CSSA

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

**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

**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

## 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?

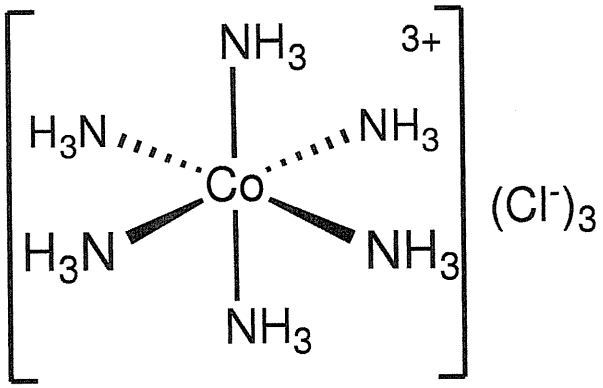
A. Disposal of toxic wastes

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. $Cl^-$

B. Co

C. $Co(NH_3)_6^{3+}$

D. $NH_3$

3 The chemistry of a swimming pool relies on equilibrium. One acid used to produce this equilibrium is hypochlorous acid, HClO.

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

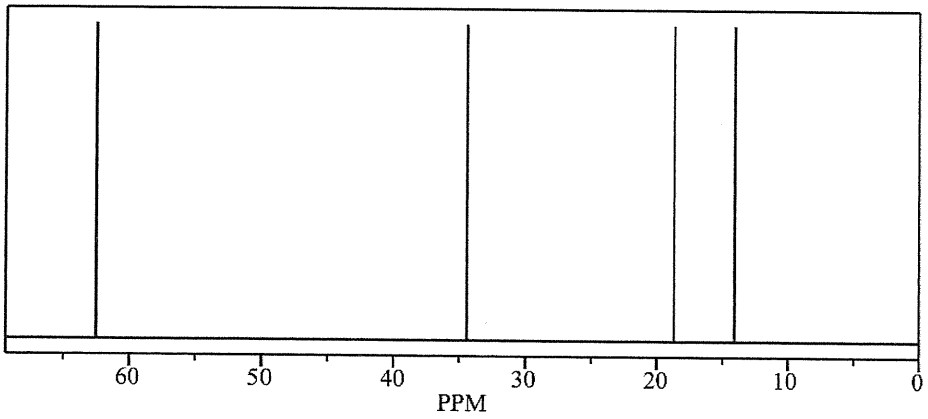
A. $[HClO]\,[Cl^-] / [ClO^-]$

B. $[ClO^-]\,[H_3O^+] / [HClO]$

C. $[H_3O^+] / [HClO^-]\,[ClO^-]$

D. $[H_3O^+]\,[ClO^-] / [HClO^-]\,[H_2O]$

4 A $^{13}C$ 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

A. activation energy of the forward reaction must be high so the particles have enough energy to collide and react.

B. activation energy of the reverse reaction must be high so the particles have enough energy to collide and react.

C. activation energy of both reactions must be low so the particles have enough energy to collide and react.

D. 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:

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

*Orange* *Yellow*

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?

| | **Equilibrium shift** | **Colour change** |
|---|---|---|
| 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?

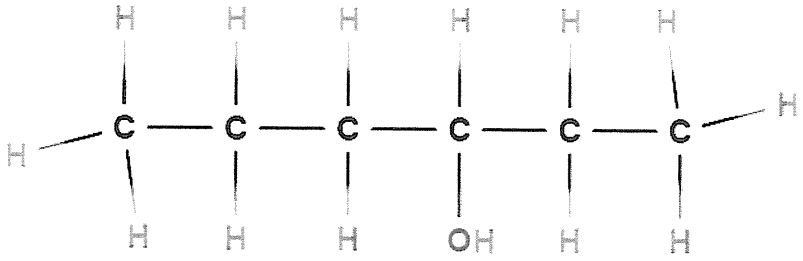
A. Barium

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, $BaCl_2$, is at equilibrium above excess solid, according to the equation:

$$BaCl_2\,(s) \rightleftharpoons Ba^{2+}\,(aq) + 2\,Cl^-\,(aq)$$

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

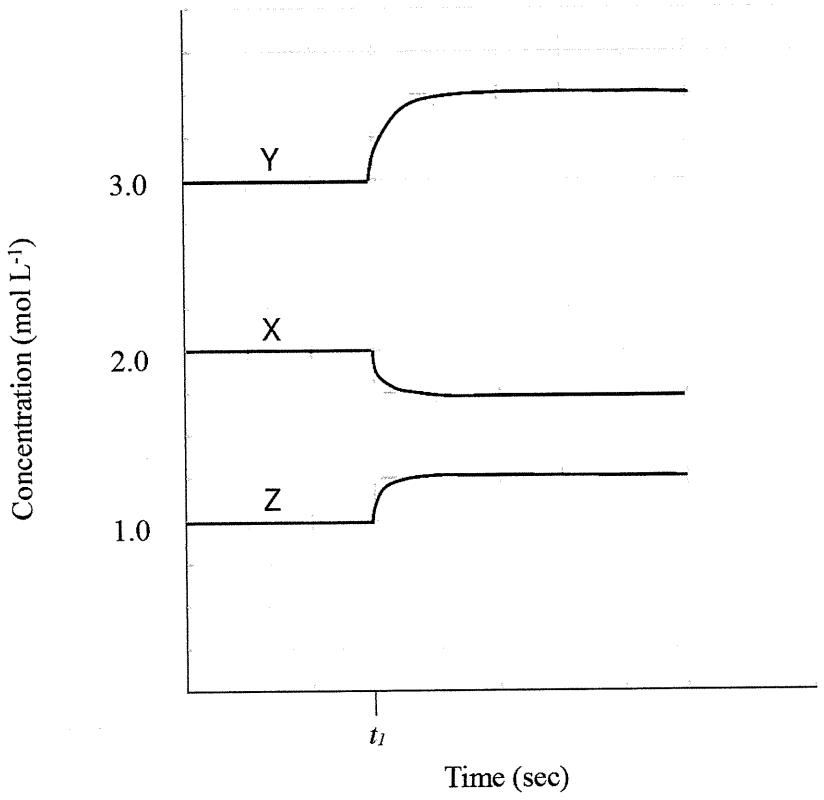
B. The addition of a small amount of solid $BaCl_2$

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.

$$PCl_5\,(g) \rightleftharpoons PCl_3\,(g) + Cl_2\,(g)$$

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: $[PCl_5] = 2.0\ molL^{-1}$, $[PCl_3] = 0.50\ molL^{-1}$ and $[Cl_2] = 0.10\ molL^{-1}$.

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:

$CN^-$ (aq) + $H_2O$ (l) $\rightleftharpoons$ HCN (aq) + $OH^-$ (aq)

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

What is the $pK_b$ of sodium cyanide at this temperature?

A. 1.1

B. 3.4

C. 3.7

D. 4.7

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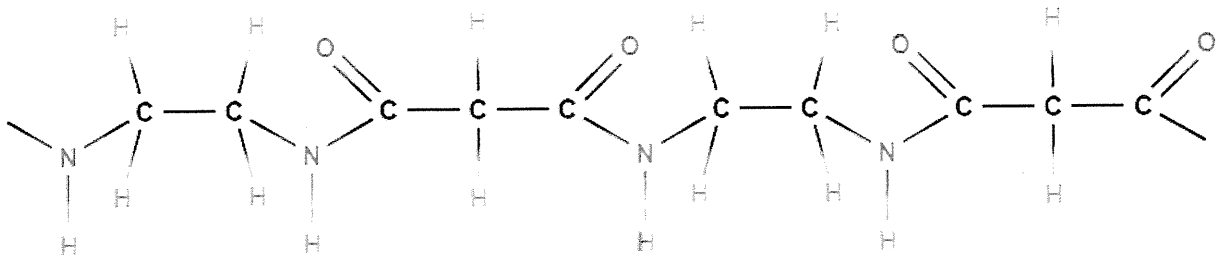
## Section II

**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**

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(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. **3**

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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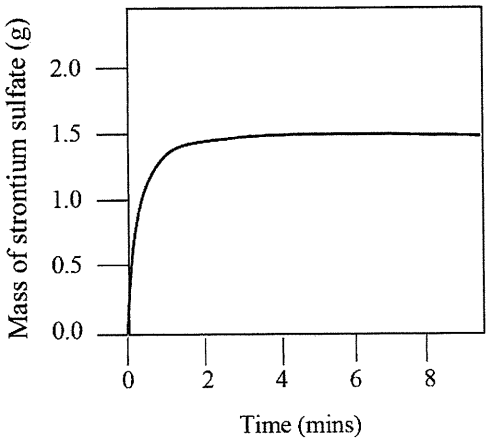
**Question 23** (6 marks)

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 ($Sr^{2+}$) ions after 4 minutes ($K_{sp}(SrSO_4) = 3.44 \times 10^{-7}$). **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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**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.

$$Co(H_2O)_6^{2+}(aq) + 4Cl^-(aq) \rightleftharpoons CoCl_4^{2-}(aq) + 6H_2O(l)$$

*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 26 (continued)

(c) The student calculated the experimental value and noticed it was much lower than the expected theoretical value. **1**

Identify an experimental error that would account for this difference.

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**Question 27** (4 marks)

A student has been given three unlabelled solutions. They have been told that each solution is one of the following: sodium sulfate, sodium chloride and sodium carbonate. **4**

Justify the chemical tests the student could use to correctly identify each solution. In your answer you should include at least TWO ionic equations.

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**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. With reference to a relevant chemical equation, explain how the presence of a natural buffer contributes to a natural system. **4**

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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**

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| Product 1 name: |
| Product 2 name: |

**Question 31** (6 marks)

The table below highlights the boiling point of four different hydrocarbons as chain length increases. **6**

| Number of Carbons | Boiling point (°C) | | | |
|---|---|---|---|---|
| | Alkane | Aldehyde | Alcohol | Carboxylic acid |
| 1 | -162 | -21 | 65 | 101 |
| 2 | -89 | 20 | 78 | 118 |
| 3 | -42 | 49 | 97 | 141 |
| 4 | -1 | 75 | 117 | 164 |
| 5 | 36 | 103 | 138 | 186 |
| 6 | 69 | 129 | 158 | 205 |
| 7 | 98 | 153 | 176 | 223 |
| 8 | 126 | 195 | 199 | 239 |

Identify and explain the differences in boiling points in the table.

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**Question 31 continues on page 23**

Question 31 (continued)

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**Question 32** (5 marks)

The pH of roses is sensitive to the pH of the soil and is dependent on a reaction involving acetic acid. The ester mainly responsible for the fragrance in roses is 2-phenylethyl acetate ($CH_3COOCH_2C_6H_5$), formed from acetic acid and phenylethanol. **5**

A farmer grew some roses in soil with a pH of 8.5.

Using relevant equations, explain why the farmer's flowers lacked fragrance and explain how the farmer should rectify the problem.

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**Question 33** (4 marks)

Photosynthesis is a complex reaction made up of numerous reactions taking place at different times, but is summarised by the following equation: 4

$$6\ CO_2(g) + 6\ H_2O(l) \rightarrow 6\ O_2(g) + C_6H_{12}O_6(s)$$

Determine if this reaction is spontaneous at 320 K, given the following data:

| *Species* | *Enthalpy of formation* ($kJ\ mol^{-1}$) | *Entropy* ($J\ K^{-1}\ mol^{-1}$) |
|---|---|---|
| $O_2$ (g) | 0 | +205 |
| $H_2O$ (l) | -285 | +70 |
| $CO_2$ (g) | -393 | +214 |
| $C_6H_{12}O_6$ (s) | -1273 | +212 |

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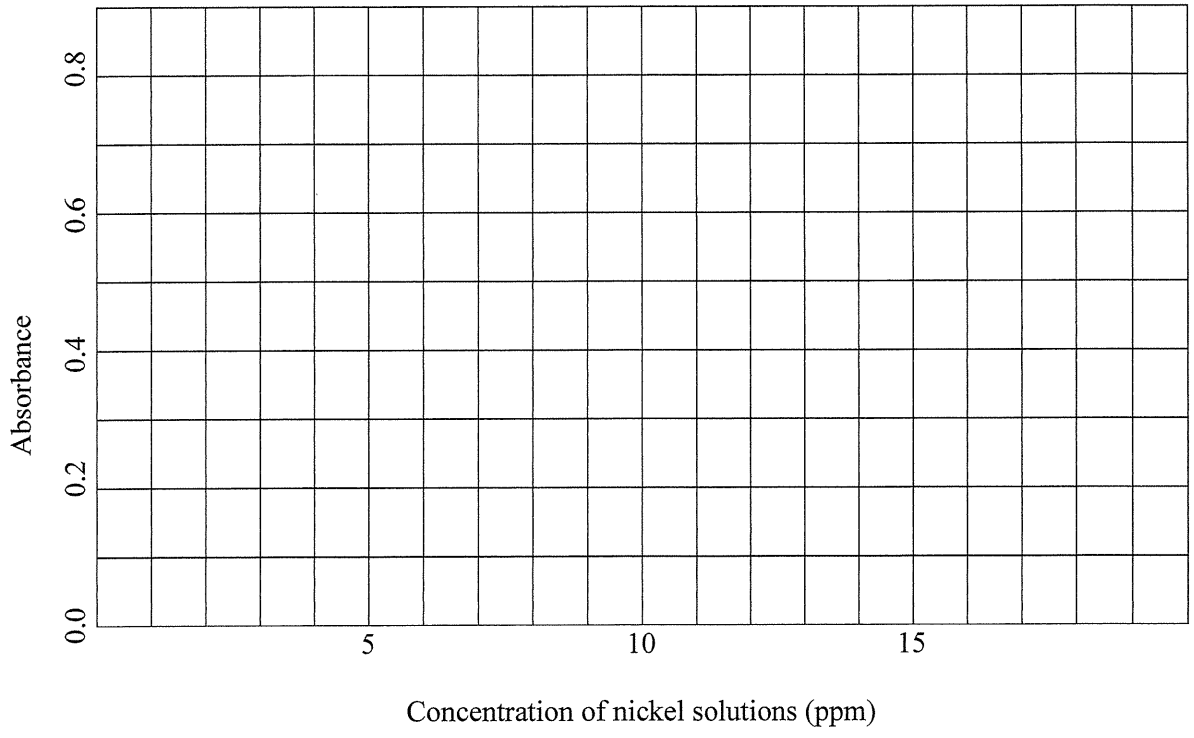
**Question 34** (6 marks)

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

The following absorbance data was collected.

| *Concentration of standard $Ni^{2+}$ solutions (ppm)* | *Absorbance* |
|---|---|
| 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. **3**

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 Indigenious 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 35 (continued)

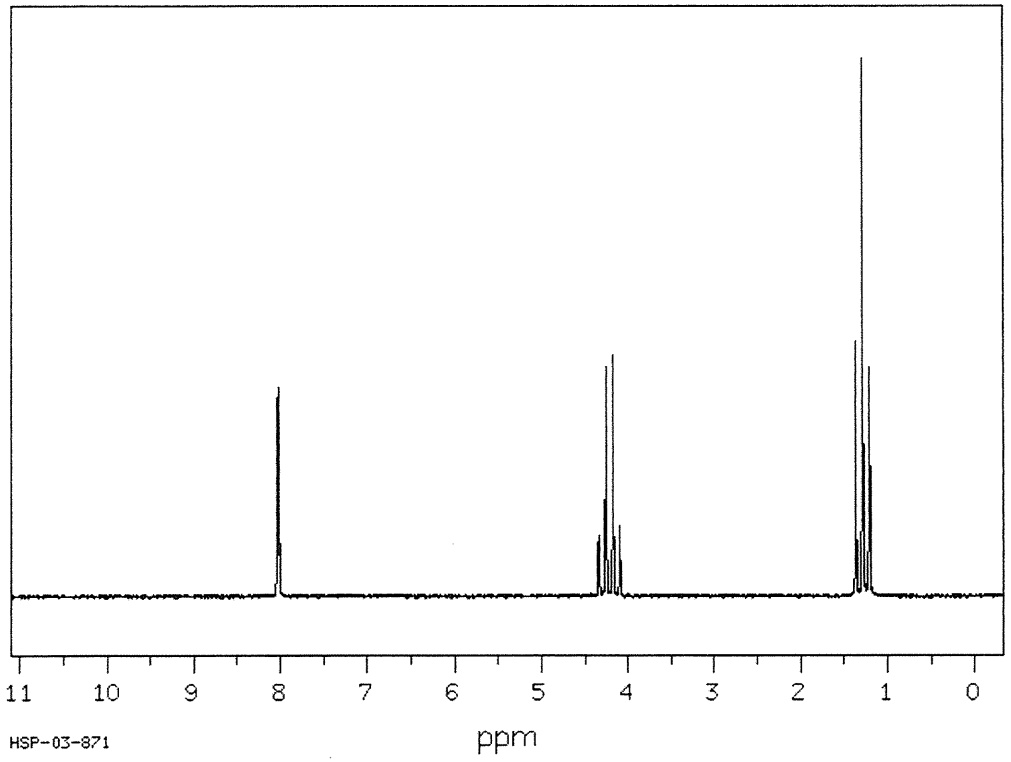
Show that the concentration of the standardised sodium hydroxide was 0.01502 mol/L and determine the percentage of the daily requirement of linolenic acid in the 20.0 g of the bush blueberries. **8**

**Question 36** (8 marks)

Below are four spectra. They belong to, in no particular order: **8**

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

**Spectrum A:**

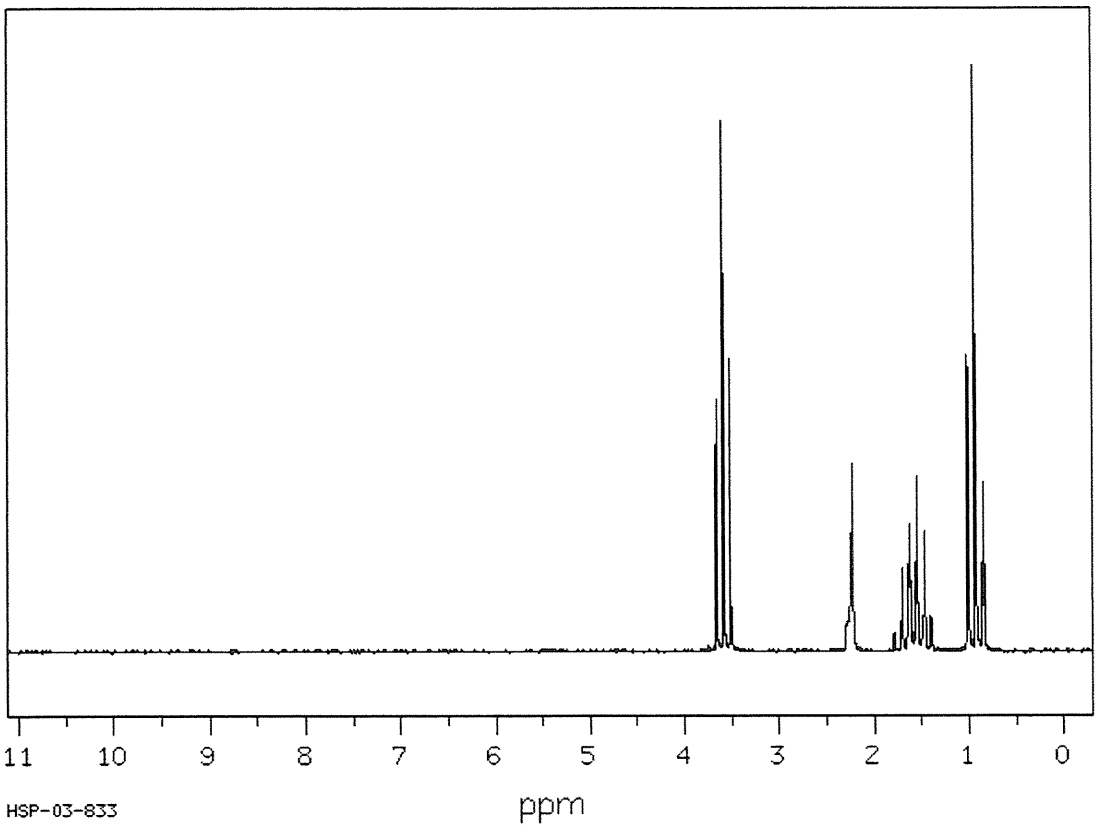



| **Data $^1$HNMR** | | |
|---|---|---|
| Chemical shift (ppm) | Relative peak area | Splitting pattern |
| 1.289 | 3 | Triplet |
| 4.215 | 2 | Quartet |
| 8.026 | 1 | Singlet |

**Question 36 continues on page 31**

Question 36 (continued)

**Spectrum B:**

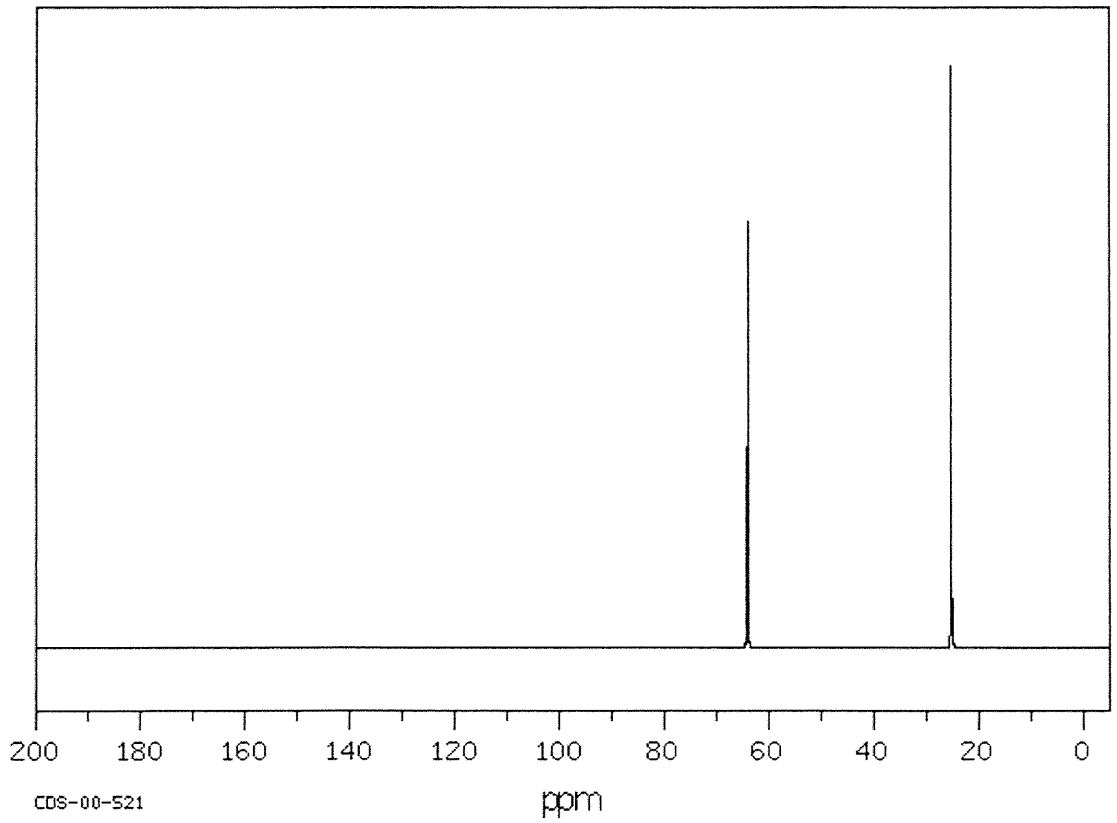



| Data $^{1}$HNMR | | |
|---|---|---|
| Chemical shift (ppm) | Relative peak area | Splitting pattern |
| 0.94 | 3 | Triplet |
| 1.57 | 2 | Sextet (6 peaks) |
| 2.26 | 1 | Singlet |
| 3.582 | 2 | Triplet |

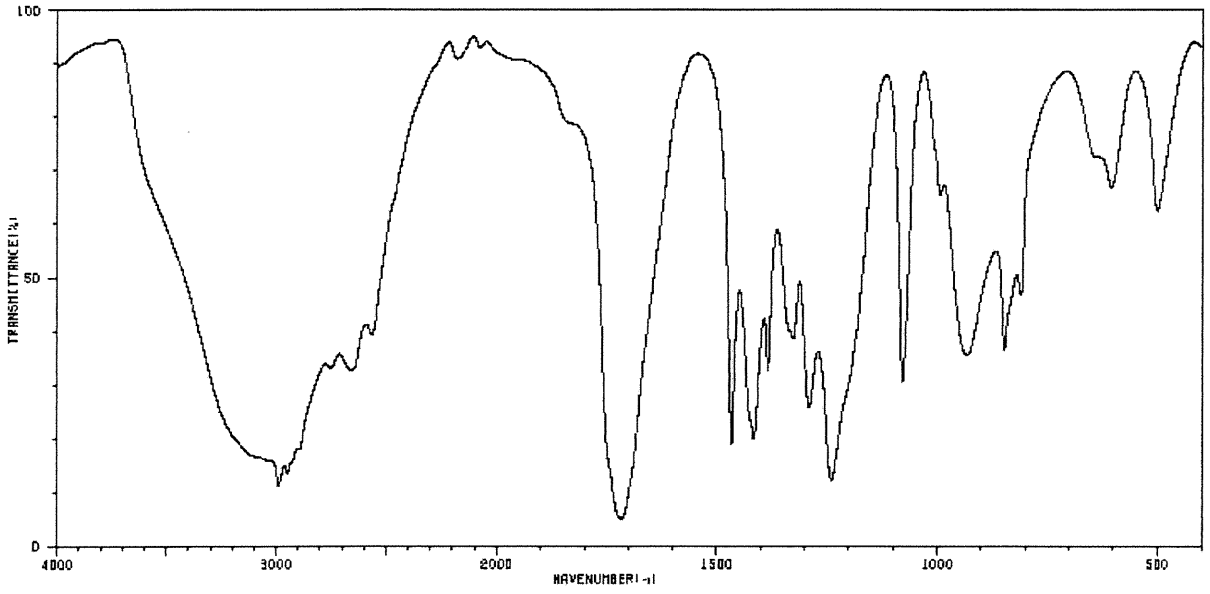
**Question 36 continues on page 32**

Question 36 (continued)

**Spectrum C:**




**Spectrum D:**




**Question 36 continues on page 33**

Question 36 (continued)

Complete the table below, identifying which compound belongs to each spectrum.

Justify your choices with reference to the spectra.

| Spectrum | Compound |
|---|---|
| A | |
| B | |
| C | |
| D | |

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Question 36 (continued)

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**End of Examination**

**Section II extra writing space**

If you use this space, clearly indicate which question you are answering by writing the question number before beginning the response.

**Section II extra writing space**

If you use this space, clearly indicate which question you are answering by writing the question number before beginning the response.

**Section II extra writing space**

If you use this space, clearly indicate which question you are answering by writing the question number before beginning the response.

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**Copyright**

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

## EXAMINERS

| | |
|---|---|
| Andrew Eaton (Convenor) | Wollondilly Anglican College, Tahmoor |
| Rhys Briscoe-Hough | Cranbrook School, Bellevue Hill |
| Suzana Juric | Monte Sant' Angelo Mercy College, North Sydney |
| Scott Tibbey | MLC School, Burwood |
| Charlotte Young | Kincoppal – Rose Bay School of the Sacred Heart, Rose Bay |

2024

TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

MARKING GUIDELINES

# Chemistry

## Section I

**20 marks**
**Questions 1–20 (1 mark each)**

| Question | Answer | Outcomes Assessed | Targeted Performance Band |
|---|---|---|---|
| 1 | B | CH12-12 | 2–3 |
| 2 | D | CH12-15 | 2–3 |
| 3 | B | CH12-13 | 2–3 |
| 4 | A | CH-11/12-6,CH12-15 | 3–4 |
| 5 | B | CH12-14 | 3–4 |
| 6 | C | CH12-12 | 3–4 |
| 7 | A | CH12-12 | 3–4 |
| 8 | A | CH12-15 | 3–4 |
| 9 | A | CH12-14 | 3–4 |
| 10 | D | CH12-15 | 3–4 |
| 11 | C | CH12-14 | 4–5 |
| 12 | B | CH11/12-6, CH12-14 | 4–5 |
| 13 | D | CH12-13 | 4–5 |
| 14 | C | CH12-12 | 4–5 |
| 15 | A | CH11/12-6, CH12-12 | 4–5 |
| 16 | C | CH12-14 | 4–5 |
| 17 | C | CH11/12-6, CH12-12 | 4–5 |
| 18 | C | CH12-15 | 5–6 |
| 19 | B | CH11/12-6, CH12-13 | 5–6 |
| 20 | D | CH11/12-6, CH12-13 | 5–6 |

## Section II

**80 marks**
**Question 21 (3 marks)**
**Question 21 (a) (1 mark)**
***Outcomes Assessed: CH12-14***
***Targeted Performance Bands: 2–3***

| Criteria | Marks |
|---|---|
| • Describes ONE difference between a condensation and addition polymer | 1 |

***Sample Answer:***

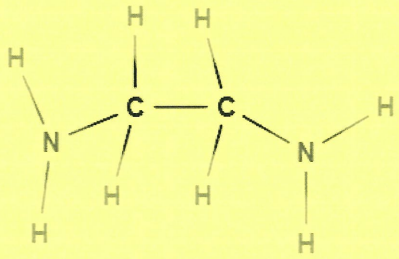
Answers may include, but not be limited to:

- Addition monomers usually have double bonds
- Simple addition polymers mainly start with one monomer
- Simple condensation polymers typically start with two different monomers
- Condensations reactions result in the polymer being more condensed than the combined monomers
- Condensation reactions usually produce a small molecule, like water, as a bi-product

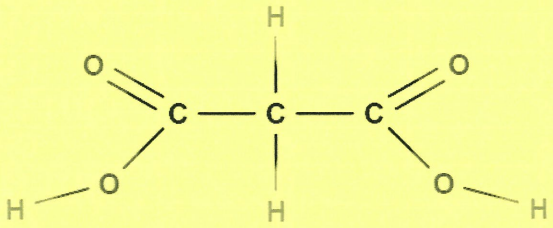
**Question 21 (b) (2 marks)**
***Outcomes Assessed: CH12-14***
***Targeted Performance Bands: 3–4***

| Criteria | Marks |
|---|---|
| • Correctly draws BOTH organic molecules | 2 |
| • Correctly draws ONE organic molecule | 1 |

***Sample Answer:***



and



**Question 22 (3 marks)**
***Outcomes Assessed: CH12-13***
***Targeted Performance Bands: 2–5***

| Criteria | Marks |
|---|---|
| • Explains the major difference between the theories using the reaction<br>• Includes a balanced chemical equation, with states | 3 |
| • Outlines the major difference between the theories<br>OR<br>• Outlines an outline of a theory AND includes a balanced chemical equation | 2 |
| • Provides some relevant information | 1 |

***Sample Answer:***

$HF(g) + NH_3(g) \rightleftharpoons NH_4F(s)$

The Arrhenius theory involves the production of hydrogen ions and hydroxide ions in solution. This reaction involves the gaseous and solid state, and there is no aqueous state for the formation of ions. However, the Bronsted-Lowry theory involves the donation and acceptance of protons, and does not require an aqueous state. Unlike the Arrhenius theory, this reaction would be considered an acid/base reaction under the Bronsted-Lowry theory.

**Question 23 (5 marks)**
**Question 23 (a) (1 mark)**
***Outcomes Assessed: CH12-12***
***Targeted Performance Bands: 3–4***

| Criteria | Marks |
|---|---|
| • Correct balanced chemical equation with at least the solid state provided | 1 |

***Sample Answer:***

$SrCl_2\,(aq) + Na_2SO_4\,(aq) \rightarrow SrSO_4\,(s) + 2\,NaCl\,(aq)$

**Question 23 (b) (3 marks)**
***Outcomes Assessed: CH11/12-5, CH12-12***
***Targeted Performance Bands: 3–6***

| Criteria | Marks |
|---|---|
| • Calculates the moles of both reactants to show they are equimolar<br>• Correctly calculates the strontium ion concentration | 3 |
| • Correctly calculates the strontium ion concentration, without justification<br>OR<br>• Shows some steps towards calculating the strontium ion concentration, with some reasonable attempt at justification | 2 |
| • Provides some relevant information | 1 |

***Sample Answer:***

$n(SrCl_2) = c \times V = 0.040\ mol/L \times 0.2000\ L = 8.0 \times 10^{-3}\ mol$
$n(Na_2SO_4) = c \times V = 0.016\ mol/L \times 0.5000\ L = 8.0 \times 10^{-3}\ mol$
Therefore, the combined solutions contain equal moles of reactants, so will have equal moles of strontium and sulfate ions in solution after precipitation.

$K_{sp}(SrSO_4) = [Sr^{2+}] \times [SO_4^{2-}] = 3.44 \times 10^{-7}$
Let $[Sr^{2+}] = x$
$x^2 = 3.44 \times 10^{-7}$
$x = 5.9 \times 10^{-4}$ (2sf)

Therefore the concentration of strontium ions is $5.9 \times 10^{-4}$ mol/L.

**Question 23 (c) (2 marks)**
***Outcomes Assessed: CH12-12***
***Targeted Performance Bands: 2–4***

| Criteria | Marks |
|---|---|
| • Accounts for change in system of strontium ions moving in and out of solution stating dynamic equilibrium. | 2 |
| • Provides some relevant information | 1 |

***Sample Answer:***

The system has reached a dynamic equilibrium where the strontium ions are moving in and out of solution, therefore radioactive strontium ions are detected in the solution, given enough time.

**Question 24 (3 marks)**
***Outcomes Assessed: CH12-15***
***Targeted Performance Bands: 2–5***

| Criteria | Marks |
|---|---|
| • Describes ONE relevant chemical production for EACH chemical<br>• Includes ONE equation (chemical or word) | 3 |
| • Describes ONE relevant chemical production for a chemical<br>OR<br>• Identifies ONE relevant chemical production for EACH chemical | 2 |
| • Identifies ONE relevant chemical industry | 1 |

***Sample Answer:***

**Sodium hydroxide:**
Sodium hydroxide is used in the saponification reaction (making soap).

Sodium hydroxide + fat/oil → glycerol + soap

(Other chemical productions include (but are not limited to) using sodium hydroxide in producing textiles, food processing, paper manufacturing and aluminium ore processing)

**Sulfuric acid:**
Concentrated sulfuric acid is used as a dehydrating agent and catalyst in the production of esters.

$$\text{Alcohol} + \text{carboxylic acid} \xrightarrow{\text{Conc. } H_2SO_4} \text{ester} + \text{water}$$

(Other chemical productions include (but are not limited to) using concentrated sulfuric acid to convert an alcohol to an alkene or using dilute sulfuric acid to convert an alkene to an alcohol)

**Question 25 (4 marks)**
**Question 25 (a) (3 marks)**
***Outcomes Assessed: CH11/12-2, CH12-12***
***Targeted Performance Bands: 2–4***

| Criteria | Marks |
|---|---|
| • Outlines a clear method for the investigation, with validity and safety included | 3 |
| • Outlines a method for the investigation. Some steps missing | 2 |
| • Some relevant steps provided | 1 |

***Sample Answer:***

1. Prepare a hot water bath and cold water bath in two 250 mL beakers.

2. Transfer 15 mL of a 0.1 M cobalt chloride solution into three separate test tubes. Ensure safety glasses and gloves are worn.

3. Place one test tube into the hot water bath and another into the cold water bath. Leave the third test tube at room temperature. Record observation in table.

**Question 25 (b) (1 mark)**
***Outcomes Assessed: CH12-12***
***Targeted Performance Bands: 4–5***

| Criteria | Marks |
|---|---|
| • Correctly justifies the reaction as endothermic, as written | 1 |

***Sample Answer:***

The cobalt chloride solution is endothermic. According the Le Chatelier's Principle, when heat is applied to an endothermic system, the forward reaction is favoured, turning the solution blue and when heat is removed from the system, the system solution turns pink, favouring the reverse reaction.

$Co(H_2O)_6^{2+}(aq) + 4\ Cl^-(aq) + ENERGY \rightleftharpoons CoCl_4^{2-}(aq) + 6\ H_2O(l)$

**Question 26 (5 marks)**
**Question 26 (a) (1 mark)**
***Outcomes Assessed: CH12-14***
***Targeted Performance Bands: 2–3***

| Criteria | Marks |
|---|---|
| • Provides correctly balanced chemical equation (states not required) | 1 |

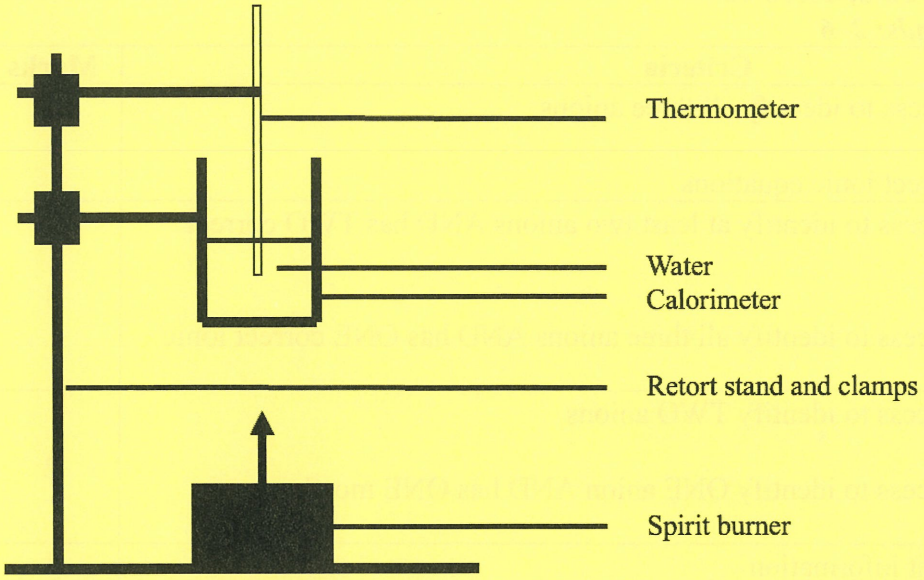
***Sample Answer:***

$C_4H_9OH\ (l) + 6\ O_2\ (g) \rightarrow 4\ CO_2\ (g) + 5\ H_2O\ (g)$

**Question 26 (b) (3 marks)**
***Outcomes Assessed: CH11/12-2, CH12-14***
***Targeted Performance Bands: 2–5***

| Criteria | Marks |
|---|---|
| • Outlines a logical method to collect data to determine the enthalpy of combustion of butanol<br>AND<br>• References quantities<br>AND<br>• Includes a correctly labelled diagram | 3 |
| • Outlines a logical method to collect data to determine the enthalpy of combustion of butanol<br>AND/OR<br>• References quantities<br>AND/OR<br>• Includes a correctly labelled diagram | 2 |
| • Provides some relevant information | 1 |

***Sample Answer:***




1. Measure 100ml of water into a calorimeter.
2. Record starting temperature.
3. Weigh spirit burner containing butanol and record starting mass.
4. Light spirit burner.
5. Record highest temperature.
6. Weigh spirit burner and record final mass.
7. Repeat steps 1-6.

**Question 26 (c) (1 mark)**
***Outcomes Assessed: CH11/12-5, CH12-14***
***Targeted Performance Bands: 3–4***

| Criteria | Marks |
|---|---|
| • Provides correct reason for difference in values | 1 |

***Sample Answer:***

Heat loss to the surroundings.

**Question 27 (4 marks)**
***Outcomes Assessed: CH11/12-2, CH12-15***
***Targeted Performance Bands: 2–6***

| Criteria | Marks |
|---|---|
| • Justifies a logical process to identify all three anions<br>AND<br>• Has at least TWO correct ionic equations | 4 |
| • Outlines a logical process to identify at least two anions AND has TWO correct ionic equations<br>OR<br>• Outlines a logical process to identify all three anions AND has ONE correct ionic equation | 3 |
| • Outlines a logical process to identify TWO anions<br>OR<br>• Outlines a logical process to identify ONE anion AND has ONE mostly correct ionic equation | 2 |
| • Provides some relevant information | 1 |

***Sample Answer:***

STEP 1:
Add silver nitrate solution to a sample of each solution. The silver cations will react with both the solutions of chloride and carbonate to form white precipitates.
$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$
$2\ Ag^+(aq) + CO_3^{2-}(aq) \rightarrow Ag_2CO_3(s)$

STEP 2:
To confirm between chloride and carbonate, add some dilute $HNO_3$ to each of the above samples. The silver carbonate will dissolve, the silver chloride will not dissolve.

STEP 3:
The sulfate sample will not form a precipitate with silver. To confirm this sample is sulfate, add barium nitrate solution to a fresh sample - a white precipitate will form and confirm the presence of sulfate.
$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

**Question 28 (6 marks)**
**Question 28 (a) (2 marks)**
***Outcomes Assessed: CH11/12-6, CH12-12***
***Targeted Performance Bands: 2–4***

| Criteria | Marks |
|---|---|
| • Correctly demonstrates the calculation of the calcium ion concentration | 2 |
| • Provides some relevant information | 1 |

***Sample Answer:***

$K_{sp} = [Ca^{2+}] \times [OH^-]^2 = 5.02 \times 10^{-6}$ (from the data sheet)
Let $[Ca^{2+}] = x$, so $[OH^-] = 2x$ (based on the solubility stoichiometry)

Therefore, $x \times (2x)^2 = 5.02 \times 10^{-6}$

$4x^3 = 5.02 \times 10^{-6} \rightarrow x^3 = 1.255 \times 10^{-6} \rightarrow x = 0.0107865$

$[Ca^{2+}] = 0.0108$ mol/L (3sf)

**Question 28 (b) (4 marks)**
***Outcomes Assessed: CH11/12-6, CH12-13***
***Targeted Performance Bands: 3–6***

| Criteria | Marks |
|---|---|
| • Provides all steps to correctly calculate change in pH | 4 |
| • Provides most steps to correctly calculate change in pH | 3 |
| • Provides some steps to correctly calculate change in pH | 2 |
| • Provides some relevant information | 1 |

***Sample Answer:***

Initial pH:

$[OH^-] = 2x = 2 \times 0.0108 = 0.0216$ mol/L

$pOH = -\log_{10}[OH^-] = -\log_{10}(0.0216) = 1.666$

$pH = 14 - pOH = 14 - 1.666 = 12.334$

Final pH:

$n(OH^-) = c \times V = 0.0216\ M \times 0.1000\ L = 2.16 \times 10^{-3}$ mol

$n(H^+) = c \times V = 0.123\ M \times 0.0500\ L = 6.15 \times 10^{-3}$ mol

Remaining $n(H^+) = 6.15 \times 10^{-3} - 2.16 \times 10^{-3} = 3.99 \times 10^{-3}$

$[H+] = n/V = 3.99 \times 10^{-3} / 0.150 = 0.0266$ mol/L

$pH = -\log_{10}[H^+] = -\log_{10}(0.0266) = 1.575$

Change in pH = 12.334 – 1.575 = 10.759

**Question 29 (4 marks)**
***Outcomes Assessed: CH12-13***
***Targeted Performance Bands: 2–5***

| Criteria | Marks |
|---|---|
| • Clearly explains how the buffer resists changes in pH, with reference to at least ONE relevant chemical equation | 4 |
| • Describes a buffer in a natural system, with reference to ONE relevant chemical equation | 3 |
| • Outlines a buffer in a natural system | 2 |
| • Provides some relevant information | 1 |

***Sample Answer:***

Students can use any valid buffering system in nature.

One of the blood buffering systems is carbonic acid ($H_2CO_3$) and its conjugate base, the bicarbonate ion ($HCO_3^-$). The equilibrium between carbonic acid and bicarbonate helps regulate the pH of blood. When excess hydronium ions ($H_3O^+$) are present, they can react with bicarbonate ions to form carbonic acid, preventing a drastic decrease in pH. If there is an excess of hydroxide ions ($OH^-$), the carbonic acid donates a proton to form bicarbonate ions, preventing a significant increase in pH. The movement/shift in the reactions is important to maintain pH for biological processes.

$HCO_3^-(aq) + H_3O^+(aq) \rightleftharpoons H_2CO_3(aq) + H_2O(aq)$

$H_2CO_3(aq) + OH^-(aq) \rightleftharpoons HCO_3^-(aq) + H_2O(aq)$

**Question 30 (5 marks)**
**Question 30 (a) (1 mark)**
***Outcomes Assessed: CH12-14***
***Targeted Performance Bands: 3–4***

| Criteria | Marks |
|---|---|
| • Correctly identifies a relevant condition | 1 |

***Sample Answer:***

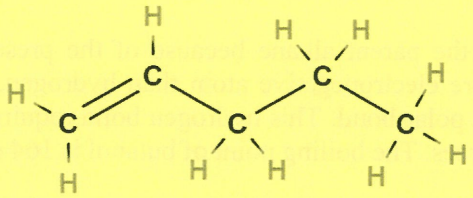
Answers may include:

- $Al_2O_3$ catalyst
- High temperatures
- Concentrated acid catalyst

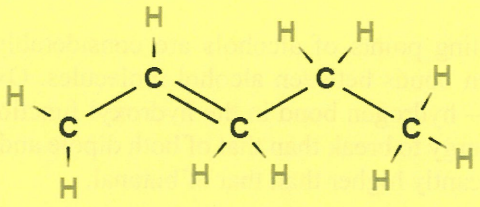
**Question 30 (b) (4 marks)**
***Outcomes Assessed: CH12-14***
***Targeted Performance Bands: 3–5***

| Criteria | Marks |
|---|---|
| • Correctly draws TWO organic products of the reaction<br>AND<br>• Correctly names TWO organic products of the reaction | 4 |
| • Correctly draws at least ONE organic product of the reaction<br>AND/OR<br>• Correctly names at least ONE organic product of the reaction | 2–3 |
| • Substantially draws a product of the reaction<br>OR<br>• Correctly names a product of the reaction | 1 |

***Sample Answer:***



Pent-1-ene



Pent-2-ene

(NB: no marks for water)

**Question 31 (6 marks)**
***Outcomes Assessed: CH11/12-6, CH12-14***
***Targeted Performance Bands: 2–6***

| Criteria | Marks |
|---|---|
| • Demonstrates an extensive knowledge of the relationship between bonding and boiling point<br>• Makes specific reference to the data in the table<br>• Correctly explains each type of bonding<br>• Links the type of bonding to HOW each affects the boiling point of a molecule<br>• Provides information to explain the higher boiling point of carboxylic acids | 6 |
| • Demonstrates a thorough knowledge of the relationship between bonding and boiling point<br>• Makes specific reference to the data in the table<br>• Explains each type of bonding<br>• Some links to the type of bonding to HOW each affects the boiling point of a molecule<br>• Attempts to explain the higher boiling point of carboxylic acids | 4–5 |
| • Demonstrates a sound knowledge of the relationship between bonding and boiling point<br>• References to the data in the table<br>• Attempts to explain each type of bonding<br>• Some links to the type of bonding and the boiling point of a molecule | 2–3 |
| • Demonstrates some understanding of how bonding affects boiling point | 1 |

***Sample Answer:***

Alkane molecules are non-polar, the only intermolecular forces of attraction between them are weak dispersion forces. As the length of the carbon chain increases, the overall forces of attraction between molecules also increase. The strength of dispersion forces between molecules increases because of the increased strength of temporary dipoles within the molecules, due to the increased number of valence electrons.

Aldehydes also have weak dispersion forces between molecules but their boiling points are much higher - butane's boiling point is -1 degree whilst butanal has a boiling point of 75 degrees. This is because aldehydes are a polar molecule due to the double bonded oxygen they contain, allowing them to form permanent dipoles that are stronger and require more energy to separate.

The boiling points of alcohols are considerably higher than the parent alkane because of the presence of hydrogen bonds between alcohol molecules. Oxygen is a more electronegative atom than hydrogen, so the oxygen – hydrogen bond in the hydroxyl functional group is a polar bond. This hydrogen bond requires even more energy to break than that of both dipole and dispersion forces. The boiling point of butanol is 164 degrees - significantly higher than that of butanal.

Carboxylic acid boiling points are much higher than alcohols of similar sizes. This is because carboxylic acids also form hydrogen bonds, but each molecule has the ability to form two hydrogen bonds and often exist as stable dimers - where the H from the OH bond is strongly attracted to the =O of a second carboxylic acid.

As the carbon chain length increases, the difference in boiling point is significantly higher in alkanes than aldehydes than alcohols and acids, implying that as the length of the carbon chain increases, the influence of dipole-dipole and hydrogen bonding becomes less important relative to the dispersion forces.

**Question 32 (5 marks)**
***Outcomes Assessed: CH12-12, CH12-13***
***Targeted Performance Bands: 2–6***

| Criteria | Marks |
|---|---|
| • Correctly writes an equilibrium word equation for esterification<br>• Correctly writes an equilibrium chemical equation for the ionisation of acetic acid<br>• Explains how an alkaline pH affects the acetic acid equilibrium and the ester equilibrium<br>• Links the high pH to lack of fragrance<br>• Explains how lowering the pH of the soil affects the acetic acid equilibrium and the ester equilibrium<br>• Links the lowering of the pH to an increase in fragrance | 5 |
| • Correctly writes a word equation for esterification AND/OR the ionisation of acetic acid<br>• Explains how an alkaline pH affects the acetic acid equilibrium AND/OR the ester equilibrium<br>• Links the pH to the level of fragrance<br>• Explains how lowering the pH of the soil affects the acetic acid equilibrium AND/OR the ester equilibrium | 3–4 |
| • Explains how pH affects the acetic acid equilibrium OR the ester equilibrium AND<br>• Provides a mostly correct word OR chemical equation | 2 |
| • Some relevant information provided | 1 |

***Sample Answer:***

The fragrance of the rose is due to an ester, 2-phenylethyl acetate. The ester is in equilibrium:

Acetic acid + phenylethanol ⇌ 2-phenylethyl acetate + water

If the pH is 8.5, the soil is alkaline in nature. Excess hydroxide ions can react with hydronium ions produced by the acetic acid, which is a weak acid.

$CH_3COOH\ (aq) + H_2O\ (l) \rightleftharpoons H_3O^+\ (aq) + CH_3COO^-\ (aq)$
Acetic acid + water ⇌ hydronium ion + acetate ion

The removal of hydronium ions results in a shift to the right-hand side of the ionisation of acetic acid, causing a decrease in acetic acid concentration.The removal of acetic acid causes a shift to the left-hand side of the ester equilibrium, decreasing the amount of the ester. Hence there will be a decrease in the amount of fragrance detected.

To rectify this issue, the farmer should apply a soil treatment to lower the pH so that it is less than 7. By increasing the acidity, it will cause a shift to the left-hand side of the acetic acid ionisation equilibrium, producing more acetic acid. The increase in acetic acid will cause a shift to the right-hand side of the ester equilibrium, producing more ester and greater fragrance.

**Question 33 (4 marks)**
***Outcomes Assessed: CH11/12-6, CH12-12***
***Targeted Performance Bands: 2–6***

| Criteria | Marks |
|---|---|
| • Correct calculations provided with units<br>• Identifies spontaneity of reaction | 4 |
| • Performs MOST steps in the calculation<br>• Identifies spontaneity of reaction | 3 |
| • Provides SOME steps in calculation | 2 |
| • Provides some relevant information | 1 |

***Sample Answer:***

Enthalpy of reaction –

$\Delta H = \Sigma\ \Delta H$ (products) – $\Sigma\ \Delta H$ (reactants)

$\Delta H = (-1273 + 0) - (\ (6 \times -393)\ + (6 \times -285)\ ) = +\ 2795\ kJ\ mol^{-1}$

Entropy of reaction –

$\Delta S = \Sigma \Delta S$ (products) – $\Sigma \Delta S$ (reactants)

$\Delta S = (212 + 6 \times 205) - (6 \times 214 + 6 \times 70) = -\ 262\ JK^{-1}\ mol^{-1} = -\ 0.262\ k\ JK^{-1}\ mol^{-1}$

Gibbs free energy –

$\Delta G = \Delta H - T\Delta S$

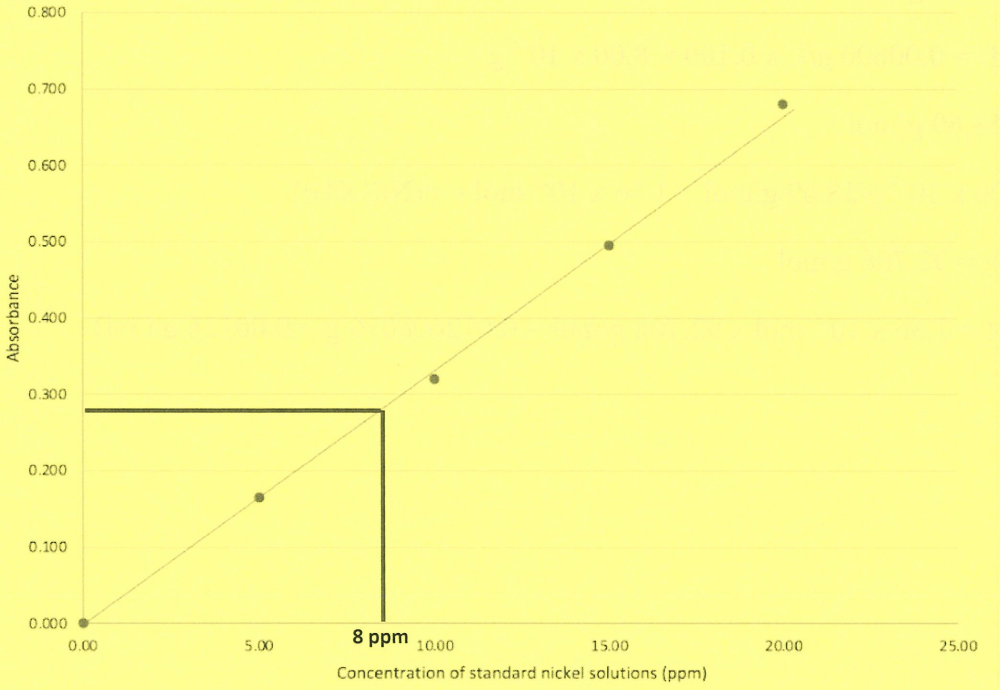
$\Delta G = 2795 - (320 \times -0.262) = +2878\ kJ\ mol^{-1}$

Therefore, the reaction is not spontaneous at 320K.

**Question 34 (6 marks)**
**Question 34 (a) (3 marks)**
***Outcomes Assessed: CH11/12-5, CH12-14***
***Targeted Performance Bands: 2–4***

| Criteria | Marks |
|---|---|
| • Correctly plotted graph<br>• Correct absorbance determined, with working on the graph | 3 |
| • Correctly plotted graph<br>OR<br>• Graph plotted with ONE error AND absorbance determined from the graph | 2 |
| • Some points correctly plotted on the graph | 1 |

***Sample Answer:***




Absorbance of 8.00 ppm solution = 0.28 ± 0.01

**Question 34 (b) (3 marks)**
***Outcomes Assessed: CH12-14***
***Targeted Performance Bands: 3–5***

| Criteria | Marks |
|---|---|
| • Correctly calculates mass of precipitate formed, with correct sig figs | 3 |
| • Provides some calculation steps | 2 |
| • Provides any relevant information | 1 |

***Sample Answer:***

Nickel concentration = 8.00 ppm

Converting, ppm converted to g/L, nickel concentration = 8.00 mg/L = 0.00800 g/L

molar mass of $Ni^{2+}$ = 58.69 g/mol

mass of $Ni^{2+}$ in 100 mL = 0.00800 g/L x 0.100 = $8.00 \times 10^{-4}$ g

molar mass of $Ni^{2+}$ = 58.69 g/mol

$n(Ni^{2+}) = m/MM = 8.00 \times 10^{-3}$ g/58.69 g/mol = $1.36 \times 10^{-5}$ mol = $n(Ni(OH)_2)$

molar mass of $Ni(OH)_2$ = 92.706 g/mol

$m(Ni(OH)_2) = n \times MM = 1.36 \times 10^{-5}$ mol x 92.706 g/mol = 0.012608016 g = 0.00126 g (3sf)

**Question 35 (8 marks)**
***Outcomes Assessed: CH11/12-6, CH12-13***
***Targeted Performance Bands: 2–6***

| Criteria | Marks |
|---|---|
| • Correctly calculates the moles of HCl<br>• Correctly calculates the volume and concentration of NaOH from HCl<br>• Correctly calculates the volume of NaOH with linolenic acid<br>• Correctly calculates the number of moles of NaOH and linolenic acid<br>• Correctly calculates the mass of linolenic acid in 20 g of berries<br>• Correctly calculates the percentage intake of 20 berries | 8 |
| • Performs MOST steps, with one or two errors | 5–7 |
| • Performs SOME steps | 2–4 |
| • Provides some relevant information | 1 |

***Sample Answer:***

Standardisation

c(HCl) = 0.01978 mol/L
V(HCl) = 25.00 mL = 0.02500 L
n(HCl) = c x V = 4.945 x $10^{-4}$ mol

n(NaOH) = n(HCl) (equimolar stoichiometry)
V(NaOH) = (32.95+32.90+32.90)/3 mL = 32.917 mL (all three titrations are concordant)

c(NaOH) = n(NaOH)/V(NaOH) = 4. 945 x $10^{-4}$ mol/0.032917 L **= 0.01502 mol/L (4sf)**

Blueberry investigation

c(NaOH) = 0.01502 mol/L
The first titration is an outlier, so ignore it.
V(NaOH) = (3.20+3.10+3.10)/3 = 3.13333333 mL
n(NaOH) = c x V = 0.01502 x 0.00313333333 = 4.7062666667 x $10^{-5}$ mol

n(linolenic acid) = n(NaOH) as the acid is monoprotic
MM(linolenic acid) = 278.7 g/mol

m(linolenic acid) = n x MM = 4.7062666667 x $10^{-5}$ x 278.7 = 0.013116 g

This is the mass in a 5.00 mL aliquot, so
m(linolenic acid in 20 g of berries) = 5 x 0.013116 = 0.06558 g

Percentage of requirement = (0.06558/1.7) x 100% = 3.87647% = 3.9% (2sf)
Therefore % of daily intake = 3.9%

**Question 36 (8 marks)**
***Outcomes Assessed: CH11/12-6, CH12-15***
***Targeted Performance Bands: 2–6***

| Criteria | Marks |
|---|---|
| • Correctly identifies FOUR spectra<br>• Justifies the correct structures, showing an extensive understanding of the interpretation of spectroscopic data | 8 |
| • Correctly identifies FOUR spectra<br>• Justifies the correct structures, showing a thorough understanding of the interpretation of spectroscopic data | 6–7 |
| • Correctly identifies TWO or THREE spectra<br>• Justifies the correct structures, showing a sound understanding of the interpretation of spectroscopic data | 4–5 |
| • Demonstrates some understanding of the interpretation of spectroscopic data | 2–3 |
| • Provides some relevant information | 1 |

***Sample Answer:***

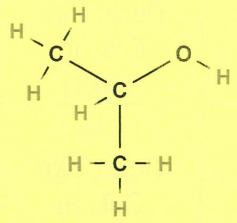
| Spectrum | Compound |
|---|---|
| A | Ethyl methanoate |
| B | 1-propanol |
| C | 2-propanol |
| D | propanoic acid |

Starting with **Spectrum D** (IR spectrum):

Big broad peak around 3000 $cm^{-1}$, indicating Spectrum D is most likely an acid (very broad peak for -OH around 2500 – 3000 $cm^{-1}$), so **propanoic acid**. This is further confirmed by a C=O peak in the 1680-1750 $cm^{-1}$ range and a C-O peak in the 1000-1300 $cm^{-1}$ range.

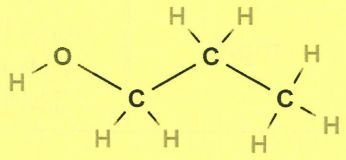
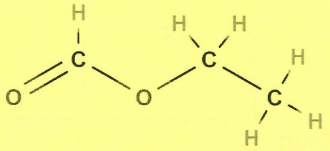
Looking next at **Spectrum C** (C-NMR):

There are only two peaks (25 ppm and 65 ppm), meaning only two carbon environments. Given that each molecule has three carbons, this means that two carbons must be in an identical environment. 2-propanol has the structure:



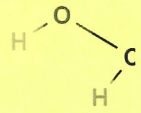
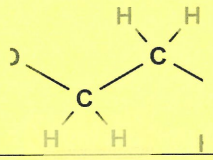
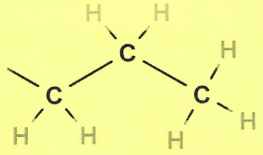
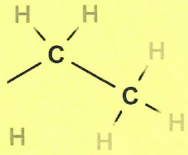
The two -$CH_3$ groups should be a single peak in the range of 5 – 40 ppm, which 25 ppm is, and one carbon is attached to the -OH group and the peak should be in the 50 -90 ppm range, which 65 ppm is. Thus, we expect that Spectrum C is **2-propanol**.

The remaining two compounds are:

| | |
|---|---|
|  |  |
| 1-propanol | Ethyl methanoate |

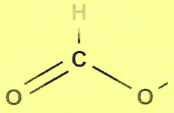
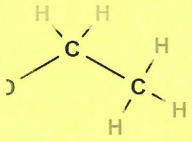
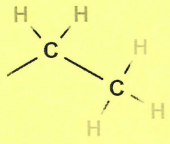
The two remaining spectra are H-NMR spectra.

If one spectrum belonged to 1-propanol, we would expect 4 hydrogen environments:

| Environment | Part of molecule (hydrogens highlighted) | Number of hydrogens | Number of hydrogen neighbours | Number of splits in spectra | Expected order from 0 ppm |
|---|---|---|---|---|---|
| 1 |  | 1 | 0 (oxygen screening) | singlet | 3/4 (least like $CH_3$ in TMS) |
| 2 |  | 2 | 2 | triplet | 3/4 (least like $CH_3$ in TMS) |
| 3 |  | 2 | 6 | sextet | 2 |
| 4 |  | 3 | 2 | triplet | 1 (most like $CH_3$ in TMS) |

**1-propanol** corresponds to Spectrum B.

If one spectrum belonged to ethyl methanoate, we would expect 3 hydrogen environments:

| Environment | Part of molecule (hydrogens highlighted) | Number of hydrogens | Number of hydrogen neighbours | Number of splits in spectra | Expected order from 0 ppm |
|---|---|---|---|---|---|
| 1 |  | 1 | 0 (oxygen screening) | singlet | 3 (least like $CH_3$ in TMS) |
| 2 |  | 2 | 3 | quartet | 2 |
| 3 |  | 3 | 2 | triplet | 1 (most like $CH_3$ in TMS) |

**Ethyl methanoate** corresponds to Spectrum A.

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