STUDENT NUMBER: _____

Pymble Ladies' College

2024 Chemistry Trial Examination

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 formulae sheet, data sheet and Periodic Table are provided separately
- For questions in Section I, record your responses on the multiple choice answer sheet provided at the back of this paper.
- For questions in Section II, show all relevant working in questions involving calculations.

Total Marks: 100

Section I – 20 marks

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

Section II – 80 marks

- Attempt Questions 21 – 34
- Allow about 2 hours and 25 minutes for this section

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Section I

20 marks
Attempt Questions 1 – 20
Allow about 35 minutes for this section

Use the multiple-choice answer sheet for Questions 1 – 20.

1. Which ONE of the following terms describes hydrocarbons that contain only single bonds?

   A. Isomers
   B. Saturated
   C. Unsaturated
   D. Homologous series

2. In which of the following techniques will the test compound always be destroyed?

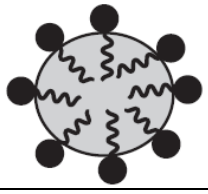
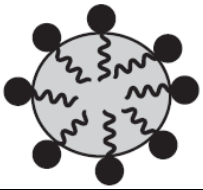
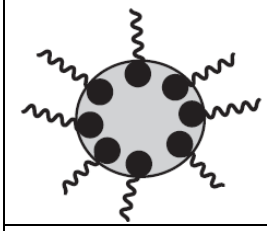
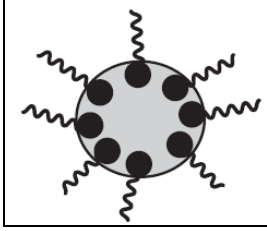
   A. Mass spectrometry
   B. Infrared spectroscopy
   C. Melting point analysis
   D. Carbon NMR spectroscopy

3. A test tube contains a liquid hydrocarbon. When bromine water (Br_2) is added to the test tube, the mixture decolourises IMMEDIATELY.

   Which row of the table correctly identifies the COMPOUND and the TYPE OF REACTION that takes place in the test tube?

	Compound	**Type of reaction**
A.	Hexane	Addition
B.	Hexane	Substitution
C.	Hex-2-ene	Addition
D.	Hex-2-ene	Substitution

4. Which row in the table best describes the ball-like structures formed when soap is added to an oil and water mixture?

	Diagram	Description
A.	water 	non-polar head dissolves in water, ionic tail dissolves in oil droplet
B.	water 	ionic head dissolves in water, non-polar tail dissolves in oil droplet
C.	water 	non-polar head dissolves in oil droplet, ionic tail dissolves in water
D.	water 	ionic head dissolves in oil droplet, non-polar tail dissolves in water

5. Which of the following compounds could be used as a primary standard?

A. Calcium carbonate
B. Hydrochloric acid
C. Sodium carbonate
D. Sodium hydroxide

6. The equation below describes a chemical system able to reach a state of dynamic equilibrium.

$$NH_3\ (g)\ +\ H_2O\ (l) \rightleftharpoons\ NH_4^+\ (aq)\ +\ OH^-\ (aq)$$

Which type of K is this reaction an example of?

A. An acid dissociation constant (K_a).
B. A base dissociation constant (K_b).
C. The self-ionisation constant of water (K_w).
D. Solubility product constant (K_{sp}).

7. Which ONE of the following is a SECONDARY alcohol?

A. $C(CH_3)_3OH$
B. $CH_3(CH_2)_3OH$
C. $CH_3(CH_2)_2CHO$
D. $CH_3CH_2CH(OH)CH_3$

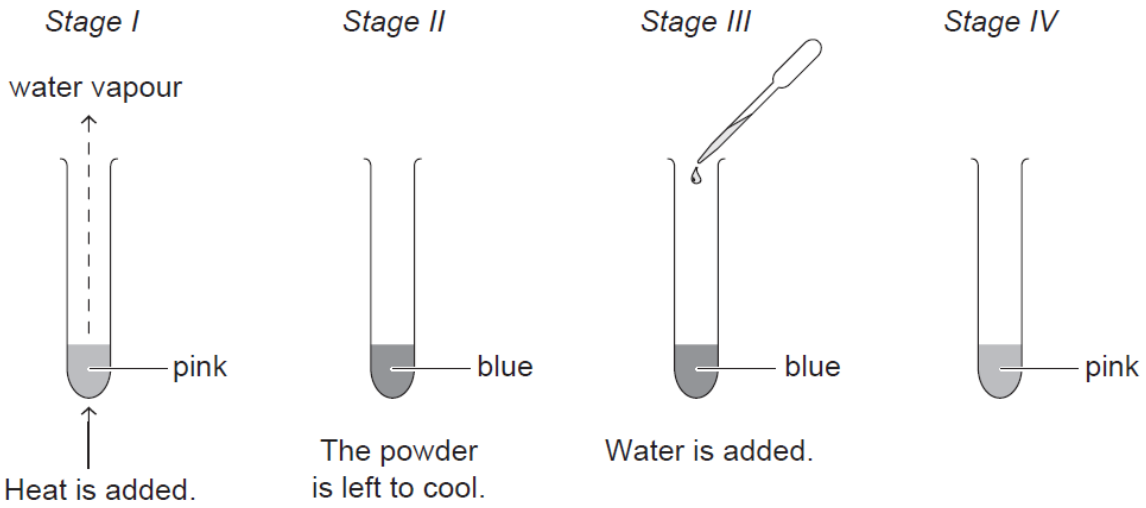
8. Which ONE of the following salts, when dissolved in water, will NOT change the pH of the water?

A. NaCl
B. HCOONa
C. NH_4Cl
D. Na_2CO_3

9. Which row of the table correctly indicates the STRONGEST intermolecular forces found in ethanoic acid and methyl propanoate respectively?

	Ethanoic acid	**Methyl propanoate**
A.	Hydrogen bonds	Hydrogen bonds
B.	Dipole-dipole forces	Dispersion forces
C.	Hydrogen bonds	Dispersion forces
D.	Hydrogen bonds	Dipole-dipole forces

10. A student was supplied with a sample of an unknown powder. The diagram shows the student's treatment of the powder.



Using the information provided, which of the following conclusions can be made?

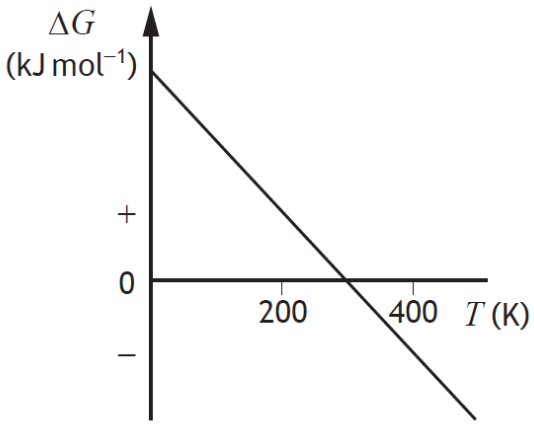
A. The reaction is exothermic.

B. The reaction is endothermic.

C. The reaction is reversible.

D. There will be no change if the compound at stage IV is heated.

11. The following graph shows the variation in ΔG with temperature (T) for a reaction.



Which of the following statements is true?

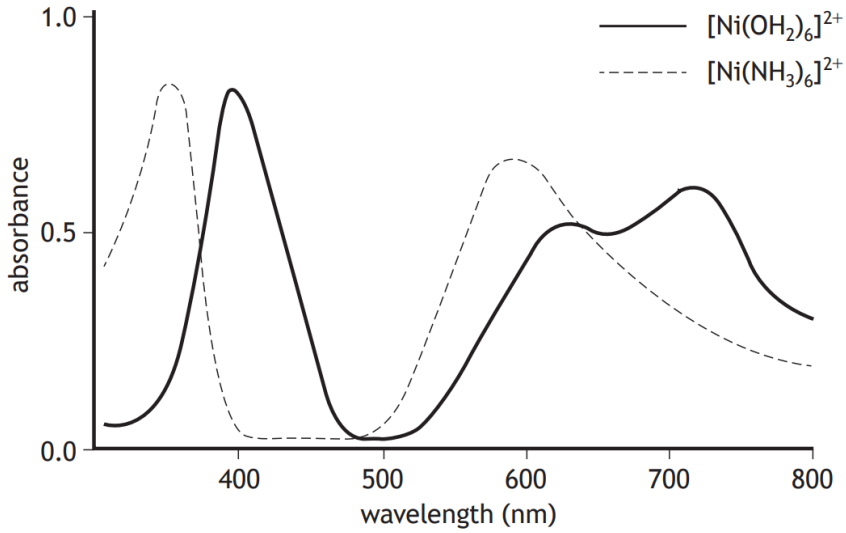
A. The reaction is spontaneous above 300 K

B. The reaction is spontaneous below 300 K

C. The reaction is never spontaneous

D. The reaction is always spontaneous

12. A UV-visible spectrometer was used to obtain the spectra of the ions $[Ni(OH_2)_6]^{2+}$ and $[Ni(NH_3)_6]^{2+}$. The absorbance spectra are shown.



The reaction between the two ions is shown below:

$$[Ni(OH_2)_6]^{2+}\ (aq) + 6NH_3\ (aq) \rightleftharpoons [Ni(NH_3)_6]^{2+}\ (aq) + 6H_2O\ (l)$$

Green Blue

A chemist needed to determine the equilibrium concentration of $[Ni(OH_2)_6]^{2+}$ using a UV-visible spectrometer.

Which would be the most appropriate wavelength to select?

A. 375 nm

B. 425 nm

C. 480 nm

D. 750 nm

13. Consider the ionisation reactions **I** and **II**

I $H_2PO_4^-\ (aq) + H_2O\ (l) \rightleftharpoons H_3O^+\ (aq) + \mathbf{X}$

II $\mathbf{X} + H_2O\ (l) \rightleftharpoons H_3O^+\ (aq) + \mathbf{Y}$

Which **ONE** of the following combinations represents the formulae of **X** and **Y** respectively?

	X	**Y**
A.	HPO_4^{2-}	PO_4^{3-}
B.	HPO_4^{2-}	H_3PO_4
C.	H_3PO_4	PO_4^{3-}
D.	HPO_4^{2-}	$H_2PO_4^-$

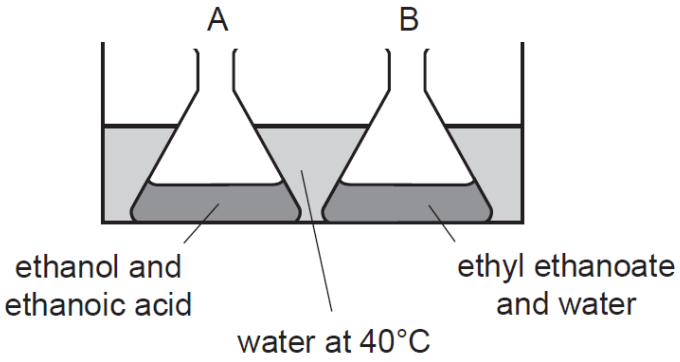
14. Consider the equilibrium represented by the balanced equation below:

Which ONE of the following changes to the equilibrium will favour the forward reaction?

$$2CrO_4^{2-}\ (aq) + 2H^+\ (aq) \rightleftharpoons Cr_2O_7^{2-}\ (aq) + H_2O\ (l) \qquad \Delta H < 0$$

	Temperature	**pH**
A.	Decrease	Increase
B.	Decrease	Decrease
C.	Increase	Increase
D.	Increase	Decrease

15. Two flasks, A and B, were placed in a water bath at 40°C.



After several days, the contents of the flasks were analysed.
Which results would be expected?

A. Flask A contains ethyl ethanoate, water, ethanol and ethanoic acid; flask B is unchanged.

B. Flask A contains only ethyl ethanoate and water; flask B is unchanged.

C. Flask A contains only ethyl ethanoate and water; flask B contains only ethanol and ethanoic acid.

D. Flask A and flask B contain ethyl ethanoate, water, ethanol and ethanoic acid.

16. The heat of combustion of hexan-1-ol is 3984 kJ mol^{-1}. Combustion takes place according to the equation:

$$C_6H_{13}OH\ (l)\ +\ 9\ O_2\ (g)\ \rightarrow\ 6\ CO_2\ (g)\ +\ 7\ H_2O\ (g)$$

What mass of carbon dioxide is formed when 2350 kJ of energy is released from combustion of hexan-1-ol?

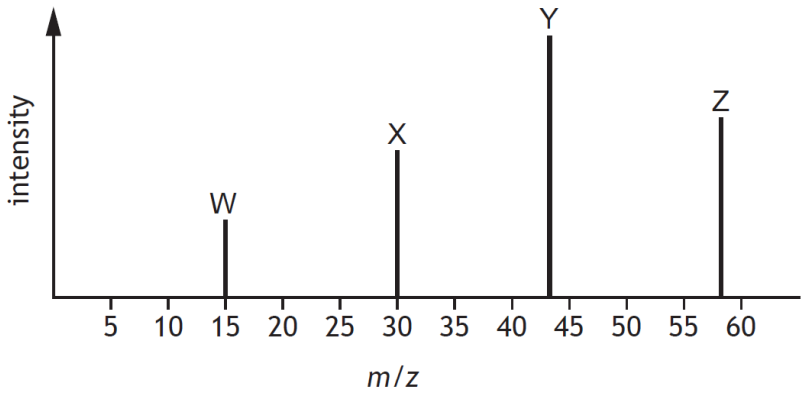
A. 60.3 g

B. 156 g

C. 173 g

D. 448 g

17. A student attempted to predict the mass spectrum of propanone. The predicted spectrum is shown below.



The actual mass spectrum of propanone contains only three main peaks.

Which of the above peaks would not appear in the actual mass spectrum?

A. W

B. X

C. Y

D. Z

18. Consider four different solutions: (K_a of CH_3COOH =1.8×10^{-5})

1. 0.10 M HCl
2. 0.10 M CH_3COOH
3. 0.01 M HCl
4. 0.01 M CH_3COOH

Which of the following correctly orders the solutions from highest to lowest pH?

A. 1, 2, 3, 4

B. 1, 3, 2, 4

C. 4, 3, 2, 1

D. 4, 2, 3, 1

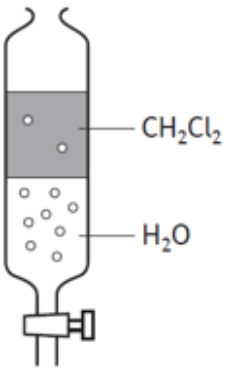
19. When substance **X** is distributed between equal volumes of two immiscible solvents, water and dichloromethane, an equilibrium will be established.

$$\mathbf{X}(H_2O) \rightleftharpoons \mathbf{X}(CH_2Cl_2) \qquad K_{eq} = 4$$

In the diagrams below, the number of dots represents the relative distribution of **X** in the two solvents. Water is less dense than dichloromethane.

Which of the following shows the correct distribution of **X** between the two solvents at equilibrium?

A.



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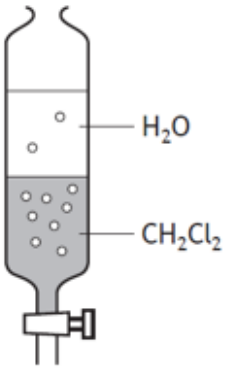
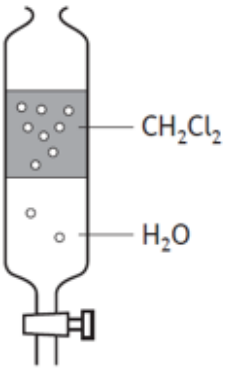
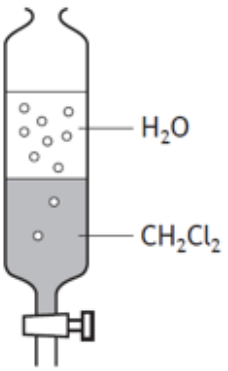


B.



D.



20. A student prepares a buffer solution by mixing 100.0 mL of 0.040 M methanamine (CH_3NH_2) with 100.0 mL of 0.050 M methanamine hydrochloride (CH_3NH_3Cl).

K_b for methanamine at 25°C is 4.4×10^{-4}.

What is the pH of the buffer?

A. 8.92

B. 9.26

C. 9.58

D. 10.54

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Chemistry

Section II
Answer Booklet

80 marks
Attempt Questions 21 – 34
Allow about 2 hours and 25 minutes for this section

Instructions

- 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.

Please turn over

Question 21 (5 marks)

Hydrogen gas, $H_2(g)$, can be produced by reacting methane, $CH_4(g)$, with steam, $H_2O(g)$, at 300 °C in the presence of a suitable catalyst.

The equation for the reaction is shown below.

$$CH_4\ (g) + 2H_2O\ (g) \rightleftharpoons CO_2\ (g) + 4H_2\ (g) \qquad \Delta H = +165\ kJ\ mol^{-1}$$

A suitable catalyst plus 25.0 mol of $CH_4(g)$ and 25.0 mol of $H_2O(g)$ are placed into an empty, sealed 100.0 L container at 300 °C.

After the reaction has reached equilibrium, the container contains 6.12 mol $H_2(g)$.

a) Write an expression for the equilibrium constant. **1**

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b) Calculate the equilibrium constant, K_{eq}, for this reaction at 300 °C. **4**

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Question 22 (7 marks)

Carbonic acid is a weak acid which dissociates in two steps in accordance with the following reactions:

Step 1: H_2CO_3 *(aq)* + H_2O *(l)* $\rightleftharpoons$ HCO_3^- *(aq)* + H_3O^+ *(aq)* $pK_a = 3.60$ at 25 °C

Step 2: HCO_3^- *(aq)* + H_2O *(l)* $\rightleftharpoons$ CO_3^{2-} *(aq)* + H_3O^+ *(aq)* $pK_a = 10.25$ at 25 °C

a) Which is a stronger acid, H_2CO_3 or HCO_3^-? Justify your choice. **3**

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b) From the two reactions shown above, which chemical species acts as both a Brønsted-Lowry acid and a Brønsted-Lowry base? **1**

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c) Compare the Arrhenius and Brønsted-Lowry theories of acids and bases using the reactions above. **3**

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Question 23 (5 marks)

Cycad seeds contain a compound called cycasin that can release hydrogen cyanide (HCN) when it reacts with water. The reaction is as follows:

$$\text{Cycasin } (s) + H_2O\ (l) \rightleftharpoons C_6H_{12}O_6\ (aq) + \text{HCN } (aq)$$

The K_{sp} value for this reaction is 1.2×10^{-3}.

a) Write the K_{sp} expression for this reaction.

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b) If 0.10 mol of cycasin is dissolved in 1.0 L of water, what are the concentrations of glucose and HCN at equilibrium?

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c) If the cycad seeds are added to running water, what would happen to the amount of HCN produced?

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d) State how the rate of detoxification can be increased.

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Question 24 (6 marks)

C_4H_9OH has four isomers that are all alcohols. They are butan-1-ol, butan-2-ol and two others (A and B).

a) Draw the structural formula of all isomers in the table below.

2

Butan-1-ol	Butan-2-ol
A	B

b) Describe a chemical test you could do to distinguish between butan-1-ol and butan-2-ol. Include the names of the reagent, any conditions required, and the expected observations.

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c) Using a different reagent, describe how you would distinguish between isomers A and B you have drawn. Include any observations that would occur.

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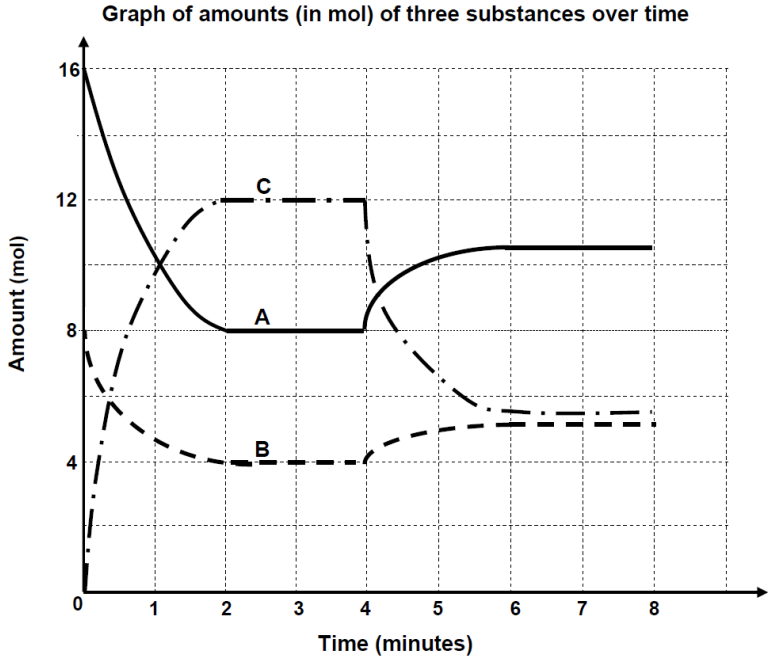
Question 25 (5 marks)

The equation below represents a hypothetical reaction that reaches equilibrium in a closed 3 L container after 2 minutes at room temperature.
The letters a, b and c represent the number of moles in the balanced equation.

$$a\text{A}\ (aq) + b\text{B}\ (aq) \rightleftharpoons c\text{C}\ (aq)$$

The graph below shows the change in the number of moles of reactants and products versus time during the reaction



a) Use the information in the graph to identify the coefficients in the equation.

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i. *a* .....

ii. *b* .....

iii. *c* .....

b) At *t* = 4 minutes, the temperature was increased to 60 °C. Determine if the reverse reaction is exothermic or endothermic. Explain your answer.

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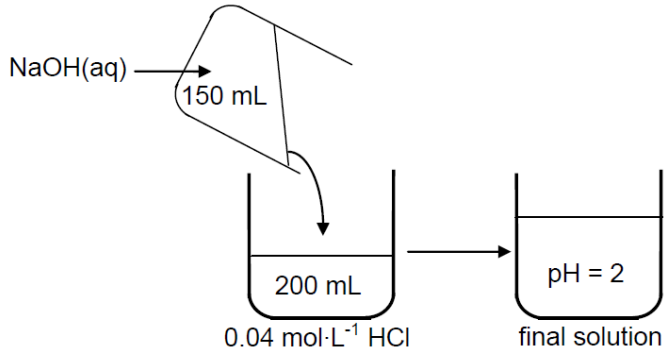
Question 26 (7 marks)

A student adds 150 mL of a sodium hydroxide solution, NaOH, of unknown concentration to 200 mL of a 0.04 mol L^{-1} hydrochloric acid solution, HCl, as illustrated below. They find that the pH of the final solution is 2. Assume that the volumes are additive.



a) Calculate the initial concentration of NaOH solution.

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b) In another reaction between sodium hydroxide and hydrochloric acid, 30.00 mL of 0.700 mol L^{-1} NaOH was mixed with 20.00 mL of 0.900 mol L^{-1} HCl.

Initial temperature of both solutions: 21.5 °C.
Measured change in molar enthalpy of neutralisation: -52.8 kJ mol^{-1}

Calculate the final temperature of the solution.

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Question 27 (6 marks)

Alcohol fermentation is a biological process by which sugars such as glucose are converted into ethanol and carbon dioxide by the action of yeast enzymes.

Molar mass of glucose ($C_6H_{12}O_6$): 180 g/mol
Molar mass of ethanol (C_2H_5OH): 46 g/mol
Molar mass of carbon dioxide (CO_2): 44 g/mol
Density of ethanol 0.79 g/mL

a) Write a balanced equation for the fermentation of glucose to ethanol and carbon dioxide. **1**

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b) A brewer starts with 180 grams of glucose in 750 mL to produce ethanol through fermentation. Calculate the theoretical yield of ethanol in grams. **3**

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c) Calculate the theoretical %v/v of ethanol in the solution. **2**

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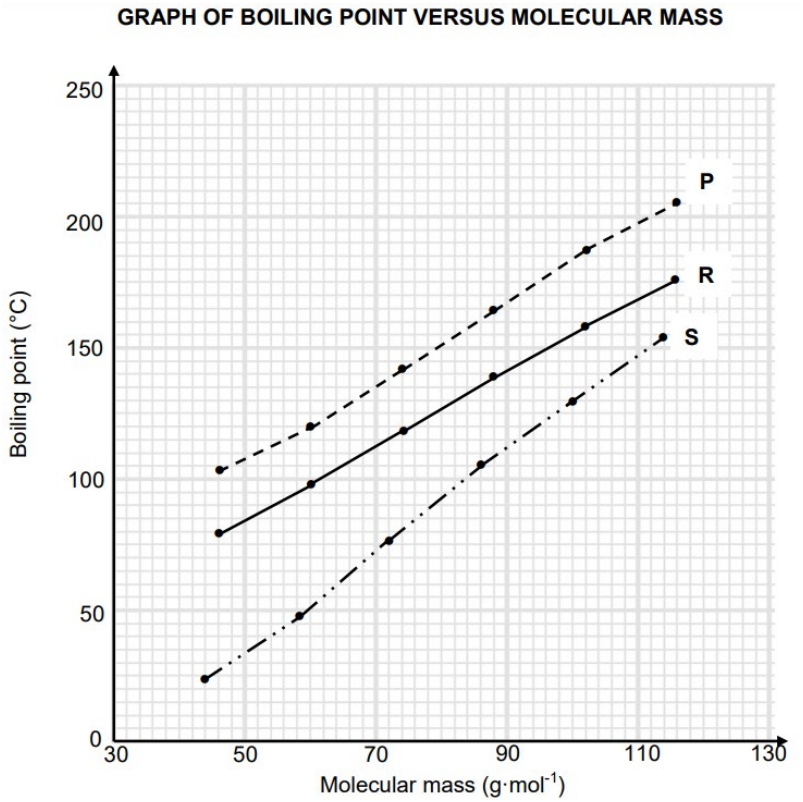
Question 28 (6 marks)

The relationship between boiling point and the molecular mass of aldehydes, carboxylic acids and primary alcohols is investigated. Curves P, R and S are obtained. All compounds used are straight chain molecules.



a) Identify the homologous series: **2**

i. P_____

ii. R_____

iii. S_____

b) Explain the position and trend of the curve of P in relation to R and S. **4**

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Question 29 (5 marks)

A precipitate of calcium fluoride CaF_2, (MM = 78.07 g mol^{-1}) was produced when 100.0 mL of 0.00200 mol L^{-1} calcium chloride solution was mixed with 100.0 mL of 0.00400 mol L^{-1} sodium fluoride solution. The mass of the dried precipitate was 0.0140 g.

What is the K_{sp} of calcium fluoride?

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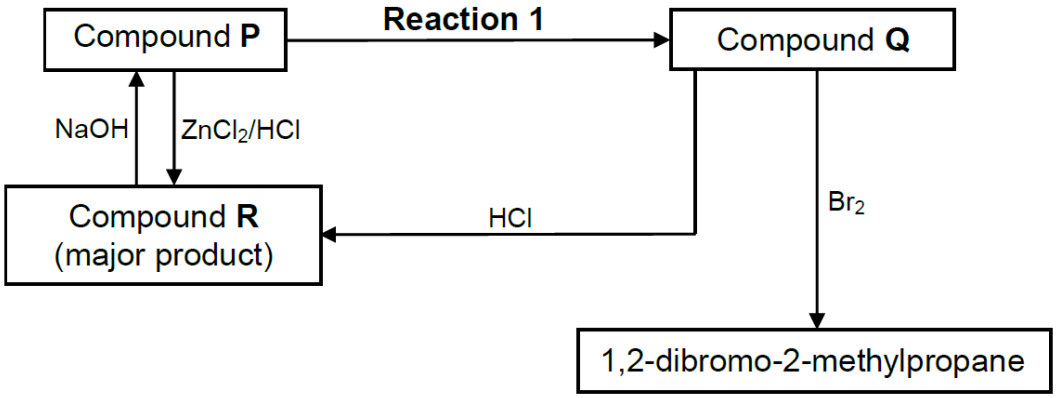
Question 30 (5 marks)

The flow chart shows reactions involving different organic compounds.



a) In the table below, draw the structural formulas and IUPAC name for compounds P, Q and R.

4

Compound	**Structural Formula**	**IUPAC Name**
P		
Q		
R		

b) Identify the reaction conditions and type of reaction for **Reaction 1**.

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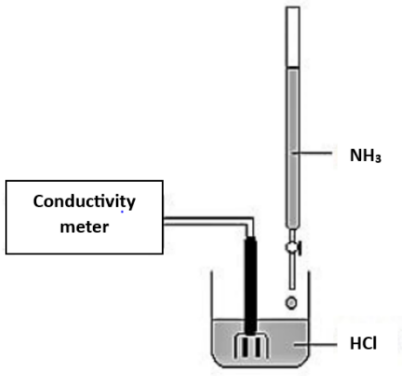
Question 31 (5 marks)

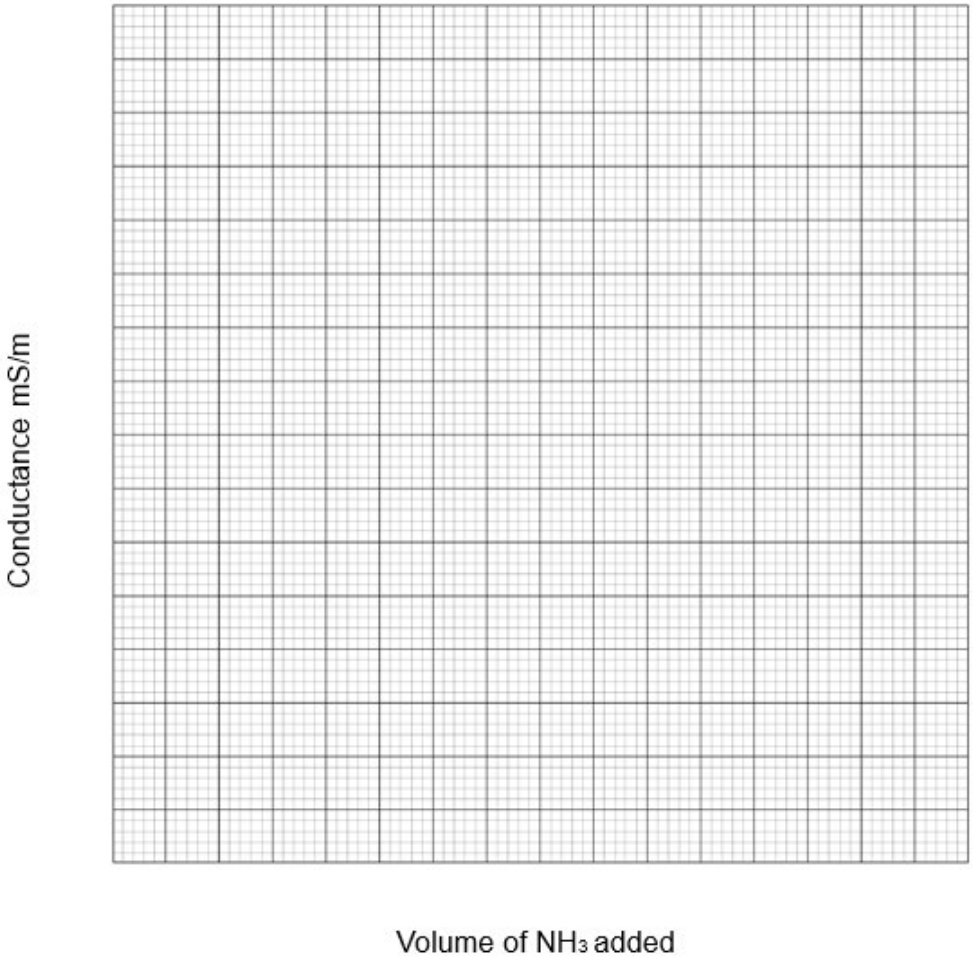
Students carried out a conductometric titration to determine the concentration of an ammonia (NH_3) solution using the equipment shown. They used a 10.0 mL aliquot of 0.10 mol L^{-1} hydrochloric acid.

a) Use the grid to graph the provided data. Annotate your graphed data to show how to find the NH_3 titre volume.

Volume of NH_3 added (mL)	Conductance (mS/m)
0.0	20.8
2.0	16.3
3.0	15.0
4.0	12.7
8.0	7.4
10.0	6.7
11.0	6.3
12.0	6.0



Graphed Data from Conductometric Titration **3**



Question 31 continues on page 25

Question 31 (continued)

b) Calculate the concentration of the ammonia solution using the graphed data.

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End of Question 31

Question 32 (4 marks)

A student determines the concentration of nitrite ions (NO_2^-) in a water sample using titration. The procedure involves the following steps:

Dilution:

A 50.0 mL sample of the water containing nitrite ions is diluted to 250.0 mL in a volumetric flask.

Titration:

25.0 mL of the diluted solution is taken and titrated with a 0.0200 M potassium permanganate ($KMnO_4$) solution in acidic medium.

The balanced chemical equation for the titration reaction is as follows:

$$5NO_2^-(aq) + 2MnO_4^-(aq) + 6H^+(aq) \rightarrow 5NO_3^-(aq) + 2Mn^{2+}(aq) + 3H_2O(l)$$

During the titration, 30.00 mL of the $KMnO_4$ solution is required to reach the endpoint.

Calculate the concentration of nitrite ions (NO_2^-) in the original 50.0 mL water sample.

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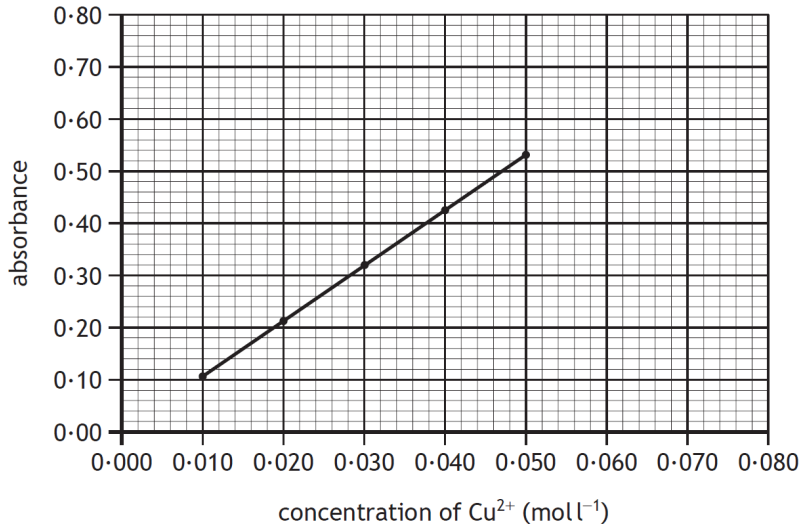
Question 33 (6 marks)

Brass is a useful alloy of copper and zinc. Atomic absorption spectroscopy was used to determine the percentage of copper in a brass screw. A student dissolved the screw in 20 mL of concentrated nitric acid and made the resulting solution up to 250 mL in a volumetric flask. Standard solutions were used to produce a calibration graph.



a) The absorbance of the sample solution was 0·71. The sample solution was then diluted to decrease the concentration by half. The absorbance of this diluted solution was then measured. Explain why the sample solution was diluted. **1**

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b) The mass of the screw was 1·43 g. The absorbance of the diluted solution was 0·34. Calculate the percentage by mass of copper in the screw. **3**

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c) The chemist was asked to determine the mass of zinc in the same sample. Assess the suitability of using AAS to determine the mass by weight of zinc in the screw. **2**

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Question 34 (8 marks)

Compound **X** has an empirical formula of C_2H_4O

The addition of acidified potassium dichromate to compound **X** results in a change of colour from orange to green and forms Compound **Y**.

Compound **Y** was further tested with the addition of Na_2CO_3, no reaction was observed.

Figures 1,2 and 3 show the spectroscopic data for compound **X** and

Figures 4, 5 and 6 show the spectroscopic data for compound **Y**

Figure 1 Mass Spectrum for compound **X**

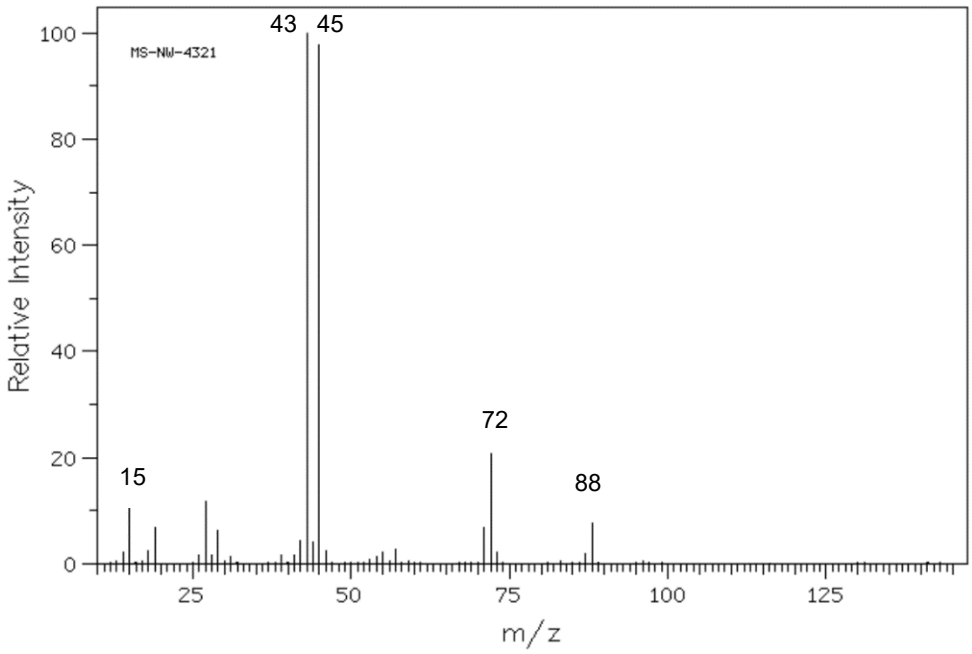


Figure 2 Infrared spectrum for compound **X**

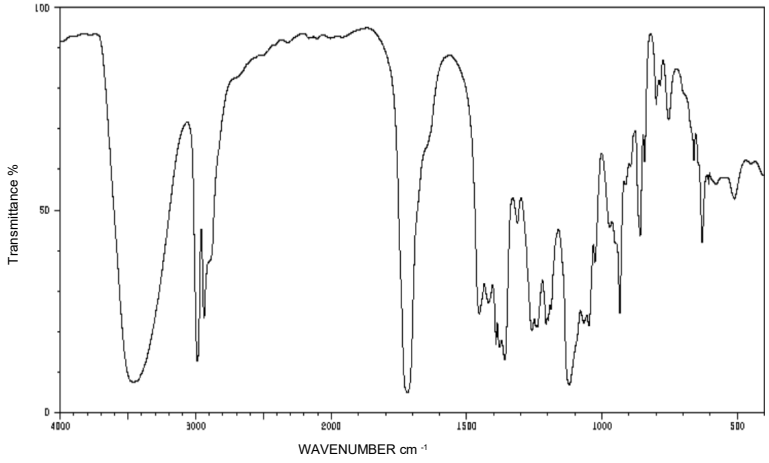


Figure 3 C13 NMR for compound **X**

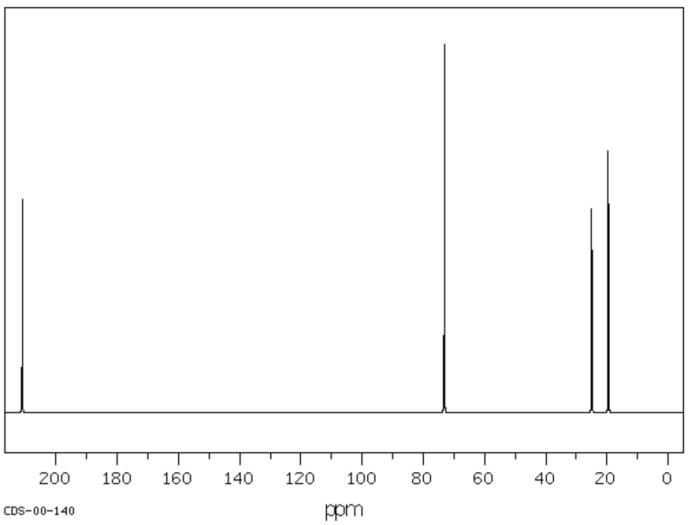


Figure 4 Mass Spectrum for compound **Y**

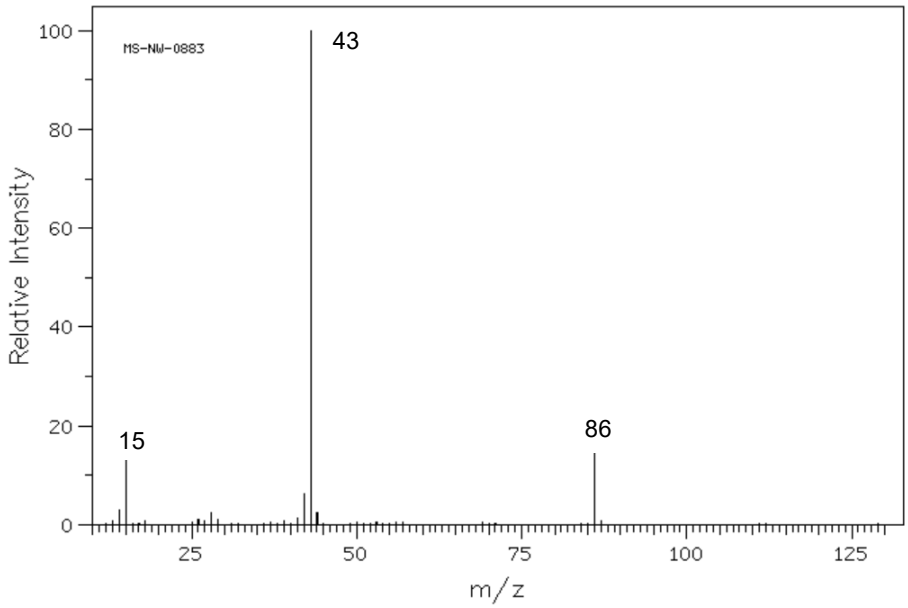


Figure 5 Infrared spectrum for compound **Y**

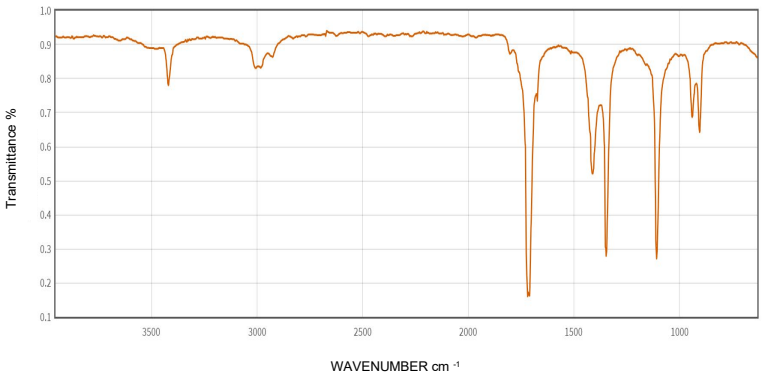
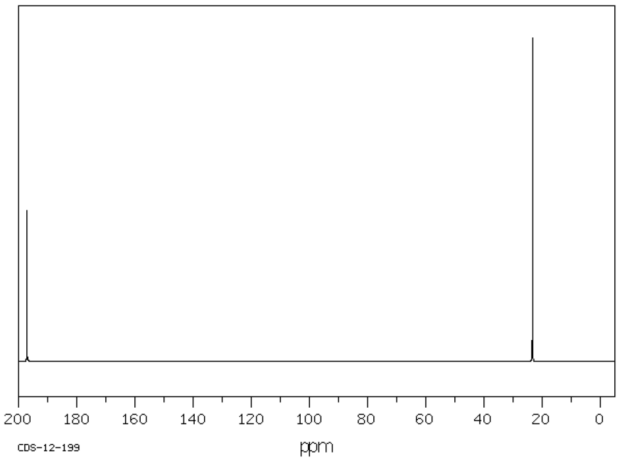


Figure 6 C13 NMR for compound **Y**



Draw the structural formulas of compound **X** and **Y**. Justify your answer with reference to the chemical and spectroscopic information provided.

Compound X	**Compound Y**

8

……

……

……

Question 34 continues on page 30

Question 34 (continued)

End of paper

Section II extra writing space

If you use this space, clearly indicate which questions you are answering.

Section II extra writing space

If you use this space, clearly indicate which questions you are answering.

Student Number: ……

Chemistry Multiple Choice Answer Sheet

Select the alternative A, B, C or D that best answers the question.

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

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

Start Here

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 ⬭