EXAM PAPERS PRACTICE

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Level: CIE AS and A Level (9701)
Subject: Chemistry
Topic: CIE Chemistry
Type: Topic Question

Chemistry CIE AS & A Level
To be used for all exam preparation for 2025+

CHEMISTRY AS and A

This to be used by all students studying CIE AS and A level Chemistry (9701) But students of other boards may find it useful

Question 1.

(a) This question is about the spectroscopy of benzene and some of its methylated derivatives.

Benzene is analysed using carbon-13 NMR spectroscopy.

Suggest why benzene has only one peak in its spectrum.

_____

(1 mark)

(b) The displayed formula of methylbenzene is shown in Fig. 1.1.

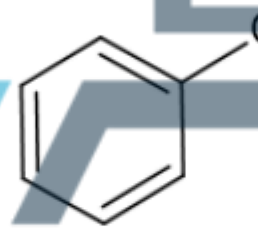


Fig. 1.1

State the number of peaks that would appear in the low resolution ^{1}H NMR spectrum of methylbenzene.

_____

(1 mark)

(c) There are three isomers of dimethylbenzene shown in Fig. 1.2:

- 1,2-dimethylbenzene
- 1,3-dimethylbenzene
- 1,4-dimethylbenzene

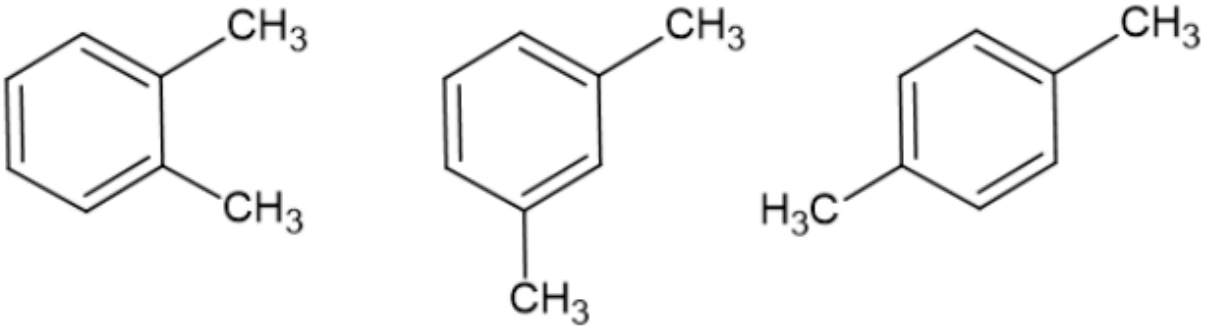


Fig. 1.2

Complete Table 1.1 to show the number of expected peaks in the low resolution ^{1}H NMR and ^{13}C NMR spectra of the three dimethylbenzene isomers.

Table 1.1

Isomer	Number of peaks in ^{1}H NMR spectrum	Number of peaks in ^{13}C NMR spectrum
1,2-dimethylbenzene		
1,3-dimethylbenzene		
1,4-dimethylbenzene		

(3 marks)

Question 2.

(a) During the production of an NMR spectrum, tetramethylsilane (TMS) is mixed with the sample.

i) Give the structural formula of the standard reference chemical used for ^{1}H NMR spectroscopy.

[1]

ii) Explain why tetramethylsilane is used as the standard reference chemical.

[2]

(3 marks)

(b) State the number of peaks in the C-13 NMR spectrum of 1,3-dichlorobenzene.

(1 mark)

(c) i) Predict the number of peaks in the ^{13}C NMR spectrum of ethylbenzene, shown in Fig. 1.1.

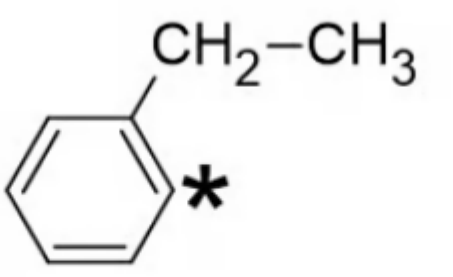


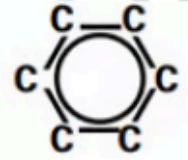
Fig. 1.1

[1]

ii) The data in Table 1.1 should be used in answering this question.

One of the carbon atoms in the structure of ethylbenzene shown in Fig. 1.1 is labelled with an asterisk (*). Suggest a C-13 chemical shift range for this carbon environment.

Table 1.1

Hybridisation of the carbon atom	Environment of carbon atom	Example	Chemical shift range δ/ppm
sp^3	alkyl	**C**H_3–, **C**H_2–, –**C**H<, >**C**<	0 – 50
sp^3	next to alkene / arene	–**C**–C=C, –**C**–Ar	25 – 50
sp^3	next to carbonyl / carboxyl	**C**–COR, **C**–O_2R	30 – 65
sp^3	next to halogen	**C**–X	30 – 60
sp^3	next to oxygen	**C**–O	50 – 70
sp^2	alkene or arene	>**C**=**C**<, 	110 – 160
sp^2	carboxyl	R–**C**OOH, R–**C**OOR	160 – 185
sp^2	carbonyl	R–**C**HO, R–**C**O–R	190 – 220
sp	nitrile	R–**C**≡N	100 – 125

[1]

(2 marks)

Question 3.

(a) Compound **A** contains the elements carbon and hydrogen forming an aromatic ring along with the elements oxygen and nitrogen.

Part of the mass spectrum of **A** is shown in Fig. 2.2.

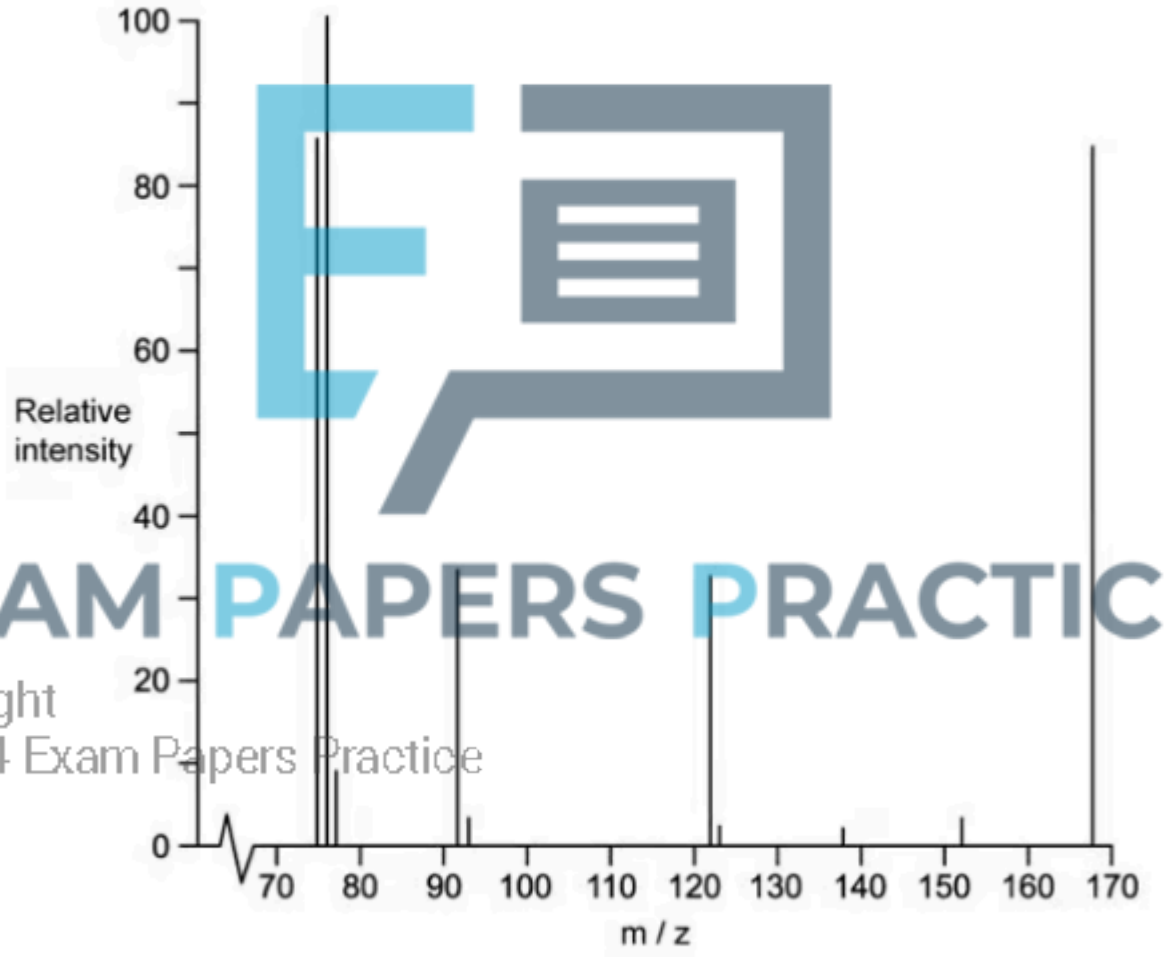


Fig. 2.2

Give the identity of the molecular ion that gives rise to the peak at $m / e = 76$ in Fig. 2.2.

_____

(1 mark)

(b) Suggest the structures of the **three** possible dinitrobenzene isomers of **A** that contain a benzene ring.

(3 marks)

(c) The C-13 NMR spectrum of compound **A** has four peaks.

Identify the structure of **A**. Explain your reasoning by labelling the different carbon environments in **all** the structures drawn in part **(ii)**.

(1 mark)

Question 4.

(a) An unknown alcohol was analysed and found to contain 64.9% carbon, 13.5% hydrogen and the rest oxygen.

The results of mass spectrometry found the mass of the alcohol to be 74.12 g mol^{-1}.

Determine the molecular formula of the unknown alcohol. Show your working.

(4 marks)

(b) The unknown alcohol can exist as four possible isomers.

i) Using your answer to part **(a)**, sketch the four possible isomers of the unknown alcohol.

[4]

ii) For each isomer, deduce the number of chemical peaks expected in the ^{13}C spectrum.

[2]

(6 marks)

(c) The ^{13}C NMR spectra of one of the isomers is shown in **Fig. 3.1**.

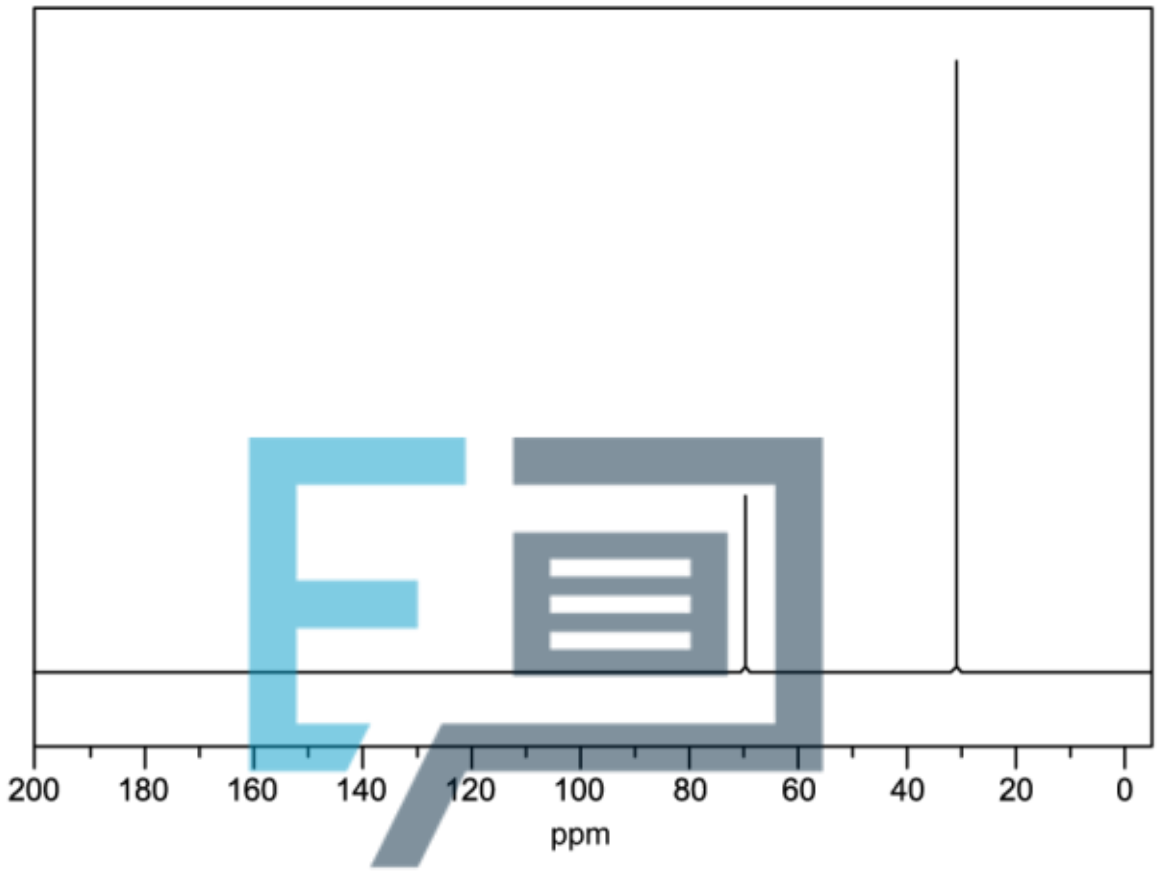


Fig. 3.1

Deduce which isomer produced the spectrum shown in **Fig. 3.1**. Explain your answer with reference to Table 3.1.

Table 3.1

Hybridisation of the carbon atom	Environment of carbon atom	Example	Chemical shift range δ/ppm
sp^3	alkyl	**C**H_3–, **C**H_2–, –**C**H<, >**C**<	0 – 50
sp^3	next to alkene / arene	–**C**–C=C, –**C**–Ar	25 – 50
sp^3	next to carbonyl / carboxyl	**C**–COR, **C**–O_2R	30 – 65
sp^3	next to halogen	**C**–X	30 – 60
sp^3	next to oxygen	**C**–O	50 – 70
sp^2	alkene or arene	>C=**C**<, 	110 – 160
sp^2	carboxyl	R–**C**OOH, R–**C**OOR	160 – 185
sp^2	carbonyl	R–**C**HO, R–**C**O–R	190 – 220
sp	nitrile	R–**C**≡N	100 – 125

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(3 marks)

Question 5.

(a) Three hydrocarbons, **L**, **M** and **N**, have the molecular formula C_8H_{10}. Information about the number of peaks seen in the carbon-13 (^{13}C) NMR spectrum of the three isomers is shown in Table 1.1.

Table 1.1

	Number of peaks
L	3
M	5
N	4

Suggest structures for compounds **L**, **M** and **N**.

L	**M**	**N**

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.....

(3 marks)

(b) Complete Table 1.1 to give details of the proton NMR spectra for isomers **L**, **M** and **N**.

Table 1.1

	Number of peaks	Relative Peak area
L		
M		
N		

(3 marks)

(c) Explain which of the three isomers, **L**, **M** or **N** has the highest melting point.

(2 marks)

Question 6.

(a) A chemist analyses a naturally occurring compound, **K**.

The percentage composition by mass is carbon 70.58%; hydrogen 5.92% and oxygen 23.50%.

The mass spectrum of the compound is shown in Fig. 5.1.

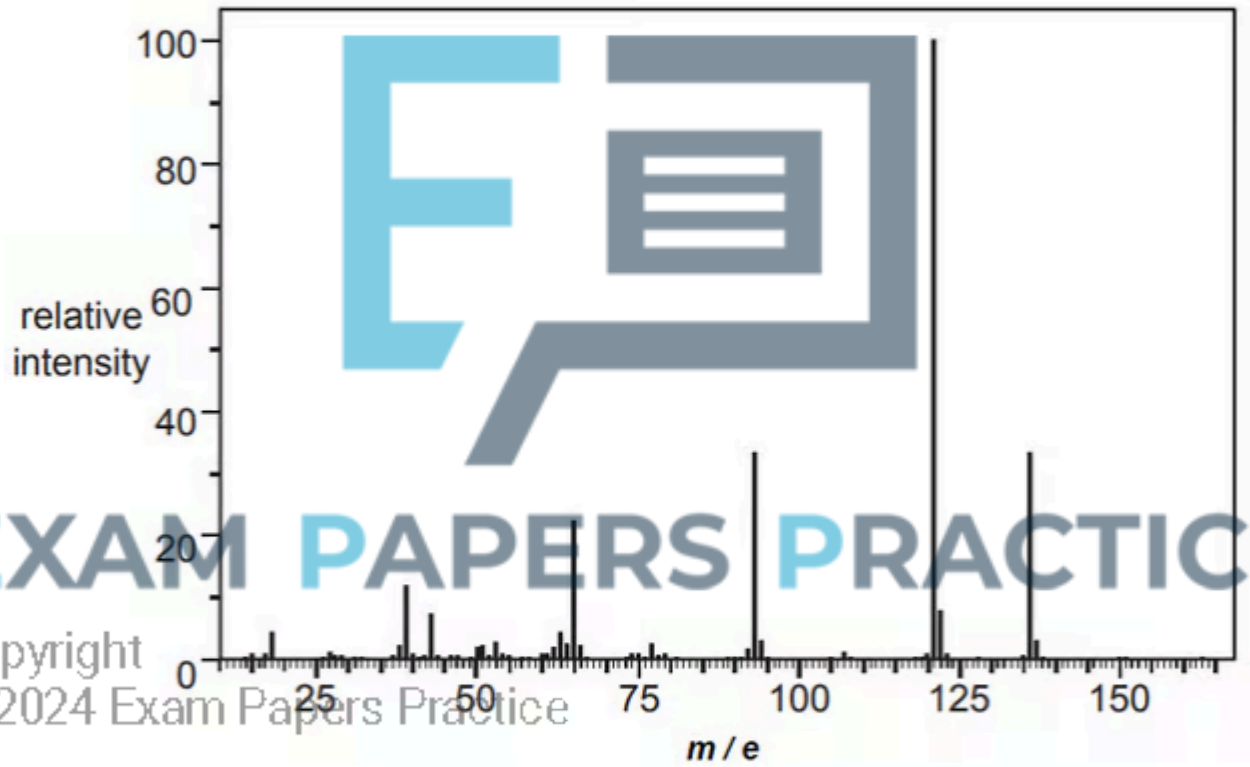


Fig. 5.1

Determine the molecular formula of the compound **K**. Show your working.

(3 marks)

(b) The results of qualitative tests performed on compound **K** are shown in Table 5.1.

Table 5.1

Test	Acidity	Na_2CO_3 (aq)	2,4-DNPH	Tollens' reagent
Observation	pH 5.0	No reaction	Orange precipitate	No reaction

Identify the functional groups present in compound **K**. Explain your answer.

(2 marks)

(c) The carbon-13 (^{13}C) NMR of compound **K** is shown in Fig. 5.2.

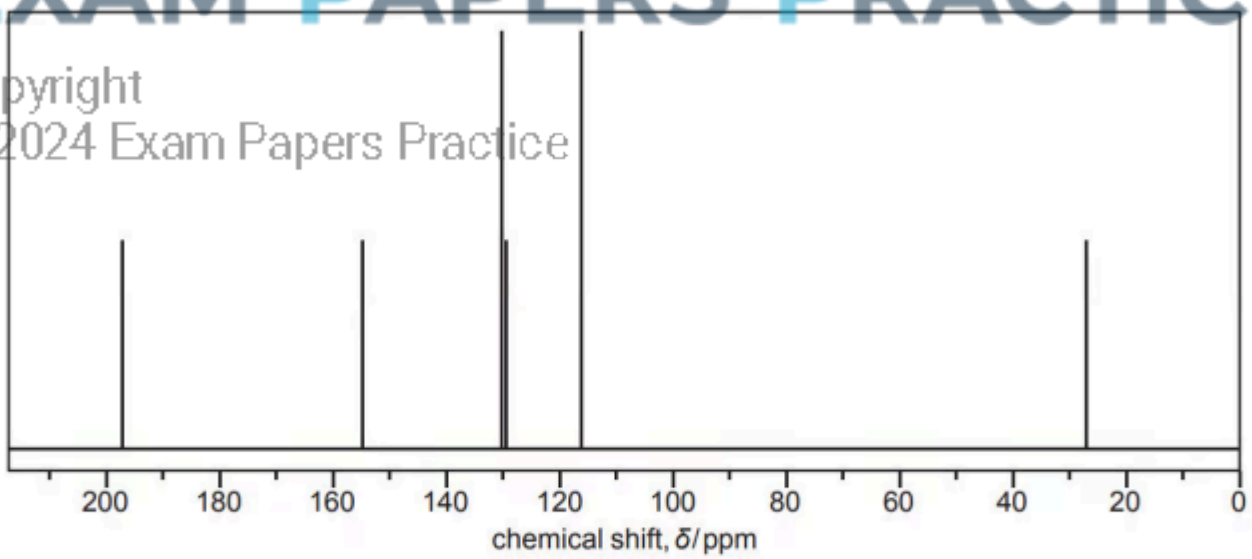
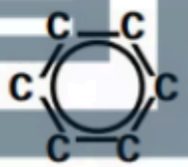


Fig. 5.2

Table 5.1

Hybridisation of the carbon atom	Environment of carbon atom	Example	Chemical shift range δ / ppm
sp^3	alkyl	**C**H_3–, **C**H_2–, –**C**H<, >**C**<	0 – 50
sp^3	next to alkene / arene	–**C**–C=C, –**C**–Ar	25 – 50
sp^3	next to carbonyl / carboxyl	**C**–COR, **C**–O_2R	30 – 65
sp^3	next to halogen	**C**–X	30 – 60
sp^3	next to oxygen	**C**–O	50 – 70
sp^2	alkene or arene	>**C**=**C**<, 	110 – 160
sp^2	carboxyl	R–**C**OOH, R–**C**OOR	160 – 185
sp^2	carbonyl	R–**C**HO, R–**C**O–R	190 – 220
sp	nitrile	R–**C**≡N	100 – 125

Suggest the structure of compound **K** using your answers to **(a)** and **(b)** along with information from Fig. 5.2 and Table 5.1. Explain your answer.

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(3 marks)