PEARSON EDEXCEL A-LEVEL CHEMISTRY · 9CH0

# CHEMISTRY



EXAM QUESTION PACK

## TOPIC 19: MODERN ANALYTICAL TECHNIQUES II

| SCORE | PERCENTAGE |
| --- | --- |
| /217 | % |

STEMUP

# These questions belong to Pearson Edexcel, not to us.

The examination questions and mark schemes in this pack were written and published by Pearson Edexcel. They are past assessment materials, reproduced here so that students can revise from them.

## What we do not own

STEMUP is not affiliated with Pearson Edexcel and does not own, and makes no claim to own, any of the question or mark scheme material in this pack. Pearson has not endorsed, approved or been involved in the production of it. Pearson, Edexcel and the qualification titles used here belong to their respective owners and appear for identification only.

## Where to find the originals

Pearson publishes its past papers and mark schemes free of charge. Always check the current specification at qualifications.pearson.com before you revise, because content and wording can change between series.

If you hold the rights to any material in this pack and would like it amended or removed, contact admin@stemup.co.uk and we will act on it.

Q1.

This question is about some carbonyl compounds with the molecular formula $C_5H_{10}O$.

An aldehyde with molecular formula $C_5H_{10}O$ has a $^{13}C$ NMR spectrum with three peaks.

The high resolution $^1H$ NMR spectrum of this aldehyde has two peaks and neither of them is split.

Deduce the **displayed** formula of this aldehyde.
Justify your answer by referring to both NMR spectra.

**(4)**

.....

.....

.....

.....

.....

**(Total for question = 4 marks)**

Q2.

**Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.**

This question is about the analysis of organic compounds.

**X** is an organic compound.

(i) The accurate relative atomic masses, $A_r$, of the four elements that could make up **X** are shown in the table.

| Element | $A_r$ |
|---|---|
| hydrogen, H | 1.0078 |
| carbon, C | 12.0000 |
| nitrogen, N | 14.0031 |
| oxygen, O | 15.9949 |

**X** gives a molecular ion peak at $m / z = 100.0522$ on its mass spectrum.

Which is the molecular formula of **X**?

**(1)**

☒ **A** $C_7H_{16}$

☒ **B** $C_6H_{12}O$

☒ **C** $C_6H_{14}N$

☒ **D** $C_5H_8O_2$

(ii) The infrared spectrum of **X** contains major absorption wavenumber ranges at 3300–2500 $cm^{-1}$, 1725–1700 $cm^{-1}$ and 1669–1645 $cm^{-1}$.

Identify the two functional groups in **X**.

**(2)**

.....

.....

(iii) **X** has an unbranched carbon chain and does **not** exhibit geometric isomerism.

Draw the **skeletal formula** of **X**.

**(1)**

**(Total for question = 4 marks)**

Q3.

This question is about the analysis of organic compounds.

There are similarities and differences in the $^{13}C$ NMR spectra and the high resolution $^{1}H$ NMR spectra of isomeric organic compounds.

Compare the NMR spectra of propan-1-ol with those of propan-2-ol.

Include the number of peaks, relative peak areas and splitting patterns, where appropriate.

Chemical shift values are **not** required.

**(6)**

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

**(Total for question = 6 marks)**

Q4.

An organic compound, **X**, was analyzed in a laboratory.

(a) Compound **X** was found to have the following percentage composition by mass:

carbon, C = 54.5%

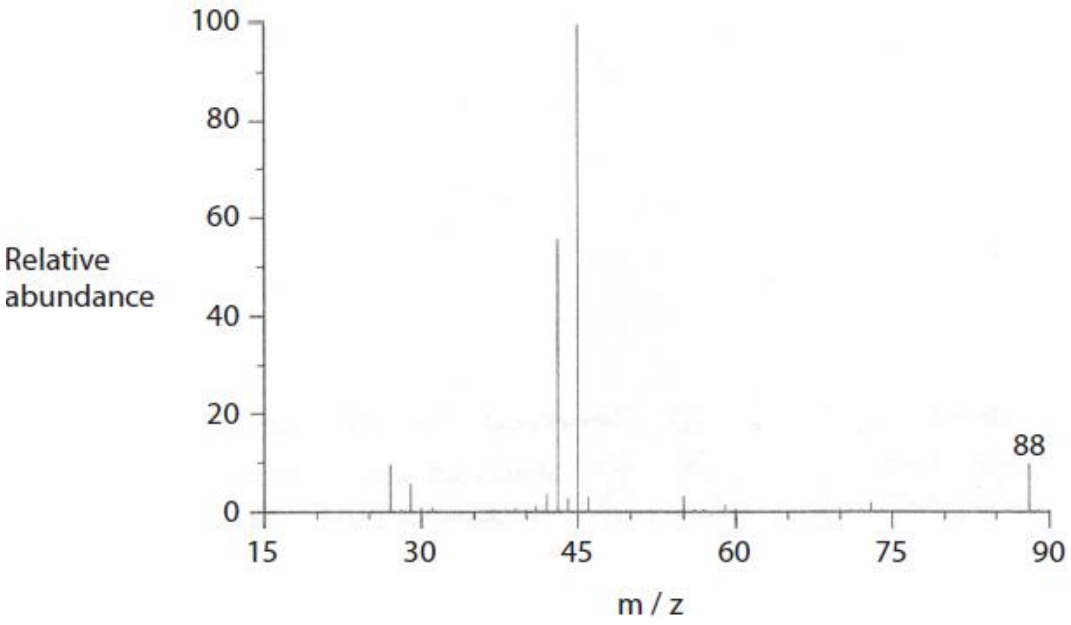
hydrogen, H = 9.1%

oxygen, O = 36.4%

(i) Use these data to calculate the empirical formula of compound **X**, showing your working.

**(2)**

(ii) The mass spectrum of **X** is shown below.




Use your answer to (a)(i), and the mass spectrum of **X**, to show that the molecular formula of compound **X** is $C_4H_8O_2$.

**(2)**

(b) The infrared spectrum of **X** has a broad peak at approximately 3500 $cm^{-1}$ and a sharp peak at approximately 1700 $cm^{-1}$. Identify the **bond** responsible for the peak at

**(2)**

3500 $cm^{-1}$

1700 $cm^{-1}$

(c) (i) Some chemical information about compound **X** is given below.

- **X** is a neutral organic compound.

- **X** has no effect on Tollens' reagent.

- **X** turns hot acidified potassium dichromate(VI) solution from orange to green.

What does each of these three pieces of information suggest about the nature of **X**?

**(4)**

.....

.....

.....

.....

.....

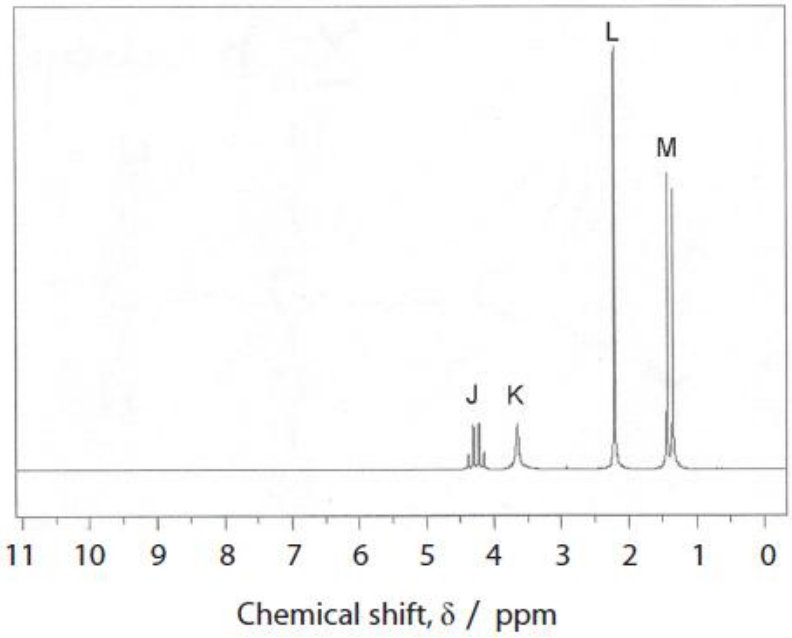
.....

(ii) Use your answers to parts (b) and (c)(i) to name the two functional groups present in **X**.

**(1)**

.....

*(d) The high resolution proton nmr spectrum of **X** is shown below.




The relative number of protons causing the peaks shown are: J = 1, K = 1, L = 3 and M = 3.

Use the information above to determine the structural formula of **X**.

In your answer, you should refer to the number of peaks, their relative sizes and their splitting patterns.

**(7)**

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

**(Total for question = 18 marks)**

Q5. This question is about the reactions of butanoic acid, $CH_3CH_2CH_2COOH$. It has a foul smell and behaves like a typical carboxylic acid.

(a) (i) The addition of sodium carbonate solution is often used as a chemical test to distinguish carboxylic acids, like butanoic acid, from other compounds, such as aldehydes.

Explain why old stocks of aldehydes often react with sodium carbonate solution.

**(1)**

.....

.....

(ii) How would the result of this test distinguish between a carboxylic acid and an old stock of an aldehyde?

**(1)**

.....

.....

(iii) Write the balanced chemical equation, including state symbols, for the reaction of sodium carbonate solution with butanoic acid.

**(2)**

*(iv) Infrared spectroscopy is a good physical method to distinguish carboxylic acids from other organic compounds. Give the wavenumbers of **two** characteristic absorptions for a carboxylic acid. Indicate the bond responsible for each absorption. Suggest why one of the absorptions is broad.

**(3)**

.....

.....

.....

.....

.....

.....

(v) High resolution nuclear magnetic resonance spectroscopy is a suitable physical method to use alongside infrared spectroscopy to identify butanoic acid. State the total number of peaks and suggest the splitting pattern for each peak that you would expect for butanoic acid, $CH_3CH_2CH_2COOH$.

**(3)**

.....

.....

.....

.....

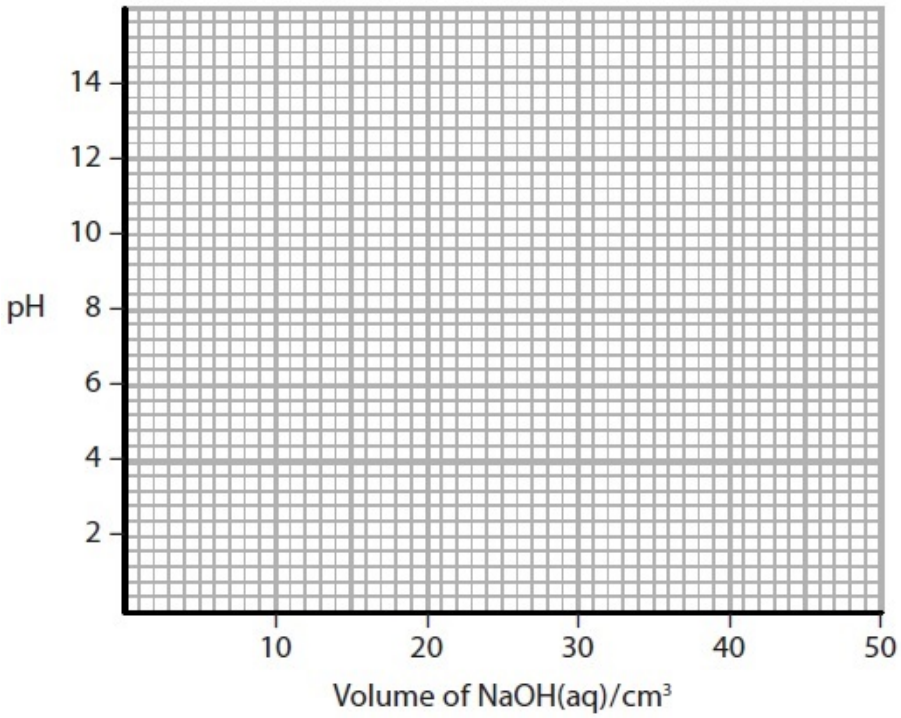
.....

.....

.....

(b) Sketch the titration curve obtained when 50 $cm^3$ of 0.10 mol $dm^{-3}$ sodium hydroxide solution is added to 25 $cm^3$ of 0.10 mol $dm^{-3}$ butanoic acid.

**(4)**




(c) (i) What would you see when phosphorus pentachloride, $PCl_5$, reacts with butanoic acid?

**(1)**

.....

.....

(ii) Give the structural formula and name of the organic product of this reaction.

**(2)**

Structural formula

Name

.....

(d) (i) Give the name or formula of the organic product of the reaction between butanoic acid and lithium tetrahydridoaluminate (lithium aluminium hydride).

**(1)**

.....

(ii) Water cannot be used as the solvent in this reaction because it reacts with lithium tetrahydridoaluminate. Suggest a suitable solvent.

**(1)**

.....

(iii) State the type of reaction that takes place between butanoic acid and lithium tetrahydridoaluminate. Justify your classification.

**(2)**

Type

.....

Justification

.....

.....

.....

(e) (i) Butanoic acid can be reacted with methanol to make methyl butanoate. State **two** conditions that help to speed up this reaction.

**(2)**

.....

.....

(ii) Draw the **displayed** formula of methyl butanoate.

**(1)**

(iii) Identify another chemical, by name or formula, which could be added to methanol to make methyl butanoate.

**(1)**

.....

*(iv) Give **two** advantages and **one** disadvantage of using the reaction occurring in (e)(iii), compared to the reaction in (e)(i), when making methyl butanoate.

**(3)**

**Advantages**

.....

.....

.....

.....

**Disadvantage**

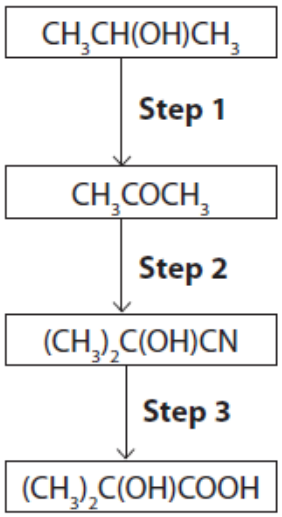
.....

.....

**(Total for Question = 28 marks)**

Q6.

A flow chart for making 2-hydroxy-2-methylpropanoic acid from propan-2-ol is shown below.




(a) (i) Give the reagents and conditions for **Step 1**.

**(2)**

.....

.....

.....

(ii) Propanone is formed in Step 1.

Give a chemical test to identify the carbonyl group and a further test to show the presence of the $H_3C–\overset{\overset{O}{\|}}{C}–$ group.

For both tests, give the observations that you would make.

**(4)**

Carbonyl group

.....

.....

.....

.....

$H_3C–\overset{\overset{O}{\|}}{C}–$ group

.....

.....

.....

.....

(b) (i) In **Step 2**, propanone undergoes an addition reaction with HCN in the presence of $CN^-$ ions.
Give the mechanism for this reaction.

**(3)**

(ii) Explain why this reaction would not take place at either a very low or very high pH.

**(2)**

Low pH

.....

.....

High pH

.....

.....

(c) (i) The reaction in **Step 3** forms 2-hydroxy-2-methylpropanoic acid, $(CH_3)_2C(OH)COOH$.
Suggest the type of reaction occurring in **Step 3**.

**(1)**

.....

(ii) Explain why the presence of the alcoholic hydroxyl group cannot be confirmed in the infrared spectrum of 2-hydroxy-2-methylpropanoic acid.

**(1)**

.....

.....

(iii) The hydrogen of the alcohol group in 2-hydroxy-2-methylpropanoic acid can be identified by a single peak in the nmr spectrum.

Give the chemical shift you would expect for this peak.

**(1)**

.....

(iv) How many peaks would you expect in a high resolution nmr spectrum for 2-hydroxy-2-methylpropanoic acid, $(CH_3)_2C(OH)COOH$?

**(1)**

.....

(v) Explain why, in high resolution nmr, the peak due to the hydrogens of the 2-methyl group in 2-hydroxy-2-methylpropanoic acid is a singlet.

**(1)**

.....

.....

(vi) Would you expect 2-hydroxy-2-methylpropanoic acid to have optical isomers?
Justify your answer.

**(1)**

.....

.....

.....

.....

(d) (i) Molecules of 2-hydroxy-2-methylpropanoic acid react together to form a condensation polymer.

Draw a **displayed** formula for this polymer, showing two repeating units.

**(2)**

(ii) Give the name of the functional group that links the two molecules in the polymer.

**(1)**

.....

**(Total for question = 20 marks)**

Q7.

A compound **Q** contains carbon, hydrogen and oxygen only.
It has a molar mass of 148 g $mol^{-1}$.

(a) Combustion analysis shows that when 0.952 g of **Q** is completely burned in excess oxygen, 2.83 g of carbon dioxide and 0.693 g of water are formed.

Use these data to determine the molecular formula of **Q**.

**(5)**

(b) Three qualitative tests are carried out on **Q**.
The results of each test are given in parts (i), (ii) and (iii).

State what can be deduced from each of these results.

(i) A very sooty flame is observed when a small sample of **Q** is burned in air.

**(1)**

.....

(ii) A yellow-orange precipitate is observed when a small amount of 2,4-dinitrophenylhydrazine is added to **Q**.

**(1)**

.....

(iii) No visible change is observed when a sample of **Q** is warmed with Tollens' reagent.

**(1)**

.....

(c) These data come from the proton NMR spectrum of **Q**.

| Chemical shift of peak / ppm | Splitting pattern | Area under peak |
|---|---|---|
| 7.5 | complex multiplet | 5 |
| 2.55 | septuplet | 1 |
| 1.25 | doublet | 6 |

(i) Deduce the structure of **Q**, using these data and your answers to (a) and (b).

Justify how all the data in the table supports your answer.

**(7)**

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

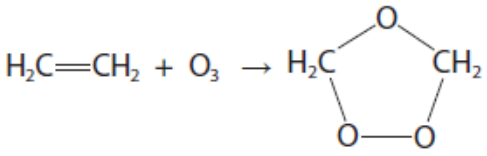
.....

.....

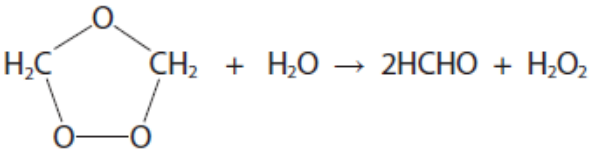
**(Total for question = 15 marks)**

Q8.

Ozone reacts with an alkene, such as ethene, dissolved in an organic solvent to form an ozonide.



When hydrolysed by warming with water and zinc dust, the ozonide splits up to form carbonyl compounds.



These reactions can be used to find the position of a double bond in an alkene.

The hydrocarbon **J** was treated with ozone and the product was hydrolysed by warming with water and zinc dust.
Two different carbonyl compounds, **K** and **L**, were formed and separated.

The mass spectrum of compound **K** showed a molecular ion peak at *m/z* 30.

The mass spectrum of compound **L** showed a molecular ion peak at *m/z* 58 and there were 2 peaks on the $^{13}C$ NMR spectrum.

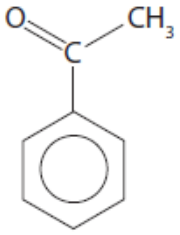
Use this information to deduce the identities of the carbonyl compounds **K** and **L** and hence the hydrocarbon **J**. Justify your answers.

Write equations for the reaction between hydrocarbon **J** and ozone and for the hydrolysis of the product.

**(5)**

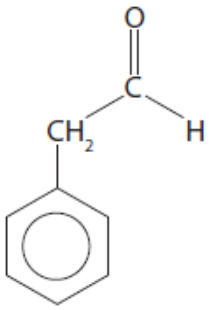
Q9.

Phenylethanone is an ingredient in many types of chewing gum.




One method for the production of phenylethanone involves the reaction of benzene with ethanoyl chloride, $CH_3COCl$.

Phenylethanone can be distinguished from its structural isomer, phenylethanal, in a number of different ways.




(i) Which would react with phenylethanone but **not** with phenylethanal?

**(1)**

☒ **A** acidified sodium dichromate(VI)

☒ **B** alkaline iodine solution

☒ **C** Fehling's solution

☒ **D** Tollens' reagent

(ii) Give the steps to show how 2,4-dinitrophenylhydrazine could be used to distinguish between phenylethanone and phenylethanal.

**(4)**

.....

.....

.....

.....

.....

.....

.....

.....

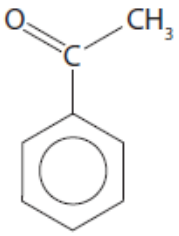
.....

.....

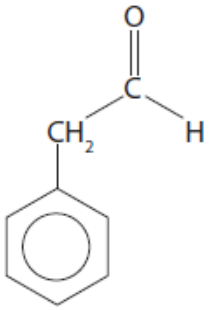
.....

* (iii) Compare and contrast the high resolution proton NMR spectra of phenylethanone and phenylethanal.

You should use the Data Booklet.




Phenylethanone




Phenylethanal

**(6)**

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

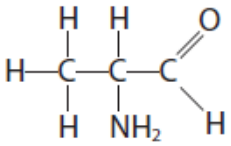
.....

.....

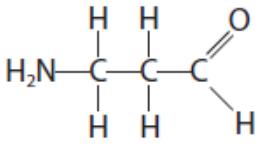
**(Total for question = 11 marks)**

Q10.

This question is about 2-aminopropanal and 3-aminopropanal.



2-aminopropanal



3-aminopropanal

(a) Explain whether each of the following methods could be used to distinguish between these substances.

**Method A** Using very accurate mass spectroscopy to measure the relative molecular mass to four decimal places.

**Method B** Measuring the rotation of the plane of plane-polarised monochromatic light.

**Method C** Reacting the substances with Fehling's solution.

**(3)**

.....

.....

.....

.....

.....

.....

.....

.....

*(b)  Describe the high resolution proton NMR spectra of 2-aminopropanal and 3-aminopropanal. Explain how the spectra can be used to distinguish between these substances.

Use of the Data booklet to determine chemical shifts is not required.

**(6)**

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

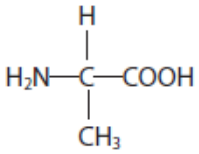
.....

.....

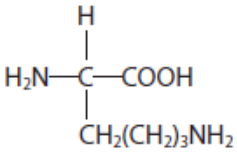
.....

Q11.

Alanine and lysine are amino acids.



alanine



lysine

(a) Draw the structure of a dipeptide formed when one molecule of alanine reacts with one molecule of lysine.

**(1)**

(b) The dipeptide formed in part (a) is hydrolysed under **acidic** conditions and the resulting mixture is analysed by column chromatography. The column uses a polar stationary phase.

Explain why lysine leaves the chromatography column after alanine.

**(2)**

.....

.....

.....

.....

**(Total for question = 3 marks)**

Q12.

Chromatography is a technique used to separate the components of a mixture.

Gas chromatography can be used both to separate the components in a mixture and to determine the amount of each present.

(i) State why argon and nitrogen are suitable carrier gases for gas chromatography.

**(1)**

.....

.....

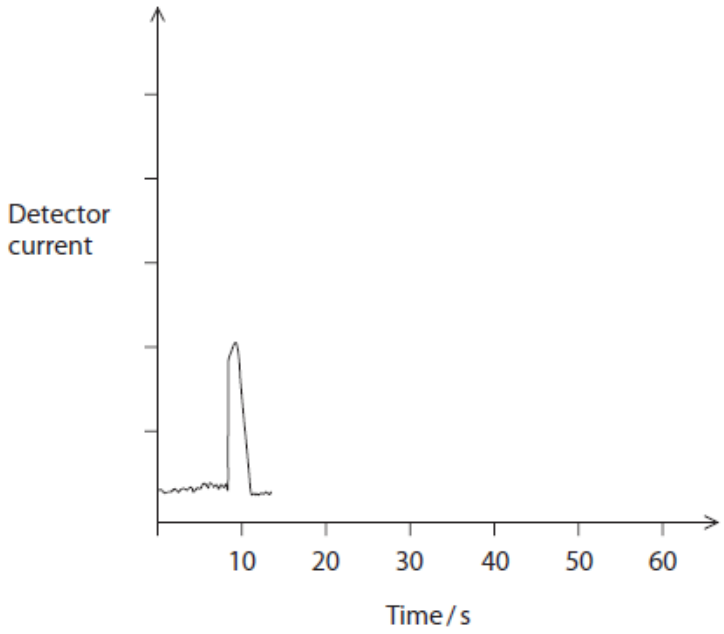
.....

(ii) A mixture containing one part substance **X**, two parts substance **Y** and one part substance **Z** was separated by gas chromatography.

Substance **X** has a retention time of 10 seconds, substance **Y** of 15 seconds and substance **Z** of 40 seconds.

Complete the sketch of this chromatogram.

**(3)**




**(Total for question = 4 marks)**

Q13.

Cinnamon is a spice that is extracted from the bark of the cinnamon tree.

It is extracted by crushing the soft bark with water, and then steam distilling the mixture to produce cinnamon oil.

(b) Compound **Q** is the main component of cinnamon oil. Some chemical tests are carried out to try to find the structure of **Q**.

The results of each test are given in parts (i) to (iii).

Deduce from the results of each test what functional group may be present in **Q**.

(i) **Q** decolourises both bromine water and acidified potassium manganate(VII).

**(1)**

.....

.....

(ii) **Q** gives a yellow precipitate with 2,4-dinitrophenylhydrazine.

**(1)**

.....

.....

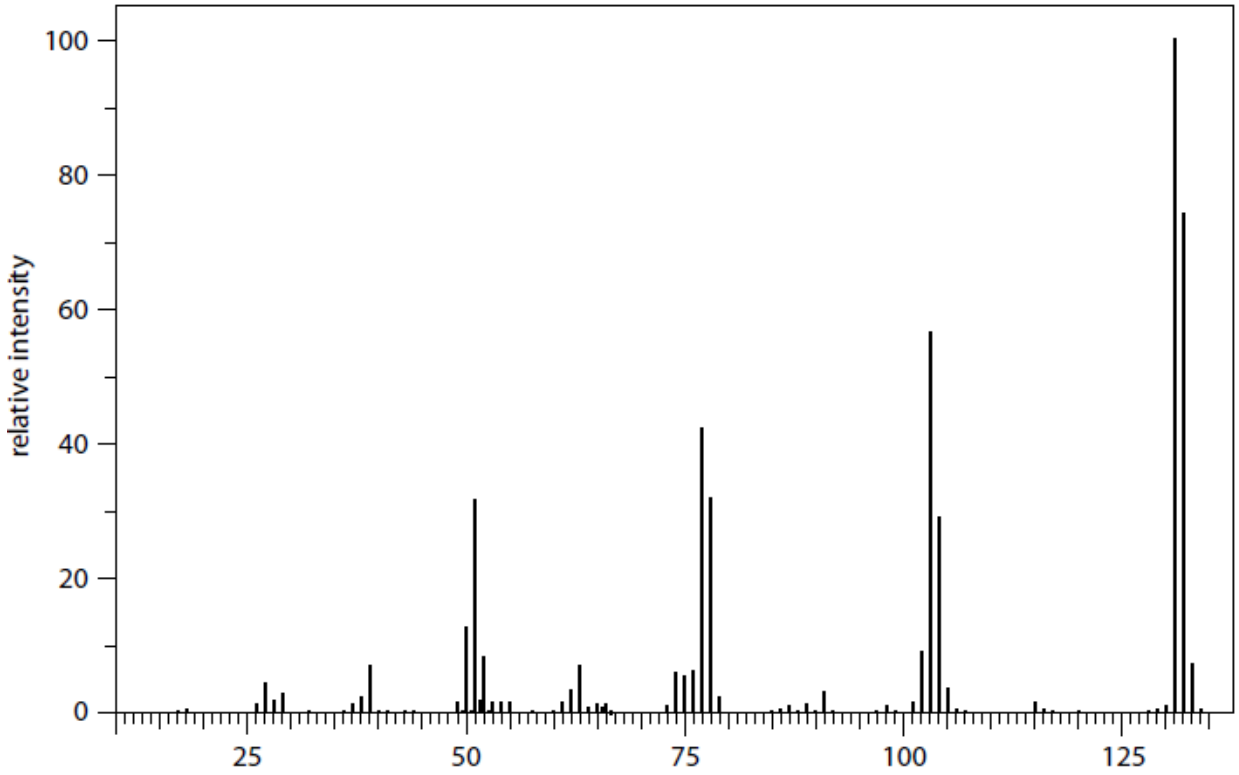
(iii) **Q** forms a red precipitate when boiled with either Benedict's or Fehling's solution.

**(1)**

.....

.....

(c) **Q** has the empirical formula $C_9H_8O$ and its mass spectrum is shown.




(i) Predict the identity of the fragment ions causing the peaks at 77 and 103.

**(2)**

| m/z | formula of fragment ion |
|---|---|
| 77 | |
| 103 | |

(ii) Deduce **two** possible displayed formulae for **Q**.

**(2)**

(iii) The peak at m/z = 132 in the mass spectrum of **Q** is the molecular ion peak. The mass spectrum also shows a peak at m/z = 133.

Give a reason why the peak at m/z = 133 occurs.

**(1)**

.....

.....

Q14.

Which gas is the **least** suitable as a carrier gas in Gas-Liquid Chromatography?

☒ **A** Argon

☒ **B** Carbon dioxide

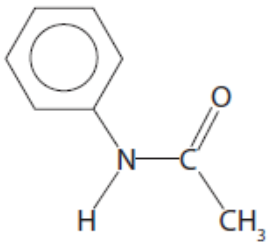
☒ **C** Oxygen

☒ **D** Nitrogen

**(Total for question = 1 mark)**

Q15.

Antifebrin was the trade name for N-phenylethanamide which was used as a painkiller until paracetamol was discovered.




Antifebrin

What is the number of peaks in a C-13 NMR spectrum of Antifebrin?

**(1)**

☒ **A** 5

☒ **B** 6

☒ **C** 7

☒ **D** 8

**(Total for question = 1 mark)**

Q16.

Which of these solvents is most likely to be warmed by microwave radiation?

☒ **A** Hexane

☒ **B** Cyclohexane

☒ **C** Cyclohexanol

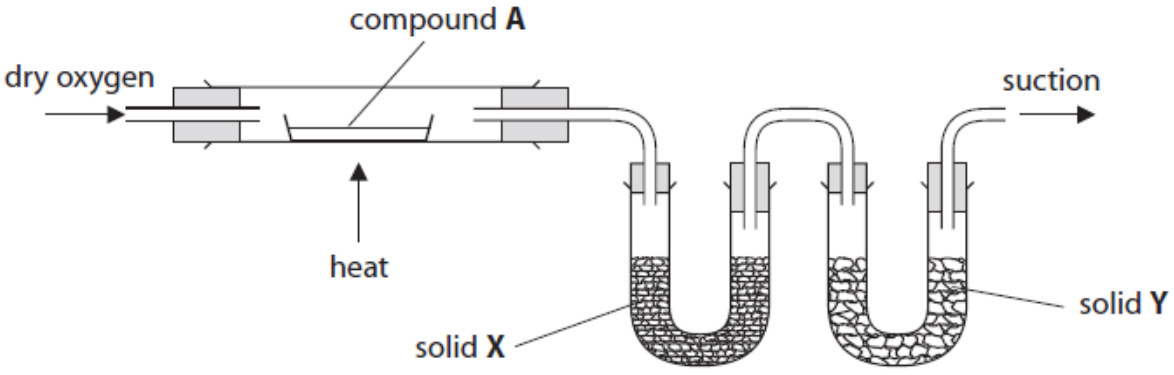
☒ **D** Cyclohexene

**(Total for question = 1 mark)**

Q17.

A compound **A**, known to contain only the elements carbon, hydrogen and oxygen, was subjected to detailed analysis.

(a) A sample of **A** was burned completely in the apparatus shown below. Solid **X** absorbed the water formed in the combustion and solid **Y** absorbed the carbon dioxide.




(i) Explain why the oxygen must be dry.

**(1)**

.....

.....

.....

.....

(ii) Suggest a suitable substance to use as solid **X**.

**(1)**

.....

.....

(iii) Suggest a suitable substance to use as solid **Y**.

**(1)**

.....

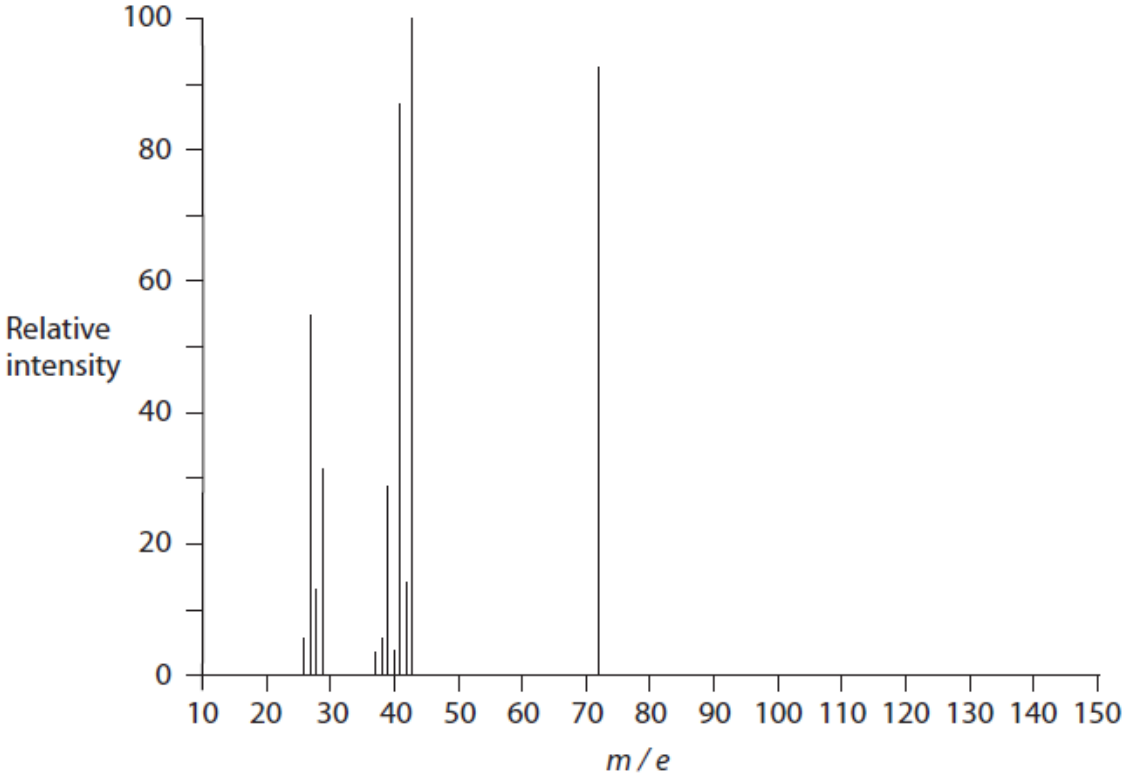
.....

(iv) 3.60 g of compound **A** was burned completely. The mass of solid **X** increased by 3.60 g and the mass of solid **Y** increased by 8.80 g.

Use these data to calculate the empirical formula of compound **A**.
You **must** show your working.

**(5)**

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




(i) Identify the molecular ion peak and hence deduce the molecular formula of **A**.

**(2)**

.....

.....

(ii) Given that **A** does **not** have a ring structure, suggest the **structural** formulae of three of the species that might cause the peak at *m*/*e* = 43 in the mass spectrum of **A**.

**(3)**

*(c) The low resolution nmr spectrum of **A** has three peaks in the ratio 6:1:1. Draw the structure of **A** and show how your structure is consistent with the nmr data.

**(3)**

.....

.....

.....

.....

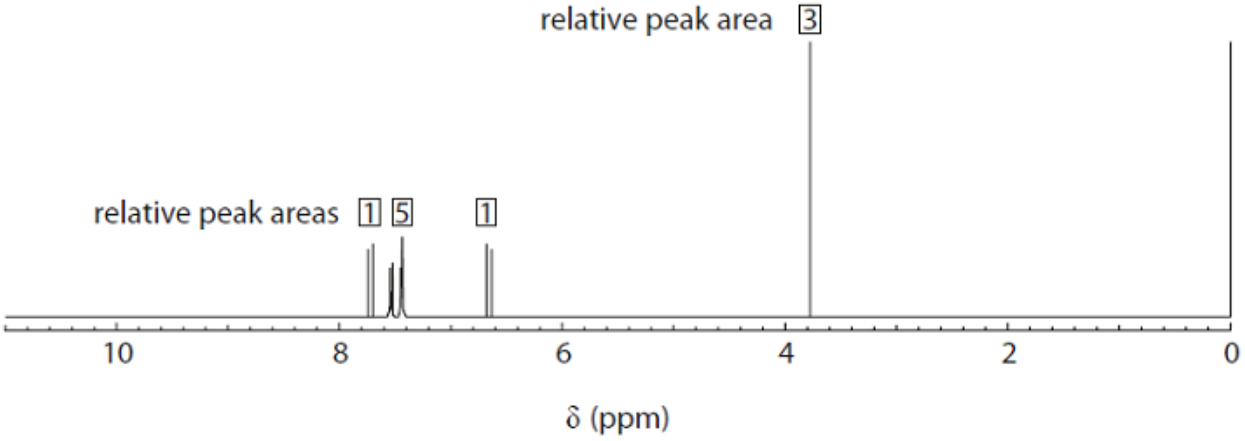
**(Total for question = 16 marks)**

Q18.

Methyl cinnamate, $C_{10}H_{10}O_2$, is a white crystalline solid used in the perfume industry.

A sample of methyl cinnamate was analysed by high resolution proton NMR spectroscopy.

A simplified spectrum is shown.




(i) Name the compound responsible for the peak at a chemical shift of 0 ppm, stating its purpose.

**(2)**

.....

.....

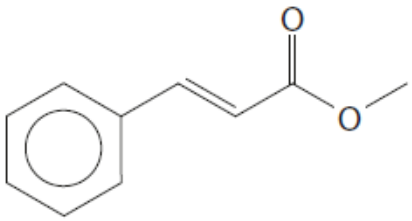
.....

.....

(ii) Identify the proton environment that causes the peak at a chemical shift of 3.8 ppm by circling it on

the diagram shown. Fully justify your answer.

**(3)**




.....

.....

.....

.....

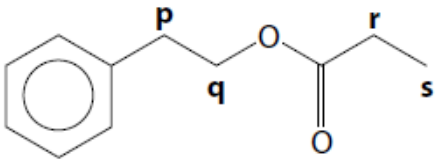
**(Total for question = 5 marks)**

Q19.

The compound 2-phenylethyl propanoate is a synthetic oil used in some fragrances due to its rose-like aroma.

Nuclear magnetic resonance (NMR) spectroscopy can be used to determine structural formulae.

An incomplete $^{1}H$ NMR spectrum for 2-phenylethyl propanoate shows a peak for the hydrogen atoms attached to the benzene ring.

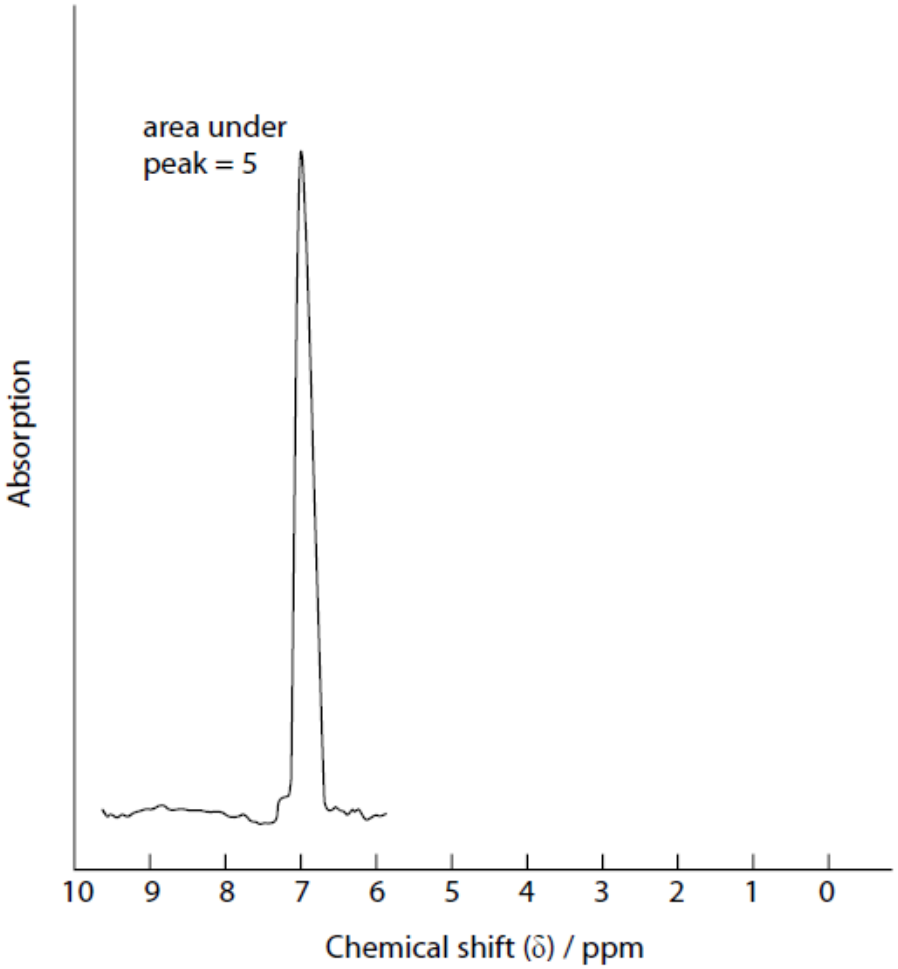



Complete the spectrum for the protons attached to the carbon atoms **p**, **q**, **r** and **s**, giving the relative areas under each peak.

You should use the Data Booklet. Your spectrum does not have to be to scale.

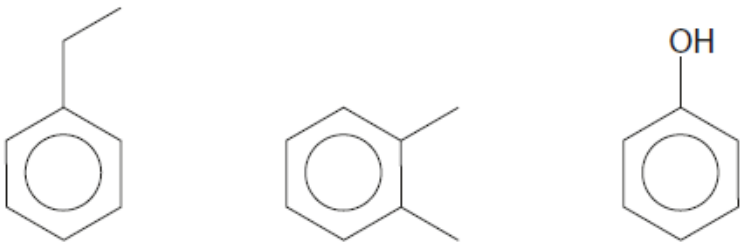
**(6)**

Predicted spectrum:




Q20.

This question is about the arenes, ethylbenzene, xylene, and phenol, which can be identified in wine samples using gas chromatography.




ethylbenzene xylene phenol

The time taken for a compound to pass through the column in gas chromatography is called the retention time.

Explain why different compounds will have different retention times in the same column, under the same conditions.

**(2)**

.....

.....

.....

.....

.....

.....

.....

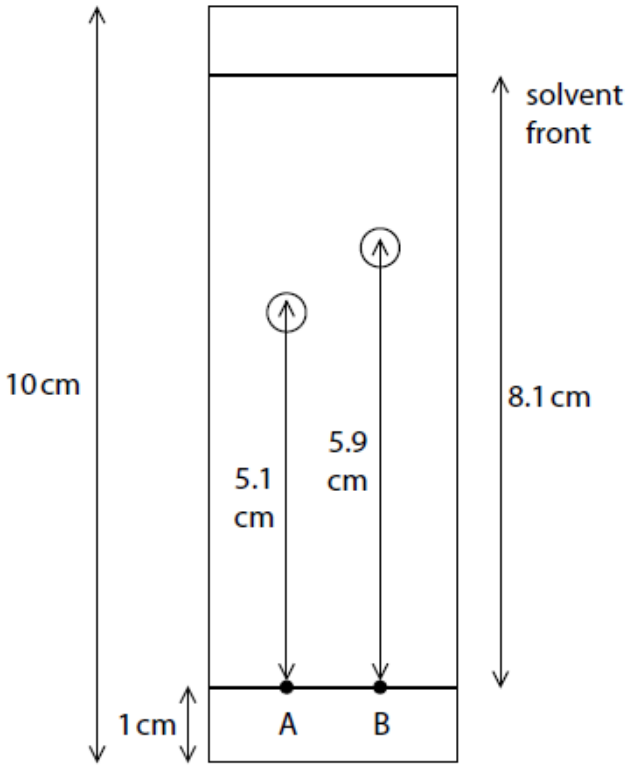
.....

**(Total for question = 2 marks)**

Q21.

This question is about the properties of amino acids and other organic compounds.

A chromatogram of two amino acids, **A** and **B**, is shown.




The $R_f$ value of amino acid A is

**(1)**

☒ **A** 0.51

☒ **B** 0.56

☒ **C** 0.63

☒ **D** 0.67

Q22. Which atoms are not detected by X-rays but are detected by nuclear magnetic resonance imaging which also shows their environments?

☒ **A** Carbon

☒ **B** Hydrogen

☒ **C** Nitrogen

☒ **D** Oxygen

**(Total for Question = 1 mark)**

Q23.

This question is about the use of NMR spectroscopy to distinguish between isomers of $C_6H_{12}O_2$.

(i) There are three other isomers of $C_6H_{12}O_2$ which are carboxylic acids with **five** peaks in their **carbon-13** NMR spectra.

Draw the structural formula of **two** of these isomers.

**(2)**

(ii) Draw the **skeletal** formula of a cyclic diol isomer of $C_6H_{12}O_2$ that has only **two** peaks in its **carbon-13** NMR spectrum.

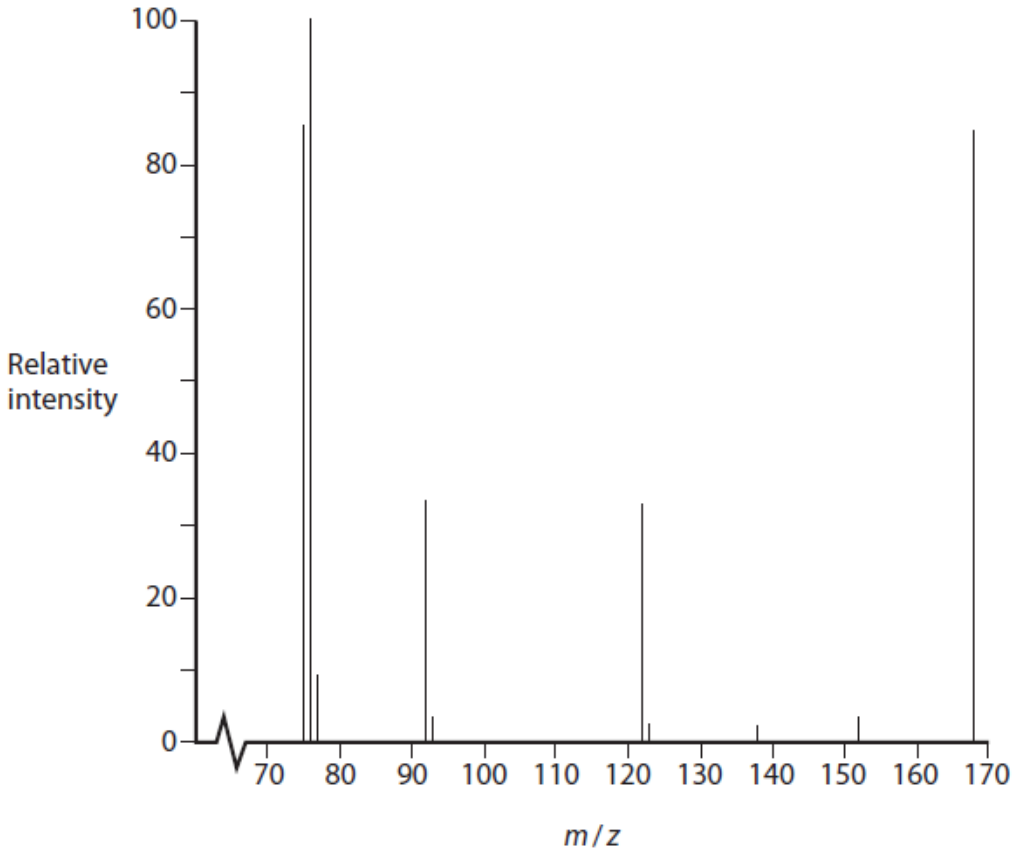
**(1)**

**(Total for question = 3 marks)**

Q24.

Organic compound **D** contains the elements carbon, hydrogen, oxygen and nitrogen only.

Part of the mass spectrum of **D** is shown.




Compound **D** contains a benzene ring.

(i) Give the molecular formula of the species that causes the peak at $m / z = 76$ in the mass spectrum of **D**.

.....

**(1)**

(ii) Draw the structures of the **three** possible isomers of **D** containing a benzene ring.

**(2)**

(iii) The $^{13}C$ NMR spectrum of compound **D** has four peaks.

Identify the structure of **D**. Justify your answer by labelling the different carbon environments in **all** the structures drawn in (ii).

**(3)**

**(Total for question = 6 marks)**

Q25.

This question is about the use of NMR spectroscopy to distinguish between isomers of $C_6H_{12}O_2$.

Tetramethylsilane (TMS) is a compound used as a standard when recording both $^{1}H$ and $^{13}C$ NMR spectra.

(i) Give the structural formula of TMS.

**(1)**

(ii) TMS is an inert and non-toxic compound. State **two** other reasons why TMS is suitable for use as a standard when recording NMR spectra.

**(2)**

.....

.....

.....

.....

**(Total for question = 3 marks)**

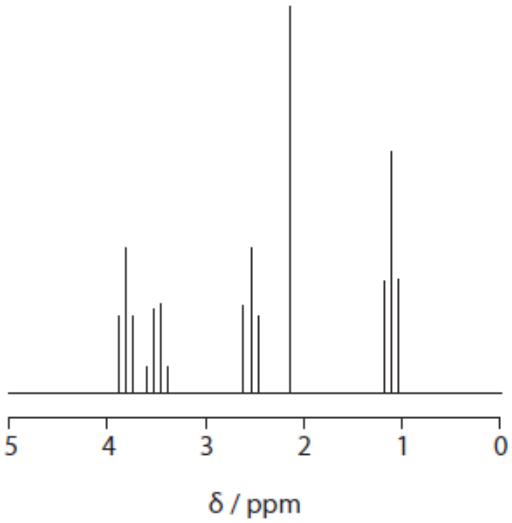
Q26.

This question is about the use of NMR spectroscopy to distinguish between isomers of $C_6H_{12}O_2$.

(i) Draw the structural formulae of the **two** esters with formula $C_6H_{12}O_2$ that each have only **two** peaks, both singlets, in their high resolution **proton** NMR spectra. The relative peak areas are 3:1 for both esters.

**(2)**

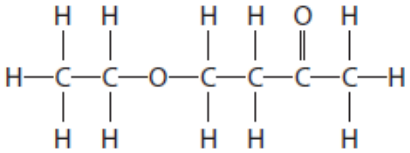
(ii) The high resolution **proton** NMR spectrum of another isomer of $C_6H_{12}O_2$ is shown.




The ratios of the number of protons for the five sets peaks in the spectrum are given in the table.

| δ / ppm | 3.8 | 3.5 | 2.6 | 2.2 | 1.2 |
|---|---|---|---|---|---|
| Ratio of the number of protons | 2 | 2 | 2 | 3 | 3 |

Show that **all** these data are consistent with the displayed formula shown. Refer to the five chemical shifts and explain **two** of the splitting patterns.



**(5)**

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

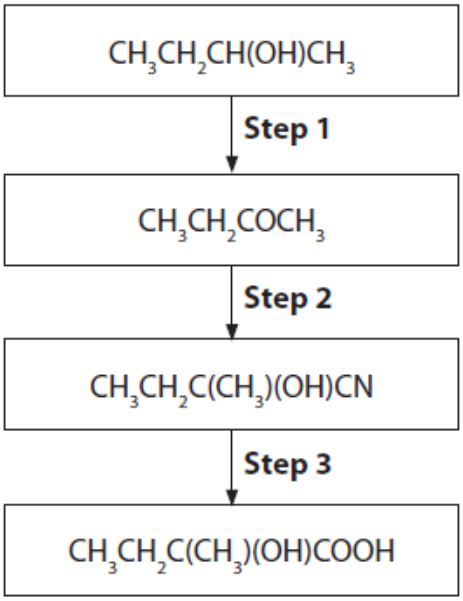
.....

.....

**(Total for question = 7 marks)**

Q27.

A flow chart for making 2-hydroxy-2-methylbutanoic acid from butan-2-ol is show below.




(a) (i) Give the reagents and conditions for **Step 1**.

**(2)**

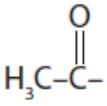
.....

.....

.....

(ii) Butanone is formed in **Step 1**.

Give a chemical test to identify the carbonyl group and a further test to show the presence of the

 group.

For both tests, give the observations that you would make.

**(4)**

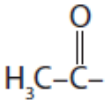
Carbonyl group

.....

.....

.....

.....

 group

.....

.....

.....

.....

(b) (i) In **Step 2**, butanone undergoes an addition reaction with HCN in the presence of $CN^-$ ions.

Give the mechanism for this reaction.

**(3)**

*(ii) By considering the mechanism of the reaction, explain why the addition of hydrogen cyanide to butanone gives a solution which has no effect on the plane of polarization of plane-polarized light.

**(3)**

.....

.....

.....

.....

.....

.....

(c) (i) Suggest the type of reaction occurring in **Step 3**.

**(1)**

.....

(ii) Explain why the presence of the alcoholic hydroxyl group cannot be confirmed in the infrared spectrum of 2-hydroxy-2-methylbutanoic acid.

**(1)**

.....

.....

(iii) The hydrogen of the alcohol group in 2-hydroxy-2-methylbutanoic acid can be identified by a single peak in the nmr spectrum.

Give the chemical shift you would expect for this peak.

**(1)**

.....

(iv) Explain why, in high resolution nmr, the peak due to the hydrogens of the 2-methyl group in 2-hydroxy-2-methylbutanoic acid is a singlet.

**(1)**

.....

.....

(d) Molecules of 2-hydroxy-2-methylbutanoic acid react together to form a condensation polymer.

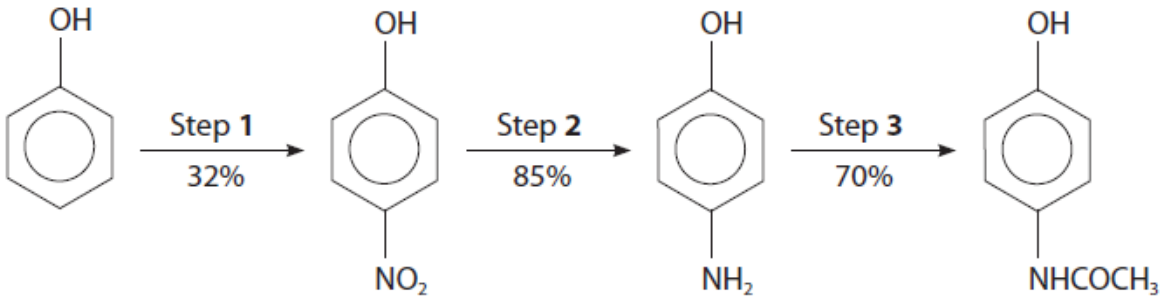
Draw a **displayed** formula for this polymer, showing two repeating units.

**(2)**

**(Total for question = 18 marks)**

Q28.

The painkiller paracetamol can be synthesised from phenol in three steps.
The percentage yield for each step is shown.

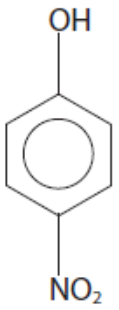
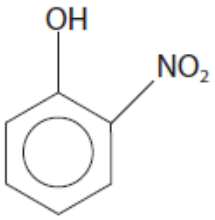



phenol paracetamol

In Step **1** another product also forms. The two products can be distinguished using their $^{13}C$ NMR spectra.

Complete the table to show the number of peaks in each $^{13}C$ NMR spectrum.

**(2)**

| Product |  |  |
|---|---|---|
| Number of peaks in the $^{13}C$ NMR spectrum | | |

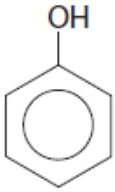




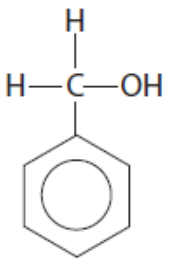
**(Total for question = 2 marks)**

Q29.

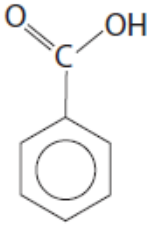
This is a question about the analysis of three aromatic substances with —OH groups.




phenol




phenylmethanol




benzoic acid

Spectroscopy is an effective means of distinguishing between molecules.

(i) Compare and contrast the infrared spectra of phenol, phenylmethanol and benzoic acid.
Include relevant bonds and their wavenumber ranges using the Data Booklet.

**(5)**

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

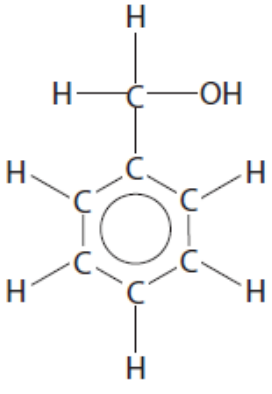
.....

.....

.....

(ii) Predict the number of peaks present, and their chemical shifts, in the $^{13}C$ nuclear magnetic resonance (NMR) spectrum of
phenylmethanol.
Use the information in the Data Booklet to help you.

**(3)**




phenylmethanol