James Ruse Agricultural High School

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2024

HIGHER SCHOOL CERTIFICATE TRIAL EXAMINATION

Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- NESA approved calculators may be used
- A formula sheet and data sheet and Periodic Table are provided.
- For questions in Section II, **show all relevant working** in questions involving calculations.
- Proton NMR data is on page 28

Total marks 100

Section I -20 marks (pages 2-12)

- Attempt Questions 1– 20
- Allow about 35 minutes for this part

Section II -80 marks (pages 13-34)

- Attempt Questions 21–35
- Allow about 2 hours and 25 minutes for this part

This paper MUST NOT be removed from the examination room.

Section I

20 marks
Attempt Questions 1-20
Allow about 35 minutes for this section.
Mark your answers on the ANSWER grid in the Answer booklet on page 13.

Select the alternative A, B, C or D that best answers the question. Fill in the response oval completely.

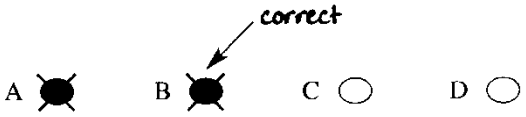
Sample: $2 + 4 =$ (A) 2 (B) 6 (C) 8 (D) 9

A ○ B ● C ○ D ○

If you think you have made a mistake, put a cross through the incorrect answer and fill in the new answer.

A ● B ⊗ C ○ D ○

If you change your mind and have crossed out what you consider to be the correct answer, then indicate the correct answer by writing the word **correct** and drawing an arrow as follows.



1. How many structural isomers have the formula C_3H_6BrCl?

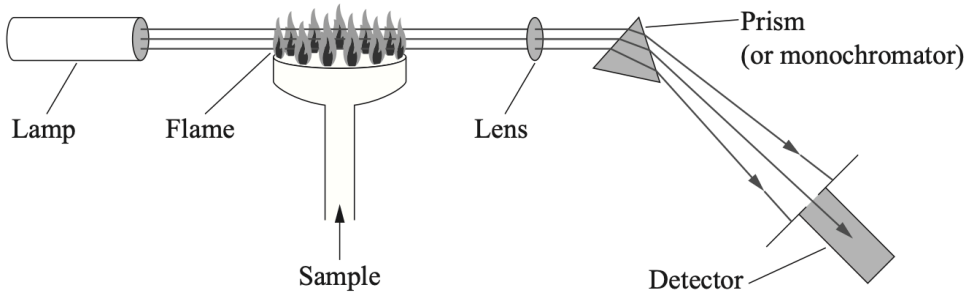
   A. 4

   B. 5

   C. 6

   D. 7

2. The diagram shows the components of an atomic absorption spectrophotometer.



   Which component is changed when testing a range of different elements?

   A. Lamp

   B. Flame

   C. Prism

   D. Detector

3. Which of the following has the best atom economy in the production of an organic molecule?

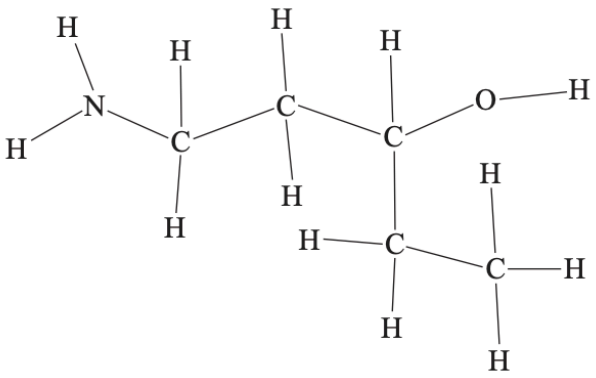
   A. complete combustion of propyne

   B. reaction of iodine, I_2, with propane

   C. reaction of bromine, Br_2, with propene

   D. reaction of 1-chloropropane with sodium hydroxide

4. Which option below names TWO functional groups in this molecule?



A. hydroxyl and amide

B. ethyl and amine

C. hydroxyl and ethyl

D. amine and hydroxyl

5. A chemist conducted a flame test experiment to determine the species of metal ion present in a solution from an unlabeled bottle. Upon testing, they witnessed a flame with a blue / grey colour.

Which of the following metal cations was responsible for this observation?

A. Ca^{2+}

B. Pb^{2+}

C. Mg^{2+}

D. Fe^{2+}

6. One traditional way in which cycad fruit has been made safe to consume is by placing the cut seeds in a basket and placing in a stream for several days.

Which concept is demonstrated by this process?

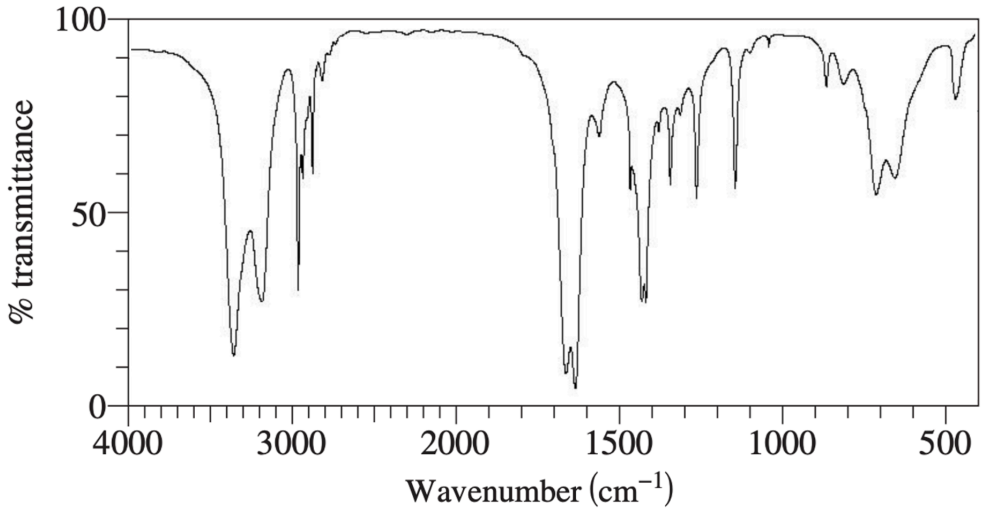
A. Open system

B. Dynamic equilibrium

C. Activation energy

D. Enthalpy

7. The infrared spectrum has been provided for an unknown organic compound.



What functional group is present in this compound?

A. Ester

B. Amine

C. Amide

D. Carboxylic acid

8. Consider the molecular structure below:

$$CH_3 - CH_2 - COO - CH_2 - CH_3$$

Which of the following identifies the compound and the substances that could be used to synthesis it?

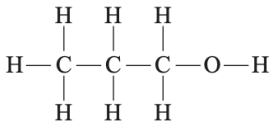
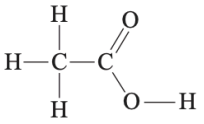
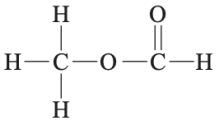
A. propylethanoate: propan-1-ol and ethanoic acid

B. propylethanoate: ethanol and propanoic acid

C. ethylpropanoate: ethanoic acid and propan-1-ol

D. ethylpropanoate: propanoic acid and ethanol

9. The following table provides information about three organic compounds X, Y and Z.

Compound	Structural formula	Molar mass ($g\ mol^{-1}$)	Boiling point (°C)
X		60	97
Y		60	118
Z		60	?

Which of the following is the best estimate for the boiling point of compound Z?

A. 32°C

B. 101 °C

C. 114 °C

D. 156 °C

10. The molar heat of combustion of glucose, $C_6H_{12}O_6$, is 2805 kJ mol^{-1}.
How much energy is released when 1 mole of oxygen is consumed in the reaction?

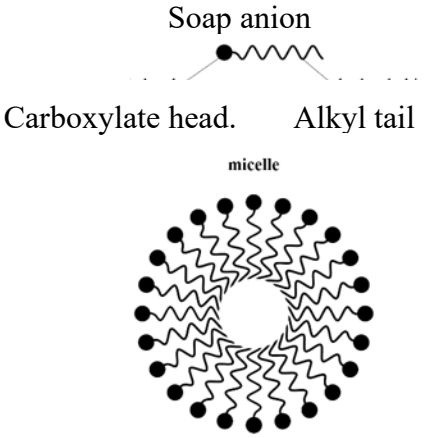
A. 467.5 kJ

B. 1402 kJ

C. 2805 kJ

D. 5610 kJ

11. Interactions between soap anions and water solvent molecules can result in the formation of micelles as shown in the diagram below.



Which alternative below correctly describes the interactions in the micelle

A. The polar alkyl tails line up inside the micelle experiencing dispersion forces and the non-polar carboxylate heads on the outside of the micelle form ion-dipole interactions with the water solvent.

B. The polar alkyl tails line up inside the micelle experiencing ion-dipole interactions and the non-polar carboxylate heads on the outside of the micelle experience dispersion forces with the water solvent.

C. The non-polar alkyl tails line up inside the micelle experiencing dispersion forces and the polar carboxylate heads on the outside of the micelle form ion-dipole interactions with the water solvent.

D. The non-polar alkyl tails line up inside the micelle forming ion-diploe interactions and the polar carboxylate heads on the outside of the micelle experience dispersion forces with the water solvent.

12. Ethanol can be prepared by the fermentation of glucose.

What volume of carbon dioxide gas is produced when 9.00 g of glucose completely ferments at 298K?

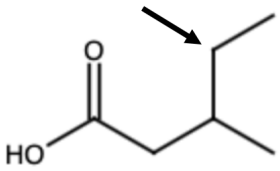
A. 1.14 L

B. 1.24 L

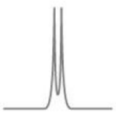
C. 2.27 L

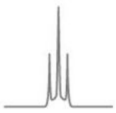
D. 2.48 L

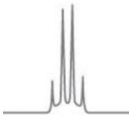
13. The skeletal formula for an organic compound is given.

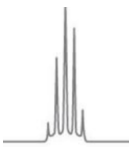


Which of the following shows the correct splitting pattern in the proton NMR spectrum for the indicated environment.

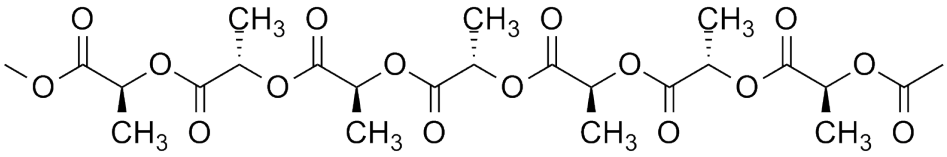
A. 

B. 

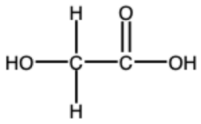
C. 

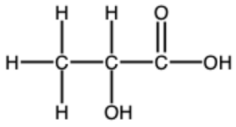
D. 

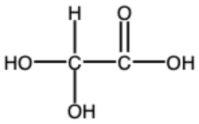
14. Consider the section of a polyester below:

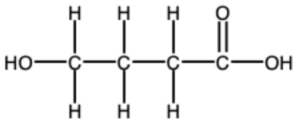


Which of the following is a monomer of this polymer?

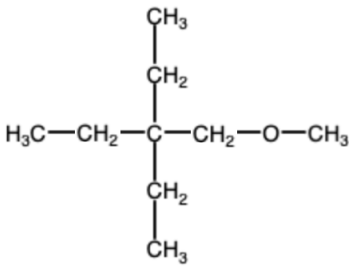
A. 

B. 

C. 

D. 

15. Consider the structural formula of the molecule presented.



How many unique signals would be presented in the ^{13}C NMR spectrum?

A. 2

B. 3

C. 4

D. 5

16. A pair of unlabeled beakers contains separate solutions of lead and barium ions.

Which of the following methods could be used to confirm the presence of both ions?

A. Performing a flame test and recording the colours observed.

B. Adding potassium hydroxide and comparing the precipitate colours.

C. Adding sodium sulfate and comparing the precipitate colours.

D. Adding magnesium chloride and comparing the precipitate colours.

17. How many moles of magnesium hydroxide will dissolve in 1.0 L water?

A. 1×10^{-6}

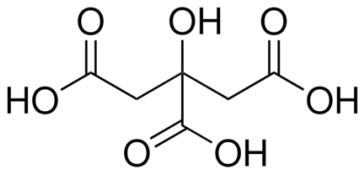
B. 2×10^{-6}

C. 1×10^{-4}

D. 2×10^{-4}

18. An equal volume of hydrochloric acid solution and a citric acid solution were found to have the same pH.

The structure of citric acid is given below.



Which statement is correct concerning the citric acid solution?

A. Both solutions contain the same number of intact acid molecules.

B. Both solutions contain the same number of ions.

C. The hydrochloric acid solution has a higher concentration of hydrogen ions.

D. The citric acid has a higher concentration of intact acid molecules than hydrochloric acid.

19. A student diluted a solution of a strong acid by mixing 25 ml of acid with 75 ml of water.
If the original acid solution had a pH of 3.1, what is the final pH of the acid solution after dilution?

A. 3.7

B. 4.1

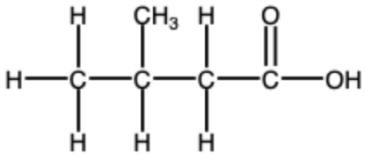
C. 4.7

D. 5.1

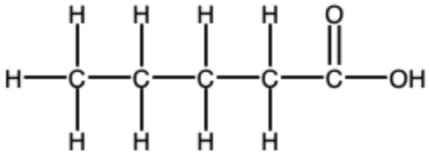
20. Which molecule is consistent with the series of observations provided?

Source	*Information*
Chemical test	Reacts with sodium carbonate powder to produce gas.
Infrared spectrum	3 key signals: Broad signal at 3480 cm^{-1} Strong signal at 3150 cm^{-1} Strong signal at 1720 cm^{-1}
Proton NMR	4 unique signals: 1 H singlet 2 H doublet 1 H multiplet 3 H doublet

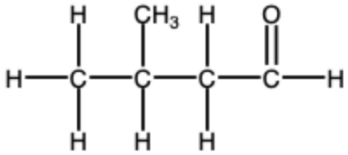
A.



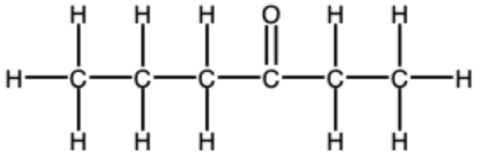
B.



C.



D.



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Starting from the left, please write your student number NEATLY in the boxes.

Mark

JRAHS Chemistry Trial 2024

Section I Multiple Choice Answers

1.	A ○	B ○	C ○	D ○
2.	A ○	B ○	C ○	D ○
3.	A ○	B ○	C ○	D ○
4.	A ○	B ○	C ○	D ○
5.	A ○	B ○	C ○	D ○
6.	A ○	B ○	C ○	D ○
7.	A ○	B ○	C ○	D ○
8.	A ○	B ○	C ○	D ○
9.	A ○	B ○	C ○	D ○
10.	A ○	B ○	C ○	D ○
11.	A ○	B ○	C ○	D ○
12.	A ○	B ○	C ○	D ○
13	A ○	B ○	C ○	D ○
14.	A ○	B ○	C ○	D ○
15.	A ○	B ○	C ○	D ○
16.	A ○	B ○	C ○	D ○
17.	A ○	B ○	C ○	D ○
18.	A ○	B ○	C ○	D ○
19.	A ○	B ○	C ○	D ○
20.	A ○	B ○	C ○	D ○

Section II

80 marks
Attempt Questions 21-35
Allow about 2 hours and 25 minutes for this section.

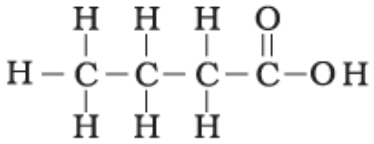
Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.

Show all relevant working in questions involving calculations.

Extra writing space is provided at the back of this booklet. If you use this space, clearly indicate which question you are answering.

Question 21 (2 marks)

Butanoic acid is shown below.

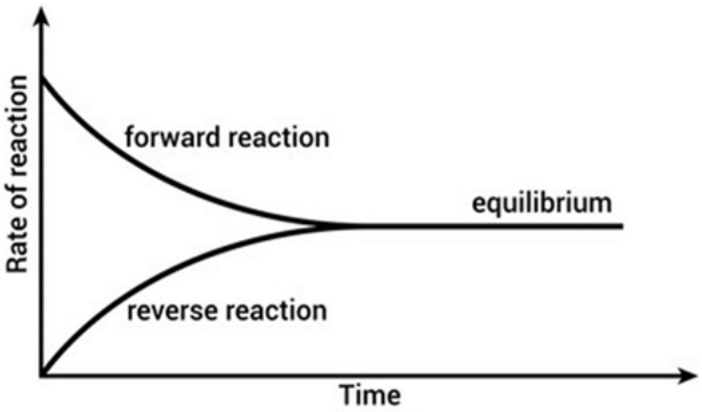


Draw in the boxes below, different isomers of butanoic acid.

A chain isomer	
A functional group isomer	

Question 22 (2 marks)

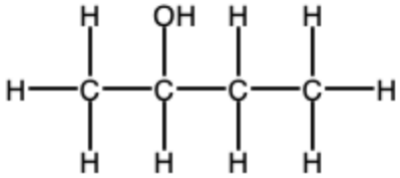
The rates of reaction for a closed system are shown below:



Annotate the graph to show the rates of reaction when the same initial concentrations are used in the same reaction vessel in the presence of a catalyst. **2**

Question 23 (2 marks)

Describe a chemical test that could be used to identify the functional group present in the following molecule and provide a relevant observation to confirm its presence.



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Question 24 (5 marks)

A 0.2845 g sample of impure sodium carbonate required 22.65 mL of an HCl solution for titration. A 0.2204 g sample of pure calcium carbonate required 20.06 mL of the HCl solution of the same concentration.

(a) Write a balanced chemical equation for the sodium carbonate reaction. **1**

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(b) What is the percentage of sodium carbonate in the sample? **4**

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Question 25 (4 marks)

(a) Justify the use of sodium hydrogen carbonate in cleaning up acid spills in the laboratory. **2**

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(b) In Arrhenius' laboratory in 1884, would he have advised the use of this same substance clean the acid spill? Give TWO reasons for your answer. **2**

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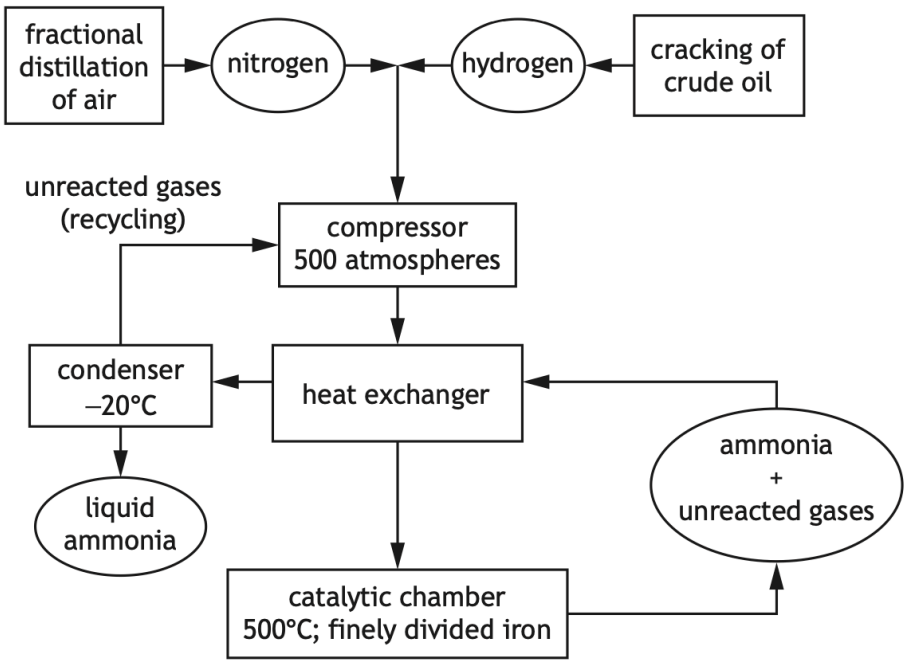
Question 26 (4 marks)

The Haber process is still currently used for the industrial production of ammonia as shown.

$$3H_2\,(g) + N_2\,(g) \rightarrow 2NH_3\,(g),\ \Delta H = -92.4\ \text{kJ mol}^{-1}$$

In a conventional chemical plant, an efficient process is achieved through the use of an iron catalyst with high pressure and low temperature conditions.
An outline for the chemical process that takes place in this plant is given in the diagram.



With reference to the diagram, identify THREE design features, not those outlined above, and explain the economic benefits they provide. **4**

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Question 27 (6 marks)

The biofuel 2-methylpropan-1-ol can be produced from proteins. 2-methylpropan-1-ol can be used in petrol engines and has a heat of combustion of 36.1 kJ g^{-1} at 298 K.

(a) Account for the difference between the heat of combustion of octane (5470 kJ mol^{-1}) and 2-methylpropan-1-ol. **3**

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(b) A small fuel burner containing 2.36 g of 2-methylpropan-1-ol was placed directly under a beaker containing 500.0 g of water and standard laboratory conditions.

Calculate the maximum temperature that the water could reach if the contents of the fuel burner underwent complete combustion. The initial T of the water was 298K. **3**

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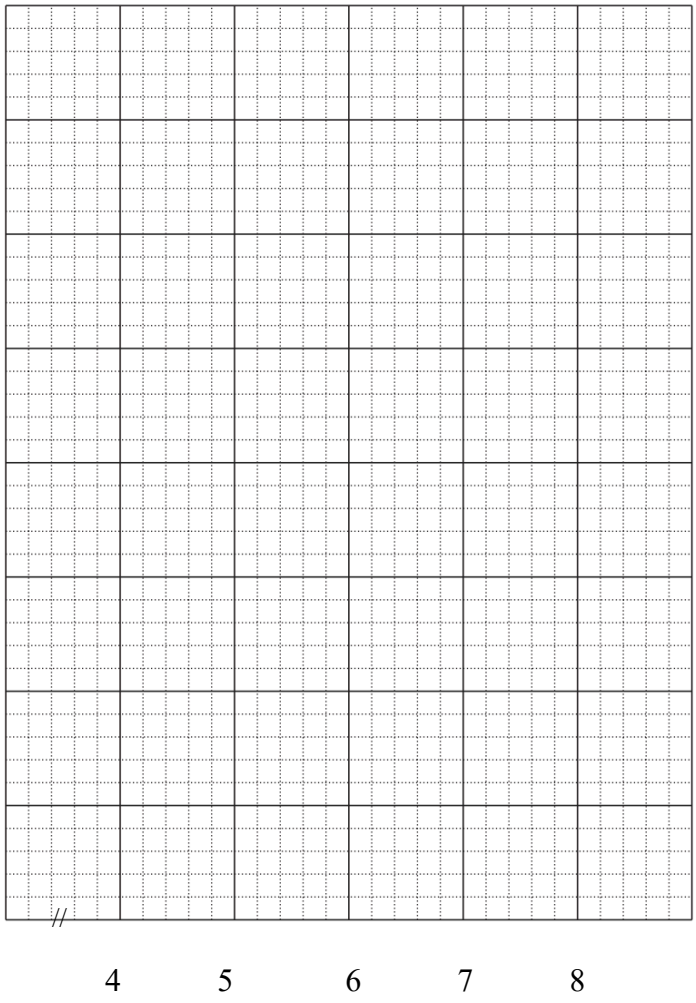
Question 28 (8 marks)

The solubility of a series of alcohols at 298K is given in the table below.

Alcohol	*Solubility in water (g L^{-1})*
Butan-1-ol	73
Pentan-1-ol	22
Heptan-1-ol	2.0
Octan-1-ol	0.5

(a) Plot the number of carbon atoms in the alcohols against solubility. **3**



Question 28 continued on page 21

(b) Estimate the solubility of hexan-1-ol in g L^{-1}. **1**

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(c) Use the data to explain the trend in the solubilities of these alcohols. Draw a relevant diagram to support your answer. **4**

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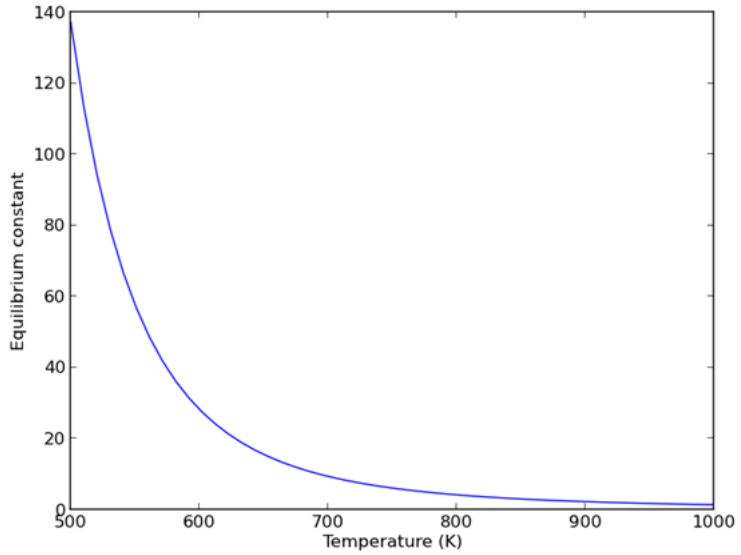
Question 29 (7 marks)

The water gas shift reaction can be used to produce hydrogen gas and consume toxic carbon monoxide:

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

The equilibrium constant for this reaction is highly temperature sensitive:



(a) Justify whether this reaction is exothermic or endothermic. **3**

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Question 29 continued on page 23

(b) 6.7×10^{-3} mol CO, 4.5 mol of H_2O and 0.4 mol of CO_2 were placed into a 5.0 L sealed reaction vessel at 500 K.

Calculate the concentration of H_2 at equilibrium. **4**

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Question 30 (4 marks)

A beaker containing pieces of copper and silver, along with a solution of their ions, is at equilibrium at t = 0:

$$Cu(s) + 2Ag^{+}(aq) \rightleftharpoons 2Ag(s) + Cu^{2+}(aq)$$

(a) Identify the effect on equilibrium position of adding another piece of copper metal to the beaker. **1**

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(b) Water is added to double the volume of the solution at t = 1, immediately reducing the intensity of the blue colour. The system then re-establishes equilibrium at t = 2.

Account for changes in appearance of the beaker contents between t = 1 and t = 2. **3**

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Question 31 (5 marks)

2.53 g of KSCN was dissolved in a 250.0 mL volumetric flask. It was added to 125 mL of 0.108 mol L^{-1} of lead (II) acetate. 2.19 g of lead thiocyanate precipitate was formed. Calculate the value of the Ksp for lead thiocyanate. **5**

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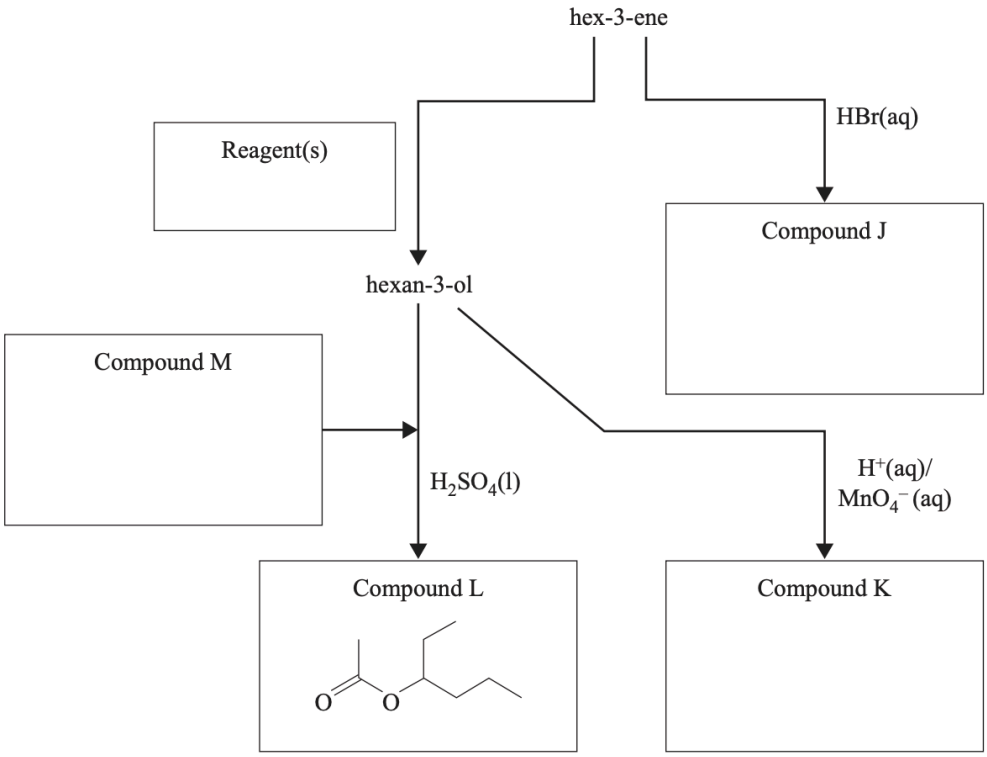
Question 32 (8 marks)
Below is a reaction pathway beginning with hex-3-ene.



(a) Justify the identification of compounds J, M and K. **6**

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(b) Draw an equation, using structural formulae, for the conversion of hex-3-ene to hexan-3-ol indicating the reagent(s) required. **2**

Question 33 (9 marks)

A student performs an experiment to determine the concentration of a solution of hypochlorous acid, HOCl (Ka = 3.5×10^{-8}). The student starts with 25.00 mL of the acid in a conical flask and titrates it against a standardised solution of sodium hydroxide with a concentration of 1.47 mol L^{-1}. The equivalence point is reached after addition of 34.23 mL of NaOH.

The equation for the reaction is $HOCl(aq) + OH^-(aq) \rightarrow OCl^-(aq) + H_2O(l)$

(a) Calculate the concentration of the HOCl. **2**

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(b) Determine the pH of the solution in the conical flask after the addition of 28.55 mL of NaOH. **5**

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Question 33 continued on page 27

(d) The actual concentration of the HOCl is found to be 1.85 mol L^{-1}.

Qualitatively discuss whether the following error may have contributed to the student's results.

The student rinsed the burette with distilled water instead of NaOH solution before filling it with NaOH. **2**

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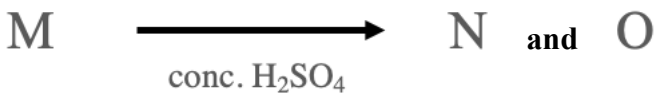
You may use this proton NMR data to answer Question 34.

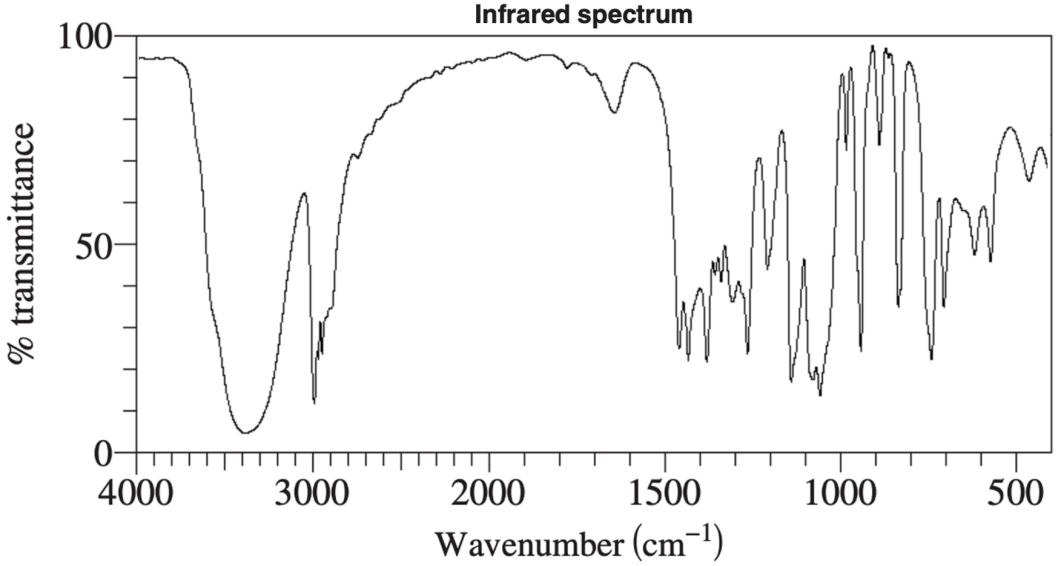
Type of proton		δ/ppm
$Si(CH_3)_4$	(TMS)	0
R—CH_3		0.7–1.3
R—CH_2—R		1.2–1.5
R—CHR_2		1.5–2.0
H_3C—CO—	(aldehydes, ketones or esters)	2.0–2.5
—CH—CO—	(aldehydes, ketones or esters)	2.1–2.6
H_3C—O—	(alcohols or esters)	3.2–4.0
—CH—O—	(alcohols or esters)	3.3–5.1
R_2—CH_2—O—	(alcohols or esters)	3.5–5.0
R—OH		1–6
R_2C=CHR	(alkene)	4.5–7.0
R—CHO	(aldehyde)	9.4–10.0
R—COOH		9.0–13.0

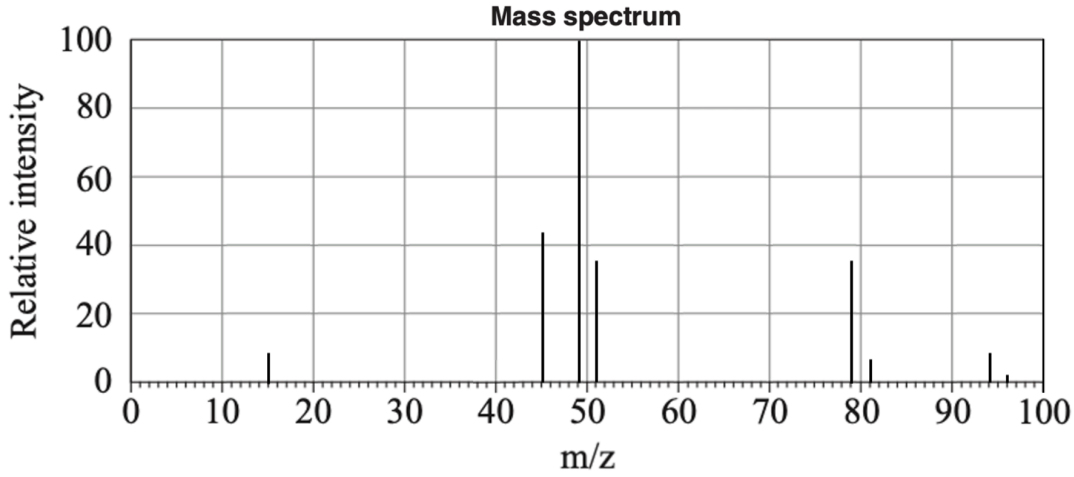
Question 34 (9 marks)

A halogenated organic compound M with a molar mass of 94.54 g mol^{-1} is known to produce TWO products, compounds N and O according to the reaction provided.



A chemist obtained the following spectral data for compound M.

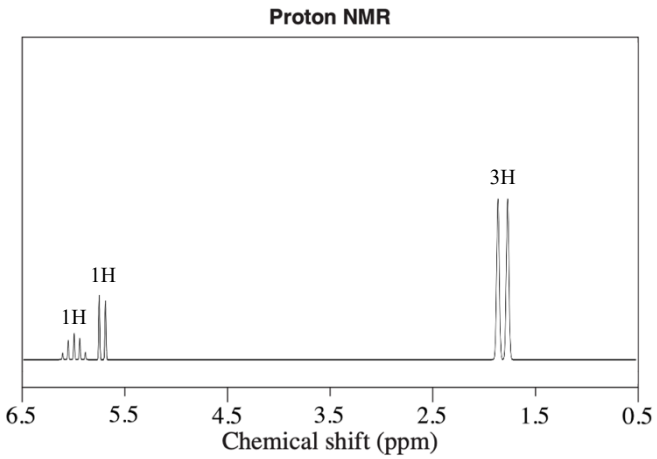


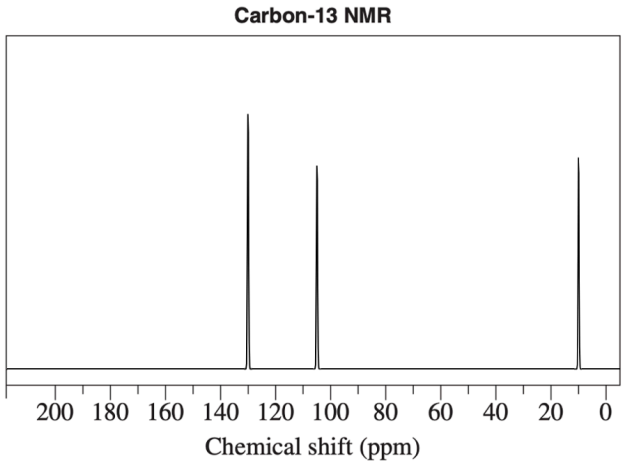


Question 34 continued on page 30

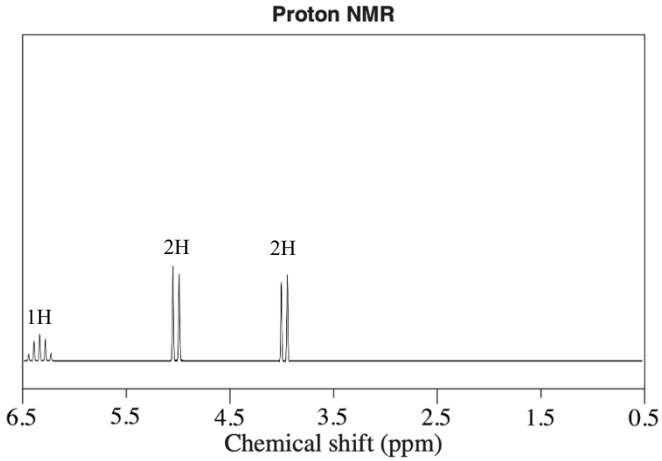
The following spectroscopic data was also obtained for the products.

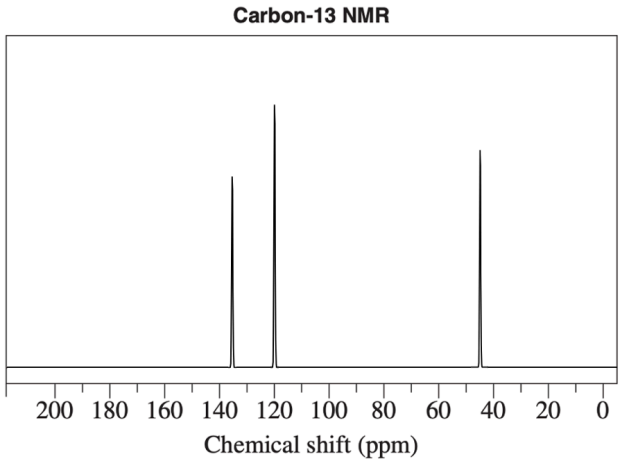
Product N





Product O





In the space provided, draw the structure and name each of the compounds, M, N, and O. Justify your answer with reference to all the information provided.

Compound M	Compound N	Compound O
Name: …… ……	Name: …… ……	Name: …… ……

Question 34 continued on page 31

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Question 35 (5 marks)

A commercial disinfectant is reported to have two active ingredients, hydrogen peroxide (H_2O_2) and peracetic acid (CH_3COOOH) at concentrations of 4 % and 12 % respectively. A titration experiment was carried out to confirm the accuracy of these values.

A 10.00 mL sample of the disinfectant solution was transferred to a 100 mL volumetric flask that was filled with demineralised water. 20.00 mL of the resultant solution was transferred to a conical flask containing 5.000 mL of 3.000 mol L^{-1} solution of sulfuric acid and titrated with a 0.2491 mol L^{-1} cerium sulfate solution.

Equation 1 – $H_2O_2\ (aq) + 2\ Ce(SO_4)_2\ (aq) \rightarrow Ce_2(SO_4)_3\ (aq) + H_2SO_4\ (aq) + O_2\ (g)$

The following results were obtained.

Titre	*Volume of $Ce(SO_4)_2$ added (mL)*
1	21.65
2	21.15
3	21.20
4	21.30

Immediately after, 5.000 mL of a 20 % (w/v) potassium iodide solution was added to the conical flask containing titre 4. This was done to react with the sulfuric acid to produce hydroiodic acid that would then reduce the peracetic acid present in the sample and form iodine.

Equation 2 – $2\ KI\ (aq) + H_2SO_4\ (aq) \rightarrow 2\ HI\ (aq) + K_2SO_4\ (aq)$

Equation 3 – $CH_3COOOH\ (aq) + 2\ HI\ (aq) \rightarrow I_2\ (aq) + CH_3COOH\ (aq) + H_2O\ (l)$

The resultant iodide solution was titrated with a 0.2250 mol L^{-1} solution of sodium thiosulfate and it was found that a titre volume of 27.35 mL was required to reach the end point.

Equation 4 – $I_2\ (aq) + 2\ Na_2S_2O_3\ (aq) \rightarrow Na_2S_4O_6\ (aq) + 2\ NaI\ (aq)$

Question 35 continued on page 33

Do the results of this experiment support the reported concentration values? Support your answer with calculations. **5**

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End of Exam

Part B extra writing space
If you use this space, clearly indicate which question you are answering here AND on your paper.

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JRAHS Chemistry Trial 2024

Section I Multiple Choice Answers

1.	A ○	B ■	C ○	D ○
2.	A ■	B ○	C ○	D ○
3.	A ○	B ○	C ■	D ○
4.	A ○	B ○	C ○	D ■
5.	A ○	B ■	C ○	D ○
6.	A ■	B ○	C ○	D ○
7.	A ○	B ○	C ■	D ○
8.	A ○	B ○	C ○	D ■
9.	A ■	B ○	C ○	D ○
10.	A ■	B ○	C ○	D ○
11.	A ○	B ○	C ■	D ○
12.	A ○	B ○	C ○	D ■
13	A ○	B ○	C ○	D ■
14.	A ○	B ■	C ○	D ○
15.	A ○	B ○	C ○	D ■
16.	A ○	B ■	C ○	D ■
17.	A ○	B ○	C ■	D ○
18.	A ○	B ○	C ○	D ■
19.	A ■	B ○	C ○	D ○
20.	A ■	B ○	C ○	D ○

1. How many structural isomers have the formula C_3H_6BrCl?

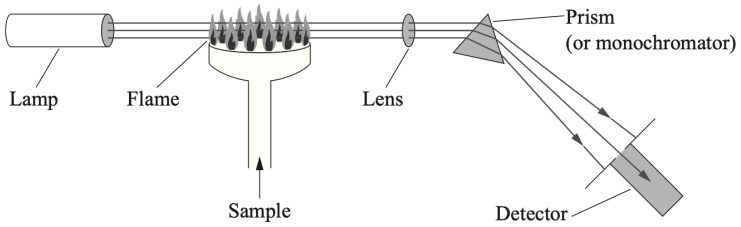
A. 4

B. 5

C. 6

D. 7

2. The diagram shows the components of an atomic absorption spectrophotometer.



Which component is changed when testing a range of different elements?

A. Lamp

B. Flame

C. Prism

D. Detector

3. Which of the following has the best atom economy in the production of an organic molecule?

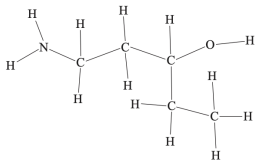
A. complete combustion of propyne

B. reaction of iodine, I_2, with propane

C. reaction of bromine, Br_2, with propene

D. reaction of 1-chloropropane with sodium hydroxide

4. Which option below names TWO functional groups in this molecule?



A. hydroxyl and amide

B. ethyl and amine

C. hydroxyl and ethyl

D. amine and hydroxyl

5. A chemist conducted a flame test experiment to determine the species of metal ion present in a solution from an unlabeled bottle. Upon testing, they witnessed a flame with a blue / grey colour.

Which of the following metal cations was responsible for this observation?

A. Ca^{2+}

B. Pb^{2+}

C. Mg^{2+}

D. Fe^{2+}

6. One traditional way in which cycad fruit has been made safe to consume is by placing the cut seeds in a basket and placing in a stream for several days.

Which concept is demonstrated by this process?

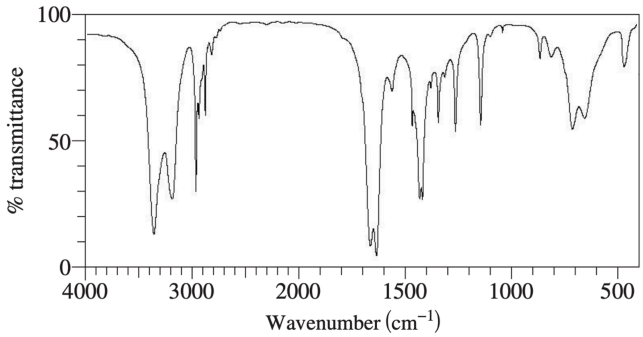
A. Open system

B. Dynamic equilibrium

C. Activation energy

D. Enthalpy

7. The infrared spectrum has been provided for an unknown organic compound.



What functional group is present in this compound?

A. Ester

B. Amine

C. Amide

D. Carboxylic acid

8. Consider the molecular structure below:

$CH_3 – CH_2 – COO – CH_2 – CH_3$

Which of the following identifies the compound and the substances that could be used to synthesis it?

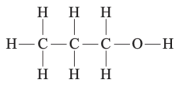
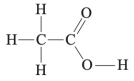
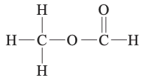
A. propylethanoate: propan-1-ol and ethanoic acid

B. propylethanoate: ethanol and propanoic acid

C. ethylpropanoate: ethanoic acid and propan-1-ol

D. ethylpropanoate: propanoic acid and ethanol

9. The following table provides information about three organic compounds X, Y and Z.

Compound	Structural formula	Molar mass (g mol^{-1})	Boiling point (°C)
X		60	97
Y		60	118
Z		60	?

Which of the following is the best estimate for the boiling point of compound Z?

A. **32 °C**

B. 101 °C

C. 114 °C

D. 156 °C

10. The molar heat of combustion of glucose, $C_6H_{12}O_6$, is 2805 kJ mol^{-1}.
How much energy is released when 1 mole of oxygen is consumed in the reaction?

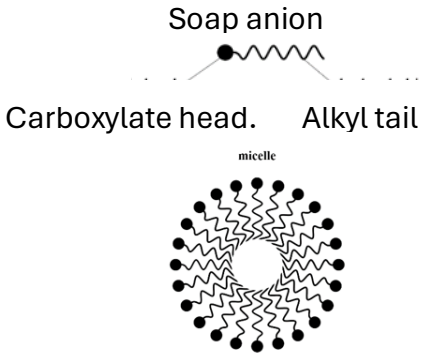
A. **467.5 kJ**

B. 1402.5 kJ

C. 2805 kJ

D. 5610 kJ

11. Interactions between soap anions and water solvent molecules can result in the formation of micelles as shown in the diagram below.



Which alternative below correctly describes the interactions in the micelle?

A. The polar alkyl tails line up inside the micelle experiencing dispersion forces and the non-polar carboxylate heads on the outside of the micelle form ion-dipole interactions with the water solvent.

B. The polar alkyl tails line up inside the micelle experiencing ion-dipole interactions and the non-polar carboxylate heads on the outside of the micelle experience dispersion forces with the water solvent.

C. **The non-polar alkyl tails line up inside the micelle experiencing dispersion forces and the polar carboxylate heads on the outside of the micelle form ion-dipole interactions with the water solvent.**

D. The non-polar alkyl tails line up inside the micelle forming ion-diploe interactions and the polar carboxylate heads on the outside of the micelle experience dispersion forces with the water solvent.

12. Ethanol can be prepared by the fermentation of glucose.

What volume of carbon dioxide gas is produced when 9.00 g of glucose completely ferments at 298K?

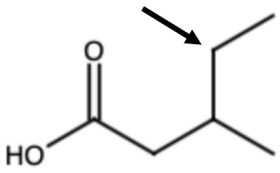
A. 1.14 L

B. 1.24 L

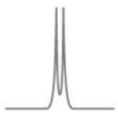
C. 2.27 L

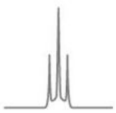
D. 2.48 L

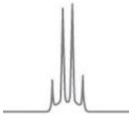
13. The skeletal formula for an organic compound is given.



Which of the following shows the correct splitting pattern in the proton NMR spectrum for the indicated environment?

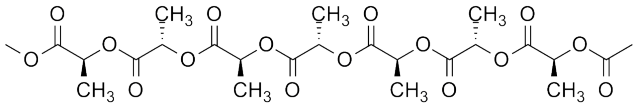
A. 

B. 

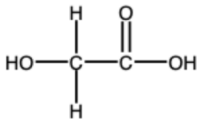
C. 

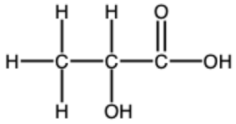
D. 

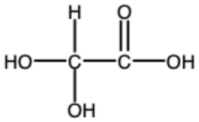
14. Consider the section of a polyester below:

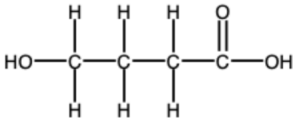


Which of the following is a monomer of this polymer?

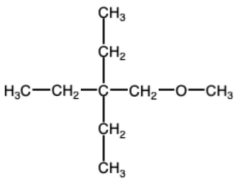
A. 

B. 

C. 

D. 

15. Consider the structural formula of the molecule presented.



How many unique signals would be presented in the ^{13}C NMR spectrum?

A. 2

B. 3

C. 4

D. 5

16. A beaker contains a mixture of lead and silver ions.

Which of the following methods could be used to confirm the presence of both ions?

A. Performing a flame test and recording the colours observed.

B. Adding potassium hydroxide and comparing the precipitate colours.

C. Adding sodium sulfate and comparing the precipitate colours.

D. Adding magnesium bromide and comparing the precipitate colours.

17. How many moles of magnesium hydroxide will dissolve in 1.0 L water?

A. 1×10^{-6}

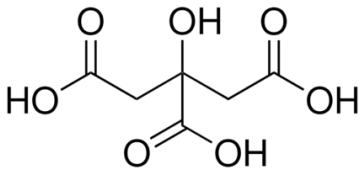
B. 2×10^{-6}

C. 1×10^{-4}

D. 2×10^{-4}

18. An equal volume of hydrochloric acid solution and a citric acid solution were found to have the same pH.

The structure of citric acid is given below.



Which statement is correct concerning the citric acid solution?

A. Both solutions contain the same number of intact acid molecules.

B. Both solutions contain the same number of ions.

C. The hydrochloric acid solution has a higher concentration of hydrogen ions.

D. The citric acid has a higher concentration of intact acid molecules than hydrochloric acid.

19. A student diluted a solution of a strong acid by mixing 25 ml with 75 ml of water. If the original acid solution had a pH of 3.1, what is the final pH of the acid solution after dilution?

A. 3.7

B. 4.1

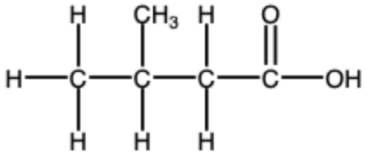
C. 4.7

D. 5.1

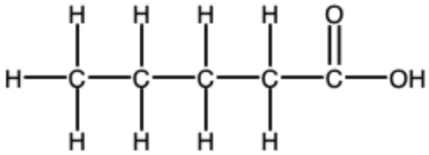
20. Which molecule is consistent with the series of observations provided?

Source	*Information*
Chemical test	Reacts with sodium carbonate powder to produce gas.
Infrared spectrum	3 key signals: Broad signal at 3480 cm^{-1} Strong signal at 3150 cm^{-1} Strong signal at 1720 cm^{-1}
Proton NMR	4 unique signals: 1 H singlet 2 H doublet 1 H multiplet 3 H doublet

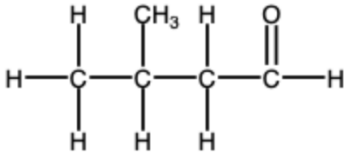
A.



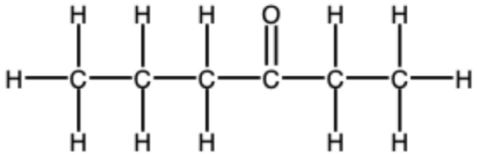
B.



C.



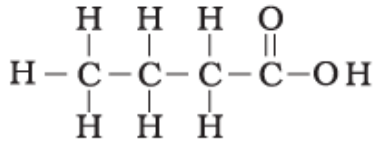
D.



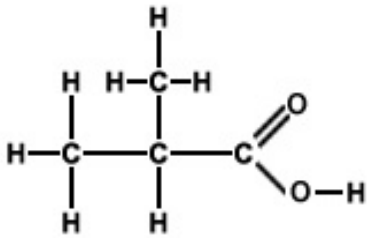
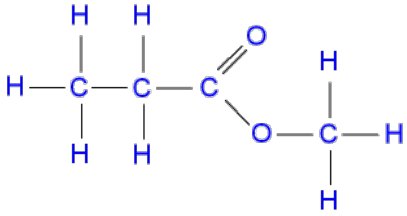
Median 73 **Mean 71.5**

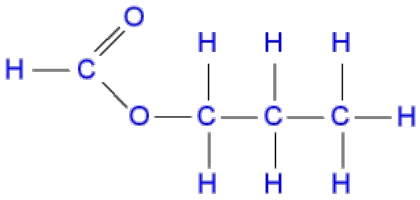
Question 21 (2 marks)

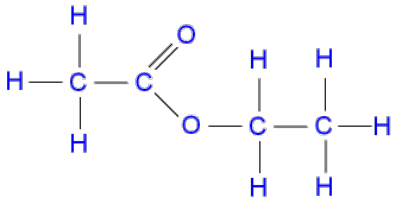
Butanoic acid is shown below.



Draw in the boxes below, different isomers of butanoic acid. **2**

A chain isomer	
A functional group isomer	

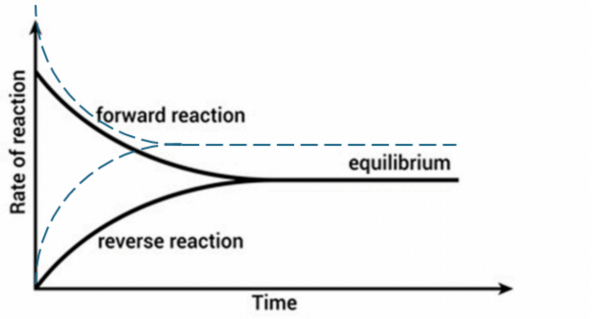




Marking Criteria	*Mark(s)*
• Two correct isomers drawn methyl propanoic acid and one of • Options for functional group isomer	2
• One correct isomer drawn	1

Question 22 (2 marks)

The rates of reaction for a closed system are shown below:



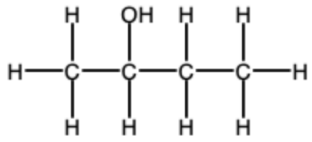
Annotate the graph to show the rates of reaction when the same initial concentrations are used in the same reaction vessel in the presence of a catalyst. **2**

Marking Criteria	*Mark(s)*
• Correctly annotates graph showing higher rate and reaching equilibrium faster	2
• Annotates graph showing higher rate or reaching equilibrium faster	1

NB: Many students were able to show the equilibrium reached faster with the use of a catalyst BUT were not able to show that the rate of both the forward and reverse reaction increased as well.

Question 23 (2 marks)

Describe a chemical test that could be used to identify the functional group present in the following molecule and provide a relevant observation to confirm its presence. **2**



Sample answer:

Potassium permanganate could be used to identify the presence of the alcohol functional group in this molecule. This reagent will react with alcohols, such as the secondary alcohol present in this case to produce a ketone. The magenta colour of the solution will disappear to provide a colourless solution as the reagent is consumed, indicating that an alcohol functional group was present.

NB : Other acceptable tests were : 1. Add sodium metal and there is a reaction producing hydrogen gas. 2 Add Lucas reagent zinc chloride and hydrochloric acid and a cloudy solution forms after a few minutes. Must state specific reagent for Lucas Reagent test.

Esterification is not a test for an -OH group in alcohol but if correct result(fruity smell) then O mark for correct result.

Marking Criteria	*Mark(s)*
• Provides an appropriate chemical test and the relevant observation.	2
• Provides some correct relevant information.	1

Question 24 (6 marks)

A 0.2845 g sample of impure sodium carbonate required 22.65 mL of an hydrochloric acid solution for titration. A 0.2204 g sample of pure calcium carbonate required 20.06 mL of the hydrochloric acid solution of the same concentration.

(a) Write a balanced chemical equation for the sodium carbonate reaction. **1**

Sample Answer : Na_2CO_3 (s) + 2HCl(aq) → 2NaCl (aq) + CO_2(g) + H_2O(l)

NB: Must be correct balanced equation with states and solid sodium carbonate as stated in information provided. H_2CO_3 not accepted as a product.

Marking Criteria	*Mark(s)*
• Correct balanced chemical equation including states	1

(b) What is the percentage of sodium carbonate in the sample? **4**

***Calculation of the concentration of standard HCl*:**

mol Ca CO_3 = m/MM = 0.2204/ 40.1 + 12.01 + 3(16) = 2.20 x 10^{-3}

mole HCl = 2 x mole $CaCO_3$

= 2 x 2.20 x 10^{-3} = 4.40 x 10^{-3}

cHCl = n/V = 4.40 x 10^{-3}/ 0.02006 = 0.2195 $molL^{-1}$

Analysis of the unknown sodium carbonate sample

Mol HCl = c x V = 0.2195 x 0.02265 = 4.97 x 10^{-3}

mole Na_2CO_3 = ½ x mol HCl = 2.4858 x 10^{-3}

mass Na_2CO_3 = mole x MM Na_2CO_3 =2.4858 x 10^{-3} x (2 (22.99) + 12.01 + 3 (16.00)

= 0.2634 g

% purity = 0.2634/0.2845 x 100 = 92.6 %

NB: Must use all the data provided in the Q to answer the Q. Calcium carbonate titration data is required to determine the [HCl] then this is used to determine the n(Na_2CO_3) in the unknown and then converted to mass then %. Must show all working clearly.

Marking Criteria	*Mark(s)*
• Correct calculation of % purity clearly showing all working	4
• One significant error in calculation or unclear working	3
• Some relevant calculations	2
• One correct calculation	1

Question 25 (4 marks)

(a) Justify the use of sodium hydrogen carbonate in cleaning up acid spills in the laboratory. **2**

Sample Answer : *Sodium hydrogen carbonate, $NaHCO_3$, since it is a weak base, a proton acceptor and it can neutralize the acid spill even if an excess is used . Visual indication of the completion of neutralization is provided by the stopping of the fizzing reaction.*

NB: One correct chemical reason – weak base and one practical reason eg. Can see when reaction reaches completion as bubbling of carbon dioxide produced stops OR cheap OR reacts as a solid with liquid therefore preventing spread of the spill. **Safety not enough as all neutralisation reactions produce safe products -salt and water.**

Marking Criteria	*Mark(s)*
• Correct suitable chemical and justification for choice	2
• Correct chemical without justification	1

(b) In Arrhenius' laboratory in 1884, would he have advised the use of this same substance clean the acid spill? Give TWO reasons for your answer. **2**

Sample Answer:

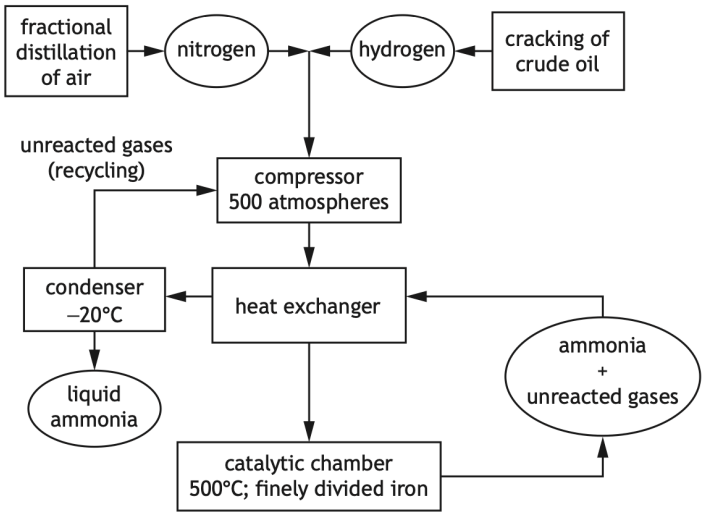
Arrhenius would NOT have advised me to use sodium hydrogen carbonate, since the only bases according to Arrhenius are those ones that dissociate in water to produce OH^- and have OH^- in their structure. In addition, the substance has to be dissolved in water to act as a base BUT $NaHCO_3$ can react/neutralise as a solid with the acid spill OR amphiprotic nature of $NaHCO_3$ not recognised by Arrhenius.

NB*: MUST mention OH^- produced in water (solution is not enough as not all solutions contain water)*

Marking Criteria	*Mark(s)*
• Suitable reasons (2) to support answer	2
• ONE suitable reason to support answer	1

Question 26 (4 marks)

The Haber process is still currently used for the industrial production of ammonia as shown.
$3H_2\,(g) + N_2\,(g) \rightarrow 2NH_3\,(g)$, $\Delta H = -92.4$ kJ mol^{-1}
In a conventional chemical plant, an efficient process is achieved through the use of an iron catalyst with high pressure and low temperature conditions.
An outline for the chemical process that takes place in this plant is given in the diagram.



With reference to the diagram, identify THREE design features, in addition to those outlined above and explain the economic benefits they provide. **4**

Sample answer:
One of the raw materials is nitrogen gas which is the largest component of the atmosphere, which can be readily sourced from air to reduce the material costs. A heat exchanger is used to collect heat energy from the products and unused reactants passing through the system and transfers it to the incoming reactants. As the materials enter the reactor with more energy, this reduces the amount of heat costs during operation. The layout is arranged to recycle unreacted gases that come out of the process, which are then fed back into the system further reducing material costs.

<u>Other plausible design features include</u>: using the hydrogen by-product from the cracking of crude oil, condensation to ammonia to reduce storage expenses, high atom economy due to the conversion of reactants into one product, and / or using high temperatures to increase rate of production.

Marking Criteria	*Mark(s)*
• Identifies 3 design features provided in the diagram. • Explains the benefit of 3 identified design features.	4
• Identifies at least 2 design features provided in the diagram. • Explains the benefit of at least 2 of the identified design features.	3
• Identifies and explains the benefit of 1 appropriate design feature • OR identifies 2 appropriate design features.	2
• Provides some relevant information.	1

Question 27 (6 marks)

The biofuel 2-methylpropan-1-ol can be produced from proteins. 2-methylpropan-1-ol can be used in petrol engines and has a heat of combustion of 36.1 kJ g^{-1} at 298 K.

(a) Explain the difference between the heat of combustion of octane (5470 kJ mol^{-1}). and 2-methylpropan-1-ol. **3**

$C_8H_{18} + 25/2\ O_2 \rightarrow 8CO_2 + 9H_20$

MM octane C_8H_{18} = 8(12.01) + 18(1.008) = 114.23

The heat of combustion of octane in kJ/g = 5470/114.23 = 47.98 kJ g^{-1}

The heat of combustion is greater than that of 2-methylpropan-1-ol. Octane releases more energy in bond formation than 2-methylpropan-1-ol as more moles of products are formed.

Marking Criteria	*Mark(s)*
• Explains the difference in the heats of combustion • Does a relevant calculation (2671 for butanol)	3
• Explains the difference in the heats of combustion OR • Outlines the difference in the heats of combustion AND • Does a relevant calculation (eg higher heat and greater MM)	2
• Gives some relevant information	1

(b) A small fuel burner containing 2.36 g of 2-methylpropan-1-ol was placed directly under a beaker containing 500.0 g of water and standard laboratory conditions.

Calculate the maximum temperature that the water could reach if the contents of the fuel burner underwent complete combustion. The initial temperature of the water was 298K. **3**

n C_4H_9OH = m/MM = 2.36/ 4(12.01) + 10(1.008) + 16 = 0.03184 mol

heat of combustion in kJ/mol = 36.1 x MM = 36.1 x 74.12 = 2675.732 kJ/mol
Heat of combustion for 0.03184 mol = 2675.732 x 0.03184 = 85.1953 kJ
$q = -mc \Delta T$
$85.1953 = 0.5 \times 4.18 \times \Delta T$
$\Delta T = 40.76\ ^oC$
Maximum temperature is 40.76 + 25 = 65.76 ^oC (339 K)

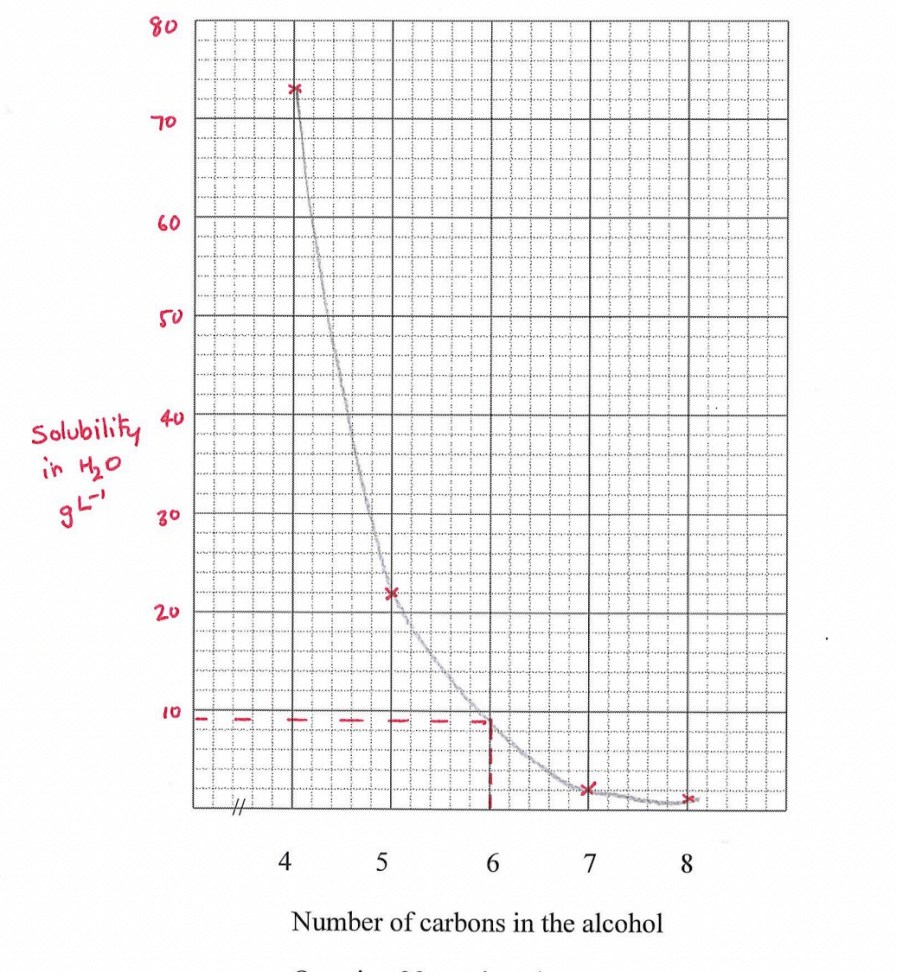
Marking Criteria	*Mark(s)*
• Correctly calculates the maximum temperature • Shows all relevant working	3
• Most working shown	2
• Some relevant calculation given	1

Question 28 (8 marks)

The solubility of a series of alcohols is given in the table below.

Alcohol	*Solubility in water (g L^{-1})*
Butan-1-ol	73
Pentan-1-ol	22.0
Heptan-1-ol	2.0
Octan-1-ol	0.5

(a) Plot the number of carbon atoms in the alcohols against solubility. **3**



Marking Criteria	*Mark(s)*
• Correct plots, scale, curve of best fit, y axis labelled	3
• Most graph features correct	2
• One correct graph feature	1

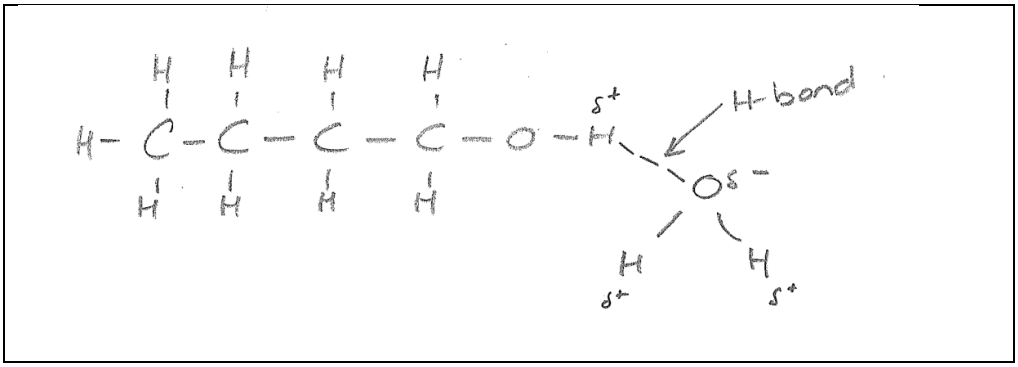
(b) Estimate the solubility of hexan-1-ol in g L^{-1}. **1**

9 g L^{-1}

Marking Criteria	*Mark(s)*
• Reads correctly from their graph, shows how the value was read from the graph.	1

(c) Use the data to explain the trend in the solubilities of these alcohols. Draw a relevant diagram to support your answer. **4**

Shorter chain alcohols (butanol, 73g L^{-1}) are more soluble in water than longer chain alcohols (octanol 0.5 g L^{-1}). With butan-1-ol there is hydrogen bonding between the molecules and water as seen in the diagram, below (solute to solvent). As the nonpolar alkyl chain gets longer, the dispersion forces become more significant and the polar hydroxyl group on the molecule becomes less influential over the solubility in the polar solvent. The non-polar long chains form dispersion forces with each other (solute to solute interactions) and the alcohols are therefore less soluble in the polar solvent.



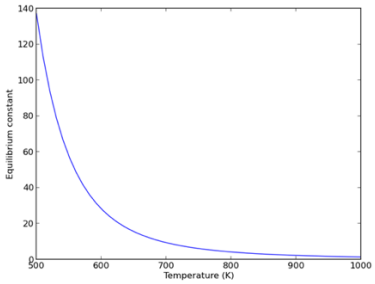
Marking Criteria	*Mark(s)*
• Explains the trend in solubility E • Uses the data D • Draws a relevant diagram indicating intermolecular forces I	4
• Explains the trend in solubility AND. E +D or E + I or D + I + EO • Uses the data OR • Draws a relevant diagram indicating intermolecular forces	3
• Shows some understanding of the trend in solubility EOI or EOD or E	2
• Gives some relevant information. EO or I or D	1

Question 29 (7 marks)

The water gas shift reaction can be used to produce hydrogen gas and consume toxic carbon monoxide:

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g)$$

The equilibrium constant for this reaction is highly temperature sensitive:



(a) Justify whether this reaction is exothermic or endothermic. **3**

As temperature increases, both the forward and reverse reaction rates increase. $K_{eq} = k_{forward}/k_{reverse}$. As the equilibrium constant decreases with increasing temperature, the reverse reaction rate must increase more than the forward reaction rate. This means that the reverse activation energy is larger than the forward activation energy, so the reaction is exothermic.

Answers could include using Le Chatelier's principle

Marking Criteria	*Mark(s)*
• Correctly links decreasing K_{eq} with temperature and exothermic reaction using cause and effect statement(s) • Provides expression for K_{eq} • Justifies answer with reference to forward and reverse reaction rates or Le Chatelier's principle	3
• 2 of the above	2
• Some relevant information accounting for exothermic reaction	1

(b) 6.7×10^{-3} mol CO, 4.5 mol of H_2O and 0.4 mol of CO_2 were placed into a 5.0 L sealed reaction vessel at 500 K.

Calculate the concentration of H_2 at equilibrium. **4**

Marking Criteria	Mark(s)
• Calculates initial concentration of species • correct expression for change in concentration • solves for change in concentration (using quadratic formula with single correct solution or correct small change approximation) • correct substitution into K_{eq}	4
• 3 of the following • Calculates initial concentration of species • correct expression for change in concentration • solves for change in concentration (using quadratic formula with single correct solution or correct small change approximation) • correct substitution into K_{eq}	3

• 2 of the following • Calculates initial concentration of species • Correct expression for change in concentration • Solves for change in concentration (using quadratic formula with single correct solution or correct small change approximation) • correct substitution into K_{eq}	2
• Some relevant calculations	1

Concentration of each species is given by number of moles/5.0.

	CO	H_2O	CO_2	H_2
I	1.34×10^{-3}	0.9	0.08	0
C	-x	-x	x	x
E	1.34×10^{-3} -x	0.9 -x	0.8 + x	x

$K_{eq} = [CO_2][H_2]/[CO][H_2O]$
$138 = (0.08 + x)(x)/(1.34 \times 10^{-3} - x)(0.9-x)$
Assume $0.08 + x \approx 0.08$
$138 = (0.08)(x)/(1.34 \times 10^{-3} - x)(0.9)$
$1575(1.34 \times 10^{-3} - x) = x$
$2.1105 – 1575x = x$
$2.1105 = 176x$
$x = 1.34 \times 10^{-3}$ which is << 0.08 (Sanity check!!)
$[H_2] = 1.34 \times 10^{-3}$ mol L^{-1}

Question 30 (4 marks)

A beaker containing pieces of copper and silver, along with a solution of their ions, is at equilibrium:

$$Cu(s) + 2Ag^+(aq) \rightleftharpoons 2Ag(s) + Cu^{2+}(aq)$$

(a) Identify the effect on equilibrium position of adding another piece of copper metal to the beaker. **1**

Marking Criteria	Mark(s)
• Correct identification	1

There will be no change to the position of the equilibrium.

(b) Water is added to double the volume of the solution at t = 1, immediately reducing the intensity of the blue colour. The system then re-establishes equilibrium at t = 2.

Account for changes in appearance of the beaker contents between t = 1 and t = 2. **3**

Marking Criteria	Mark(s)
• Correctly compares Q to K OR discusses change to amount of metals present • Justifies shift in equilibrium position using Q or Le Chatelier's principle • Identifies changes to appearance of beaker contents	3
• Justifies shift in equilibrium position using Q or Le Chatelier's principle • Links to change in colour of solution or amounts of metals	2
• Identifies correct colour change or appearance/disappearance of relevant metals • OR • Some relevant information	1

Before adding water $Q=K_{eq}=[Cu]/[Ag^+]^2$. When the water is added, the concentration of each is halved, so Q is doubled i.e. it is greater than K. The equilibrium will shift to the left, consuming blue $Cu^{2+}(aq)$ and Ag(s) and producing more Cu(s) and $Ag^+(aq)$. The solution will be less blue after the dilution (which would be less blue than before the dilution). More copper metal would be present, and less silver metal would be present.

Question 31 (5 marks)

2.53 g of KSCN was dissolved in a 250.0 mL volumetric flask. It was added to 125 mL of 0.108 mol L^{-1} of lead (II) acetate. 2.19 g of lead thiocyanate precipitate was formed. Calculate the value of the Ksp for lead thiocyanate. **5**

$Pb^{2+}(aq) + 2SCN^-(aq) \rightleftharpoons Pb(SCN)_2(s)$

Moles $Pb(SCN)_2$ (s) = mass/MM = 2.19/(207.2 + 32.07 * 2 + 12.01 *2 + 14.01 * 2) = 2.19/323.38 = 0.006772

Mol KSCN = mass/MM = 2.53/(39.1+32.07+12.01+14.01) = 2.53/97.19 = 0.0260315

Mol $Pb(CH_3COO)_2$ = cv = 0.108*0.125 = 0.0135

Total volume = 0.375 L

Pb^{2+} in solution = 0.0135-0.006772 = 0.006728

$[Pb^{2+}]$ = 0.06728/0.375 = 0.01794 mol L^{-1}

SCN^- in solution = 0.0260315 – 2*0.006772 = 0.0124875

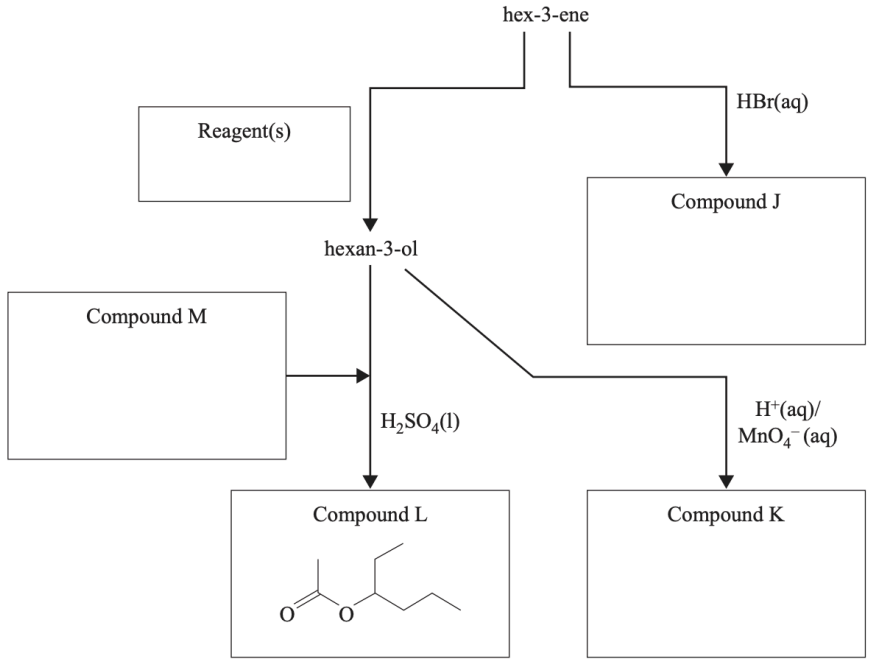
$[SCN^-]$ = 0.0124875/0.375 = 0.0333

$Ksp = [Pb^{2+}][SCN^-]^2 = 0.01794 * 0.0333^2 = 1.99 \times 10^{-5}$

Marking Criteria	*Mark(s)*
• Provides correct calculation for the Ksp of lead thiocyanate (amount of $Pb(SCN)_2$ ppt, initial $[Pb^{2+}]$ and $[SCN^-]$, equilibrium $[Pb^{2+}]$ and $[SCN^-]$, and Ksp expression) • Includes a correct balanced chemical equation.	5
• Provides a substantially correct calculation for the Ksp of lead thiocyanate (at least 3 points above). • Includes a correct balanced chemical equation.	4
• Provides the main steps in the calculation for the Ksp of lead thiocyanate (at least 2 points above). • Includes an appropriate chemical equation.	3
• Provides some steps in the calculation of the Ksp of lead thiocyanate (at least 2 points above) OR • Some relevant features involved with the calculation.	2
• Provides some relevant working.	1

Question 32 (8 marks)

Below is a reaction pathway beginning with hex-3-ene.

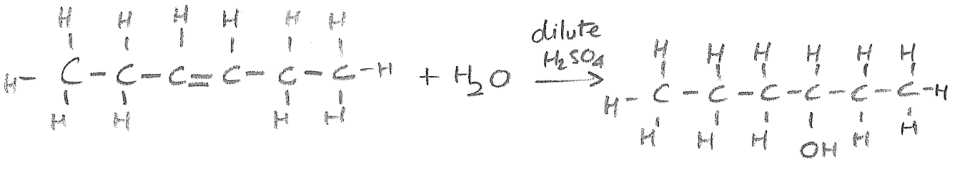


(a) Justify the identification of compounds J, M and K. **6**

Compound J is 3-bromohexane and it is formed by the addition of HBr to hex-3-ene. Compound L is 3 hexyl ethanoate. The acid being added in this esterification is compound M, ethanoic acid. Compound K is made by the oxidation of hexan-3-ol, a secondary alcohol. The product, K is hexan-3-one.

Marking Criteria	*Mark(s)*
• Identifies 3 compounds and justifies the identifications (reaction type)	6
• Identifies 3 of the names and justifies 2 identifications	5
• Identifies 2 of the names and justifies 2 identifications	4
• Gives 3 relevant identifications/justifications	3
• Gives 2 relevant identifications/justifications	2
• Identifies one of the names or reactions	1

(b) Draw an equation, using structural formulae, for the conversion of hex-3-ene to hexan-3-ol indicating the reagent(s) required. **2**



Marking Criteria	*Mark(s)*
• Correct structural equation with the conditions for hydration	2
• Correct equation	1

Question 33 (9 marks)

A student performs an experiment to determine the concentration of a solution of hypochlorous acid, HOCl (Ka = 3.5 x 10^{-8}). The student starts with 25.00 mL of the acid in a conical flask and titrates it against a standardised solution of sodium hydroxide with a concentration of 1.47 mol L^{-1}. The equivalence point is reached after addition of 34.23 mL of sodium hydroxide.

The equation for the reaction is $HOCl(aq) + OH^-(aq) \rightarrow OCl^-(aq) + H_2O(l)$

(a) Calculate the concentration of the HOCl. **2**

Sample Answer: At equivalence point moles of acid are equal to moles of base.
n(NaOH) = c x V = 1.47 x 0.03423) = 0.0503 mol
c(Acid) = 0.0503 / 0.02500 = 2.01 mol L^{-1}

Marking Criteria	*Mark(s)*
• Correct calculation of concentration of HCl	2
• One correct calculation in the process	1

(b) Determine the pH of the solution in the conical flask after the addition of 28.55 mL of sodium hydroxide. **5**

Sample Answer:

Ratio of chemical species form balanced equation 1:1:1

$n(NaOH) = c \times V$ 1.47 mol L^{-1} x 0.002855 = 0.0419685 mol = $n(OH^-)$
n(HOCl) = 2.01 x 0.02500) = 0.0503 mo0l HOCl 1 mark for 2 x mol calc.
n(HOCl) used = 0.0419685 as 1:1 ratio
n(HOCl) remaining = 0.0503181 – 0.0419685 = 0.0083496 1 mark for n(HOCl) remaining
$n(OCl^-)$formed = n(NaOH) used = 0.0419685

$[HOCl]remaining = n/V_L = 0.0083496 / 0.02855 + 0.025 = 0.15592$ mol L^{-1}
$[OCl^-] = n/V_L =$ 0.0419685/0.05355 = 0.7837 mol L 1 mark for 2 x concentrations in mol L^{-1}

Use ICE Table to determine equilibrium concentrations of each species present.

	[HOCl]	$[H^+]$	$[OCl^-]$
Initial	0.15592	0	0
Change	- x	+ x	+ x
Equilibrium	0.15592 – x	x	0.7837 + x

1 mark for ICE Table

$Ka = [OCl^-] \times [H^+] / [HOCl]$ $Ka = 3.5 \times 10^{-8}$ is very small
Thus x is small thus 0.15592 – x = 0.15592

Thus $3.5 \times 10^{-8} = (0.7837 + x)x / 0.15592$
$3.58 \times 10^{-8} \times 0.15592 = (0.7837 + x)x$
$x^2 = 0.7837x - 5.45 \times 10^{-9}$
$x = 6.9632 \times 10^{-9}$
$pH = -\log_{10} [H^+] = -\log_{10} (6.9632 \times 10^{-9}) = 8.157 = 8.2$ 1 mark for pH calculation

OR

Ratio of chemical species from balanced equation is 1:1:1

n(NaOH) = c x V 1.47 mol L^{-1} x 0.002855 = 0.0419685 mol = n(OH^-) 1mark for 2 x mol cal.
n(HOCl) = 2.01 x 0.02500) = 0.0503 mo0l HOCl
n(HOCl) used = 0.0419685 as 1:1 ratio
n(HOCl) remaining = 0.0503181 – 0.0419685 = 0.0083496 1 mark for n(HOCl) remaining
n(OCl^-)formed = n(NaOH) used = 0.0419685

	n(HOCl)	n(OH^-)	n(OCl^-)
Initial	0.0503	0.0420	0
Change	-0.0420	-0.0420	0
Equilibrium	0.0083	0	0.0420

1 mark for ICE Table

Total Volume at equilibrium = 25.00 mL + 28.55 mL = 0.15 mol L^{-1}

So concentration at new equilibrium will be:
[HOCl] = 0.0083 / 0.05355 = 0.15 mol L^{-1} 1 mark for 2 x concentrations in mol L^{-1}
[OCl^{-1}] = 0.0420 / 0.05355 = 0.784 mol L^{-1}

pH = pKa + log[OCl^{-1}] / [HOCl] = -log(3.5×10^{-8}) + log(0.784/0.15)
= 7.5 + 0.72 = 8.2 1 mark for pH calculation

Marking Criteria	*Mark(s)*
• Correct pH determination showing all working including use of ICE table	5
• Correct calculations showing all working with one computational error and ICE Table	4
• Some errors in computations with ICE Table	3
• Two correct steps in calculations showing all working	2
• One correct step in calculation showing working	1

(c) The actual concentration of the HOCl is found to be 2.25 mol L^{-1}.
Quantitatively discuss the following error which may have contributed to the student's results.

The student rinsed the burette with distilled water instead of sodium hydroxide

solution before filling it with sodium hydroxide.. **2**

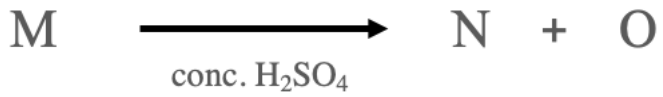
Sample Answer : If the burette was not rinsed with the NaOH solution prior to filling it, the concentration of the NaOH would be diluted by the water inside the burette. The student would have to add a greater volume of NaOH to reach equivalence. However in the calculations, using the original concentration of NaOH multiplied by the higher volume would lead to an artificially high number of moles of NaOH and thus, more apparent moles of HOCl would lead to a larger numerator in the acid molarity calculation and thus a larger apparent molarity. As the student's calculated molarity was too low, this could not have caused the error.

(a) Write the net ionic equation for the reaction that occurs in the flask. **1**

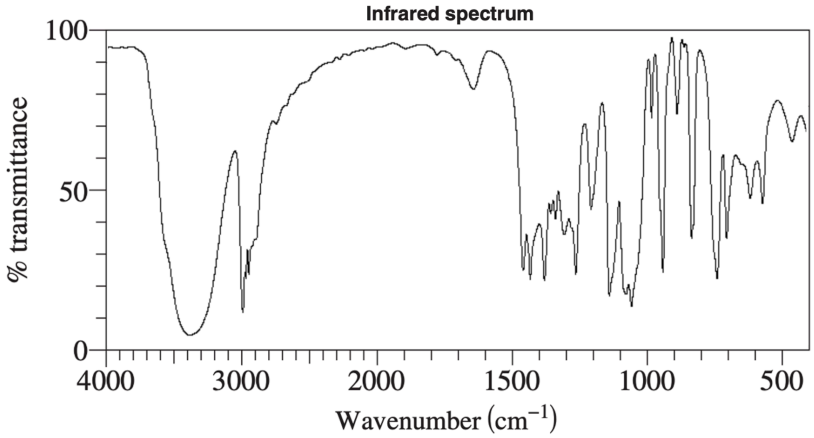
Marking Criteria	*Mark(s)*
• Correct discussion incorporating quantitative aspects of the error	2
• Correct discussion but does not incorporate quantitative aspect	1

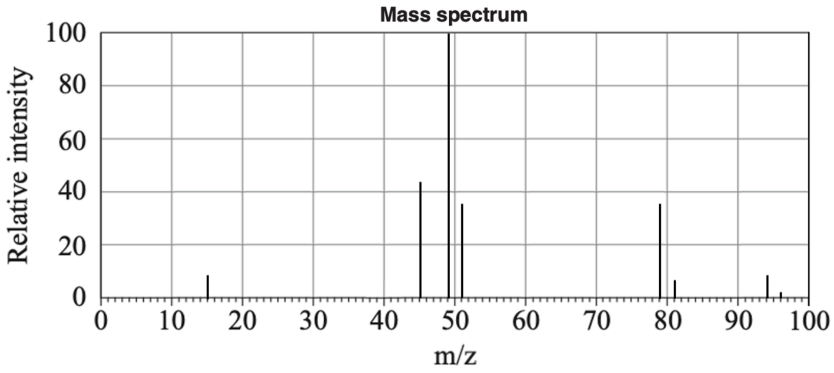
Question 34 (9 marks)

A halogenated organic compound M with a molar mass of 94.54 g mol^{-1} is known to produce TWO products, compounds N and O according to the reaction provided.



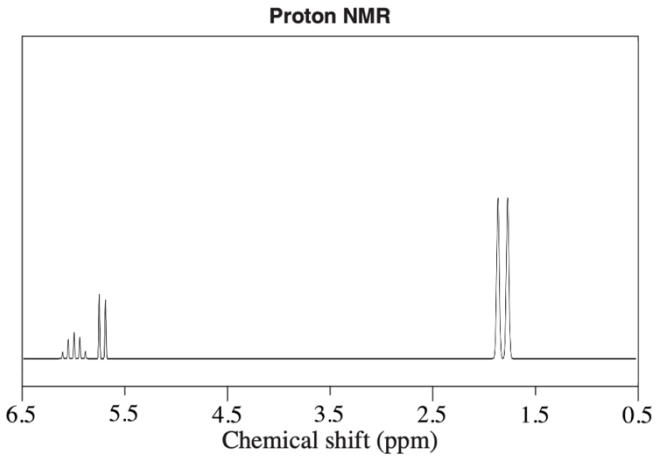
A chemist obtained the following spectral data for compound M.

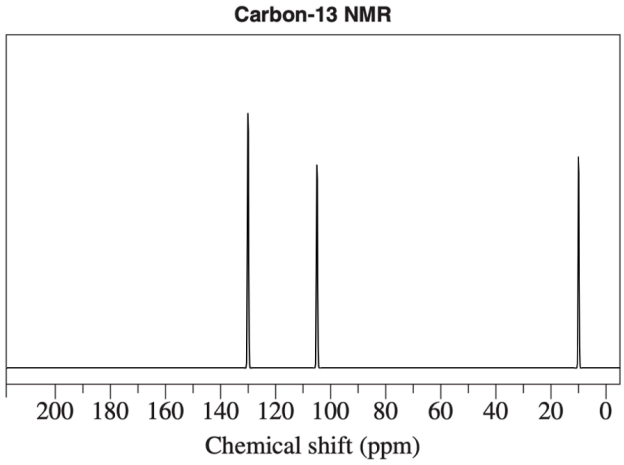




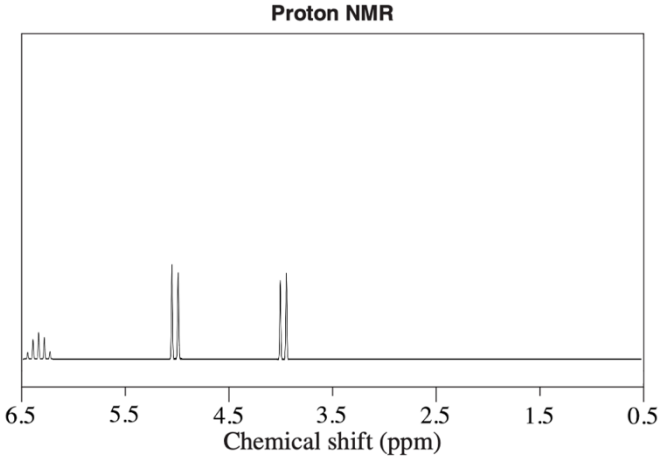
The following spectroscopic data was also obtained for the products.

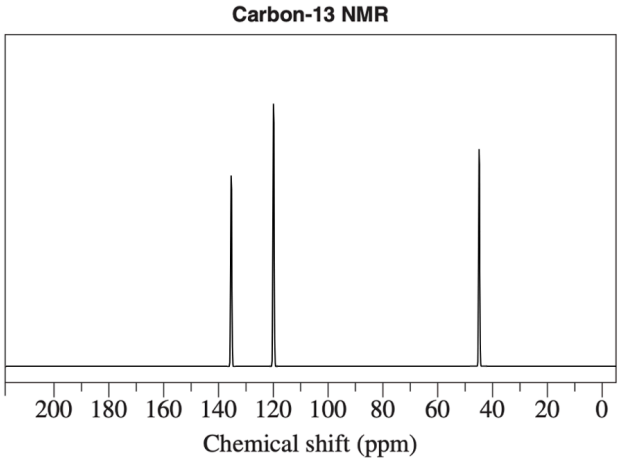
Product N





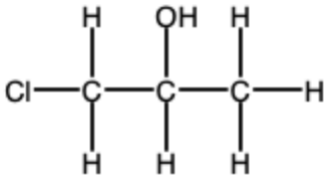
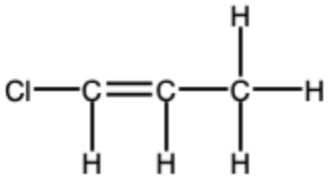
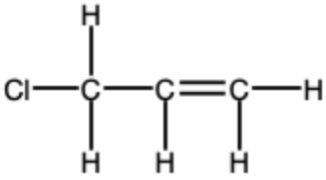
Product O





In the space provided, draw the structure and name each of the compounds, M, N, and O. Justify your answer with reference to all the information provided.

Sample answer:

Compound M	Compound N	Compound O
		
Name: 1-chloropropan-2-ol	Name: 1-chloropro-1-ene	Name: 3-chloroprop-1-ene

Compound M

The infrared spectrum provides a broad signal at 3400 cm^{-1} which corresponds to an O–H stretch in the molecule. This is diagnostic for the presence of an alcohol functional group.

The mass spectrum contains multiple pairs of signals where m/z = 94 / 96, 79 / 81, and 49 / 51 which are present in a 4:1 ratio that is characteristic for the presence of a single chlorine atom in the molecule. There is a m/z = 15 signal that corresponds to a $[CH_3]^+$ fragment, whereas the m/z = 45 signal is $[CH_3CHOH]^+$ fragment. Since both of these signals exist alone, it confirms that the chlorine atom is not attached. The m/z = 49 / 51 pair of signals relates to the other half of the molecule which is the $[ClCH_2]^+$ fragment. By combining the m/z = 45 signal with the m/z = 49 / 51 signals we end up with the molecular ion $[CH_3CHOHCH_2Cl]^+$.

This gives us the structure of compound M as 1-chloropropan-2-ol.

The use of concentrated sulfuric acid is characteristic for a dehydration reaction, which would involve removal of a water molecule from compound M via the OH group of the alcohol and an adjacent H atom. This results in the production of two isomeric haloalkene products.

Compound N

In the carbon NMR there are 2 signals at 105 ppm and 130 ppm respectively that confirms the presence of a C=C double bond within the molecule. The other signal at 10 ppm identifies a typical alkane carbon atom. The proton NMR has a 1H pentet at 6.0 ppm which indicates a CH group adjacent to 4 other H atoms. There is a 1H doublet at 5.2 ppm which indicates a CH group adjacent to 1 other H atom and a 3H doublet at 1.8 ppm for a CH_3 group that is also adjacent to 1 other H atom. This indicates that the CH group of the 1H pentet lies between the CH and CH_3 group from the other signals resulting in a $CH{=}CHCH_3$ carbon chain.

This gives us the structure of compound N as 1-chloroprop-1-ene.

Compound O

Similar to the previous, the carbon NMR has a pair of signals at 120 ppm and 135 ppm respectively that flags the presence of a C=C double bond within the molecule. There is also a signal at 43 ppm which identifies a typical alkane carbon atom, however this is slightly downfield shifted indicating that it is in closer proximity to the highly electronegative chlorine atom. The proton NMR also contains a 1H pentet at 6.4 ppm which indicates a CH group that is adjacent to 4 other H atoms. There are two 2H doublet at 5.0 ppm and 4.0 ppm respectively which corelates with CH_2 groups that are adjacent to 1 other H atom. This provides an arrangement where the CH group of the 1H pentet lies between both the CH_2 groups from the other signals to provide a $CH_2CH{=}CH_2$ carbon chain.

This gives us the structure of compound O as 3-chloroprop-1-ene.

Marking Criteria	*Mark(s)*
• Draws all THREE correct structures for M, N, and O and includes the correct IUPAC names for each. • Justifies the correct structure of M showing an extensive understanding of the interpretation of spectra and chemical reactions **(M4: infrared, mass spectrum, chlorine, reaction)** • Justifies the correct structures for N and O showing an extensive understanding of the interpretation of spectra (**H2: multiplicity + structure & C2: alkene signals + deshielding)** • Refers to relevant spectroscopic data for all compounds.	9
• Draws at least TWO correct structures for M and N / O. • Justifies the correct structure of M showing a thorough understanding of the interpretation of spectra and chemical reactions **(at least M3)** • Justifies the correct structures for N and O showing a thorough understanding of the interpretation of spectra **(H2 + C2, H2 + C, H + C2, or CH).** • Refers to relevant spectroscopic data for most compounds.	7–8
• Draws at least ONE structure consistent with analysis. • Shows a sound understanding of the interpretation of spectra and / or chemical reactions **(at least M2 with H + C or H or C).** • Uses relevant information present in the question to explain structure presented.	5–6
• Demonstrates some understanding of the interpretation of spectroscopic data and / or chemical reactions.	3–4
• Provides some relevant information.	1-2

Question 35 (5 marks)

A commercial disinfectant is reported to have two active ingredients, hydrogen peroxide (H_2O_2) and peracetic acid (CH_3COOOH) at concentrations of 4 % and 12 % respectively. A titration experiment was carried to confirm the accuracy of these values.

A 10.00 mL sample of the disinfectant solution was transferred to a 100 mL volumetric flask that was filled with demineralised water. 20.00 mL of the resultant solution was transferred to a conical flask containing 5.000 mL of 3.000 mol L^{-1} solution of sulfuric acid and titrated with a 0.2491 mol L^{-1} cerium sulfate solution.

$H_2O_2\ (aq) + 2\ Ce(SO_4)_2\ (aq) \rightarrow Ce_2(SO_4)_3\ (aq) + H_2SO_4\ (aq) + O_2\ (g)$

The following results were obtained.

Titre	*Volume of $Ce(SO_4)_2$ added (mL)*
1	21.65
2	21.15
3	21.20
4	21.30

Immediately after, 5.000 mL of a 20 % (w/v) potassium iodide solution was added to the conical flask containing titre 4. This was done to react with the sulfuric acid to produce hydroiodic acid that would then reduce the peracetic acid present in the sample and form iodine.

$$2\ KI\ (aq) + H_2SO_4\ (aq) \rightarrow 2\ HI\ (aq) + K_2SO_4\ (aq)$$

$$CH_3COOOH\ (aq) + 2\ HI\ (aq) \rightarrow I_2\ (aq) + CH_3COOH\ (aq) + H_2O\ (l)$$

The resultant iodide solution was titrated with a 0.2250 mol L^{-1} solution of sodium thiosulfate and it was found that a titre volume of 27.35 mL was required to reach the end point.

$$I_2\ (aq) + 2\ Na_2S_2O_3\ (aq) \rightarrow Na_2S_4O_6\ (aq) + 2\ NaI\ (aq)$$

Do the results of this experiment support the reported concentration values? Support your answer with calculations. **5**

Sample answer:
V_{avg} = (21.15 + 21.20 + 21.30) / 3 = 21.22 mL = 0.02122 L
$n(Ce(SO_4)_2)$ = c x v = 0.2491 x 0.02122 = 5.285 x 10^{-3} mol
$n(H_2O_2) = n(Ce(SO_4)_2) / 2$ = 2.643 x 10^{-3} mol (in 20 mL)
$n(H_2O_2)$ x 5 = 1.321 x 10^{-2} mol (in 100 mL; 10 mL diluted solution)
$n(H_2O_2)$ x 10 = 0.1321 mol (100 mL original solution)
$m(H_2O_2)$ = n x MM = 0.1321 x (16.00 x 2 + 1.008 x 2) = 4.494 g
H_2O_2(w/v) = 4.494 %
$n(Na_2S_2O_3)$ = 0.2250 x 0.02735 = 6.154 x 10^{-3} mol
$n(I_2) = n(Na_2S_2O_3) / 2$ = 3.077 x 10^{-3} mol
$n(CH_3COOOH) = n(I_2)$ = 3.077 x 10^{-3} mol (in 20 mL)
$n(CH_3COOOH)$ x 5 = 1.538 x 10^{-2} mol (in 100 mL; 10 mL diluted solution)
$n(CH_3COOOH)$ x 10 = 0.1538 mol (100 mL original solution)
$m(CH_3COOOH)$ = 0.1538 x (12.01 x 2 + 16.00 x 3 + 1.008 x 4) = 11.70 g
CH_3COOOH(w/v) = 11.70 %

The report values are accurate for the hydrogen peroxide content, but inaccurate for the peracetic acid content.

Marking Criteria	*Mark(s)*
• Provides correct calculations for the concentration of hydrogen peroxide AND peracetic acid (average volume, moles of components, stoichiometric ratio, series of dilutions, w/v fraction). • Assesses the accuracy of the component concentration values.	5
• Provides correct calculations for the concentration of hydrogen peroxide OR peracetic acid (moles of components, stoichiometric ratio, series of dilutions, w/v fraction).	4
• Provides a correct calculation for the amount of hydrogen peroxide AND / OR peracetic acid (average volume, moles of component/s, stoichiometric ratio).	3
• Provides some relevant calculation steps. (moles of component/s, stoichiometric ratio).	2
• Provides a relevant calculation step.	1