Oxford Cambridge and RSA

Tuesday 18 June 2024 – Morning

A Level Chemistry A

H432/02 Synthesis and analytical techniques

Time allowed: 2 hours 15 minutes

You must have:
- the Data Sheet for Chemistry A

You can use:
- a scientific or graphical calculator
- an HB pencil

Please write clearly in black ink. **Do not write in the barcodes.**

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

First name(s) _____

Last name _____

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- Quality of extended response will be assessed in questions marked with an asterisk (*****).
- This document has **32** pages.

ADVICE
- Read each question carefully before you start your answer.

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Section A

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

Write your answer to each question in the box provided.

1 All organic compounds have covalent bonds.

What is the electrostatic attraction in a covalent bond between?

A A shared pair of electrons and the nuclei of the bonded atoms

B Cations and delocalised electrons

C Oppositely charged ions

D Two molecules

Your answer ☐

[1]

2 Hydrogen reacts much more readily with alkenes than with alkanes.

Why is this?

A Alkenes are polar molecules whereas alkanes are not.

B All atoms in an alkane have a full outer shell of electrons.

C The bond enthalpy of C–C σ bonds is **higher** than that of π bonds.

D The bond enthalpy of C–C σ bonds is **lower** than that of π bonds.

Your answer ☐

[1]

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3 A student investigates the rate of hydrolysis of different iodoalkanes using aqueous silver nitrate in ethanol.

What colour of precipitate is seen?

A Brown

B Cream

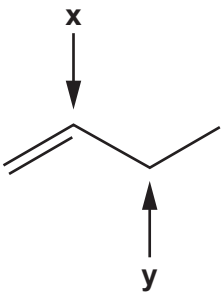
C White

D Yellow

Your answer ☐

[1]

4 The structure of but-1-ene is shown below.



Which row has the correct **shape** around carbon atoms labelled **x** and **y**?

	x	**y**
A	Tetrahedral	Pyramidal
B	Trigonal planar	Tetrahedral
C	Trigonal planar	Pyramidal
D	Pyramidal	Tetrahedral

Your answer ☐

[1]

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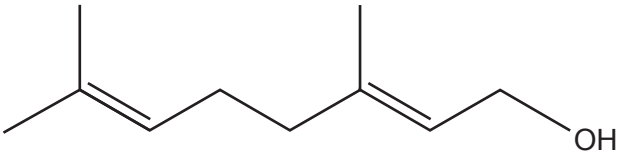
5 Geraniol, shown below, is a component in many natural oils.



Geraniol

Which pair of reagents identifies both functional groups in geraniol?

A Acidified dichromate(VI) and 2,4-dinitrophenylhydrazine.

B Bromine water and 2,4-dinitrophenylhydrazine.

C Bromine water and acidified dichromate(VI).

D Tollens' reagent and aqueous silver nitrate in ethanol.

Your answer ☐

[1]

6 4.30 g of the alcohol C_5H_9OH, (M_r = 86.0), is burned in oxygen.

$C_5H_9OH(l) + 7O_2(g) \rightarrow 5CO_2(g) + 5H_2O(l)$

Which volume of oxygen gas is needed, in dm^3, for this complete combustion of C_5H_9OH, at RTP?

A 1.2

B 2.4

C 5.8

D 8.4

Your answer ☐

[1]

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7 Which statement gives a valid scientific reason for global warming?

A Infrared radiation causes bonds in CH_4 molecules to vibrate more.

B Infrared radiation causes O_2 molecules to vibrate more.

C Ultraviolet radiation causes bonds in CO_2 to vibrate more.

D Ultraviolet radiation causes bonds in CFC molecules to break.

Your answer ☐

[1]

8 The CFC CCl_2F_2 can cause the breakdown of ozone in the upper atmosphere.

Which initiation step could occur with ultraviolet radiation to catalyse this breakdown?

A $CCl_2F_2 \rightarrow \bullet C + \bullet Cl_2F_2$

B $CCl_2F_2 \rightarrow \bullet F + \bullet CCl_2F$

C $CCl_2F_2 \rightarrow \bullet Cl + \bullet CClF_2$

D $CCl_2F_2 \rightarrow \bullet Cl_2 + \bullet CF_2$

Your answer ☐

[1]

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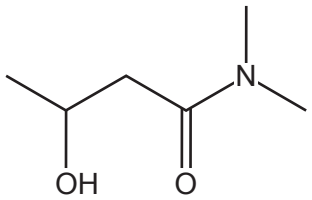
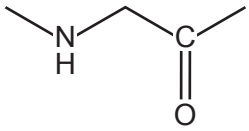
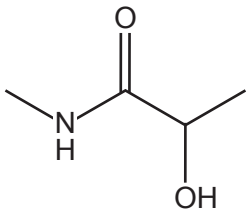
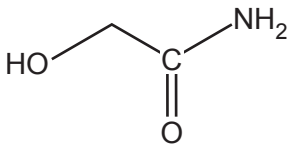
9 Which compound is a secondary amide?

A	
B	
C	
D	

Your answer ☐

[1]

10 1.35 g of ethylamine gas, $CH_3CH_2NH_2$ (M_r = 45.0), is reacted with 20 cm^3 of 2.0 mol dm^{-3} hydrochloric acid forming a solution of ethylammonium chloride.

$CH_3CH_2NH_2(g) + HCl(aq) \rightarrow CH_3CH_2NH_3^+(aq) + Cl^-(aq)$

What is the concentration of ethylammonium chloride in mol dm^{-3}?

A 0.03

B 0.67

C 1.50

D 2.00

Your answer ☐

[1]

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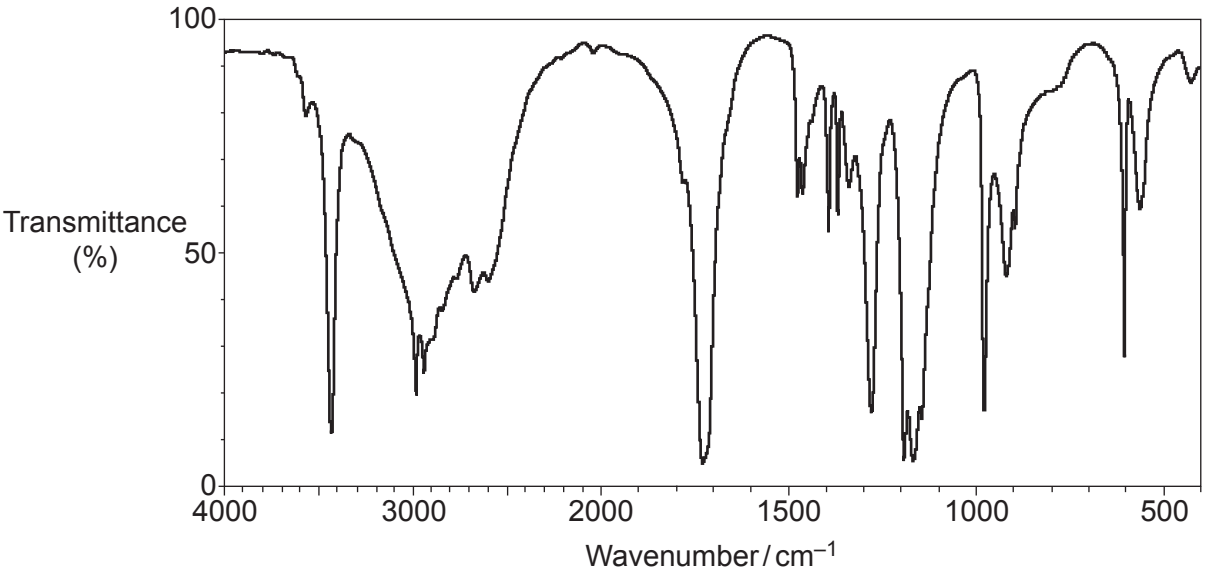
11 Which compound could have produced the IR spectrum shown below?



A $HOCH_2CHO$

B CH_3CH_2COOH

C $CH_3CH_2COOCH_3$

D $(CH_3)_2C(OH)COOH$

Your answer ☐

[1]

12 1,6-Diaminohexane, $H_2N(CH_2)_6NH_2$, reacts with hexanedioyl dichloride, $ClOC(CH_2)_4COCl$ to form a polyamide and one other product.

What is the other product formed in this reaction?

A HCl

B H_2O

C CO

D NH_3

Your answer ☐

[1]

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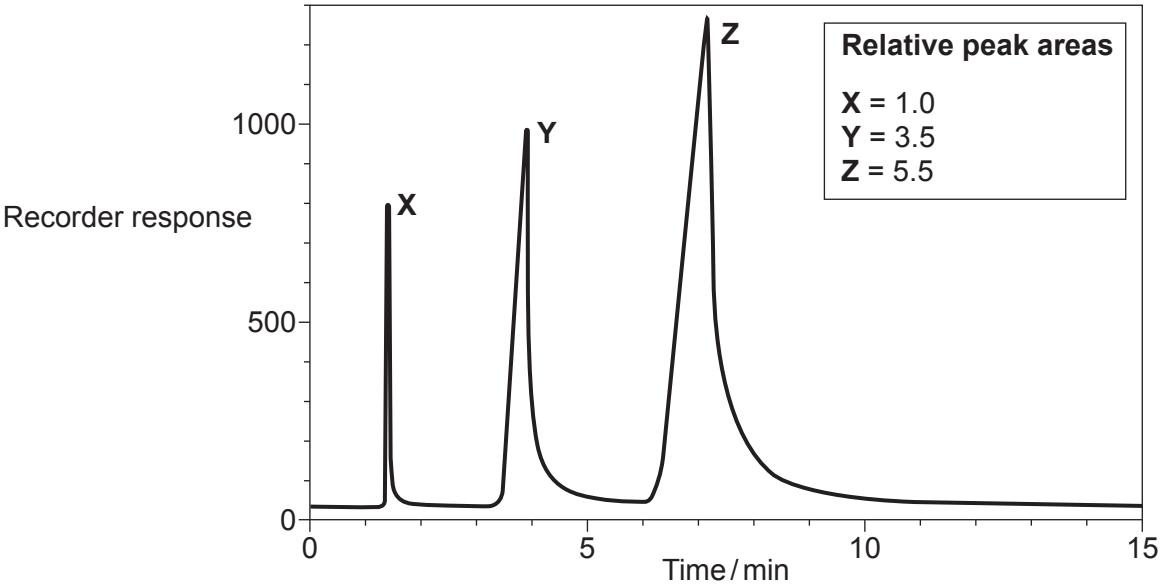
13 A sample containing a mixture of 3 components, **X**, **Y** and **Z**, is analysed using gas chromatography.

The gas chromatogram below is obtained.
The relative peak areas of **X**, **Y** and **Z** are included.



Which statement(s) is/are true?

1 The peak for component **X** shows the mass of one mole.

2 Component **Y** stays in the column for longer than component **X**.

3 Component **Z** consists of more than half of the sample.

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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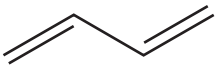
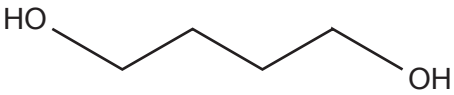
14 The structures of 3 compounds, **1**, **2** and **3**, are shown below.

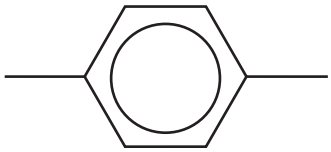
Which compound(s) would produce a carbon-13 NMR spectrum with 2 peaks?



1



2



3

A 1, 2 and 3

B Only 1 and 2

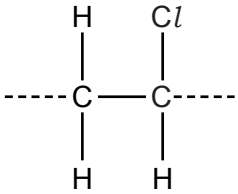
C Only 2 and 3

D Only 1

Your answer ☐

[1]

15 Polymers, such as poly(chloroethene), shown below, are difficult to dispose of.



Poly(chloroethene)

Which statement(s) is/are true about poly(chloroethene)?

1 It is a photodegradable or biodegradable polymer.

2 When incinerated, it produces toxic waste products which need to be removed.

3 It can be recycled and processed for use as an organic feedstock.

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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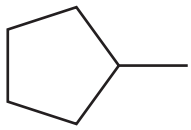
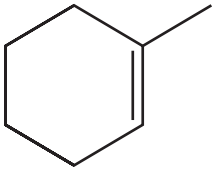
Section B

16 This question is about hydrocarbons.

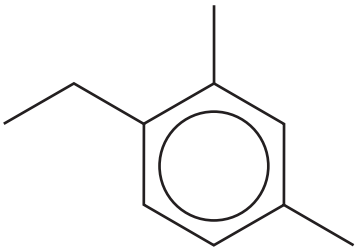
The structures of hydrocarbons **A–E** are shown below.



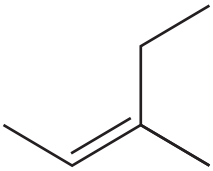
A



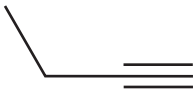
B



C



D



E

(a) Which hydrocarbons are unsaturated?

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

(b) Which hydrocarbons are alicyclic?

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

(c) Which hydrocarbons have the general formula C_nH_{2n}?

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

(d) What is the systematic name of hydrocarbon **C**?

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

(e) Explain why hydrocarbon **D** is a *Z*-stereoisomer.

.....

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..... **[2]**

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17 This question is about reactions of alcohols.

There are 4 structural isomers of $C_4H_{10}O$ that are alcohols:
$CH_3CH_2CH_2CH_2OH$
$CH_3CH_2CHOHCH_3$
$(CH_3)_2CHCH_2OH$
$(CH_3)_3COH$

Alcohols take part in many different types of reaction, including
- elimination
- oxidation
- substitution
- esterification.

For each type of reaction, choose appropriate reagent(s) and/or catalyst, and show the organic product formed.

(a) Elimination reaction of $CH_3CH_2CH_2CH_2OH$

Reagent(s) and/or catalyst

.....

.....

organic product

[2]

(b) Oxidation reaction of $CH_3CH_2CHOHCH_3$

Reagent(s) and/or catalyst

.....

.....

organic product

[2]

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(c) Substitution reaction of $(CH_3)_2CHCH_2OH$

Reagent(s) and/or catalyst

.....

.....

organic product

[2]

(d) Esterification reaction of $(CH_3)_3COH$

Reagent(s) and/or catalyst

.....

.....

organic product

[2]

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18 This question is about haloalkanes.

(a) Haloalkanes can be synthesised by reacting alkanes with halogens in the presence of ultraviolet radiation.

An alkane reacts with bromine to form 2-bromo-2-methylpropane.

(i) Write the equation for this reaction, showing the structures of the organic compounds.

Name the reaction mechanism and the type of bond fission that occurs.

Equation

Name of reaction mechanism .....

Type of bond fission .....

[3]

(ii) Describe **two** limitations of the synthesis of 2-bromo-2-methylpropane from an alkane and bromine.

1 .....

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2 .....

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[2]

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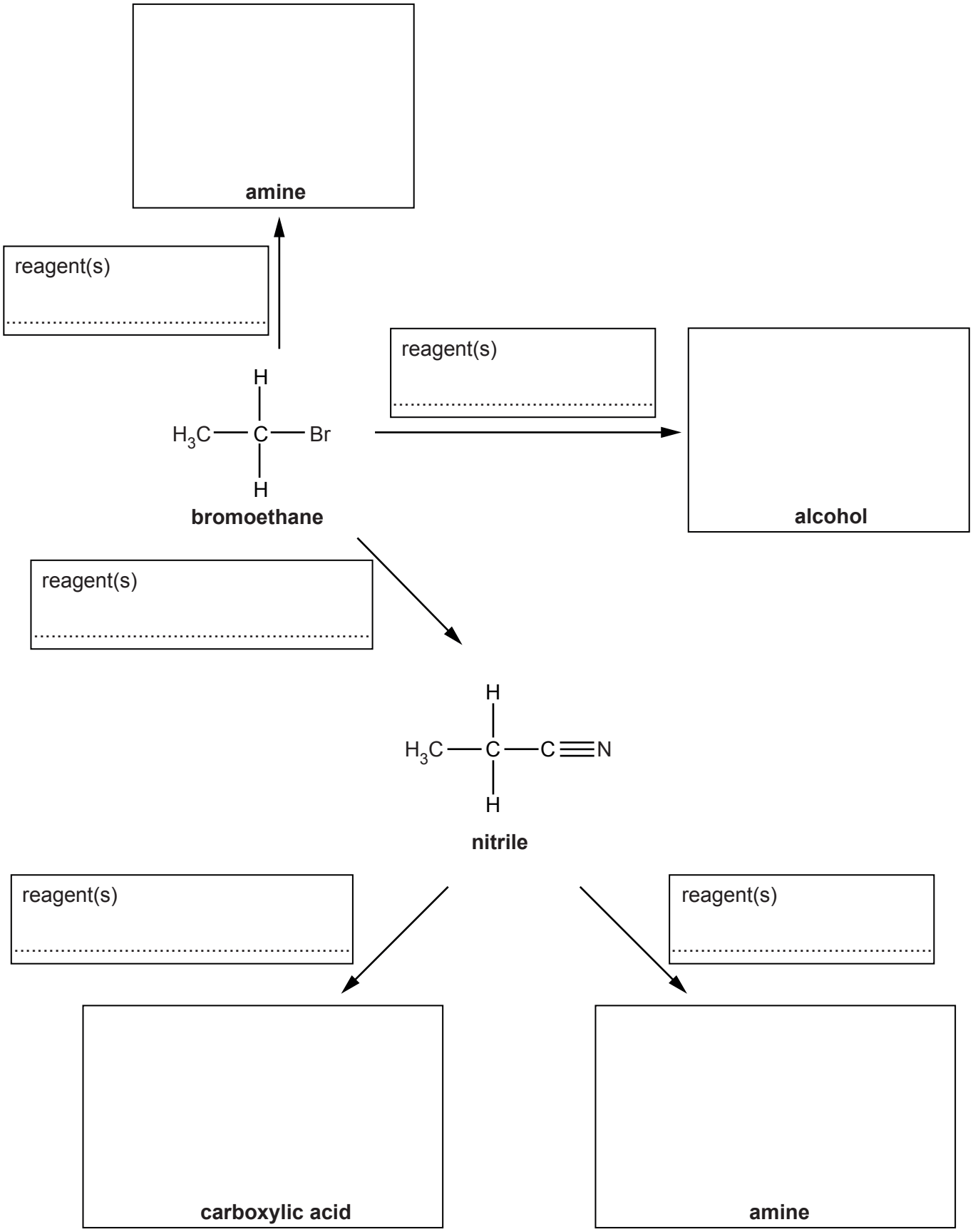
(b) Complete the flowchart by filling in each box.



[9]

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19* Alkenes and carbonyl compounds take part in addition reactions.

Describe **one** addition reaction of an alkene and **one** addition reaction of a carbonyl compound. Include reagents and reaction mechanisms. **[6]**

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Extra answer space if required.

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Turn over for the next question

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20 This question is about carboxylic acids and esters.

(a) Short-chain carboxylic acids, such as methanoic acid, HCOOH, are soluble in water.

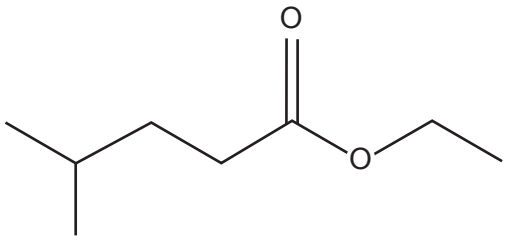
Explain, with a labelled diagram, how HCOOH interacts with water when it dissolves.

.....

.....

..... **[2]**

(b) Ester **F** has the structure shown below.



Ester F

(i) What is the systematic name for this ester?

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

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(ii) Ester **F** can be prepared from a carboxylic acid in two steps.

Step 1 The carboxylic acid is converted into an acyl chloride.

Step 2 The acyl chloride is converted into ester **F**.

Write equations for **Step 1** and **Step 2**.

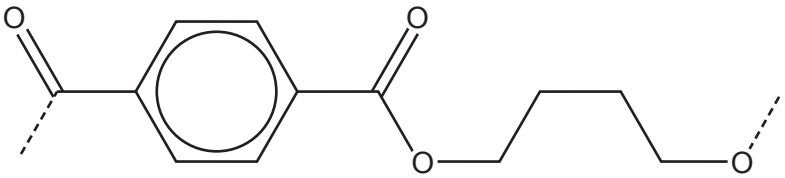
Show organic compounds as structures.

Step 1

Step 2

[4]

(c) The repeat unit of a polyester is shown below.



Draw the structures of monomers required to form this polyester.

[2]

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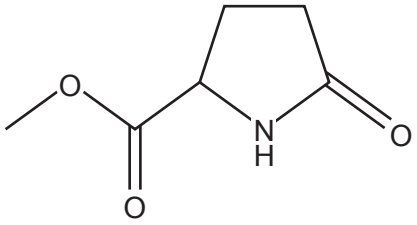
(d) The compound below contains an ester and an amide group.



Draw the structures of the organic products formed by the complete **alkaline** hydrolysis of this compound using NaOH(aq).

[4]

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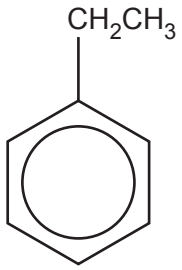
21 This question is about aromatic compounds.

(a) Ethylbenzene, $C_6H_5CH_2CH_3$, can be prepared by reacting benzene with chloroethane, CH_3CH_2Cl, in the presence of $AlCl_3$. The $AlCl_3$ acts as a halogen carrier.



Ethylbenzene

In the mechanism, chloroethane reacts with the halogen carrier to form a carbocation, which acts as the electrophile.

(i) What is meant by the term **electrophile**?

.....

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

(ii) Outline the mechanism for this reaction, including the role of $AlCl_3$ as a halogen carrier.

[5]

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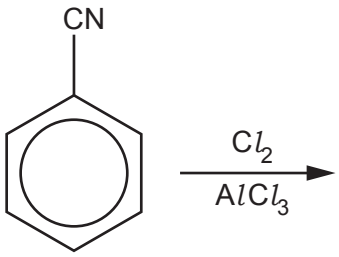
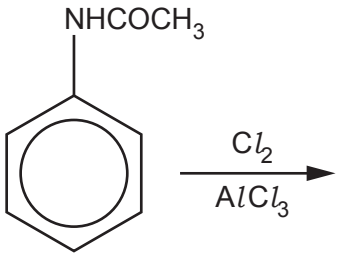
(b) The table shows directing effects for different groups in the electrophilic substitution of aromatic compounds.

Directing effect	**2- and 4- directing**	**3-directing**
Group	–OH	$–NO_2$
	$–NH_2$	$–COCH_3$
	$–NHCOCH_3$	–CN

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

Reaction	**Monosubstituted Product(s)**
	
	

[3]

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(ii) The reactions of $C_6H_5NH_2$ are similar to the reactions of phenol.

Write an equation for the tri-substitution of $C_6H_5NH_2$ with chlorine.

[2]

(iii) Explain why chlorine reacts much more readily with $C_6H_5NH_2$ than with benzene.

.....

.....

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.....

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.....

.....

.....

.....

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

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22 α-Amino acids have the general formula $RCH(NH_2)COOH$.

The R group in an α-amino acid contains C and H only.

This R group has a molar mass of $91\,g\,mol^{-1}$.

(a) A polymer is formed from 500 molecules of this α-amino acid.

Determine the molar mass of this polymer.

Give your answer to the nearest whole number.

molar mass of polymer = ... $g\,mol^{-1}$ **[3]**

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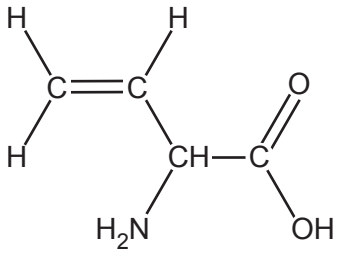
(b) The amino acid below can form addition and condensation polymers.



Draw **2** repeat units of these polymers.
Display the sections linking the monomers together.

addition polymer (2 repeat units)

condensation polymer (2 repeat units)

[3]

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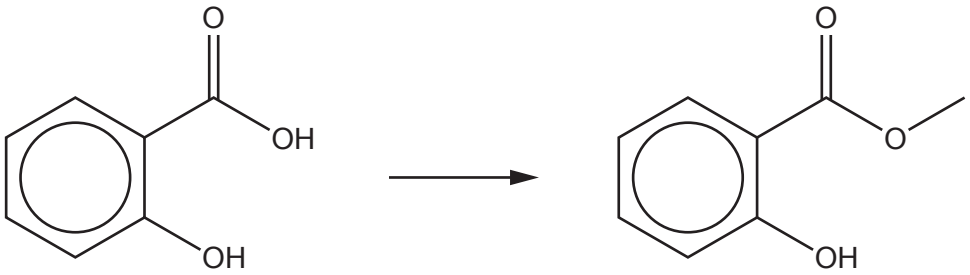
23 Oil of wintergreen is a liquid used in medicine to relieve muscle pain.

Compound **H** is a component in oil of wintergreen and can be synthesised from compound **G**, as shown below. The boiling point and density of compound **H** are stated.



Compound G **Compound H**

boiling point = 222 °C
density = 1.174 g cm^{-3}

A student prepares a sample of compound **H** by the method below.

Step 1 Reflux 8.97 g of compound **G** for 30 minutes with an excess of methanol in the presence of a small amount of sulfuric acid as a catalyst.

Step 2 Add an excess of aqueous sodium carbonate, Na_2CO_3(aq). Two layers are obtained.

Step 3 Purify the impure compound **H** that forms from the resulting mixture.

The student follows this method and obtains 5.32 g of pure compound **H**.

(a) Why does the student use reflux in **Step 1**?

.....

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

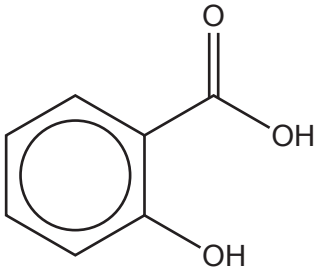
(b)
(i) In **Step 2**, Na_2CO_3(aq) removes the sulfuric acid catalyst **and** any unreacted compound **G** from the mixture.

Write equations for this removal.

Removal of sulfuric acid

.....

Removal of unreacted compound **G**



Compound G

[3]

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(ii) Another student suggests that adding aqueous sodium hydroxide would be more effective in removing the sulfuric acid catalyst than Na_2CO_3(aq).

Comment on whether the student's suggestion is an improvement for the preparation of compound **H**.

.....

.....

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

(c) Calculate the percentage yield of compound **H**.

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

percentage yield = ... % **[3]**

(d) Describe how to purify the impure compound **H** from the two layers in **Step 2**.

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

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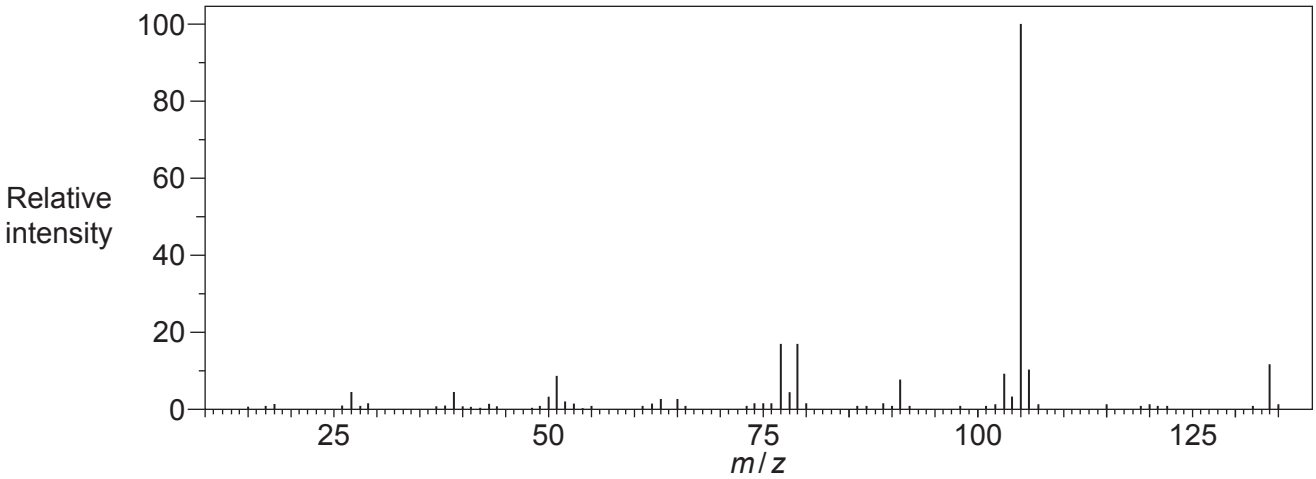
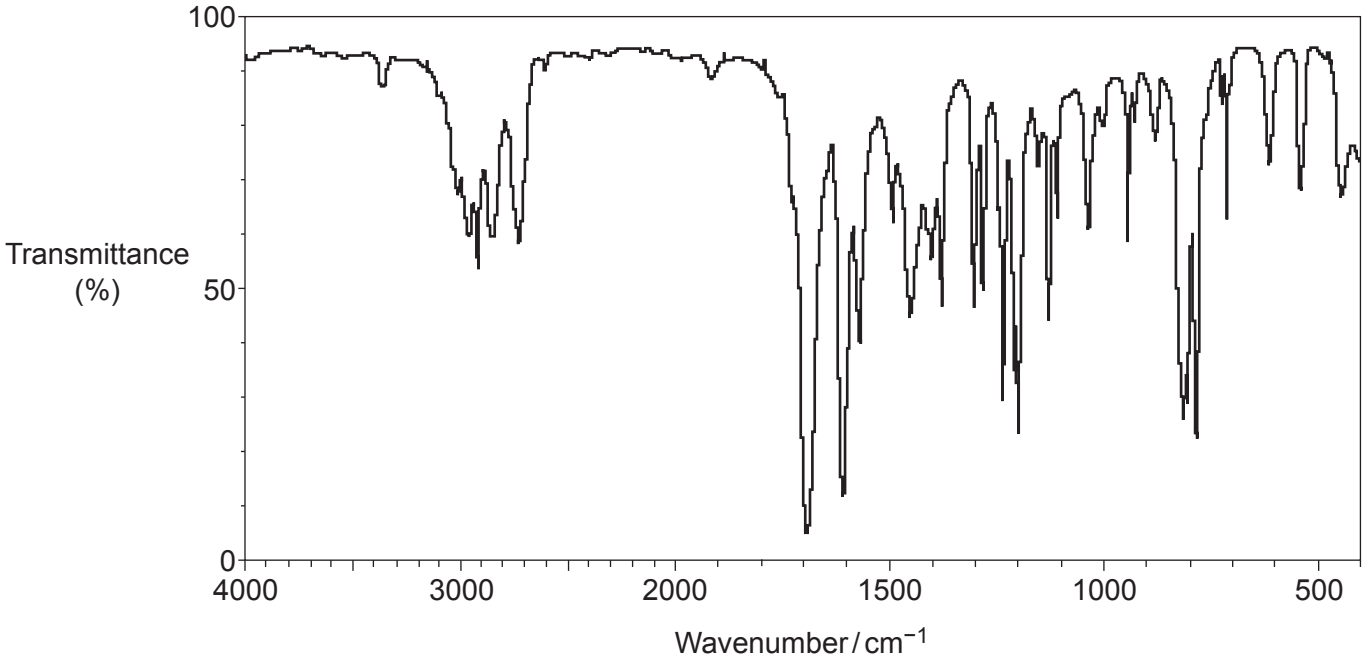
24* Analysis of an unknown organic compound **J** produces the following results.

Elemental analysis by mass of compound J
C, 80.60%; H, 7.46%; O, 11.94%

Mass spectrum of compound J



IR spectrum of compound J



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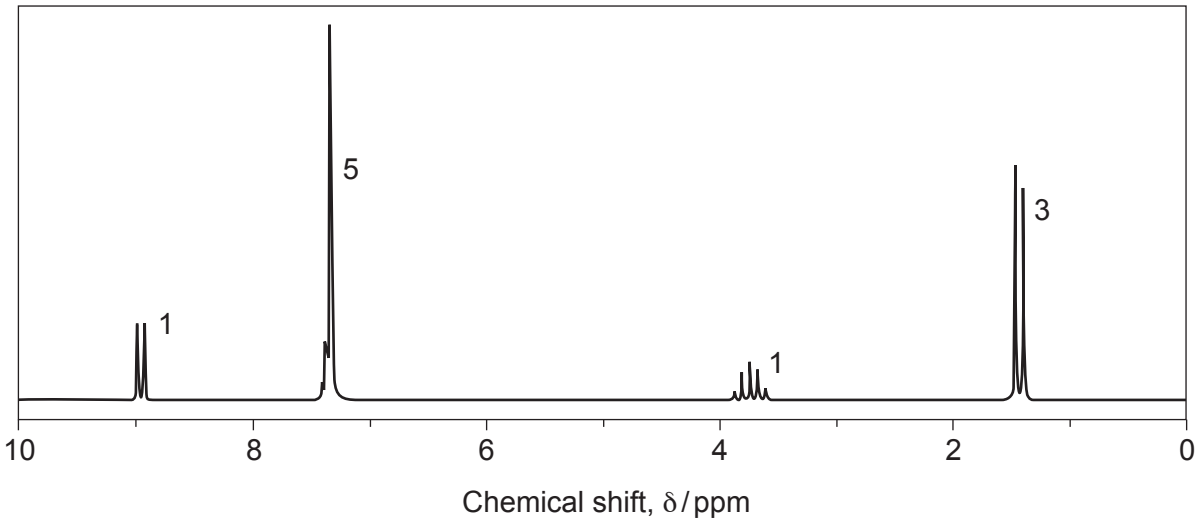
Proton NMR spectrum of compound J



The numbers by the peaks are the relative peak areas.

Determine the structure of compound **J**, showing **all** your reasoning. **[6]**

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Extra answer space if required.

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END OF QUESTION PAPER

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EXTRA ANSWER SPACE

If you need extra space use these lined pages. You must write the question numbers clearly in the margin.

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