

Tuesday 18 June 2024 – Morning

A Level Chemistry A

H432/02 Synthesis and analytical techniques

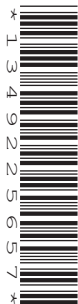
Time allowed: 2 hours 15 minutes

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

StemUp Model Solution

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.

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

A

[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

C

[1]

3

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

What colour of precipitate is seen?

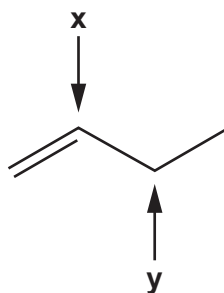
- A Brown
- B Cream
- C White
- D Yellow

Your answer

D

[1]

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



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

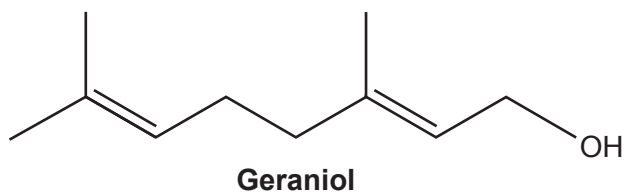
	x	y
A	Tetrahedral	Pyramidal
B	Trigonal planar	Tetrahedral
C	Trigonal planar	Pyramidal
D	Pyramidal	Tetrahedral

Your answer

B

[1]

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



Which pair of reagents identifies both functional groups in geraniol?

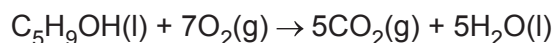
- A Acidified dichromate(VI) and 2,4-dinitrophenylhydrazine.
- B Bromine water and 2,4-dinitrophenylhydrazine.
- C Bromine water and acidified dichromate(VI).
- D Tollens' reagent and aqueous silver nitrate in ethanol.

Your answer

C

[1]

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



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

D

[1]

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

A

[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?

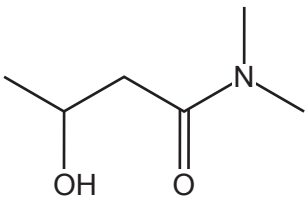
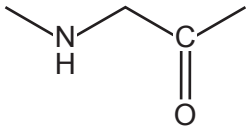
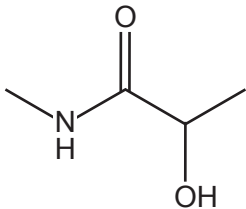
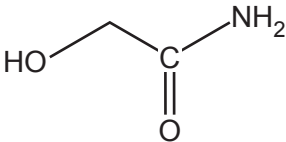
- A $\text{CCl}_2\text{F}_2 \rightarrow \bullet\text{C} + \bullet\text{Cl}_2\text{F}_2$
- B $\text{CCl}_2\text{F}_2 \rightarrow \bullet\text{F} + \bullet\text{CCl}_2\text{F}$
- C $\text{CCl}_2\text{F}_2 \rightarrow \bullet\text{Cl} + \bullet\text{CClF}_2$
- D $\text{CCl}_2\text{F}_2 \rightarrow \bullet\text{Cl}_2 + \bullet\text{CF}_2$

Your answer

C

[1]

9 Which compound is a secondary amide?

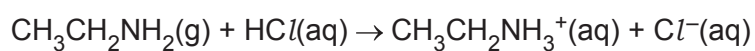
A	
B	
C	
D	

Your answer

C

[1]

10 1.35 g of ethylamine gas, $\text{CH}_3\text{CH}_2\text{NH}_2$ ($M_r = 45.0$), is reacted with 20 cm^3 of 2.0 mol dm^{-3} hydrochloric acid forming a solution of ethylammonium chloride.



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

A 0.03

B 0.67

C 1.50

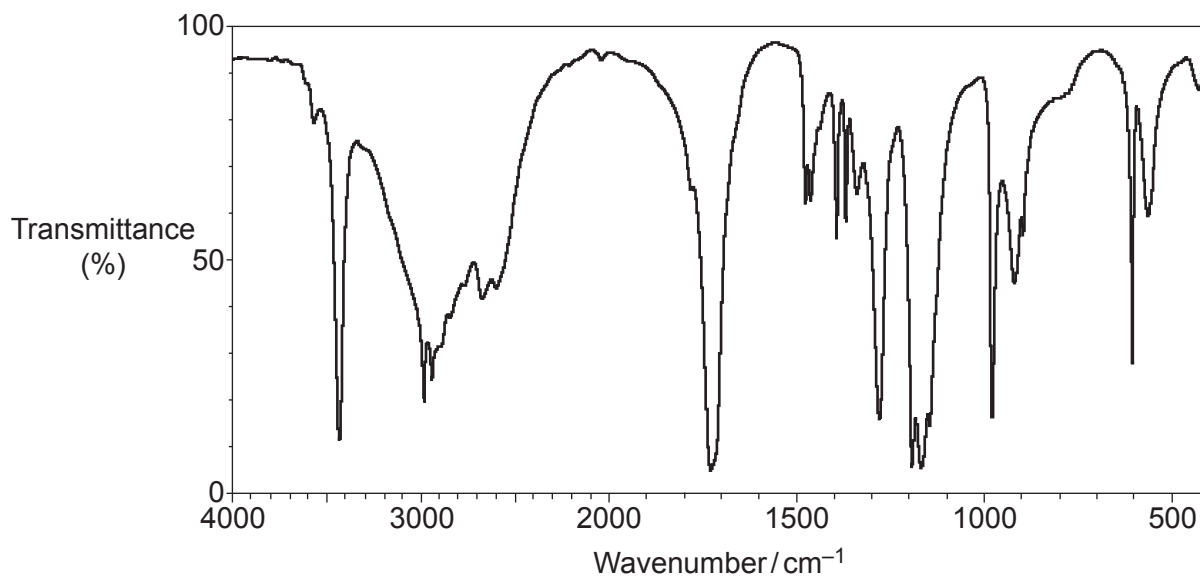
D 2.00

Your answer

C

[1]

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



- A HOCH_2CHO
- B $\text{CH}_3\text{CH}_2\text{COOH}$
- C $\text{CH}_3\text{CH}_2\text{COOCH}_3$
- D $(\text{CH}_3)_2\text{C}(\text{OH})\text{COOH}$

Your answer

D

[1]

12 1,6-Diaminohexane, $\text{H}_2\text{N}(\text{CH}_2)_6\text{NH}_2$, reacts with hexanedioyl dichloride, $\text{ClOC}(\text{CH}_2)_4\text{COCl}$ 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

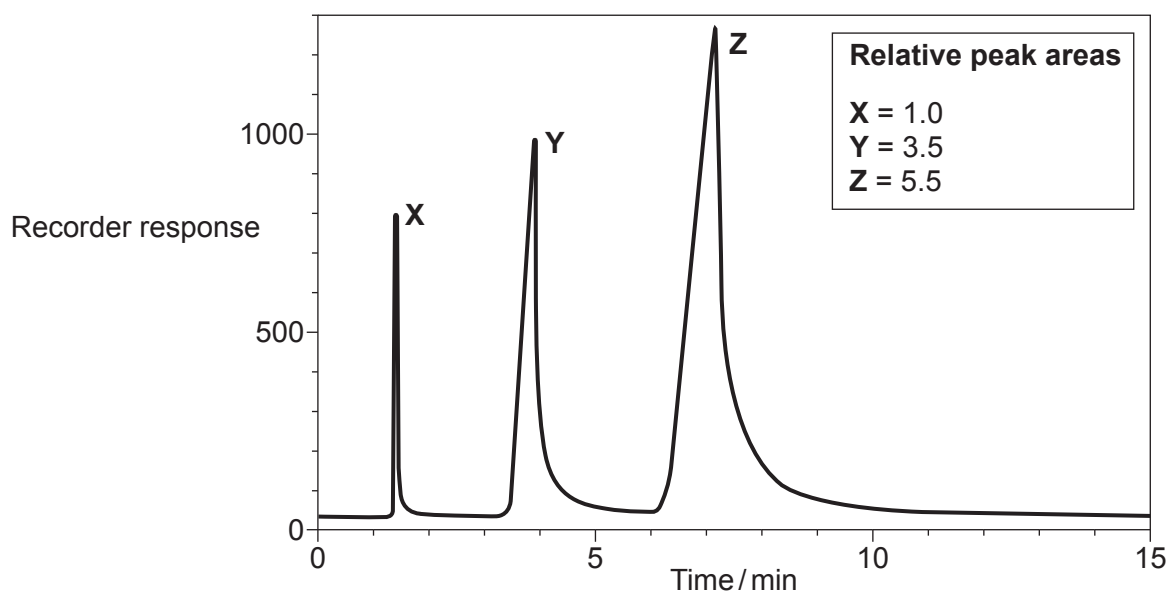
A

[1]

- 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

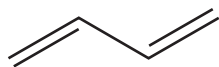
Your answer

C

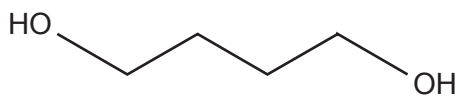
[1]

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

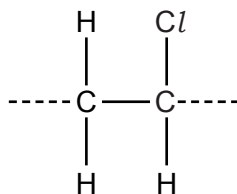
- A** 1, 2 and 3
B Only 1 and 2
C Only 2 and 3
D Only 1

Your answer

B

[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

C

[1]

Turn over

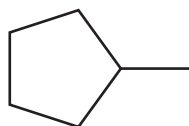
10
BLANK PAGE

PLEASE DO NOT WRITE ON THIS PAGE

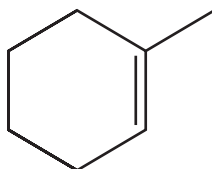
11
Section B

16 This question is about hydrocarbons.

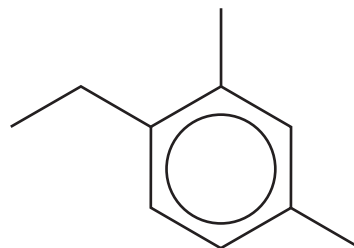
The structures of hydrocarbons **A–E** are shown below.



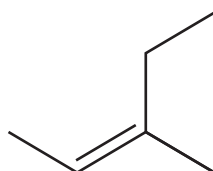
A



B



C



D



E

(a) Which hydrocarbons are unsaturated?

B, C, D and E [1]

(b) Which hydrocarbons are alicyclic?

A and B [1]

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

A and D [1]

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

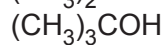
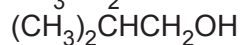
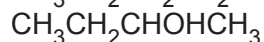
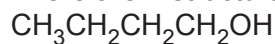
1-ethyl-2,4-dimethylbenzene [1]

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

On each carbon of the $C=C$, the highest priority groups are CH_3 (on one carbon) and C_2H_5 (on the other carbon). These highest priority groups are on the same side of the double bond, so D is the Z-isomer. [2]

17 This question is about reactions of alcohols.

There are 4 structural isomers of $C_4H_{10}O$ that are alcohols:



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

H_2SO_4 (concentrated sulfuric acid catalyst)

heat



organic product

[2]

(b) Oxidation reaction of $CH_3CH_2CHOHCH_3$

Reagent(s) and/or catalyst

$K_2Cr_2O_7$ and H_2SO_4 (acidified dichromate)

heat under reflux



organic product

[2]

(c) Substitution reaction of $(\text{CH}_3)_2\text{CHCH}_2\text{OH}$

Reagent(s) and/or catalyst

NaBr and H_2SO_4 (sodium bromide and sulfuric acid)

heat



organic product

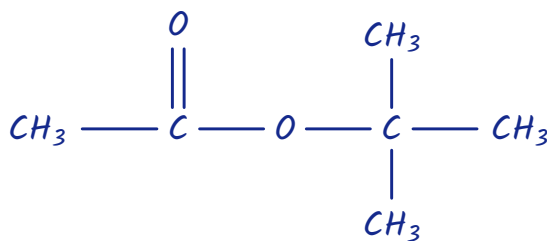
[2]

(d) Esterification reaction of $(\text{CH}_3)_3\text{COH}$

Reagent(s) and/or catalyst

CH_3COOH (ethanoic acid) with H_2SO_4 catalyst

heat under reflux



organic product

[2]

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 ..*radical substitution*.....

Type of bond fission ..*homolytic fission*.....

[3]

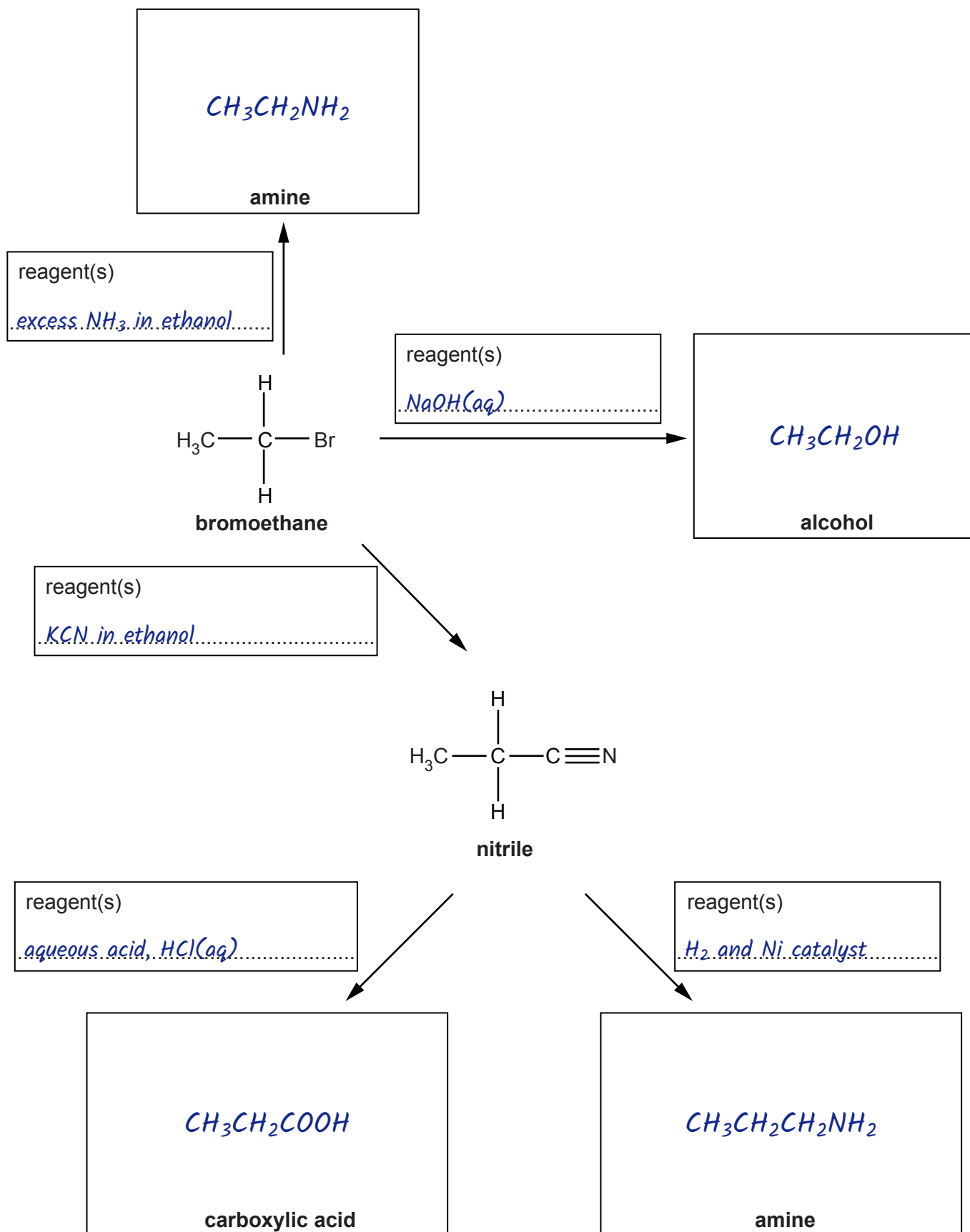
- (ii) Describe **two** limitations of the synthesis of 2-bromo-2-methylpropane from an alkane and bromine.

1 ..*Further substitution can occur: more than one H atom is replaced, giving*
dibromo or multibromo compounds, e.g. $CH_2BrCBr(CH_3)_2$

2 ..*Substitution can occur at a different carbon along the chain, e.g. forming*
1-bromo-2-methylpropane, $CH_2BrCH(CH_3)_2$, so a mixture of products forms......

[2]

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



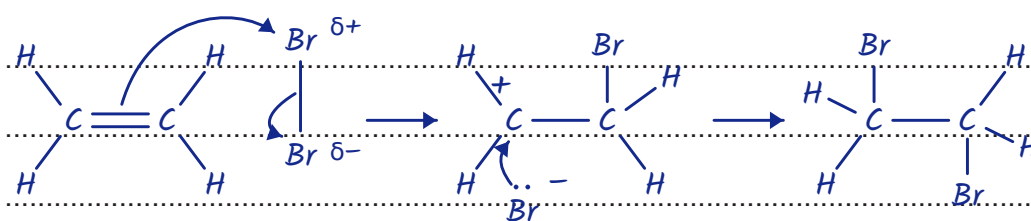
[9]

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]

Alkene: ethene reacts with bromine, Br_2 , at room temperature by electrophilic addition to form 1,2-dibromoethane, $\text{CH}_2\text{BrCH}_2\text{Br}$.

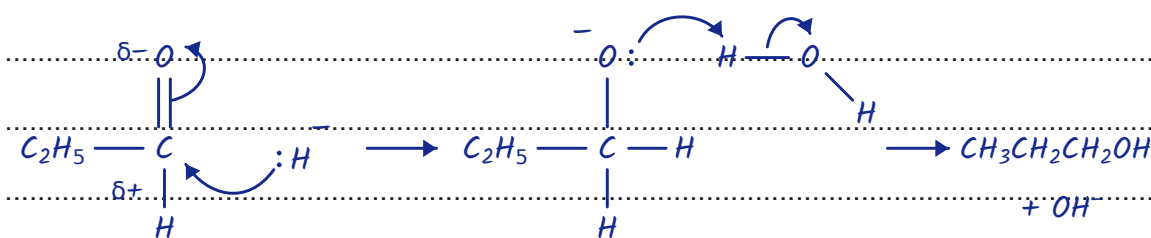
The $\text{C}=\text{C}$ π bond is a region of high electron density, which induces a dipole in Br_2 ($\text{Br}^{\delta+}-\text{Br}^{\delta-}$):



The $\text{Br}-\text{Br}$ bond breaks by heterolytic fission, forming a carbocation intermediate and a Br^- ion, which then bonds to the C^+ .

Carbonyl: propanal, $\text{CH}_3\text{CH}_2\text{CHO}$, is reduced by aqueous NaBH_4 to propan-1-ol by nucleophilic addition.

The nucleophile, H^- , attacks the $\delta+$ carbon of the polar $\text{C}=\text{O}$ bond:



The π bond of $\text{C}=\text{O}$ breaks by heterolytic fission, giving an alkoxide

Extra answer space if required.

intermediate, which is protonated by water to give propan-1-ol (aldehydes give primary alcohols, ketones give secondary alcohols).

Both reactions are addition reactions: two species join to form one product.

Alkenes undergo electrophilic addition, but the polar $\text{C}=\text{O}$ bond undergoes nucleophilic addition.

17
BLANK PAGE

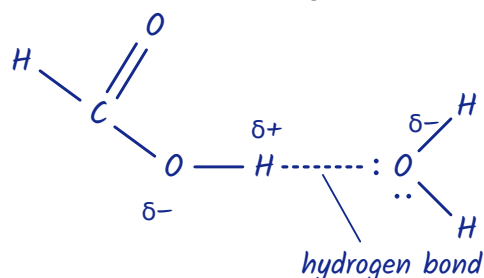
PLEASE DO NOT WRITE ON THIS PAGE

Turn over for the next question

20 This question is about carboxylic acids and esters.

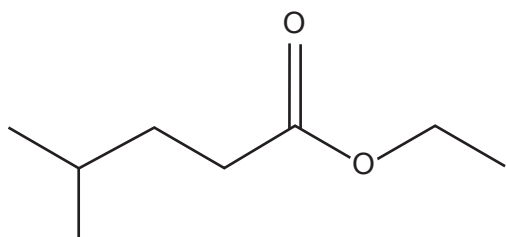
(a) Short-chain carboxylic acids, such as methanoic acid, HCOOH , are soluble in water.

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



HCOOH forms hydrogen bonds with water: a lone pair on the δ^- oxygen of a water molecule forms a hydrogen bond to the δ^+ H of the O-H group in HCOOH. [2]

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



Ester F

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

ethyl 4-methylpentanoate [1]

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

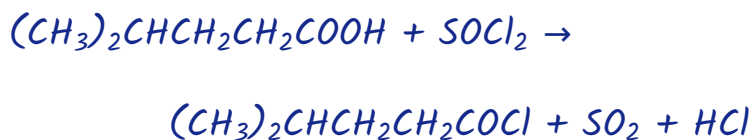
Step 1 The carboxylic acid is converted into an acyl chloride.

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

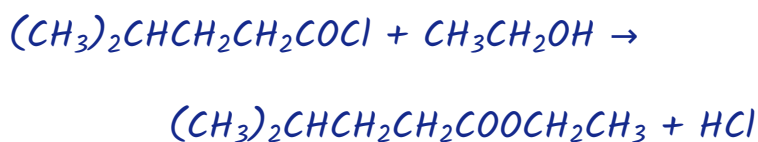
Write equations for **Step 1** and **Step 2**.

Show organic compounds as structures.

Step 1

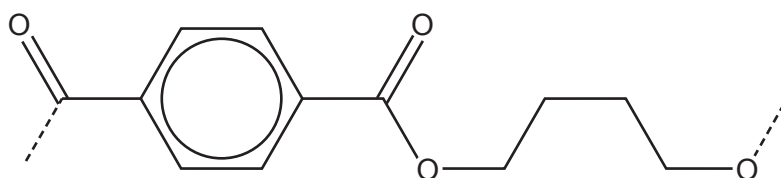


Step 2

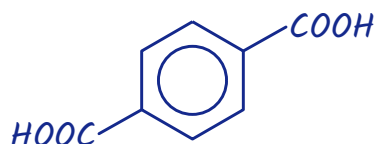


[4]

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

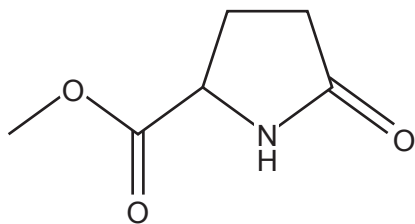


Draw the structures of monomers required to form this polyester.

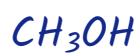
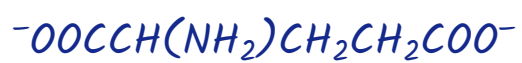


[2]

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



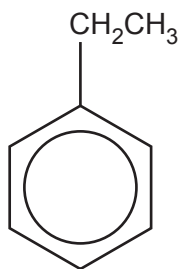
Draw the structures of the organic products formed by the complete **alkaline** hydrolysis of this compound using NaOH(aq).



[4]

21 This question is about aromatic compounds.

- (a) Ethylbenzene, $\text{C}_6\text{H}_5\text{CH}_2\text{CH}_3$, can be prepared by reacting benzene with chloroethane, $\text{CH}_3\text{CH}_2\text{Cl}$, in the presence of AlCl_3 . The AlCl_3 acts as a halogen carrier.



Ethylbenzene

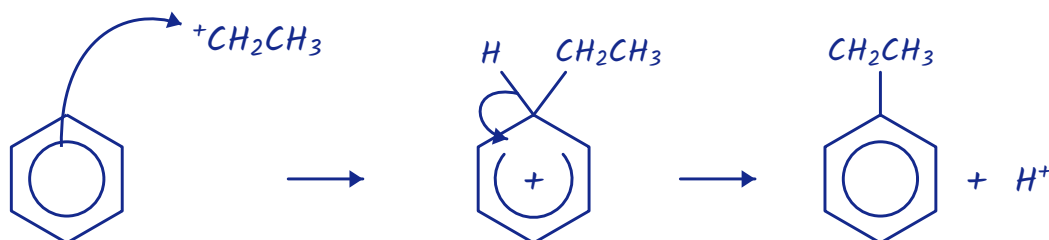
In the mechanism, chloroethane reacts with the halogen carrier to form a carbocation, which acts as the electrophile.

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

A species that accepts a pair of electrons (an electron pair acceptor).

[1]

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



AlCl_3 is regenerated, so it acts as a catalyst (halogen carrier) by generating the CH_3CH_2^+ electrophile. The π electrons of benzene attack it (electrophilic substitution) and loss of H^+ restores the stable delocalised ring.

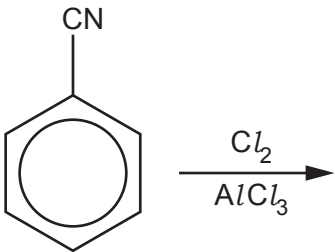
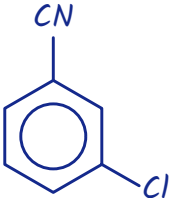
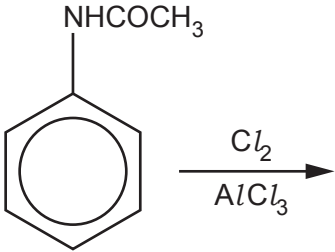
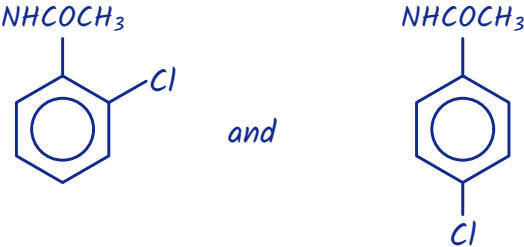
[5]

Turn over

- (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

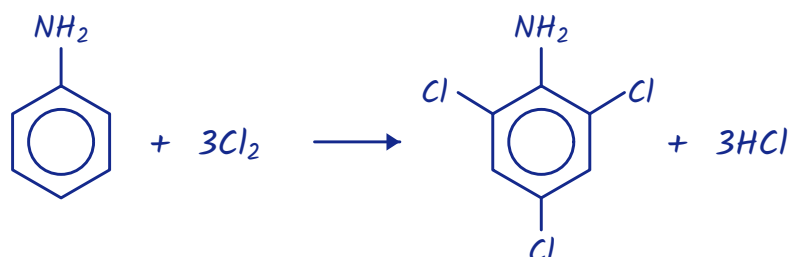
- (i) Draw all organic products formed from monosubstitution reactions of the substituted benzene compounds shown below.

Reaction	Monosubstituted Product(s)
	
	

[3]

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

Write an equation for the tri-substitution of $\text{C}_6\text{H}_5\text{NH}_2$ with chlorine.



[2]

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

..In $\text{C}_6\text{H}_5\text{NH}_2$, a lone pair of electrons on the nitrogen atom is (partially) delocalised into the π -system of the benzene ring.
 ..This increases the electron density of the ring compared with benzene.
 ..So $\text{C}_6\text{H}_5\text{NH}_2$ is more susceptible to electrophilic attack: its ring can polarise Cl_2 molecules (induce a dipole) and attract the electrophile more strongly.
 ..Benzene has a lower electron density, so it cannot polarise Cl_2 and needs a halogen carrier.

[3]

22 α -Amino acids have the general formula $\text{RCH}(\text{NH}_2)\text{COOH}$.

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.

$R = \text{C}_7\text{H}_7$ ($M = 91$), so the amino acid is $\text{C}_7\text{H}_7\text{CH}(\text{NH}_2)\text{COOH}$

M_r of amino acid = $91 + 74 = 165$

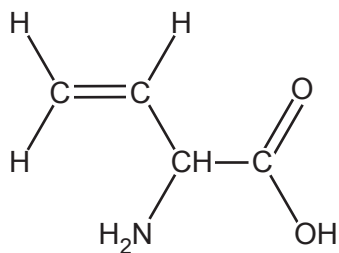
M_r of 500 molecules = $500 \times 165 = 82500$

499 peptide bonds form, losing 499 H_2O : $499 \times 18.0 = 8982$

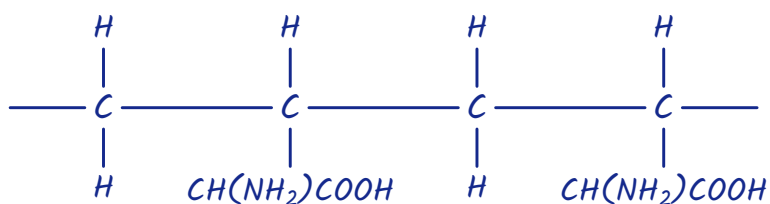
M_r of polymer = $82500 - 8982 = 73518$

molar mass of polymer = ...73518..... g mol^{-1} [3]

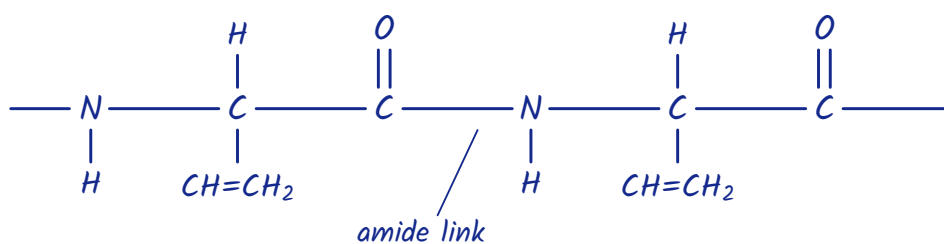
(b) The amino acid below can form addition and condensation polymers.



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



addition polymer (2 repeat units)

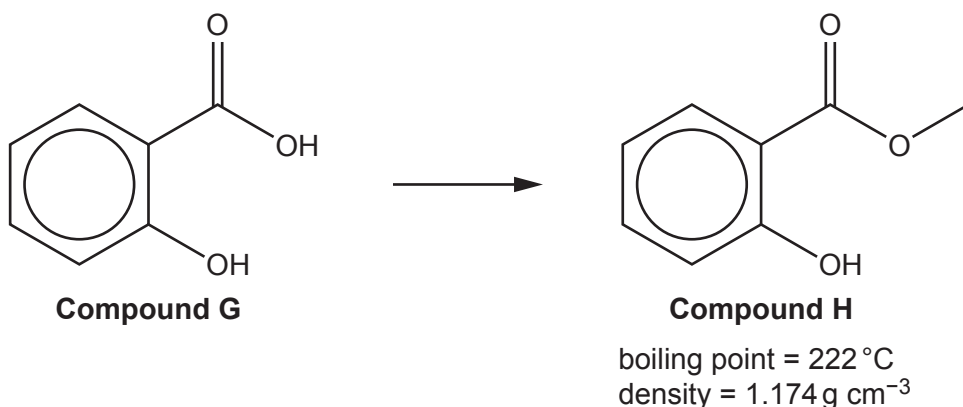


condensation polymer (2 repeat units)

[3]

- 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.



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, Na₂CO₃(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**?

*To prevent loss of volatile methanol and product by evaporation; vapour
condenses and returns to the flask, so it does not boil dry.* [1]

- (b)

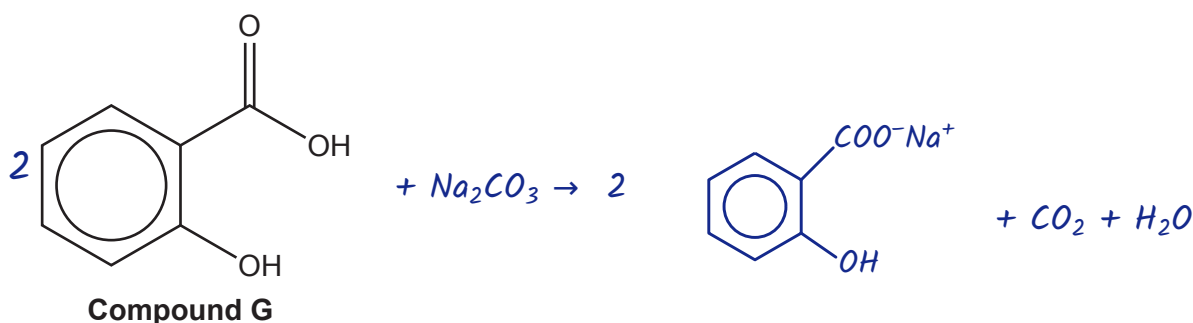
- (i) In **Step 2**, Na₂CO₃(aq) removes the sulfuric acid catalyst **and** any unreacted compound **G** from the mixture.

Write equations for this removal.

Removal of sulfuric acid



Removal of unreacted compound **G**



- (ii) Another student suggests that adding aqueous sodium hydroxide would be more effective in removing the sulfuric acid catalyst than $\text{Na}_2\text{CO}_3(\text{aq})$.

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

No, it is not an improvement. NaOH would also react with the phenol (-OH) group in H and would hydrolyse the ester (compound H), lowering the yield. [1]

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

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

$$M_r(G) = 138.0; \quad M_r(H) = 152.0$$

$$n(G) = 8.97 \div 138.0 = 0.0650 \text{ mol} = \text{theoretical } n(H)$$

$$n(H) \text{ obtained} = 5.32 \div 152.0 = 0.0350 \text{ mol}$$

$$\% \text{ yield} = (0.0350 \div 0.0650) \times 100 = 53.8\%$$

percentage yield = *53.8* % [3]

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

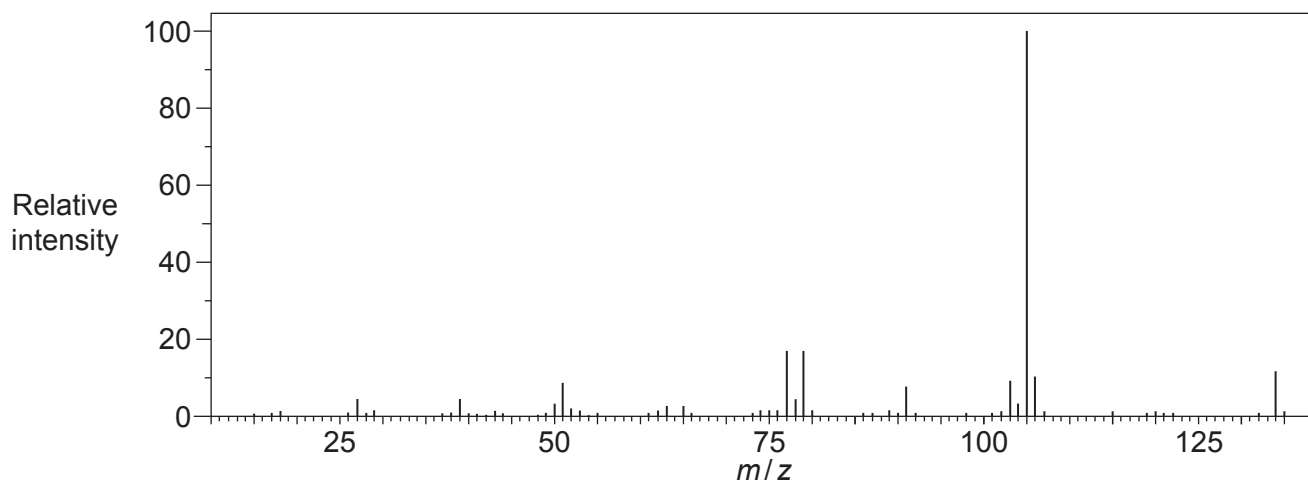
Pour the mixture into a separating funnel, allow the layers to separate and keep the lower organic layer containing H (density 1.174 g cm^{-3}); discard the upper aqueous layer.
Dry the organic layer with an anhydrous salt, e.g. anhydrous MgSO_4 or CaCl_2 , then filter (decant) off the drying agent.
Redistil the liquid and collect the fraction boiling at 222°C (pure compound H). [4]

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

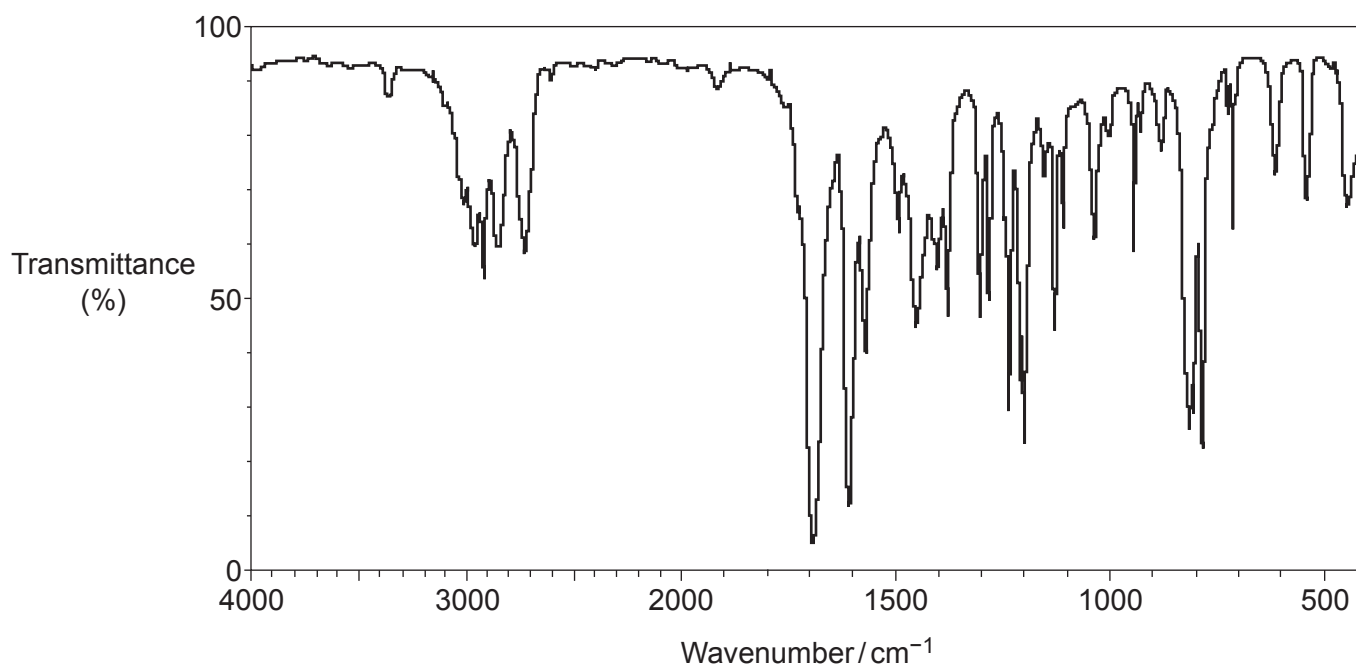
Elemental analysis by mass of compound J

C, 80.60%; H, 7.46%; O, 11.94%

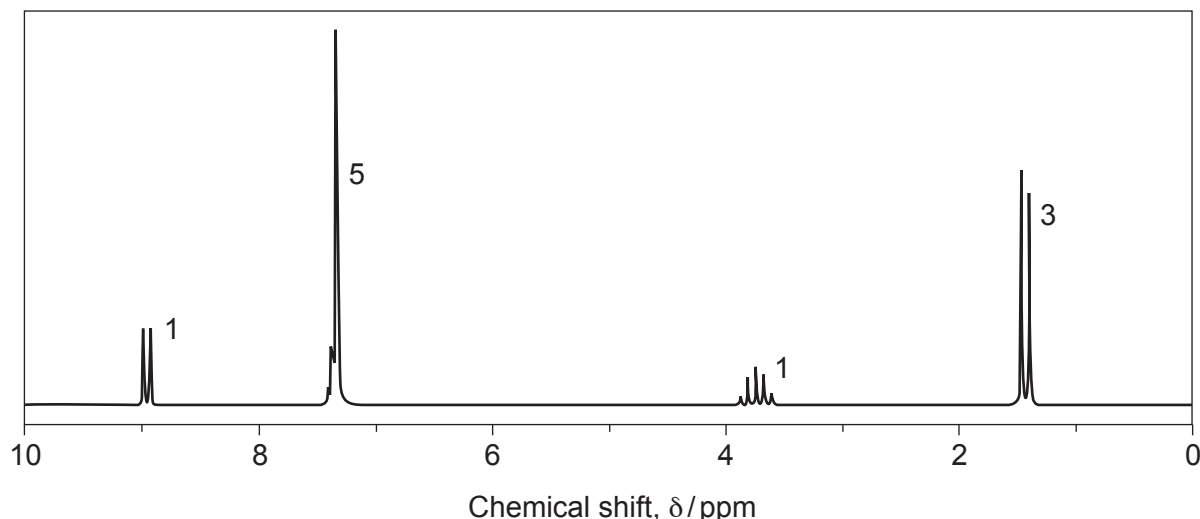
Mass spectrum of compound J



IR spectrum of compound J



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]

Empirical formula: $C : H : O = 80.60/12.0 : 7.46/1.0 : 11.94/16.0 = 6.72 :$

$7.46 : 0.746 = 9 : 10 : 1$, so the empirical formula is $C_9H_{10}O$ ($M = 134$).

Mass spectrum: molecular ion peak at $m/z = 134$, so the molecular formula is

also $C_9H_{10}O$. Fragments: $m/z = 105$ is $C_6H_5CHCH_3^+$, $m/z = 77$ is $C_6H_5^+$ and

$m/z = 29$ is CHO^+ .

IR: strong absorption at about 1700 cm^{-1} is the $C=O$ bond, so J is an aldehyde

or ketone. No broad $O-H$ absorption. Absorptions near 1500 to 1600 cm^{-1} are

$C=C$ bonds in an arene ring.

Proton NMR (5 environments of H):

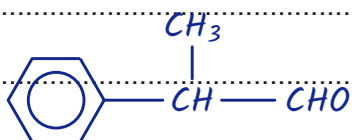
$\delta = 9.0$ ppm, doublet, 1H: aldehyde H (CHO) next to a CH with 1 H.

$\delta = 7.3$ ppm, singlet, 5H: C_6H_5 , a monosubstituted benzene ring.

$\delta = 3.8$ ppm, quintet, 1H: CH with 4 adjacent H (CH_3 and CHO).

$\delta = 1.4$ ppm, doublet, 3H: CH_3 next to the CH (CH_3CH).

So J is 2-phenylpropanal, $C_6H_5CH(CH_3)CHO$.



Extra answer space if required.

.....

.....

.....

.....

.....

END OF QUESTION PAPER

This image shows a blank sheet of white paper designed for handwriting practice. It features a solid vertical line on the left side, creating a narrow margin. The rest of the page is filled with evenly spaced horizontal dashed lines, providing guides for letter height and placement. There are no other markings, text, or illustrations on the page.

Copyright Information

If OCR has unwittingly failed to correctly acknowledge or clear any third-party content in this assessment material, OCR will be happy to correct its mistake at the earliest possible opportunity.

OCR is part of Cambridge University Press & Assessment, which is itself a department of the University of Cambridge.

stemup.co.uk