

Student Name: _____



CHEMISTRY 2024

Unit 4

Key Topic Test 4 Instrumentation and Organic Chemistry

Recommended writing time*: 50 minutes

Total number of marks available: 50 marks

QUESTION BOOK

* The recommended writing time is a guide to the time students should take to complete this test. Teachers may wish to alter this time and can do so at their own discretion.

Conditions and restrictions

- Students are permitted to bring into the room for this test: pens, pencils, highlighters, erasers, sharpeners, rulers, a scientific calculator.
- Students are NOT permitted to bring into the room for this test: blank sheets of paper and/or white out liquid/tape.

Materials supplied

- Question and answer book of 17 pages.
- 2024 VCE Chemistry Data Book

Instructions

- Print your name in the space provided on the top of the front page.
- All written responses must be in English.

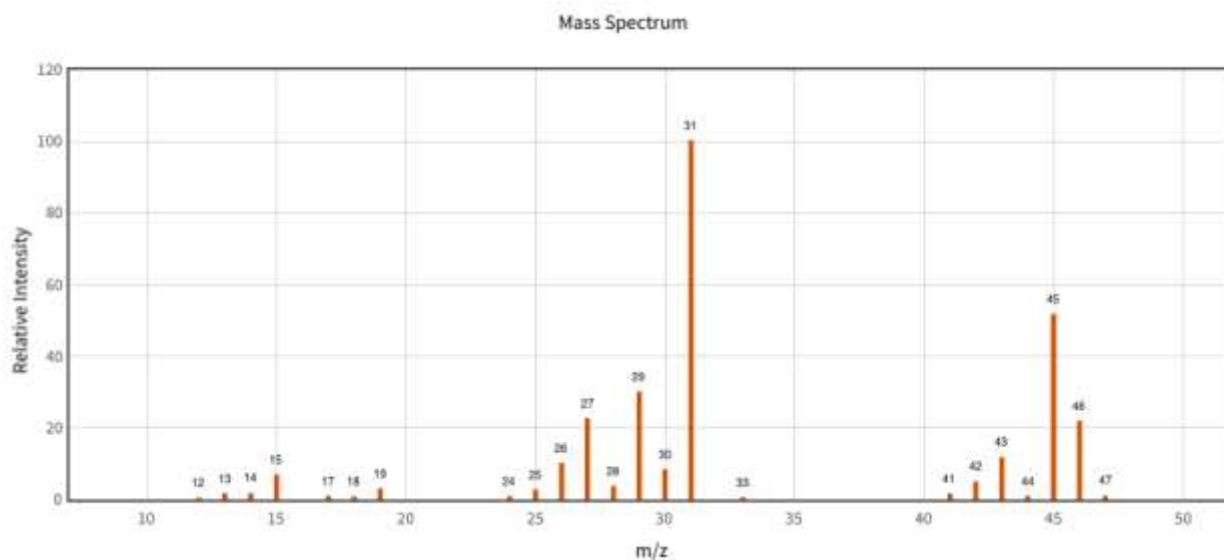
Students are NOT permitted to bring mobile phones and/or any other unauthorised electronic communication devices into the room for this test.

SECTION A – Multiple-choice questions**Instructions for Section A**

Choose the most correct answer for each question. Each question is worth 1 mark.

Question 1

The mass spectrum for ethanol is shown below:



Source: <https://webbook.nist.gov/cgi/cbook.cgi?ID=C64175&Mask=200>

What fragment ion could be responsible for the peak observed at $m/z = 31$?

- A. CH_3^+
- B. CH_3CH_2^+
- C. CH_2OH^+
- D. CH_2O^+

Question 2

A group of organic compounds were analysed using HPLC. The stationary phase was non-polar, while the mobile phase was polar. Assuming each analysis was performed under the same conditions, which of the following compounds would have the shortest retention time?

- A. Ethanol
- B. Butanone
- C. Octane
- D. Heptanol

Use the following information to answer Question 3 and 4

The table below shows data related to $^1\text{H-NMR}$ spectra of a particular compound.

Peak Number	1	2
Relative peak area	2	3
Peak splitting pattern	4	3

Question 3

How many hydrogen environments are in the compound?

- A. 1
- B. 2
- C. 3
- D. 4

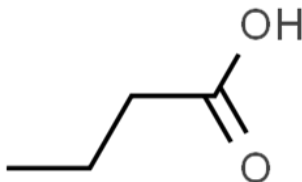
Question 4

The identity of the hydrogen environment of peak 2 could be:

- A. CH
- B. CH_2
- C. CH_3
- D. CH_4^+

Use the following information to answers Questions 5 and 6.

The skeletal formula for butanoic acid is shown below.

**Question 5**

If butanoic acid was analysed using $^{13}\text{C-NMR}$, how many peaks would be observed on the spectrum?

- A. 1
- B. 2
- C. 3
- D. 4

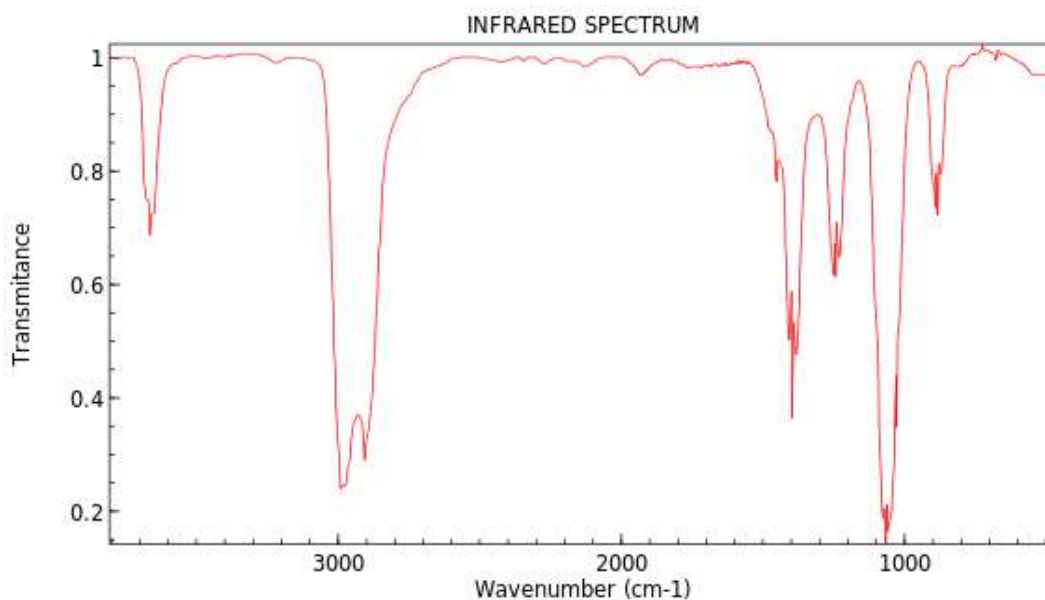
Question 6

If butanoic acid was analysed using $^1\text{H-NMR}$, how many peaks would be observed?

- A. 2
- B. 3
- C. 4
- D. 5

Question 7

The infrared spectra for a compound that contains carbon, oxygen, and hydrogen is shown below.



NIST Chemistry WebBook (<https://webbook.nist.gov/chemistry>)

Which of the following is likely to be a functional group that is present in the compound?

- A. Amine
- B. Amide
- C. Hydroxyl
- D. Carboxyl

Question 8

The information below relates to the spectroscopic data obtained for a particular organic compound.

m/z of molecular ion peak	58
¹³ C-NMR number of peaks	3
¹ H-NMR number of peaks	3

Which of the following could be the organic compound?

- A. Propanone
- B. Propan-2-ol
- C. Ethanoic acid
- D. Propanal

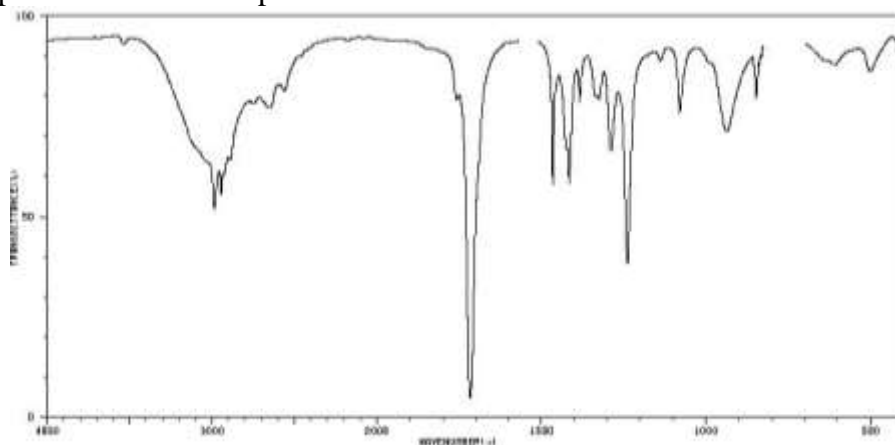
Question 9

Which of the following analyses would high-performance liquid chromatography be the least appropriate analytical technique to use?

- A. Determining whether an organic compound contains a carbonyl or carboxyl functional group
- B. Determining whether vitamin C is present in a urine sample
- C. Determining the percentage of caffeine in different coffee samples
- D. Testing the purity of a sample of paracetamol

Question 10

The structure of an unknown organic compound with the molecule formula C₃H₆O₂. Below shows the infrared spectrum for the compound.



Source: https://www.chemicalbook.com/SpectrumEN_79-09-4_IR1.htm

Which of the following is the semi-structural formula of the compound that produces this spectrum?

- A. CH₃COOCH₃
- B. CH₃CH₂COOH
- C. CH₃COCH₂OH
- D. CH₃CH₂CHO

SECTION B- Short-answer Questions**Instructions for Section B**

Answer all questions in the space provided. For questions involving calculations, provide your final answer to the appropriate number of significant figures, and with required units.

Question 1 (4 marks)

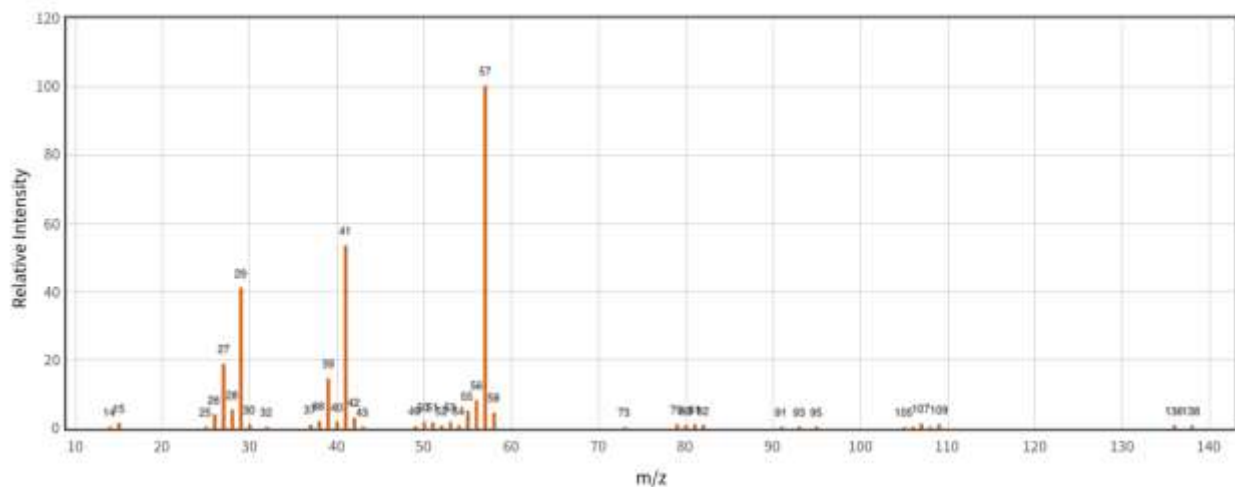
Complete the table below with the analytical technique that best matches the description of information obtained.

Analytical Technique	Information obtained
	Provides information about functional groups present through vibration of bonds.
	Identification of a compound in a mixture through its retention time under specific conditions.
	Provides information about how atoms are connected through producing fragment ions.
	Provides information about the number and type of carbon environments.

1 + 1 + 1 + 1 = 4 marks

Question 2 (8 marks)

The mass spectrum of a straight chain bromoalkane which has a relative molecular mass of 136.9 is shown below.



<https://webbook.nist.gov/cgi/cbook.cgi?ID=C78762&Mask=200>

- a. Provide the molecular formula of the bromoalkane.

1 mark

- b. What is the m/z ratio of the base peak?

1 mark

- c. Account for the two peaks present at m/z 136 and 138.

2 marks

- d. Provide a potential formula for the species responsible for the peak at m/z=29.

1 mark

Below shows information related to the four peaks observed on the ^1H -NMR spectrum for the bromoalkane.

Chemical shift (ppm)	Relative peak area	Peak splitting
1.0	3	3
1.8	3	2
1.9	2	5
4.1	1	6

- e. What information does the number of peaks on the ^1H -NMR spectrum provide about the molecule?

1 mark

- f. The peak with a chemical shift of 1.9 has a quintet peak splitting pattern. What information does this peak splitting pattern provide about the molecule?

1 mark

- g. Draw the structural formula for the bromoalkane that was analysed.

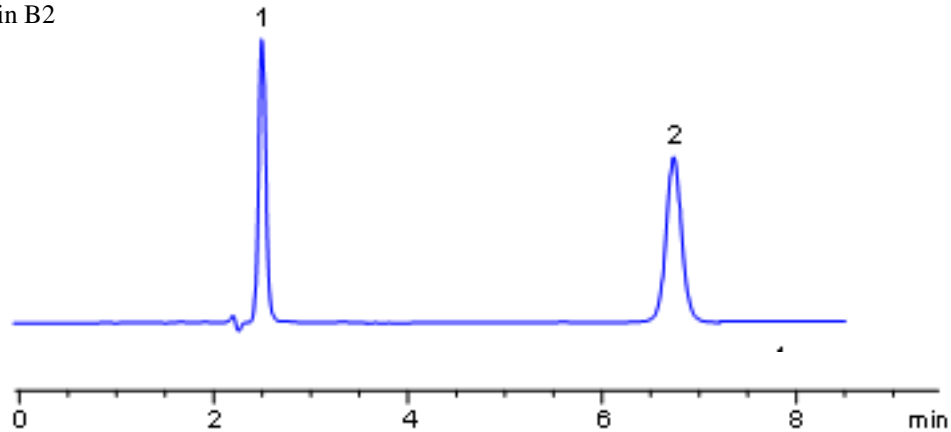
1 mark

 $1 + 1 + 2 + 1 + 1 + 1 + 1 = 8$ marks

Question 3 (8 marks)

A sample containing two water-soluble vitamins; vitamin C and vitamin B2 was analysed using High-Performance Liquid Chromatography (HPLC). The column used for analysis contained a non-polar stationary phase, and a polar mobile phase. The sample was analysed at 25°C, using a flowrate of 1.5 mL min⁻¹. The chromatogram obtained is shown below.

1. Vitamin C
2. Vitamin B2



<https://sielc.com/Application-HPLC-Separation-of-Vitamin-C-and-Vitamin-B2>

- a. What is the retention time of vitamin B2?

1 mark

- b. Based on the chromatogram, compare the polarities of vitamin C and vitamin B2.

2 marks

A brand of juice claims to contain a vitamin C concentration of 300 mg L^{-1} .

- c. Referring to the chromatogram above, describe how you could confirm if vitamin C is present in the juice sample.

2 marks

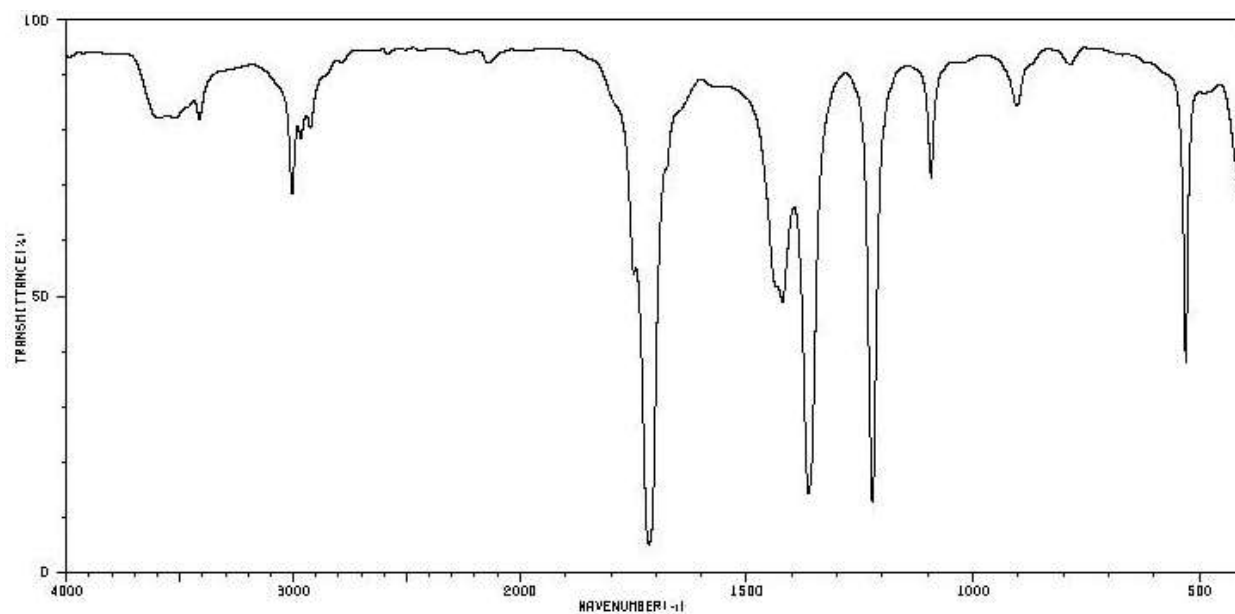
- d. Assuming vitamin C is present in the sample, describe the process that would allow you to determine the concentration of vitamin C in the juice using HPLC.

3 marks

1 + 2 + 2 + 3 = 8 marks

Question 4 (8 marks)

An organic compound with the molecular formula C_3H_6O was examined using multiple analytical techniques. The infrared (IR) spectrum for the compound is shown below.



https://www.chemicalbook.com/SpectrumEN_67-64-1_IR1.htm

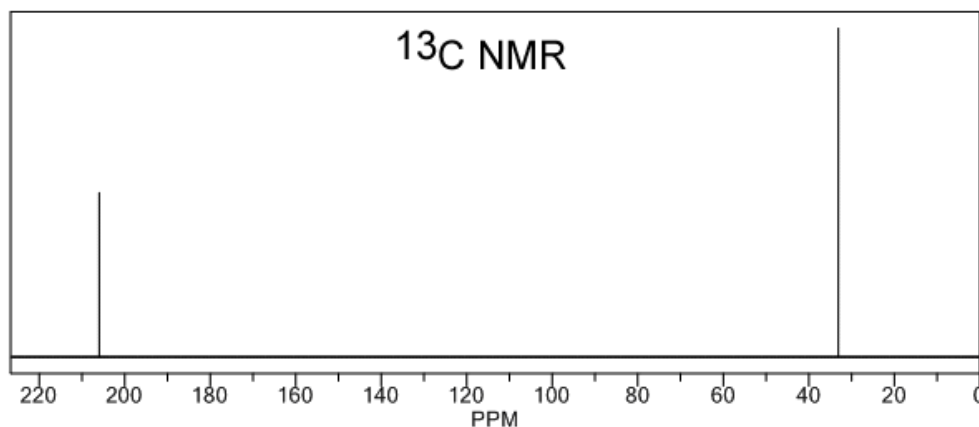
- a. Identify a piece of evidence from the spectrum that indicates the molecule is not an alcohol.

1 mark

- b. Identify the bond that could be responsible for the peak observed at 1720 cm^{-1} .

1 mark

The ^{13}C NMR spectra for the compound is shown below.



<https://scilearn.sydney.edu.au/OrganicSpectroscopy/NMRSpectraExamplesJS.cfm?ID=26&unit=>

- c. Identify the number of carbon environments in the compound.

1 mark

- d. Identify the type of carbon that caused the peak at 207 ppm.

1 mark

- e. Based on the information provided, draw the skeletal formula of the compound.



2 marks

The sample underwent further analysis using mass spectroscopy, and the following peaks were observed in the mass spectrum.

- f. Identify the fragment ions that caused the following peaks at the specified m/z ratios.

- i. Peak at m/z = 15

1 mark

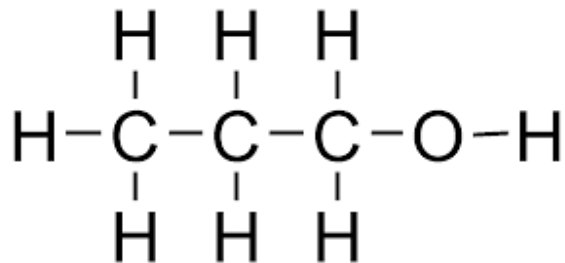
- ii. Peak at m/z = 43

1 mark

1 + 1 + 1 + 1 + 2 + 1 + 1 = 8 marks

Question 5 (6 marks)

Below shows the structural formula of a molecule of propanol.



Assuming a sample of propanol was analysed using ^1H NMR.

- a. Identify the number of peaks that would be present on the spectrum.

_____ 1 mark

- b. Identify the relative peak area ratios for propanol.

_____ 1 mark

One of the sets of peaks on the spectrum would show a sextet (6) peak splitting pattern.

- c. On the above molecule, label which hydrogen environment would split this way. Use an asterisk (*) to indicate the hydrogen.

1 mark

A structural isomer of propanol is propan-2-ol.

- d. Draw the structural formula for propan-2-ol in the space below.



1 mark

Assuming propan-2-ol were analysed using NMR spectroscopy.

- e. Complete the table for the data that you would expect to observe based on the information from the analytical technique.

Analytical technique	Information	Expected observed data for propan-2-ol
^{13}C NMR	Number of peaks	
^1H NMR	Number of peaks	

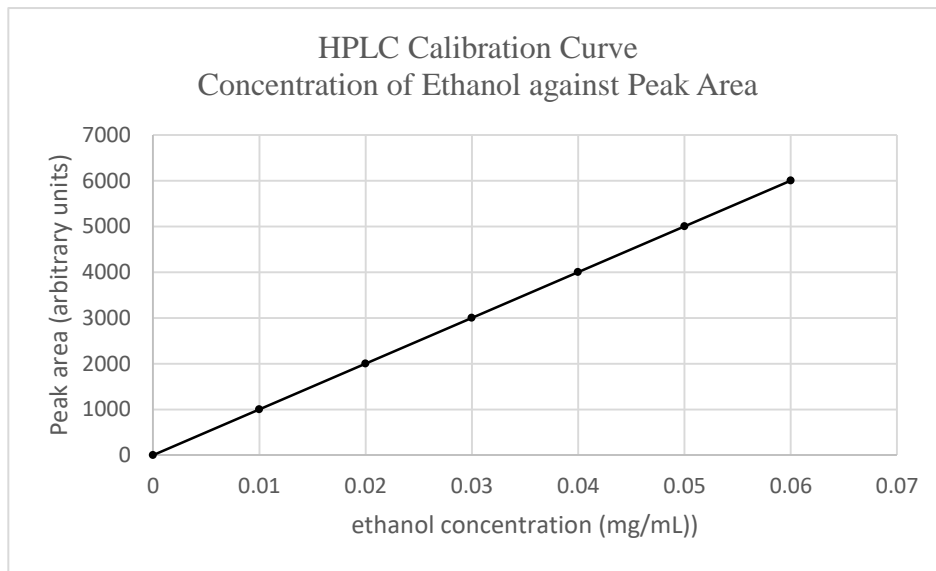
1 + 1 = 2 marks

1 + 1 + 1 + 1 + 2 = 6 marks

Question 6 (6 marks)

Blood alcohol concentration (BAC) is commonly used as a guide for the impact alcohol has on behaviour and cognitive abilities. Ethanol is the ingredient in drinking alcohol that causes these effects. A blood alcohol concentration above 0.05% (0.05 g/100 mL) is likely to put someone at risk of impaired concentration and judgement, therefore, driving a vehicle above this limit is illegal.

High Performance Liquid Chromatography (HPLC) can be used to measure the alcohol concentration of a blood sample. A calibration curve for a set of ethanol standards is shown below.



- a. What is meant by a set of 'ethanol standards'?

1 mark

- b. Following a roadside breathalyser test showing a reading above 0.05%, Steph is taken to the police station for a blood test to undergo further analysis.

A 1.00 mL sample of blood is collected, diluted to 20.00 mL, and the diluted sample is analysed using HPLC. The peak area obtained for the diluted blood sample was 3500 arbitrary units.

Determine whether Steph has a blood alcohol concentration above the legal driving limit.

3 marks

Methanol is a toxic alcohol that can also be produced in the fermentation process of making ethanol.

- c. Identify one analytical technique that could be utilised to distinguish between a sample of ethanol and a sample of methanol, and how the data obtained would differ for the two molecules.

2 marks

1 + 3 + 2 = 6 marks

END OF KEY TOPIC TEST