Please keep your worksheet duration under the maximum of 180 minutes

CHEMISTRY

Stage 6

Module 8: Applying Chemical Ideas

Organic Substances

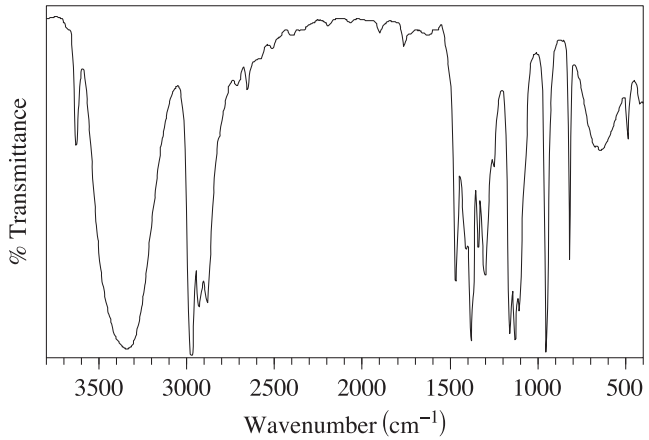
Teacher: Samantha Wong

Exam Equivalent Time: 201 minutes *(based on allocation of 1.5 minutes per mark)*

Questions

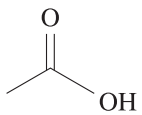
1. CHEMISTRY, M8 2024 HSC 4 MC

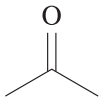
An infrared spectrum of an organic compound is shown.

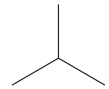


Which of the following compounds would produce the spectrum shown?

A. 

B. 

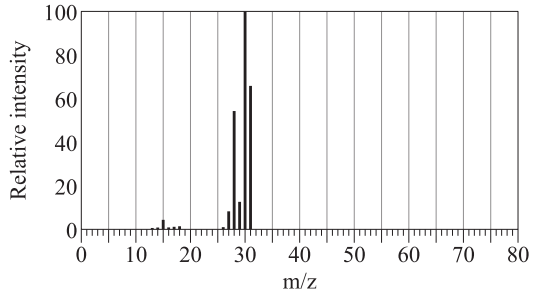
C. 

D. 

2. CHEMISTRY, M8 2024 HSC 9 MC

Which of the following is the mass spectrum of ethanamine?

A.



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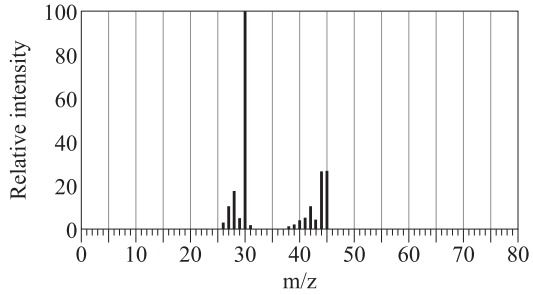
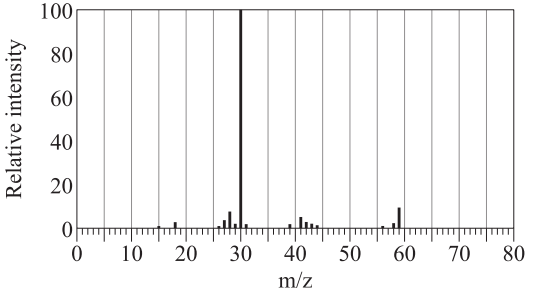
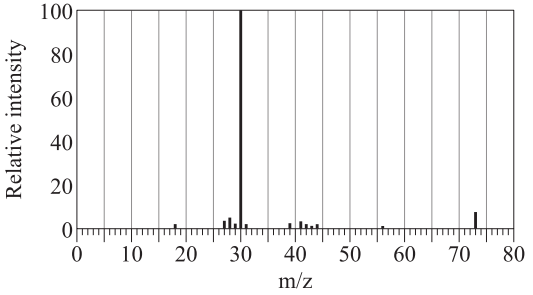


C.

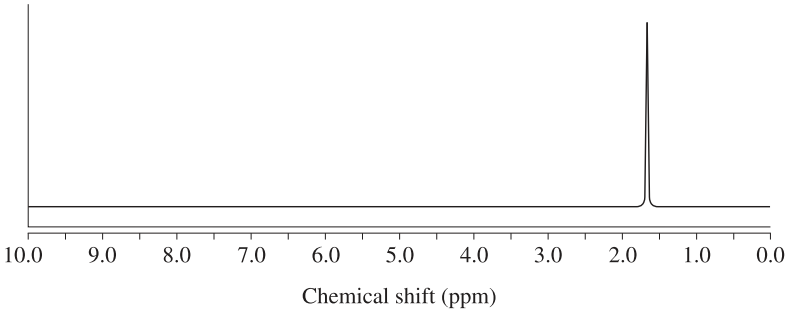


D.

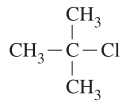


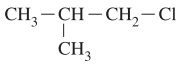
3. CHEMISTRY, M8 2019 HSC 14 MC

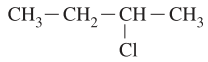
A molecule, C_4H_9Cl, is analysed. The ^1H NMR spectrum of this molecule is shown.



What is the structural formula of this molecule?

A. 

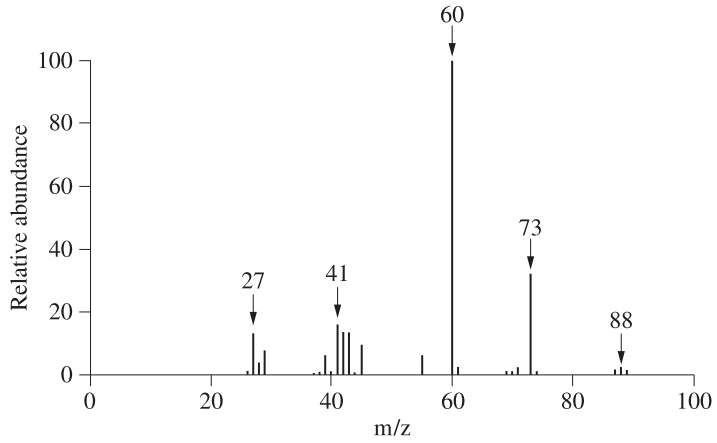
B. 

C. 

D. $CH_3-CH_2-CH_2-CH_2-Cl$

4. CHEMISTRY, M8 2019 HSC 4 MC

The diagram shows the mass spectrum of an organic compound.



Which compound was analysed?

A. Butan-1-amine

B. Butanoic acid

C. Ethanoic acid

D. Iron(II) sulfide

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5. CHEMISTRY, M8 2020 HSC 1 MC

What is the function of the magnetic field in a mass spectrometer?

A. It detects the mass of the particles.

B. It deflects the stream of charged particles.

C. It excites electrons to higher energy levels.

D. It produces a stream of electrons that bombards the sample.

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6. CHEMISTRY, M8 2020 HSC 4 MC

Which pair of compounds would be difficult to distinguish using infrared spectroscopy?

A. Butane and propane

B. Ethane and propan-1-ol

C. Propanol and propanoic acid

D. Methanamine and propanone

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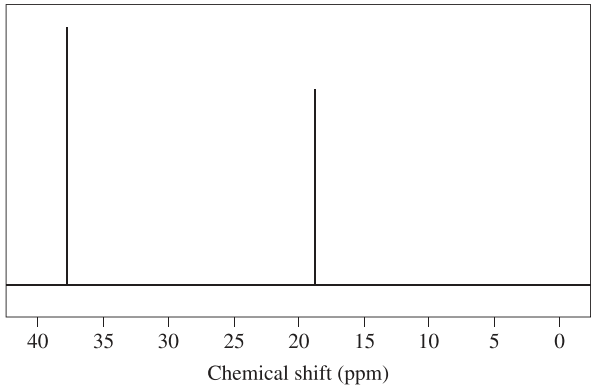
7. CHEMISTRY, M8 2020 HSC 5 MC

A ^{13}C NMR spectrum is shown.



Which compound gives rise to this spectrum?

A. chloroethane

B. 1-chloropropane

C. 1, 2-dichloroethane

D. 1, 2-dichloropropane

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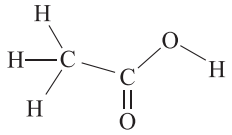
8. CHEMISTRY, M8 2021 VCE 11 MC

The spectroscopy information for an organic molecule is given below.

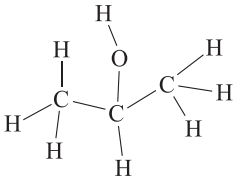
number of peaks in ^{13}C NMR	2
number of sets of peaks in ^{1}H NMR	3
m/z of the last peak in the mass spectrum	60
infra-red (IR) spectrum	an absorption peak appears at 3350 cm^{-1}

The organic molecule is

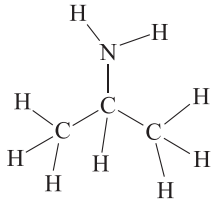
A.



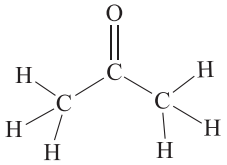
B.



C.

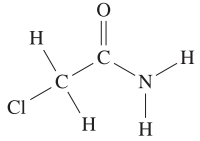


D.



9. CHEMISTRY, M8 2020 HSC 15 MC

The structure of chloroacetamide is shown.



The common isotopes of chlorine are ^{35}Cl and ^{37}Cl.

The mass spectrum of chloroacetamide contains a peak at m/z = 51.

What is the most likely source of this peak?

A. $[OCl]$

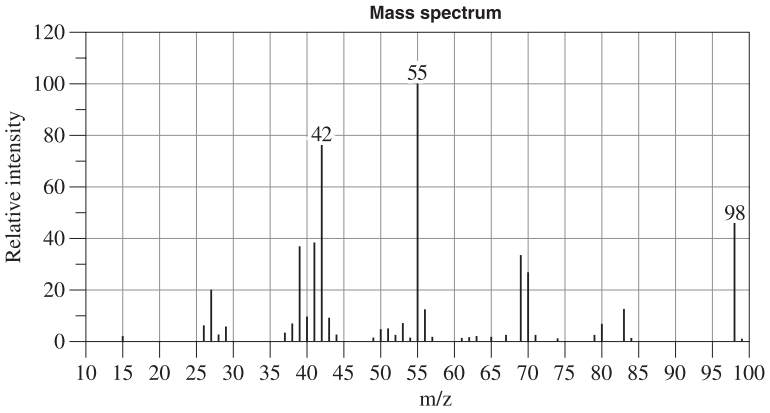
B. $[NH_2]^+$

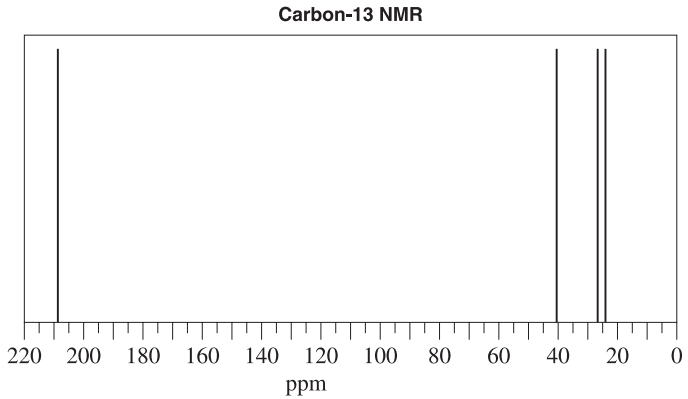
C. $[C_4H_3]^+$

D. $[CH_2Cl]^+$

10. CHEMISTRY, M8 2021 HSC 12 MC

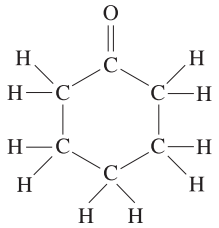
The mass spectrum and carbon-13 NMR for an organic compound are shown.



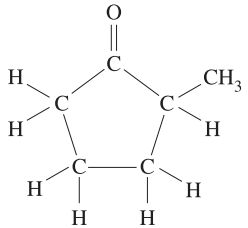


Which compound could produce the two spectra?

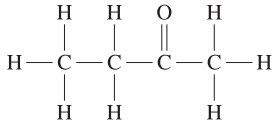
A.



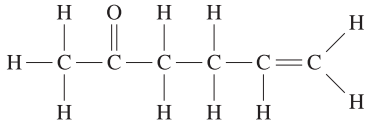
B.



C.



D.



11. CHEMISTRY, M8 2021 HSC 18 MC

The table lists the information from a proton NMR spectrum.

Chemical shift (ppm)	*Multiplicity*	*Number of hydrogens*
1.0	Triplet	3
1.4	Singlet	3
1.8	Quartet	2

Which compound could have produced this spectrum?

A. 1,2,2-trichlorobutane

B. 1,3-dichloro-2-methylpropane

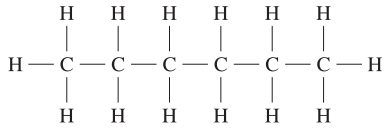
C. 2-chloro-2-methylbutane

D. 2,2-dichlorobutane

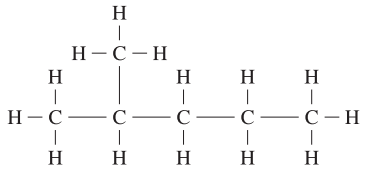
12. CHEMISTRY, M8 2022 HSC 12 MC

Which isomer of C_6H_{14} would have the fewest signals in ^{13}C NMR?

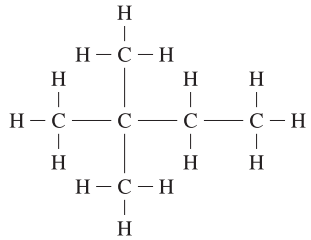
A.



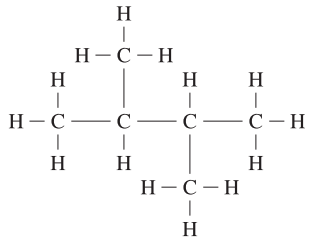
B.



C.

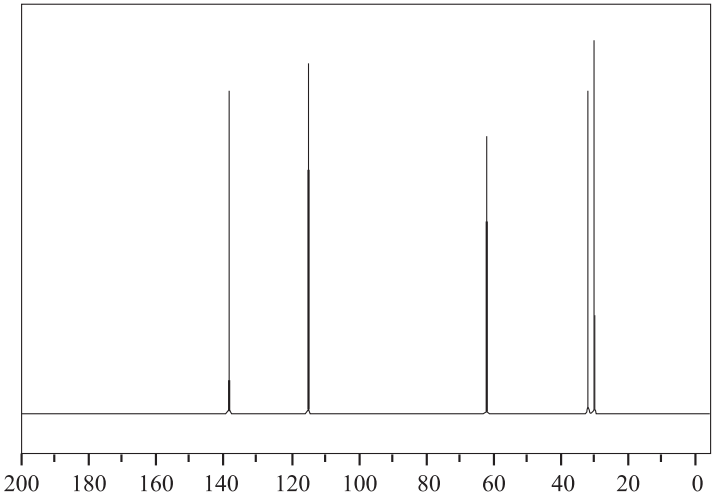


D.



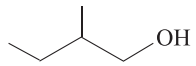
13. CHEMISTRY, M8 2022 VCE 28 MC

The ^{13}C NMR spectrum of an organic compound is shown below.

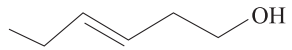


The organic compound could be

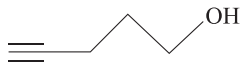
A.



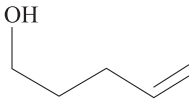
B.



C.

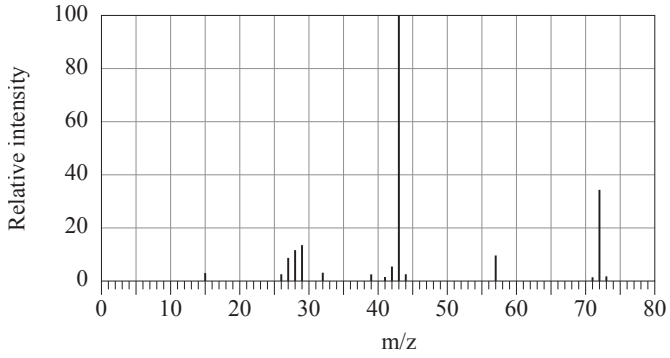


D.



14. CHEMISTRY, M8 2023 HSC 19 MC

The diagram shows a simplified mass spectrum for butan-2-one.



Which equation best represents the process that produces the particle responsible for the peak at m/z 43 ?

A. $CH_3COCH_2CH_3^+ \rightarrow CH_3CO + {}^+CH_2CH_3$

B. $CH_3COCH_2CH_3^+ \rightarrow CH_3CO^+ + CH_2CH_3$

C. $CH_3COCH_2CH_3^+ \rightarrow CH_3CH_2CH_2 + {}^+CHO$

D. $CH_3COCH_2CH_3^+ \rightarrow CH_3CH_2CH_2^+ + CHO$

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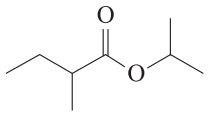
15. CHEMISTRY, M8 2023 VCE 16 MC

Consider the following molecule.



How many peaks will be observed in a ^{13}C NMR spectrum of this molecule

A. 5

B. 6

C. 7

D. 8

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16. CHEMISTRY, M8 2023 VCE 29 MC

Which one of the following statements about mass spectrometry is always correct?

A. The relative molecular mass of a molecule is determined from the base peak.

B. The peaks in a mass spectrum are caused by the presence of different isotopes.

C. The base peak is formed when an uncharged species is removed from the molecule.

D. The height of each peak in the mass spectrum is measured relative to the height of the base peak.

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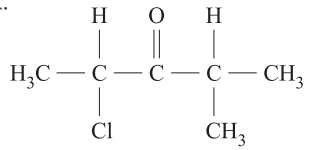
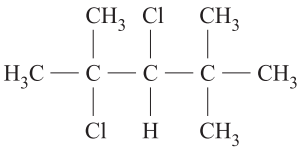
17. CHEMISTRY, M8 2024 HSC 19 MC

Which of the following compounds produces TWO doublets in the ^1H NMR spectrum?

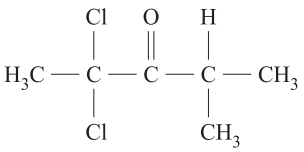
A.



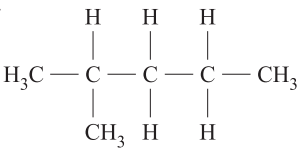
B.



C.



D.



18. CHEMISTRY, M8 2019 HSC 19 MC

Compound X shows three signals in its ^{13}C NMR spectrum.

Treatment of X with hot acidified potassium permanganate produces a compound Y. Compound Y turns blue litmus red.

Compound X produces compound Z upon reaction with hot concentrated sulfuric acid.

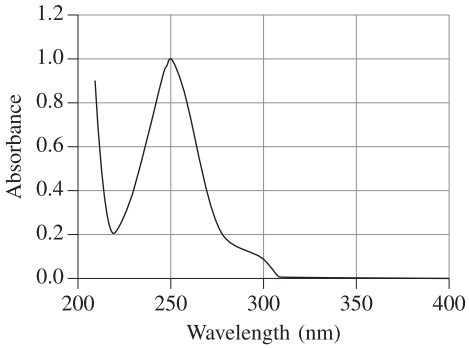
Which of the following correctly identifies compounds X, Y and Z?

	Compound X	*Compound* Y	*Compound* Z
A.	butan-1-ol	butanoic acid	but-1-ene
B.	butan-2-ol	butanone	but-2-ene
C.	methyl ethanoate	methanoic acid	ethene
D.	2-methylpropan-1-ol	2-methylpropanoic acid	2-methylprop-1-ene

19. CHEMISTRY, M8 2021 HSC 9 MC

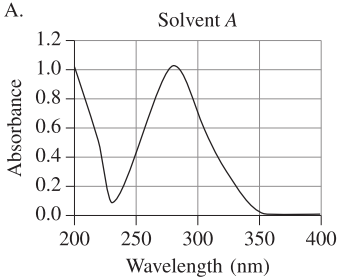
The amount of paracetamol in a sample needs to be determined.

The UV absorption spectrum of paracetamol is shown.

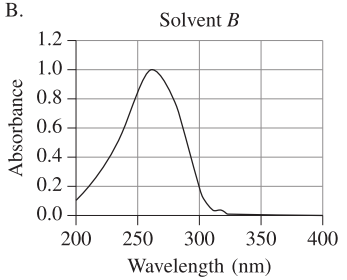


Based on the absorption spectra provided, which solvent should be used to determine the amount of paracetamol?

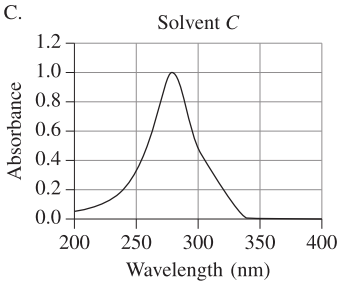
A.



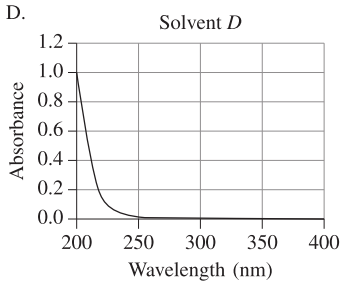
B.



C.



D.



20. CHEMISTRY, M8 2021 VCE 16 MC

Which one of the following statements about IR spectroscopy is correct?

A. IR radiation changes the spin state of electrons.

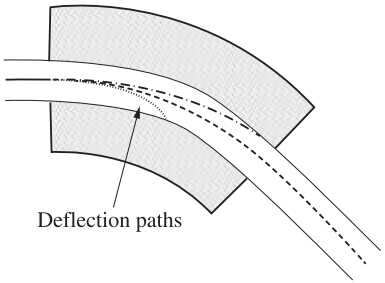
B. Bond wave number is influenced only by bond strength.

C. An IR spectrum can be used to determine the purity of a sample.

D. In an IR spectrum, high transmittance corresponds to high absorption.

21. CHEMISTRY, M8 EQ-Bank 21

The diagram shows the deflection paths of different ions through a mass spectrometer.



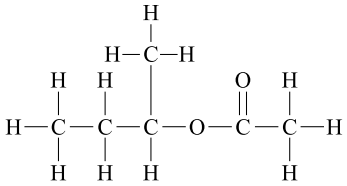
Account for the different deflection paths. *(3 marks)*

22. CHEMISTRY, M8 EQ-Bank 27

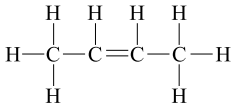
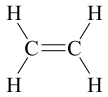
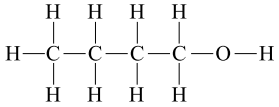
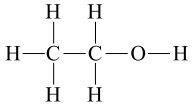
Explain how infrared spectroscopy is used in the analysis and identification of organic substances. *(3 marks)*

23. CHEMISTRY, M7 2015 VCE 5a

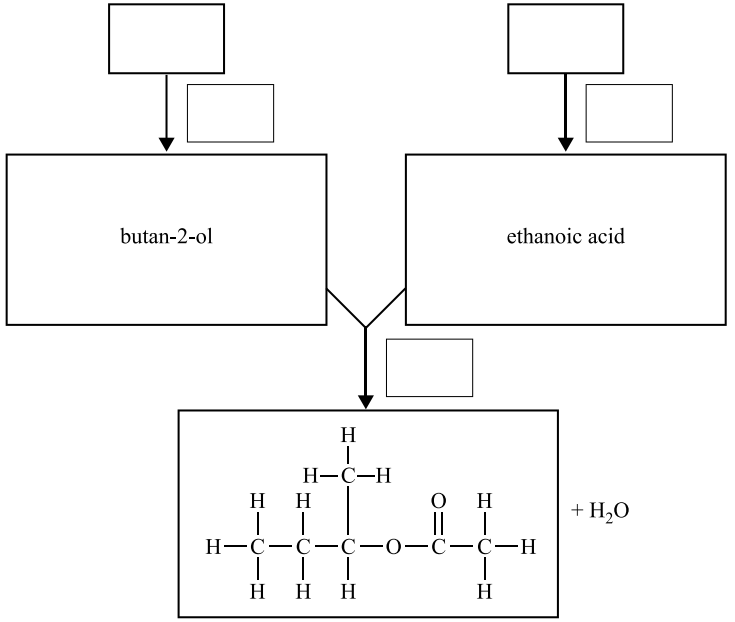
A reaction pathway is designed for the synthesis of the compound that has the structural formula shown below.



The table below gives a list of available organic reactants and reagents.

Letter	Available organic reactants and reagents
A	acidified $KMnO_4$
B	concentrated H_2SO_4
C	H_2O and H_3PO_4
D	
E	
F	
G	

Complete the reaction pathway design flow chart below. Write the corresponding letter for the structural formula of all organic reactants in each of the boxes provided. The corresponding letter for the formula of other necessary reagents should be shown in the boxes next to the arrows. *(5 marks)*



24. CHEMISTRY, M8 2021 HSC 21

Four organic liquids are used in an experiment. The four liquids are

- hexane
- hex-1-ene
- propan-1-ol
- propanoic acid

a. State ONE safety concern associated with organic liquids and suggest ONE way to address this safety concern. ***(2 marks)***

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b. The organic liquids are held separately in four flasks but the flasks are not labelled. Tests were conducted to identify these liquids. The outcomes of the tests are summarised below. ***(2 marks)***

Flask	*Reaction with acidified oxidant* $\left(KMnO_4/H^+\right)$*?*	*Miscible with water?*
1	No	Yes
2	Yes	No
3	Yes	Yes
4	No	No

Identify the FOUR liquids.

Flask	*Liquid*
1	
2	
3	
4	

c. What chemical test, other than those used in part (b), could be used to confirm the identification of ONE of the liquids? Include the expected observation in your answer. ***(2 marks)***

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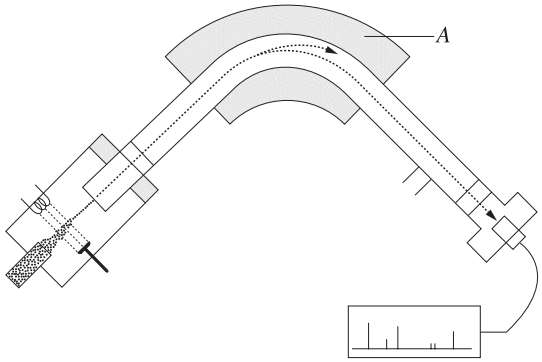
25. CHEMISTRY, M8 EQ-Bank 22

a. The diagram is a schematic representation of a mass spectrometer.

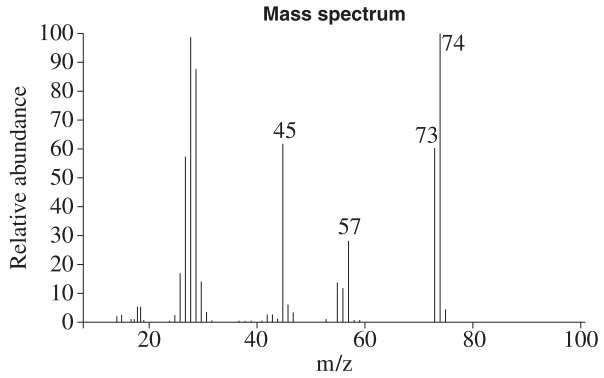


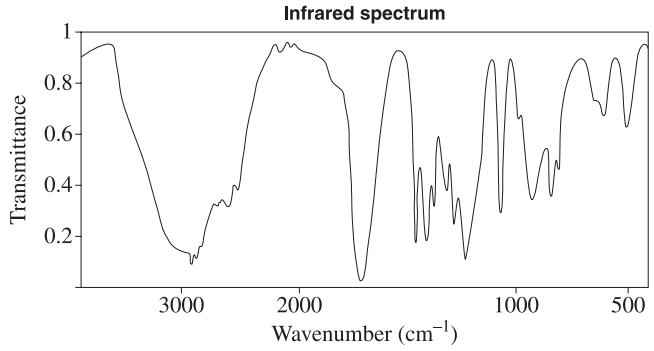
Name and outline the function of the part labelled A in the diagram. ***(2 marks)***

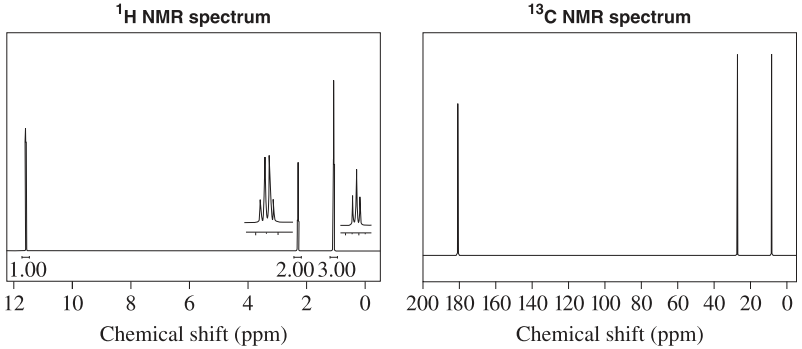
b. Outline the advantages of using mass spectrometry for analysis of a compound. ***(3 marks)***

26. CHEMISTRY, M8 2019 HSC 26a

The following data were obtained for an organic compound containing carbon, hydrogen and oxygen. The compound is a colourless liquid that reacts with sodium carbonate powder to produce bubbles.







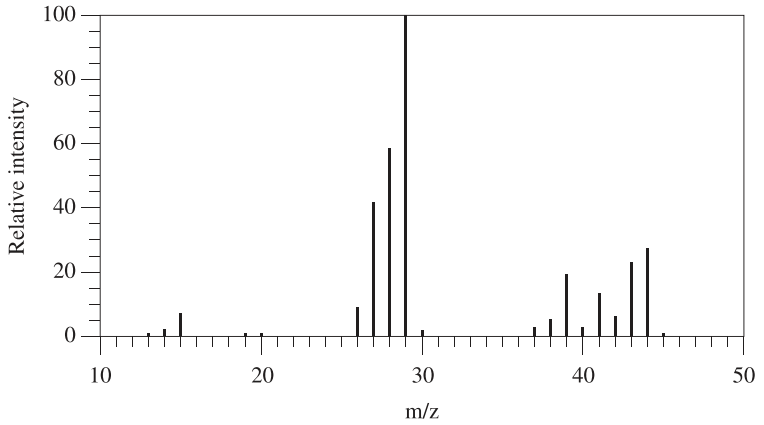
What is the structural formula of this compound? Justify your answer with reference to the information given on its reactivity and to at least THREE of the provided spectra. ***(5 marks)***

27. CHEMISTRY, M8 2019 HSC 26b

Explain why a chemist should use more than one spectroscopic technique to identify an organic compound. Use TWO spectroscopic techniques to support your answer. ***(3 marks)***

28. CHEMISTRY, M8 2020 HSC 21

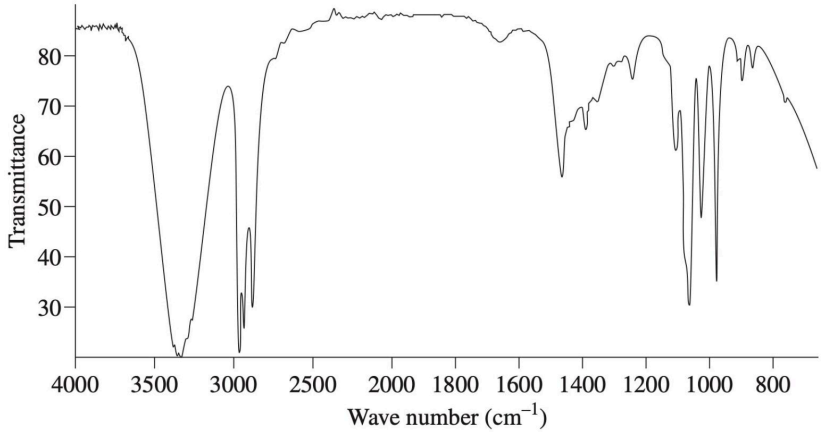
The mass spectrum of an alkane is shown.



Use the information provided to identify the alkane and justify your choice. ***(2 marks)***

29. CHEMISTRY, M8 EQ-Bank 25

The diagram shows the infrared spectrum of a compound.



The molecular weight of the compound analysed is approximately 60 g mol $^{-1}$. Suggest TWO possible compounds that could fit this spectrum and justify your selection. ***(4 marks)***

30. CHEMISTRY, M8 2022 HSC 27

A bottle labelled 'propanol' contains one of two isomers of propanol.

a. Draw the TWO isomers of propanol. *(2 marks)*

b. Describe how $^{13}\mathrm{C}$ NMR spectroscopy might be used to identify which isomer is in the bottle. *(2 marks)*

c. Each isomer produces a different product when oxidised.

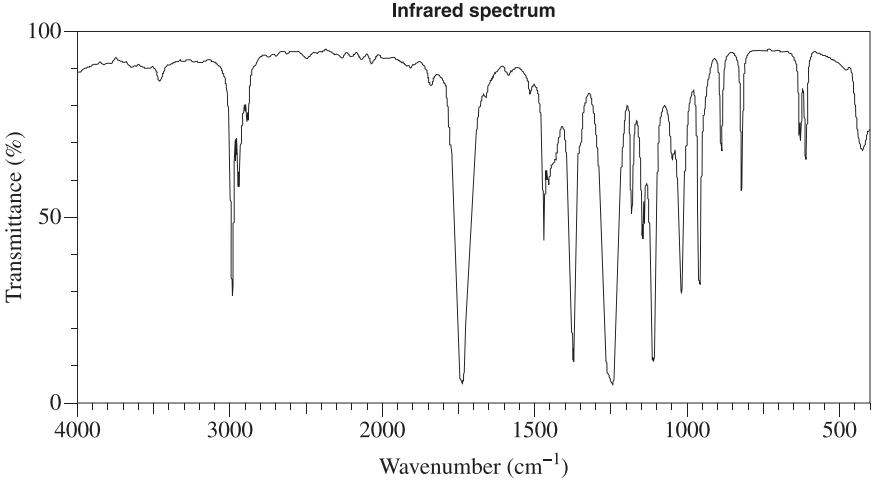
Write equations to represent the oxidation reactions of the two isomers. Include reaction conditions. *(3 marks)*

31. CHEMISTRY, M8 2020 HSC 30

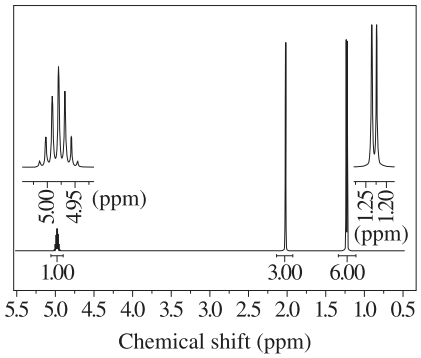
A chemist discovered a bottle simply labelled '$C_5H_{10}O_2$'.

To confirm the molecular structure of the contents of the bottle, a sample was submitted for analysis by infrared spectroscopy and ^1H and ^{13}C NMR spectroscopy. The resulting spectra are shown.

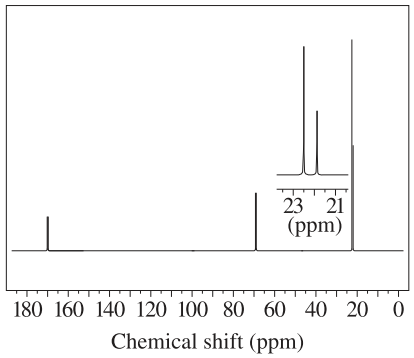
Infrared spectrum



^{1}H NMR spectrum



^{13}C NMR spectrum



Data from ^{1}H NMR spectrum

Chemical shift	*Relative peak area*	*Splitting pattern*
1.2	6	doublet (2)
2.0	3	singlet (1)
5.0	1	septet (7)

^{1}H NMR chemical shift data

Type of proton		δ/ppm
$Si(\mathbf{C}H_3)_4$	(TMS)	0
R—$\mathbf{C}H_3$		0.7–1.3
R—$\mathbf{C}H_2$—R		1.2–1.5
R—$\mathbf{C}HR_2$		1.5–2.0
$\mathbf{H}_3$C—CO—	(aldehydes, ketones or esters)	2.0–2.5
—$\mathbf{C}H$—CO—	(aldehydes, ketones or esters)	2.1–2.6
$\mathbf{H}_3$C—O—	(alcohols or esters)	3.2–4.0
—$\mathbf{C}H$—O—	(alcohols or esters)	3.3–5.1
R_2—$\mathbf{C}H_2$—O—	(alcohols or esters)	3.5–5.0
R—O**H**		1–6
R_2C=$\mathbf{C}H$R	(alkene)	4.5–7.0
R—$\mathbf{C}H$O	(aldehyde)	9.4–10.0
R—COO**H**		9.0–13.0

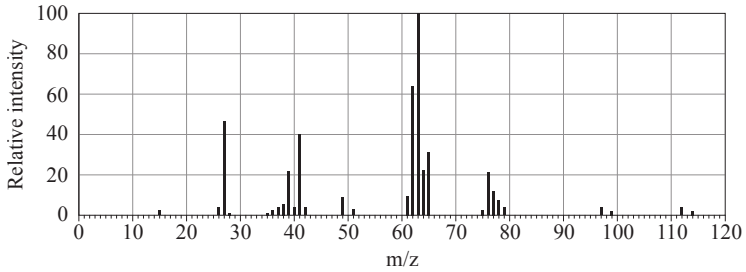
Draw a structural formula for the unknown compound that is consistent with all of the information provided. Justify your answer with reference to the information provided. ***(7 marks)***

32. CHEMISTRY, M8 2023 HSC 28

Alkene Q undergoes an addition reaction with chlorine gas to form compound R.

a. Describe a chemical test that could be done in a school laboratory to confirm that Q is an alkene. Include expected observations in your answer. ***(2 marks)***

b. Compound R was analysed and found to contain approximately 32% carbon by mass. The mass spectrum of compound R is shown.

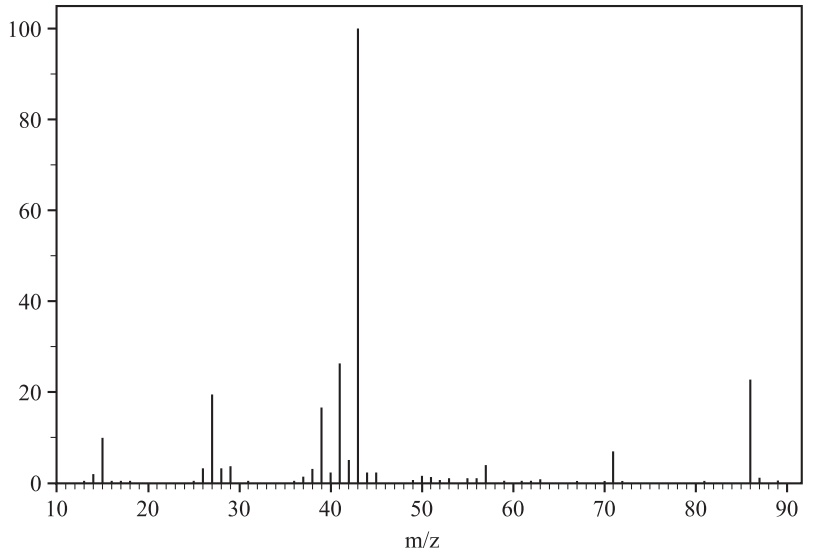


Provide a structural formula for compound R. Support your answer with calculations. ***(3 marks)***

33. CHEMISTRY, M8 2023 VCE 7-1*

Molecule V contains only carbon atoms, hydrogen atoms and one oxygen atom.

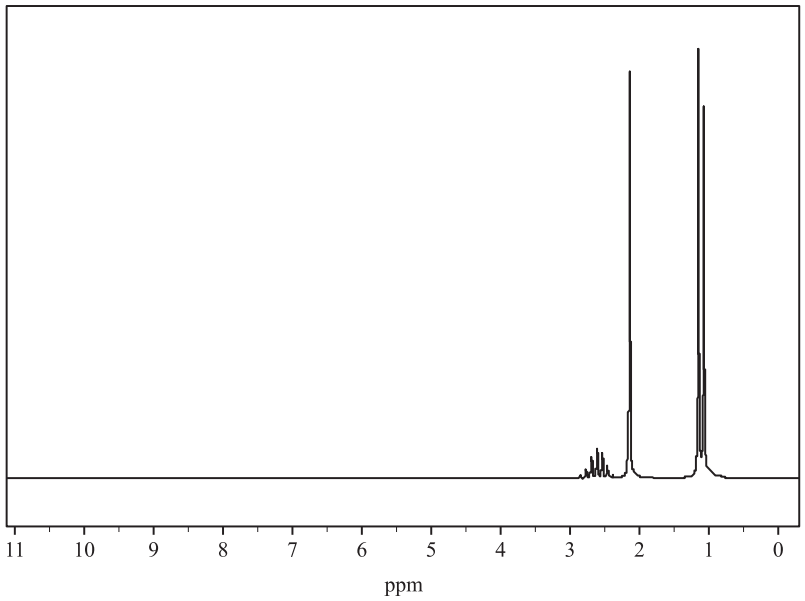
The mass spectrum of molecule V is shown below.



a. **i.** State the molecular formula of molecule V. Justify your answer by using the information in the mass spectrum. ***(2 marks)***

ii. State why there is a small peak at $m/z = 87$. ***(1 mark)***

The ^{1}H NMR spectrum of molecule V is shown below.



b. State what information the doublet at 1.1 ppm provides about the structure of the molecule. *(1 mark)*

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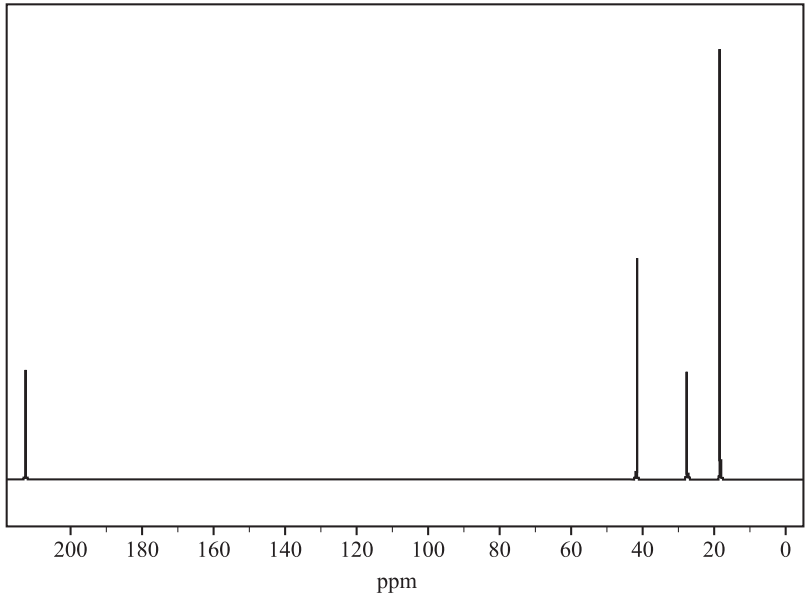
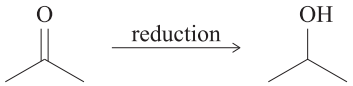
The ^{13}C NMR spectrum of molecule V is shown below.



c. In the space below, draw a structural formula of molecule V that is consistent with the information provided in parts a.-c. *(3 marks)*

34. CHEMISTRY, M8 2024 HSC 33

Acetone can be reduced, as shown.

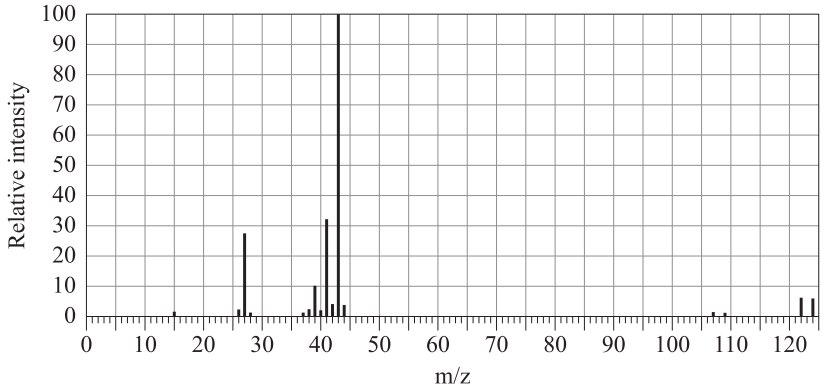


a. Identify the shape around the central carbon atom in each molecule. ***(2 marks)***

b. Explain how $^{13}\mathrm{C}$ NMR spectroscopy could be used to monitor the progress of this reaction. ***(3 marks)***

35. CHEMISTRY, M8 2024 HSC 38

Compounds A and B are isomers with formula C_3H_7X, where X is a halogen. The mass spectrum for compound A is shown.



Compounds A and B undergo substitution reactions in the presence of hydroxide ions, producing alcohols C and D. Compound D can be oxidised to a ketone; compound C can also be oxidised, but does not produce a ketone.

$$\text{A} \xrightarrow{OH^-} \text{C}$$

$$\text{B} \xrightarrow{OH^-} \text{D} \xrightarrow{\text{oxidation}} \text{ketone}$$

Compound E can be produced by refluxing 3-methylbutanoic acid, with one of the alcohols C or D, in the presence of a catalyst.

The ^{1}H NMR spectrum for compound E contains the following features.

^{1}H NMR spectrum data for compound E

Chemical shift (ppm)	*Integration*	*Peak splitting*
0.95	3	Triplet
0.96	6	Doublet
1.7	2	Multiplet
2.1	1	Multiplet
2.2	2	Doublet
4.0	2	Triplet

Reference ^{1}H chemical shift data

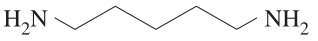
Type of proton	δ/ppm
$-CH_3$, $-CH_2-$, $-CH-$	0.7–2.1
H_3C-CO- H_2C-CO- H_2C-CO (aldehydes, ketones, carboxylic acids or esters)	2.2–2.6
H_3C-O- H_2C-O- $HC-O-$ (alcohols or esters)	3.2–5.0

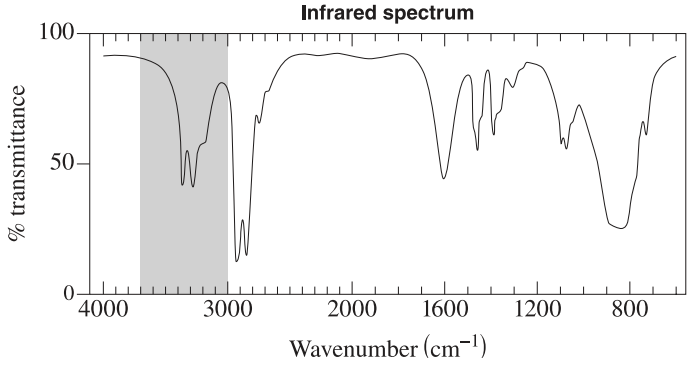
Draw the structure of compounds A, B and E. Explain your answer with reference to the information provided. ***(7 marks)***

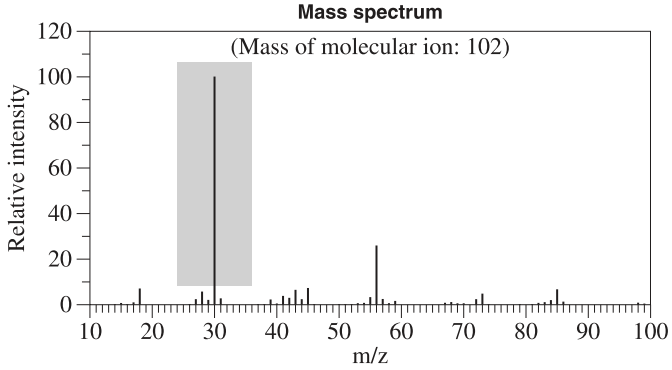
Compound A
Compound B
Compound E

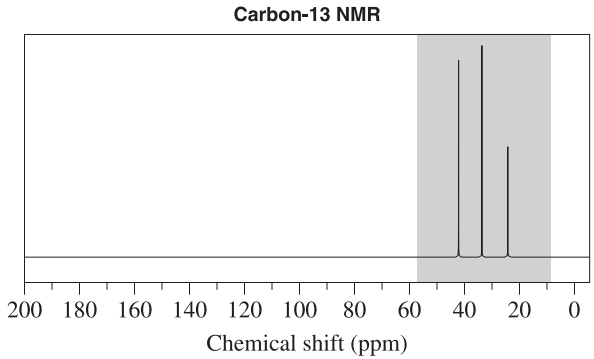
36. CHEMISTRY, M8 2021 HSC 29

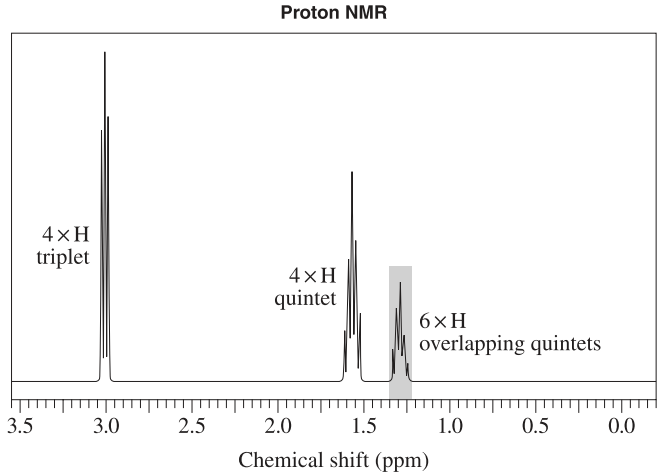
A chemist obtained spectral data of pentane-1,5-diamine ($C_5H_{14}N_2$).







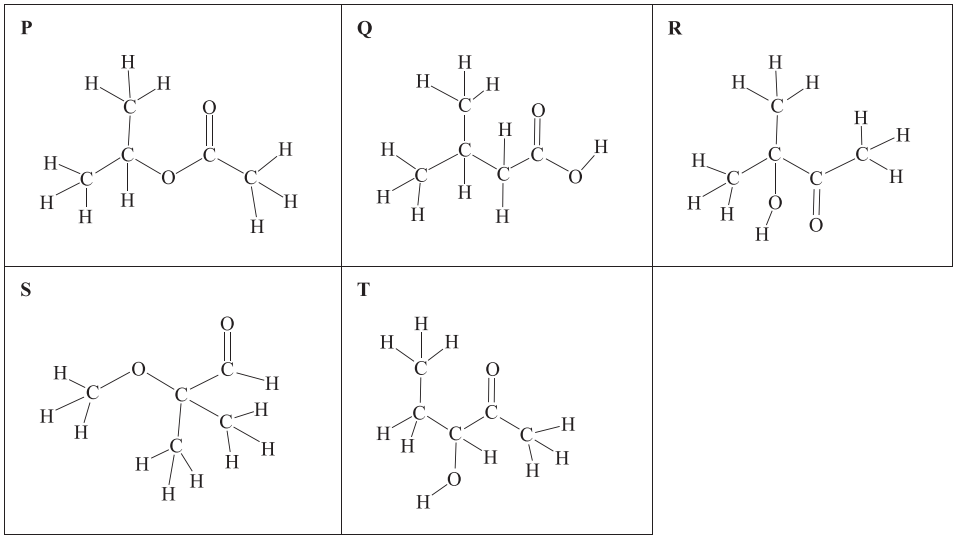




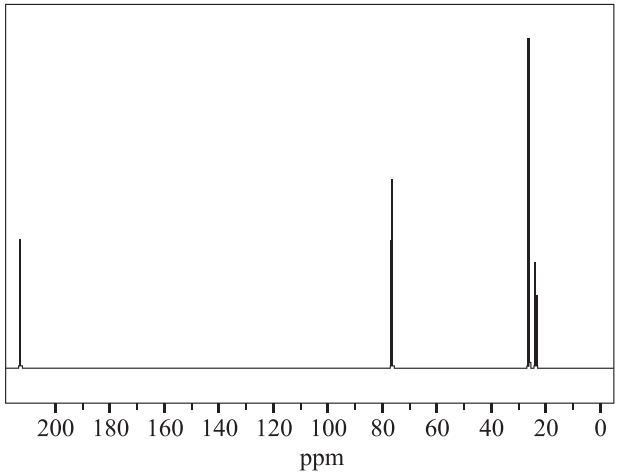
Relate the highlighted features of the spectra to the structure of pentane-1,5-diamine. ***(7 marks)***

37. CHEMISTRY, M8 2021 VCE 7*

Two students are given a homework assignment that involves analysing a set of spectra and identifying an unknown compound. The unknown compound is one of the molecules shown below.

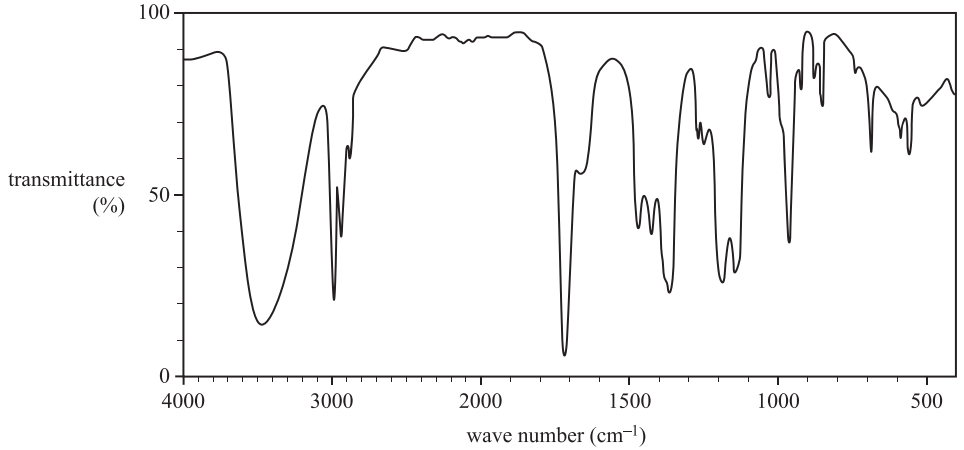


The ^{13}C NMR spectrum of the unknown compound is shown below.



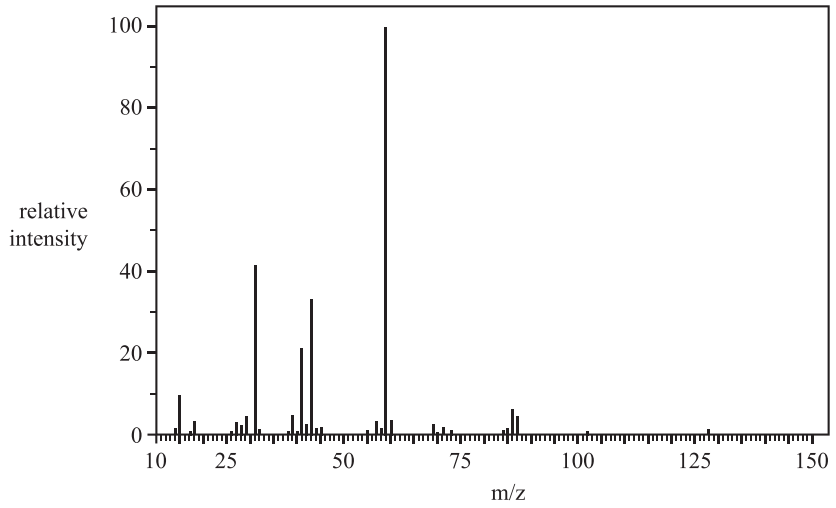
a. Based on the number of peaks in the ^{13}C NMR spectrum above, which compound – P, Q, R, S or T – could be eliminated as the unknown compound? *(1 mark)*

b. The infra-red (IR) spectrum of the unknown compound is shown below.



Identify which of the five compounds (1 or more) can be eliminated on the basis of the IR spectrum. Justify your answer using data from the IR spectrum. *(3 marks)*

c. The mass spectrum of the unknown compound is shown below.



i. Write the chemical formula of the species that produces a peak at m/z = 43. *(1 mark)*

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ii. Explain why one molecule can produce multiple peaks on a mass spectrum. *(2 mark)*

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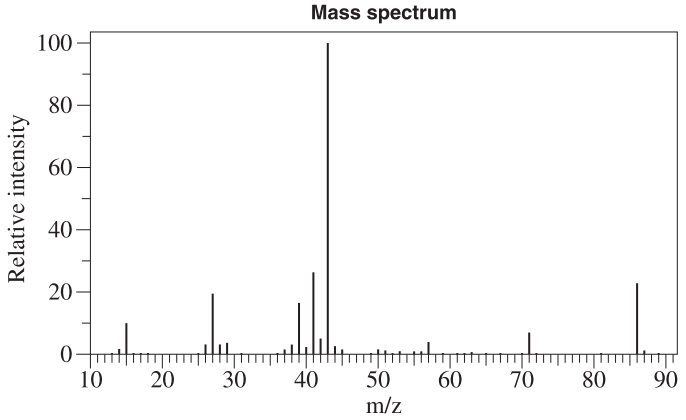
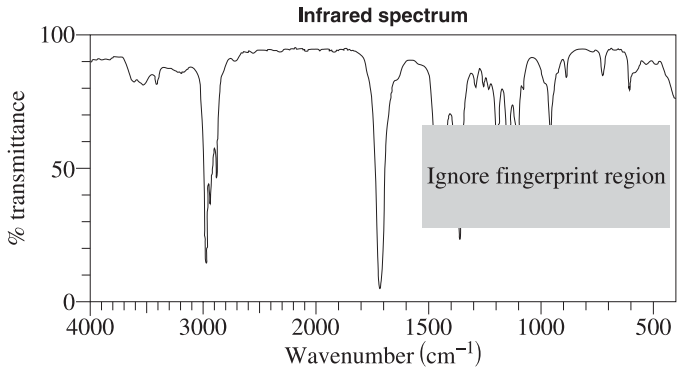
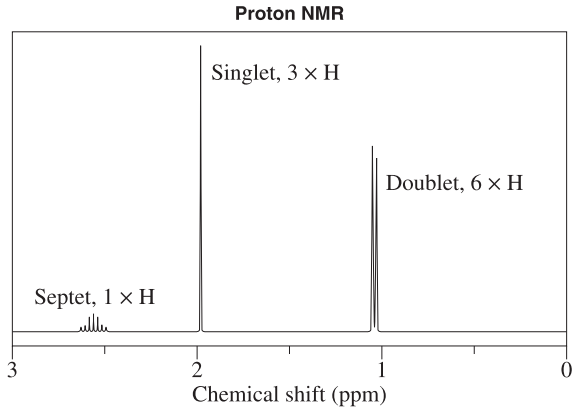
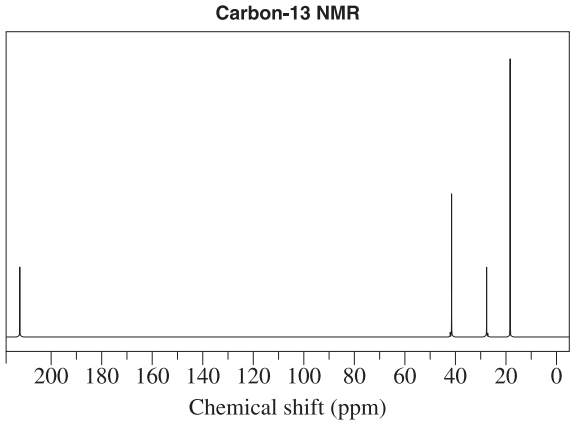
38. CHEMISTRY, M8 2022 HSC 30

The following spectra were obtained for an unknown organic compound.









In the space provided, draw and name the unknown compound that is consistent with all the information provided. Justify your answer with reference to the information provided. ***(7 marks)***

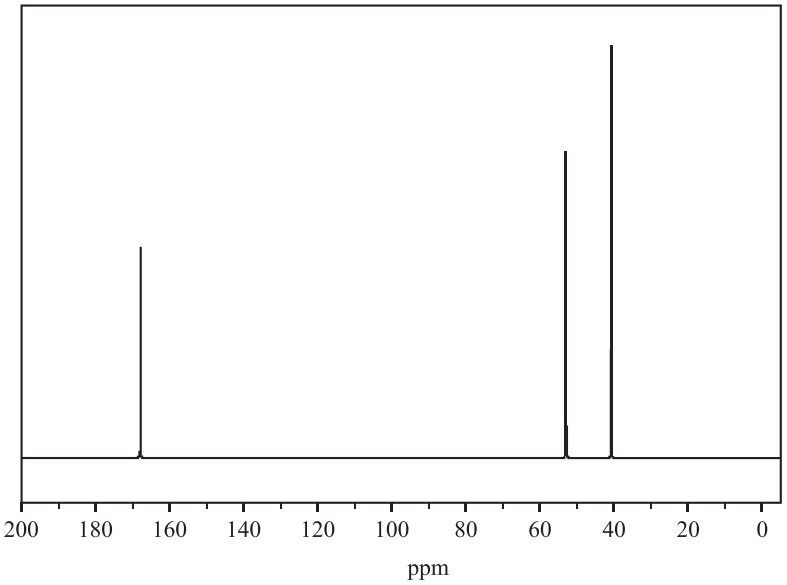
Structure:

Name: .....

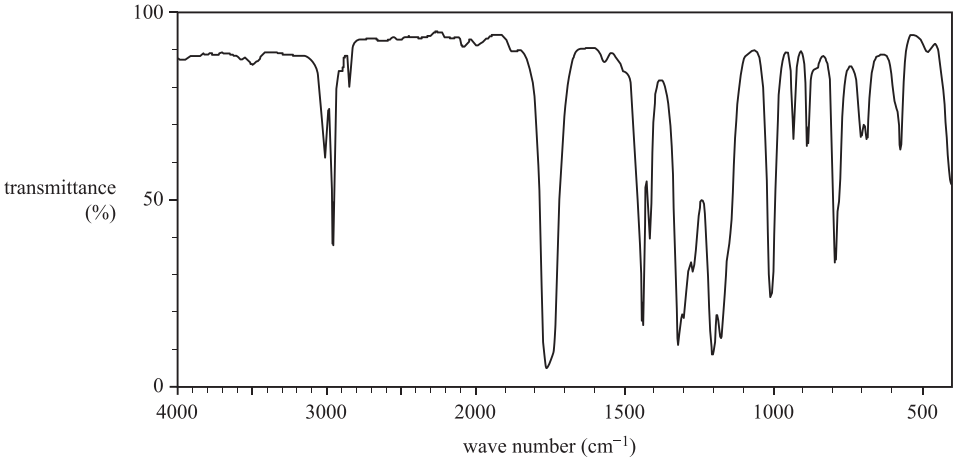
39. CHEMISTRY, M8 2022 VCE 5*

A chemist uses spectroscopy to identify an unknown organic molecule, Molecule J, that contains chlorine.

The ^{13}C NMR spectrum of Molecule J is shown below.



The infra-red (IR) spectrum of Molecule J is shown below.

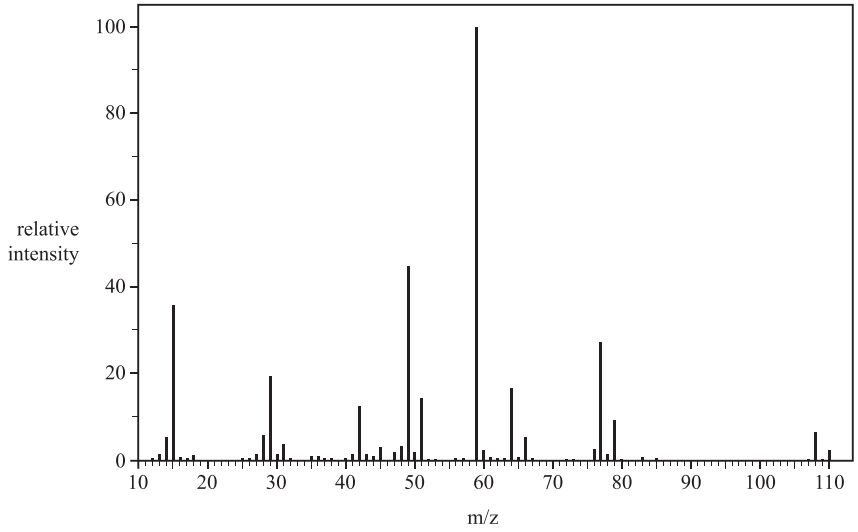


a. Name the functional group that produces the peak at 168 ppm in the ^{13}C NMR spectrum on the first image, which is consistent with the IR spectrum shown above. Justify your answer with reference to the IR spectrum. *(2 marks)*

.....

.....

The mass spectrum of Molecule J is shown below



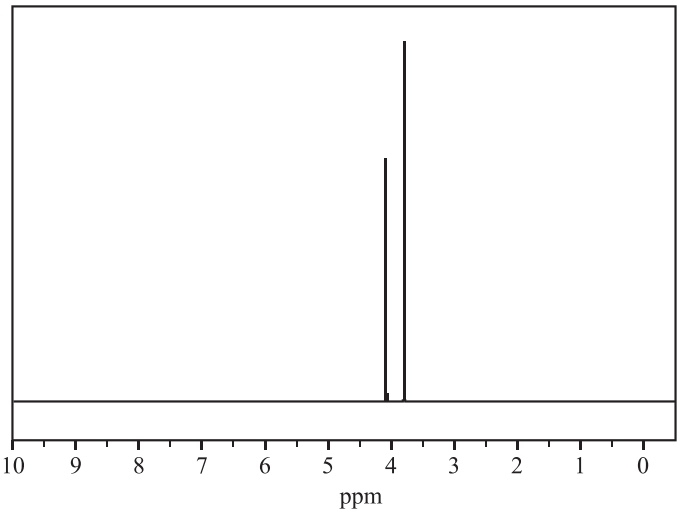
b. The molecular mass of Molecule J is 108.5

Explain the presence of the peak at 110 m/z. *(1 mark)*

.....

.....

The ^{1}H NMR spectrum of Molecule J is shown below.



c. The ^{1}H NMR spectrum consists of two singlet peaks.

What information does this give about the molecule? ***(2 marks)***

.....

.....

.....

d. Draw a structural formula for Molecule J that is consistent with the information provided in parts a–c. ***(2 marks)***

40. CHEMISTRY, M8 2023 HSC 36

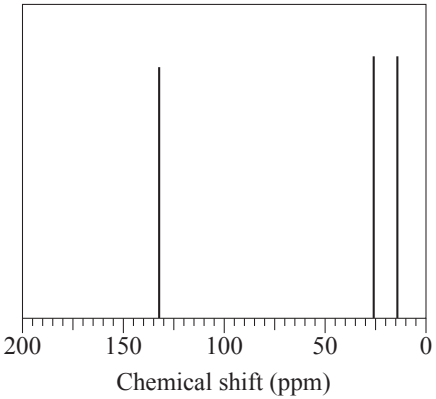
An organic reaction pathway involving compounds A, B, and C is shown in the flow chart.

$$\text{A} \xrightarrow{\text{Dilute } H_2SO_4} \text{B} \xrightarrow[H^+/\text{heat}]{KMnO_4} \text{C}$$

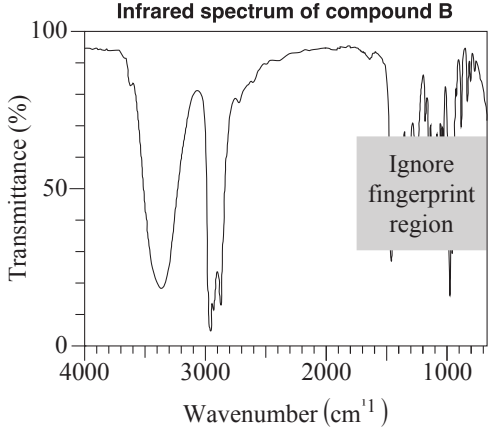
The molar mass of A is 84.156 g mol^{-1}.

A chemist obtained some spectral data for the compounds as shown.

^{13}C NMR spectrum of compound A



Infrared spectrum of compound B



Data from ^{1}H NMR spectrum of compound C

Chemical Shift (ppm)	*Relative peak area*	*Splitting pattern*
1.01	3	Triplet
1.05	3	Triplet
1.65	2	Multiplet
2.42	2	Triplet
2.46	2	Quartet

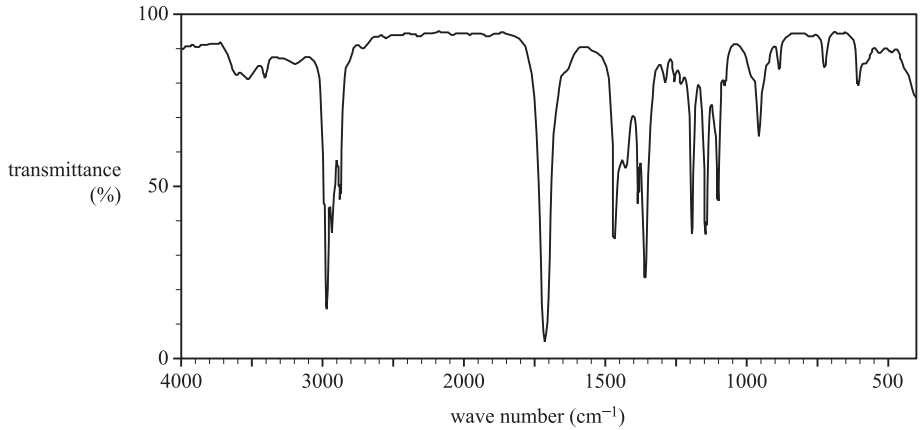
^{1}H NMR chemical shift data

Type of proton	δ/ppm
R − C**H**3, R − C**H**2 − R	0.7 − 1.7
H3 C − CO − − C**H**2 − CO − (aldehydes, ketones, carboxylic acids or esters)	2.0 − 2.6
R − C**H**O	9.4 − 10.00
R − COO**H**	9.0 − 13.0

Identify the functional group present in each of compounds A to C and draw the structure of each compound. Justify your answer with reference to the information provided. *(9 marks)*

41. CHEMISTRY, M8 2023 VCE 7-2*

The infrared (IR) spectrum of the molecule 3-methyl-2-butanone is shown below.



Explain why different frequencies of infrared radiation can be absorbed by the same molecule as shown in the spectrum above. ***(3 marks)***

Worked Solutions

1. CHEMISTRY, M8 2024 HSC 4 MC

→ The broad absorption peak between 3500 to 3250 indicates the presence of an $\mathrm{O-H}$ alcohol group.

$\Rightarrow A$

---

2. CHEMISTRY, M8 2024 HSC 9 MC

→ The molar mass of ethanamine, $\mathrm{CH_3CH_2NH_2}$, is 45.086 g $\mathrm{mol^{-1}}$

→ The peak with the largest mass to charge ratio displays the molar mass of the substance.

→ Therefore, the parent ion peak will be at 45.

$\Rightarrow B$

---

3. CHEMISTRY, M8 2019 HSC 14 MC

→ The $^1\mathrm{H\ NMR}$ spectrum exhibits a single signal, which suggests that all the hydrogens in the sample are present in the same chemical environment.

→ Therefore, the answer A, where all the hydrogens are chemically equivalent is correct.

$\Rightarrow A$

---

4. CHEMISTRY, M8 2019 HSC 4 MC

→ The parent ion in the mass spectrum has a mass to charge ratio (m/z) of 88 that matches the molar mass of butanoic acid.

$\Rightarrow B$

---

5. CHEMISTRY, M8 2020 HSC 1 MC

Magnetic fields cause charged particles to travel in a circular path.

$\Rightarrow B$

---

6. CHEMISTRY, M8 2020 HSC 4 MC

→ Infrared spectroscopy is able to identify the functional groups present.

→ Butane and propane are similar in bonds and functional groups, and thus have similar infrared sprectra. The other pairs of compounds have different functional groups.

$\Rightarrow A$

---

7. CHEMISTRY, M8 2020 HSC 5 MC

→ The $^{13}\text{C NMR}$ spectrum shows two signals, indicating 2 unique carbon environments.

→ Chloroethane is the only compound with 2 unique carbon environments.

$\Rightarrow A$

---

8. CHEMISTRY, M8 2021 VCE 11 MC

→ Only B and C have three different hydrogen environments (eliminate A and D).

→ The molar mass of B is 60 g mol^{-1} which matches the last m/z peak in the mass spectrum.

$\Rightarrow B$

---

9. CHEMISTRY, M8 2020 HSC 15 MC

By elimination:

→ A has no charge (eliminate)

→ B has an m/z = 16 (eliminate)

→ C has 4 carbon fragments (eliminate)

$\Rightarrow D$

Mean mark 51%.

---

10. CHEMISTRY, M8 2021 HSC 12 MC

→ The mass spectrum indicates that the m/z peak is at 98, indicating that the molecular mass of the substance is approximately 98.

→ Additionally, the C-13 NMR spectrum shows 4 signals indicating that there are 4 unique carbon environments.

→ Thus, only A has a molecular mass of 98 and fits the 4 unique carbon environments.

$\Rightarrow A$

♦♦ Mean mark 35%.

---

11. CHEMISTRY, M8 2021 HSC 18 MC

By elimination:

There are 8 hydrogen atoms in total (3 + 3 + 2 = 8)

→ Eliminate A and C

Compound has a 3H singlet

→ Eliminate B

$\Rightarrow D$

♦♦ Mean mark 39%.

---

12. CHEMISTRY, M8 2022 HSC 12 MC

→ Structure D only contains two unique carbon environments, and thus would only contain two signals on a $^{13}\text{C NMR}$ spectrum.

→ Structure A contains 3 C signals, structure B contains 5 C signals, and structure C contains 4 C signals.

$\Rightarrow D$

♦ Mean mark 49%.

13. CHEMISTRY, M8 2022 VCE 28 MC

→ The $^{13}\text{C NMR}$ has five peaks indicating 5 different carbon environments within the molecule.

→ The peak at 140 indicates the presence of the $\text{C} = \text{C}$.

$\Rightarrow D$

♦ Mean mark 42%.
COMMENT: Solving by elimination is an effective strategy here.

14. CHEMISTRY, M8 2023 HSC 19 MC

→ The peaks in mass spectra represent fragments of organic molecules.

→ Mass Spectrometers can only detect charged particles meaning the peak at 43 m/z could only represent:

$\text{CH}_3\text{COCH}_2\text{CH}_3{}^+$, $^+\text{CH}_2\text{CH}_3$, CH_3CO^+, ^+CHO, or $\text{CH}_3\text{CH}_2\text{CH}_2{}^+$

→ The m/z ratio is indicative of a fragment's molecular weight which corresponds to CH_3CO^+

$\Rightarrow B$

♦ Mean mark 51%.

15. CHEMISTRY, M8 2023 VCE 16 MC

→ There are 7 different carbon environments in the molecule:

$\Rightarrow C$

♦ Mean mark 43%.

16. CHEMISTRY, M8 2023 VCE 29 MC

→ The relative molecular mass of a molecule is determined from the peak with the largest m/z ratio (eliminate A).

→ The peaks in a mass spectrum is caused by the molecules splitting up into different ions as they are bombarded with electrons. Some peaks that differ by a value of 1 are caused by the presence of different isotopes but this is not for all peaks (eliminate B).

→ All peaks on the mass spectrometry graph are charged ions (eliminate C).

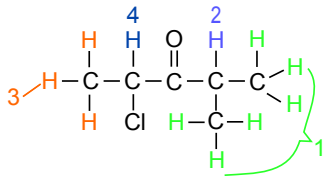
→ The base peak is the largest peak on a mass spectrometry graph and therefore the abundances of each peak are relative to the height of the base peak.

$\Rightarrow D$

♦ Mean mark 46%.

17. CHEMISTRY, M8 2024 HSC 19 MC

→ For two doublets to occur, the substance must have two chemically different hydrogen environments that both have one neighbouring hydrogen on an adjacent carbon atom.



→ This is displayed by option A where the hydrogen atoms in environments 1 and 3 both have only one neighbouring hydrogen atom each.

$\Rightarrow A$

♦ Mean mark 48%.

18. CHEMISTRY, M8 2019 HSC 19 MC

→ The given information suggests that compound Y is a carboxylic acid because it is produced through the oxidation of compound X, a primary alcohol, with an oxidising agent and turns blue litmus red.

→ The treatment of compound X with hot concentrated sulfuric acid results in a dehydration reaction.

→ In summary, the information provided suggests that compound Y is a carboxylic acid and compound X is a primary alcohol, and that the treatment of compound X with hot concentrated sulfuric acid results in a dehydration reaction.

$\Rightarrow D$

♦♦♦ Mean mark 33%.

---

19. CHEMISTRY, M8 2021 HSC 9 MC

→ The solvent used shouldn't have an absorption spectrum with a maximum that corresponds to that of the paracetamol.

→ This is to ensure that the absorption of solvent will have little to no impact on the measured absorption of the paracetamol sample.

$\Rightarrow D$

♦♦♦ Mean mark 24%.

---

20. CHEMISTRY, M8 2021 VCE 16 MC

→ Every pure compound has a different fingerprint region on the Infrared spectrum.

→ Hence the fingerprint region of the sample can be compared against the fingerprint region of the pure substance to determine the purity of the sample.

$\Rightarrow C$

♦♦♦ Mean mark 15%.

---

21. CHEMISTRY, M8 EQ-Bank 21

→ Mass spectrometers use an electric field to accelerate positively charged ions before passing them through a magnetic field.

→ Once in the magnetic field, the ions travel in a curved path, the direction of which depends on whether the ion is positively or negatively charged.

→ The amount of curvature is dependent on the speed at which the ion is travelling and its mass to charge ratio.

→ Lighter ions have less momentum and are deflected more strongly than heavier ions.

---

22. CHEMISTRY, M8 EQ-Bank 27

→ When analysing organic substances, IR radiation of specific wavelengths will be absorbed by certain atoms of the organic molecules. The absorption is dependent on the length of the compound's atomic bonds.

→ By utilising the complete IR spectrum, the particular bonds in a molecule can be identified. The degree of the absorption can be used to calculate the relative number of each specific bond.

→ The resulting absorption data can be used to create an absorption spectrum of the organic material. This spectrum can then be compared to published data and used to identify the organic material.

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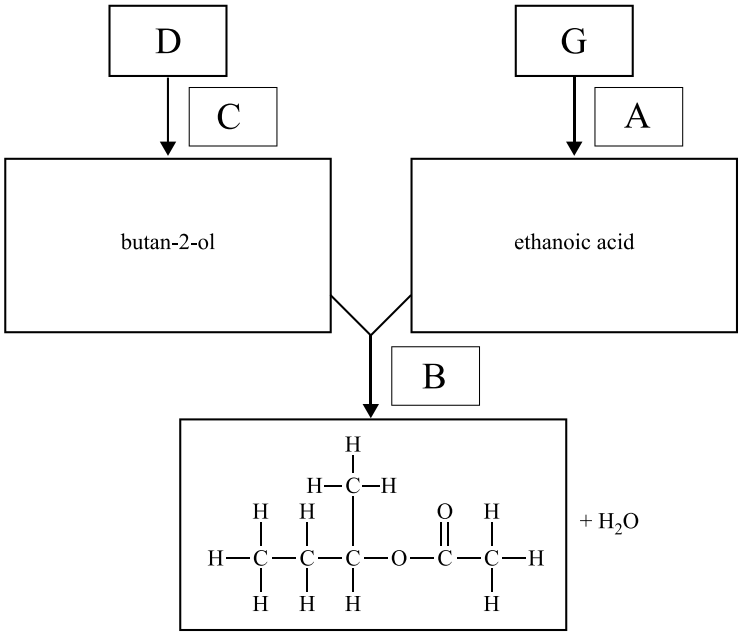
23. CHEMISTRY, M7 2015 VCE 5a



24. CHEMISTRY, M8 2021 HSC 21

a. A safety concern is that the organic liquids are flammable.

To address this, keep substance away from open flames and keep away from ignition sources.

b. Flask 1: propanoic acid (carboxylic acids can't be oxidised and are polar)

Flask 2: hex-1-ene (alkenes can be oxidised and are non-polar)

Flask 3: propan-1-ol (primary alcohols can be oxidised and are polar)

Flask 4: hexane (alkanes don't react with acidified oxidants and are non-polar)

c. Hex-1-ene

→ Could be identified using the bromine water test.

→ The addition of brown bromine water to an alkene causes an addition reaction where the solution changes colours from brown to colourless.

Propanoic acid

→ Could be identified through a neutralisation reaction using Na_2CO_3.

→ Effervescent reaction will result.

Propan-1-ol

→ Could be identified through an oxidation reaction using acidified dichromate.

→ The reaction would cause the solution to change from green to orange.

25. CHEMISTRY, M8 EQ-Bank 22

a. → A is a magnet.

→ It bends the charged particles that are accelerated through an electric field and directed through it.

→ The amount of bending can then be used to distinguish between and identify the particles/ions.

b. Advantages of mass spectrometry

→ The mass spectrometer can identify the mass/charge ratio of ions that pass through it. This data can then be used to identify components of a mixture or components in a compound.

→ Different isotopes of elements in a compound can be identified by mass spectrometers. This allows the compound to be matched to a sample.

→ Mass spectrometry can provide both qualitative and quantitative data on a compound.

→ Mass spectrometers only require a small quantity of a compound to perform detailed analysis, as well as being fast and sensitive.

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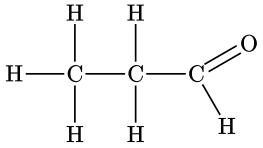
26. CHEMISTRY, M8 2019 HSC 26a



→ The compound exhibits characteristics that suggest it is an organic acid.

→ This is demonstrated by its reaction with sodium carbonate, which produces carbon dioxide bubbles, as well as the presence of a strong absorption around 1700 cm^{-1} in the IR spectrum, which is characteristic of a CO bond, and another broad absorption in the region 2500-3500 cm^{-1}, which is characteristic of an OH bond in acids.

→ The mass spectrum of the compound has a parent peak at m/z = 74, which is consistent with its molecular formula $C_3H_6O_2$ (molar mass = 74 g mol^{-1}).

→ The ^{13}C NMR spectrum shows 3 signals, including one around 180 ppm, which is characteristic of a carbonyl carbon, and the ^{1}H NMR spectrum shows 3 signals, including a quartet with an integration of 2 and a triplet with an integration of 3, indicating the presence of a CH_3 group and CH_2 group respectively.

→ These observations confirm the presence of a $COOH$ group in the compound.

---

27. CHEMISTRY, M8 2019 HSC 26b

→ Different techniques in organic chemistry can be used to identify and characterise the structure of organic molecules.

→ These techniques such as ^{1}H NMR spectroscopy and mass spectrometry, provide different pieces of information about the molecule's structure.

→ ^{1}H NMR spectroscopy can be used to identify functional groups and distinguish between isomers by providing information about the chemical environment and relative number of hydrogen nuclei.

→ Mass spectrometry, on the other hand, gives information about the molecular weight of a molecule and its characteristic fragments.

→ It is important to use a combination of these techniques in order to obtain a complete understanding of the structure of an organic compound.

---

28. CHEMISTRY, M8 2020 HSC 21

→ The alkane is propane.

→ The mass spectrum has a molecular ion peak of 44, which indicates that the alkane is C_3H_8 (propane).

---

29. CHEMISTRY, M8 EQ-Bank 25

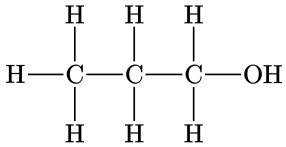
→ The absorbance shows an initial trough in the range 3100 – 3600 cm^{-1}. This absorbance maximises at around 3350 cm^{-1}. This data indicates the likely presence of a hydroxyl group within the compound.

→ The next trough occurs in the range 3100 – 3600 cm^{-1}. Its intensity trough is not broad. This data is consistent with the presence of a $C-H$ bond.

→ There is little absorbance between 2500 – 1500 cm^{-1}. This data indicates the absence of any $C=O$ group, discounting the possibility of the compound being carboxylic acid or a ketone.

→ An absorption peak between 1250 – 1050 cm^{-1} indicates the presence of a $C-O$ bond.

→ Propanol is a compound whose structure is consistent with the data above:



→ The molecular weight of propanol is 60.01 g mol^{-1} which is also supported by the data.

→ Since the spectrum of isomers is similar, the two possible compounds that fit this are propan-1-ol or propan-2-ol.

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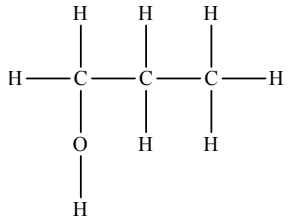
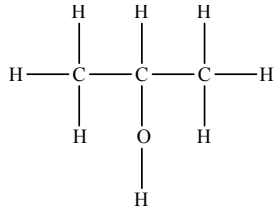
30. CHEMISTRY, M8 2022 HSC 27

a. Isomer 1:



Isomer 2:

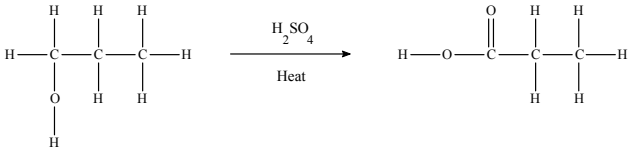


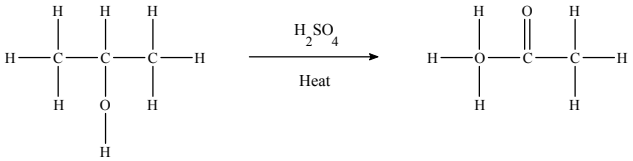
b. Identifying isomers with ^{13}C NMR spectroscopy:

→ this can be used to identify the isomers in the bottle because they show a different number of signals which helps deduce the carbon environment.

→ Propan-1-ol contains 3 C environments so it would have 3 peaks on a ^{13}C NMR spectrum whereas propan-2-ol only contains 2 C environments (due to symmetry), so it would only have 2 signals on a ^{13}C NMR spectrum.

c.





♦ Mean mark (c) 52%.

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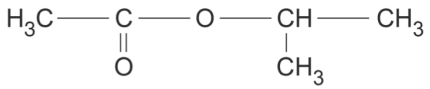
31. CHEMISTRY, M8 2020 HSC 30



Mean mark 55%.

Infrared Spectrum

→ There's a signal between 1680 – 1750 cm^{-1}, indicating the presence of a $C=O$ bond (consistent with carbonyl group).

→ No absorption at 3230 – 3550 cm^{-1} indicates the absence of the $O-H$ bond (rules out carboxylic acid $-COOH$).

^{13}C NMR:

→ The ^{13}C NMR spectrum has 4 peaks, indicating that there are 4 unique carbon environments in the compound.

→ This is consistent with the proposed structure of the compound.

→ The peak at 170 ppm is characteristic of the carbonyl carbon, and the peak at 70 ppm corresponds to a carbon nucleus adjacent to an oxygen, which confirms the presence of an ester group.

The ^{1}H NMR Spectrum:

→ A septet in the ^{1}H NMR spectrum is consistent with the presence of six neighbouring hydrogen atoms on two CH_3 groups.

→ A doublet in the spectrum is consistent with one neighbouring hydrogen atom.

→ The combination of a septet and a doublet is consistent with the presence of a $-CH(CH_3)_2$ group in the compound.

→ A singlet in the spectrum is consistent with the absence of neighbouring hydrogen atoms, which would be produced by an isolated methyl group.

32. CHEMISTRY, M8 2023 HSC 28

a. Chemical test for an alkene

→ Prepare a sample of alkene Q in a clean test tube.

→ Add a few drops of bromine water to the sample.

→ The bromine water will be decolourised if Q is an alkene.

Other correct answers could include:

→ The addition of potassium permanganate will also be decolourised by Q if it is an alkene.

♦ Mean mark (b) 53%.

b. Molecular ion is present at m/z = 114

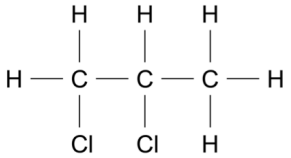
Atomic mass of C (in compound R) = 32% × 114 = 36

C atoms in 1 molecule of R = 36 ÷ 12 = 3

Mass (non-C) = 114 – 36 = 78

$\Rightarrow$ Two atoms of Cl are in compound R

$\therefore$ R has the formula $C_3H_6Cl_2$, and structure:



33. CHEMISTRY, M8 2023 VCE 7-1*

a.i. Molar mass of $\mathrm{V} = 86\ \mathrm{g\ mol^{-1}}$

→ Indicated by the parent ion peak at 86 m/z.

→ Molecular formula: $\mathrm{C_5H_{10}O}$

a.ii. Small peak at m/z = 87:

→ A carbon-13 isotope being present in the molecule.

b. The doublet peak at 1.1 ppm:

♦ Mean mark (b) 50%.

→ Indicates there is a single hydrogen with a different hydrogen environment bonded to an adjacent carbon atom.

c. From the carbon NMR graph:

♦ Mean mark (c) 43%.

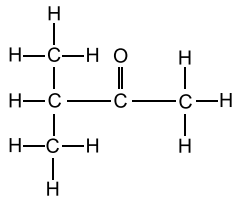
→ There are 4 carbon environments, one shifted above 200 ppm indicating a ketone or aldehyde.

→ As there are 5 carbons, 2 of the carbons must have the same environment.

From the hydrogen NMR graph:

→ There are 3 hydrogen environments.

→ The septet peak indicates there are 6 hydrogens with the same chemical environment on adjacent carbon atoms.



34. CHEMISTRY, M8 2024 HSC 33

a. Acetone:

♦ Mean mark (a) 44%.

→ Double bond and 2 single bonds coming off the central carbon atom ⇒ trigonal planar.

Product:

→ Contains single bonds coming off the central carbon atom ⇒ tetrahedral. (Note: the hydrogen bonded to the central carbon atom in the product molecule is not shown due to the skeletal structure)

b. $^{13}\mathrm{C\ NMR}$ Spectroscopy:

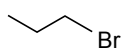
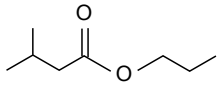
→ $^{13}\mathrm{C\ NMR}$ will differentiate between molecules with different carbon environments. This produces different signals on the $^{13}\mathrm{C\ NMR}$ spectrum.

→ The acetone would produce two signals on the $^{13}\mathrm{C\ NMR}$ spectrum. The first signal would be due to the $\mathrm{CH_3}$ groups either side of the central carbon between 20-50 ppm. The second signal would be from the carbonyl group between 190-220 ppm.

→ The product of the reduction would also produce two signals on the $^{13}\mathrm{C\ NMR}$ spectrum. The carbon with the hydroxyl group attached to it would produce a signal between 50-90 ppm and the $\mathrm{CH_3}$ groups either side would produce a signal between 5-40 ppm.

→ The reaction can be monitored by observing the disappearance of the carbonyl signal (190-220 ppm) and appearance of the hydroxyl signal (50-90 ppm) as acetone is reduced to the product.

35. CHEMISTRY, M8 2024 HSC 38

Compound A 
Compound B 
Compound E 

♦ Mean mark 52%.

→ The mass spectrum has two peaks to the far right of the spectrum of similar height at 122 m/z and 124 m/z. This is due to the halogen having two isotopes with the same relative abundance.

→ Isotope X must be bromine, whose isotopes are Br-79 and Br-81. The two molecular ion peaks both correspond correctly to the molar mass of the parent molecule, $\mathrm{C_3H_7Br}$, depending on which isomer is present in the compound.

$$MM(\mathrm{C_3H_7Br\text{-}79}) = 3 \times 12 + 1 \times 7 + 79 = 122$$

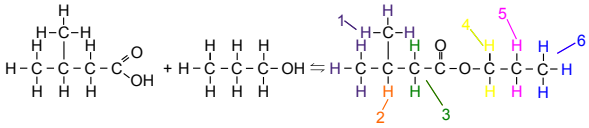
$$MM(\mathrm{C_3H_7Br\text{-}81}) = 3 \times 12 + 1 \times 7 + 81 = 124$$

→ The two isomers of $\mathrm{C_3H_7Br}$ are 1-bromopropane and 2-bromopropane and when they undergo a substitution reaction with $\mathrm{OH^-}$, they will produce propan-1-ol and propan-2-ol respectively.

→ Only secondary alcohols will oxidise to produce a ketone. Hence compound D must be propan-2-ol and compound C must be propan-1-ol which can be oxidised to an aldehyde and the aldehyde can be oxidised to a carboxylic acid.

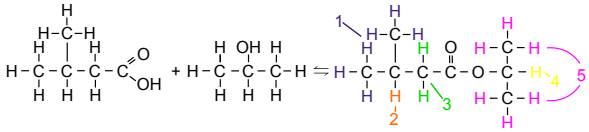
→ Therefore, compound B is 2-bromopropane and compound A is 1-bromopropane as during the substitution reaction the bromine atom is substituted with the hydroxide ion.

→ When 3-methylbutanoic acid is reacted with alcohol C (propan-1-ol) the following reaction takes place:



3-methylbutanoic acid + propan-1-ol Propyl 3-methylbutanoate

→ When 3-methylbutanoic acid is reacted with alcohol D (propan-2-ol) the following reaction takes place:



3-methylbutanoic acid + propan-2-ol propan-2-yl 3-methylbutonoate

→ There are 6 unique hydrogen environments present in compound E. Therefore compound E must be the ester produced in the reaction between 3-methylbutanoic acid and propan-1-ol (it has 6 hydrogen environments vs propan-2-ol ester which has 5).

→ Compound E is propyl 3-methylbutanoate.

→ This can be confirmed by the integration (ratio of hydrogens in each environment) and peak splitting columns (number of splits = number of adjacent hydrogens + 1)

→ The shift at 0.96 is due to environment 1 which has six hydrogen atoms and has one neighbouring hydrogen atom (produces a doublet).

→ The shift at 2.1 is due to environment 2 which has one hydrogen 1 atom and has 8 neighbouring hydrogen atoms a (produces a mutliplet of 9)(.

→ The shift at 4.0 is due to environment 4. This $\mathrm{CH_2}$ group is bonded to an oxygen atom corresponding to a large chemical shift between 3.2–5.0. It also has 2 neighbouring hydrogens and so produces a triplet.

→ Other answers could have included a further explanation regarding the integration and peak splitting of all the hydrogen environments and their relative chemical shifts.

36. CHEMISTRY, M8 2021 HSC 29

Infrared Spectrum:

→ IR spectrum allows us to find key functional groups in a molecule.

→ There is a peak signal at 3300 – 3400 cm^{-1}, indicating the presence of the amino group.

♦ Mean mark 55%.

Mass spectrum:

→ The mass spectrum represents the molecular mass and fragments of a molecule. The highlighted feature shows a 30 m/z signal, this is due to the fragmentation of the molecule.

→ The highlighted signal depicts the fragment $CH_2NH_2^+$, which has a molecular mass of 30 (12 × 1 + 1.0 × 4 + 14 × 1 = 30).

Carbon 13 NMR Spectrum:

→ The molecule has 5 carbon atoms, however, the spectrum only has 3 signals. This indicates symmetry, and that there are 3 different carbon environments in the molecule.

→ Carbon 1 and 5 are in the same carbon environment, carbon 2 and 4 are in the same carbon environment, and carbon 3 is in a unique carbon environment.

→ The signals at 24 and 33 ppm are due to the $–CH_2–CH_2–$ carbon atoms.

→ The signal at 42 ppm is due to the $C–N–H$ groups.

Proton NMR:

→ The highlighted signal results from the middle three CH_2 groups. It is formed from similar chemical shifts of protons in two different environments, which creates an overlap of a $2H$ signal and a $4H$ signal, giving $6H$.

→ The quintets arise because each H atom has four H atoms on neighbouring C atoms.

37. CHEMISTRY, M8 2021 VCE 7*

a. → The $^{13}C\ NMR$ shows 4 different carbon environments.

→ Compound T has 5 unique carbon environments and can be eliminated.

b. → Compounds P, Q and S can be eliminated.

→ Compounds S and P both don't have an OH alcohol group, however the IR spectrum clearly shows an OH alcohol group with an absorbance at 3500 cm^{-1}.

→ Compound Q contains an OH acid group whereas the IR spectrum shows an OH alcohol group at 3500 cm^{-1}. There is no evidence of a broad OH acid group between 2500–3000 cm^{-1}.

♦ Mean mark (b) 43%.
COMMENT: Recognise the difference between OH alcohols and OH acid groups.

c.i. → The unknown compound is compound R.

→ The chemical species are fragments of the original compound with a positive charge.

→ The chemical formulas could include $[CH_3CO]^+$ or $[C_2H_3O]^+$

♦ Mean mark (c.i.) 50%.
COMMENT: Ions require a positive charge.

ii. → Ions of that molecule must be formed to produce peaks on the mass spectrum.

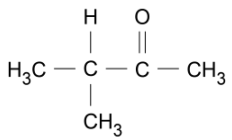
→ Organic compounds can be split up into numerous different ions when producing fragment patterns leading to multiple different peaks on the mass spectrum.

♦ Mean mark (c.ii.) 39%.

38. CHEMISTRY, M8 2022 HSC 30

Structure: 3-methylbutan-2-one

♦ Mean mark 51%.



Mass spectrum:

→ There is a parent ion peak at m/z = 86, indicating that the compound has a molar mass of 86 g mol^{-1}.

IR spectrum:

→ There is a strong absorption at 1680 – 1750 cm^{-1}, indicating a carbonyl functional group.

→ There isn't a strong absorption at 2500 – 3000 cm^{-1}, indicating an absence of hydroxyl group (consistent with a ketone).

Proton NMR spectrum:

→ There are 3 signals, indicating 3 unique hydrogen environments:

→ The signal at 1.1 ppm, consists of 6 hydrogens and is a doublet.

→ The signal at 2 ppm, consists of 3 hydrogens and is a singlet.

→ The signal at 2.6 ppm, consists of 1 hydrogen and is a septet.

Carbon-13 NMR spectrum:

→ There are 4 signals, indicating 4 unique carbon environments.

→ A signal at 19 ppm indicates a carbon atom single bonded to another adjacent carbon atom.

→ A signal at 28 ppm indicates a carbon adjacent to a carbonyl carbon.

→ A signal at 41 ppm indicates a carbon adjacent to a carbonyl carbon and methyl groups.

→ A signal at 210 indicates a ketone carbon.

39. CHEMISTRY, M8 2022 VCE 5*

a. → Absence of a very broad OH acid peak between 2500–3000.

→ Molecule J must be an ester.

♦ Mean mark (a) 41%.

b. The peak at 110 m/z:

→ due to the Chlorine-37 isotope which is slightly heavier than the more abundant Chlorine-35.

♦♦♦ Mean mark (b) 15%.
COMMENT: Know the masses of common isotopes.

c. The two singlet peaks indicate:

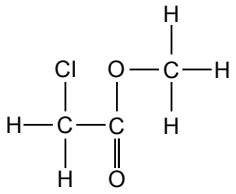
→ two different hydrogen environments within the molecule.

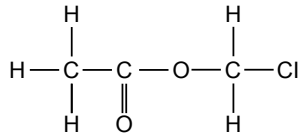
→ there are no adjacent hydrogen environments.

→ The relative heights of the peaks show the ratios of the hydrogens in the environments are 2 : 3.

d. Either of the two molecules show below are correct:

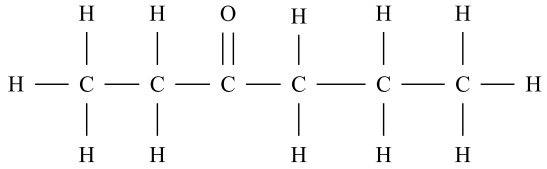
♦ Mean mark (d) 40%.



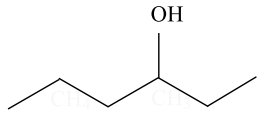


40. CHEMISTRY, M8 2023 HSC 36

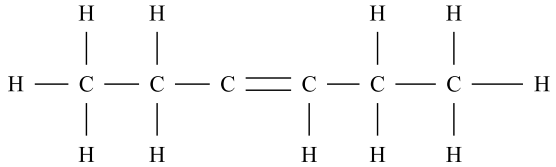
Compound A: Alkene



Compound B: Secondary alcohol



Compound C: Ketone



Reasoning as follows:

→ Compound A is able to undergo an addition reaction to add water across a $C = C$ bond $\Rightarrow$ Alkene

→ Compound B is the product of the above hydration reaction and is therefore an alcohol.

→ The ^{13}C NMR spectrum of Compound A confirms it is an alkene (132 ppm peak corresponding to the $C = C$ atoms). 3 spectrum peaks indicate 3 carbon environments. The molar mass of compound A is 84.156 g mol^{-1} which suggests symmetry within the molecule.

→ The Infrared Spectrum of Compound B has a broad peak at approximately 3400 cm $^{-1}$. This indicates the presence of an hydroxyl group and confirms B is an alcohol.

→ Compound C is produced by the oxidation of Compound B with acidified potassium permanganate.

→ Compound C is a carboxylic acid if B is a primary alcohol or a ketone if B is a secondary alcohol.

→ Since the ^1H NMR spectrum of C does not show any peaks between 9.0 – 13.0 ppm, it cannot be a carboxylic acid. Compound C is therefore a ketone and Compound B is a secondary alcohol.

→ The ^1H NMR spectrum shows 5 peaks $\Rightarrow$ 5 hydrogen environments.

→ Chemical shift and splitting patterns information indicate:

1.01 ppm – 1.05 ppm: CH_3 (next to a CH_2)

1.65 ppm: CH_2 (with multiple neighbouring hydrogens)

2.42 ppm: CH_2 (next to the ketone $C = O$ and a CH_2)

2.46 ppm: CH_2 (next to the ketone $C = O$ and a CH_3)

41. CHEMISTRY, M8 2023 VCE 7-2*

♦♦ Mean mark 30%.
COMMENT: A deep understanding of the principles behind analytical techniques required here.

→ As infrared radiation is passed through the molecules, the different bonds within the molecule vibrate at specific wavelengths leading to the absorption of the infrared radiation.

→ In this way, different frequencies of infrared radiation can be absorbed by a molecule as bonds differ in electronegativity, dipole strengths and in the masses of atoms at the end of bonds.

→ For example, the double bond between the oxygen atom and carbon atom in the given molecule has a greater dipole than the carbon-hydrogen bonds. This causes a transmittance at 1450 whereas $C - H$ bonds have a transmittance at 3000.

→ An oxygen atom has a higher molecular mass than hydrogen atoms and this also leads to different frequencies of infrared radiation being absorbed in the one molecule.

(Students could have also discussed the strength of bonds, bond length or molecular vibrations)