CSSA

2023

TRIAL HIGHER SCHOOL CERTIFICATE EXAMINATION

DO NOT REMOVE PAPER FROM EXAMINATION ROOM

Centre Number

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)

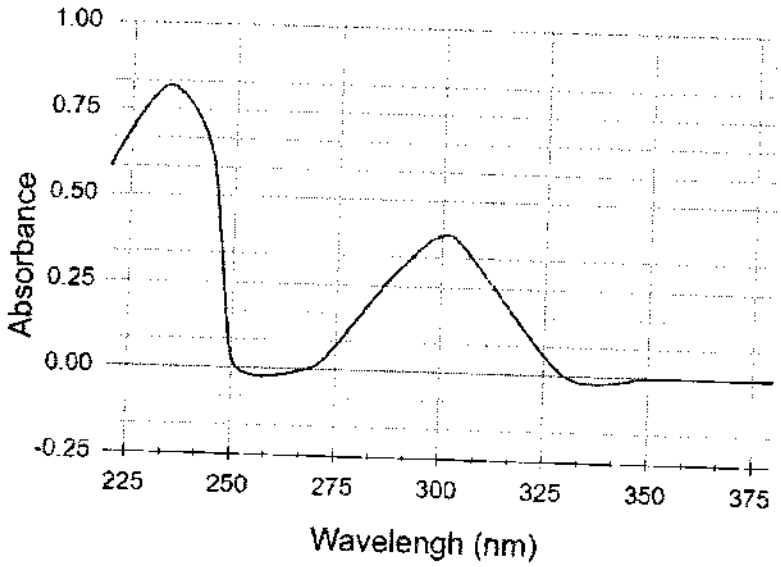
- Attempt Questions 21–36
- Allow about 2 hours and 25 minutes for this section

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. CH_3CO_2H

B. H_2O

C. $(CH_3)_3N$

D. NH_4^+

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

A. 2

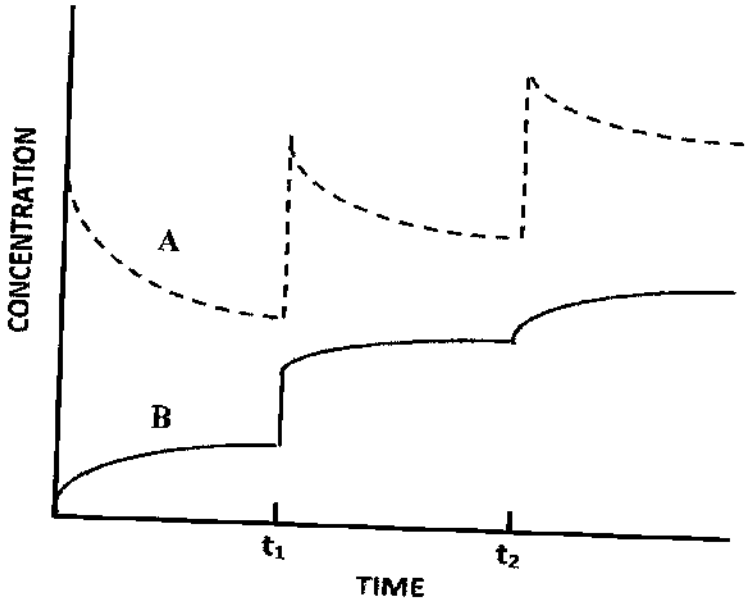
B. 3

C. 4

D. 5

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

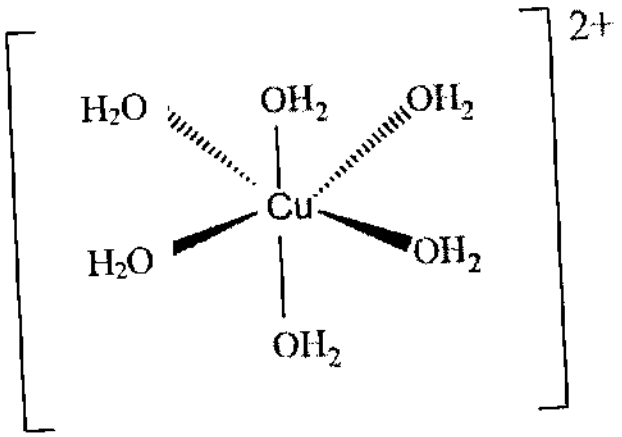
$$2A(g) \rightleftharpoons B(g)$$



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?



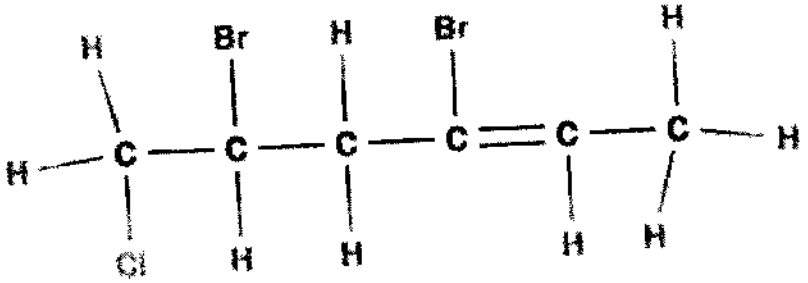
A. Cu^{2+}

B. H_2O

C. OH^-

D. $Cu(OH)_2$

9 What is the IUPAC name for the compound below?



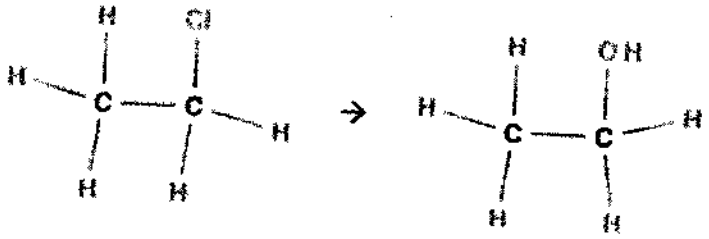
A. 1-chloro-2,4-dibromohex-4-ene

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?



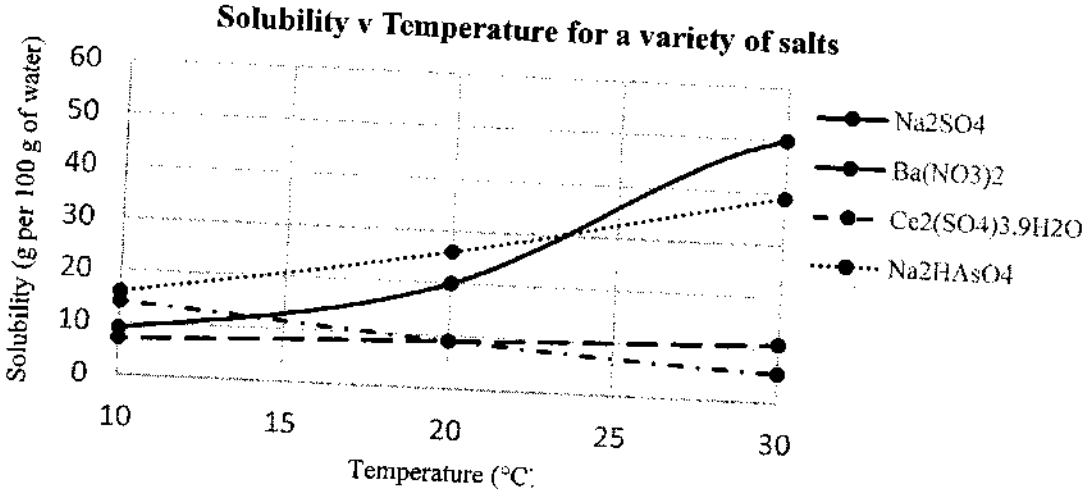
A. Addition reaction

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}), $Ba(NO_3)_2$ (MM = 261.3 g mol^{-1}), $Ce_2(SO_4)_3.9H_2O$ (MM = 730.6 g mol^{-1}) and Na_2HAsO_4 (MM = 185.9 g mol^{-1}). The solubility of these salts is shown below.

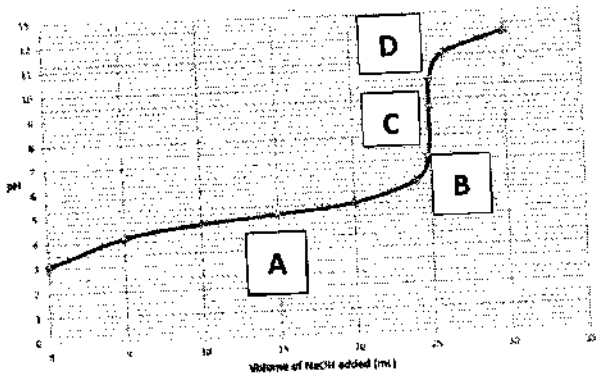


The student set up four beakers with 100 g of water at 20°C. To each beaker they added 0.1 moles of two different salts and stirred (assume no temperature change).

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	$Ce_2(SO_4)_3.9H_2O$
B.	Na_2SO_4	Na_2HAsO_4
C.	$Ba(NO_3)_2$	$Ce_2(SO_4)_3.9H_2O$
D.	$Ba(NO_3)_2$	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 $Ba(OH)_2$.

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?

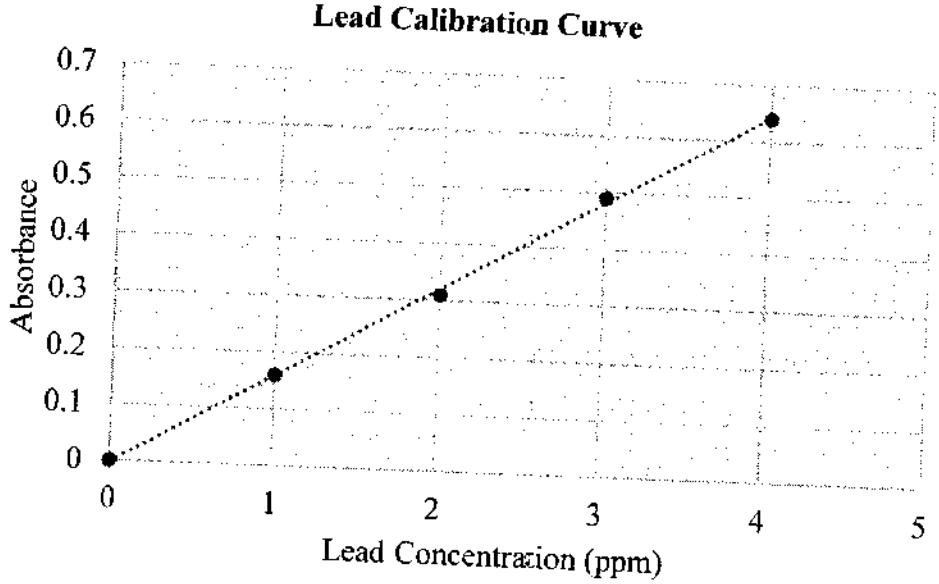
A. Methanal

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 $NH_2COCH_2CH_2CH_2COOH$ (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 g mol^{-1}

B. 230 000 g mol^{-1}

C. 262 000 g mol^{-1}

D. 298 000 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 $Ca(OH)_2$ 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 $Ca(OH)_2$ 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?

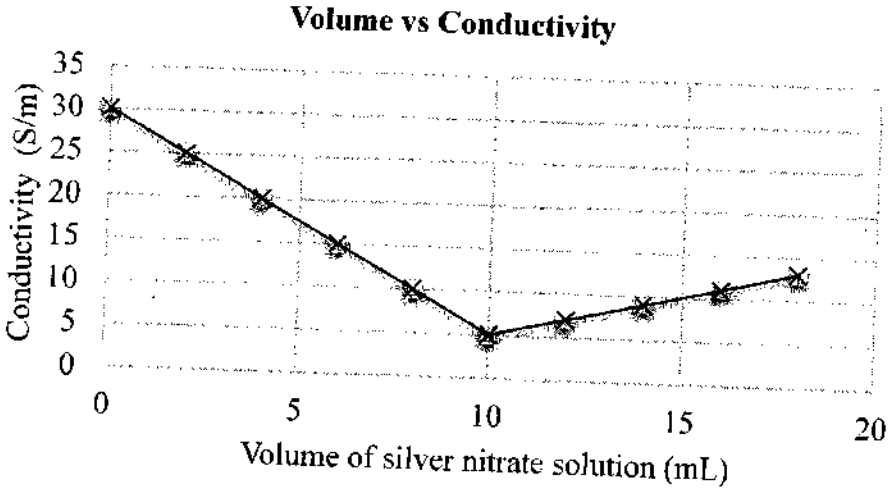
A. $\Delta T_1 > \Delta T_2$

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:

$3Ca(NO_3)_2\ (aq) + 2Li_3PO_4\ (aq) \rightarrow Ca_3(PO_4)_2\ (s) + 6LiNO_3\ (aq)$

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

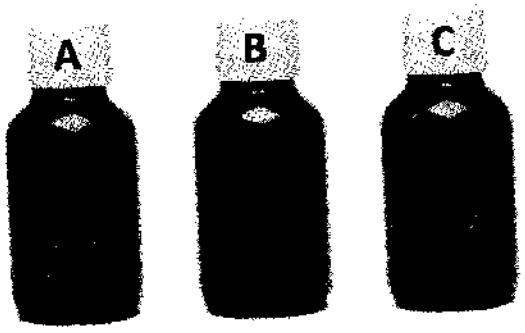
Section II

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. **1**

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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.

$NO_2(g) + ClNO(g) \rightleftharpoons ClNO_2(g) + NO(g)$. $\Delta H = -55\ kJmol^{-1}$

(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 NO_2. At equilibrium, there were 0.15 moles of nitrogen monoxide present. **2**

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 ($ClNO_2$). **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 ($gmol^{-1}$)**
Butane	58.12
Ethanamide	59.07
Propanal	58.08

(a) Order the above molecules from lowest to highest boiling point. **1**

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(b) Account for the differences in boiling point between the THREE molecules. **4**

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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.

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. 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. **3**

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

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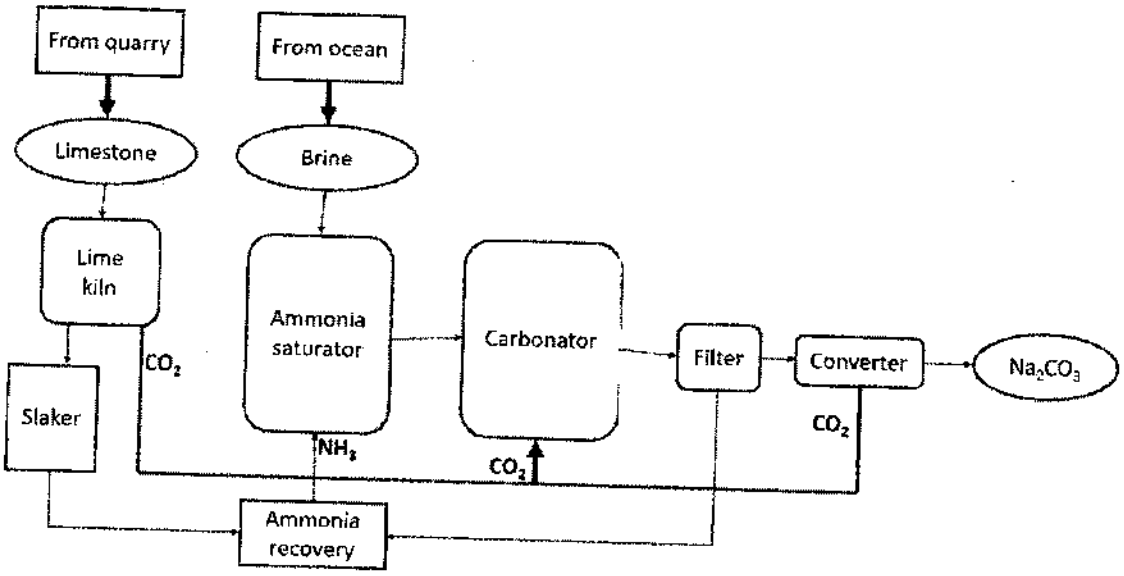
Question 27 (3 marks)

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**

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.

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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:
   $c(acid\ in\ vinegar) = \frac{c(NaOH) x\ V(NaOH)}{V(diluted\ vinegar)}$.

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

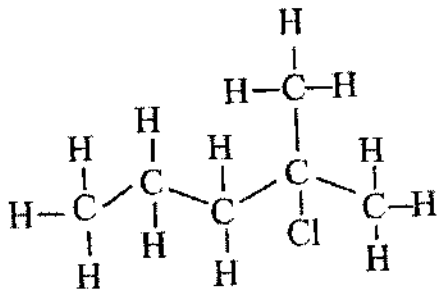
Question 30 (5 marks)

A solution of magnesium chloride has a concentration of 0.0073 mol L^{-1}. **5**
Concentrated sodium hydroxide solution is added (with negligible change in volume).

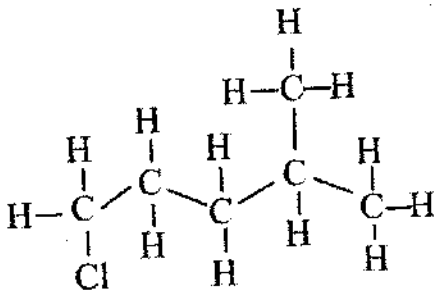
Calculate the pH at which this solution will begin to form a precipitate.

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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Question 32 (7 marks)

Silicon tetrachloride reacts with water according to the following equation: 7

$$SiCl_4(s) + 2H_2O(l) \rightarrow SiO_2(s) + 4HCl(aq)$$

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.

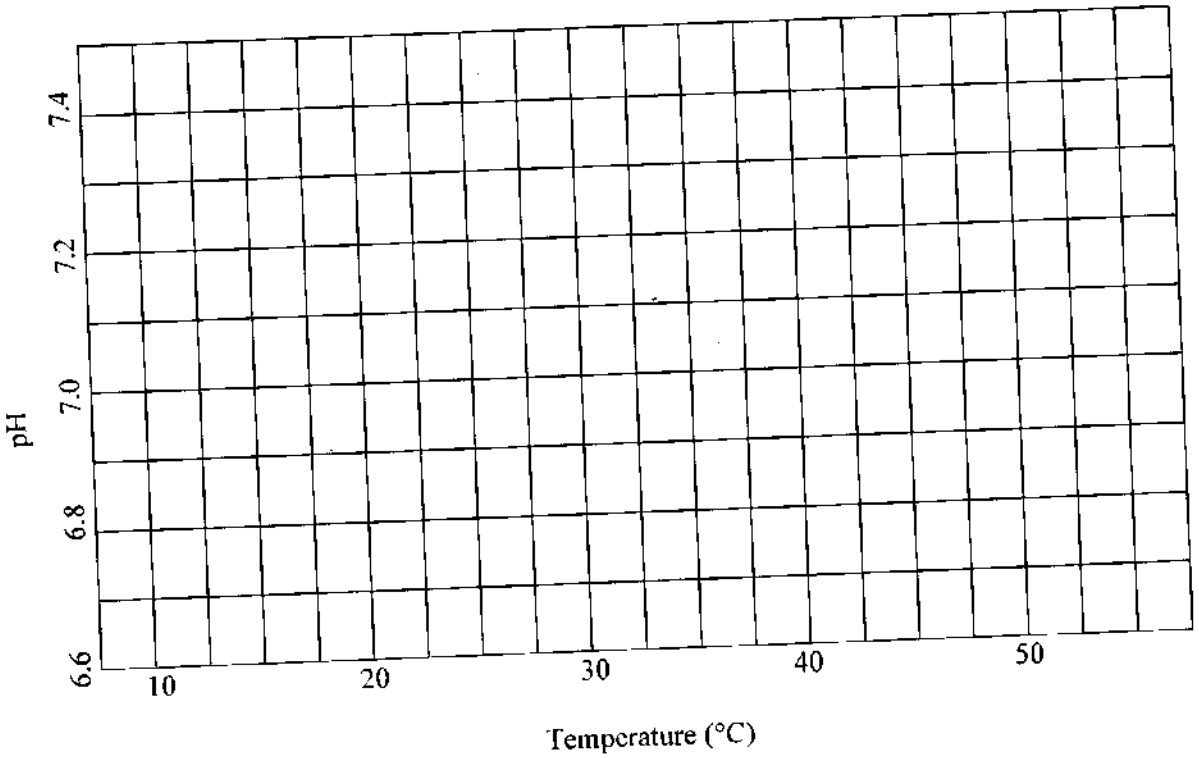
What is the percentage purity of the silicon tetrachloride?

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

(a) Plot the data on the grid below, including a line of best fit. **1**



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

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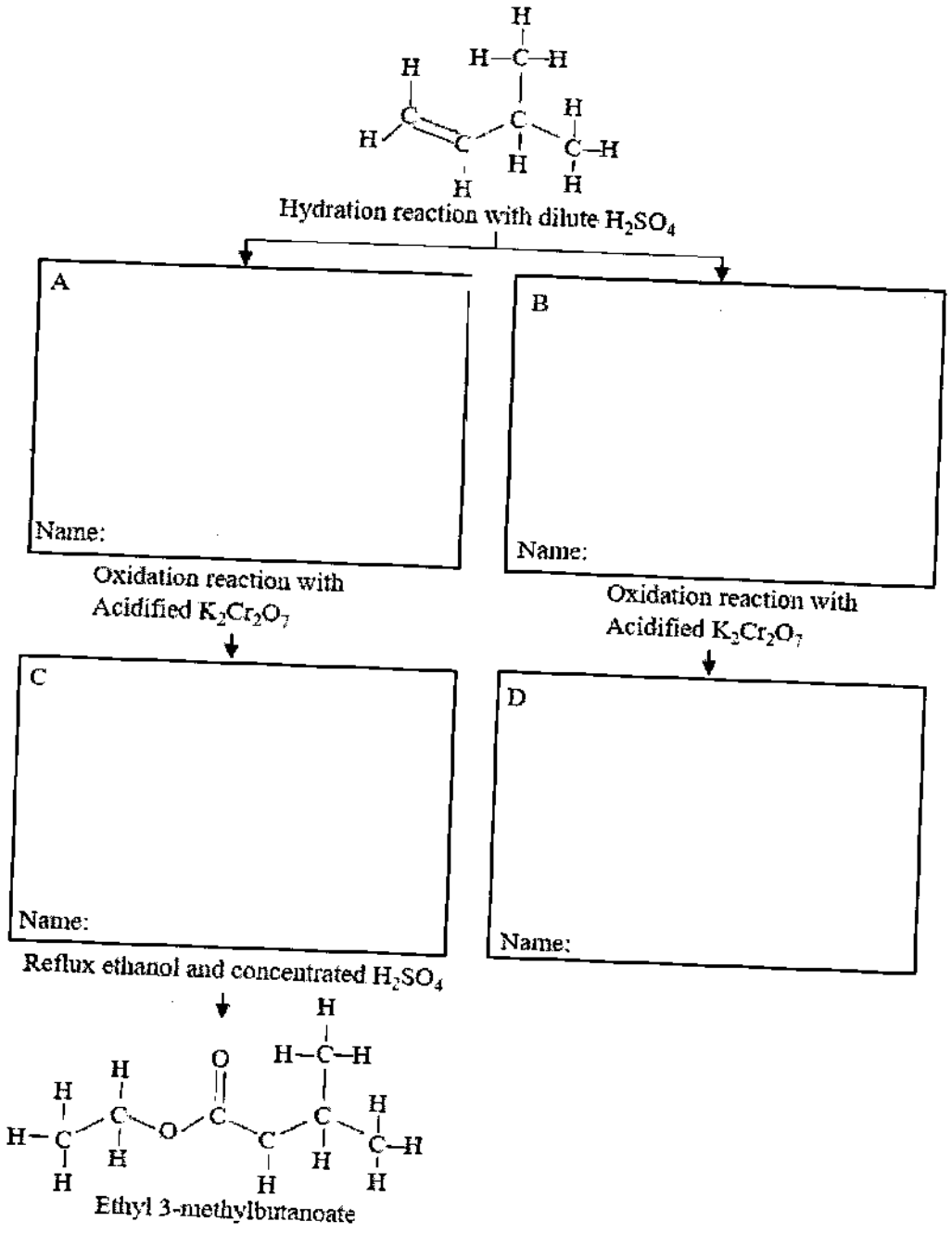
Question 34 (6 marks)

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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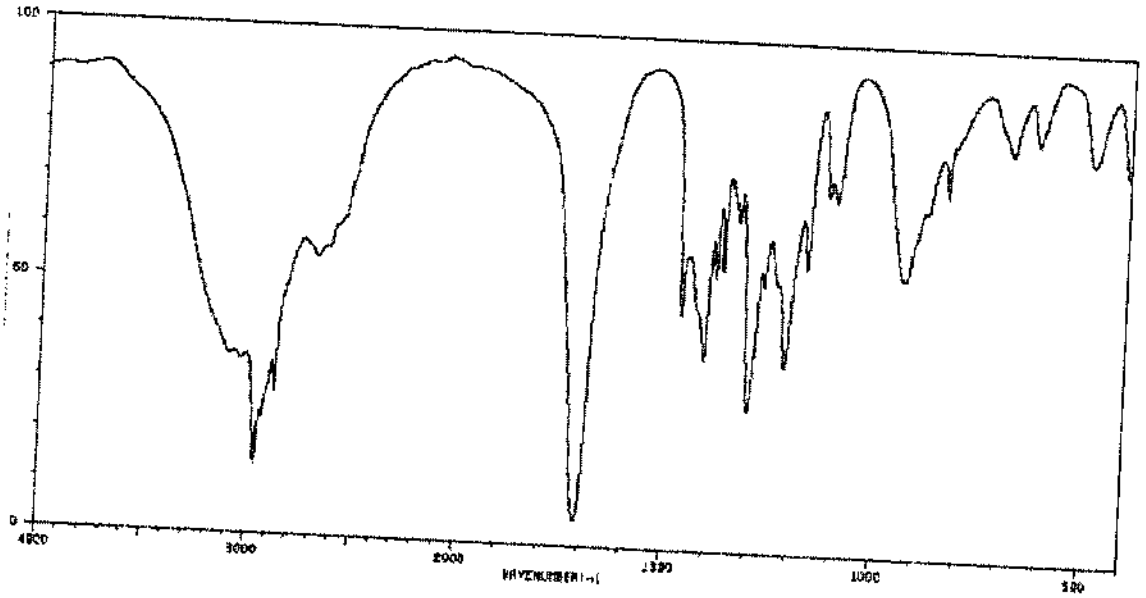
Question 35 (7 marks)

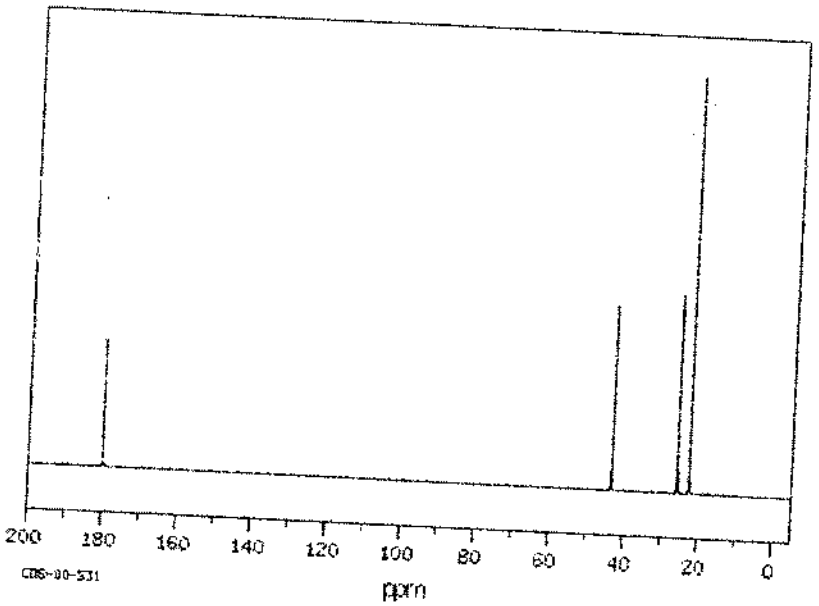
A chemist finds an unlabelled bottle containing a large quantity of organic **Compound Y**, a colourless liquid with the molecular formula $C_5H_{10}O_2$.

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



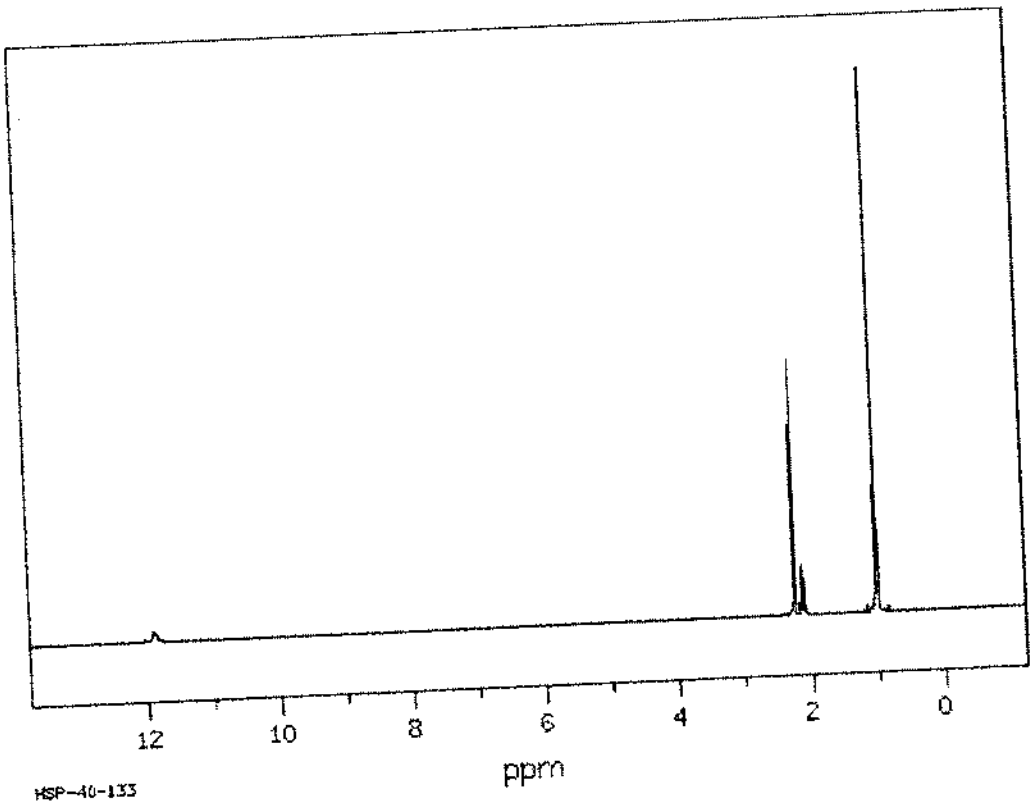
^{13}CNMR: AIST:Spectral Database for Organic Compounds, SDBS



Question 35 continues on page 27

Question 35 (continued)

^{1}HNMR: AIST:Spectral Database for Organic Compounds, SDBS



Data ^{1}HNMR		
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.

(a) Calculate the molar solubility of barium ions in a saturated solution. **2**
(K_{sp}(barium nitrate) = 4.6×10^{-3}).

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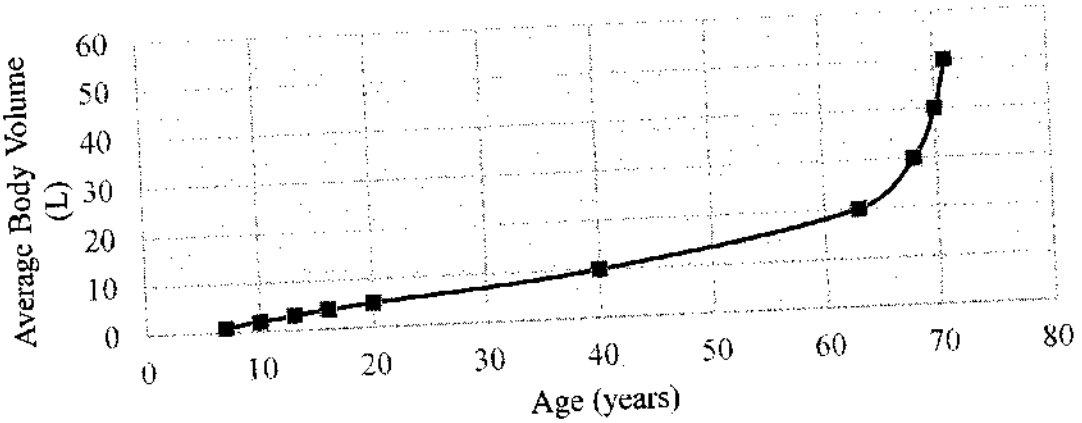
(b) Traditionally 10 g of paint is applied to the body each day, with the ceremony lasting 10 days. The traditional paint contains 0.01% by mass of barium nitrate. There are a number of performers, ranging in age from 18 to 80. The average body volume for people of a given age is shown below: **4**



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

Section II extra writing space

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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.

Copyright

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', *Wikimedia Commons, the free media repository*, 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 *Aist:spectral database for organic compounds,sdbs* n.d., [Accessed 02 April. 2023]. https://sdbs.db.aist.go.jp/sdbs/cgi-bin/cre_index.cgi .

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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