-}$ |
| | | (iii) | because the intermediate/carbocation in the formation of compound **B** is less stable (than the intermediate in the formation of compound **A**) ✓ | **1** | |
| | | (iv) |  ✓<br>(Formation of) white precipitate/solid/suspension<br>**AND** (ppt is) silver chloride/AgC*l* ✓ | **2** | **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous |

<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td></td><td>(d)</td><td></td><td>

***Use of elemental analysis data***

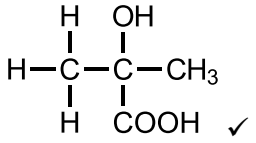
<table>
<tr><td></td><td>C</td><td>H</td><td>O</td></tr>
<tr><td>%</td><td>46.1</td><td>7.7</td><td>46.2</td></tr>
<tr><td>mol</td><td>3.84</td><td>7.7</td><td>2.89</td></tr>
<tr><td>ratio</td><td>1.33</td><td>2.66</td><td>1</td></tr>
</table>

atom ratio with calculation ✓<br>
empirical formula = $C_4H_8O_3$ ✓

***IR spectrum***<br>
(very) broad absorption 2500–3300 $cm^{-1}$ (CO**OH**)<br>
**AND** absorption 1640–1750 $cm^{-1}$ (C=O) ✓<br>
absorption 3450 $cm^{-1}$ (alcohol **–OH**) ✓

***Identification***

conclusion from data: compound contains –COOH and –OH (empirical formula confirms no other C=O than in COOH) in place of the previous chlorine-containing groups



✓

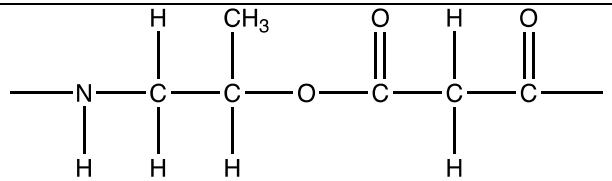
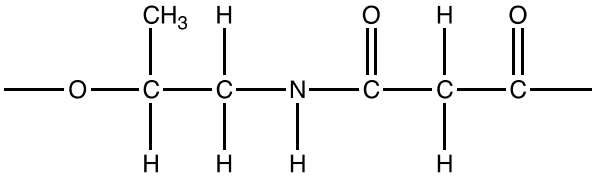
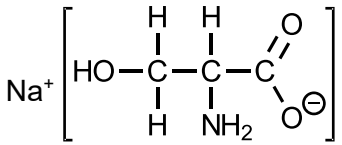
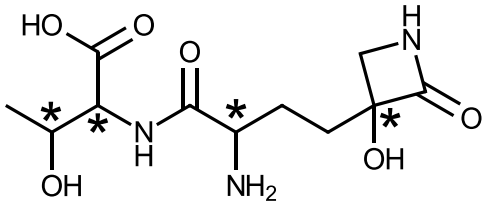
</td><td>5</td><td>

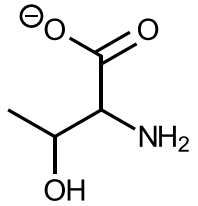
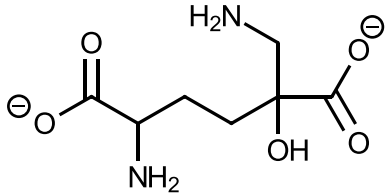
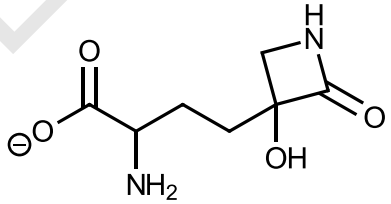
**ALLOW** any values given within ranges given on Data Sheet

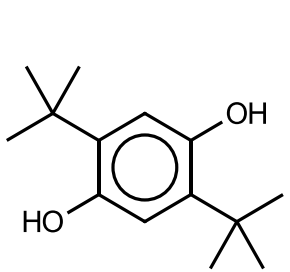
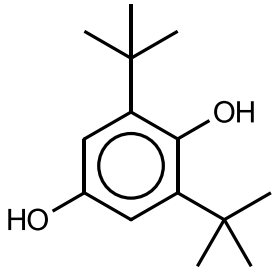
**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous

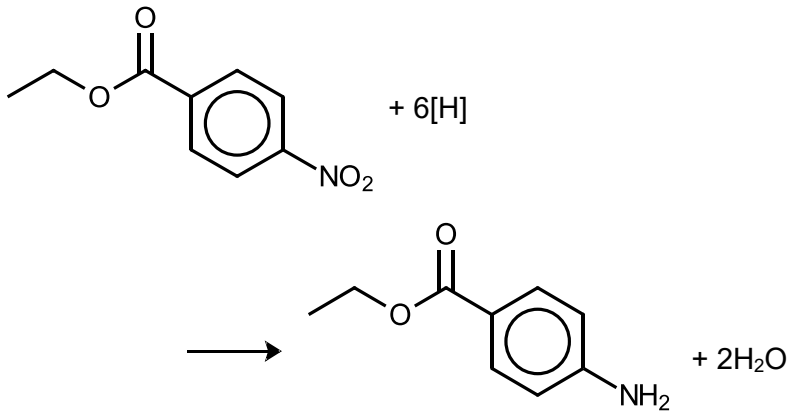
</td></tr>
<tr><td></td><td></td><td></td><td>**Total**</td><td>**20**</td><td></td></tr>
</table>

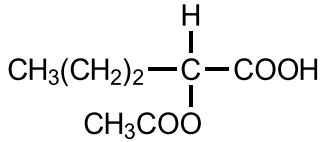
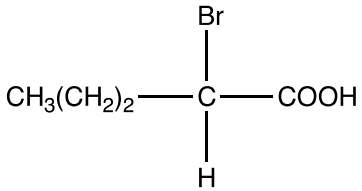
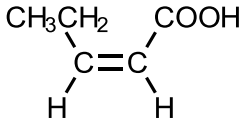
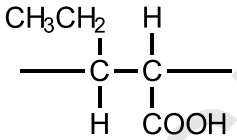
| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 17 | (a) | (i) | **Step 1**: add HCN **OR** $H_2SO_4$/KCN ✓<br><br>$CH_3CHO + HCN \rightarrow CH_3CH(OH)CN$ ✓<br><br>**Step 2**: react with $H_2$/Ni ✓<br><br>$CH_3CH(OH)CN + 2H_2 \rightarrow CH_3CH(OH)CH_2NH_2$ ✓ | 4 | **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous<br>first mark can be implicit from equation<br><br>third mark can be implicit from equation if Ni shown as catalyst<br>(*e.g.* above the reaction arrow)<br>**ALLOW**<br>$CH_3CH(OH)CN + 4[H] \rightarrow CH_3CH(OH)CH_2NH_2$ |
| | | (ii) | because (compound **D**) forms hydrogen bonds form **with** water ✓<br><br>demonstrated through diagram showing:<br>- dashed line between —OH and (:)$OH_2$ ✓<br>- dashed line between —$NH_2$ and (:)$OH_2$ ✓ | 3 | <br><br>dipole and lone pair are **not** required<br>**IGNORE** bond angles<br>Diagram does **not** need to show all of Compound **D** (and **IGNORE** if wrong) |

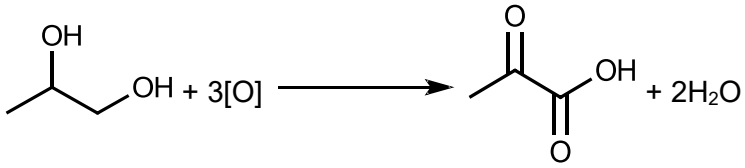
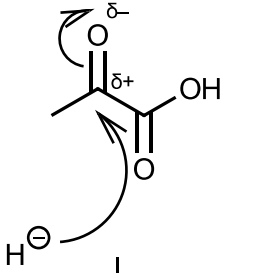
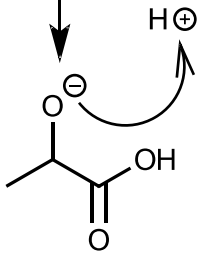
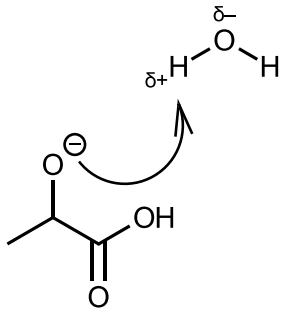
| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| | | (iii) |  <br>**OR**<br>  <br>ester **AND** amide link ✓<br>rest of structure ✓ | **2** | **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous<br>'End bonds' **MUST** be shown (solid or dotted)<br>**IGNORE** brackets and/or *n* |
| | **(b)** | **(i)** | Atom **A**: 3 bonding pairs **AND** 1 lone pair ✓<br>(therefore) pyramidal **AND** 107° ✓<br><br>Atom **B**: 3 bonding centres (and 0 lone pairs) ✓<br>(therefore) trigonal planar **AND** 120° ✓ | **4** | **ALLOW** 106–108°<br><br>**ALLOW** 4 bonding pairs but with 1 double/π-bond (therefore 3 bonding centres) |
| | | **(ii)** |  ✓<br>filter solution ✓<br>recrystallise ✓ | **3** | **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous |
| | **(c)** | **(i)** |  ✓ for all four | **1** | |

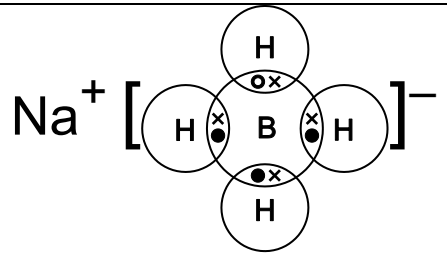
| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| | | (ii) | ***Left-hand fragment***<br>  <br>**OR** structure with COOH rather than $COO^-$ ✓<br><br>***Right-hand fragment***<br>  <br>**OR** structure with COOH rather than $COO^-$ ✓✓<br><br>Two **OR** three $COO^-$ shown ✓ | **4** | **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous<br><br>**ALLOW** 1 mark for structure with right-hand ring still intact<br>  |
| | | | **Total** | **21** | |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 18 | (a) | (i) |  **OR**  ✓ | 1 | **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous<br>**ALLOW** disubstituted compound with *tert*-butyl groups adjacent |
| | | (ii) | (The student's friend is correct because)<br>the lone pair of electrons on the oxygen atom(s) ✓<br>is donated to/partially delocalised into the π system ✓<br>making quinol more susceptible to electrophilic attack ✓ | 3 | **ALLOW** "the oxygen p-orbital overlaps with…"<br>**ALLOW** diagrammatic answer for 1st and 2nd marks:<br>1st mark: π system **OR** 6×p orbitals shown<br>2nd mark: O lone pair **OR** O p-orbital **AND** interaction<br>**ALLOW** undergoes electrophilic substitution more easily<br>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** $CH_3CH_2OH$ ✓ | 1 | **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| | | (ii) |   **BOTH** organic structures ✓<br>balanced equation ✓ | **2** | **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous |
| | | | **Total** | **7** | |

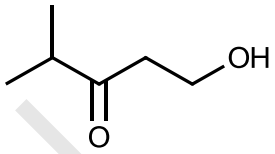
| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 19 | (a) | (i) | **Product from reaction 1:**<br>  <br><br>✓<br><br>**Product from reaction 2:**<br>  <br><br>✓ | **2** | **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous |
| | | **(ii)** | (*E*)-pent-2-enoic acid ✓ | **1** | **ALLOW** "*E*" with or without brackets |
| | | **(iii)** | compound **H** =  <br><br>✓<br><br>addition polymer =  <br><br>✓ | **2** | **ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous<br><br>'End bonds' **MUST** be shown (solid or dotted)<br>**IGNORE** brackets and/or *n* |
| | | **(iv)** | combustion for energy production ✓<br>use as an organic feedstock for the production of plastics and other organic chemicals ✓ | **2** | |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| | (b) | (i) | Oxidising agent = acidified (potassium/sodium) dichromate(VI) ✓<br><br>**(Oxidation) equation**<br>  <br><br>✓<br><br>**(Reduction) mechanism**<br>  <br><br>curly arrow from $H^-$ to $C^{\delta+}$ ✓<br>dipole **AND** curly arrow from C=O bond to O ✓<br><br>  <br><br>intermediate<br>**AND** curly arrow to $H^+$ ✓ | 5 | **ALLOW** $Cr_2O_7^{2-}$ **OR** $K_2Cr_2O_7$ **OR** $Na_2Cr_2O_7$ for dichromate<br>**ALLOW** $H^+$ **OR** (conc.) sulfuric acid for "acidified"<br><br>**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous<br><br>**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous<br><br>  <br><br>**ALLOW**<br>for second stage<br>**IF** $H_2O$ is used it **MUST** show the curly arrow from the intermediate to $H^{\delta+}$ in $H_2O$ **AND** from the O—H bond to the O<br>**IGNORE** product<br>**IGNORE** stereochemistry of intermediate |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| | | (ii) |  ✓<br>$1s^2\ 2s^2\ 2p^6$ ✓ | 2 | **IGNORE** inner electron shells for both ions<br><br>Three different symbols required to identify electrons from different elements<br><br>**DO NOT ALLOW** [Ne] **OR** [He] $2s^2\ 2p^6$ |
| | (c) | | *n*(NaOH) used in titration = 0.150 × 18.80/1000<br>= 0.00282 (mol) ✓<br><br>*n*($H^+$/COOH) in 25.0 $cm^3$ = 0.00282 (mol)<br>**AND** *n*($H^+$/COOH) in 250 $cm^3$ = 0.0282 (mol) ✓<br><br>'Molar' mass of **K** = 1.89/0.0282 = 67.0 g $mol^{-1}$ ✓<br><br>**K** must be diprotic ✓<br><br>**K** is malic acid/$HOOCCH_2CHOHCOOH$ ✓ | 5 | Determined through realisation that none of the compounds listed have *M* = 67.0 g $mol^{-1}$ |
| | | | **Total** | 19 | |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| 20 | (a)* | | *Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.*<br><br>**Level 3 (5–6 marks)**<br>Correctly labelled diagram of apparatus that works, with no safety problems<br>**AND**<br>Full appreciation of further two steps required to gain pure sample<br><br>*There is a well-developed diagram which is clear and structured. The information on further purification is detailed and relevant.*<br><br>**Level 2 (3–4 marks)**<br>Labelled diagram of apparatus but with safety/procedural problems **OR** clear diagram of functional apparatus without labelling<br>**AND**<br>Some details of further purification steps<br><br>*The diagram presents apparatus that is in the most-part relevant with some correct labelling, and supported by some details of further purification steps.*<br><br>**Level 1 (1–2 marks)**<br>Diagram of apparatus drawn with no labelling **OR** labelled diagram with significant safety/procedural problems<br>**AND**<br>Few or imprecise details about further purification stages<br><br>*The diagram is basic and unstructured. Any mention of purification steps is limited to generic term, e.g. 'drying', without relevant detail.* | 6 | **Indicative scientific points may include:**<br><br>**Diagram**<br><br><u>Includes following components:</u><br><br>distillation flask<br>heat source<br>thermometer at outlet (bulb **level** with outlet)<br>still-head<br>water condenser (**correct direction** of water flow)<br>receiving vessel<br>**open** system.<br><br>**Further purification**<br><br>Shake and leave to settle in a separating funnel<br>Separate layers by tapping off<br><br>Add (a small amount of) anhydrous magnesium sulfate/anhydrous calcium chloride to organic layer (in a dry conical flask)<br><br>(Re)distil the organic layer<br>Collect fraction distilling at (between 150 °C and) 156 °C. |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| | | | *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.*<br><br>**0 marks**<br>No response or no response worthy of credit. | | |
| | **(b)** | | Lack of (further) effervescence ✓ | **1** | **ALLOW** fizzing/bubbling stops |
| | **(c)** | | Take samples from reaction mixture at regular intervals ✓<br>Spot/run on a TLC plate, alongside cyclohexanol (and cyclohexanone) controls ✓ | **2** | **ALLOW** "frequent" for "regular"<br>**ALLOW** measure/compare $R_f$ value to cyclohexanol<br>**IGNORE** reference to solvent or visualising chemicals/UV |
| | **(d)** | | React (sample of distillate) with 2,4-dinitrophenylhydrazine ✓<br>recrystallise **AND** determine the melting point ✓<br>Compare melting point to known/library value for cyclohexanone (derivative) ✓ | **3** | **ALLOW** (2,4-)DNPH/Brady's reagent |
| | | | **Total** | **12** | |

| Question | Answer | Marks | Guidance |
|---|---|---|---|
| 21* | *Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.*<br><br>**Level 3 (5–6 marks)**<br>Structure correct<br>**AND**<br>Analysed all $^{1}$H NMR signals with at least two supporting statements made.<br><br>*The analysis is clear and logically structured. The supporting statements are relevant to the correct structure drawn.*<br><br>**Level 2 (3–4 marks)**<br>Structure has correct molecular formula **AND** C=O **AND** OH but in incorrect positions<br>**AND**<br>Analysed at least three $^{1}$H NMR signals with one or two supporting statements made<br><br>*The analysis is presented with some structure. The supporting statements are in the most-part relevant to the structure drawn.*<br><br>**Level 1 (1–2 marks)**<br>Structure has correct molecular formula **AND** C=O **OR** OH but in incorrect positions<br>**AND**<br>Analysed at least two $^{1}$H NMR signals with no or one supporting statements made<br><br>*The analysis is basic and communicated in an unstructured way. The relationship of the supporting evidence to the structure may not be clear.* | 6 | **Indicative scientific points may be included:**<br>**Structure**<br>  <br><br>**L** =<br>**$^{1}$H NMR spectrum**<br>$\delta$ = 3.8 ppm, triplet, 2H $CH_2$—**$CH_2$—O**<br>$\delta$ = 3.7 ppm, singlet, 1H O—**H**<br>$\delta$ = 3.1 ppm, triplet, 2H $CH_2$—**$CH_2C$=O**<br>$\delta$ = 2.7 ppm, septet, 1H $(CH_3)_2C$**HC=O**<br>$\delta$ = 1.0 ppm, doublet, 6H **$(CH_3)_2$**CH<br><br>**Supporting statements**<br>$\delta$ = 3.7 ppm lost after $D_2O$, indicating —O**H**<br>$\delta$ = 213 ppm in $^{13}$C NMR but no $\delta$ = 9–10 ppm in $^{1}$H NMR so ketone, **not** aldehyde<br>$M_r(C_3H_6O) = 58$ 116/58 = 2 → $C_6H_{12}O_2$ |

| Question | | | Answer | Marks | Guidance |
|---|---|---|---|---|---|
| | | | *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.*<br><br>**0 marks**<br>No response or no response worthy of credit. | | |
| | | | **Total** | **6** | |

## Summary of updates

| Date | Version | Change |
|---|---|---|
| January 2019 | 2.0 | Minor accessibility changes to the paper:<br>i) Additional answer lines linked to Level of Response questions<br>ii) One addition to the rubric clarifying the general rule that working should be shown for any calculation questions |

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