



**2024**  
**TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION**

**DO NOT REMOVE PAPER FROM EXAMINATION ROOM**

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Centre Number

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Student Number

# Chemistry

Morning Session  
Tuesday, 13 August 2024

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**General****Instructions**

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- NESA-approved calculators may be used
- Use the Multiple-Choice Answer Sheet provided
- A formulae sheet, data sheet and Periodic Table are provided  
**SEPARATELY**
- Write your Centre Number and Student Number at the top of this page

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**Total marks:**  
**100****Section I – 20 marks (pages 2–10)**

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

**Section II – 80 marks (pages 12–34)**

- Attempt Questions 21–36
- Allow about 2 hours and 25 minutes for this section

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## Section I

20 marks

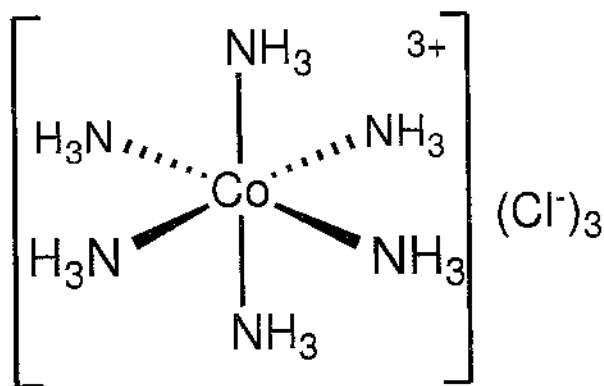
Attempt Questions 1–20

Allow about 35 minutes for this part

Use the Multiple-Choice Answer Sheet for Questions 1–20.

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- 1 Which of the following is NOT a valid environmental consideration for a chemical industry?
- A. Disposal of toxic wastes
  - B. Purity of the main product
  - C. The extraction of mineral catalysts
  - D. Use of renewable raw materials
- 2 The following ionic salt is dissolved in water.



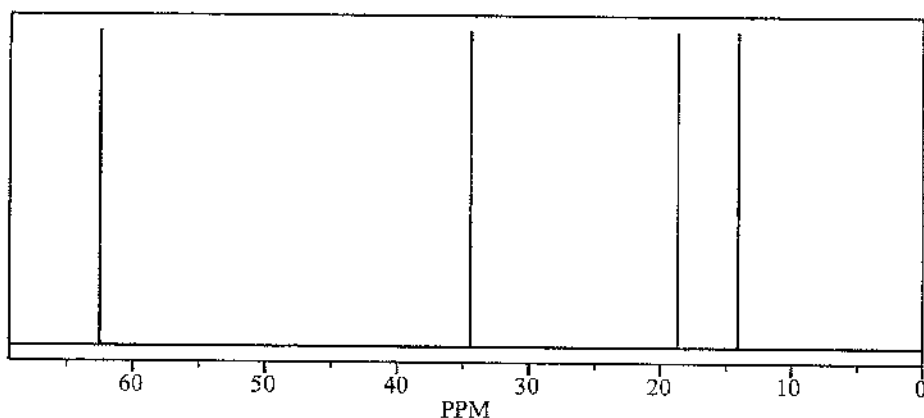
Which part of the salt is the *ligand*?

- A.  $\text{Cl}^-$
- B.  $\text{Co}$
- C.  $\text{Co}(\text{NH}_3)_6^{3+}$
- D.  $\text{NH}_3$

- 3 The chemistry of a swimming pool relies on equilibrium. One acid used to produce this equilibrium is hypochlorous acid,  $\text{HClO}$ .

Which of the following is correct for the  $K_a$  expression?

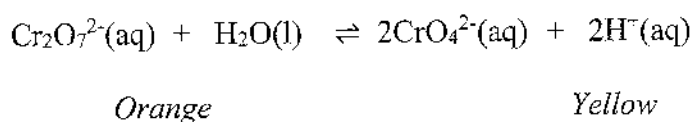
- A.  $[\text{HClO}] [\text{Cl}^-] / [\text{ClO}^-]$   
B.  $[\text{ClO}^-] [\text{H}_3\text{O}^+] / [\text{HClO}]$   
C.  $[\text{H}_3\text{O}^+] / [\text{HClO}^-] [\text{ClO}^-]$   
D.  $[\text{H}_3\text{O}^+] [\text{ClO}^-] / [\text{HClO}^-] [\text{H}_2\text{O}]$
- 4 A  $^{13}\text{C}$  NMR spectrum is shown below.



Which compound would produce peaks consistent with the graph?

- A. Butan-1-ol  
B. Butanal  
C. Ethyl acetate  
D. Propan-2-one
- 5 Which of the following is the organic compound with the most basic characteristic?
- A. Propanamide  
B. Propanamine  
C. Propane  
D. Sodium hydroxide

- 6 For a chemical reaction to proceed, in either the forward or the reverse reaction, the
- activation energy of the forward reaction must be high so the particles have enough energy to collide and react.
  - activation energy of the reverse reaction must be high so the particles have enough energy to collide and react.
  - activation energy of both reactions must be low so the particles have enough energy to collide and react.
  - activation energy of only the forward reaction must be low so the particles have enough energy to collide and react.
- 7 Chromate and dichromate ions are coloured yellow and orange respectively and form an equilibrium system according to the following equation:



Three drops of concentrated hydrochloric acid are added to a beaker of solution with the above equilibrium.

Which row of the table below correctly identifies what will happen to the system?

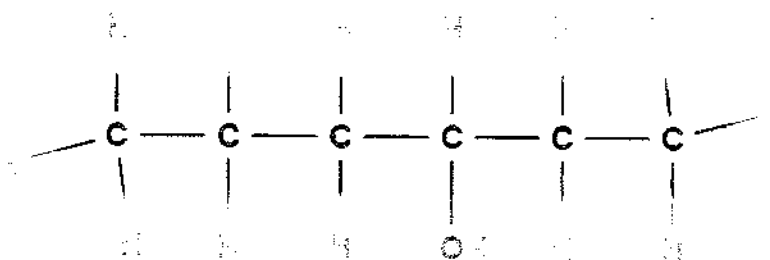
	<b>Equilibrium shift</b>	<b>Colour change</b>
A.	To the left	More orange
B.	To the right	More yellow
C.	To the left	More yellow
D.	To the right	More orange

- 8 A student adds sodium sulfate solution to a solution of a sample containing an unknown cation, producing a white precipitate. The sample produces a green flame in the flame test.

Which element can be identified?

- A. Barium
- B. Calcium
- C. Copper
- D. Magnesium

- 9 The molecule below undergoes a strong oxidation reaction:

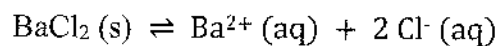


What is the product from this reaction?

- A. Hexan-3-one
  - B. Hexanal
  - C. Hexanoic acid
  - D. Hex-2-ene
- 10 Which spectroscopy would be most suitable for determining the concentration of copper ions in a solution?
- A. Infrared
  - B. Mass
  - C. Proton NMR
  - D. UV-visible

- 11 Which of the following straight-chain organic compounds is considered *saturated*?
- A.  $C_3H_4$
  - B.  $C_3H_6$
  - C.  $C_3H_7OH$
  - D.  $C_4H_7OH$
- 12 How many isomers have the molecular formula  $C_4H_9Cl$ ?
- A. 2
  - B. 4
  - C. 6
  - D. 8
- 13 A student had four 1.0 mol/L solutions:  $NH_3$ ,  $NaOH$ ,  $NH_4CH_3COO$ ,  $NH_4Cl$ . Which of the following lists ranks the solutions in increasing alkalinity?
- A.  $NH_3 < NaOH < NH_4CH_3COO < NH_4Cl$
  - B.  $NaOH < NH_4CH_3COO < NH_4Cl < NH_3$
  - C.  $NH_4CH_3COO < NH_4Cl < NH_3 < NaOH$
  - D.  $NH_4Cl < NH_4CH_3COO < NH_3 < NaOH$

- 14 A saturated solution of barium chloride,  $\text{BaCl}_2$ , is at equilibrium above excess solid, according to the equation:

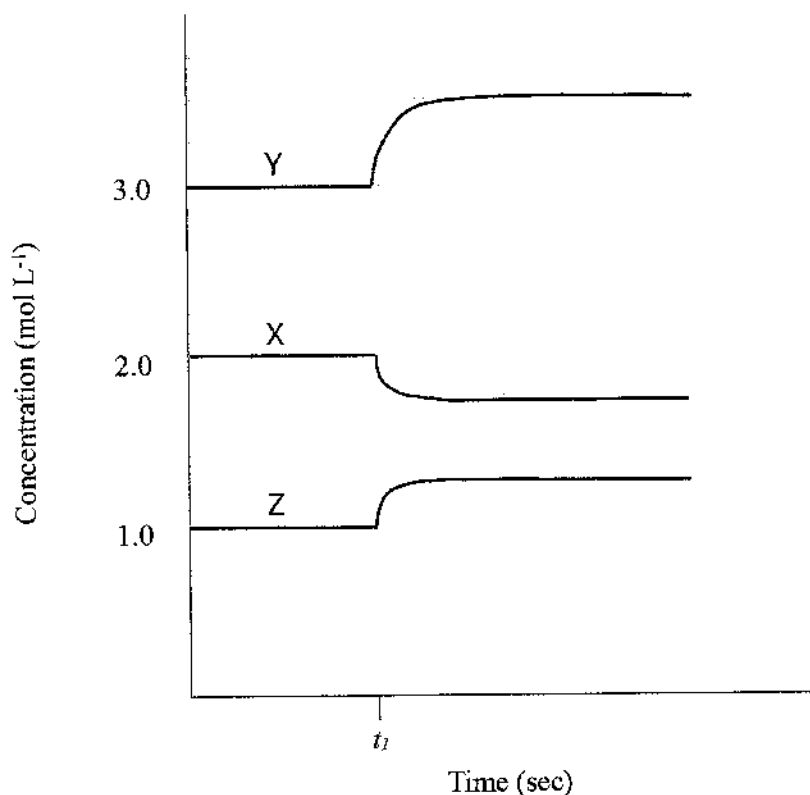


Compared to the original saturated solution, which of the following changes will result in an *increase* in the chloride ion concentration once equilibrium has been re-established?

- A. The addition of a small volume of water
- B. The addition of a small amount of solid  $\text{BaCl}_2$
- C. The addition of a small volume of dilute sodium sulfate solution
- D. The addition of a small volume of concentrated silver nitrate solution

**Turn over the page**

- 15 Three gases, X, Y and Z, are in an enclosed 1.0 L container and have reached equilibrium. At time  $t_1$  the mixture is cooled.



The equilibrium system that represents the graph is

- A.  $X(g) \rightleftharpoons 2Y(g) + Z(g)$  and the forward reaction is exothermic.  
 B.  $2Y(g) + Z(g) \rightleftharpoons X(g)$  and the forward reaction is exothermic.  
 C.  $2Y(g) \rightleftharpoons X(g) + Z(g)$  and the forward reaction is endothermic.  
 D.  $X(g) + 2Y(g) \rightleftharpoons Z(g)$  and the forward reaction is endothermic.
- 16 Which of the following compounds is a functional isomer of butanoic acid?
- A. Butanal  
 B. Butanone  
 C. Ethyl ethanoate  
 D. 2-Methylpropanoic acid



- 17 At 480°C,  $K_{eq}$  for the reaction below is 0.020.



A mixture of  $PCl_5$ ,  $PCl_3$  and  $Cl_2$  is in a 1.0 L vessel at 480°C and have the following concentrations:  $[PCl_5] = 2.0 \text{ molL}^{-1}$ ,  $[PCl_3] = 0.50 \text{ molL}^{-1}$  and  $[Cl_2] = 0.10 \text{ molL}^{-1}$ .

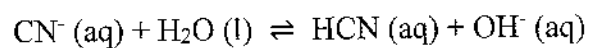
Which of the following statements is correct?

- A.  $Q = K_{eq}$  and the system is at equilibrium.
  - B.  $Q$  is less than  $K_{eq}$  and more  $PCl_5$  will be produced.
  - C.  $Q$  is greater than  $K_{eq}$  and more  $PCl_5$  will be produced.
  - D.  $Q$  is less than  $K_{eq}$  and more  $PCl_3$  and  $Cl_2$  will be produced.
- 18 Which of the following describes the correct number of peaks and splitting pattern for the proton NMR spectrum of ethyl ethanoate?
- A. 2 peak sets: both singlets
  - B. 3 peak sets: 2 x triplets, doublet
  - C. 3 peak sets: singlet, triplet, quartet
  - D. 4 peak sets: singlet, triplet, septet, triplet
- 19 A solution was made by adding 2.0 g of benzoic acid ( $C_6H_5COOH$ ,  $K_a = 6.3 \times 10^{-5}$ ) to 50 mL of water. Benzoic acid has a solubility of 3.4 g/L at room temperature.

What is the final pH of the solution?

- A. 1.9
- B. 2.9
- C. 3.9
- D. 4.9

- 20 The pH of a 0.01 mol/L sodium cyanide (NaCN) solution was 10.64. The cyanide ion reacts with water:



The equilibrium expression for this reaction is called  $K_b$  (similar to  $K_a$  but for a base).

What is the  $\text{p}K_b$  of sodium cyanide at this temperature?

- A. 1.1
- B. 3.4
- C. 3.7
- D. 4.7

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## Section II

80 marks

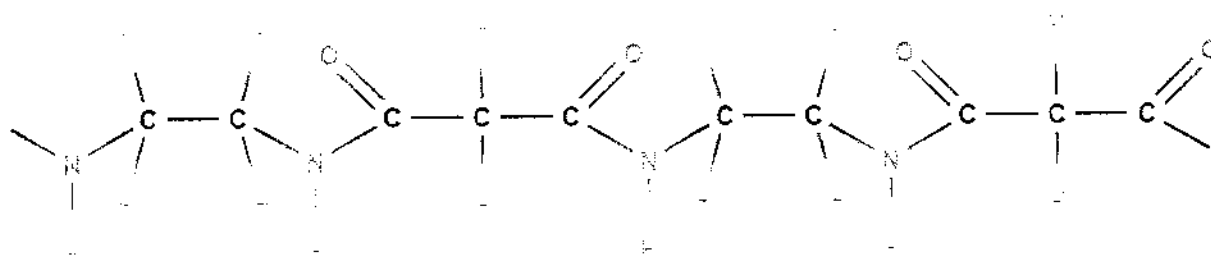
Attempt Questions 21–36

Allow about 2 hours and 25 minutes for this section

- 
- Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.
  - Show all relevant working in questions involving calculations.
  - Extra writing space is provided on pages 35–37. If you use this space, clearly indicate which question you are answering.
- 

### Question 21 (3 marks)

Certain polymers can be created when a diamine and a dicarboxylic acid react under certain conditions to form condensation polymers. Below is a segment of such a polymer.



- (a) Describe ONE way that condensation polymer reactions differ from addition polymer reactions. **1**
- .....
- .....
- (b) In the space below, draw the TWO organic reactants that formed the polymer shown above. **2**

**Question 22 (3 marks)**

Hydrogen fluoride gas and ammonia gas can react in air to produce white crystals.

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Contrast how the Bronsted-Lowry and Arrhenius theories of acids and bases each interpret this reaction. In your answer, include a balanced chemical equation for the reaction.

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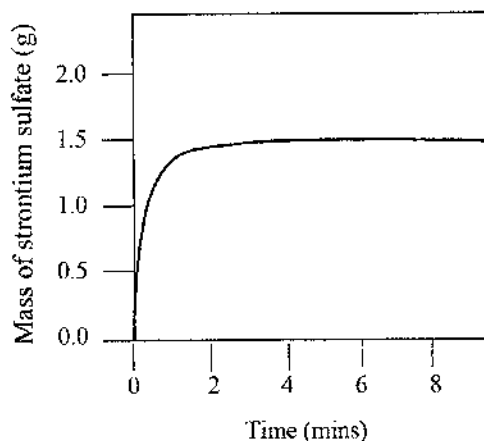
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**Question 23** (6 marks)

A student performed an experiment to determine the mass of a precipitate that can be formed. 200.0 mL of 0.040 mol/L strontium chloride solution was added to 500.0 mL of 0.016 mol/L sodium sulfate solution and a precipitate slowly formed. The mass of the precipitate formed is shown in the graph below.



- (a) Write a balanced chemical equation for the formation of the precipitate. 1

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- (b) Calculate, with justification, the concentration of the strontium ( $\text{Sr}^{2+}$ ) ions after 4 minutes ( $K_{\text{sp}}(\text{SrSO}_4) = 3.44 \times 10^{-7}$ ). 3

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**Question 23 continues on page 15**

Question 23 (continued)

- (c) Some solid strontium chloride, containing radioactive strontium, was added to the system after 6 minutes. After 10 minutes, radioactive strontium was detected in the solution. Account for this change. 2

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**Question 24** (3 marks)

Many chemicals produced by chemical industries have important uses in society, some of which you have studied in this course. 3

For the following TWO chemicals, describe how each is used to make a chemical product that is useful for society. Include at least ONE relevant equation in your response.

**Sodium hydroxide**

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**Sulfuric acid**

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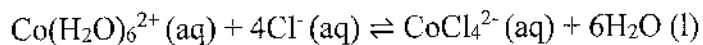
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**Question 25** (4 marks)

A student wanted to conduct an investigation to observe temperature changes made to a cobalt chloride equilibrium system and the effect it has on shifting the equilibrium position.



*Pink*

*Blue*

- (a) Outline a valid method used to conduct this investigation, including ONE safety feature of the method. **3**

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- (b) When heated, the solution turns blue. For the forward reaction above, justify whether the reaction is endothermic or exothermic. **1**

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**Question 26 (5 marks)**

A student is asked to investigate the enthalpy of the combustion of butanol.

- (a) Write the balanced equation for the complete combustion of butanol. **1**

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- (b) Outline a method the student could perform to collect the required data. Include a labelled diagram to support your answer. **3**

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**Question 26 continues on page 18**



**Question 28** (6 marks)

A student made a 200 mL saturated solution of calcium hydroxide, with excess solid on the bottom of the beaker.

- (a) Show that the calcium ion concentration of this solution at 25°C is 0.0108 mol/L. **2**

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- (b) A 50.0 mL solution of 0.123 mol/L hydrochloric acid was added to a beaker containing 100.0 mL of the saturated calcium hydroxide solution. **4**

Determine the change in pH of the calcium hydroxide solution due to the addition of the acid.

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**Question 29 (4 marks)**

Natural buffers are critically important in many natural systems, including biological systems. **4**  
With reference to a relevant chemical equation, explain how the presence of a natural buffer contributes to a natural system.

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**Question 30** (5 marks)

Alcohols, such as pentan-2-ol, can undergo dehydration reactions.

- (a) State a condition required for this reaction to occur. 1

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- (b) Name and draw the TWO organic products of the dehydration of pentan-2-ol. 4

Product 1 name:
Product 2 name:











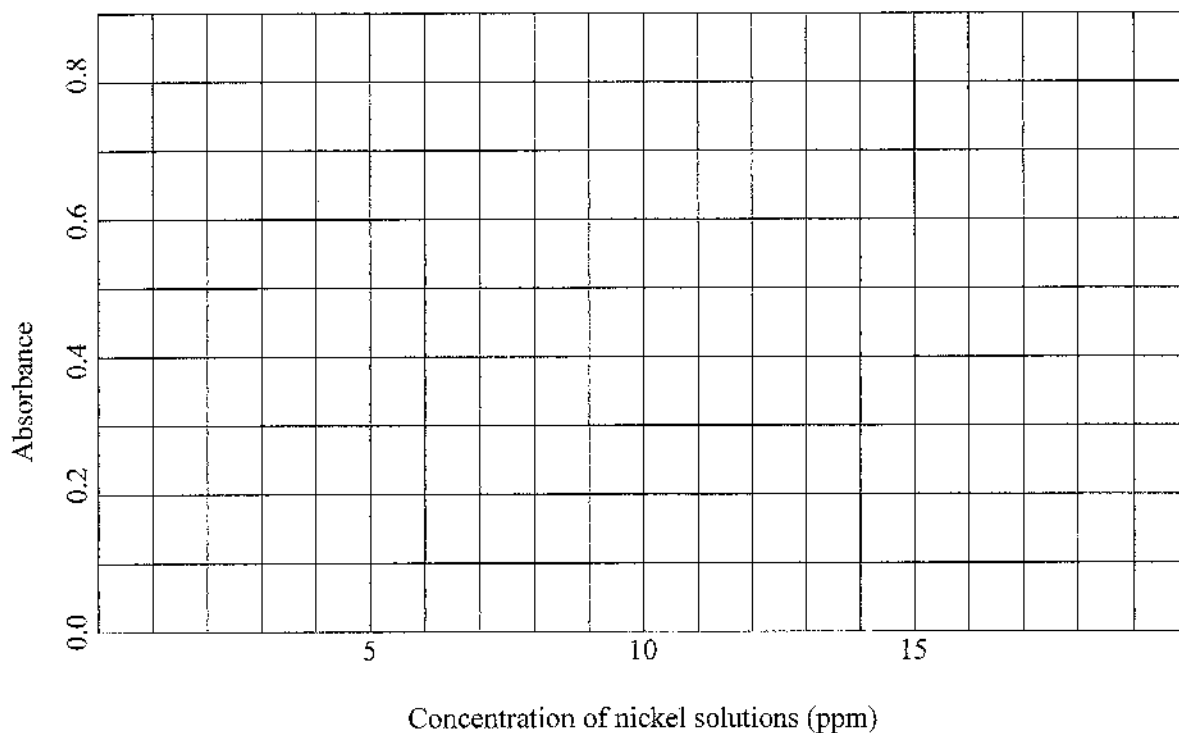
**Question 34** (6 marks)

Atomic absorption spectroscopy (AAS) was used to analyse a solution containing nickel ions.

The following absorbance data was collected.

<i>Concentration of standard Ni<sup>2+</sup> solutions (ppm)</i>	<i>Absorbance</i>
0.00	0.000
5.00	0.165
10.00	0.320
15.00	0.495
20.00	0.680

- (a) Drawing an appropriate graph of the data, with a straight line of best fit, determine the expected absorbance for a sample with a nickel concentration of 8.00 ppm. Show your working on the graph. **3**



Absorbance of 8.00 ppm solution: \_\_\_\_\_

**Question 34 continues on page 27**

Question 34 (continued)

- (b) 100.0 ml of the sample solution was reacted with excess sodium hydroxide.  
The precipitate was then filtered, dried and weighed.

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What was the mass of the precipitate formed?

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**Question 35** (8 marks)

Blueberry lily (bush blueberry) is a native plant commonly found in the Australian sclerophyll forests. In spring it produces blue orchid-like flowers that form a blue fruit similar to a blueberry with a nutty flavour.

The bush blueberry is important to many Indigenous communities. The nutty flavour is derived from linolenic acid, a monoprotic fatty acid ( $C_{18}H_{30}O_2$ , MM = 278.7 g/mol). Linolenic acid is important for maintaining neural pathways that regulate human growth and development, plus it helps maintain heart rhythm. The recommended daily intake of linolenic acid, from all sources, is approximately 1.7 g.

A researcher wanted to determine how much linolenic acid was in the bush blueberries. Initially, the researcher standardised a sodium hydroxide solution against 25.00 mL aliquots of 0.01978 mol/L hydrochloric acid, for the following results:

Trial	Volume of NaOH (mL)
1	32.95
2	32.90
3	32.90

The researcher then separated linolenic acid from 20.0 g of bush blueberries into a 25.00 mL volumetric flask and filled to the mark with distilled water. 5.00 mL aliquots of the extracted acid were titrated against the standardised NaOH solution.

Trial	Volume of NaOH (mL)
1	3.50
2	3.20
3	3.10
4	3.10

**Question 35 continues on page 29**



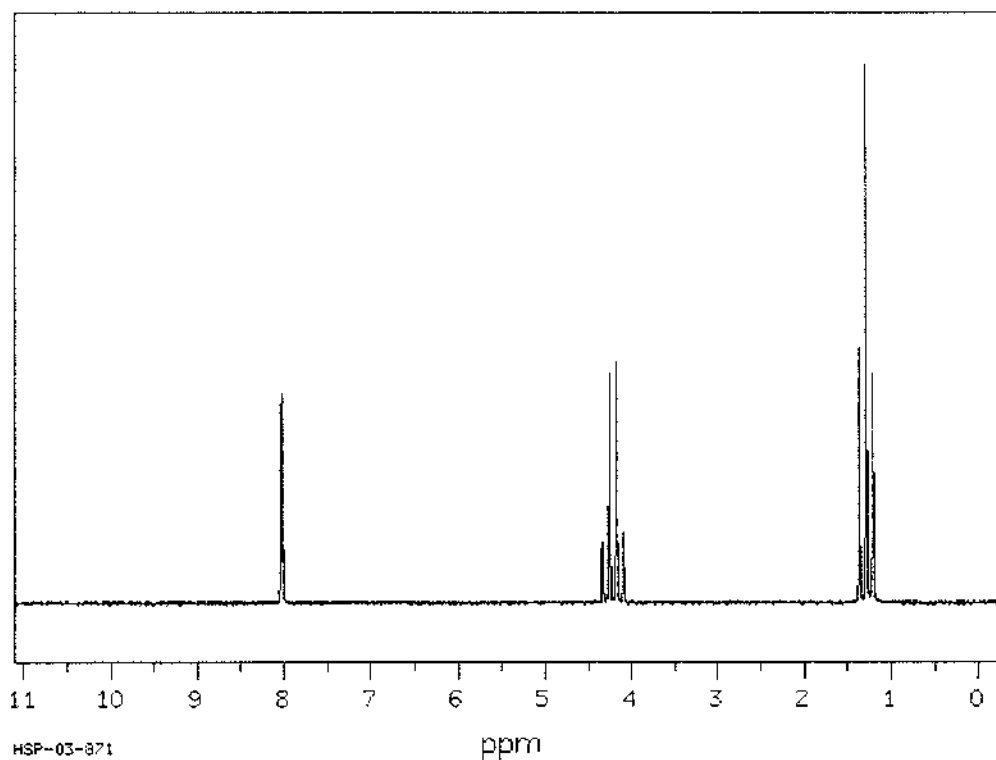
**Question 36** (8 marks)

Below are four spectra. They belong to, in no particular order:

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1-propanol, 2-propanol, propanoic acid and ethyl methanoate.

**Spectrum A:**

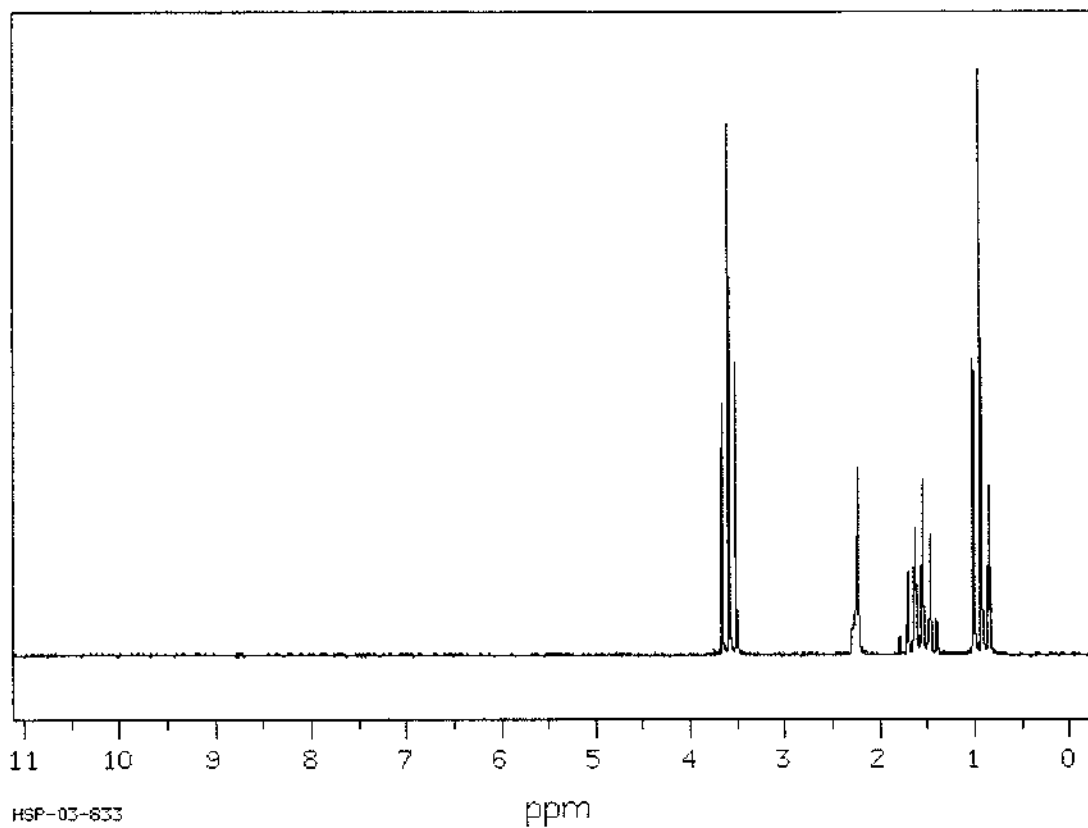


Data <sup>1</sup> H NMR		
Chemical shift (ppm)	Relative peak area	Splitting pattern
1.289	3	Triplet
4.215	2	Quartet
8.026	1	Singlet

Question 36 continues on page 31

Question 36 (continued)

**Spectrum B:**

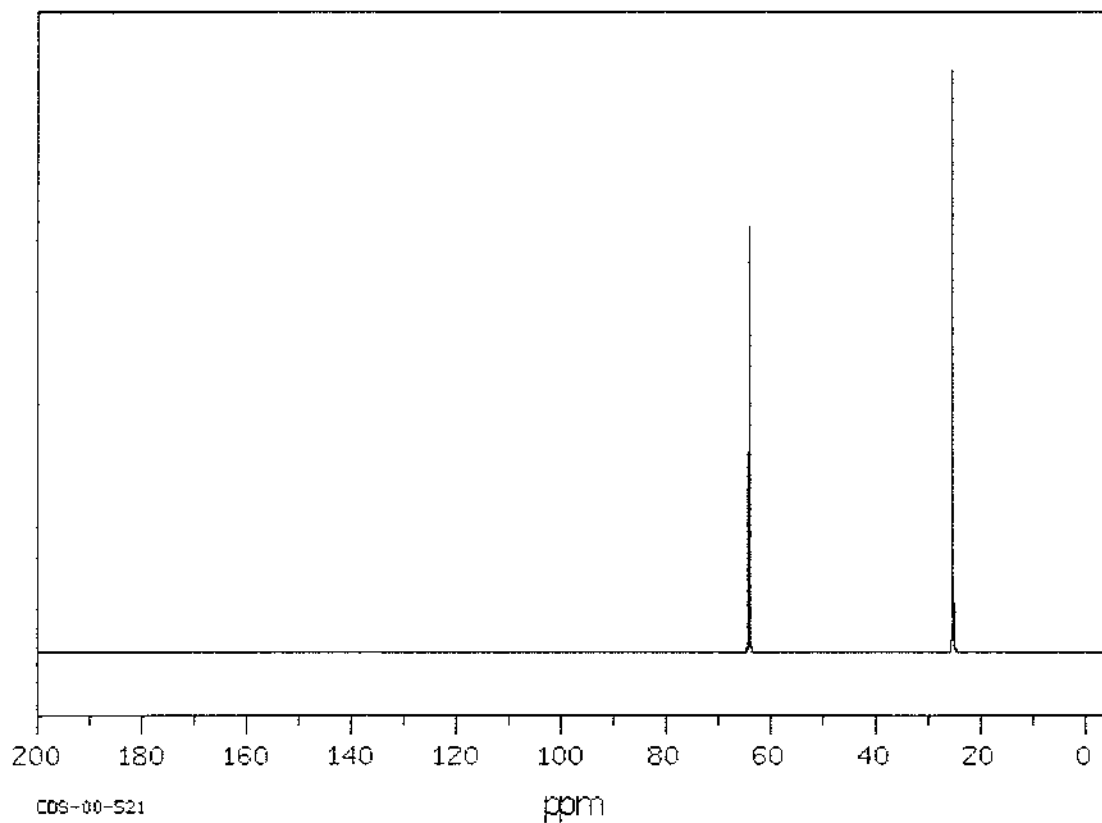


Data <sup>1</sup> H NMR		
Chemical shift (ppm)	Relative peak area	Splitting pattern
0.94	3	Triplet
1.57	2	Sextet (6 peaks)
2.26	1	Singlet
3.582	2	Triplet

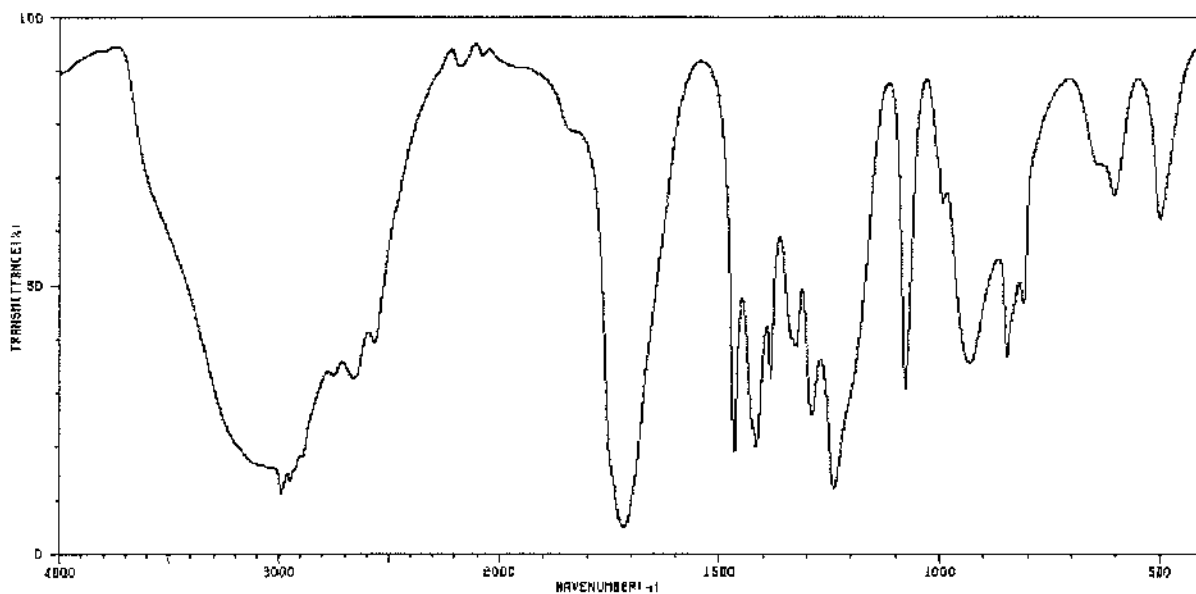
Question 36 continues on page 32

Question 36 (continued)

**Spectrum C:**



**Spectrum D:**



Question 36 continues on page 33





Question 36 (continued)

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**End of Examination**







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Question	Citation
2	Image: Smokefoot (2020). <i>Afrikaans: [Co(NH3)6]3+, met 6-koördinaatmetaalsentrum met oktaedriese molekulêre omringing</i> . Wikimedia Commons. Available at: <a href="https://commons.wikimedia.org/wiki/File:CoA6Cl3.svg#file">https://commons.wikimedia.org/wiki/File:CoA6Cl3.svg#file</a> [Accessed 19 Feb. 2024]. Used with permission.
4	Spectrum comes from <a href="http://www.chem.ucla.edu">www.chem.ucla.edu</a> . (n.d.). <i>Illustrated Glossary of Organic Chemistry - 13C-NMR</i> . Available at: <a href="https://www.chem.ucla.edu/~harding/IGOC/C/c_nmr.html">https://www.chem.ucla.edu/~harding/IGOC/C/c_nmr.html</a> [Accessed 19 Feb. 2024]. Used with permission.
9	Structure drawn by the 2024 CSSA Trial HSC Examination Chemistry – Committee using MolView ( <a href="https://molview.org/">https://molview.org/</a> ).
21	Structure drawn by the 2024 CSSA Trial HSC Examination Chemistry – Committee using MolView ( <a href="https://molview.org/">https://molview.org/</a> ).
36	All spectra come from <i>Aist: spectral database for organic compounds, sdb</i> s n.d., Accessed 19 February 2024, <a href="https://sdb.sdb.aist.go.jp/sdb/cgi-bin/cre_index.cgi">https://sdb.sdb.aist.go.jp/sdb/cgi-bin/cre_index.cgi</a> . Used with permission.

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