SYDNEY GRAMMAR SCHOOL

TRIAL EXAMINATION 2024

FORM VI CHEMISTRY

Candidate No:

General Instructions

- Reading Time: 5 minutes
- Working Time: 3 hours
- Write using black pen

Structure of Paper & Instructions

- Section 1: Multiple-choice (20 marks). Spend 35 minutes on this section.
- Section 2: Written answer (80 marks). Spend 2 hours 25 minutes on this section.

Exam Instructions

- Remove the centre staple and hand in all parts of the paper in a neat bundle.
- Show all relevant working.
- **Write your candidate number in the space provided on pages 11, 17, 23 and 29.**

Total marks: 100

Monday 19 August

8:40 am

Checklist

Each boy should have the following:

☐ 1 question paper

☐ 1 multiple-choice answer sheet

☐ 1 data sheet

JL Senczyszyn

Examiners: CXS, JEMH, EJS, JLS

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SECTION I: MULTIPLE CHOICE QUESTIONS
20 marks

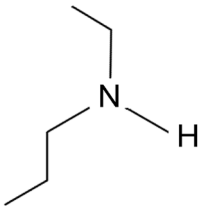
Attempt ALL Questions

Use the Multiple-Choice Answer Sheet.

1 During a titration, which piece of glassware should be used to transfer a 25 mL aliquot of a substance to the conical flask?

(A)		(B)	
(C)		(D)	

2 What is the systematic name for the molecule shown?



(A) *N*-ethylpropanamide

(B) *N*-ethylpropanamine

(C) *N*-propylethanamine

(D) *N*-pentan-3-amine

3 Consider the following equilibrium system:

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92 \text{ kJ mol}^{-1}$$

Which set of conditions will produce the highest yield of ammonia?

(A) High temperature, high pressure

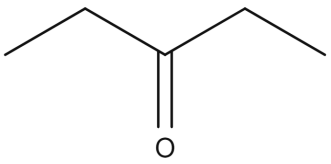
(B) High temperature, low pressure

(C) Low temperature, high pressure

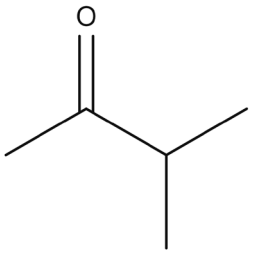
(D) Low temperature, low pressure

4 Which of the following is a **position** isomer of pentan-2-one?

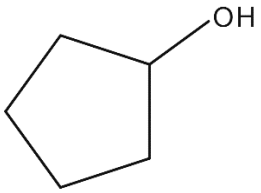
(A)



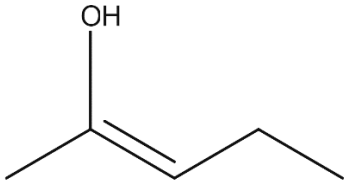
(B)



(C)



(D)



5 Which analytical technique relies on particles being initially ionised?

(A) ^{1}H NMR

(B) ^{13}C NMR

(C) Infrared spectroscopy

(D) Mass spectrometry

6 Consider the following equilibrium reaction in an aqueous solution:

$$Fe^{3+}(aq) + SCN^{-}(aq) \rightleftharpoons [Fe(SCN)]^{2+}(aq)$$

At 298 K, the equilibrium constant, K_{eq}, for the reaction is 200. A student prepares a solution containing 0.12 mol L^{-1} $Fe^{3+}(aq)$ ions and 0.12 mol L^{-1} $SCN^{-}(aq)$ ions at equilibrium.

What is the equilibrium concentration of $[Fe(SCN)]^{2+}(aq)$ at 298 K?

(A) 0.12 mol L^{-1}

(B) 0.24 mol L^{-1}

(C) 1.4 mol L^{-1}

(D) 2.9 mol L^{-1}

7 HInd is an acid-base indicator used in titration that exists in two equilibrium forms when dissolved in water.

$$HInd(aq) + H_2O(l) \rightleftharpoons H_3O^{+}(aq) + Ind^{-}(aq)$$

yellow *purple*

Which statement(s) are correct?

i. In a strongly acidic solution, yellow is observed.
ii. When the concentration of $HInd(aq)$ is less than the concentration of $Ind^{-}(aq)$, yellow is observed.
iii. The concentrations of $HInd(aq)$ and $Ind^{-}(aq)$ are approximately equal at the end point of a titration.

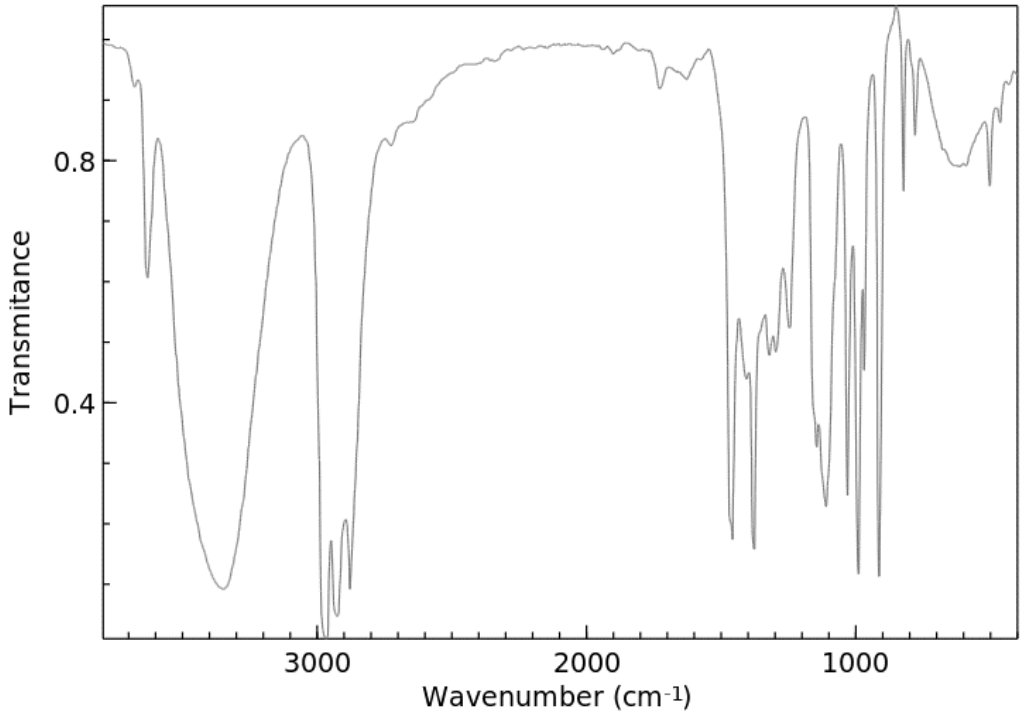
(A) i and ii only

(B) i and iii only

(C) ii and iii only

(D) i, ii and iii

8 Which organic molecule could have produced this infrared spectrum?



(A) But-2-ene

(B) Butan-2-one

(C) Butan-2-ol

(D) Butanoic acid

9 Consider the following equilibrium system:

$$2ICl(s) \rightleftharpoons I_2(s) + Cl_2(g) \qquad \Delta H = +17 \text{ kJ mol}^{-1}$$

Which of the following changes will increase the chemical amount, in moles, of chlorine that can be produced?

(A) Removing some of the solid I_2.

(B) Adding more solid ICl.

(C) Removing the Cl_2 gas as it is formed.

(D) Decreasing the temperature.

10 Photosynthesis is a highly endothermic reaction. Which of the following is true for the equilibrium constant, K_{eq}, at low temperatures?

(A) $K_{eq} = 0$

(B) $K_{eq} = 1$

(C) $K_{eq} >> 1$

(D) $K_{eq} << 1$

11 Which peak would you find in a mass spectrum for propanal but not in a mass spectrum for propan-2-one?

(A) $m/z = 15$

(B) $m/z = 29$

(C) $m/z = 43$

(D) $m/z = 58$

12 Ibuprofen is a drug used for pain-relief.

Chemical tests were performed on a sample of ibuprofen and the results of the tests are given below.

Chemical test	*Result with ibuprofen*
Aqueous sodium carbonate	Effervescence
Bromine water	Solution remained orange
Acidified potassium permanganate	Solution remained purple

Which functional group must be present in a molecule of ibuprofen?

(A) COOH

(B) C=C

(C) OH

(D) Br

13 A 0.15 mol L^{-1} sample of hydrofluoric acid, HF, has a pH of 2.00.

Calculate the K_a of hydrofluoric acid.

(A) 7.14×10^{-4} mol L^{-1}

(B) 3.57×10^{-4} mol L^{-1}

(C) 6.67×10^{-3} mol L^{-1}

(D) 3.32×10^{-2} mol L^{-1}

14 In a glucose fermentation reaction, 1.50 g of ethanol was produced. What volume of carbon dioxide (measured at 25°C and 100 kPa) was also produced in this reaction?

(A) 0.206 L

(B) 0.807 L

(C) 1.43 L

(D) 1.61 L

15 Which combination of organic reactant and reaction conditions could be used to produce 2-bromohexane as the sole product in a single step?

	Organic reactant	*Reaction conditions*
(A)	hex-2-ene	Br_2*(l)*, room temperature
(B)	hex-2-ene	dilute H_2SO_4*(aq)*, heat
(C)	hex-3-ene	HBr*(g)*, room temperature
(D)	2-bromohex-3-ene	H_2*(g)*, Pd/C catalyst, heat

16 Which statement is true for both ethanol and ethanal?

They both produce:

(A) A molecular ion peak at m/z = 46 in mass spectrometry.

(B) A sharp peak between 1680-1750 cm^{-1} in IR spectroscopy.

(C) Two peaks in ^{1}H NMR spectroscopy.

(D) Two peaks in ^{13}C NMR spectroscopy.

17 Aqueous dilution of IO_4^- results in the following reaction:

$$IO_4^-(aq) + 4H_2O(l) \rightleftharpoons H_4IO_6^-(aq) \qquad K_{eq} = 3.5 \times 10^{-2}$$

50.0 mL of a 0.896 mol L^{-1} solution of $KIO_4(aq)$ is diluted to 250.0 mL with water.

How many moles of $H_4IO_6^-(aq)$ are present at equilibrium?

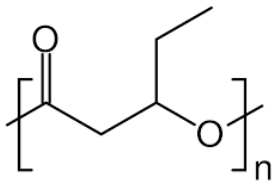
(A) 1.51×10^{-3} mol

(B) 6.06×10^{-3} mol

(C) 6.27×10^{-3} mol

(D) 4.48×10^{-2} mol

18 A section of the polyester poly(3-hydroxyvalerate) is shown.



A single chain of this polymer is found to have a molar mass of 9530 g mol^{-1} (calculated to 3 significant figures). How many monomer units of 3-hydroxyvaleric acid were required to make a chain with this molar mass?

(A) 81

(B) 95

(C) 100

(D) 102

19 Calculate the mass of solid ammonium chloride that must be added to 25.0 mL of water to make a solution with a pH of 4.85.

pK_a of NH_4^+ is 9.24

MM of NH_4Cl is 53.492 g mol^{-1}

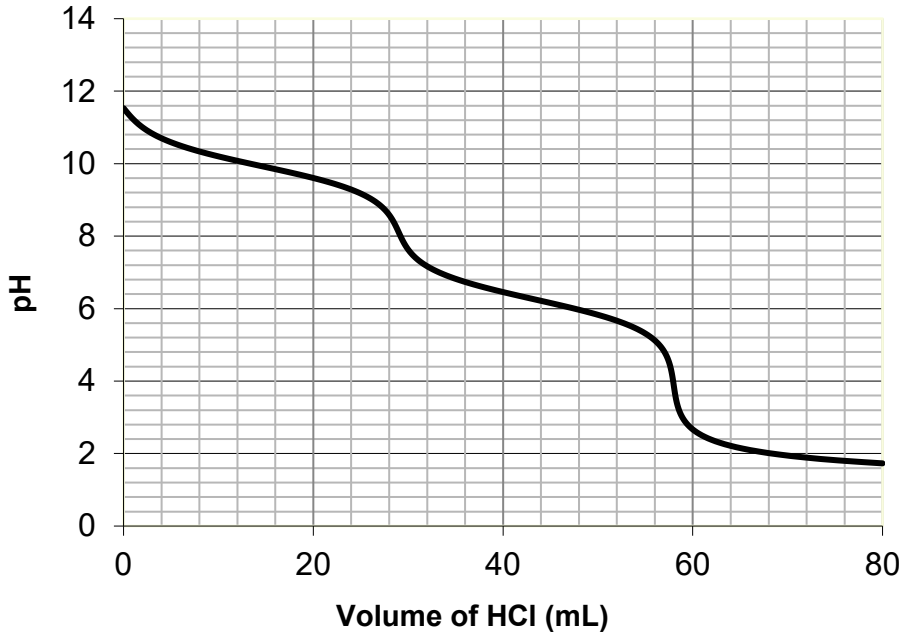
(A) 0.141 g

(B) 0.464 g

(C) 1.86 g

(D) 18.5 g

20 A data logger was used to measure the pH changes during a titration. Hydrochloric acid with a concentration of 0.1024 mol L^{-1} was added to a solution of sodium carbonate that was contaminated with sodium chloride.



The mass and density of the mixture of sodium carbonate and sodium chloride solution aliquot used was 36.98 g and 2.360 g mL^{-1} respectively. What was the concentration of sodium carbonate in the solution?

(A) 0.01567 mol L^{-1}

(B) 0.04654 mol L^{-1}

(C) 0.1895 mol L^{-1}

(D) 0.3790 mol L^{-1}

SECTION II: WRITTEN ANSWER QUESTIONS
80 marks

Attempt ALL Questions

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Question 21 (5 marks) **Marks**

Consider the following reaction at 300 K.

$$2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g)$$

1.00 mol of $NO_2(g)$ is placed into a 2.00 L container and the system was allowed to reach equilibrium. At equilibrium, the concentration of $NO_2(g)$ was found to be 0.250 mol L^{-1}.

(a) Write the K_{eq} expression for the reaction.

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(b) Calculate the equilibrium concentrations of $NO(g)$ and $O_2(g)$ at 300 K.

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(c) Calculate the equilibrium constant, K_{eq}, at this temperature.

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Question 22 (6 marks) **Marks**

Propene readily undergoes hydration to produce a mixture of two products, **A** and **B** as shown. When separated, compounds **A** and **B** can be oxidised to produce compounds **C** and **D** as shown.

(a) Complete the diagram below by drawing the structures of **A** and **C** and stating the names of **A**-**D**.

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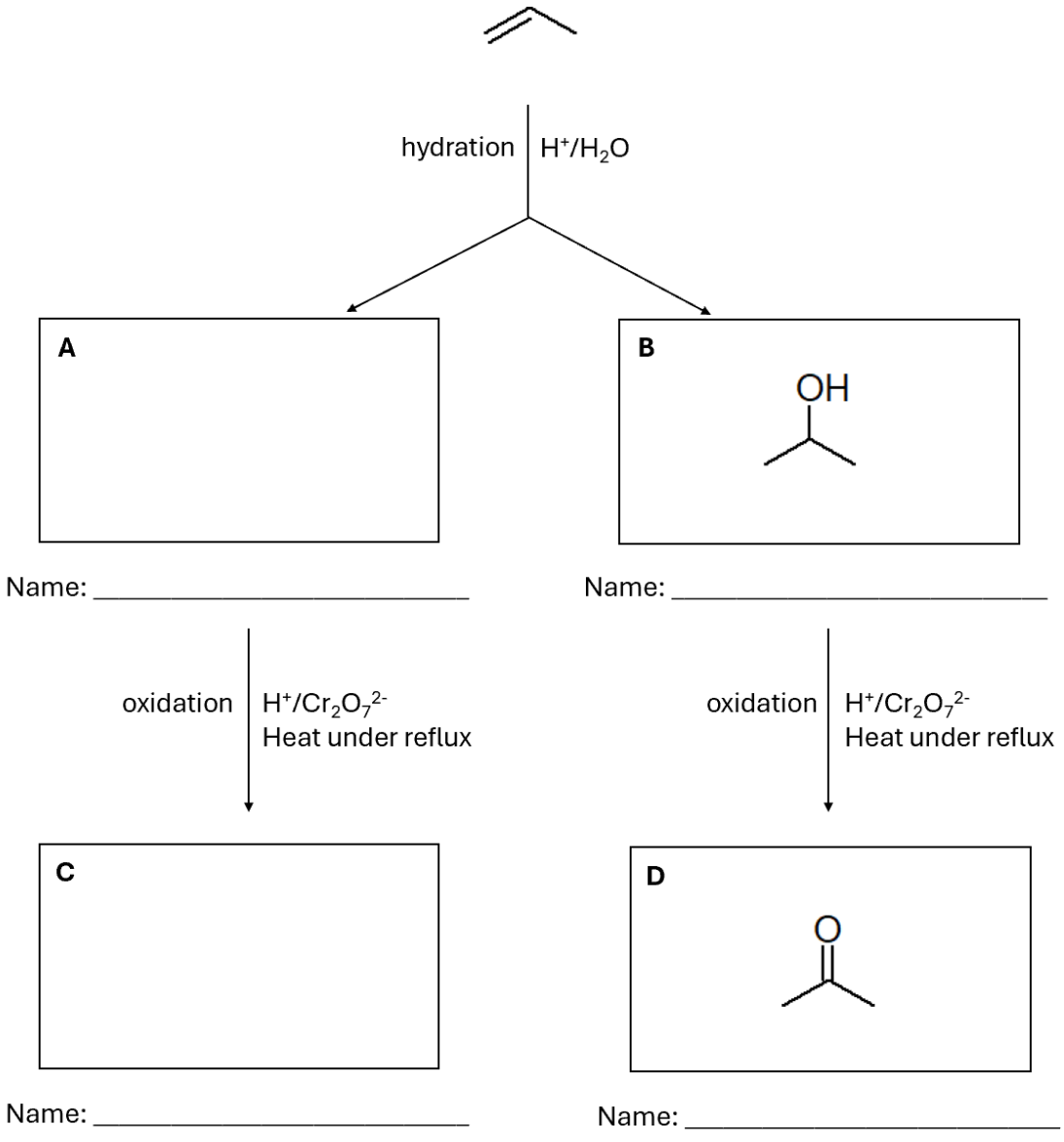

Question cont. **Marks**

(b) Compound **B** has a boiling point of 82°C and compound **D** has a boiling point of 56°C. Explain why compound **B** has a higher boiling point than compound **D**.

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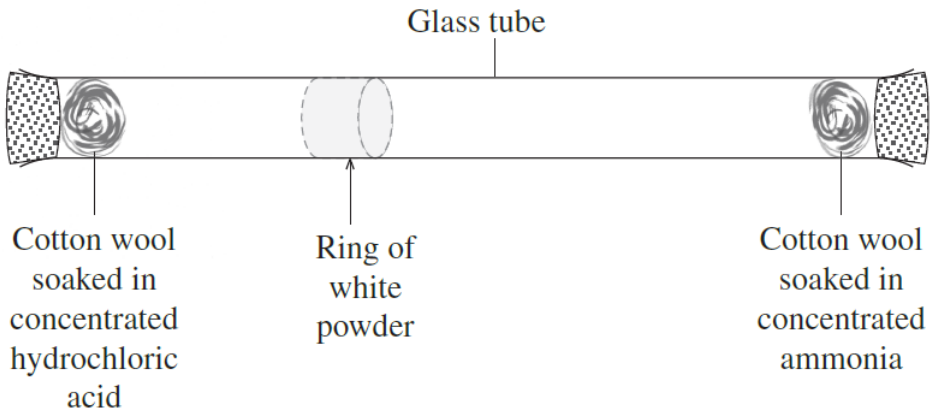
Question 23 (3 marks) **Marks**

Two pieces of cotton wool soaked in concentrated hydrochloric acid and concentrated ammonia were placed at opposite ends of a glass tube. After some time, the solutions vaporise, and the two gases react to produce a ring of white powder.



(a) Write an equation for the reaction that occurs inside the glass tube.

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(b) State which acid-base theory explains the behaviour in this reaction and justify your answer.

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Question 24 (6 marks) **Marks**

Consider the following equilibrium reaction:

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$$

(a) Use collision theory to explain how a decrease in volume would affect the rates of the forward and reverse reactions initially and until equilibrium is re-established.

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(b) Describe how the addition of a catalyst would affect the rates of the forward and reverse reactions and the position of the equilibrium.

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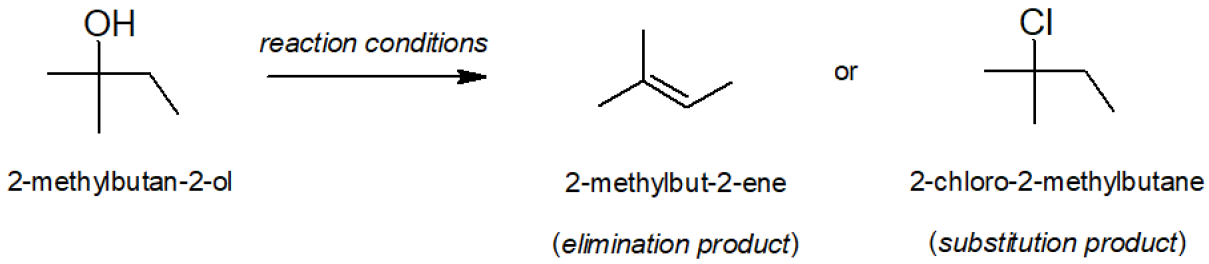
Question 25 (2 marks) **Marks**

Alcohols can undergo elimination and substitution reactions under different conditions.

A sample of 2-methylbutan-2-ol was subjected to an experimental set of conditions to determine whether elimination or substitution would occur.

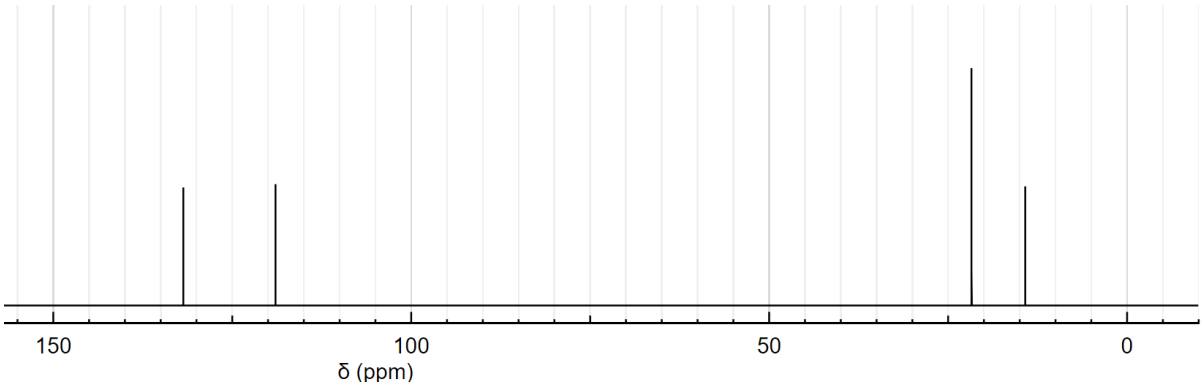


2-methylbutan-2-ol

2-methylbut-2-ene (*elimination product*)

2-chloro-2-methylbutane (*substitution product*)

The sole product of the reaction was purified and analysed using ^{13}C NMR spectroscopy. The ^{13}C NMR spectrum is shown below.



Deduce which of the two possible products was formed in the reaction. Explain your choice using ^{13}C NMR data.

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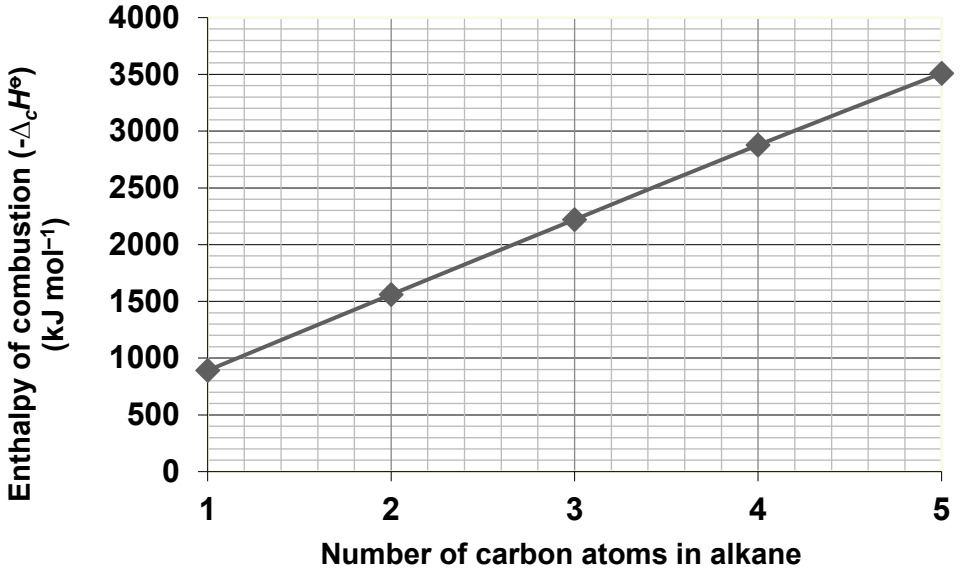
Question 26 (5 marks) **Marks**

The graph shows the trend in standard enthalpy of combustion values (reported as $-\Delta_c H^{\ominus}$) for five alkanes in kJ mol^{-1}.



(a) Explain the trend observed.

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(b) Calculate the energy released from the combustion of pentane, in kJ g^{-1}.

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Question 27 (5 marks) **Marks**

A beaker contains 105 mL of saturated calcium sulfate solution at 25°C.

The K_{sp} for $CaSO_4$ is 4.93×10^{-5} at 25°C.

(a) Calculate the molar solubility of calcium sulfate in water at this temperature.

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(b) 145 mL of 0.500 mol L^{-1} sodium sulfate solution is added to the saturated calcium sulfate. Determine whether a precipitate will form and justify your answer with calculations.

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Question 28 (4 marks) **Marks**

The following reactions are performed at 823 K.

Reaction 1: $CoO(s) + H_2(g) \rightleftharpoons Co(s) + H_2O(g)$ $K_{eq}1 = 67$

Reaction 2: $CoO(s) + CO(g) \rightleftharpoons Co(s) + CO_2(g)$ $K_{eq}2 = 490$

(a) Use the information provided to calculate the value for the equilibrium constant, $K_{eq}3$, at 823 K. Show your working.

Reaction 3: $H_2(g) + CO_2(g) \rightleftharpoons CO(g) + H_2O(g)$ $K_{eq}3 = ?$

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(b) At 1973 K the value of the equilibrium constant, K_{eq}, for reaction 3 is 4.9. Using your value calculated in part (a), justify whether the forward reaction is endothermic or exothermic.

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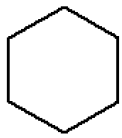
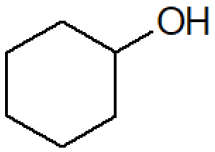
Question 29 (4 marks) **Marks**

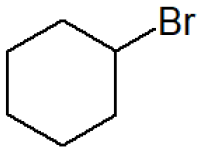
The structures of four cyclic organic compounds are shown below.



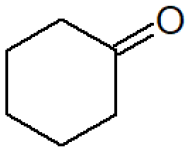
cyclohexane



cyclohexanol



bromocyclohexane



cyclohexanone

(a) Outline how infrared spectroscopy could be used to distinguish between a sample of cyclohexanone and cyclohexanol.

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(b) Samples of cyclohexane and bromocyclohexane cannot be easily distinguished from one another using infrared spectroscopy. Suggest another analytical technique that can be used to distinguish the two and refer to any differences in the spectra.

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Question 30 (3 marks) **Marks**

Calculate the volume of water that must be added to a 220.0 mL solution of sodium hydroxide with a pH of 13.030 to achieve a solution with a final pH of 12.699 at 25°C.

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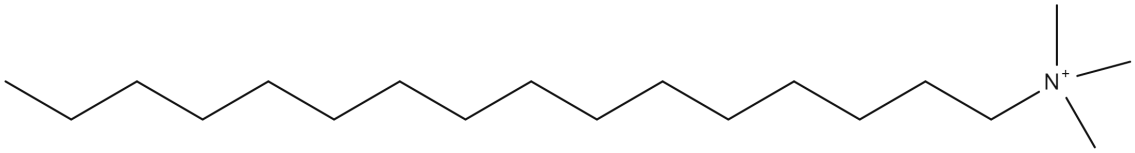
Question 31 (4 marks) **Marks**

The structure of a cationic detergent, cetrimonium, is shown.



With reference to its structure, explain how cetrimonium can be used to produce a stable emulsion of oil in water.

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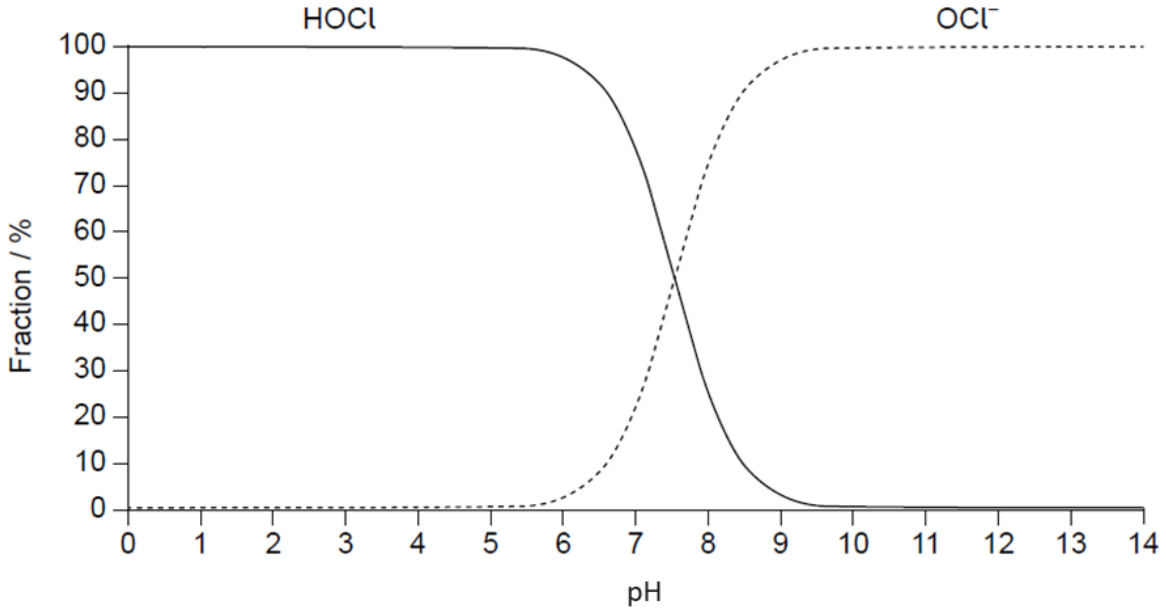
Question 32 (6 marks) **Marks**

Hypochlorous acid, HOCl, is a sterilising agent used in swimming pools. It is produced when chlorine reacts with water according to the equation shown.

$$Cl_2(aq) + H_2O(l) \rightleftharpoons HOCl(aq) + HCl(aq)$$

HOCl ionises to form the hypochlorite ion, OCl^-, which is a less effective disinfectant than the undissociated acid. The graph shows the concentrations of $HOCl(aq)$ and $OCl^-(aq)$ at different pH values at 25°C.



(a) Deduce the pH range where the water is most effectively sterilised.

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(b) With reference to the graph, determine the pK_a of HOCl at 25°C.

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Question cont. **Marks**

(c) Calculate the pH of 0.100 mol L^{-1} NaOCl at 25°C.

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Question 33 (5 marks)

A new brand of orange juice claims to contain at least 300.0 mg of vitamin C, $C_6H_8O_6$, per 100 mL serving size on its label.

A back titration involving iodine was performed to test this claim.

Iodine was produced by adding 10.93 mL of 0.001025 mol L^{-1} aqueous potassium iodate, $KIO_3(aq)$, to an excess of aqueous potassium iodide solution.

$$KIO_3(aq) + 6H^+(aq) + 5I^-(aq) \rightarrow 3I_2(aq) + 3H_2O(l) + K^+(aq)$$

A 100.0 mL sample of the commercial orange juice was then diluted to 1.000 L using deionised water. A 25.00 mL aliquot of the diluted orange juice was then added to the iodine produced.

$$C_6H_8O_6(aq) + I_2(aq) \rightarrow C_6H_6O_6(aq) + 2I^-(aq) + 2H^+(aq)$$

The excess iodine was then titrated against 0.001135 mol L^{-1} thiosulfate solution as shown.

$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$$

The experiment was repeated, and the results are shown below.

Trial	Volume of $Na_2S_2O_3$ added (mL)
1	19.80
2	12.25
3	12.35
4	12.30

Question cont. **Marks**

Assess the accuracy of the claim made on the label of the orange juice and show your working.

The *MM* of Vitamin C is 176.124 g mol^{-1}.

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Question 34 (4 marks) **Marks**

The enthalpy of solution is described by the following equation:

$$\Delta H_{sol}^{\ominus} = \Delta H_{latt}^{\ominus} + \Delta H_{hyd}^{\ominus}$$

Values for the lattice enthalpy ($\Delta H_{latt}^{\ominus}$), hydration enthalpy ($\Delta H_{hyd}^{\ominus}$) and entropy of solution ($\Delta S_{sol}^{\ominus}$) have been given for two ionic compounds, lead(II) chloride and lead(II) iodide.

Compound	$\Delta H_{latt}^{\ominus}$ *(kJ mol^{-1})*	$\Delta H_{hyd}^{\ominus}$ *(kJ mol^{-1})*	$\Delta S_{sol}^{\ominus}$ *(J K^{-1} mol^{-1})*
$PbCl_2$	+683	–1820	+136.0
PbI_2	+591	–1540	+174.9

State which of the two lead(II) salts is the most soluble and use all values in the table to explain this difference in solubility of lead(II) chloride and lead(II) iodide in water.
Note: You do not need to calculate ΔG to answer this question.

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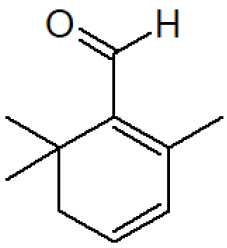
Question 35 (5 marks) **Marks**

Safranal (shown below) is a compound that naturally occurs in saffron.



(a) On the diagram above, circle and label two different functional groups found in safranal.

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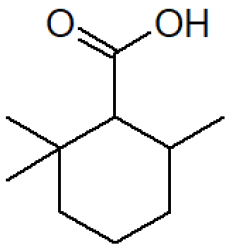
Safranal can be converted into the compound shown below in two steps.



(b) Describe how you could produce this compound from safranal, stating the reagents and conditions required for each step, and draw the intermediate compound.

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Question 36 (4 marks) **Marks**

What mass of solid sodium hydroxide should be added to 100.0 mL of 0.500 M HCl to increase the temperature by 5.00°C?

You can assume that the specific heat capacity of the solution is 4.18×10^3 J kg^{-1} K^{-1}.

$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$ $\Delta H = -56.1$ kJ mol^{-1}

$NaOH(s) \rightarrow NaOH(aq)$ $\Delta H = -44.5$ kJ mol^{-1}

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Question 37 (9 marks)

Compounds **X**, **Y** and **Z** are isomers containing 68.1% carbon, 13.7% hydrogen and 18.2% oxygen by mass. They have a molar mass of less than 100 g mol^{-1}.

A student performs chemical tests on the three compounds. Results of the tests are shown in the table below.

Compound	*Addition of oxidant, acidified potassium dichromate solution*	*Addition of Lucas reagent (conc. HCl(aq) and $ZnCl_2$(aq))*
X	Orange solution remains	Precipitate forms immediately
Y	Orange solution turns green	Colourless solution remains
Z	Orange solution turns green	Precipitate forms after 5 minutes

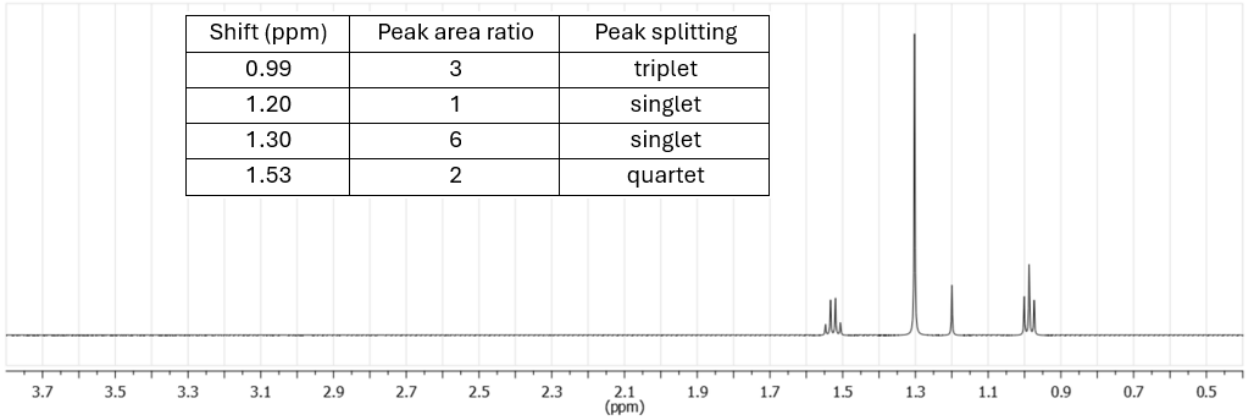
Question continues on next page.

Question continued.

^{1}H NMR data is also given for compounds **X**, **Y** and **Z**.

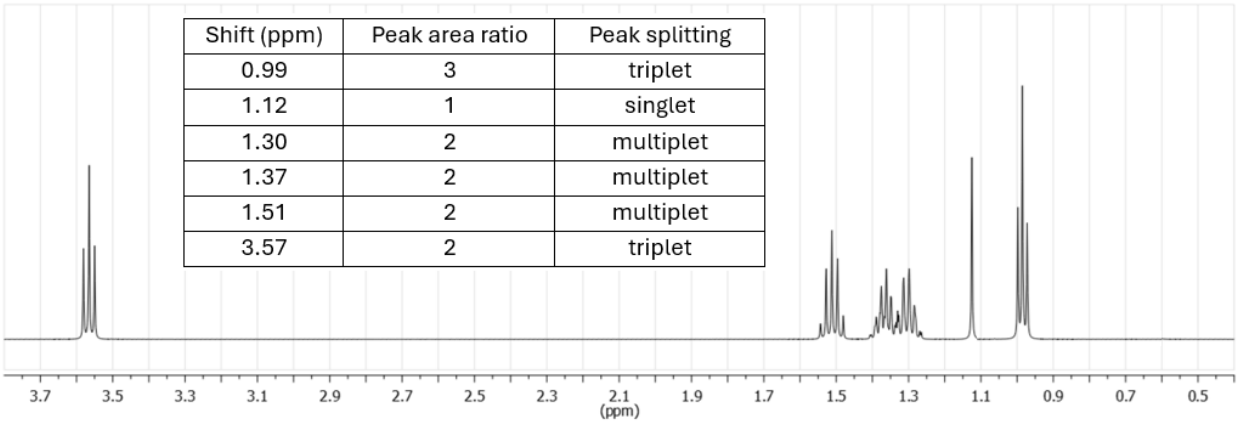
Compound **X**

Shift (ppm)	Peak area ratio	Peak splitting
0.99	3	triplet
1.20	1	singlet
1.30	6	singlet
1.53	2	quartet



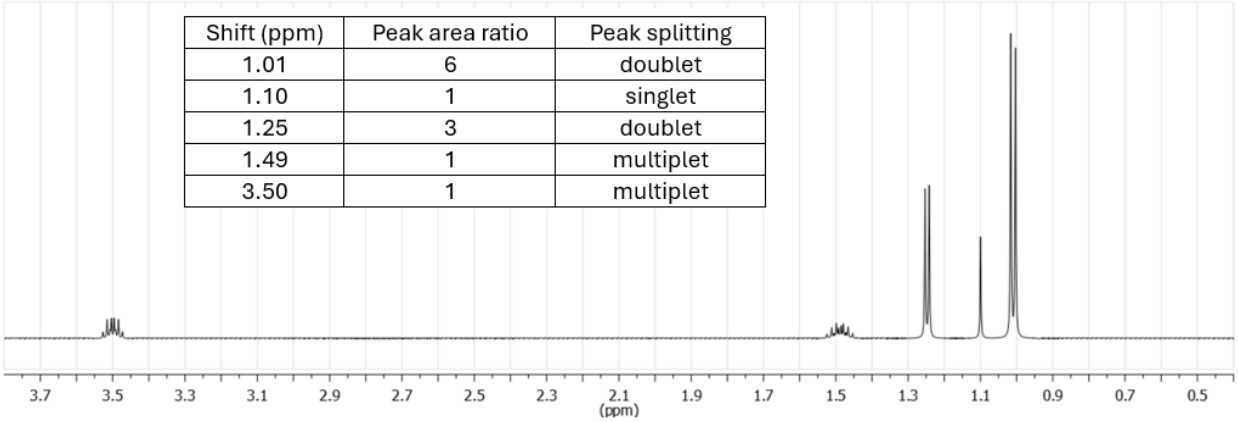
Compound **Y**

Shift (ppm)	Peak area ratio	Peak splitting
0.99	3	triplet
1.12	1	singlet
1.30	2	multiplet
1.37	2	multiplet
1.51	2	multiplet
3.57	2	triplet



Compound **Z**

Shift (ppm)	Peak area ratio	Peak splitting
1.01	6	doublet
1.10	1	singlet
1.25	3	doublet
1.49	1	multiplet
3.50	1	multiplet



Question continued.

^{1}H NMR chemical shift data

Type of proton	δ/ppm
$Si(C\mathbf{H}_3)_4$ (TMS)	0
R–C$\mathbf{H}_3$	0.9–1.0
R–C$\mathbf{H}_2$–R	1.2–1.5
R–C$\mathbf{H}R_2$	1.5–2.0
R–C≡C–**H** (alkyne)	2.0–3.1
–CO–C$\mathbf{H}_2$– (aldehydes, ketones or esters)	2.1-2.7
R–C$\mathbf{H}_2$–NH_2	2.4–3.0
R–C$\mathbf{H}_2$–X (X = F, Cl, Br, I)	3.0–4.5
–C$\mathbf{H}_2$–O– (alcohols, ethers or esters)	3.3–4.8
R–O**H**	1–6
R–N$\mathbf{H}_2$	1–5
R_2C=C**H**R (alkene)	4.5–7.0
R–COON**H**–R (amide)	5–9
Ar-**H** (aromatic)	6.9–9.0
R–C**H**O (aldehyde)	9.4–10.0
R–COO**H**	9.0–13.0

Question continues on next page.

Question continued. **Marks**

Draw and name compounds **X**, **Y** and **Z** and, by using all information given, justify your choice for **compound X**.

9

Compound **X** Name: ……..
Compound **Y** Name: ……..
Compound **Z** Name: ……..

Question continued.

*Justification for compound **X**:*

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END OF EXAMINATION

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2019 | HIGHER SCHOOL CERTIFICATE EXAMINATION

Chemistry

FORMULAE SHEET

$$n = \frac{m}{MM} \qquad c = \frac{n}{v} \qquad PV = nRT$$

$$q = mC\Delta T \qquad \Delta G^\circ = \Delta H^\circ - T\Delta S^\circ \qquad \text{pH} = -\log_{10}[\text{H}^+]$$

$$pK_a = -\log_{10}[K_a] \qquad A = \varepsilon lc = \log_{10}\frac{I_o}{I}$$

Avogadro constant, N_A ..... 6.022×10^{23} mol^{-1}

Volume of 1 mole ideal gas: at 100 kPa and

at 0°C (273.15 K) ..... 22.71 L

at 25°C (298.15 K) ..... 24.79 L

Gas constant ..... 8.314 J mol^{-1} K^{-1}

Ionisation constant for water at 25°C (298.15 K), K_w ..... 1.0×10^{-14}

Specific heat capacity of water ..... 4.18×10^3 J kg^{-1} K^{-1}

DATA SHEET

Solubility constants at 25°C

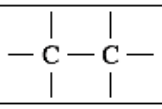
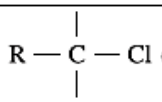
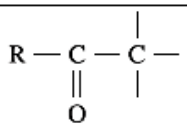
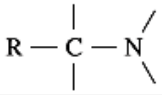
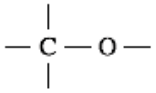
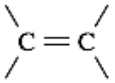
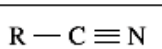
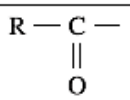
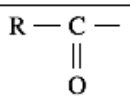
Compound	K_{sp}	*Compound*	K_{sp}
Barium carbonate	2.58×10^{-9}	Lead(II) bromide	6.60×10^{-6}
Barium hydroxide	2.55×10^{-4}	Lead(II) chloride	1.70×10^{-5}
Barium phosphate	1.3×10^{-29}	Lead(II) iodide	9.8×10^{-9}
Barium sulfate	1.08×10^{-10}	Lead(II) carbonate	7.40×10^{-14}
Calcium carbonate	3.36×10^{-9}	Lead(II) hydroxide	1.43×10^{-15}
Calcium hydroxide	5.02×10^{-6}	Lead(II) phosphate	8.0×10^{-43}
Calcium phosphate	2.07×10^{-29}	Lead(II) sulfate	2.53×10^{-8}
Calcium sulfate	4.93×10^{-5}	Magnesium carbonate	6.82×10^{-6}
Copper(II) carbonate	1.4×10^{-10}	Magnesium hydroxide	5.61×10^{-12}
Copper(II) hydroxide	2.2×10^{-20}	Magnesium phosphate	1.04×10^{-24}
Copper(II) phosphate	1.40×10^{-37}	Silver bromide	5.35×10^{-13}
Iron(II) carbonate	3.13×10^{-11}	Silver chloride	1.77×10^{-10}
Iron(II) hydroxide	4.87×10^{-17}	Silver carbonate	8.46×10^{-12}
Iron(III) hydroxide	2.79×10^{-39}	Silver hydroxide	2.0×10^{-8}
Iron(III) phosphate	9.91×10^{-16}	Silver iodide	8.52×10^{-17}
		Silver phosphate	8.89×10^{-17}
		Silver sulfate	1.20×10^{-5}

Aylward and Findlay, *SI Chemical Data* (5th Edition) is the principal source of data for this examination paper. Some data may have been modified for examination purposes.

Infrared absorption data

Bond	Wavenumber/cm^{-1}
N—H (amines)	3300–3500
O—H (alcohols)	3230–3550 (broad)
C—H	2850–3300
O—H (acids)	2500–3000 (very broad)
C≡N	2220–2260
C=O	1680–1750
C=C	1620–1680
C—O	1000–1300
C—C	750–1100

^{13}C NMR chemical shift data

Type of carbon		δ/ppm
		5–40
		10–70
		20–50
		25–60
	alcohols, ethers or esters	50–90
		90–150
		110–125
		110–160
	esters or acids	160–185
	aldehydes or ketones	190–220

UV absorption

(This is not a definitive list and is approximate.)

Chromophore	λ_{max} (nm)
C—H	122
C—C	135
C=C	162

Chromophore	λ_{max} (nm)
C≡C	173 178 196 222
C—Cl	173
C—Br	208

Some standard potentials

$K^+ + e^-$	$\rightleftharpoons$	$K(s)$	–2.94 V
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	$Ba(s)$	–2.91 V
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	$Ca(s)$	–2.87 V
$Na^+ + e^-$	$\rightleftharpoons$	$Na(s)$	–2.71 V
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	$Mg(s)$	–2.36 V
$Al^{3+} + 3e^-$	$\rightleftharpoons$	$Al(s)$	–1.68 V
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	$Mn(s)$	–1.18 V
$H_2O + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g) + OH^-$	–0.83 V
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	$Zn(s)$	–0.76 V
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	$Fe(s)$	–0.44 V
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	$Ni(s)$	–0.24 V
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	$Sn(s)$	–0.14 V
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	$Pb(s)$	–0.13 V
$H^+ + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g)$	0.00 V
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2(aq) + 2H_2O$	0.16 V
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	$Cu(s)$	0.34 V
$\frac{1}{2}O_2(g) + H_2O + 2e^-$	$\rightleftharpoons$	$2OH^-$	0.40 V
$Cu^+ + e^-$	$\rightleftharpoons$	$Cu(s)$	0.52 V
$\frac{1}{2}I_2(s) + e^-$	$\rightleftharpoons$	I^-	0.54 V
$\frac{1}{2}I_2(aq) + e^-$	$\rightleftharpoons$	I^-	0.62 V
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	0.77 V
$Ag^+ + e^-$	$\rightleftharpoons$	$Ag(s)$	0.80 V
$\frac{1}{2}Br_2(l) + e^-$	$\rightleftharpoons$	Br^-	1.08 V
$\frac{1}{2}Br_2(aq) + e^-$	$\rightleftharpoons$	Br^-	1.10 V
$\frac{1}{2}O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O	1.23 V
$\frac{1}{2}Cl_2(g) + e^-$	$\rightleftharpoons$	Cl^-	1.36 V
$\frac{1}{2}Cr_2O_7^{2-} + 7H^+ + 3e^-$	$\rightleftharpoons$	$Cr^{3+} + \frac{7}{2}H_2O$	1.36 V
$\frac{1}{2}Cl_2(aq) + e^-$	$\rightleftharpoons$	Cl^-	1.40 V
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	1.51 V
$\frac{1}{2}F_2(g) + e^-$	$\rightleftharpoons$	F^-	2.89 V

PERIODIC TABLE OF THE ELEMENTS

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

KEY

Atomic Number
Symbol
Standard Atomic Weight
Name

79
Au
197.0
Gold

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Standard atomic weights are abridged to four significant figures.

Elements with no reported values in the table have no stable nuclides.

Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).

The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of all other data. Some data may have been modified.

SYDNEY GRAMMAR SCHOOL

C	R	I	B				
CANDIDATE NUMBER							

2024
TRIAL EXAMINATION

CHEMISTRY

Section I - Multiple Choice

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.

correct ↓

A ⊗ B ⊗ C ○ D ○

Start Here →

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

SECTION II: WRITTEN ANSWER QUESTIONS
80 marks
Attempt ALL Questions

CANDIDATE NUMBER							

Question 21 (5 marks) **Marks**

Consider the following reaction at 300 K.

$$2NO_2(g) \rightleftharpoons 2NO(g) + O_2(g)$$

1.00 mol of $NO_2(g)$ is placed into a 2.00 L container and the system was allowed to reach equilibrium. At equilibrium, the concentration of $NO_2(g)$ was found to be 0.250 mol L^{-1}.

(a) Write the K_{eq} expression for the reaction.

Sample Answer:

$$K_{eq} = \frac{[NO]^2[O_2]}{[NO_2]^2}$$

Mark Guide:
Correct expression including K = ……1 mark

(b) Calculate the equilibrium concentrations of $NO(g)$ and $O_2(g)$ at 300 K.
Sample Answer:

	$2NO_2(g)$	$\rightleftharpoons$	$2NO(g)$	$O_2(g)$
Initial	1.00/2.00 = 0.500		0	0
Change	–0.250		+0.250	+ 0.250/2
Equilibrium	0.250		0.250	0.125

So the equilibrium concentration of $NO(g)$ is 0.250 M and that of $O_2(g)$ is 0.125 M.

Mark Guide:
Initial concentrations ……..1 mark
Concentrations of NO and O_2 correct ……. ……..……1 mark

(c) Calculate the equilibrium constant, K_{eq}, at this temperature.

2

Sample Answer:

$$K_{eq} = \frac{[0.250]^2[0.125]}{[0.250]^2} = 0.125$$

Mark Guide:
Correct calculation ……..1 mark
Correct number of significant figures ……..1 mark

Question 22 (6 marks) **Marks**

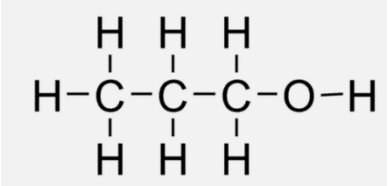
Propene readily undergoes hydration to produce a mixture of two products, **A** and **B** as shown. When separated, **A** and **B** can be oxidised to produce **C** and **D** as shown.

(a) Complete the diagram below by drawing the structures of **A** and **C** and stating the names of **A**-**D**.

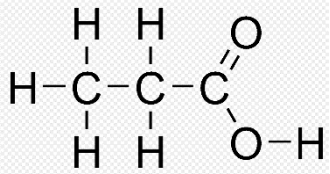
3

Sample Answer:

Structure A



Structure C



Name A: propan-1-ol
Name B: propan-2-ol
Name C: propanoic acid
Name D: propanone

Mark Guide:
Correct structure for compound A .....1 mark
Correct structure for compound C .....1 mark
All names, A to D, correct .....1 mark

Question continues on next page.

Question cont. **Marks**

(b) Compound **B** has a boiling point of 82°C and compound **D** has a boiling point of 56°C. Explain why compound **B** has a higher boiling point than compound **D**.

3

Sample Answer:

Compound B (Propan-2-ol) contains a hydroxyl group (-OH), which allows it to form hydrogen bonds as its most significant intermolecular force, between its molecules. These hydrogen bonds significantly increase the amount of energy required to separate the molecules, leading to a higher boiling point.

Compound D (Propanone), on the other hand, has a carbonyl group (C=O) as its functional group. While this allows for dipole-dipole interactions, as its most significant intermolecular force, between the slightly positive carbonyl carbon and the slightly negative carbonyl oxygen of neighbouring molecules, these forces are weaker than hydrogen bonds. As a result, less energy is needed to separate the molecules in compound D, leading to a lower boiling point compared to compound B.

Mark Guide:

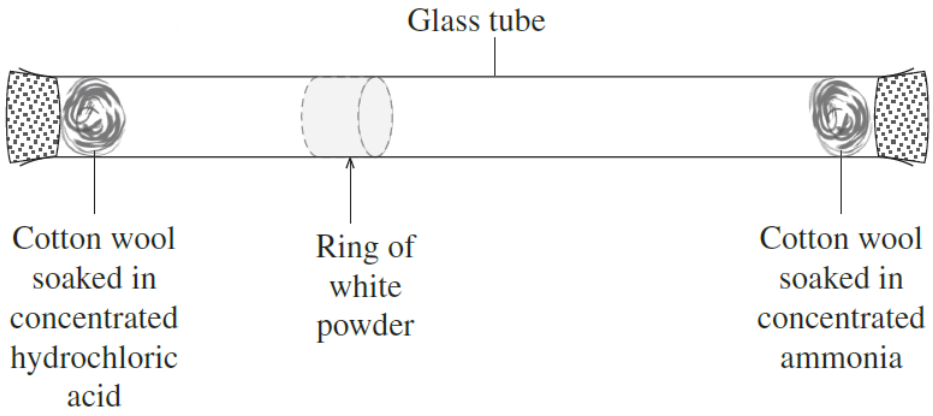
Identifying that compound B has Hydrogen bonding as its significant intermolecular force while compound D has dipole/dipole forces as its significant intermolecular force ……..…..1 mark

Identifying that hydrogen bonds are stronger than dipole/dipole forces ……1 mark

Identifying that it takes more energy to break a stronger force ……...1 mark

Question 23 (3 marks) **Marks**

Two pieces of cotton wool soaked in concentrated hydrochloric acid and concentrated ammonia were placed at opposite ends of a glass tube. After some time, the solutions vaporise and the two gases react to produce a ring of white powder.



(a) Write an equation for the reaction that occurs inside the glass tube.

1

Sample Answer:

$HCl(g) + NH_3(g) \rightarrow NH_4Cl(s)$

Mark Guide:

Correct equation with states ……1 mark

(b) State which acid-base theory explains the behaviour in this reaction and justify your answer.

2

Sample Answer:

Bronsted-Lowry theory

The acid, HCl, is donating a proton to the base. The base, NH_3 is accepting a proton from the acid

Mark Guide:

Correct theory identified …… 1 mark

Correctly defines an acid as a proton donor and a base as a proton acceptor …..1 mark

CANDIDATE NUMBER								Marks

Question 24 (6 marks)

Consider the following equilibrium reaction.

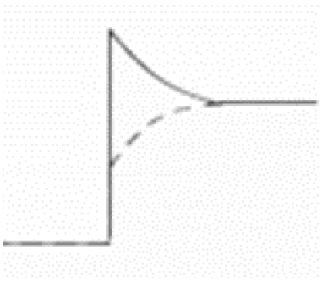
$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$$

(a) Use collision theory to explain how a decrease in volume would affect the rates of the forward and reverse reactions initially and until equilibrium is re-established.

4

Sample Answer:
Collision theory states that for a reaction to occur, reactant molecules must collide with sufficient energy and proper orientation. The rate of a reaction depends on the frequency of collisions between the reactant molecules and the energy of those collisions.

When the volume of the system is decreased, the pressure increases because the same number of gas molecules now occupy a smaller space. According to collision theory, the decrease in volume leads to an increase in the concentration (or partial pressures) of all gases in the system.
Therefore, the frequency of successful collisions between reactant molecules and product molecules increases.
Since a volume decrease increases concentrations of **all** reactants and products, the forward and backward reaction rates increase. Since there are now more increased collisions for the reverse reaction, the rate of the reverse reaction should increase more than the forward.
The rate of the reverse reaction will slow and the forward will increase until a new equilibrium is established.
Both rates adjust to be equal and higher as equilibrium is reached once more.



- - - - - - - - - = Forward reaction
_____ = Reverse reaction

Mark Guide:

Code	Detail required in answer	Marks
MC *More collisions*	The frequency of successful **collisions** between reactant molecules and product molecules **increases** initially, increase the rates of both the forward and reverse reactions	1
FR *Favours reverse*	The **reverse reaction** involves more moles of gas, so the reverse reaction will involve relatively **more successful** collisions compared to the forward reaction and be faster	1
RS *Reverse slows*	The rate of the forward reaction will increase over time as the system moves towards equilibrium. The **reverse reaction will decrease in rate**	1
EE *Equal rate at new equilibrium*	When **equilibrium** is re-established, forward and reverse rates are faster and **equal**	1

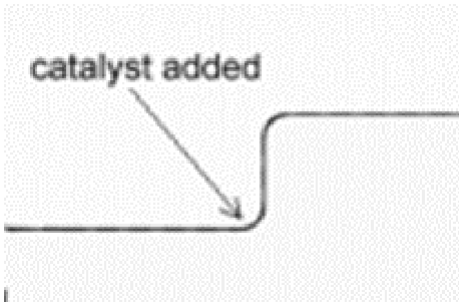
(b) Describe and explain how the addition of a catalyst would affect the rates of the forward and reverse reactions and the position of the equilibrium.

2

Sample Answer:

When a catalyst is added, it increases the rates of both the forward and reverse reactions by providing an alternative reaction pathway with a lower activation energy. This means that more reactant molecules and product molecules have sufficient energy to overcome the energy barrier, leading to an increased rate of the forward and reverse reactions equally.

The position of equilibrium is determined by the relative rates of the forward and reverse reactions. Since the catalyst affects both the forward and reverse reactions equally, it does not change the equilibrium concentrations of reactants and products. Therefore, the position of equilibrium remains unchanged.



Mark Guide:

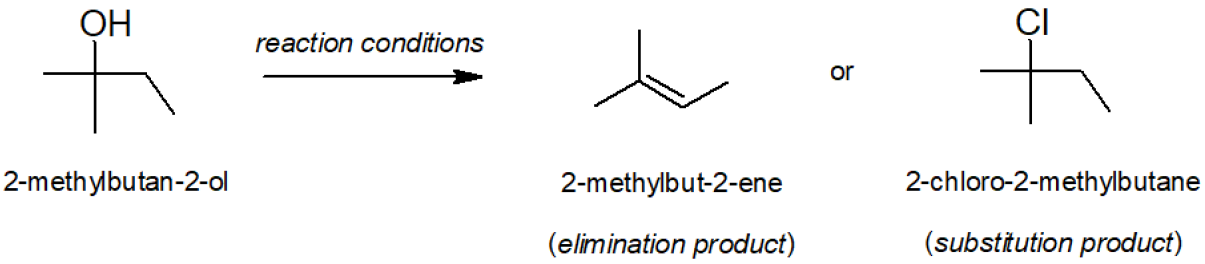
Increases the rate of forward and reverse equally ……..……..1 mark

The position of the equilibrium is unchanged (or K value unchanged)……..…..1 mark

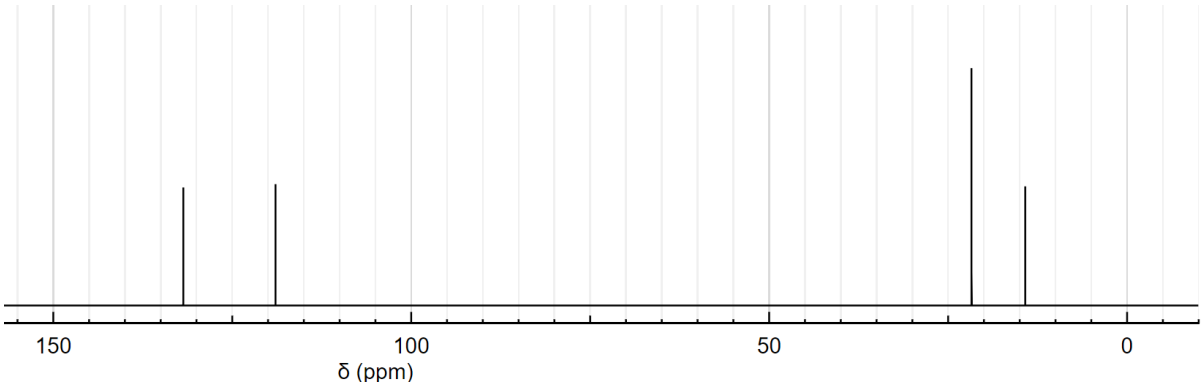
Question 25 (2 marks) **Marks**

Alcohols can undergo elimination and substitution reactions under different conditions.

A sample of 2-methylbutan-2-ol was subjected to an experimental set of conditions to determine whether elimination or substitution would occur.



The sole product of the reaction was purified and analysed using ^{13}C NMR spectroscopy. The ^{13}C NMR spectrum is shown below.



Deduce which of the two possible products was formed in the reaction. Explain your choice using ^{13}C NMR data.

Sample Answer

The product is 2-methylbut-2-ene.

This is because there are 2 signals above 100 ppm, (one at 138 and one at 163 ppm approx.). These correspond to the signal emitted by a carbon with a double bond. (90 – 150 ppm).

2-chloro-2-methylbutane will not emit any signals above 100 ppm.

Mark Guide:

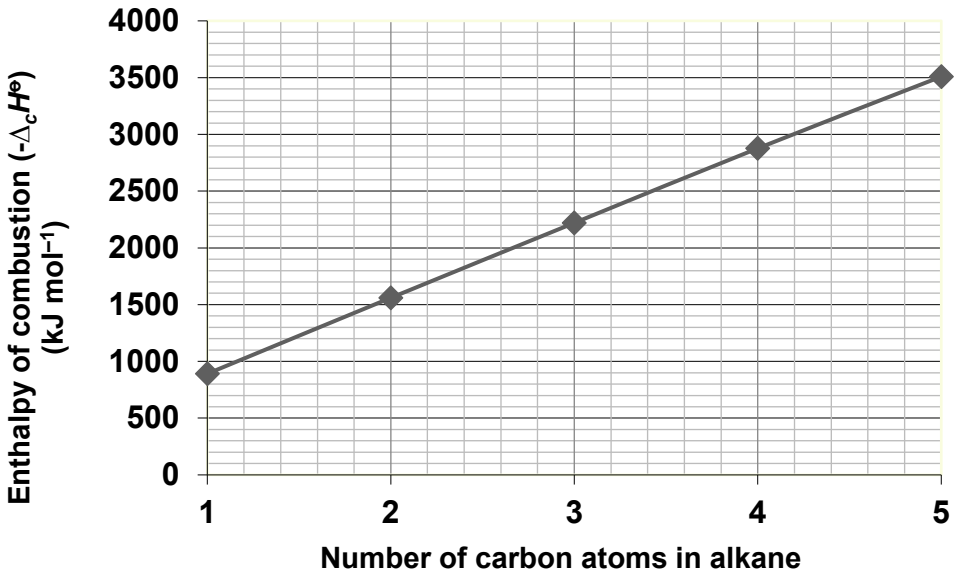
Correct identification of 2-methylbut-2-ene (or elimination product)……1 mark

Explanation relates the shift seen in the spectrum to the expected C=C shift according to the shift data supplied (90 – 150 ppm)……1 mark

CANDIDATE NUMBER							

Question 26 (5 marks) **Marks**

The graph shows the trend in standard enthalpy of combustion values (reported as $-\Delta_c H^{\ominus}$) for five alkanes in kJ mol^{-1}.



(a) Explain the trend observed.

3

Criteria	Marks
• States trend • Links to increased moles of products and exothermic nature of bond making • Links to per mole of alkane combusted or refers to **net increase** in energy released (ie weighs up energy in (endo) vs energy out (exo))	3
Any two of the above	2
One of the above	1

Sample answer:

As number of Carbon atoms in alkane increase, the enthalpy of combustion, $-\Delta_c H^{\ominus}$, increases in a **regular** fashion. Ie **more heat is released per mole** of alkane combusted.

Each alkane differs by a -CH_2 unit, therefore as C atoms increase there is an **increase in the number of moles of CO_2 and H_2O** formed. **Forming these strong bonds** in CO_2 and H_2O is an **exothermic process.**

Since the formation of bonds in the products **release more energy than is absorbed** in breaking the additional bonds in the reactants **more energy is released/mole of alkane** combusted.

Markers Note:
In general this question was poorly answered with students being muddled re endothermic bond breaking process and exothermic bond making process. A thorough explanation of

the trend and relating it to per mole of alkane combusted was required to score full marks.

(b) Calculate the energy released from the combustion of pentane, in kJ g^{-1}.

2

Criteria	Marks
• Shows correct working • Calculates energy released as 48.51 kJ g^{-1}	2
Any relevant information such as: • Reads enthalpy value of -3500 KJ/mol from graph correctly • Calculates molar mass of pentane correctly as 72.146g/mol	1

Sample answer:

From graph: $\Delta_c H$ = -3500 kJ/mol
MM pentane = 72.146 g/mol

Energy released = 3500/72.146 = 48.51 kJ/g

Markers Note:
Students are reminded to use all data from data sheet in calculations and not quote MM pentane as 72 g/mol. In general this question was well answered.

Question 27 (5 marks) **Marks**

A beaker contains 105 mL of saturated calcium sulfate solution at 25°C.

The K_{sp} for $CaSO_4$ is 4.93×10^{-5} at 25°C.

(a) Calculate the molar solubility of calcium sulfate in water at this temperature.

2

Criteria	Marks
• Shows correct working • Correct answer with units	2
• Correct working	1

Sample answer:

$K_{sp} = [Ca^{2+}][SO_4^{2-}] = 4.93 \times 10^{-5}$
Let $[Ca^{2+}] = [SO_4^{2-}] = x$
$x^2 = 4.93 \times 10^{-5}$
$x = 0.00702\ldots$
Molar solubility = 7.02×10^{-3} mol/L

Markers Note:
In general this question was well answered. Students are reminded to give answers with units.

(b) 145 mL of 0.500 mol L^{-1} sodium sulfate solution is added to the saturated calcium sulfate. Determine whether a precipitate will form and justify your answer with calculations.

3

Criteria	Marks
Correct answer with working and statement	3
1 missing step or 1 error but correct method followed	2
Any relevant information	1

Sample answer:

$Q_{sp} = [Ca^{2+}]\,[SO_4^{2-}]$

Number of moles of Ca^{2+} initially in 105 mL = 7.02…. x 10^{-3} x 0.105 = 7.3725 x 10^{-4} mol

$[Ca^{2+}] = 7.37 \times 10^{-4} / 0.250 = 2.949 \times 10^{-3}$ mol/L

Number of moles of SO_4^{2-} initially in 105 mL = 7.02… x 10^{-3} x 0.105 mol = 7.3725 x 10^{-4} mol
Number of moles of SO_4^{2-} added = 0.500 x .145 = 0.0725
Total moles of SO_4^{2-} = 0.0725 + 7.3725 x 10^{-4} = 0.073237 mol

$[SO_4^{2-}] = 0.073237…/.250 = 0.29295$ mol/L

$Q_{sp} = = [Ca^{2+}]\,[SO_4^{2-}] = 8.64 \times 10^{-4}$ mol/L

Q_{sp} > Ksp, therefore a ppt will form.

Markers Note:
To get 2 marks students needed to at least have **$[Ca^{2+}]$ OR $[SO_4^{2-}]$** correct with correct method for calculating Qsp and statement.

Question 28 (4 marks) **Marks**

The following reactions are performed at 823 K.

Reaction 1: $CoO(s) + H_2(g) \rightleftharpoons Co(s) + H_2O(g)$ $K_{eq}1 = 67$

Reaction 2: $CoO(s) + CO(g) \rightleftharpoons Co(s) + CO_2(g)$ $K_{eq}2 = 490$

(a) Use the information provided to calculate the value for the equilibrium constant, $K_{eq}3$, at 823 K. Show your working.

Reaction 3: $H_2(g) + CO_2(g) \rightleftharpoons CO(g) + H_2O(g)$ $K_{eq}3 = ?$

2

Criteria	Marks
• Correct working • Correct answer	2
Any relevant information such as: • 67 x 490 = 32830 (student knows k_1 x k_2)	1

Sample answer:

~~$CoO(s)$~~ + $H_2(g) \rightleftharpoons$ ~~$Co(s)$~~ + $H_2O(g)$ $K_{eq}1 = 67$

~~$Co(s)$~~ + $CO_2(g) \rightleftharpoons$ ~~$CoO(s)$~~ + $CO(g)$ $K_{eq}2 = 1/490$

$H_2(g) + CO_2(g) \rightleftharpoons CO(g) + H_2O(g)$ $K_{eq}3 = 67 \times 1/490 = 0.137$

Markers Note:
This question was quite well answered by the majority of students.

(b) At 1973 K the value of the equilibrium constant, K_{eq}, for reaction 3 is 4.9. Using your value calculated in part (a), justify whether the forward reaction is endothermic or exothermic.

2

Criteria	Marks
• Determines endothermic • Correct justification	2
• Correct determination (endo) for students k values (follow on error (f.o.e) if k was incorrectly calculated in part a)	1

Sample answer:

$$K = \frac{[CO]\,[H_2O]}{[H_2]\,[CO_2]}$$

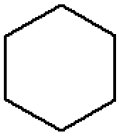
Since K increased as temperature increased, equilibrium shifted towards RHS (products), therefore **forward reaction must be endothermic** (LCP, the reaction shifts to oppose the increased temp therefore shifts to decrease temp, favours endo rxn.)

OR
Since K increases with temperature, endothermic reaction is favoured. Due it its higher activation energy it has a greater proportional increase in successful collisions than the reverse reaction, hence forward rate (endo) increases more than backward rate until a new equilibrium position is established.

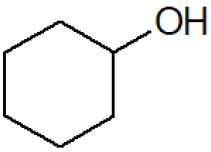
Markers Note:
This question was quite well answered by many students.

Question 29 (4 marks) **Marks**

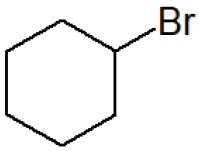
The structures of four cyclic organic compounds are shown below.



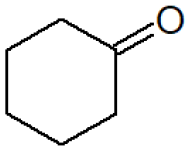
cyclohexane



cyclohexanol



bromocyclohexane



cyclohexanone

(a) Outline how infrared spectroscopy could be used to distinguish between a sample of cyclohexanone and cyclohexanol.

2

Criteria	Marks
• A thorough comparison of both spectra with reference to data from data sheet for BOTH compounds	2
• A sound comparison but lacks detail eg refers to only one piece of correct data from data sheet.	1

Sample answer:

Cyclohexanol will have a broad IR absorption at 3230 – 3550 cm^{-1} due to the -OH group in the alkanol, whereas cyclohexanone will not show this absorption (1 mark). Cyclohexanone will have a C=O absorption at 1680 – 1750 cm^{-1} that will not be present in the cyclohexanol spectrum. (2 marks)

Markers Note:
This question was well answered. Students are reminded to refer to wavenumber/cm^{-1} when they quote the data and be to be careful that they refer to the correct data! (-OH stretch data for the alcohol rather than -OH stretch for acid groups)

(b) Samples of cyclohexane and bromocyclohexane cannot be easily distinguished from one another using infrared spectroscopy. Suggest another analytical technique that can be used to distinguish the two and refer to any differences in the spectra.

2

Criteria	Marks
• States analytical technique with specific details of differences in spectra for BOTH compounds	2
• States analytical technique with a specific correct detail of the spectra for ONE compound	1

Sample answer:

Mass Spectrometry:

cyclohexane – molecular ion peak at 84
bromocyclohexane – molecular ion peak at 162/164 (isotope effect of ^{79}Br and of ^{81}Br)

C – 13 NMR:

cyclohexane – 1 peak as 1 Carbon environment
bromocyclohexane – 4 peaks as 4 Carbon environments

Proton NMR:

cyclohexane – 1 peak as 1 proton environment
bromocyclohexane – 4 peaks as 4 proton environments

Markers Note:
A number of responses incorrectly identified the m/z peak for bromocyclohexane at 163.
(A specific isotope of Br will be present in the molecular ion, so 2 molecular ion peaks formed with same ratio of abundance (approx. 50:50) at 162 if ^{79}Br is in the molecular ion and at 164 if ^{81}Br present).
If students gave molecular ion as 163 they could only score 2 marks if student gave another identifying feature eg 2 x M^+ peaks of equal ratio as abundance of ions is approx1:1 etc.

Some responses were too general eg molecular ion peak for bromocyclohexane is greater than molecular ion peak for cyclohexane. This scored 0 marks. Some specific detail was required.

Students are reminded to read the question carefully as some students responded referring to cyclohexanone and cyclohexanol from part a.

Question 30 (3 marks) **Marks**

Calculate the volume of water that must be added to a 220.0 mL solution of sodium hydroxide with a pH of 13.030 to achieve a solution with a final pH of 12.699 at 25°C.

3

Criteria	Marks
• Correct $[OH^-]$ calculations before and after dilution. • Correct total volume of water • Correct answer with units	3
1 error but correct method.	2
Any relevant information (look for follow on error)	1

Sample answer:
Initial pH = 13.031, therefore pOH = 0.97, $[OH^-] = 10^{-0.97}$
Final pH = 12.699, therefore pOH = 1.301, $[OH^-] = 10^{-1.301}$

$c_1v_1 = c_2v_2$
$10^{-0.97} \times 220 = 10^{-1.301} \times v_2$
V_2 = 471.4359 mL

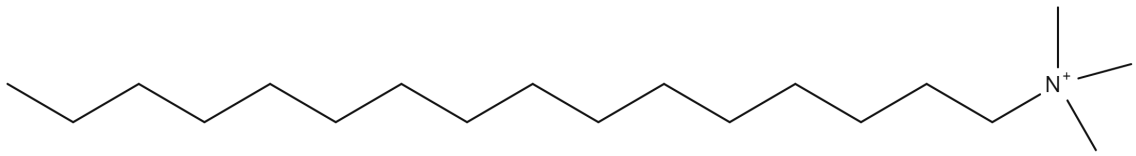
Volume of water added = 471.4359 – 220 = 251.44 mL = **251 mL**

Markers Note:

Students introduced unnecessary errors into their final answer by rounding down too early in the calculation.

Question 31 (4 marks) **Marks**

The structure of a cationic detergent, cetrimonium, is shown.



With reference to its structure, explain how cetrimonium can be used to produce a stable emulsion of oil in water.

4

• Identifies the hydrophobic and hydrophilic regions of cetrimonium • Explains the interaction of cetrimonium with oil • Explains the interaction of cetrimonium with water • Describes the formation of micelles and their role in forming a stable emulsion	4
• Insufficient detail for one of the above	3
• Relates structure of cetrimonium to its interactions with water and oil OR • Relates structure of cetrimonium to formation of specific intermolecular forces OR • Describes a micelle	2
• Relevant information	1

Notes

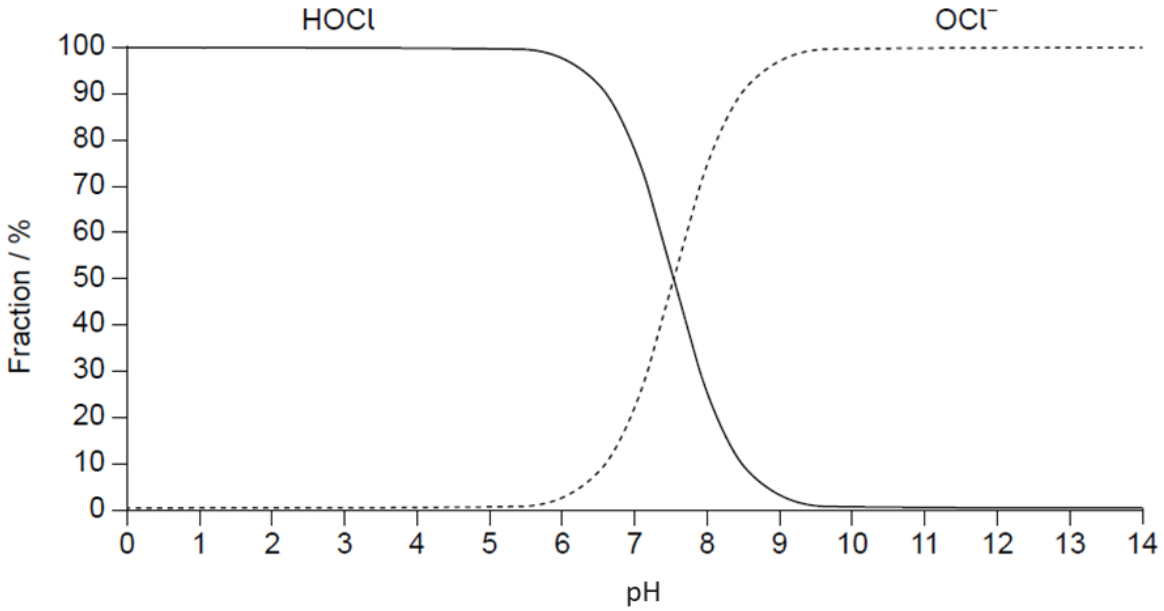
- A clear, labelled diagram along with written detail was acceptable for micelle formation
- "Hydrophobic" and "hydrophilic" look very similar if your handwriting is bad enough
- The cationic head group forms ion-dipole interactions with water
- Many students answered this question as if it was about cleaning, not formation of an emulsion, and some answered it referring to the structure of soap. Please answer the question given in the exam!

Question 32 (6 marks) **Marks**

Hypochlorous acid, HOCl, is a sterilising agent used in swimming pools. It is produced when chlorine reacts with water according to the equation shown.

$$Cl_2(aq) + H_2O(l) \rightleftharpoons HOCl(aq) + HCl(aq)$$

HOCl ionises to form the hypochlorite ion, OCl^-, which is a less effective disinfectant than the undissociated acid. The graph shows the concentrations of $HOCl(aq)$ and $OCl^-(aq)$ at different pH values at 25°C.



(a) **Deduce the pH range where the water is most effectively sterilised.**

1

0-6 acceptable

(b) With reference to the graph, determine the pK_a of HOCl at 25°C.

1

Any value 7.3-7.7 inclusive

Question cont.

Marks

(c) Calculate the pH of 0.100 mol L^{-1} NaOCl at 25°C.

	Marks
• Correctly calculates the pH using value from (b) • Shows all relevant steps of the calculation, including the expression for K_b.	4
• One error OR missing a calculation step	3
• Provides some steps of the calculation	2
• Provides at least one correct calculation or other relevant information	1

Sample calculation (Error carried from (b))

$pK_a = 7.5$

$\therefore pK_b = 14 - 7.5 = 6.5$

$\therefore K_b = 10^{-pK_b} = 10^{-6.5}$

	OCl^-	+ H_2O	$\rightleftharpoons$	$HOCl$	+ OH^-
i	0.1	/		0	0
c	$-x$	/		$+x$	$+x$
e	$0.1-x$	/		x	x

$K_b = \dfrac{[HOCl][OH^-]}{[OCl^-]}$

$\therefore 10^{-6.5} = \dfrac{x^2}{0.1-x}$ (assume $x \ll 0.1$)

$\therefore x = 1.778 \times 10^{-4}$ (assumption valid)

$[OH^-] = 1.778 \times 10^{-4}$ M

$pOH = -\log_{10}[OH^-] = 3.75$

$pH = 14 - 3.75 = 10.25$

Question 33 (5 marks)

A new brand of orange juice claims to contain at least 300.0 mg of vitamin C, $C_6H_8O_6$, per 100 mL serving size on its label.

A back titration involving iodine was performed to test this claim.

Iodine was produced by adding 10.93 mL of 0.001025 mol L^{-1} aqueous potassium iodate, $KIO_3(aq)$, to an excess of aqueous potassium iodide solution.

$$KIO_3(aq) + 6H^+(aq) + 5I^-(aq) \rightarrow 3I_2(aq) + 3H_2O(l) + K^+(aq)$$

A 100.0 mL sample of the commercial orange juice was then diluted to 1.000 L using deionised water. A 25.00 mL aliquot of the diluted orange juice was then added to the iodine produced.

$$C_6H_8O_6(aq) + I_2(aq) \rightarrow C_6H_6O_6(aq) + 2I^-(aq) + 2H^+(aq)$$

The excess iodine was then titrated against 0.001135 mol L^{-1} thiosulfate solution as shown.

$$I_2(aq) + 2S_2O_3^{2-}(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$$

The experiment was repeated, and the results are shown below.

Trial	Volume of $Na_2S_2O_3$ added (mL)
1	19.80
2	12.25
3	12.35
4	12.30

Question cont. **Marks**

Assess the accuracy of the claim made on the label of the orange juice and show your working.

The *MM* of Vitamin C is 176.124 g mol^{-1}.

5

• Correctly calculates the mass of vitamin C per 100 mL (187.6 mg) • States correct conclusion • Shows all relevant steps of the calculation	5
• One minor error OR missing a calculation step	4
• Provides most of the steps of the calculation	3
• Provides some steps of the calculation	2
• Provides at least one correct calculation or other relevant information	1

Most common errors were in the dilution step or using stoichiometric ratios, so read carefully!

Sample calculation

$\bar{V} = \frac{12.25 + 12.35 + 12.30}{3} = 12.30$ mL

$n(\text{thiosulfate}) = C \times V = 0.00135 \times 0.01230 = 1.396 \times 10^{-5}$ mol

$\therefore n(I_2 \text{ excess}) = \frac{1}{2} \times n(\text{thiosulfate}) = 6.980 \times 10^{-6}$ mol

$n(\text{total } I_2 \text{ added}) = 3 \times n(KIO_3) = 3 \times (0.001025 \times 0.01093)$

$= 3.361 \times 10^{-5}$ mol

$n(I_2 \text{ reacted with VitC}) = \text{total added} - \text{excess}$

$= 3.361 \times 10^{-5} - 6.980 \times 10^{-6}$

$= 2.662 \times 10^{-5}$ mol

$n(\text{Vit C}) = n(I_2) = 2.662 \times 10^{-5}$ mol per 25 mL titration

$n(\text{VitC in original 100mL}) = 5 \times 2.662 \times 10^{-5}$ mol

$= 1.0648 \times 10^{-3}$ mol

$m(\text{VitC}) = n \times MM = 1.0648 \times 10^{-3} \times 176.124$

$= 0.1875$ g

$= 187.5$ mg per 100mL

187.5 mg < 300mg per 100 mL

∴ claim is not accurate

Question 34 (4 marks) **Marks**

The enthalpy of solution is described by the following equation:

$$\Delta H_{sol}^{\ominus} = \Delta H_{latt}^{\ominus} + \Delta H_{hyd}^{\ominus}$$

Values for the lattice enthalpy ($\Delta H_{latt}^{\ominus}$), hydration enthalpy ($\Delta H_{hyd}^{\ominus}$) and entropy of solution ($\Delta S_{sol}^{\ominus}$) have been given for two ionic compounds, lead(II) chloride and lead(II) iodide.

Compound	$\Delta H_{latt}^{\ominus}$ *(kJ mol^{-1})*	$\Delta H_{hyd}^{\ominus}$ *(kJ mol^{-1})*	$\Delta S_{sol}^{\ominus}$ *(J K^{-1} mol^{-1})*
$PbCl_2$	+683	–1820	+136.0
PbI_2	+591	–1540	+174.9

State which of the two lead(II) salts is the most soluble and use all values in the table to explain this difference in solubility of lead(II) chloride and lead(II) iodide in water.
Note: You do not need to calculate ΔG to answer this question.

4

• Discussed contribution of ΔH_{latt} and ΔH_{hyd} to ΔH_{sol} values for both salts OR directly calculated ΔH_{sol} • Discussed the relative contributions of ΔH_{sol} to the solubility of each salt • Discussed the relative contributions of ΔS_{sol} to the solubility of each salt • Explained the relative significance of ΔS_{sol} and ΔH_{sol} values to solubility • Correctly identified $PbCl_2$ as more soluble	4
• Insufficient detail for one of the above	3
• Any two correct points from above identified	2
• Relevant information	1

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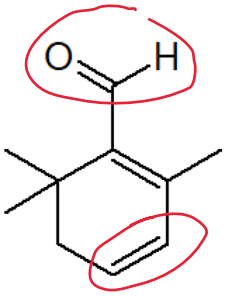
CANDIDATE NUMBER

Question 35 (5 marks) **Marks**

Safranal (shown below) is a compound that naturally occurs in saffron.

Note: Lots of students labeled the carbonyl group (C=O)
A carbonyl group is found in an aldehyde/ketone functional group.



aldehyde

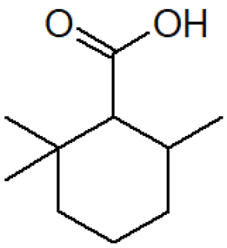
alkene

(a) On the diagram above, circle and label two different functional groups found in safranal.

Marking criteria **2**

2 Marks Two correct labels
1 Mark One correct label

Safranal can be converted into the compound shown below in two steps.

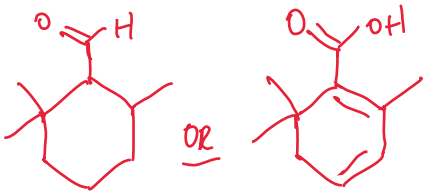


(b) Describe how you could produce this compound from safranal, stating the reagents and conditions required for each step, and draw the intermediate compound.

Marking criteria **3**

1 Mark Correct hydrogenation conditions (hydrogen gas **and** Pd/C catalyst)
1 Mark Correct oxidation conditions (acidified potassium dichromate/acidified potassium permanganate/Tollens' reagent)
1 Mark Correctly drawn intermediate

Order of steps was ignored.



Note: This question was generally done well by students.

Question 36 (4 marks) **Marks**

What mass of solid sodium hydroxide should be added to 100.0 mL of 0.500 M HCl to increase the temperature by 5.00°C?

You can assume that the specific heat capacity of the solution is 4.18×10^3 J kg^{-1} K^{-1}.

$NaOH(aq) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$ $\Delta H = -56.1$ kJ mol^{-1}

$NaOH(s) \rightarrow NaOH(aq)$ $\Delta H = -44.5$ kJ mol^{-1}

Marking criteria **4**

4 Marks All 4 correct steps and correct answer
3 Marks 3 correct steps
2 Marks 2 correct steps
1 Mark 1 correct step / any relevant information

Sample answer

Step 1 Calculation of combined ΔH for $NaOH(s) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l)$
$\Delta H = -56.1$ kJ $mol^{-1} - 44.5$ kJ $mol^{-1} = -100.6$ kJ mol^{-1}

Step 2 Calculation of q
$q = mc\Delta T$
$q = 100 \times 4.18 \times 5 = 2090$ J

Step 3 Calculation of n(NaOH)
$n(NaOH) = q / \Delta H$
$n(NaOH) = 2.090$ kJ $/ 100.6$ kJ $mol^{-1} = 0.02078$ mol

Step 4 Calculation of m(NaOH)
$m(NaOH) = n \times FW(NaOH)$
$m(NaOH) = 0.02078 \times 39.998 =$ **0.831 g**

Other correct answers for 4 marks (with working):
Taking into account the HCl in mass of solution: 0.846 g
Taking into account the NaOH in mass of solution: 0.838 g
Taking into account the HCl and NaOH in mass of solution: 0.853 g

Note:
Many students did not use $q = mc\Delta T$ correctly. m is the mass of the solution, not the mass of NaOH.

Question 37 (9 marks)

Compounds **X**, **Y** and **Z** are isomers containing 68.1% carbon, 13.7% hydrogen and 18.2% oxygen by mass. They have a molar mass of less than 100 g mol^{-1}.

A student performs chemical tests on the three compounds. Results of the tests are shown in the table below.

Compound	*Addition of oxidant, acidified potassium dichromate solution*	*Addition of Lucas reagent (conc. HCl(aq) and $ZnCl_2$(aq))*
X	Orange solution remains	Precipitate forms immediately
Y	Orange solution turns green	Colourless solution remains
Z	Orange solution turns green	Precipitate forms after 5 minutes

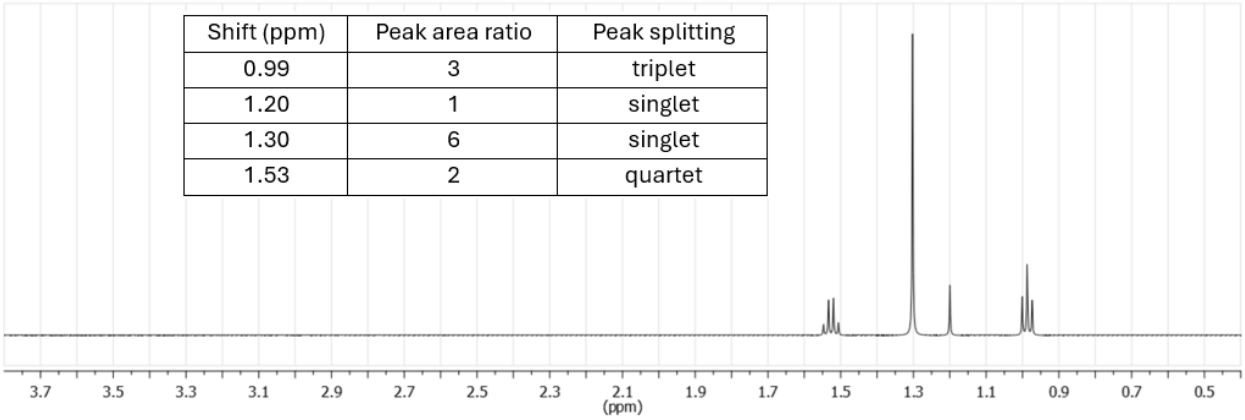
Question continues on next page.

Question continued.

^{1}H NMR data is also given for compounds **X**, **Y** and **Z**.

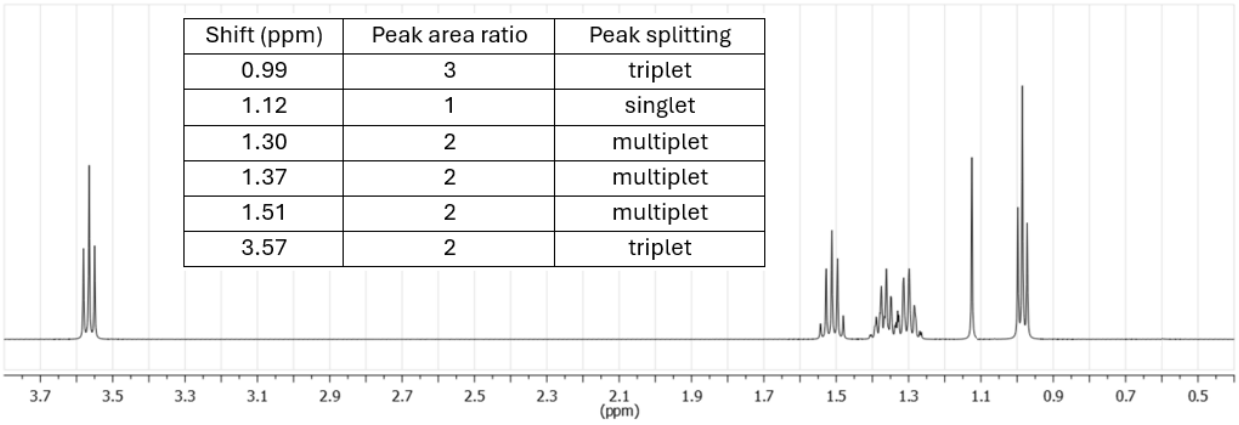
Compound **X**

Shift (ppm)	Peak area ratio	Peak splitting
0.99	3	triplet
1.20	1	singlet
1.30	6	singlet
1.53	2	quartet



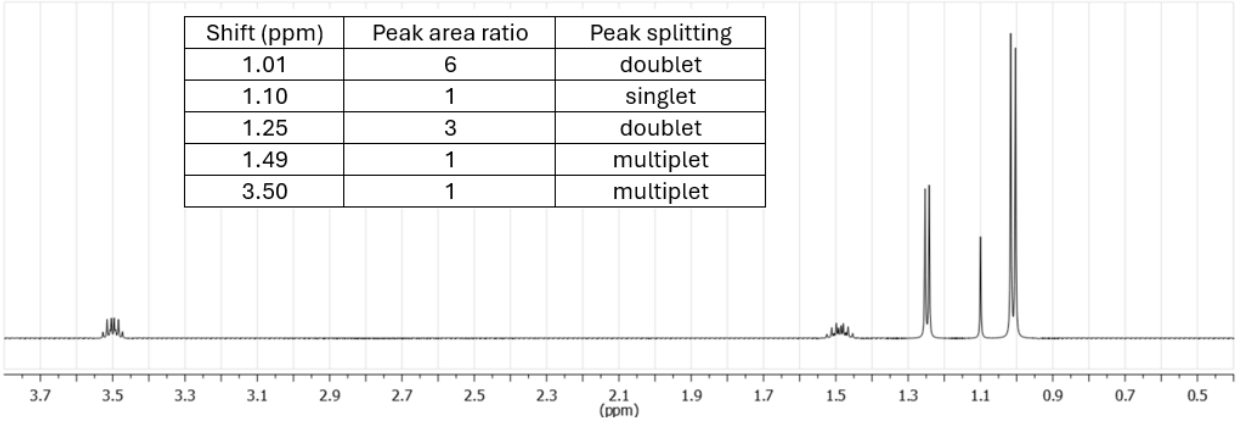
Compound **Y**

Shift (ppm)	Peak area ratio	Peak splitting
0.99	3	triplet
1.12	1	singlet
1.30	2	multiplet
1.37	2	multiplet
1.51	2	multiplet
3.57	2	triplet



Compound **Z**

Shift (ppm)	Peak area ratio	Peak splitting
1.01	6	doublet
1.10	1	singlet
1.25	3	doublet
1.49	1	multiplet
3.50	1	multiplet

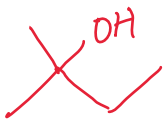


Question continued. **Marks**

Draw and name compounds **X**, **Y** and **Z** and, by using all information given, justify your choice for **compound X**.

9

Compound **X**

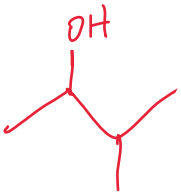


Name: 2-methylbutan-2-ol

Compound **Y**

Name: pentan-1-ol

Compound **Z**



Name: 3-methylbutan-2-ol

Justification for compound X:

Marking criteria

M1 Correct structure and name for compound X (2-methylbutan-2-ol)

M2 Correct structure and name for compound Y (pentan-1-ol)

M3 Correct structure and name for compound Z (3-methylbutan-2-ol)

M4 **Use** %mass data in justification by:
- calculating empirical formula (and showing working)
- calculating molar ratio from percentage masses and formula weight/number of H NMR peaks)

M5 **Use** mass limit of 100 g mol^{-1} in your justification by:
- stating formula weight and comparing to 100 g mol^{-1}
- eliminating possibility of $C_{10}H_{24}O_2$

M6 Use **both** chemical tests to confirm X is a tertiary alcohol

M7-9 H NMR justification was marked holistically

3 marks for full justification including:
- reference to all four peaks in H NMR spectrum
- explanation for splitting patterns in relation to structure
- justification of peak area ratio
- chemical shifts in relation to structure

2 marks for good justification including 2/3 of the following:
- reference to all peaks in H NMR spectrum
- explanation for splitting patterns
- justification of peak area ratio
- chemical shifts in relation to structure

1 mark for any weak justification

Entry level marks (max 1, for students on 2 marks or less using marking guidelines above)

Naming - any correct name
Structure - any correct structure
Formula - correct formula or formula weight
ID alcohol.

Notes:

The best answers included:
- a diagram with labels for the four proton environments, which could be referred to in the justification
- separate headings for mass data, chemical tests and spectral data

A tip: If you don't know where to start on a question like this in the HSC exam, start by annotating your spectra!