



H432/02 Synthesis and analytical techniques

Time allowed: 2 hours 15 minutes



- the Data Sheet for Chemistry A

- a scientific or graphical calculator
- a ruler (cm/mm)

First name										
Last name										
Centre number						Candidate number				

- Use black ink. You may use an HB pencil for graphs and diagrams.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the barcodes.

- 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 **28** pages.

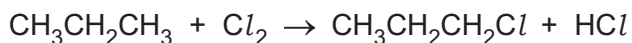
2
SECTION A

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

Write your answer to each question in the box provided.

Answer **all** the questions.

- 1** Propane reacts with chlorine as shown below.



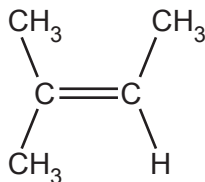
What is the mechanism of this reaction?

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

Your answer

[1]

- 2** A chemist reacts the following compound with hydrogen bromide, HBr.



What is the name of the **major** product?

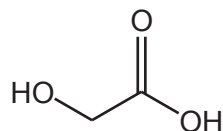
- A** 2-Bromo-3-methylbutane
- B** 2-Bromo-2-methylbutane
- C** 3-Bromo-3-methylbutane
- D** 3-Bromo-2-methylbutane

Your answer

[1]

3

- 3 The compound shown below reacts with a mixture of NaBr and H₂SO₄.



What is the relative molecular mass of the organic product?

- A 138.9
B 155.9
C 201.8
D 235.8

Your answer

[1]

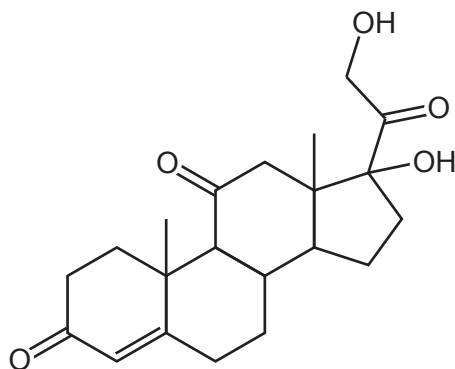
- 4 What is the number of sigma bonds in a benzene molecule?

- A 3
B 6
C 9
D 12

Your answer

[1]

- 5 What is the number of chiral centres in the molecule below?



- A 4
B 5
C 6
D 7

Your answer

[1]

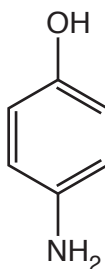
- 6 Which compound **cannot** be hydrolysed?

- A CH_3COOH
B CH_3COCl
C $\text{CH}_3\text{CONHCH}_3$
D $\text{CH}_3\text{COOCH}_3$

Your answer

[1]

- 7 The compound shown below can be prepared from phenol.



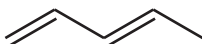
Which reagent(s) is/are required?

- A Concentrated NH_3
- B Dilute NH_3
- C Dilute HNO_3 and then concentrated HCl/Sn
- D Dilute HNO_3 and then NaBH_4

Your answer

[1]

- 8 The compound shown below reacts with hydrogen chloride gas at room temperature and pressure to form a saturated compound.



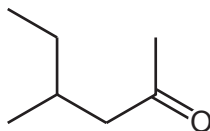
What volume of hydrogen chloride reacts with 0.25 mol of the compound?

- A 6 cm^3
- B 12 cm^3
- C 6 dm^3
- D 12 dm^3

Your answer

[1]

- 9 What is the systematic name of the compound below?



- A 2-Ethylpentan-4-one
 B 4-Ethylpentan-2-one
 C 3-Methylhexan-5-one
 D 4-Methylhexan-2-one

Your answer

[1]

- 10 A student plans the two-step synthesis below.



Which compound could be the student's intermediate?

- A $\text{HOOCCH}=\text{CHCOOH}$
 B $\text{HOCH}_2\text{CH}_2\text{CHICOOH}$
 C $\text{HOCH}_2\text{CH}_2\text{CH}(\text{OH})\text{CH}_2\text{OH}$
 D $\text{HOCH}_2\text{CH}(\text{OH})\text{CH}(\text{OH})\text{CH}_2\text{OH}$

Your answer

[1]

- 11 Which reagent could be used to distinguish between $\text{CH}_3\text{CH}_2\text{OH}$ and $\text{C}_6\text{H}_5\text{OH}$?

- A $\text{AgNO}_3(\text{aq})$ in ethanol
 B CH_3COCl
 C $\text{Na}_2\text{CO}_3(\text{aq})$
 D Bromine water

Your answer

[1]

12 How many peaks are observed in the ^{13}C NMR spectrum of 1,3-dimethylbenzene?

- A 3
- B 4
- C 5
- D 6

Your answer

[1]

13 $\text{CH}_3\text{CH}_2\text{Cl}$ reacts with an excess of ethanolic NH_3 .

Which compound is the main organic product?

- A $\text{CH}_3\text{CH}_2\text{NH}_2$
- B $(\text{CH}_3\text{CH}_2)_2\text{NH}$
- C $(\text{CH}_3\text{CH}_2)_3\text{N}$
- D $(\text{CH}_3\text{CH}_2)_4\text{N}^+$

Your answer

[1]

14 Which bond angle(s) is/are present in a molecule of but-2-en-1-ol?

- 1 120°
- 2 109.5°
- 3 104.5°

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

Your answer

[1]

15 Which term(s) best describe(s) the following molecule?



- 1 aromatic
- 2 unsaturated
- 3 alicyclic

- 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 This question is about two different homologous series, the alcohols and the haloalkanes.

(a) (i) Define the term *homologous series*.

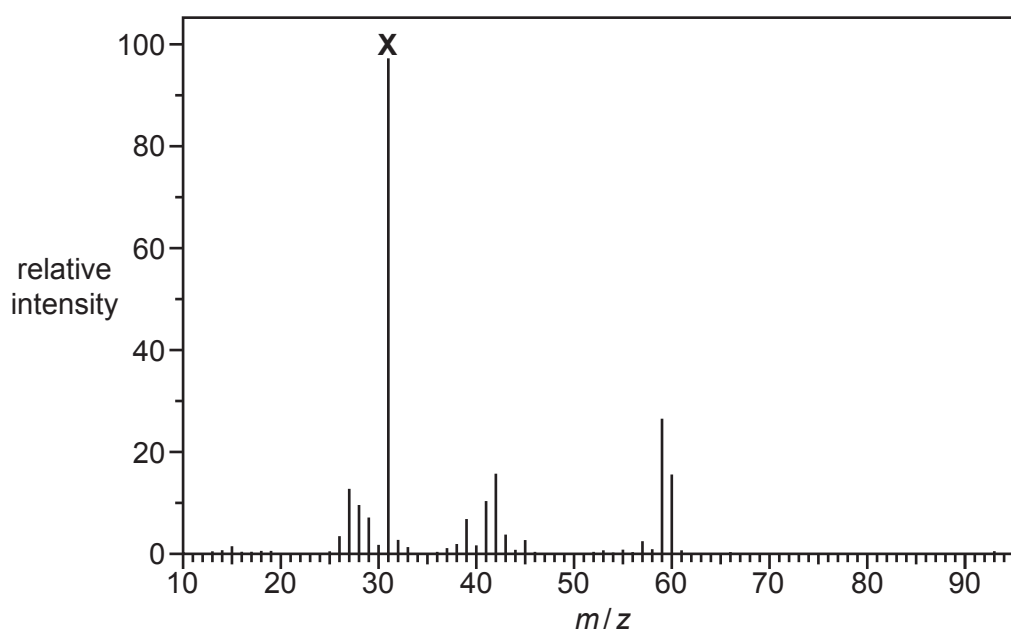
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 [2]

(ii) What is the general formula of a member of the alcohols homologous series?

..... [1]

(b) The mass spectrum of alcohol **A** is shown below.



Determine the structure of alcohol **A** and fragment ion **X**.

Explain your reasoning.

.....

 [3]

(c) Haloalkanes are hydrolysed by aqueous sodium hydroxide.

(i) Outline the mechanism of the reaction of 1-bromobutane with aqueous sodium hydroxide.

Include curly arrows, relevant dipoles and the structure of the organic product.

[3]

(ii) Name the type of mechanism in (c)(i).

..... [1]

(iii) The organic product in (c)(i) can be formed faster using a different haloalkane than 1-bromobutane.

Identify this haloalkane.

Explain your answer.

Haloalkane

Explanation

.....

..... [1]

- (d) The use of some haloalkanes, such as chlorotrifluoromethane, has been banned as they form $Cl\cdot$ radicals which break down ozone.

- (i) Construct an equation to show the formation of $Cl\cdot$ radicals from chlorotrifluoromethane.

..... [1]

- (ii) Ozone is broken down by $Cl\cdot$ radicals in a two-step process.

Write the equations for the two steps and the overall equation for this process.

Step 1

Step 2

Overall equation [3]

- (iii) A research chemist found that 1.00 g of $Cl\cdot$ radicals can breakdown 135 kg of O_3 .

Calculate the number of O_3 molecules removed by one $Cl\cdot$ radical.

Give your answer in **standard form** and to **three** significant figures.

number of O_3 molecules = [3]

Compound	Boiling point/°C
B	−12
C	0
D	35
E	48
F	97

$$\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3, \text{CH}_3\text{CH}_2\text{CH}_2\text{NH}_2, \text{CH}_3\text{CH}_2\text{CH}_2\text{OH}, \text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_3, \text{CH}_3\text{CHClCH}_3$$

Explain your reasoning.

..... [6]

17 This question is about α -amino acids.

(a) Serine, $\text{H}_2\text{NCH}(\text{CH}_2\text{OH})\text{COOH}$, is a naturally occurring α -amino acid.

(i) Serine has two optical isomers.

Explain what is meant by the term *optical isomers*, and draw the two optical isomers of serine.

.....

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.....

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[3]

(ii) Serine can react with the α -amino acid glycine, $\text{H}_2\text{NCH}_2\text{COOH}$, to form **three** different organic products, each with the molecular formula $\text{C}_5\text{H}_{10}\text{N}_2\text{O}_4$.

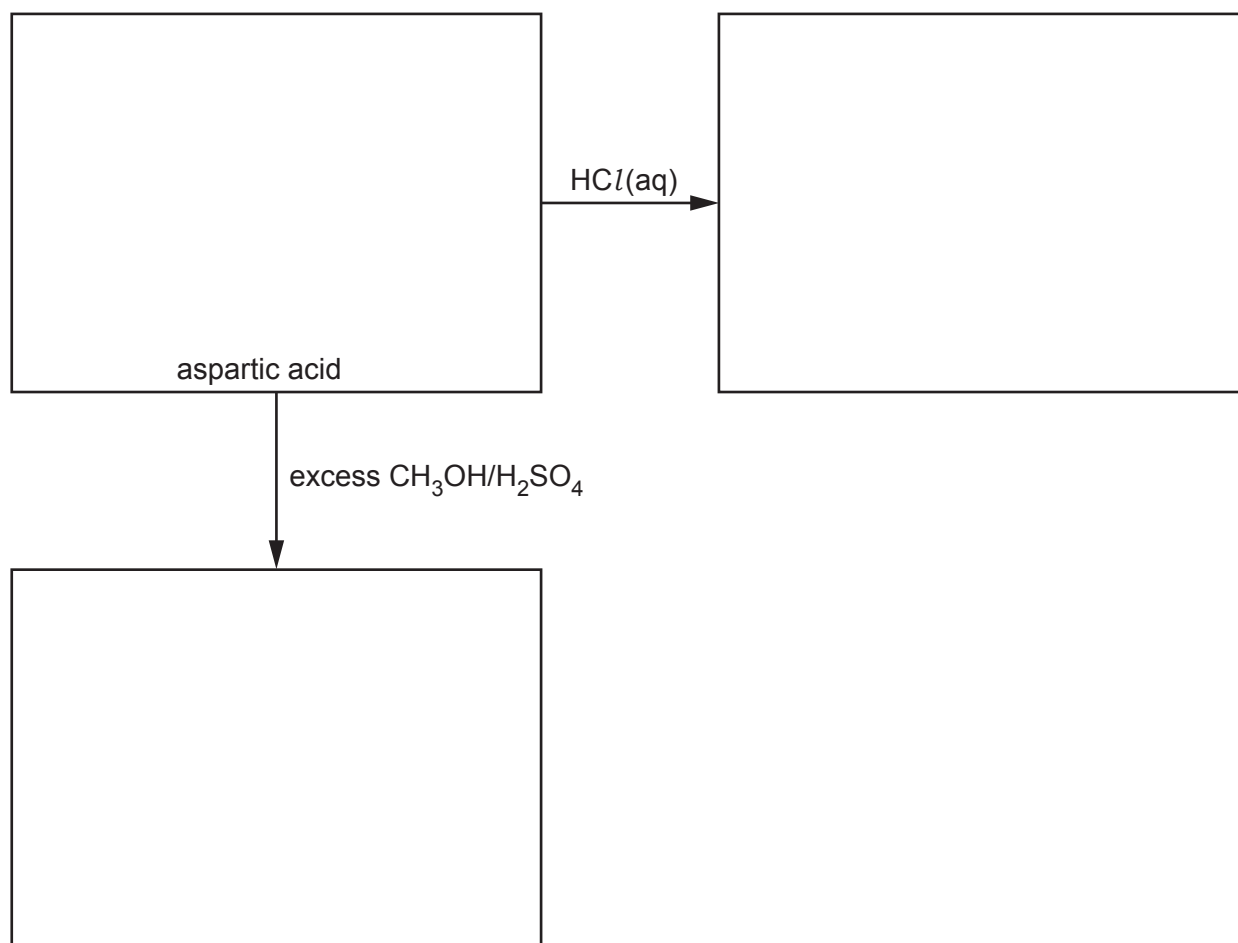
Draw the structures of the **three** organic products that can be formed by the reaction of serine with glycine.

[3]

(b) The general formula of an α -amino acid is $\text{RCH}(\text{NH}_2)\text{COOH}$.

(i) Aspartic acid ($\text{R} = \text{CH}_2\text{COOH}$) is reacted as shown in the flowchart below.

Draw the structures of aspartic acid and the missing organic products in the boxes.



[4]

(ii) Compound **G** is an α -amino acid with a **branched** R group.

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

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

[2]

- (c) A student hydrolyses a sample of protein and uses Thin-Layer Chromatography (TLC) to analyse the mixture of amino acids produced.

The chromatogram obtained is shown in **Fig. 17.1**.

Table 17.1 shows the R_f values for different amino acids in the solvent used.

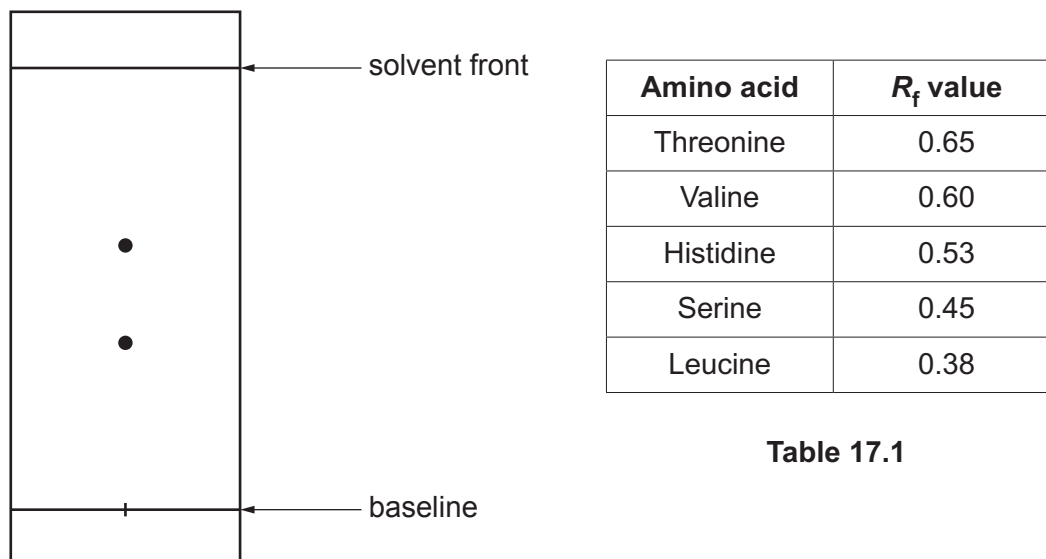


Fig. 17.1

- (i) Analyse the chromatogram to identify the amino acids.

..... [1]

- (ii) The student runs a second chromatogram on the sample using a more polar solvent.

Predict the effect, if any, on the R_f values of the amino acids. Explain your reasoning.

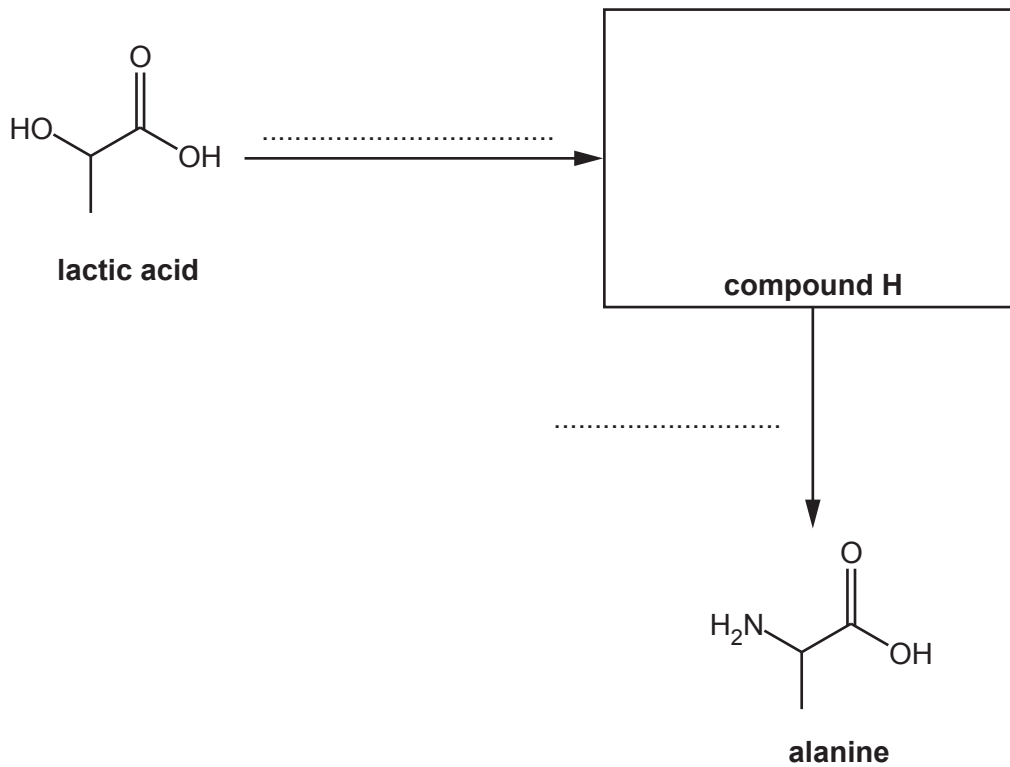
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 [2]

(d) A student plans a two-stage synthesis of alanine from lactic acid, $\text{CH}_3\text{CH}(\text{OH})\text{COOH}$.

The synthesis first prepared compound **H**, as shown in the flowchart.

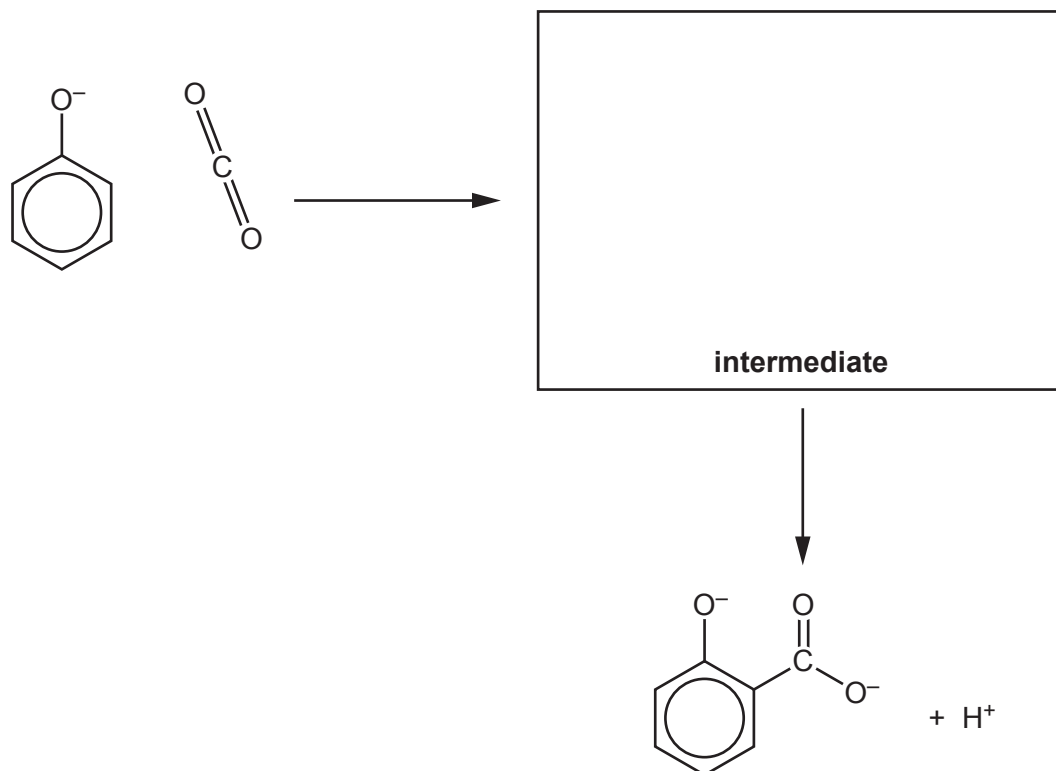
Draw the structure of compound **H** in the box and add the formulae of the reagents for each stage on the dotted lines.



[3]

phenol $\xrightarrow[\text{NaOH(aq)}]{\text{Stage 1}}$ $\text{C}_6\text{H}_5\text{O}^-$ $\xrightarrow[\text{CO}_2]{\text{Stage 2}}$ $\text{C}_6\text{H}_4(\text{O}^-)(\text{COO}^-)$ $\xrightarrow[\text{HCl(aq)}]{\text{Stage 3}}$ salicylic acid

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



[3]

Explain your answer.

Type of reaction

Explanation

..... [2]

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

Calculate the mass of phenol that the chemist uses.

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

mass of phenol = g [3]

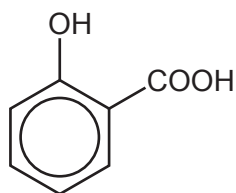
- (b) Aspirin is an ester of salicylic acid.

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

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

[2]

- (c) 'Oil of wintergreen' is used to relieve aching muscles and can be prepared by reacting salicylic acid with methanol.



salicylic acid

- (i) Suggest the structure of oil of wintergreen and the conditions needed to prepare oil of wintergreen from salicylic acid.

Structure

Conditions [1]

- (ii) After its preparation, oil of wintergreen can be purified by distillation.

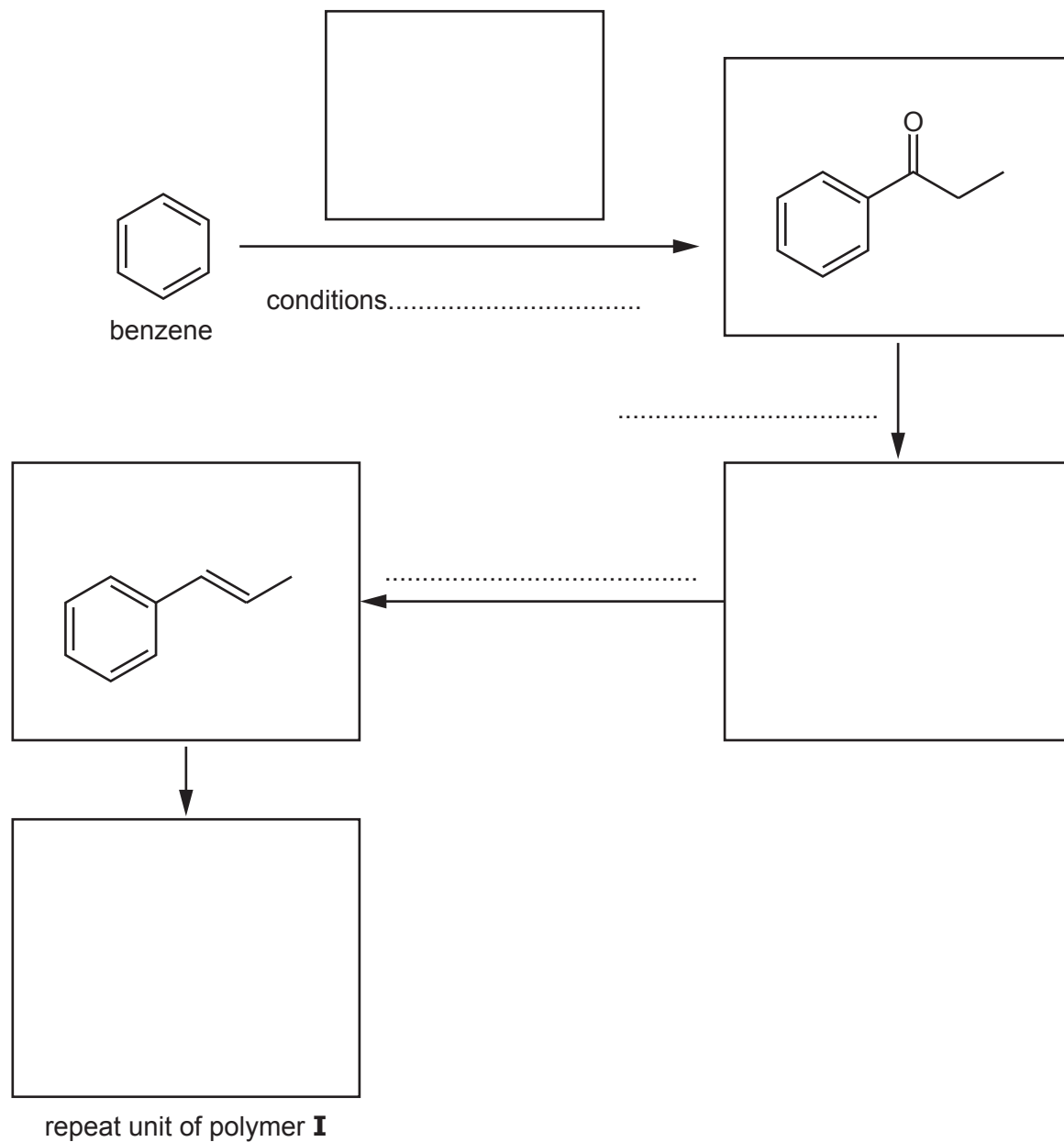
Draw a **labelled** diagram showing how the apparatus is set up for distillation.

[2]

19 This question is about the synthesis of a polymer.

(a) The flowchart below shows the synthesis of polymer **I** starting from benzene.

Draw the structures of the missing compounds in the boxes and add the missing reagents on the dotted lines.



[6]

(b) Polymer **I** cannot be disposed of in landfill sites as it is not biodegradable.

Suggest **one** way of processing waste polymer **I** other than landfill and recycling.

.....

.....

..... [1]

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

(a) Suggest chemical tests to identify the carboxylic acid and aldehyde.

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

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

(i) Test for carboxylic acid.

Reagent(s)

Observation(s)

.....

Equation

[2]

(ii) Test for aldehyde.

Reagent(s)

Observation(s)

.....

Equation

[2]

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

Reagent(s)

Observation(s)

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

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

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

The student plans the following:

- hydrolyse the two esters using aqueous sodium hydroxide.
 - separate the hydrolysis products.
 - carry out tests on the hydrolysis products.
- (i) Write an equation for the hydrolysis of one of the two esters with aqueous sodium hydroxide.

Show the structures for the organic compounds.

[2]

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

Write an equation for one reaction that takes place.

Show the structures for the organic compounds.

Reagent(s)

Observation(s)

.....

Equation

[2]

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

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

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

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..... [3]

- (d) The ketone and aldehyde provided to the student both contain five carbon atoms.

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

Suggest **all** possible structures for the ketone and identify the aldehyde.

Show **all** your reasoning.

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..... [5]

21* Compound **J** is an organic compound containing carbon, hydrogen and nitrogen only.

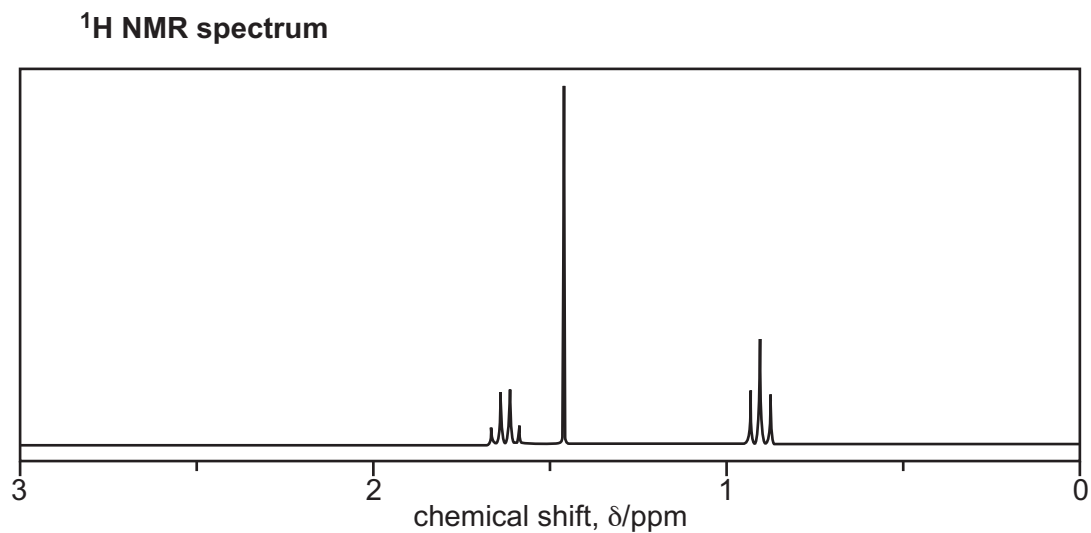
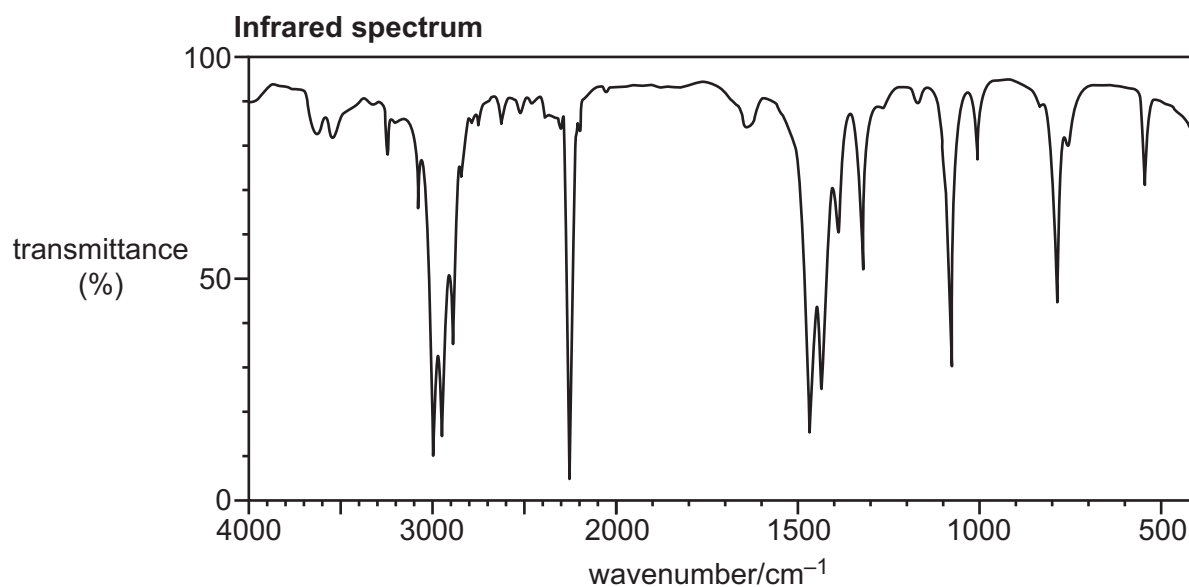
A chemist analyses compound **J** and the results are shown below:

Elemental analysis by mass:

C: 74.17%; H: 11.41%; N, 14.42%

Mass spectrum

Molecular ion peak at $m/z = 97.0$



..... [6

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[illegible]

H432/02