



2023

TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

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Centre Number

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Student Number

Chemistry

Afternoon Session
Friday, 4 August 2023

**General
Instructions**

- Reading time – 5 minutes
- Working time – 3 hours
- Write using black pen
- Draw diagrams using pencil
- Calculators approved by NESA 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 11–30)

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

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Section I

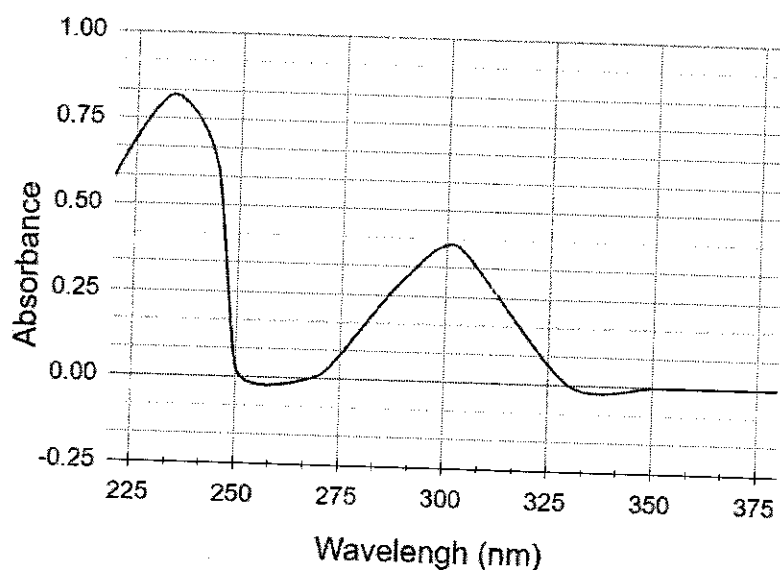
20 marks

Attempt Questions 1–20

Allow about 35 minutes for this part

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

- 1 Salicylic acid is widely used in medical treatments. Below is the UV-Visible absorption spectrum of paracetamol, which contains salicylic acid.



What wavelengths would be selected to determine the concentration of salicylic acid in a sample?

- A. 234 nm and 302 nm
 - B. 234 nm and 330 nm
 - C. 255 nm and 302 nm
 - D. 255 nm and 330 nm
- 2 What is the most accurate piece of equipment to measure the volume of the solution going into a conical flask just prior to titration?
- A. Beaker
 - B. Burette
 - C. Measuring cylinder
 - D. Volumetric pipette

3 Which of the following correctly identifies **two** conditions required for fermentation?

- A. 20–30°C and a high-oxygen environment
- B. 20–30°C and a low-oxygen environment
- C. 70–80°C and a high-oxygen environment
- D. 70–80°C and a low-oxygen environment

4 The table below outlines some properties of a variety of indicators.

Indicator	Colour in acid	pH range of colour change	Colour in base
Methyl violet	Yellow	0.0 – 1.6	Blue
Bromocresol green	Yellow	3.8 – 5.4	Blue
Thymol blue	Yellow	8.0 – 9.6	Blue
Thymolphthalein	Colourless	9.4 – 10.6	Blue

Which indicator's endpoint most closely matches the equivalence point when a weak acid is neutralised by a strong base?

- A. Bromocresol green
- B. Methyl violet
- C. Thymol blue
- D. Thymolphthalein

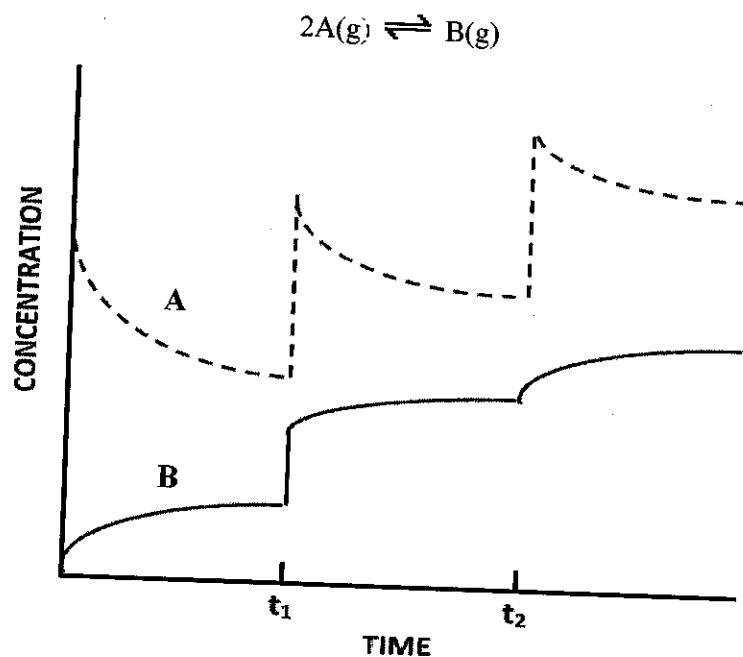
5 Which one of the following species is NOT a Bronsted-Lowry acid?

- A. $\text{CH}_3\text{CO}_2\text{H}$
- B. H_2O
- C. $(\text{CH}_3)_3\text{N}$
- D. NH_4^+

6 How many structural isomers does C_5H_{12} have?

- A. 2
- B. 3
- C. 4
- D. 5

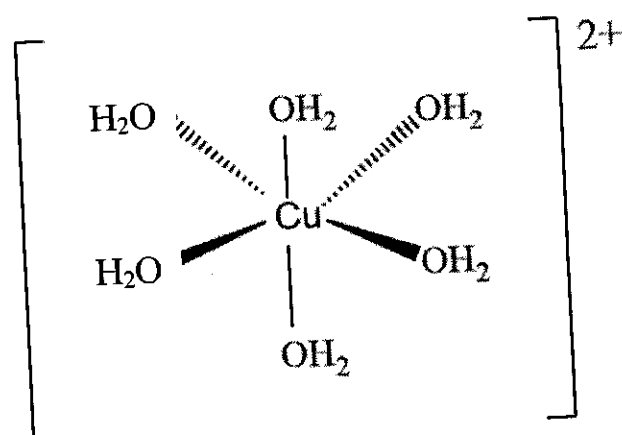
7 The graph below shows the changes that occur to an equilibrium system for the following reaction.



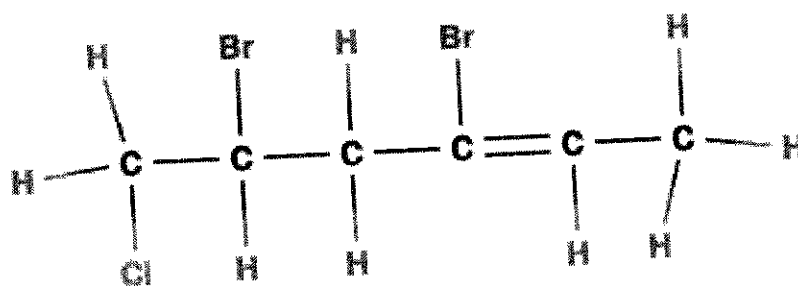
Which row of the table below describes how the changes at times t_1 and t_2 affect the reverse reaction rate immediately after each change?

	Change to reverse reaction rate at t_1	Change to reverse reaction rate at t_2
A.	Decrease	No effect
B.	Increase	Decrease
C.	Increase	No effect
D.	No effect	No effect

- 8 What is the ligand in the metal ion complex below?

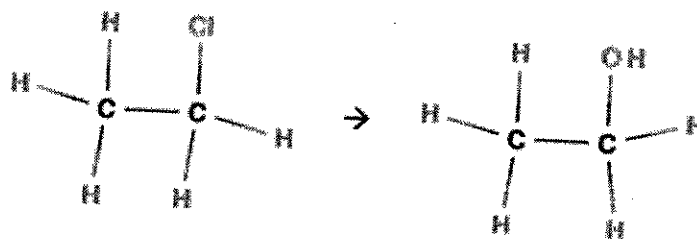


- A. Cu^{2+}
 B. H_2O
 C. OH^-
 D. $\text{Cu}(\text{OH})_2$
- 9 What is the IUPAC name for the compound below?



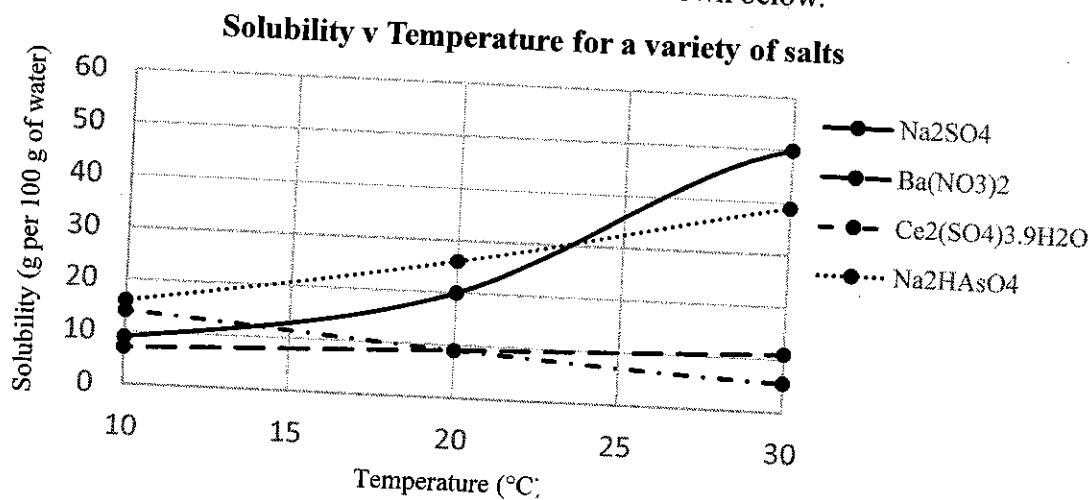
- A. 1-chloro-2,4-dibromohex-4-ene
 B. 6-chloro-3,5-dibromohex-2-ene
 C. 2,4-dibromo-1-chlorohex-4-ene
 D. 3,5-dibromo-6-chlorohex-2-ene

10 What type of reaction is the following?



- A. Addition reaction
- B. Complexation formation
- C. Dehydration reaction
- D. Substitution reaction

11 A student has four samples of solid salts: Na_2SO_4 (MM = 142.0 g mol^{-1}), $\text{Ba}(\text{NO}_3)_2$ (MM = 261.3 g mol^{-1}), $\text{Ce}_2(\text{SO}_4)_3 \cdot 9\text{H}_2\text{O}$ (MM = 730.6 g mol^{-1}) and Na_2HAsO_4 (MM = 185.9 g mol^{-1}). The solubility of these salts is shown below.

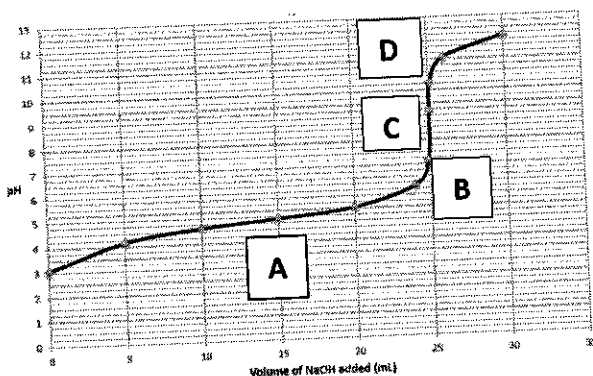


The student set up four beakers with 100 g of water at 20°C . To each beaker they added 0.1 moles of two different salts and stirred (assume no temperature change).

Which row of the table shows a combination that will NOT have a solid at the bottom of the solution at the end?

A.	Na_2SO_4	$\text{Ce}_2(\text{SO}_4)_3 \cdot 9\text{H}_2\text{O}$
B.	Na_2SO_4	Na_2HAsO_4
C.	$\text{Ba}(\text{NO}_3)_2$	$\text{Ce}_2(\text{SO}_4)_3 \cdot 9\text{H}_2\text{O}$
D.	$\text{Ba}(\text{NO}_3)_2$	Na_2HAsO_4

- 12 The graph shows a pH curve produced when a strong base is added to a weak acid.



Which point on the curve represents a solution that can act as a buffer?

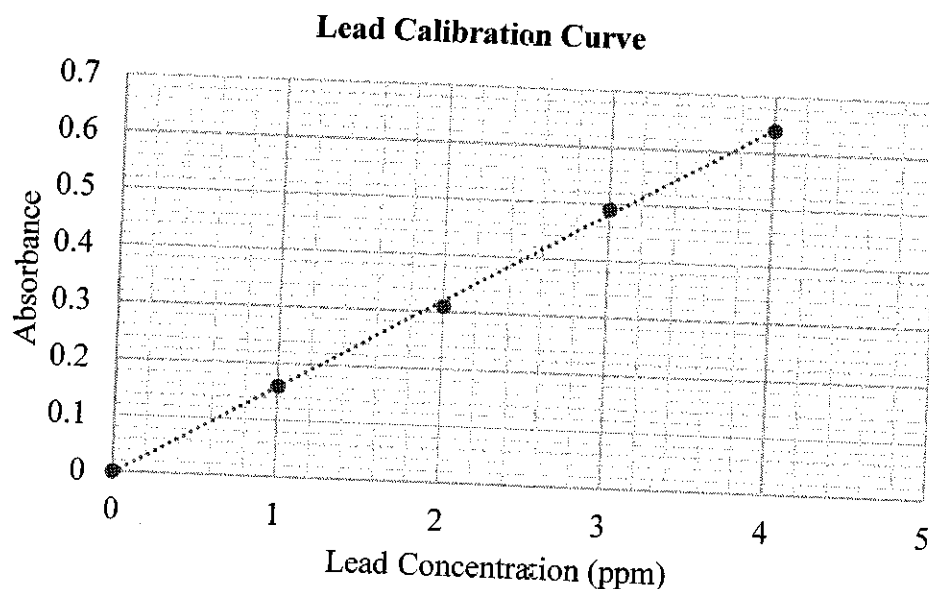
- A. Point A
 - B. Point B
 - C. Point C
 - D. Point D
- 13 25 mL of 0.10 M nitric acid is combined with 35 mL of 0.10 M of $\text{Ba}(\text{OH})_2$.

What is the resulting pH?

- A. 1.12
 - B. 2.35
 - C. 11.65
 - D. 12.88
- 14 Which of the following molecules would NOT have covalent bonds in a tetrahedral shape around the carbon atom?

- A. Methanal
- B. Methanamine
- C. Methane
- D. Methanol

- 15 An atomic absorption spectrometer can be used to determine the level of lead in soils. The calibration curve below plots the absorbance of four standard lead solutions against the concentration of lead ions in ppm.

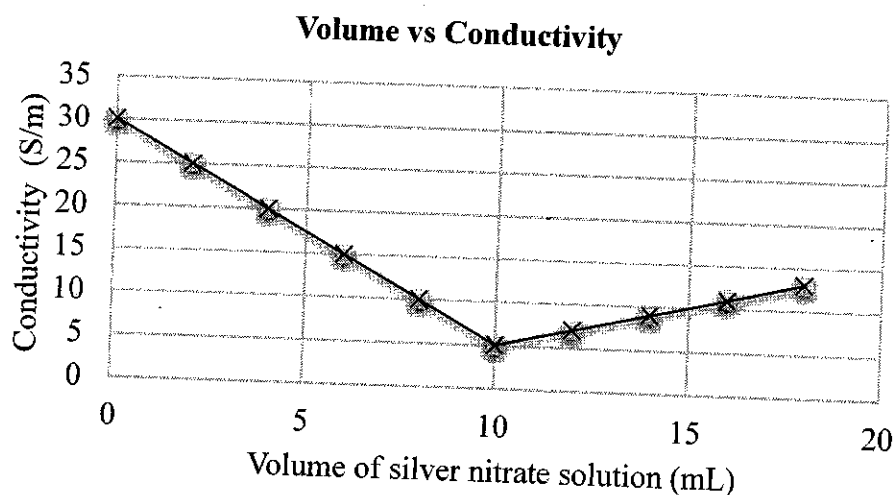


If the test solution gave an absorbance reading of 0.55, what would be the concentration of lead ions in the solution in mol L^{-1} ?

- A. 1.69×10^{-5}
- B. 3.50×10^{-3}
- C. 1.69×10^{-2}
- D. 3.50

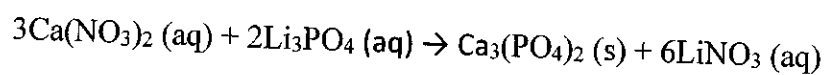
- 16 The molecule $\text{NH}_2\text{COCH}_2\text{CH}_2\text{CH}_2\text{COOH}$ (molar mass = 131 g mol^{-1}) forms a condensation polymer. The average polymer molecule contains 2000 monomer units. What is the approximate molar mass of the polymer?
- A. $226\,000 \text{ g mol}^{-1}$
B. $230\,000 \text{ g mol}^{-1}$
C. $262\,000 \text{ g mol}^{-1}$
D. $298\,000 \text{ g mol}^{-1}$
- 17 20.0 mL of 0.200 mol/L lead(II) nitrate is combined with 20.0 mL of 0.500 mol/L of sodium iodide.
- What is the mass of precipitate formed?
- A. No precipitate
B. 1.33 g
C. 1.84 g
D. 4.61 g
- 18 Consider the following neutralisation reactions:
1. If 30.0 mL of a 0.1M $\text{Ca}(\text{OH})_2$ solution is added to 30.0 mL of a 0.1M H_2SO_4 solution, the temperature increase is ΔT_1 .
2. If 60.0 mL of a 0.1M $\text{Ca}(\text{OH})_2$ solution is added to a 60.0 mL of a 0.1M H_2SO_4 solution, the temperature increase is ΔT_2 .
- Which statement is true?
- A. $\Delta T_1 > \Delta T_2$
B. $\Delta T_1 < \Delta T_2$
C. $\Delta T_1 = \Delta T_2$
D. $\Delta T_1 = 2\Delta T_2$

- 19 A student used a conductivity meter to determine the amount of phosphate in a sample of treated water. The student used a burette to add 0.010 M solution of silver nitrate.



What was the mass of phosphate present in the sample?

- A. 1.6 mg
 - B. 3.2 mg
 - C. 26 mg
 - D. 68 mg
- 20 The reaction between lithium phosphate and calcium nitrate produces a precipitate of calcium phosphate, according to the reaction below:



If 4.82 g of calcium phosphate forms, what mass of calcium nitrate is needed to form this precipitate? Assume lithium phosphate is in excess.

- A. 0.85 g
- B. 2.55 g
- C. 5.40 g
- D. 7.65 g

Section II

80 marks

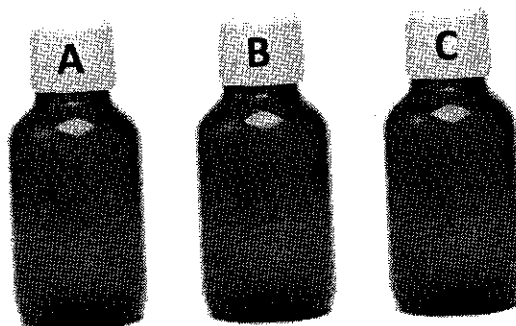
Attempt Questions 21–36

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 page 31–33. If you use this space, clearly indicate which question you are answering.

Question 21 (4 marks)

Bottles A, B and C contain aqueous solutions of iron (Fe^{2+}), calcium (Ca^{2+}) and silver (Ag^+) ions respectively. 4



Describe chemical tests that could identify which bottle contains which cation. Include at least one relevant chemical equation.

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Question 22 (4 marks)

Portable camping stoves generally contain butane as the fuel.
The heat of combustion of butane is 2.88×10^3 kJ/mol.

- (a) Write the equation for the complete combustion of butane.

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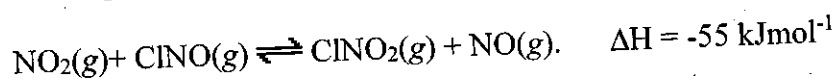
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- (b) If this camping stove was used to heat 500 ml of water inside a kettle from 20°C to boiling, what mass of butane was used? 3

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Question 23 (5 marks)

The reaction below is an important reaction precursor for the chlorination of organic compounds for the production of plastics.



- (a) A demonstration reaction was performed in a 5.0 L reaction vessel that initially contained 4.0 moles of ClNO and 2.4 moles of NO₂. At equilibrium, there were 0.15 moles of nitrogen monoxide present.

Show that the equilibrium constant at this temperature is 2.6×10^{-3} .

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- (b) Explain how a plastic manufacturer would control both kinetics and equilibrium to maximise the yield of chlorine nitrite (ClNO₂). 3

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Question 24 (5 marks)

The table below shows three molecules with different functional groups and similar masses.

Molecule	Molar mass (g mol^{-1})
Butane	58.12
Ethanamide	59.07
Propanal	58.08

- (a) Order the above molecules from lowest to highest boiling point.

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- (b) Account for the differences in boiling point between the THREE molecules.

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Question 25 (6 marks)

The world has become highly dependent on products from the petrochemical industry. With the issues surrounding the use of fossil fuels, scientists are looking for renewable fuel sources such as biofuels. 6

Compare the use of fossil fuels and biofuels, AND evaluate the environmental, social and economic impacts of both.

Support your answer with at least ONE relevant chemical equation.

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Question 26 (6 marks)

- (a) Draw a diagram or describe a model to demonstrate the difference between the addition of a strong acid to water and a weak acid to water. 3

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- (b) A student found three beakers containing clear and colourless solutions in the lab. 3
The labels that had fallen off the beakers indicated that they were all salt solutions – NaCl, NH_4Cl and NaF. The student added universal indicator to each beaker.

Explain the colour differences the student observed for each salt solution, using relevant chemical equations.

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Question 27 (3 marks)

Blood needs to be stored in a very narrow pH range (approximately 7.35 to 7.45). A commonly used buffer for the storage of blood products is sodium dihydrogen phosphate (NaH_2PO_4). Describe how sodium dihydrogen phosphate acts as a buffer, including relevant chemical equations. 3

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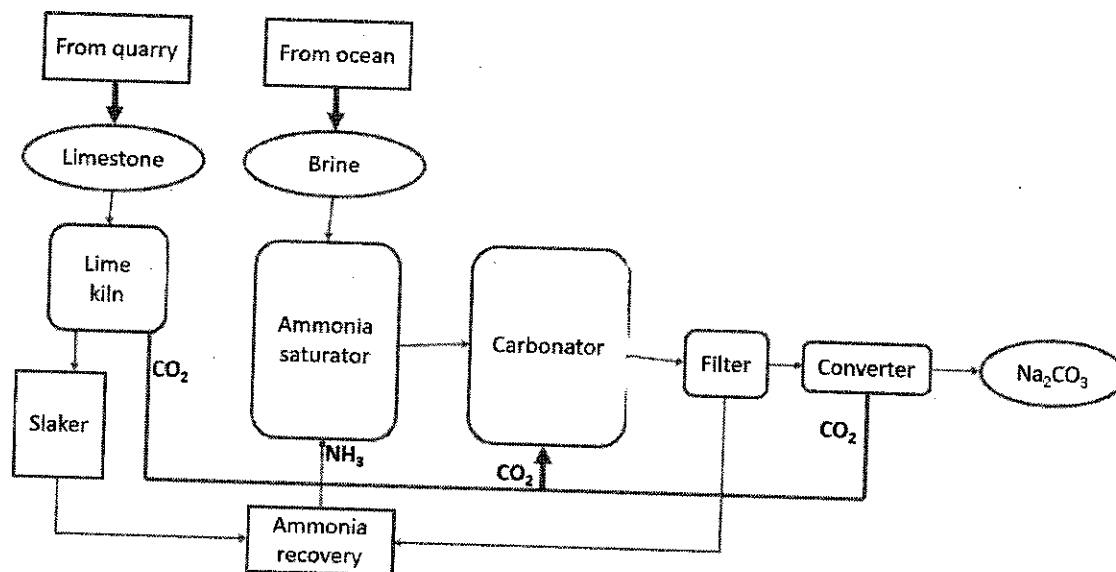
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Question 28 (4 marks)

The Solvay Process is commonly used to make sodium carbonate. The flowchart below summarises the key synthesis stages of some Solvay plants.

4



Using the flowchart, account for THREE factors that would be considered in locating a chemical plant to use the Solvay Process.

Question 29 (4 marks)

A popular brand of vinegar is claimed to contain 5% (v/v) of acetic acid. A student used the following procedure to determine if the company was telling the truth. 4

1. A student pipetted a 25 mL sample of vinegar into a volumetric flask and filled to the mark with distilled water.
2. The student prepared a standard solution of sodium carbonate. They dissolved 2.6 g of anhydrous sodium carbonate in 250 mL of water.
3. The student titrated 27.55 mL of the standardised sodium carbonate solution against 25 mL solution of hydrochloric acid using phenolphthalein, and calculated the concentration of hydrochloric acid.
4. The student used a pipette to deliver 25 mL of the known hydrochloric acid to a clean dry beaker. The acid solution was titrated against a recently prepared solution of sodium hydroxide, which required 35.20 mL of sodium hydroxide using phenolphthalein indicator, and calculated the concentration of sodium hydroxide solution.
5. The sodium hydroxide solution was titrated against the 25 mL of the diluted vinegar sample until the phenolphthalein turned the slightest shade of pink. This step was repeated 4 times and an average was calculated, which was 18.33 mL of sodium hydroxide.
6. The student then calculated the concentration of the acetic acid in the vinegar solution using:

$$c(\text{acid in vinegar}) = \frac{c(\text{NaOH}) \times V(\text{NaOH})}{V(\text{diluted vinegar})}$$

Evaluate this procedure for determining the validity of the company's claim.

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Question 30 (5 marks)

A solution of magnesium chloride has a concentration of $0.0073 \text{ mol L}^{-1}$.
Concentrated sodium hydroxide solution is added (with negligible change in volume).

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Calculate the pH at which this solution will begin to form a precipitate.

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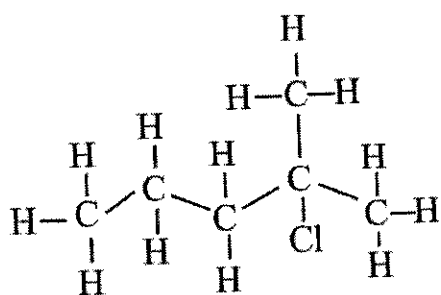
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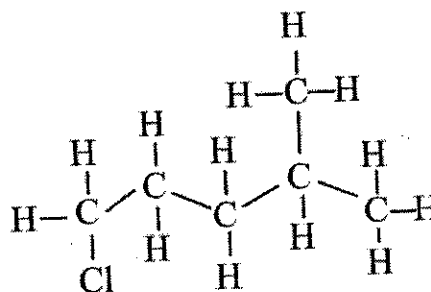
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Question 31 (4 marks)

The structural formulae for two compounds are shown below.



Isomer A



Isomer B

- (a) Account for why these two molecules are considered position isomers? 1

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- (b) 4-Methyl-1-pentene is used to produce two compounds, including Isomer B. 3
However, one of the products is made in a greater amount than the other.

Identify the second reactant, and name and draw the second product in this reaction.
Also identify the major product from this reaction.

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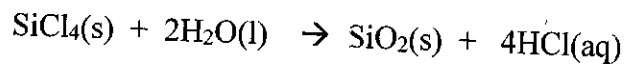
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Question 32 (7 marks)

Silicon tetrachloride reacts with water according to the following equation:

7



A 1.49 g impure sample of silicon tetrachloride was reacted with excess water and the resulting solution was made up to 250.0 mL. A 25.0 mL aliquot of the solution was titrated against 0.15 mol L^{-1} standardised sodium hydroxide and 19.3 mL of this solution was required to neutralise the hydrochloric acid.

What is the percentage purity of the silicon tetrachloride?

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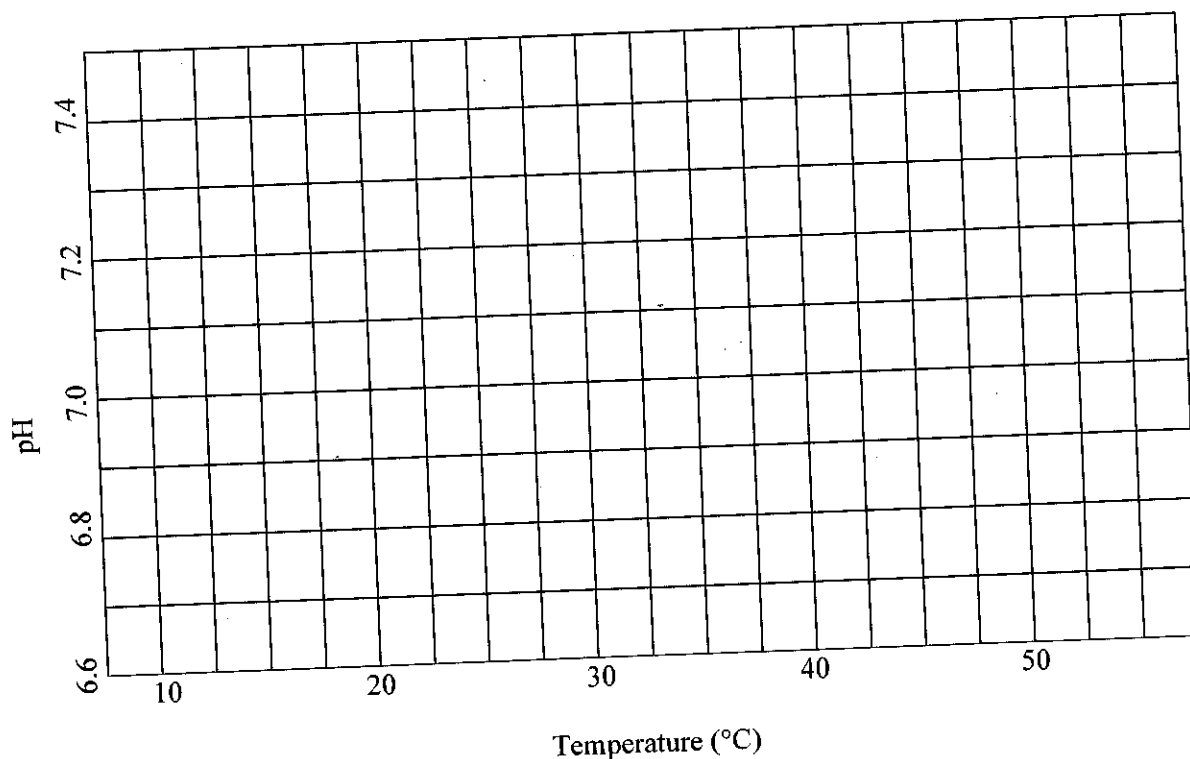
Question 33 (4 marks)

The pH of pure water is known to change with temperature, as shown in the table below.

T(°C)	10	20	30	40	50
pH	7.27	7.08	6.92	6.77	6.63

1

- (a) Plot the data on the grid below, including a line of best fit.



- (b) Using the graph, determine the K_w of a pure water sample at 35°C. Show all working. 3

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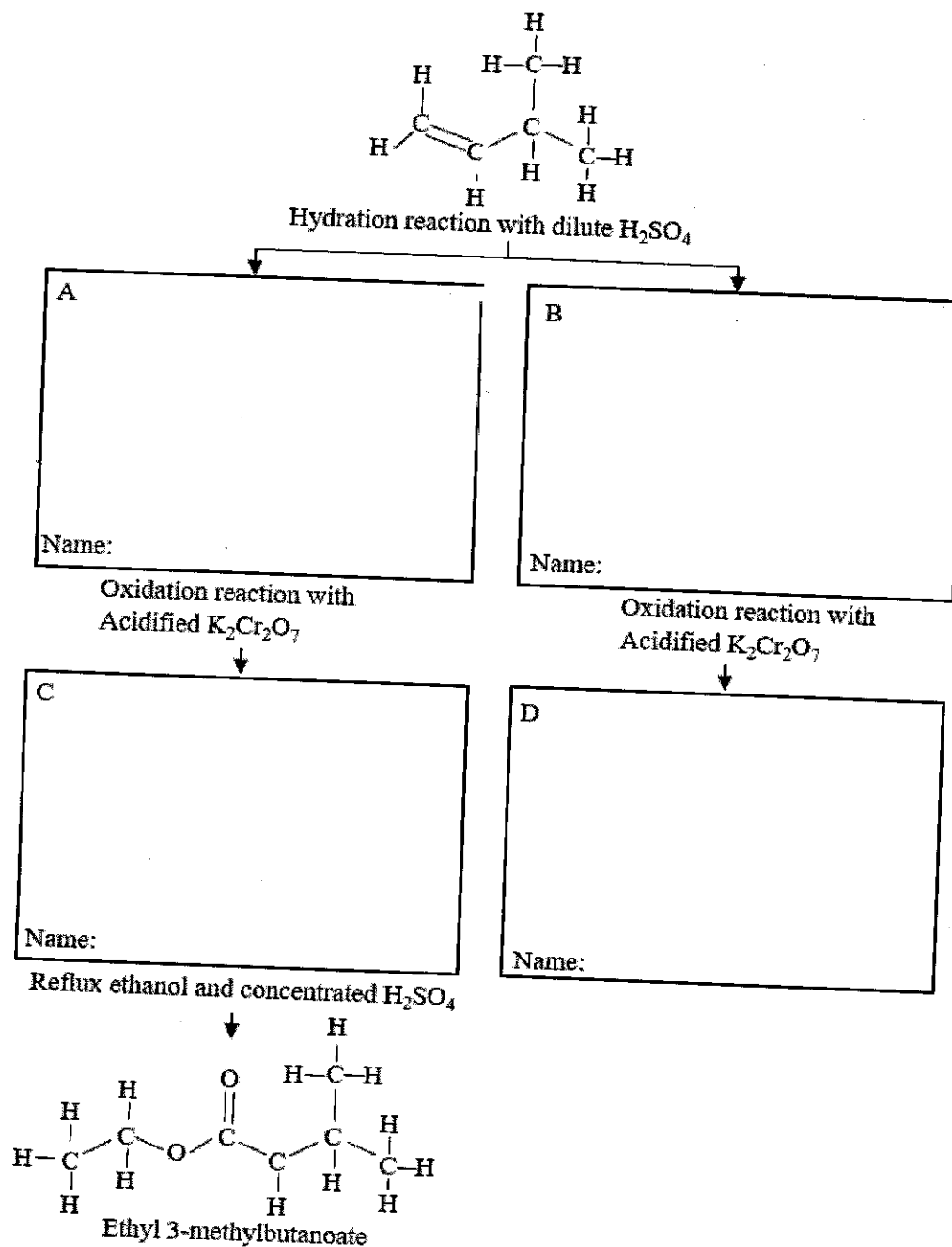
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Question 34 (6 marks)

An organic reaction pathway, starting with 3-methylbut-1-ene, is shown in the flowchart below.

- (a) Complete the flowchart by drawing the structural formulae AND stating the IUPAC names for compounds A, B, C and D.

5



Question 34 continues on page 25

Question 34 (continued)

(b) Provide ONE reason for using a reflux apparatus to synthesise ethyl 3-methylbutanoate. **1**

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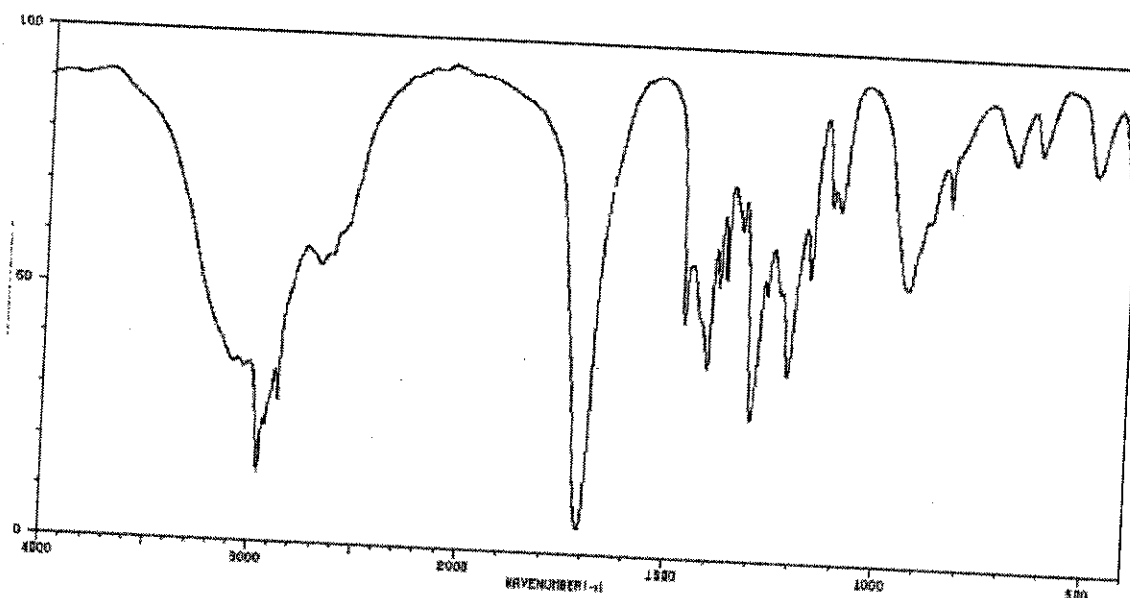
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Question 35 (7 marks)

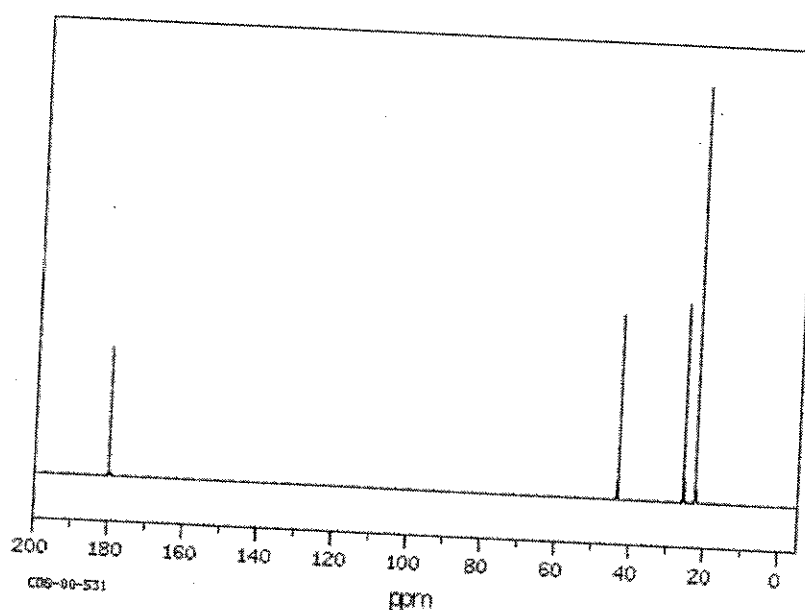
A chemist finds an unlabelled bottle containing a large quantity of organic **Compound Y**, a colourless liquid with the molecular formula $C_5H_{10}O_2$.

To identify the molecular structure of Compound Y, a sample is submitted for spectroscopic analysis. The following data was obtained.

IR Spectrum: AIST:Spectral Database for Organic Compounds, SDBS



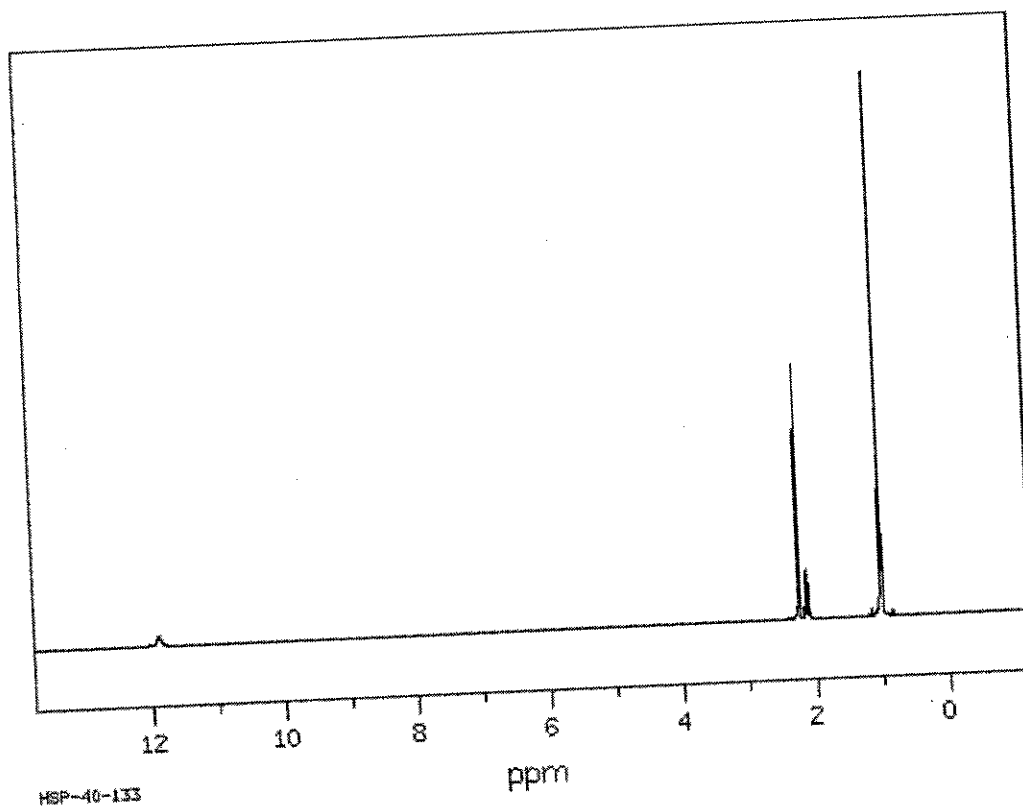
^{13}C NMR: AIST:Spectral Database for Organic Compounds, SDBS



Question 35 continues on page 27

Question 35 (continued)

^1H NMR: AIST:Spectral Database for Organic Compounds, SDBS



Data ^1H NMR		
Chemical Shift (ppm)	Relative Peak Area	Splitting Pattern
11.9	1	Singlet
2.2	2	Doublet
2.1	1	Nonet (9)
0.9	6	Doublet

Question 35 continues on page 28

Question 35 (continued)

Draw below the structural formula of Compound Y. Justify your answer with reference to all THREE of the provided spectra.

7

End of Question 35

Question 36 (6 marks)

Some traditional body paint was found to contain barium nitrate and concerns were raised about the effects of barium on heart rhythm. Once the paint is mixed and applied to the skin, barium ions are almost instantly absorbed through the skin and circulated by the blood. A barium level of 0.125 mg/L (across the volume of the body) is thought to impact the heart.

2

- (a) Calculate the molar solubility of barium ions in a saturated solution.
($K_{sp}(\text{barium nitrate}) = 4.6 \times 10^{-3}$).

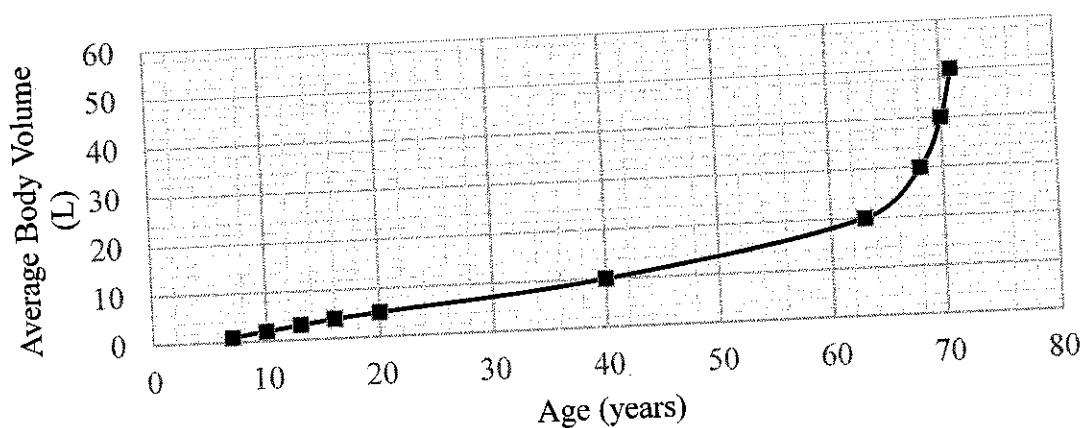
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- (b) Traditionally 10 g of paint is applied to the body each day, with the ceremony lasting 10 days. The traditional paint contains 0.01% by mass of barium nitrate. There are a number of performers, ranging in age from 18 to 80. The average body volume for people of a given age is shown below: 4



Question 36 continues on page 30

Question 36 (continued)

Determine if the use of this traditional body paint over the ceremonial period poses a risk to the health of performers. Assume the performers have the average body volume for their age.

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End of Examination

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Question 9	Structure created by the 2023 CSSA Trial HSC Examination Chemistry Committee using MolView (https://molview.org/).
Question 10	Structure drawn by the 2023 CSSA Trial HSC Examination Chemistry Committee using MolView (https://molview.org/).
Question 11	Graph created by the 2023 CSSA Trial HSC Examination Chemistry Committee based on Wikimedia Commons contributors, 'File:SolubilityVsTemperature.png', <i>Wikimedia Commons, the free media repository</i> , 8 October 2020, 20:11 UTC, < https://commons.wikimedia.org/w/index.php?title=File:SolubilityVsTemperature.png&oldid=484398035 > [Accessed 2 April 2023].
Question 34	Structure created by the 2023 CSSA Trial HSC Examination Chemistry Committee using MolView (https://molview.org/).
Question 35	All spectra come from <i>Aist:spectral database for organic compounds,sdbs</i> n.d.. [Accessed 02 April. 2023]. https://sdbs.db.aist.go.jp/sdbs/cgi-bin/cre_index.cgi .

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Rhys Briscoe-Hough
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Rose Bay

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Chemistry

Section I

20 marks

Questions 1-20 (1 mark each)

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

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Section II

80 marks

Question 21 (4 marks)

Outcomes Assessed: CH11/12-2, CH12-15

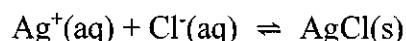
Targeted Performance Bands: 2-4

Criteria	Marks
• Describes chemical tests that clearly identify the THREE separate cations AND includes a correct relevant equation	4
• Describes chemical tests that clearly identify THREE separate cations OR • Describes chemical tests that clearly identify TWO separate cations AND includes a correct relevant equation	3
• Describes chemical tests that clearly identify TWO separate cations	2
• Any relevant information	1

Sample Answer:

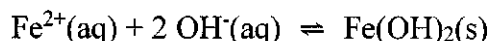
1. Add dilute HCl to a sample of each (or any source of chloride ions like NaCl).

A white precipitate will form indicating the presence of Ag^+ .



2. To the remaining samples, add dilute NH_3 (or any source of dilute hydroxide ions, like NaOH).

A pale green precipitate will form indicating the presence of Fe^{2+} .



3. To confirm the presence of Ca^{2+} , conduct a flame test.

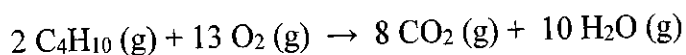
A red flame indicates the presence of Ca^{2+} .

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Question 22 (4 marks)**Question 22 (a) (1 mark)****Outcomes Assessed: CH12-14****Targeted Performance Bands: 3-4**

Criteria	Marks
<ul style="list-style-type: none"> Provides correctly balanced symbol equation 	1

Sample Answer:**Question 22 (b) (3 marks)****Outcomes Assessed: CH12-14, CH11/12-6****Targeted Performance Bands: 3-5**

Criteria	Marks
<ul style="list-style-type: none"> Correctly calculates the mass of butane used 	3
<ul style="list-style-type: none"> Provides some correct calculations 	2
<ul style="list-style-type: none"> Provides some relevant understanding 	1

Sample Answer:

$$q = m \times c \times \Delta T$$

$$q = 500 \text{ ml} \times 4.18 \times 80$$

$$q = 167200 \text{ J}$$

$$q = 167.2 \text{ kJ}$$

$$\Delta H_c = q/n$$

$$n = q/\Delta H_c$$

$$n = 167.2/2.88 \times 10^3 \text{ kJ/mol}$$

$$n = 0.0581 \text{ mol}$$

$$m (\text{butane}) = n \times \text{MM}$$

$$m (\text{butane}) = 0.0581 \times 58.12 \text{ g/mol}$$

$$m = 3.37 \text{ g}$$

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Question 23 (5 marks)**Question 23 (a) (2 marks)****Outcomes Assessed: CH11/12-6, CH12-12****Targeted Performance Bands: 3-4**

Criteria	Marks
• Writes a correct equilibrium expression and correctly substitutes the concentrations	2
• Writes a correct equilibrium expression OR correctly calculates the concentrations	1

Sample Answer:

	NO ₂ (g)	+	CINO(g)	⇌	CINO ₂ (g)	+	NO(g)
R	1		1		1		1
I	2.4		4.0		0		0
C	-0.15		-0.15		+0.15		+0.15
E	2.25		3.85		0.15		0.15
[] (V=5 L)	0.45		0.77		0.03		0.03

$$K = [\text{CINO}_2] \times [\text{NO}] / ([\text{NO}_2] \times [\text{CINO}]) = (0.03 \times 0.03) / (0.45 \times 0.77) = 2.6 \times 10^{-3}$$

Question 23 (b) (3 marks)**Outcomes Assessed: CH12-12****Targeted Performance Bands: 2-5**

Criteria	Marks
• Explains how both kinetics AND equilibrium could be controlled to maximise yield	3
• Describes features of kinetics and/or equilibrium for controlling yield	2
• Identifies a relevant feature of kinetics or equilibrium	1

Sample Answer:

An increase in pressure causes more favourable collisions, but both sides have equal moles of gases, so there is no effect on the equilibrium position. So, a higher (safe) pressure would be preferred.

An increase in temperature will add kinetic energy to the systems increase the number of collisions, however, the endothermic reaction is favoured as temp increases, so a decrease will favour the products. So, a moderate temperature is preferred.

A catalyst creates an alternate reaction pathway with lower energy which will make the reaction reach equilibrium faster, countering a lower than ideal temperature for kinetics.

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Question 24 (5 marks)**Question 24 (a) (1 mark)****Outcomes Assessed: CH12-14****Targeted Performance Bands: 3-4**

Criteria	Marks
<ul style="list-style-type: none"> Correctly orders molecules from lowest to highest boiling point 	1

Sample Answer:**Lowest - butane -propanal - ethanamide - highest****Question 24 (b) (4 marks)****Outcomes Assessed: CH12-14****Targeted Performance Bands: 3-5**

Criteria	Marks
<ul style="list-style-type: none"> Correctly identifies the different types of intermolecular bonding AND Correctly links strength of bond to the boiling point 	4
<ul style="list-style-type: none"> Correctly identifies some of the different types of intermolecular bonding OR Correctly links strength of bond to the boiling point 	2-3
<ul style="list-style-type: none"> Any relevant information 	1

Sample Answer:

- Butane has the lowest boiling point as the only forces present are weak dispersion forces. Less energy is needed to break these bonds between molecules thus a lower boiling point.
- Propanal also has dispersion forces but additionally contains polar bonds (C=O) and can therefore form dipole-dipole forces with other molecules. These attractions are stronger and therefore require more energy to overcome, hence a higher boiling point.
- Ethanamide has the highest boiling point as it is able to form strong hydrogen bonds with other molecules (NH--OC), as well as dispersion and dipole-dipole forces. These require more energy to break and therefore result in a high boiling point.

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Question 25 (6 marks)**Outcomes Assessed: CH12-14****Targeted Performance Bands: 2-6**

Criteria	Marks
<ul style="list-style-type: none"> Shows a comprehensive understanding of the environmental, social and economic impacts of fossil fuels and biofuels Outlines positive and negative aspects of both fuels Makes an informed judgement Includes a relevant chemical equation 	6
<ul style="list-style-type: none"> Shows a detailed understanding of the environmental, social and economic impacts of fossil fuels and biofuels Outlines positive and negative aspects of both fuels AND Makes an informed judgement OR Includes a relevant chemical equation 	4-5
<ul style="list-style-type: none"> Describes positive features of either fuel OR Describes negative features of either fuel OR Describes some environmental, social and economic impacts of fossil fuels and biofuels 	2-3
<ul style="list-style-type: none"> Provides any relevant information 	1

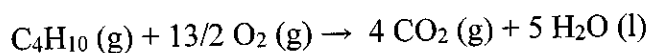
Sample Answer:**Fossil Fuels**

- Used for fuels – such as natural gas for cooking, crude oil for petrol, diesel and aviation fuel, and coal for electrical power stations. Our society derives most its domestic and industrial energy needs from these fossil fuels.
- Used as a starting material for other organics, such as ethanol and polymers. Our society and economics have a huge reliance on fossil fuels for a breadth of consumer products. Fossil fuels remain the dominant supplier of starting ingredients for these compounds.
- High energy content compared to other sources so more cost efficient compared to other fuel sources.
- Limited reserves resulting in high prices, leading to negative effects on members of society, such as inequity between social classes based on income.
- Combustion of fossil fuels releases carbon dioxide which contributes heavily to global warming and the effects of climate change. Governments are beginning to acknowledge the massive impact this could have on the environment and society for generations to come.
- Extraction process is harmful to the environment - mining/oil spills etc.

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As an example, the complete combustion of butane produces carbon dioxide, a greenhouse gas:



Biofuels

- Widespread, but limited, use as a petrol extender. The cost of producing usable quantities of biofuels has been relatively high and not competitive with fossil fuel production, thereby requiring significant government investment (potentially at the expense of alternative projects for society).
- Renewable resource but land space is needed to grow crops, therefore land needs to be cleared and possibly at the expense of food crops for a growing population.
- Can be made from waste products and therefore reduces waste, which is beneficial to the economy, the environment and society in general.
- Carbon dioxide production is partially offset by growing crops. While not completely carbon-neutral (due to energy requirements for harvesting and processing), it does minimise the impact on the atmosphere as a cyclic process.
- Lower energy content than petrol, more needs to be combusted to release the same amount. This leads to higher fuel costs for families and/or greater investment by governments.

Judgement: Considering the non-renewable nature of fossil fuels, coupled with the harsh environmental impacts, biofuels offer a sustainable alternative with reduced environmental impacts. More investment is needed to promote the use of biofuels in society.

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Question 26 (6 marks)

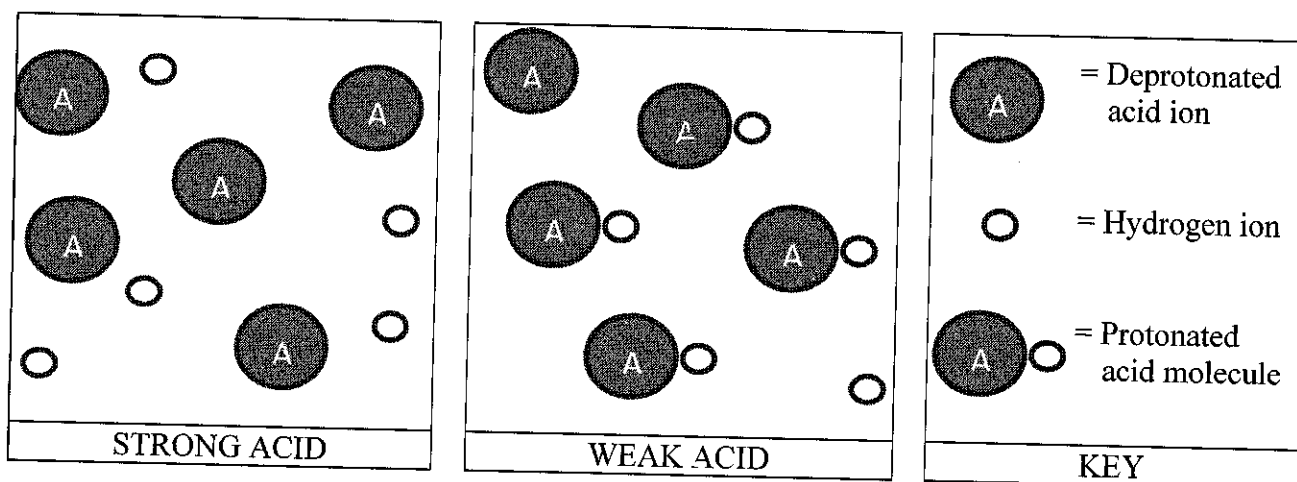
Question 26 (a) (3 marks)

Outcomes Assessed: CH12-13

Targeted Performance Bands: 2-4

Criteria	Marks
• Draws a clear diagram or clearly describes a model, which demonstrates a clear difference between the ionisation of strong and weak acids, including labelling	3
• Draws a diagram or describes a model, which demonstrates some difference between the ionisation of strong and weak acids	2
• Provides some relevant information	1

Sample Answer:



An alternative answer could show dance partners in a dance hall– strong acids have decoupled dancers (like the start of a primary school dance!), while weak acids are like a dance floor with most couples together.

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Question 26 (b) (3 marks)**Outcomes Assessed: CH11/12-6, CH12-13****Targeted Performance Bands: 3-6**

Criteria	Marks
• Explains all THREE colours correctly for the salt solutions, with appropriate equations	3
• Describes at least TWO colours correctly for the salt solutions, with ONE appropriate equation	2
• Identifies ONE correct colour OR writes a correct equation	1

Sample Answer:

- NH_4Cl is the product of the neutralisation of a strong acid (HCl) and a weak base (NH_3), so it will be an acidic salt. Hence the colour would red/orange. NH_4^+ is the conjugate acid of a weak base, so will predominantly form ammonia and the hydronium ion, which will cause the solution to be acidic.
$$\text{NH}_4^+(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{NH}_3(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$$
- NaCl is the product of the neutralisation of a strong acid (HCl) and a strong base (NaOH), so it will be a neutral salt solution, and so it would be green.
- $$\text{NaOH}(\text{aq}) + \text{HCl}(\text{aq}) \rightarrow \text{NaCl}(\text{aq}) + \text{H}_2\text{O}(\text{l})$$
- NaF is the product of the neutralisation of a weak acid (HF) and a strong base (NaOH), so it will be a basic salt solution. Hence the colour would be dark green/purple. The F^- is the conjugate of a weak acid and therefore will react with water to form OH^- , which will cause the solution to be basic:
$$\text{F}^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{HF}(\text{aq}) + \text{OH}^-(\text{aq})$$

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Question 27 (3 marks)**Outcomes Assessed: CH12-13****Targeted Performance Bands: 3-5**

Criteria	Marks
<ul style="list-style-type: none">Provides a clear definition of a buffer ANDProvides TWO correct chemical equations	3
<ul style="list-style-type: none">Provides a clear definition of a buffer AND ONE correct chemical equation ORProvides TWO correct chemical equations	2
<ul style="list-style-type: none">Provides some relevant information	1

Sample Answer:

- The pH of a buffer resists small additions of acids or bases. H_2PO_4^- is amphiprotic, so can gain or lose protons to form conjugate acids and bases.
- If a small amount of acid is added, the H_2PO_4^- ion can react with the additional acid to form phosphoric acid, thus partially removing some of the additional hydronium ions and minimising the pH change:
$$\text{H}_2\text{PO}_4^-(\text{aq}) + \text{H}_3\text{O}^+(\text{aq}) \rightleftharpoons \text{H}_3\text{PO}_4(\text{aq}) + \text{H}_2\text{O}(\text{l})$$
- If a small amount of base is added, the H_2PO_4^- ion can react with the additional hydroxide ions to form HPO_4^{2-} ions, thus partially removing some of the hydroxide ions and minimising the pH change:
$$\text{H}_2\text{PO}_4^-(\text{aq}) + \text{OH}^-(\text{aq}) \rightleftharpoons \text{HPO}_4^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l})$$
- Hence, the addition of small amounts of acid or base result in only very small changes in blood pH.

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Question 28 (4 marks)**Outcomes Assessed: CH11/12-5, CH11/12-6, CH12-15****Targeted Performance Bands: 3-6**

Criteria	Marks
<ul style="list-style-type: none"> Accounts for THREE relevant factors Makes specific reference to the flow chart 	4
<ul style="list-style-type: none"> Accounts for TWO relevant factors with some reference to the flow chart OR Accounts for THREE relevant factors without specific reference to the flow chart 	3
<ul style="list-style-type: none"> Accounts for ONE relevant factor OR Outlines TWO relevant factors 	2
<ul style="list-style-type: none"> Any relevant information 	1

Sample Answer:

Students could choose three factors from any of the factors below (anything reasonable based on the process):

- Access to raw materials needs to be considered. The plant would be located near the ocean so that brine would be easily accessible.
- Also, it would be preferable that the plant would be located near a limestone quarry with a road/rail network to get the limestone.
- Markets need to be accessed for sodium carbonate. This means that the product can be sold to suppliers ensuring the process is economically viable. So, the plant would need to be located near a port and/or road and rail networks, to meet supply needs.
- While ammonia is recovered during the process, so it can then be reused, it will still be needed, so access to ports will be necessary (or access to a Haber plant?).
- The plant will need energy/electricity to run, so will need to be located to have reliable access to energy (renewable energy would be good – solar, wind and/or tidal).
- Pollution needs to be considered. Ammonia is a smelly, poisonous gas, and if it escaped it could cause respiratory problems for people. So, you want the plant away from residential areas if possible (but not so far that it is hard for workers to commute to the plant).

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Question 29 (4 marks)**Outcomes Assessed:** CH11/12-2, CH12-15**Targeted Performance Bands:** 3-6

Criteria	Marks
• Evaluates at least FOUR steps, including explaining at least THREE errors	4
• Evaluates at least THREE steps, including describing at least TWO errors	3
• Evaluates at least TWO steps, including identifying at least ONE error	2
• Provides some relevant information	1

Sample Answer:

Step 1: Good step. The reason for the dilution to make the concentration required for neutralisation less, for a more workable volume.

Step 2: A standard solution is accepted way to determine the concentration of an acid, as you know the exact concentration of the sodium carbonate, because it has been made by the company. **BUT** should have specified the distilled water as the ions in the normal tap water may cause other reaction and also impact concentration, as there is no control over the ions present in the water, there may be carbonate ions present in the water, which will impact concentration; **AND** there is no mention of the glassware needed for this step (presumably a volumetric flask).

Step 3: The student describes a typical titration, which is the next reasonable step **BUT** does not explicitly include a burette in the method **AND** they have not chosen an appropriate indicator for this type of titration (weak base/strong acid).

Step 4: Because the student is determining unknown acetic acid, it is reasonable to prepare a primary standard for an acid, then to standardise a base (NaOH). NaOH cannot be used as a primary standard for a number of reasons, such as being hygroscopic. **HOWEVER**, some might expect the titration to take place in a conical flask.

Step 5: Due to the addition of a base the pH will rise and phenolphthalein changes to pink around pH10 and is a reasonable indicator. This step is repeated to find an average which increases the reliability of the experiment.

Step 6. A calculation is needed **BUT** this step doesn't mention that the final value needed to be multiplied by 10, due to the 1 in 10 dilution of the original vinegar solution. **ALSO**, this calculation will give you a concentration in mol/L and needs to be converted to compare with the original units of 5% (v/v).

Students may suggest using a different primary standard, such as oxalic acid or potassium hydrogen phthalate, to standardise the sodium hydroxide, thereby skipping a couple of steps (and potential errors). This is a valid and beneficial alternative to the given procedure and so, holistically, depending on the depth of the explanation, could be worth higher than one mark.

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Question 30 (5 marks)**Outcomes Assessed: CH11/12-5, CH12-12****Targeted Performance Bands: 3-6**

Criteria	Marks
• Correctly calculates the pH, with working	5
• Calculates the pH, with ONE error	4
• Correctly shows some steps in the calculation	2-3
• Identifies a correct step	1

Sample Answer:

$$K_{sp} = [\text{Mg}^{2+}][\text{OH}^-]^2$$

$$\text{Let } [\text{OH}^-] = S$$

$$5.61 \times 10^{-12} = 0.0073 \times S^2$$

$$S^2 = \frac{5.61 \times 10^{-12}}{0.0073}$$

$$0.0073$$

$$S = \sqrt{7.68493 \times 10^{-10}}$$

$$S = 2.7717 \times 10^{-5}$$

$$\text{pOH} = -\log[2.7717 \times 10^{-5}] = 4.55716$$

$$\text{pH} = 14 - 4.55716$$

$$\text{pH} = 9.44$$

Solution will start to precipitate at pH 9.44

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Question 31 (4 marks)**Question 31 (a) (1 mark)****Outcomes Assessed: CH12-14****Targeted Performance Bands: 3-4**

Criteria	Marks
<ul style="list-style-type: none"> Correctly explains why the molecules are position isomers 	1

Sample Answer:

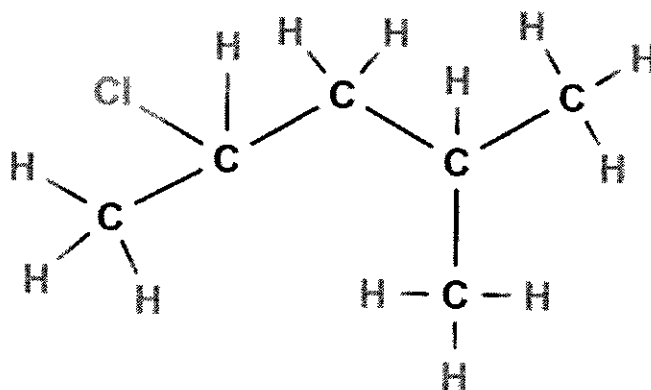
Isomer A and B have the same molecular formula and the same functional group. The functional group is located on a different carbon atom.

Question 31 (b) (3 marks)**Outcomes Assessed: CH12-14, CH11/12-6****Targeted Performance Bands: 3-6**

Criteria	Marks
<ul style="list-style-type: none"> Identify the second reactant Draw the second product Name the second product Identify the major product 	3
<ul style="list-style-type: none"> Any TWO of the above 	2
<ul style="list-style-type: none"> Identifies a second reactant OR product 	1

Sample Answer:

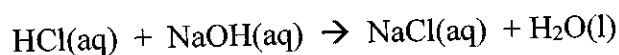
The alkene needs to be reacted with **HCl**. From this reaction, Isomer B will be produced. The other product, and **major product** will be **2-chloro-4-methylpentane** (due to Markovnikov's Rule – but explanation is not required):

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Question 32 (7 marks)**Outcomes Assessed: CH11/12-5, CH11/12-6, CH12-13****Targeted Performance Bands: 2-6**

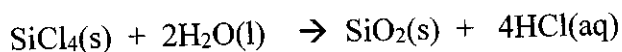
Criteria	Marks
<ul style="list-style-type: none"> Fully correct answer with <ul style="list-style-type: none"> writes equation, with states for HCl + NaOH calculates moles NaOH shows ratio of HCl:NaOH moles of SiCl₄ mass of SiCl₄ % purity of SiCl₄ Correct significant figures 	7
<ul style="list-style-type: none"> Answer has major steps with some errors 	4-6
<ul style="list-style-type: none"> Answer contains ONE or TWO valid steps 	2-3
<ul style="list-style-type: none"> Contains some relevant information 	1

Sample Answer:

$$n(\text{NaOH}) = 0.15 \times 0.0193 = 0.002895 \text{ mol NaOH}$$

From the equation, $n(\text{NaOH}):n(\text{HCl}) = 1:1$, therefore 0.002895 mol HCl

25 mL aliquot taken from 250 mL, therefore (x10) 0.02895 mol HCl



From the equation, $n(\text{SiCl}_4) = \frac{1}{4} \times n(\text{HCl})$

$$n(\text{SiCl}_4) = 0.02895/4 = 0.0072375 \text{ mol}$$

$$m = n \times \text{MM}$$

$$0.0072375 \times 169.89 = 1.2296 \text{ g SiCl}_4 \text{ in sample}$$

$$\% \text{ purity} = 1.2296/1.49 \times 100 = 82.522\% = 83\% \text{ pure SiCl}_4 \text{ in sample (2sf)}$$

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Question 33 (4 marks)

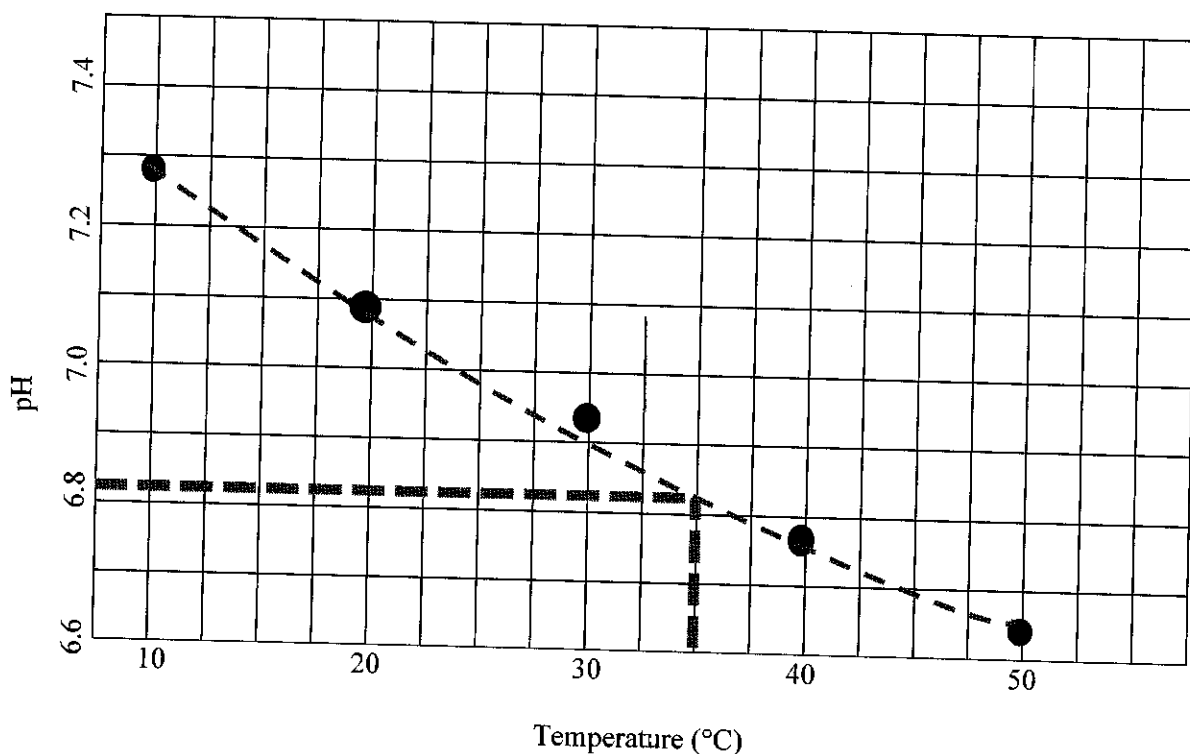
Question 33 (a) (1 mark)

Outcomes Assessed: CH11/12-4

Targeted Performance Bands: 2-3

Criteria	Marks
<ul style="list-style-type: none"> Correctly plots all points and includes a reasonable line of best fit (straight or slightly curved) 	1

Sample Answer:



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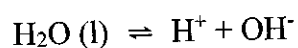
Question 33 (b) (3 marks)**Outcomes Assessed: CH11/12-5, CH12-12****Targeted Performance Bands: 3-6**

Criteria	Marks
<ul style="list-style-type: none">• Uses graph to approximate pH• Determines $[H^+]$ using $pH = \log[H^+]$• Determines $[OH^-]$ using $[H^+]$• Correctly calculates K_w	3
<ul style="list-style-type: none">• Correctly completes at least TWO steps in the calculation	2
<ul style="list-style-type: none">• Identifies any relevant information	1

Sample Answer:

From the graph, $pH = 6.82 \pm 0.02$ (depends on their graph).

$$[H^+] = 10^{-pH} = 10^{-6.82}$$



$$\text{So } [OH^-] = [H^+] = 10^{-6.82}$$

$$K_w = [H^+] \times [OH^-] = 10^{-6.82} \times 10^{-6.82} = 10^{-13.64} = 2.3 \times 10^{-14}$$

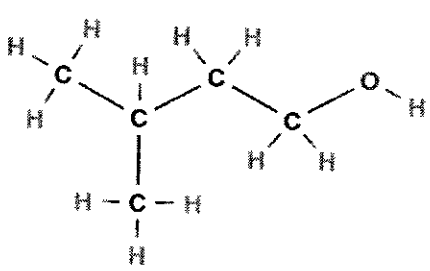
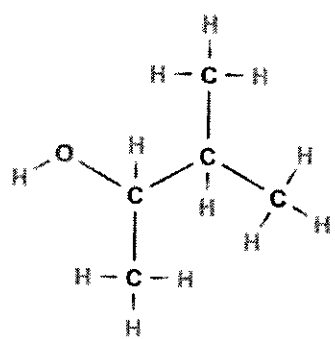
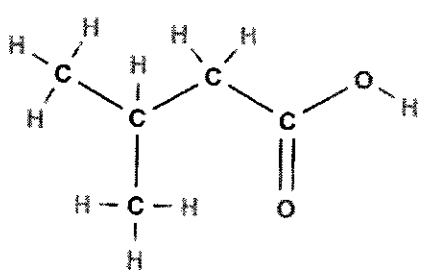
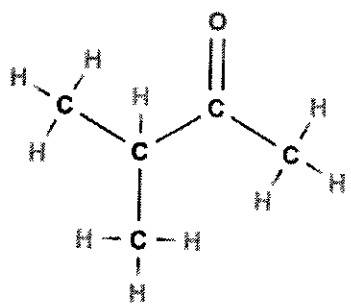
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Question 34 (6 marks)**Question 34 (a) (5 marks)****Outcomes Assessed:** CH11/12-6, CH12-14, CH12-15**Targeted Performance Bands:** 2-6

Criteria	Marks
• Correctly draws AND names all FOUR organic molecules	5
• Correctly draws AND names some of the four molecules	3-4
• Correctly draws OR names some of the four molecules	2
• Correctly draws OR names ONE of the four molecules	1

Sample Answer:

 <p>A - 3-methylbutan-1-ol</p>	 <p>B - 3-methylbutan-2-ol</p>
 <p>C - 3-methylbutanoic acid</p>	 <p>D - 3-methylbutan-2-one</p>

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Question 34 (b) (1 mark)

Outcomes Assessed: CH11/12-2, CH12-14

Targeted Performance Bands: 3-4

Criteria	Marks
• Correctly provides ONE reason for using a reflux apparatus	1

Sample Answer:

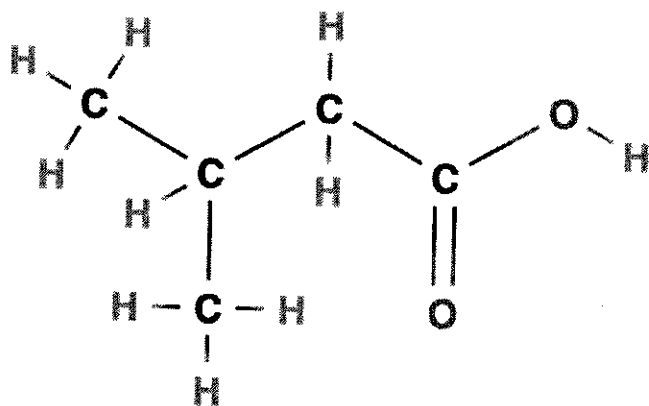
The condenser on the reflux apparatus allows for volatile products and reactants to remain in liquid form to react. Reflux allows the reaction to occur under high heat, which speeds up the reaction.

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Question 35 (7 marks)**Outcomes Assessed:** CH11/12-5, CH11/12-6, CH12-14, CH12-15**Targeted Performance Bands:** 2-6

Criteria	Marks
<ul style="list-style-type: none">• Draws correct structure of 3-methylbutanoic acid• Justifies the correct structure showing an extensive understanding of the interpretation of spectroscopic data• References the relevant spectroscopic data	7
<ul style="list-style-type: none">• Draws correct structure for 3-methylbutanoic acid• Justifies the structure showing a thorough understanding of the interpretation of spectroscopic data• References spectroscopic data	6
<ul style="list-style-type: none">• Shows a sound understanding of the interpretation of spectroscopic data• Uses relevant information presented in the question to justify the structure of the compound• Provides a structural formula consistent with the analysis	4-5
<ul style="list-style-type: none">• Demonstrates some understanding of the interpretation of spectroscopic data	2-3
<ul style="list-style-type: none">• Provides any relevant information	1

Sample Answer:**Infra-red**O-H (broad) peak at $2500-3000\text{cm}^{-1}$ consistent with carboxylic acidC=O peak at $1680-1750\text{cm}^{-1}$ consistent with carboxylic acid**Disclaimer**

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¹³C-NMR

4 peaks = 4 carbon environments, however 5 carbons in molecular formula, suggesting symmetrical carbon environments for two carbons.

Peak at 180ppm is consistent with acids.

¹H-NMR

4 peaks = 4 hydrogen environments

A singlet (OH) – peak area and splitting are consistent with an isolated hydrogen atom on an oxygen.

A doublet (CH₂) – peak area is consistent with a CH₂ group, with splitting consistent with having a neighbouring carbon with one hydrogen atom.

A nonet (CH) – peak area is consistent with a CH group, with splitting consistent with having neighbouring carbons with 8 hydrogen atoms in total (2xCH₃ + CH₂)

A doublet (2xCH₃) – peak area is consistent with two CH₃ groups attached to the same carbon, which has a single hydrogen atom, which is consistent with the splitting.

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Question 36 (6 marks)**Question 36 (a) (2 marks)****Outcomes Assessed:** CH11/12-5, CH12-12**Targeted Performance Bands:** 3-5

Criteria	Marks
• Correctly calculates the concentration	2
• Provides some relevant information	1

Sample Answer:

$$K_{sp} = [\text{Ba}^{2+}][\text{NO}_3^-]^2 = 4.6 \times 10^{-3}$$

$$\text{Let } [\text{Ba}^{2+}] = x; \text{ therefore } [\text{NO}_3^-] = 2x$$

$$[x][2x]^2 = 4x^3 = 4.6 \times 10^{-3}$$

$$x = 0.1048 \text{ mol/L}$$

Question 36 (b) (4 marks)**Outcomes Assessed:** CH11/12-5, CH11/12-6, CH12-12**Targeted Performance Bands:** 2-6

Criteria	Marks
• Determines the correct age range for people affected by the barium	4
• Completes most of the main steps	3
• Completes ONE relevant calculation	2
• Provides some relevant information	1

Sample Answer:

$$\text{Mass of Ba(NO}_3)_2 \text{ in the paint} = (10 \times 10) \times (0.01/100) = 0.01 \text{ g}$$

$$m(\text{Ba}^{2+}) = 0.01 \times (137.3/261.32) = 0.00525 \text{ g} = 5.25 \text{ mg}$$

Divide by the minimum value (0.125 mg/L) to determine the critical body volume:

$$\text{Critical volume to impact heart is } 5.25/0.125 = 42 \text{ L}$$

People with a body mass less than 42 litres would suffer some effects of barium poisoning, that is, an average person under about 71 years of age.

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