PEARSON EDEXCEL A-LEVEL CHEMISTRY · 9CH0

CHEMISTRY



EXAM QUESTION PACK

TOPIC 7: MODERN ANALYTICAL TECHNIQUES I

SCORE	PERCENTAGE
/170	%

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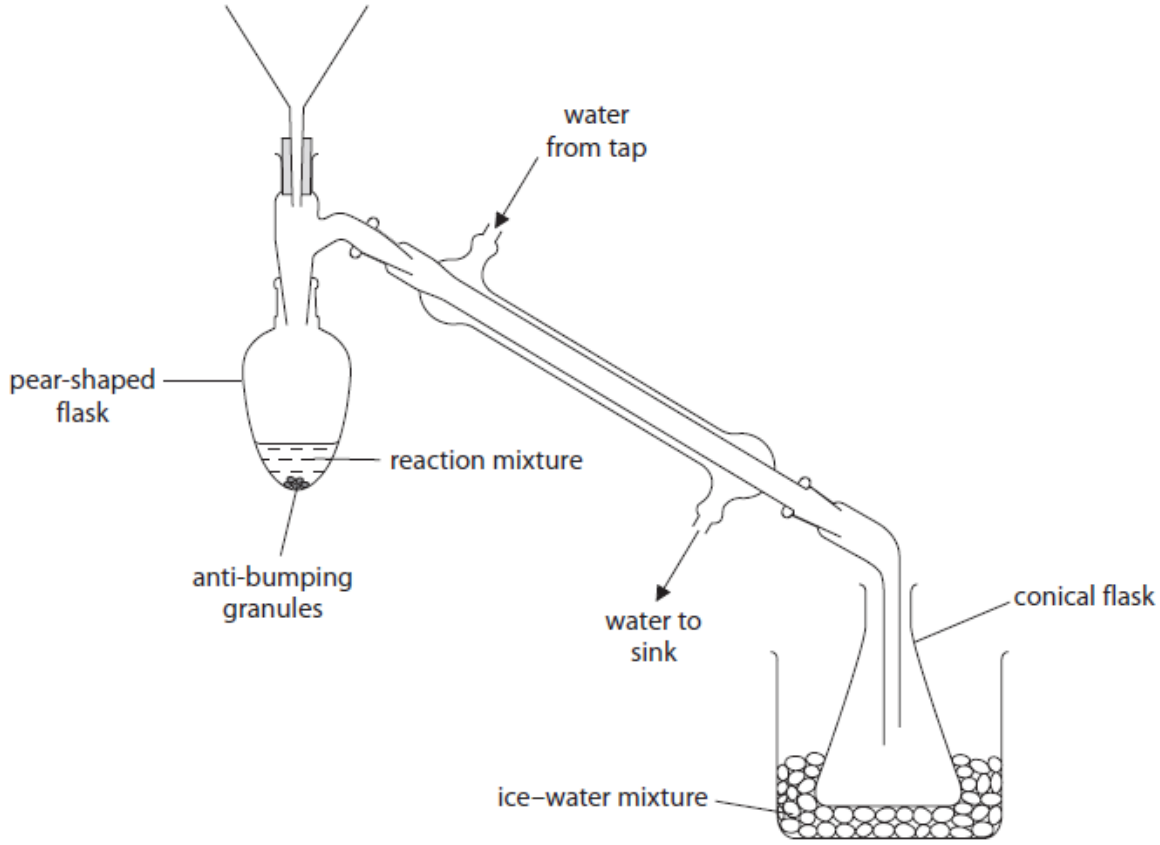
Q1.

This question is about the preparation of a sample of the ketone, 3-methylbutan-2-one.

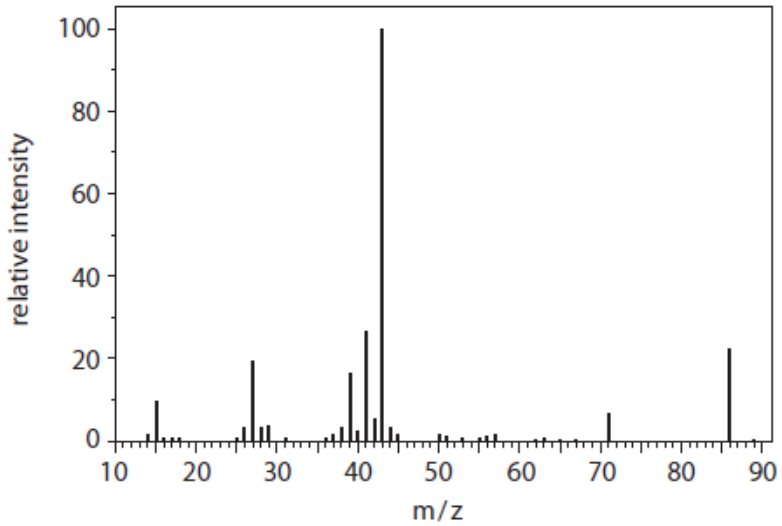
A student's research suggested that 3-methylbutan-2-one may be prepared by oxidising 3-methylbutan-2-ol with acidified potassium dichromate(VI) solution.

The student sets up the apparatus as shown in the diagram. You may assume that all the equipment is suitably clamped.

The student adds dilute sulfuric acid to the pear-shaped flask. A mixture of potassium dichromate(VI) and 3-methylbutan-2-ol is then added slowly to the dilute sulfuric acid in the flask.



The mass spectrum of pure 3-methylbutan-2-one is shown.



(i) State how you would find the molar mass of 3-methylbutan-2-one from the mass spectrum.

(1)

.....

.....

(ii) The mass spectrum shows a peak at m/z = 43.

Draw the **displayed** formulae of two fragment **ions** that might be responsible for this peak.

(2)

(Total for question = 3 marks)

Q2.

Benzene

Benzene was first discovered by Michael Faraday in London in 1825. He identified it by distilling a liquid obtained from condensing a gas produced by heating whale oil.

In 1834, Mitscherlich discovered the same liquid could be obtained by heating benzoic acid with lime.

Benzene is now produced from petroleum. Petroleum is fractionally distilled and benzene is obtained from the hexane in the naphtha fraction.

Hexane is heated to about 770 K. It then passes to a reactor where it reacts to form cyclohexane and hydrogen. The cyclohexane is then dehydrogenated to form benzene. Other aromatic products like methylbenzene and dimethylbenzenes are also produced. The aromatic products are separated by further distillation.

Benzene is the starting compound for a large number of useful chemicals and materials. For example it is used to make the polymer, poly(phenylethene).

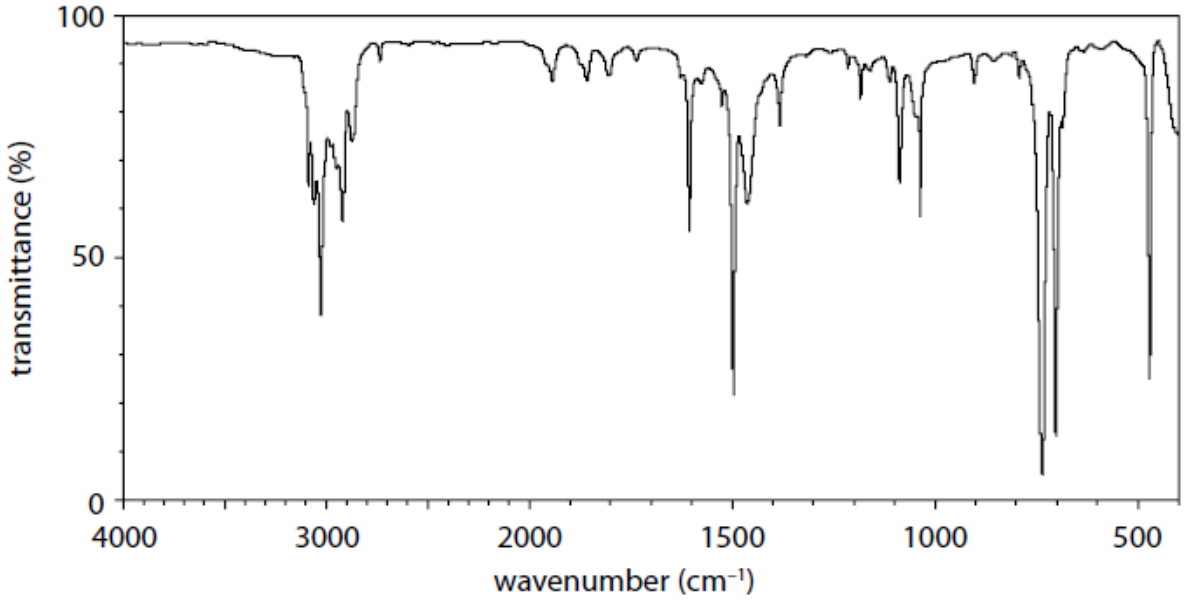
The infrared spectra of benzene and methylbenzene are shown.

Identify which infrared spectrum is that of methylbenzene.

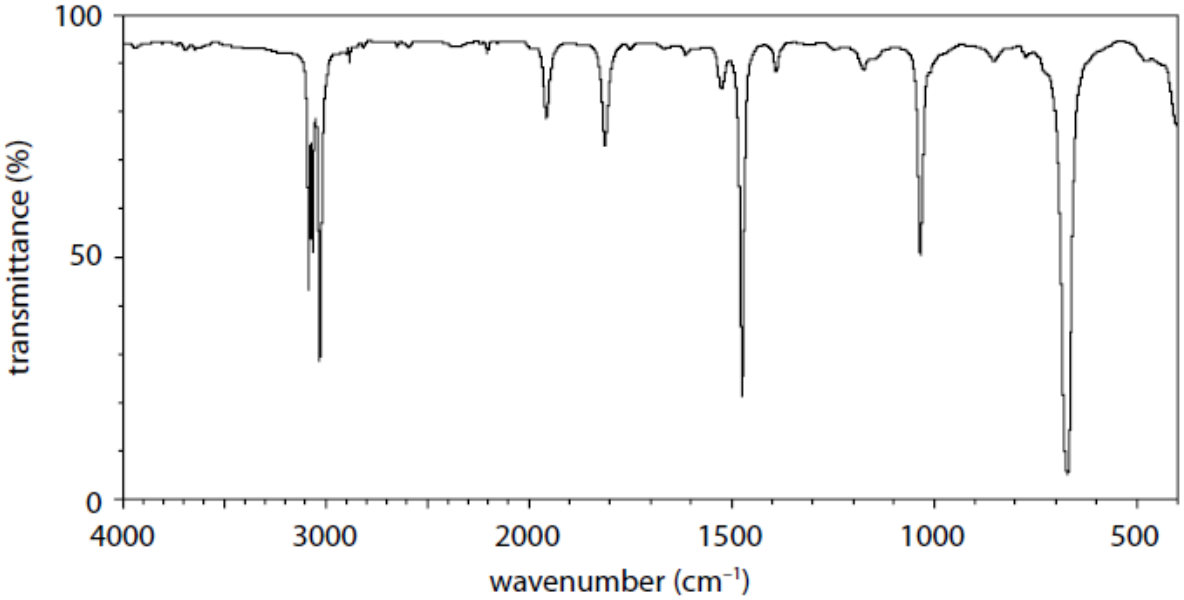
Justify your answer by identifying **one** distinguishing feature in your chosen spectrum.

(2)

Spectrum 1



Spectrum 2



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Q3.

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%

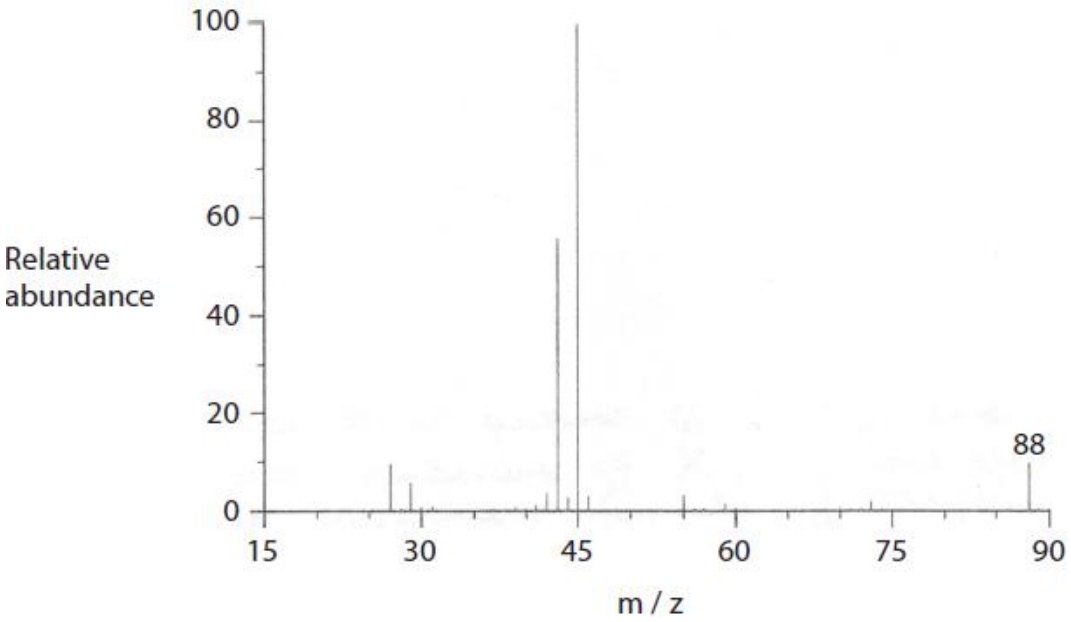
hydrogen, H = 9.1%

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)

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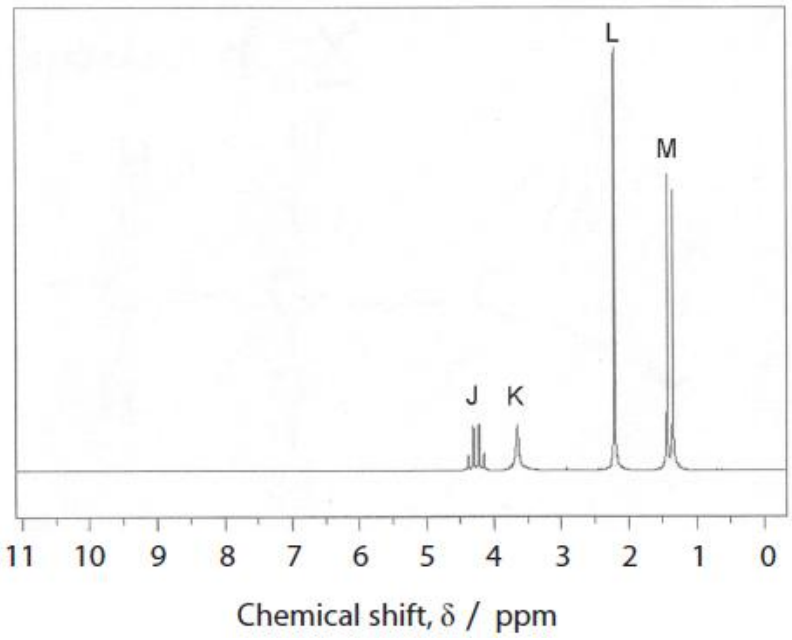
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(ii) Use your answers to parts (b) and (c)(i) to name the two functional groups present in **X**.

(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)

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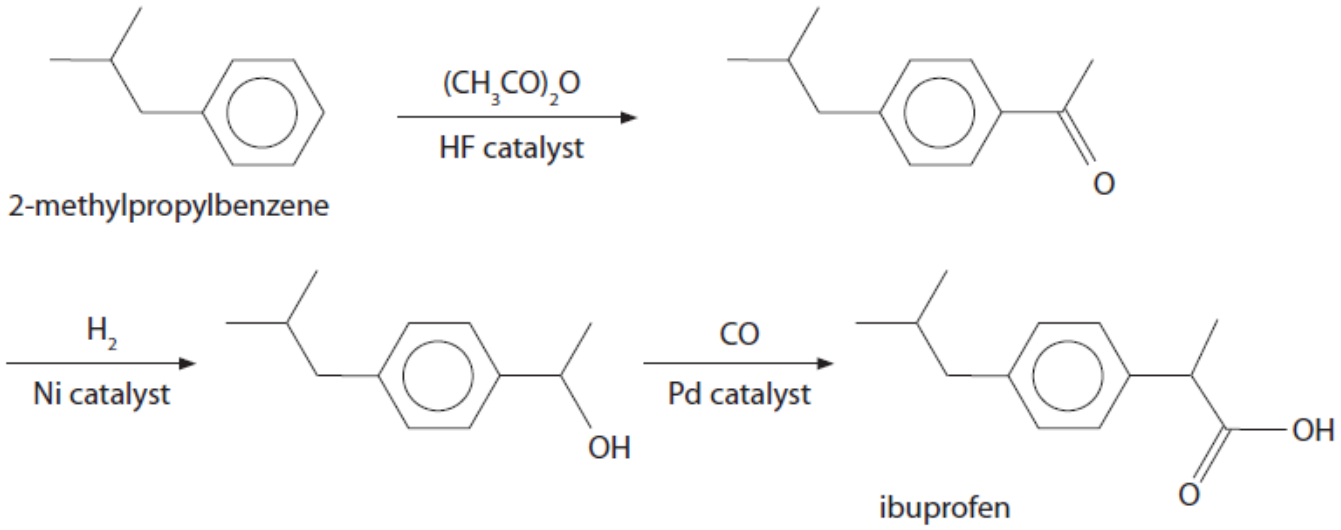
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(Total for question = 18 marks)

Q4.

Ibuprofen is a nonsteroidal anti-inflammatory drug (NSAID) widely used as an analgesic (pain reliever). It was discovered in the 1960s by the Boots Group which developed a six step synthesis from 2-methylpropylbenzene. The synthesis shown below was introduced in the 1990s by the BHC Company and received a Presidential Green Chemistry Challenge award in 1997. The citation noted that the synthesis has just three steps, all of which are catalytic, and an effective atom economy of 99%. Both syntheses are carried out in solution.



(a) (i) Suggest why a three step synthesis is likely to be 'greener' than a six step process.

(1)

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(ii) Why does the use of catalysts make processes 'greener' (as well as faster)?

(1)

.....

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(b) The first step of the synthesis is an electrophilic substitution which is usually carried out in a school laboratory using ethanoyl chloride and an aluminium chloride catalyst.

(i) Write an equation showing the formation of the electrophile in the **school** experiment.

(1)

(ii) Give the mechanism for the electrophilic substitution of 2-methylpropylbenzene by ethanoyl chloride, using the electrophile you have given in (b)(i).

(3)

(iii) Suggest **one** environmental benefit of using $(CH_3CO)_2O$, rather than ethanoyl chloride, in the manufacture of ibuprofen.

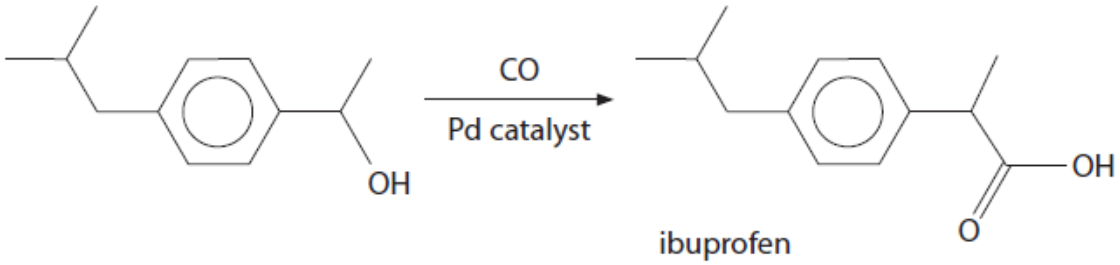
(1)

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(c) The final stage of the modern synthesis for ibuprofen is shown below.



ibuprofen

(i) Suggest a benefit of using a **solid** catalyst in this reaction.

(1)

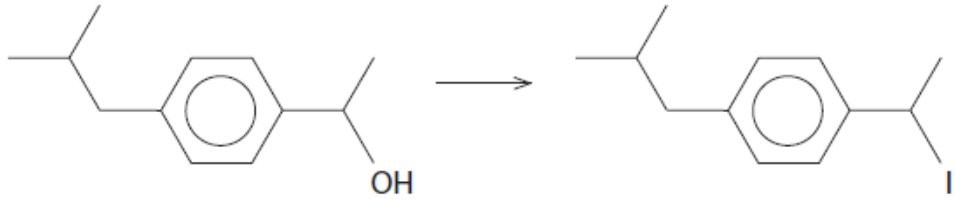
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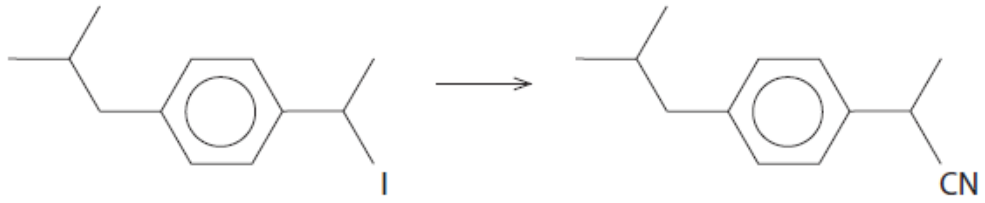
(ii) The preparation in part (c) can be carried out in a laboratory in three reactions.

(3)

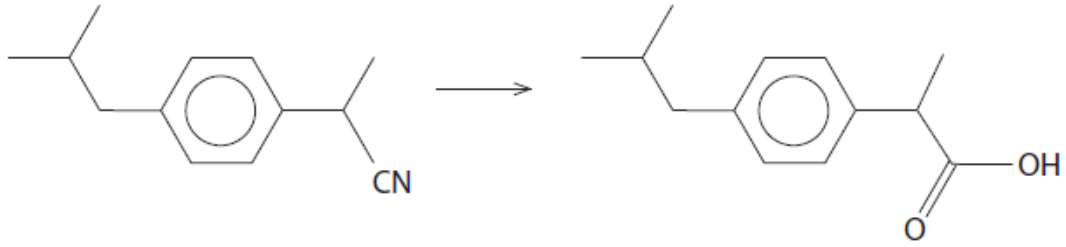
Reaction 1



Reaction 2



Reaction 3



Give:

The reagents for **Reaction 1**

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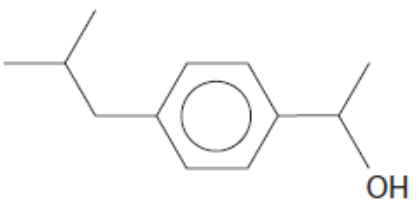
The reagents and conditions for **Reaction 3**

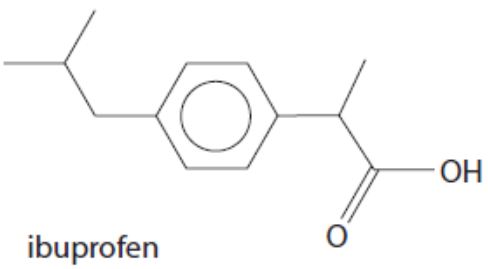
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(iii) Using your Data Booklet, explain how infrared spectroscopy can be used to distinguish between the two structures shown below.

(2)





ibuprofen

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(d) Ibuprofen is a chiral molecule and only one of its enantiomers is biologically active. However, although the synthesis produces a racemic mixture, an isomerase enzyme in the body converts the inactive enantiomer into the active enantiomer.

(i) Explain the term 'chiral molecule'.

(1)

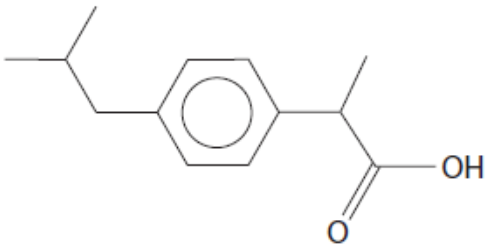
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(ii) Mark with an asterisk (*) the chiral centre on the structure of ibuprofen below.

(1)



(iii) Explain the term 'racemic mixture'.

(1)

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(Total for question = 16 marks)

Q5. A solution of 2,4-dinitrophenylhydrazine (Brady's reagent) is used as a test for organic functional groups.

(a) The positive result of the test is the formation of

(1)

= **A** a yellow solution.

= **B** an orange precipitate.

= **C** a red solution.

= **D** a green precipitate.

(b) Which of the following gives a positive result with a solution of 2,4-dinitrophenylhydrazine?

(1)

= **A** Only aldehydes

= **B** Only ketones

= **C** Only aldehydes and ketones

= **D** Any compound containing the C=O group

(c) The initial attack by 2,4-dinitrophenylhydrazine, when it reacts, is by

(1)

= **A** a free radical.

= **B** an electrophile.

= **C** a nucleophile.

= **D** a negative ion.

(d) The product of a positive test, a 2,4-dinitrophenylhydrazone, contains which of the following bonds?

(1)

= **A** N=N

= **B** C=N

= **C** C=C

= **D** C=O

(Total for Question = 4 marks)

Q6. In one type of high-performance liquid chromatography (HPLC), the stationary phase is non-polar and a polar solvent is used as the eluent. Which of the following would travel through the chromatography column most quickly?

☒ **A** Tetrachloromethane

☒ **B** Chloromethane

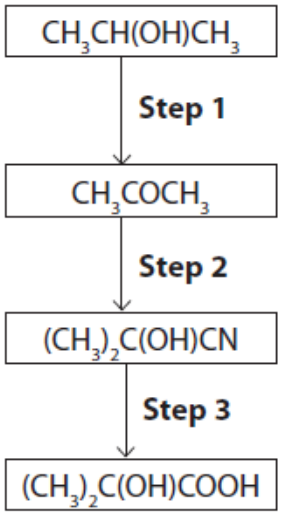
☒ **C** Iodomethane

☒ **D** Hexane

(Total for Question = 1 mark)

Q7.

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**.

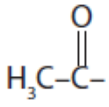
(2)

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(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  group.

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

(4)

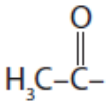
Carbonyl group

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 group

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(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.

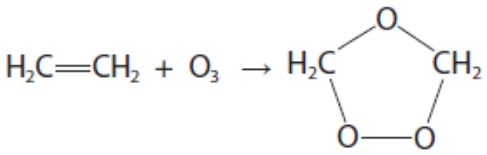
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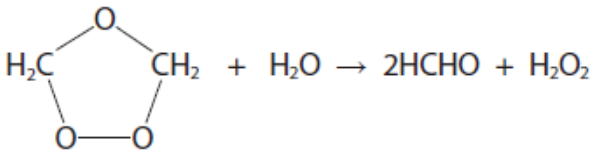
(Total for question = 20 marks)

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.

This question is about flame tests for Group 1 and 2 metal ions.

(i) State the colour of the flame produced by separate samples of potassium and strontium ions.

(1)

Potassium ions
.....

Strontium ions
.....

(ii) Give a reason why carrying out a flame test on a mixture of potassium chloride and strontium chloride does not
clearly show that two different metal ions are present.

(1)

.....

.....

.....

(Total for question = 2 marks)

Q10.

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)

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

(1)

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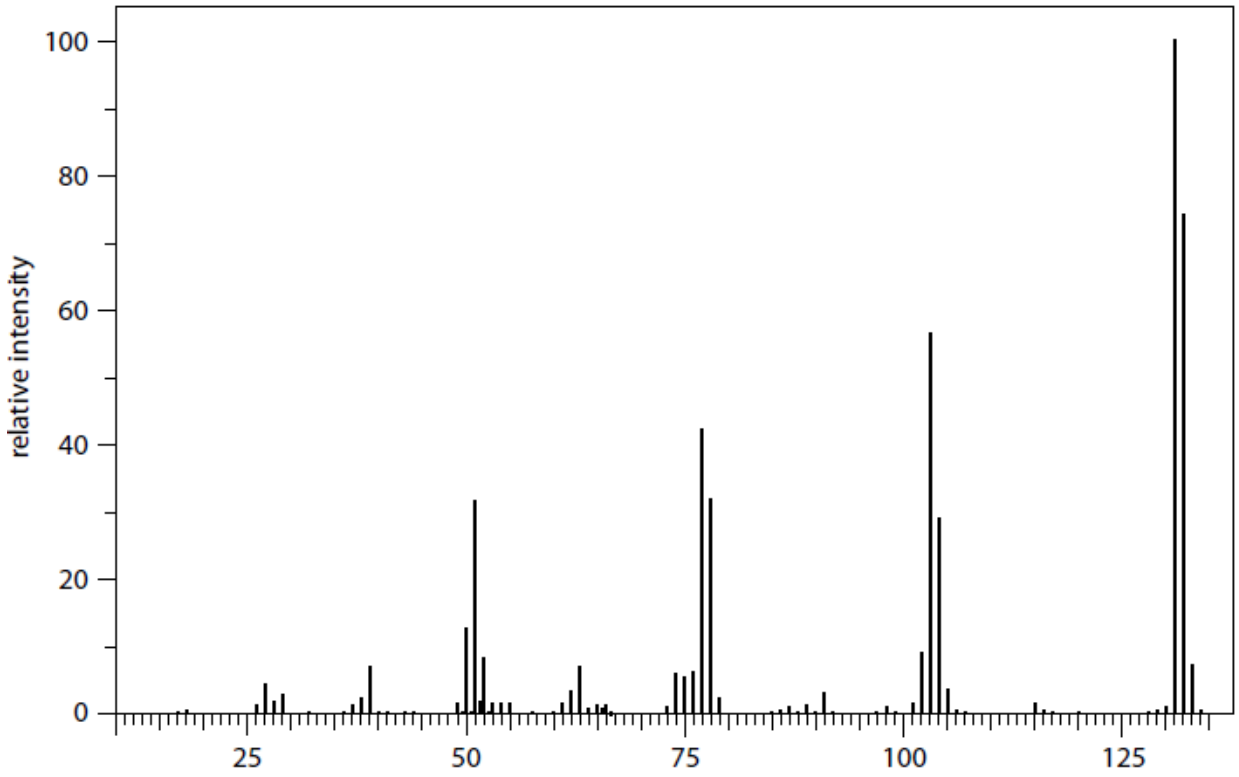
(iii) **Q** forms a red precipitate when boiled with either Benedict's or Fehling's solution.

(1)

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.....

(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)

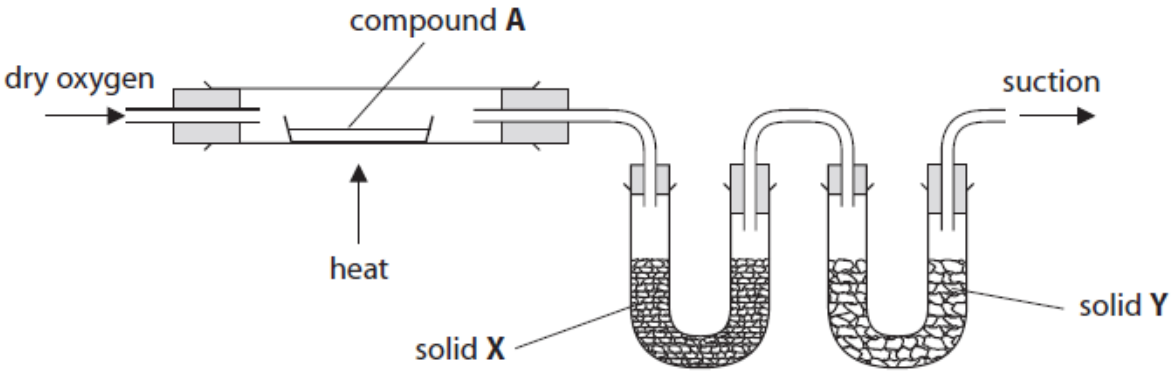
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Q11.

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)

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

(1)

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

(1)

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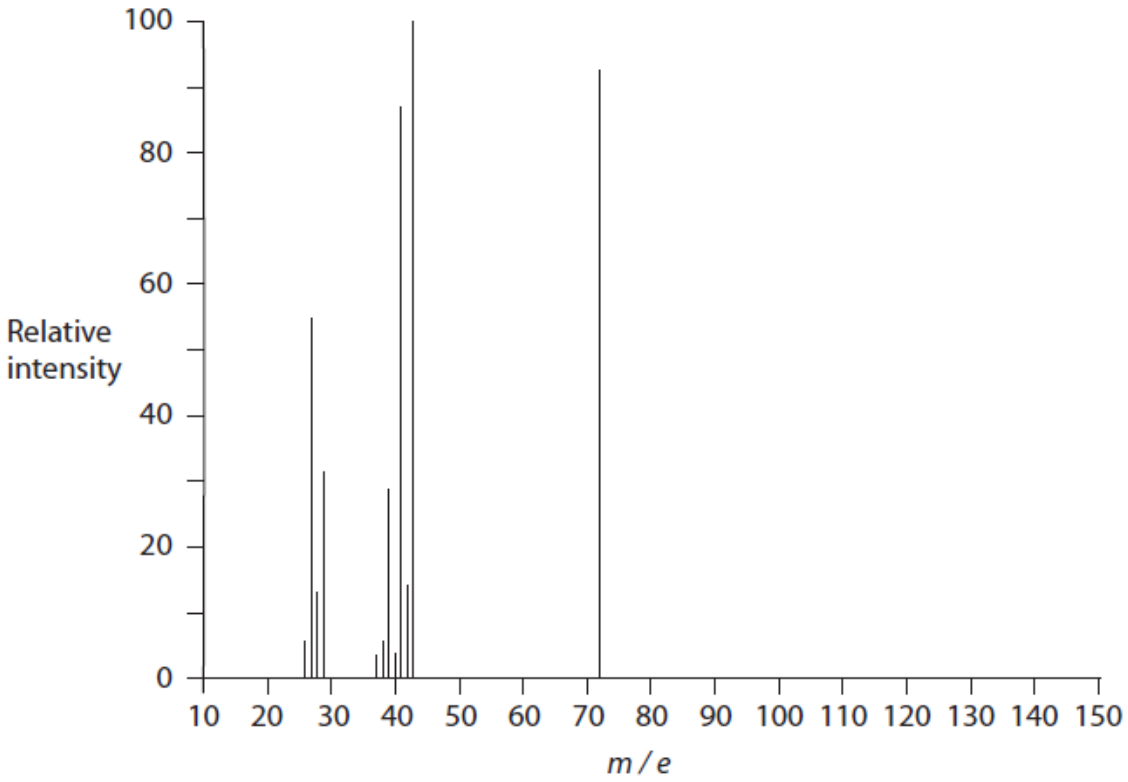
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(iv) 3.60 g of compound **A** was burned completely. The mass of solid **X** increased by 3.60 g and the mass of solid **Y** increased by 8.80 g.

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)

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(Total for question = 16 marks)

Q12.

Analysis shows that a compound has the molecular formula $C_4H_8O_2$.

A student suggests that the compound could be either **A** or **B**.

$CH_3CH_2CH_2COOH$ **A** or $HOCH_2CH{=}CHCH_2OH$ **B**

Another student suggests that the compound could contain an aldehyde and an alcohol functional group, with structure **C**.

$HOCH_2CH_2CH_2CHO$ **C**

Complete the table to show how the infrared spectra of **A**, **B** and **C** would be expected to differ in the wavenumber range **1800-1600 cm^{-1}**.
Use information from the Data Booklet.

(3)

Absorbance	Wavenumber range / cm^{-1}
Absorbance expected in infrared spectrum of **A** but **not** in **B** or **C**	
Absorbance expected in infrared spectrum of **B** but **not** in **A** or **C**	
Absorbance expected in infrared spectrum of **C** but **not** in **A** or **B**	

(Total for question = 3 marks)

Q13.

Tests are carried out on aqueous solutions of two salts, **X** and **Y**.

X contains one cation and one anion.

The observations for each test are recorded in the table.

(i) Complete the table by writing the names or formulae of the species.

(2)

Test	Observation	Inference
Test 1 Add aqueous sodium hydroxide to an aqueous solution of **X**	A green precipitate forms The precipitate turns brown on the top after a few minutes	The cation in **X** is .....
Test 2 To an aqueous solution of **X**, add dilute hydrochloric acid followed by aqueous barium chloride	A white precipitate forms	The anion in **X** is .....

(ii) Write the ionic equation for the reaction between the cation in **X** and aqueous sodium hydroxide in **Test 1**. Include state symbols.

(2)

(iii) Give a reason why the green precipitate turns brown on the top after a few minutes.

(1)

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(iv) Give a reason why dilute hydrochloric acid is needed in **Test 2**.

(1)

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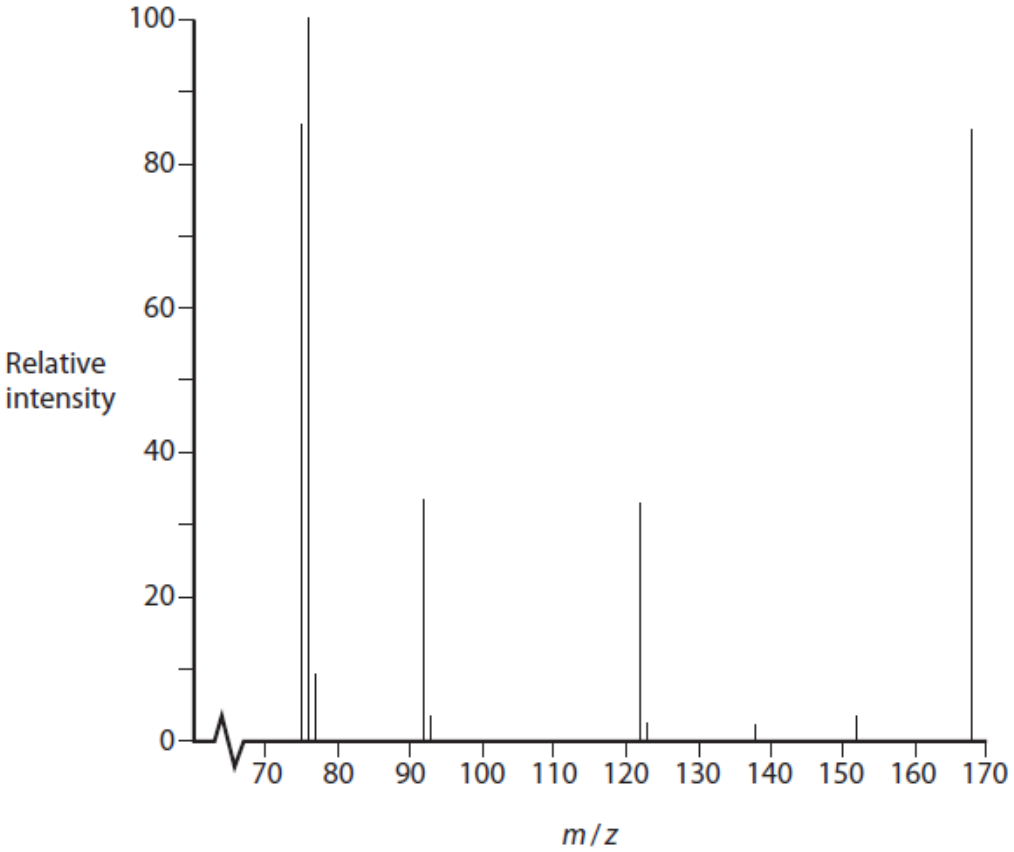
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(Total for question = 6 marks)

Q14.

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

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



Deduce the molecular formula of **D**. Justify your answer.

(2)

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(Total for question = 2 marks)

Q15.

Compound **C** is a pink crystalline solid containing two cations and one anion.

Three tests were carried out on **C**. The observation made for each test was recorded in the table.

(i) Complete the statements in the inference column by writing the names or formulae of the

species.

(6)

Test	Observation	Inference
Test 1 Aqueous sodium hydroxide was added to solid **C** and the mixture warmed The gas evolved was tested with damp red litmus paper	 The red litmus paper turned blue	The gas evolved was ..... One of the cations in **C** is .....
Test 2 Concentrated hydrochloric acid was added to an aqueous solution of **C**	The pink solution turned blue	The other cation in **C** is ..... The formula of the complex ion in the blue solution is .....
Test 3 Dilute hydrochloric acid and aqueous barium chloride were added to an aqueous solution of **C**	A white precipitate formed	The white precipitate is ..... The anion in **C** is .....

(ii) Use the results of the tests in (i) to give a formula of **C**.

Do not include water of crystallisation.

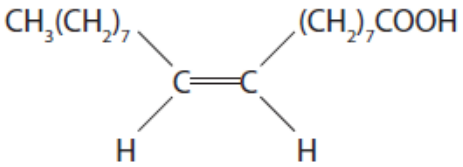
(1)

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(Total for question = 7 marks)

Q16.

The formula for oleic acid, which is present in fingerprints, is shown below.



(a) The systematic name for oleic acid is

(1)

- ☒ **A** *E*-octadec-9-enoic acid.
- ☒ **B** *Z*-octadec-9-enoic acid.
- ☒ **C** *E*-octadec-8-enoic acid.
- ☒ **D** *Z*-octadec-8-enoic acid.

(b) Which intermolecular forces are present between oleic acid molecules?

(1)

- ☒ **A** Hydrogen bonds only.
- ☒ **B** Hydrogen bonds and permanent dipole-dipole forces only.
- ☒ **C** Hydrogen bonds, permanent dipole-dipole forces and London forces.
- ☒ **D** Hydrogen bonds and London forces only.

(c) Which of the following species is most likely to cause a peak at *m/e* = 45 in the mass spectrum of oleic acid?

(1)

- ☒ **A** CH_2CH_2OH
- ☒ **B** $CH_2CH_2OH^+$
- ☒ **C** COOH
- ☒ **D** $COOH^+$

(d) What would you expect to see if oleic acid is tested separately with bromine water and with phosphorus(V) chloride, PCl_5?

(1)

	Bromine water	Phosphorus(V) chloride, PCl_5
☐ **A**	Decolorises	Steamy fumes
☐ **B**	No colour change	No visible change
☐ **C**	Decolorises	No visible change
☐ **D**	No colour change	Steamy fumes

(Total for question = 4 marks)

Q17.

Aqueous sodium carbonate and aqueous sodium sulfate are both colourless solutions.

Give the reagent and the observation to show the presence of carbonate ions.

(2)

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(Total for question = 2 marks)

Q18.

Aqueous sodium carbonate and aqueous sodium sulfate are both colourless solutions.

Give the reagent and the observation to show the presence of sulfate ions.

(2)

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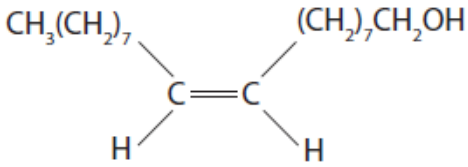
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(Total for question = 2 marks)

Q19.

The formula for oleyl alcohol, which is present in sperm whale oil and was used as a lubricant, is shown below.



(a) The systematic name for oleyl alcohol is

(1)

☒ **A** *E*-octadec-9-en-1-ol.

☒ **B** *Z*-octadec-9-en-1-ol.

☒ **C** *E*-octadec-8-en-1-ol.

☒ **D** *Z*-octadec-8-en-1-ol.

(b) Which intermolecular forces are present between oleyl alcohol molecules?

(1)

☒ **A** London forces only

☒ **B** Hydrogen bonds and London forces only

☒ **C** Hydrogen bonds and permanent dipole–dipole forces only

☒ **D** Hydrogen bonds, permanent dipole–dipole and London forces

(c) Which of the following is the most likely structure of the species to cause a peak at *m/e* 31 in the mass spectrum of oleyl alcohol?

(1)

☒ **A** CH_3O

☒ **B** CH_2OH

☒ **C** CH_3O^+

☒ **D** CH_2OH^+

(d) What would you expect to see if oleyl alcohol is tested separately with bromine water and heated with acidified sodium dichromate(VI) solution?

(1)

	Bromine water	Acidified sodium dichromate(VI) solution
☒ **A**	Decolorises	Turns green
☒ **B**	No colour change	No colour change
☒ **C**	Decolorises	No colour change
☒ **D**	No colour change	Turns green

(Total for question = 4 marks)

Q20.

Tests are carried out on aqueous solutions of two salts, **X** and **Y**.

Y contains one cation and one anion.

The observations for each test are recorded in the table.

(i) Complete the table by writing the names or formulae of the species.

(2)

Test	Observation	Inference
Test 3 Add dilute aqueous ammonia to an aqueous solution of **Y** until it is present in excess	A pale blue precipitate forms The precipitate dissolves in excess ammonia to form a deep blue solution	The cation in **Y** is .....
Test 4 To an aqueous solution of **Y**, add dilute nitric acid followed by aqueous silver nitrate	A white precipitate forms	The anion in **Y** is .....

(ii) Give the formula of the complex ion present in the deep blue solution at the end of **Test 3**.

(1)

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(iii) Give a reagent that could be added to the mixture at the end of **Test 4** to confirm the identity of the anion in **Y**.

Include the observation when this reagent is added.

(2)

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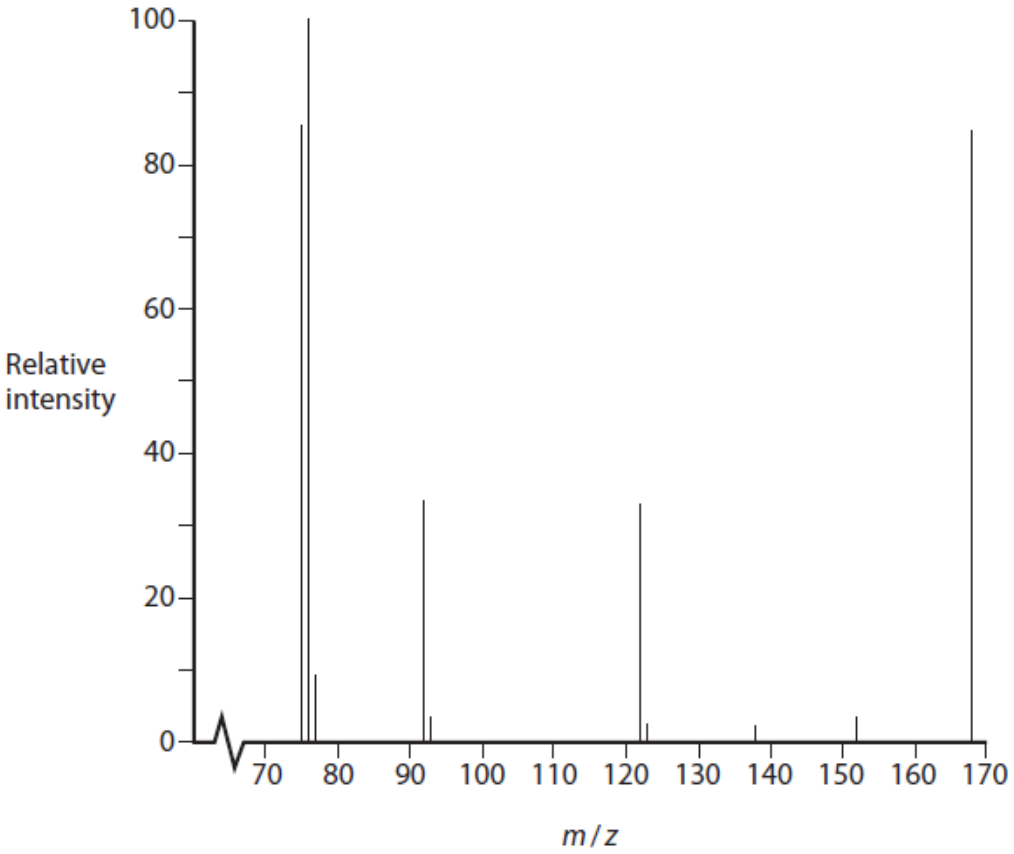
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(Total for question = 5 marks)

Q21.

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)

Q22.

Brass is an alloy of copper and zinc.

A sample of brass was weighed on a balance, reading to two decimal places. The mass of the sample was recorded as 5.00 g.

This sample of brass was reacted with excess concentrated nitric acid and the resulting solution was made up to 250 ^{3} in a volumetric flask using distilled water.

25.0 cm^3 portions were taken from this solution using a pipette. Each portion was neutralised by adding sodium carbonate solution; and excess potassium iodide solution was then added. The liberated iodine was titrated with 0.250 mol dm^{-3} sodium thiosulfate solution, using a freshly prepared solution of starch as indicator.

The mean titre was 22.70 cm^3.

(i) Use the equation for the reaction to give two observations when nitric acid reacts with copper.

$$Cu(s) + 2NO_3^-(aq) + 4H^+(aq) \rightarrow Cu^{2+}(aq) + 2NO_2(g) + 2H_2O(l)$$

(2)

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(ii) Complete the equation for the reaction between iodine and thiosulfate ions. Include state symbols.

(1)

$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow$

(iii) Copper(II) ions react with iodide ions to form iodine.

$$2Cu^{2+}(aq) + 4I^-(aq) \rightarrow 2CuI(s) + I_2(aq)$$

Calculate the percentage by mass of copper in the brass. Give your answer to an appropriate number of significant figures.

(5)

(iv) A student wants to identify the piece of apparatus that contributes most to measurement uncertainties in this experiment, so that the procedure can be modified.

The percentage measurement uncertainty is marked on the pipette as ±0.24%, and on the volumetric flask as ±0.08%.

By using appropriate calculations for the other apparatus used, deduce the **most** significant source of measurement uncertainty in this procedure.

(2)

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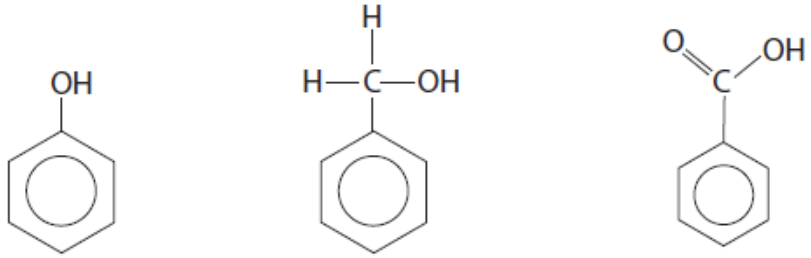
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Q23.

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)

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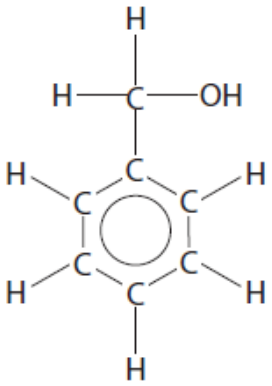
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(ii) Predict the number of peaks present, and their chemical shifts, in the ^{13}C nuclear magnetic resonance (NMR) spectrum of
phenylmethanol.
Use the information in the Data Booklet to help you.

(3)



phenylmethanol

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(iii) Give the formula of a fragment ion, with its *m*/*z* value, that you would expect to be present in the mass spectrum of
benzoic acid but **not** in the mass spectrum of phenol or the mass spectrum of phenylmethanol.

(2)

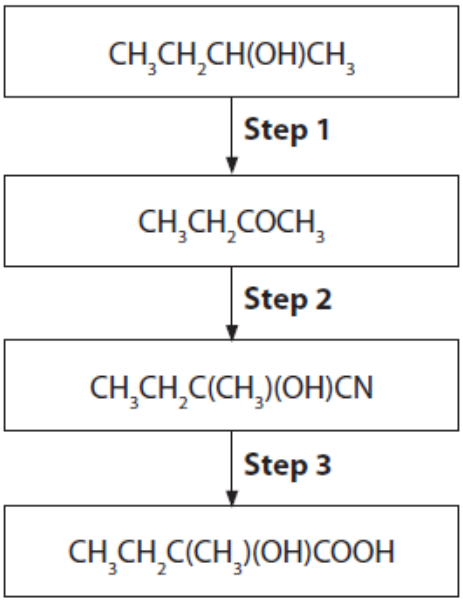
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(Total for question = 10 marks)

Q24.

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)

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(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 $H_3C-\overset{\overset{O}{\|}}{C}-$ group.

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

(4)

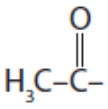
Carbonyl group

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 group

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(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)

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

(1)

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

(1)

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