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2023 Higher School Certificate Trial Examination Chemistry

General Instructions

- Reading time – 5 minutes
- Working time – 3 hours
- Write using a black pen
- Draw diagrams using a pencil
- NESA-approved calculators may be used
- Write your student number on this examination and on the multiple-choice answer sheet.
- Three data sheets and a Periodic Table are provided at the back of this paper

Total marks: 100

Section I – 20 marks

- Attempt Questions 1-20 (pages 2-11)
- Allow about 35 minutes for this section

Section II – 80 marks

- Attempt Questions 21-30 (pages 12-32)
- Allow about 2 hours and 25 minutes for this section

Disclaimer

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Section I Multiple-Choice

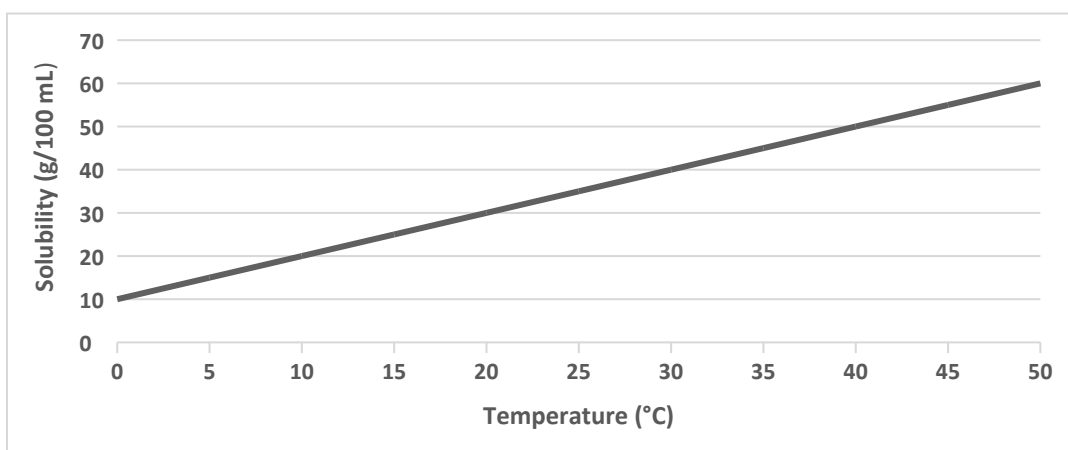
20 marks

Attempt Questions 1-20

Allow about 35 minutes for this section

Use the multiple-choice answer sheet provided to answer Questions 1-20

- 1 The following graph shows how the solubility of an unidentified substance changes with the temperature of the solution.

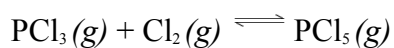


What mass of precipitate will be produced when 20 mL of a saturated solution at 40°C is cooled to 10°C?

- A. 6 g
- B. 12 g
- C. 15 g
- D. 30 g
- 2 0.1 moles of each of the following substances is dissolved in 1 L of water. For which substance would the pH of the resultant solution be closest to 14?
- A. NH_4Cl
- B. $\text{CH}_3\text{CH}_2\text{OH}$
- C. $\text{Ca}(\text{OH})_2$
- D. NaCH_3COO

- 3 Which of the following pairs of compounds will form a precipitate when 0.1 mol L⁻¹ solutions of each are mixed?
- A. AgNO₃ and Ba(NO₃)₂
- B. K₂SO₄ and Cu(NO₃)₂
- C. Ca(NO₃)₂ and KBr
- D. NaOH and CuCl₂
- 4 The molar masses of C₂H₆, CH₃OH and CH₃F are similar. Which of the following lists these compounds in order of increasing boiling point?
- A. C₂H₆ < CH₃OH < CH₃F
- B. CH₃OH < CH₃F < C₂H₆
- C. CH₃F < CH₃OH < C₂H₆
- D. C₂H₆ < CH₃F < CH₃OH
- 5 Iodine monochloride (ICl) reacts with carbon-carbon double bonds (one ICl per double bond). If 0.105 g of a molecule of molar mass 304.5 g mol⁻¹ reacts with exactly 0.224 g of ICl, how many carbon-carbon double bonds are present in the molecule?
- A. 3
- B. 4
- C. 5
- D. 8

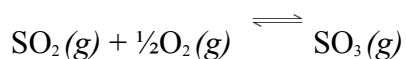
- 6 The following endothermic reaction is at equilibrium in a sealed container:



Which of the following changes would result in an increase in the number of moles of $\text{PCl}_5(g)$ present at equilibrium?

- I. Increasing the temperature
 - II. Increasing the volume
- A. I only
- B. II only
- C. Both I and II
- D. Neither I nor II
- 7 What is the pH of a 0.20 M solution of sodium benzoate, $\text{Na}(\text{C}_6\text{H}_5\text{COO})$? The K_a of benzoic acid, $\text{C}_6\text{H}_5\text{COOH}$, is 6.5×10^{-5} .
- A. 5.26
- B. 8.74
- C. 9.09
- D. 11.56
- 8 What mass of silver chloride ($MM = 143.4$) will dissolve in 1.00 L of water? The K_{sp} of AgCl is 1.8×10^{-10} .
- A. 1.4 mg
- B. 1.9 mg
- C. 2.9 mg
- D. 3.8 mg

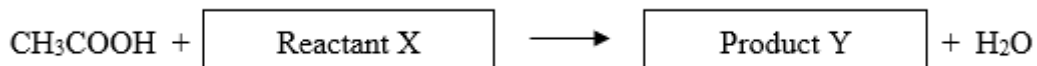
- 9 Sulfur trioxide is formed from the reaction of sulfur dioxide and oxygen:



At 1000 K, an equilibrium mixture has partial pressures of 0.562 atm SO_2 , 0.101 atm O_2 and 0.332 atm SO_3 . What is the equilibrium constant K_p for the reaction at this temperature?

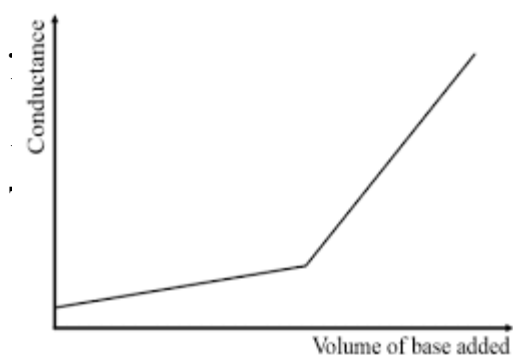
- A. 1.86
 - B. 3.46
 - C. 5.85
 - D. 16.8
- 10 The ^1H NMR spectrum of an organic compound has three unique sets of peaks: a single peak, a septet and, a doublet.
The compound is
- A. 3-methyl butanoic acid.
 - B. 2-methyl propanoic acid.
 - C. 2-chloro-2-methylpropane.
 - D. 1,2-dichloro-2-methylpropane.
- 11 How many isomers have the formula $\text{C}_2\text{H}_2\text{Br}_2$?
- A. 1
 - B. 2
 - C. 3
 - D. 4

- 12 Which of the following identifies Reactant X and Product Y in the condensation reaction shown below?



	<i>Reactant X</i>	<i>Product Y</i>
A.	$\text{CH}_3\text{CH}_2\text{OH}$	$\text{CH}_3\text{CHOHCH}_2\text{CH}_3$
B.	$\text{CH}_3\text{CH}_2\text{NH}_2$	$\text{CH}_3\text{CH}_2\text{CONHCH}_3$
C.	CH_3CH_3	$\text{CH}_3\text{COCH}_2\text{CH}_3$
D.	CH_3NH_2	$\text{CH}_3\text{CONHCH}_3$

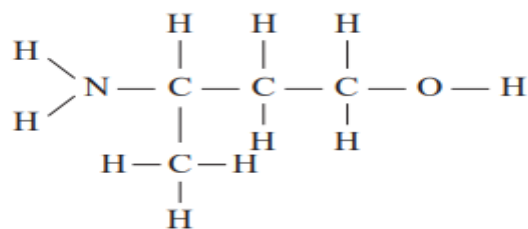
- 13 A conductometric titration was carried out using an acid and a base of similar concentration and the graph below was recorded.



The acid and base used could have been:

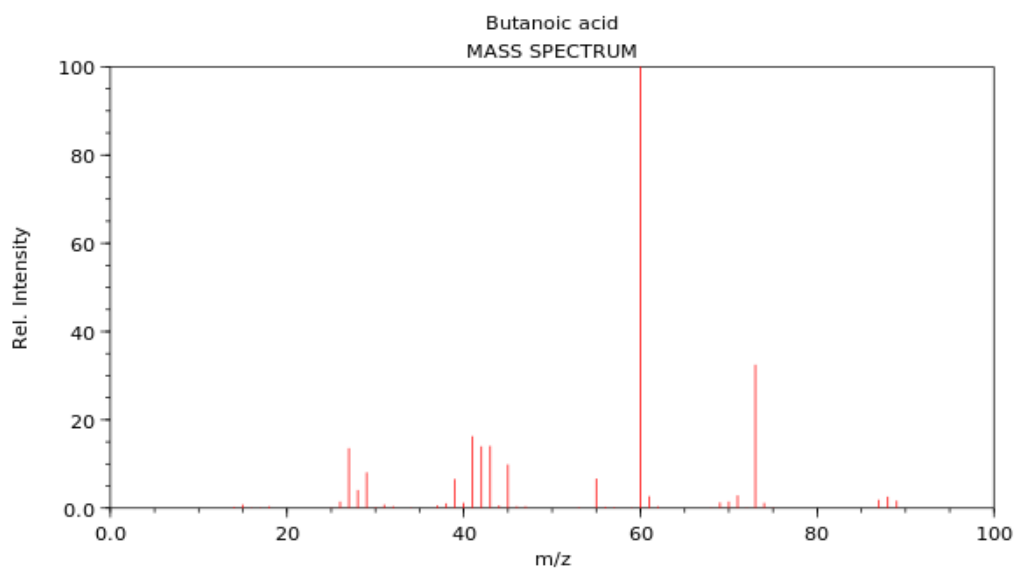
- A. H_2SO_4 and $\text{Ba}(\text{OH})_2$
- B. H_2SO_4 and NH_3
- C. CH_3COOH and NH_3
- D. CH_3COOH and KOH

- 14 Which one of the following statements indicates why ethanol produced from sugar cane is defined as a biofuel whereas ethanol produced from coal is not?
- A. Ethanol produced from sugar cane generates less greenhouse gases when used as a fuel than ethanol produced from coal
 - B. Ethanol produced from coal can be used to generate electrical energy whereas ethanol produced from sugar cane cannot
 - C. Sugar cane is recently living organic matter whereas coal is formed over millions of years
 - D. Sugar cane is a natural resource whereas coal is not
- 15 The IUPAC systematic name for the following molecule is



- A. 3-aminobutan-1-ol.
- B. 4-hydroxybutan-2-amine.
- C. 3-methyl-3-aminopropan-1-ol.
- D. 3-hydroxy-1-methylpropan-1-amine.

- 16 An unidentified organic substance with the molecular formula $C_4H_8O_2$ is found to react with a base. Mass spectrometry shows the parent molecular ion has a mass-to-charge ratio, m/z , of 88.

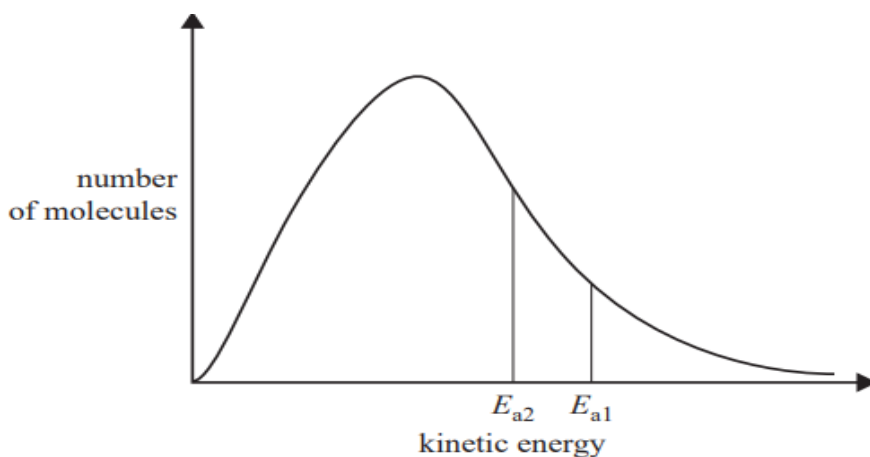


Which one of the following species is consistent with a peak on the mass spectrum at $m/z = 45$?

- A. $COOH^+$
- B. $CH_3CH_2O^+$
- C. $CH_3CH_2OH^+$
- D. $CH_3CH_2CH_2COOH^+$

- 17 The diagram below represents the distribution of kinetic energy in a sample of gaseous reactant molecules.

The activation energy E_{a1} has been changed to activation energy E_{a2} . This change increases the reaction rate.



Which of the following gives the most likely cause of the change from E_{a1} to E_{a2} and explains why the reaction rate would increase?

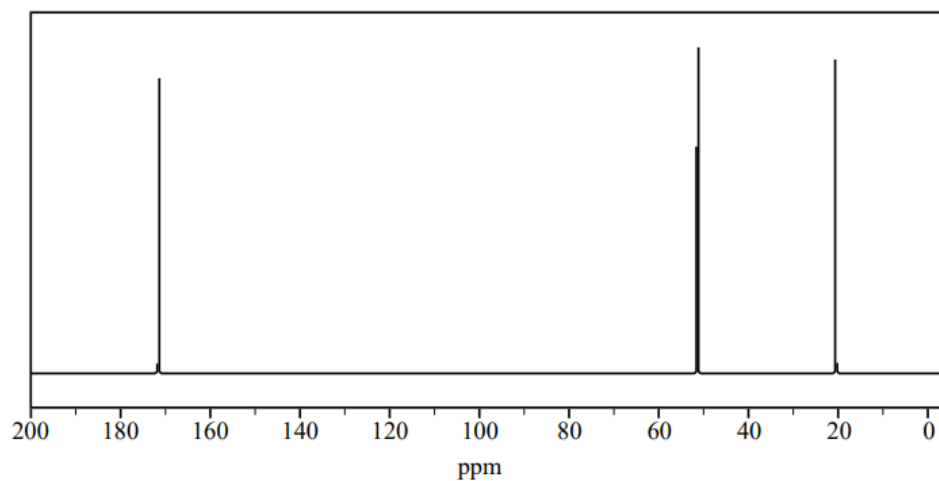
	<i>Cause of the change</i>	<i>Why the reaction rate increases</i>
A.	Catalyst added	Molecules move faster, resulting in more successful collisions
B.	Catalyst added	Greater proportion of reactants collide with sufficient energy to react
C.	Temperature increased	Greater proportion of reactants collide with the correct orientation to react
D.	Concentration of reactants increased	Greater frequency of collisions, resulting in more successful collisions

- 18 100 mL of 0.4 M nitric acid, HNO_3 , is added to 100 mL of 0.1 M barium hydroxide, $\text{Ba}(\text{OH})_2$. The pH of the resulting solution is

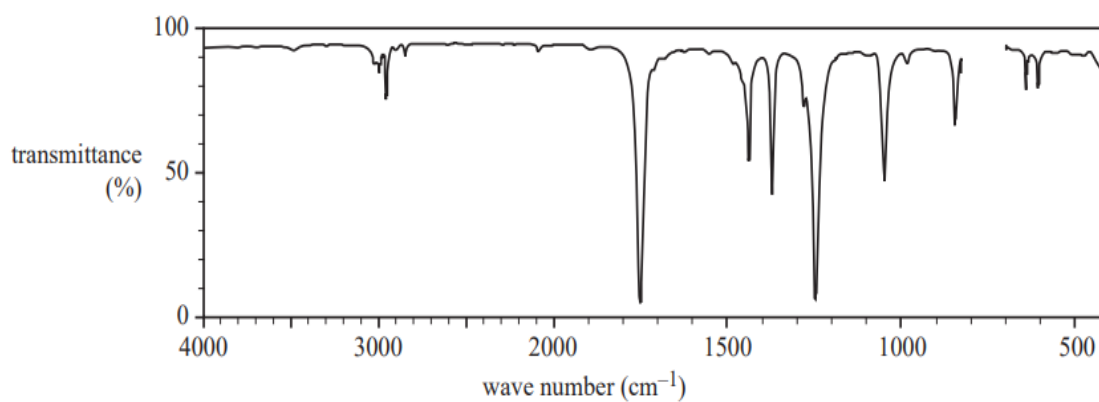
- A. 0.3
- B. 0.7
- C. 0.8
- D. 1.0

- 19 The following two spectra were obtained for a pure organic substance, Compound W.

^{13}C NMR spectrum



Infra-red spectrum



The formula of Compound W that is consistent with the spectra above is

- A. $\text{CH}_2(\text{OH})\text{CH}_2\text{CH}_2\text{OH}$
- B. $\text{CH}_3\text{CH}_2\text{COOH}$
- C. $\text{CH}_3\text{COOCH}_3$
- D. CH_3COCH_3

- 20** A 20.00 mL sample of vinegar is placed in a volumetric flask. The volumetric flask is then filled up to the line marking its designated volume. Then a 20.00 mL aliquot of the diluted sample of vinegar is titrated against a 0.102 M solution of potassium hydroxide, KOH, using a phenolphthalein indicator. If the undiluted sample of vinegar has a concentration of 3.16% m/v acetic acid, CH₃COOH, which volumetric flask should be selected to be able to dilute the original sample of vinegar and obtain titres of about 20 mL?
- A. 100 mL volumetric flask
 - B. 200 mL volumetric flask
 - C. 250 mL volumetric flask
 - D. 1000 mL volumetric flask

END OF SECTION I

Section II Short Response
80 marks

Attempt Questions 21-30

Allow about 2 hours and 25 minutes for this section.

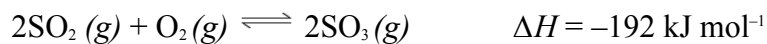
Answer the questions in the spaces provided. These spaces provide guidance for the expected length of response.

Show all relevant working for questions involving calculations.

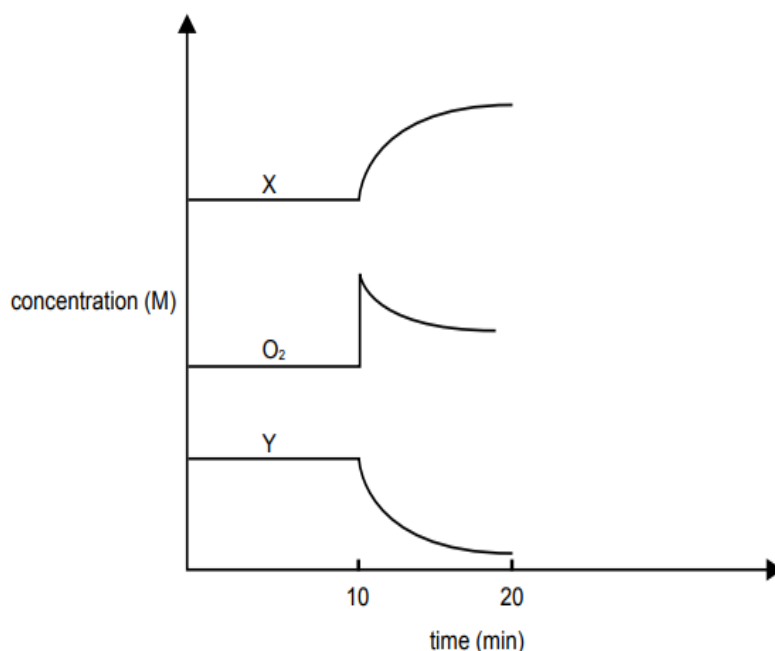
Extra writing space is provided on pages 33 and 34. If you use this space, clearly indicate which question you are answering.

Question 21 (5 marks)

Part of the contact process for the manufacture of sulfuric acid involves the conversion of sulfur dioxide to sulfur trioxide, as shown by the equation:



As part of a laboratory study of this process, a container was filled with an equilibrium mixture of sulfur dioxide, sulfur trioxide, and oxygen in the presence of a catalyst. The container was initially at 450°C . Concentrations during the following experiment are shown in the diagram below.



- (a) What change occurred at the 10-minute point?

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- (b) Which components of the equilibrium mixture are represented by X and Y?

1

X = Y =

Question 21 continues on the next page

Question 21 (continued)

- (c) Give explanations, using Le Chatelier’s principle, for the changes in concentration that occurred in X, Y and O₂ between 10 and 20 minutes. If no further changes were imposed on the equilibrium after 20 minutes had elapsed, predict the shape of the graph after the 20-minute mark.

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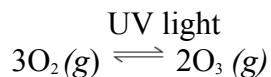
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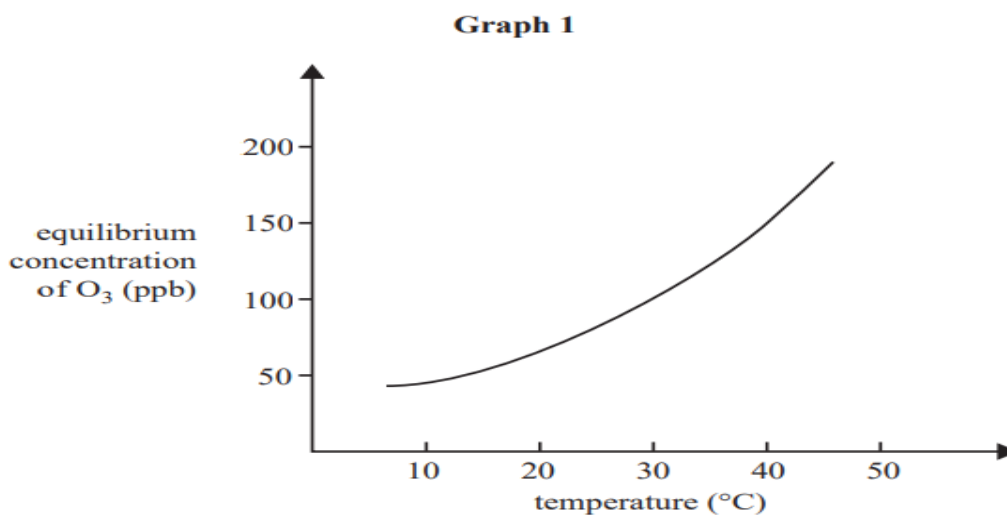
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Question 22 (9 marks)

In the upper atmosphere, ozone, $\text{O}_3(\text{g})$, is formed from oxygen, $\text{O}_2(\text{g})$, in the presence of ultraviolet (UV) light. An equation that represents this chemical reaction is:



Graph 1(below) shows the effect of temperature on the equilibrium concentration of $\text{O}_3(\text{g})$ in a sealed container containing only $\text{O}_2(\text{g})$ and $\text{O}_3(\text{g})$. The container is clear and exposed to UV light.



- (a) State whether the forward reaction is endothermic or exothermic.

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- (b) Explain your answer to part (a).

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Question 22 continues on the next page

Question 22 (continued)

- (c) Conversion of $\text{O}_3(\text{g})$ to $\text{O}_2(\text{g})$ is the reverse reaction.

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Sketch the energy profile for the conversion of $\text{O}_3(\text{g})$ on the axes provided.



- (d) 7.50×10^{-2} mol of $\text{O}_2(\text{g})$ was placed in an evacuated and sealed 3.00 L container at 30°C . This clear container was exposed to UV light. At equilibrium, 1.56×10^{-7} mol of $\text{O}_3(\text{g})$ had formed in the container. Calculate the equilibrium constant at 30°C .

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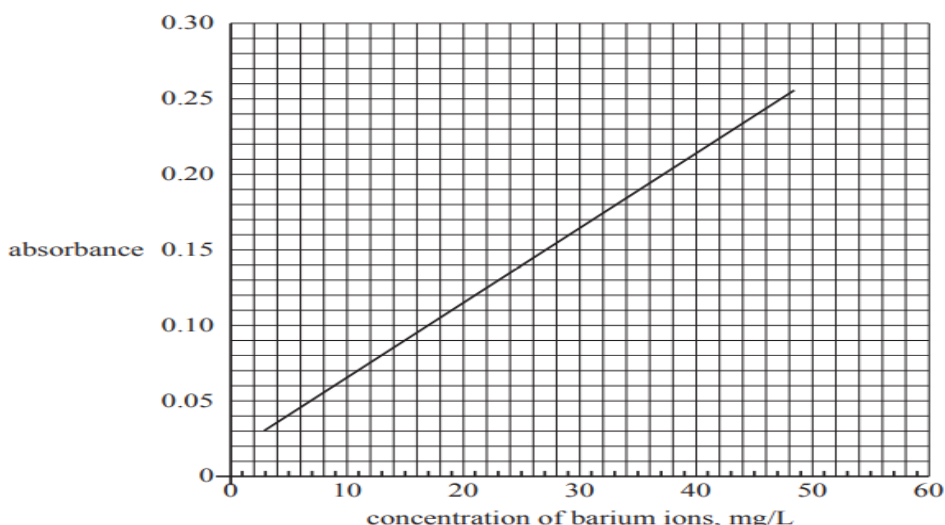
Question 23 (8 marks)

Elemental sulfur can be used to control outbreaks of powdery mildew on grapes. However, sulfur remaining on the grapes after harvest can be converted to a number of undesirable compounds during fermentation in wine production. A wine chemist uses atomic absorption spectroscopy to determine the amount of sulfur remaining on grapes.

In a particular analysis, 100.0 g of grapes were treated with 100.0 mL of surfactant solution to remove the sulfur remaining on the grapes when they were harvested. 25.00 mL of this surfactant solution was treated to convert all of the sulfur to sulfate ions and then dried to produce an ash containing the sulfate ions. This ash was transferred to a 10.00 mL volumetric flask containing 2.00 mL of 200 mg/L solution of barium Ba^{2+} ions. The volume of solution in the volumetric flask was then made up to the calibration line. A precipitate of BaSO_4 formed and settled to the bottom of the volumetric flask.

A small amount of the solution containing the unreacted Ba^{2+} ions was removed from the volumetric flask and analysed using atomic absorption spectroscopy. This solution gave an absorbance of 0.11.

A calibration curve was prepared using standard solutions of 10, 20, 30 and 40 mg/L $\text{Ba}^{2+}(\text{aq})$.



- (a) Determine the concentration of barium ions remaining in the 10.00 mL sample solution. Hence determine the mass of barium ions, in mg, remaining in the 10.00 mL sample solution. 2

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Question 23 continues on the next page

Question 23 (continued)

- (b) Determine the amount of barium ions, in moles, that reacted to produce the barium sulfate precipitate. **2**

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- (c) Determine the mass of sulfur, in mg, remaining on the 100.0 g of harvested grapes. **2**

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- (d) The amount of sulfur remaining on the grapes can also be determined using gravimetric analysis. Explain two reasons why atomic absorption spectroscopy is a better way to determine the residual sulfur on the grapes, compared to gravimetric analysis. **2**

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Question 24 (8 marks)

A small organic molecule contains carbon, hydrogen, oxygen and chlorine atoms. A pH probe was inserted into a dilute aqueous solution of this compound and the pH was 4.5.

The mass spectrum, infrared spectrum, ^1H NMR spectrum and ^{13}C NMR spectrum of this compound are provided on pages 21 and 22.

- (a) On the infrared spectrum, on page 22, label the peaks that correspond to the presence of two functional groups involving carbon, hydrogen and/or oxygen atoms in this compound. 1
Please note that the peak due to the C-Cl stretch has been labelled.

- (b) What information is provided by the pH of the aqueous solution? 1

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- (c) What information is provided by the mass spectrum? 1

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- (d) What specific information about the structure of the compound is provided by the splitting pattern in the ^1H NMR spectrum and the data table on page 23? 2

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Question 24 continues on the next page

Question 24 (continued)

- (e) Use the data provided to determine the number of carbon and hydrogen atoms in a molecule of this compound. Explain your reasoning.

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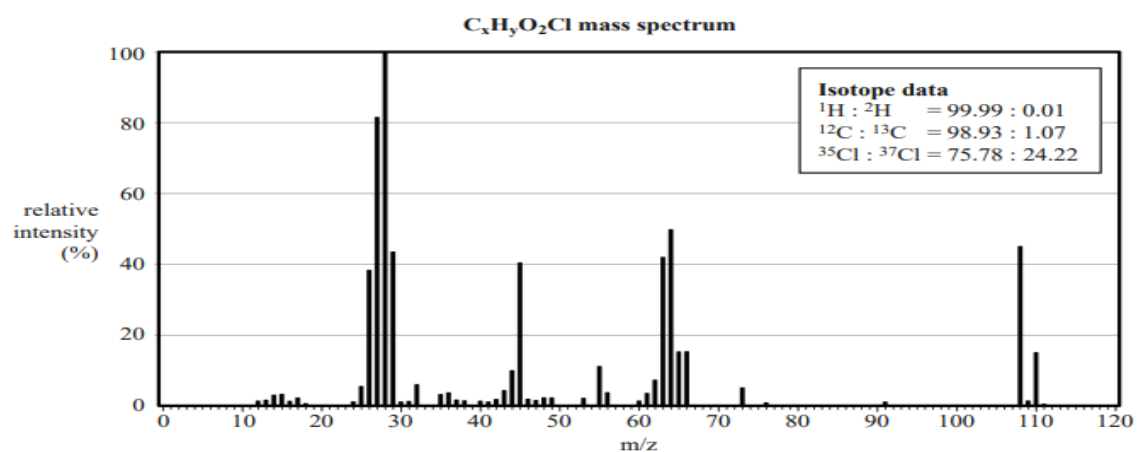
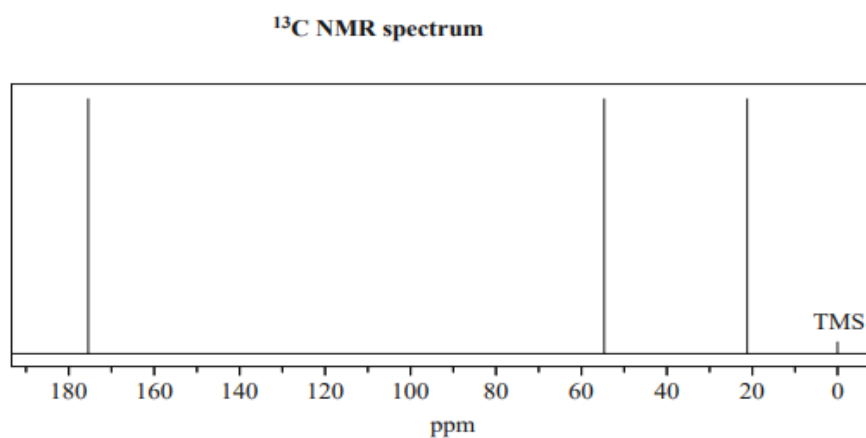
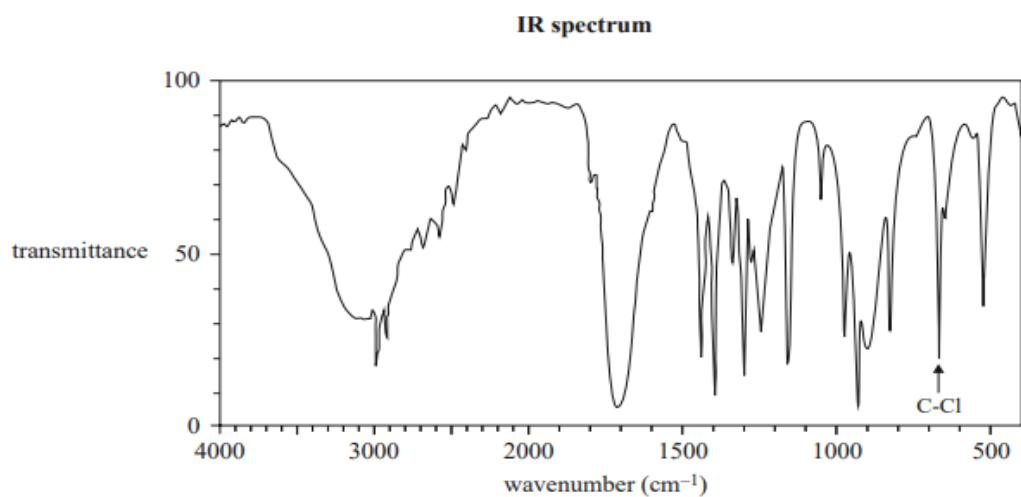
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- (f) Draw a molecular structure for this molecule.

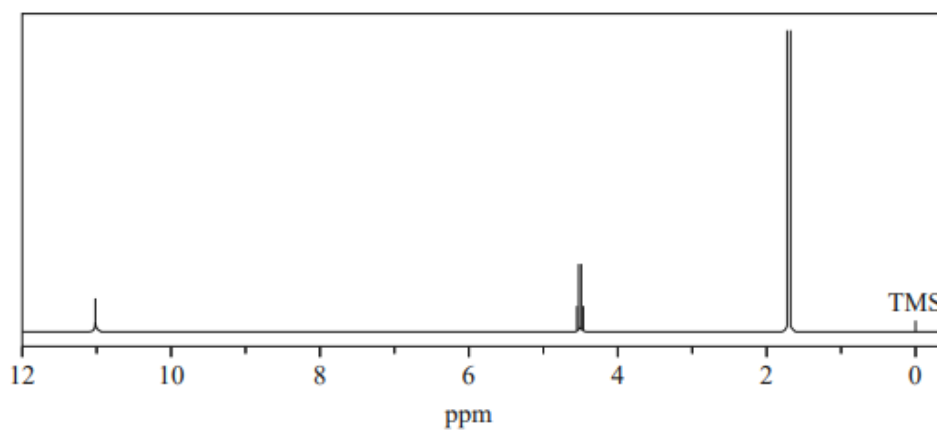
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Question 24 (continued)



Question 24 (continued)

^1H NMR spectrum



^1H NMR data

Chemical shift (ppm)	Peak splitting	Relative peak area
1.7	doublet (2 peaks)	3
4.5	quartet (4 peaks)	1
11.2	singlet (1 peak)	1

Question 25 (11 marks)

A student was given 4 colourless liquids that were labelled **A**, **B**, **C** and **D**. They were known to be ethanol, ethanoic acid, pentane and hex-3-ene, but the exact identity of each liquid was unknown. The student tested the properties of each liquid and obtained the following results.

	A	B	C	D
Solubility in water	insoluble	soluble	soluble	insoluble
Addition of red-coloured bromine solution (<i>aq</i>)	colour disappears	no immediate reaction	no immediate reaction	no immediate reaction
Addition of sodium carbonate solution (<i>aq</i>)	no reaction	gas evolved	no reaction	no reaction

- (a) Identify each of the liquids. **2**

A =

B =

C =

D =

- (b) Identify the type of reaction occurring between compound **A** and bromine solution, write a balanced equation and draw the structure(s) of the compound(s) formed. **3**

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- (c) Identify the type of reaction occurring between compound **B** and Na₂CO₃ solution, write a balanced equation and draw the structure of the anion formed. **3**

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Question 25 continues on the next page

Question 25 (continued)

- (d) Discuss the different solubilities of the 4 compounds in water.

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Question 26 (13 marks)

- (a) Acids and bases have been defined differently by scientists over several centuries. Justify this statement by comparing the theories of Arrhenius and Brønsted-Lowry, using appropriate examples.

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- (b) Calculate the pH values of 0.001 M solutions of hydrochloric acid and hypochlorous acid, HOCl, which has an acid dissociation constant, K_a , of 3.0×10^{-8} at 25°C.

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Question 26 continues on the next page

Question 26 (continued)

- (c) Account for the different pH values calculated in part (b).

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- (d) A buffer solution is prepared by combining 100 mL of 0.010 M hydrocyanic acid (HCN) and 0.055 g of solid NaCN. $K_a \text{ HCN} = 4.9 \times 10^{-10}$

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Calculate the pH of this buffer solution and explain the classification of the solution as a buffer.

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Question 27 (6 marks)

The ammonium ion, NH_4^+ , is a weak acid with an acid dissociation constant of 5.6×10^{-10} at 25°C . A saturated solution of ammonium chloride has a pH of 4.67 at 25°C .

- (a) Calculate the K_{sp} of ammonium chloride at 25°C . **3**

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- (b) What is the solubility of ammonium chloride in water at this temperature? **1**

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- (c) If 0.10 mL of a 2.0×10^{-5} M solution of silver nitrate were added to 100 mL of a saturated solution of ammonium chloride, will a precipitate form? **2**

$K_{sp} \text{ AgCl} = 1.77 \times 10^{-10}$

Show all calculations and reasoning.

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Question 28 (8 marks)

A solution of sodium carbonate of concentration 1.0 M has a pH which is close to 11. When this sodium carbonate solution is titrated with 1.0 M HCl solution, 2 equivalence points are observed. These occur at pH values of approximately 8 and 4.

- (a) Write an equation for the overall reaction between Na_2CO_3 and HCl when excess HCl is available. **1**

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- (b) Explain why there are 2 equivalence points for this titration and write equations for the 2 reactions that occur. **3**

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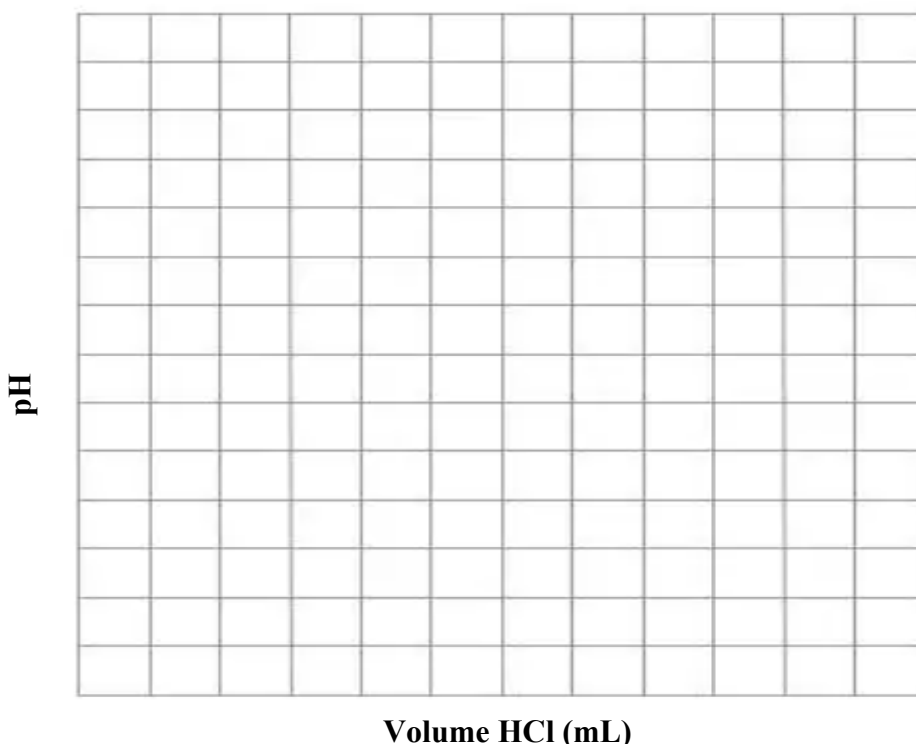
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- (c) Sketch a graph to show the titration curve for this reaction when excess HCl is available. **2**



Question 28 continues on the next page

Question 28 (continued)

- (d) Identify the species present in the titration flask at the equivalence point at pH 8. **1**

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- (e) Name 2 indicators, one which would change colour at pH 8, and another which would change colour at pH 4. **1**

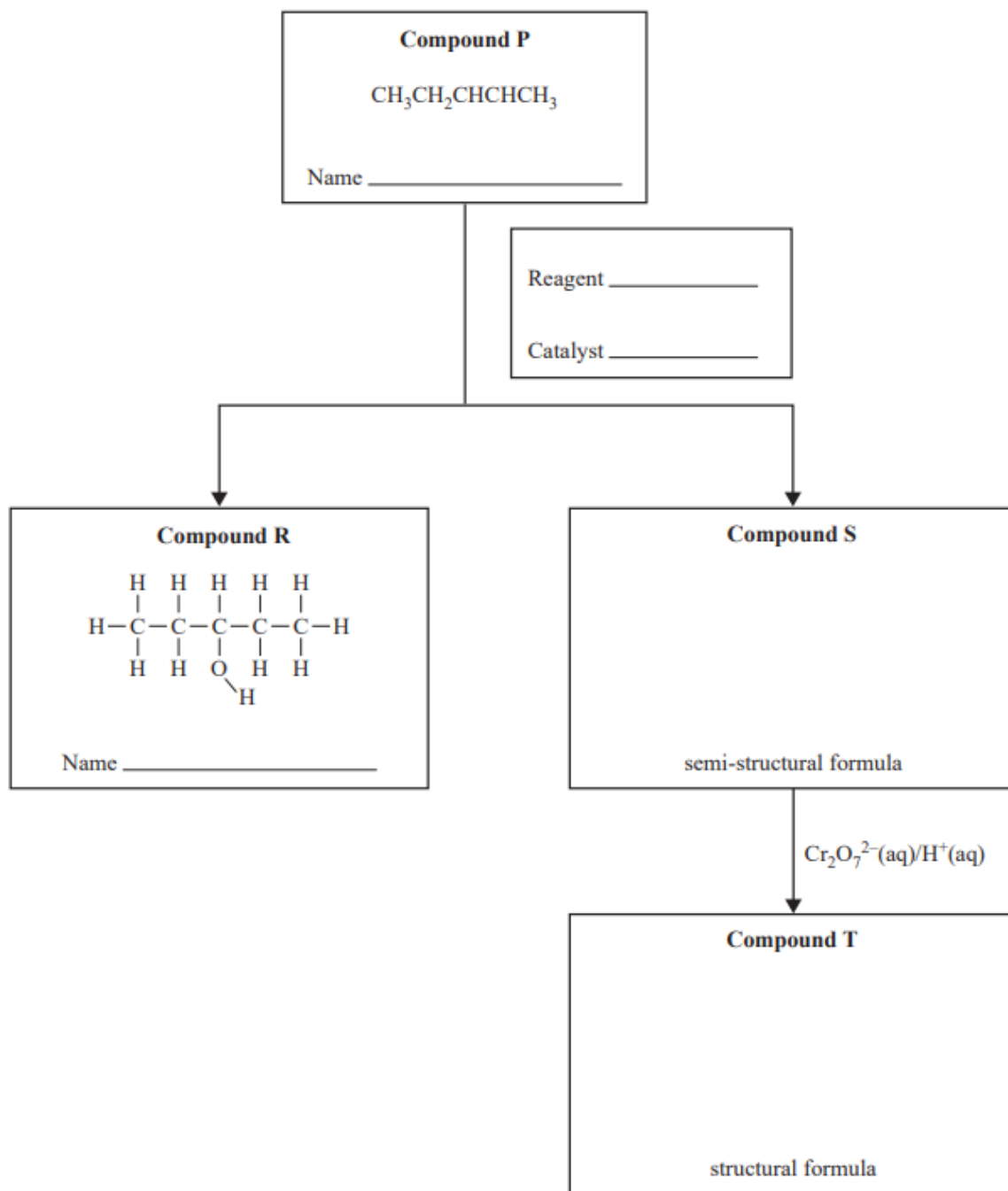
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Question 29 (8 marks)

Complete the information required in the boxes below.

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Question 30 (4 marks)

An object recovered from the ocean was found to contain residues of oil and salt water. Scientists decided to soak the object in fresh water containing a surfactant, such as soap, over a prolonged period, with the soap solution being replaced and discarded at regular intervals.

- (a) Identify the structure and properties of a surfactant, such as soap, which makes its use suitable in this recovery process. Use appropriate diagrams in your response. **2**

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Question 30 continues on the next page

Question 30 (continued)

- (b) Compare the process of repeated washing of the object recovered from the ocean with the process of removal of toxins in food products traditionally used by Aboriginal and Torres Strait Islander Peoples. **2**

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END OF PAPER

Section II - Extra writing space

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

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Section II - Extra writing space

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

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Student Number:

CHEMISTRY – MULTIPLE-CHOICE ANSWER SHEET

ATTEMPT ALL QUESTIONS

Place an X in your response for each multiple-choice question to indicate your choice.

Question				
1	A	B	C	D
2	A	B	C	D
3	A	B	C	D
4	A	B	C	D
5	A	B	C	D
6	A	B	C	D
7	A	B	C	D
8	A	B	C	D
9	A	B	C	D
10	A	B	C	D
11	A	B	C	D
12	A	B	C	D
13	A	B	C	D
14	A	B	C	D
15	A	B	C	D
16	A	B	C	D
17	A	B	C	D
18	A	B	C	D
19	A	B	C	D
20	A	B	C	D

Chemistry

FORMULAE SHEET

$$n = \frac{m}{MM}$$

$$q = mc\Delta T$$

$$pK_a = -\log_{10}[K_a]$$

$$c = \frac{n}{V}$$

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

$$A = \epsilon lc = \log_{10} \frac{I_o}{I}$$

$$PV = nRT$$

$$\text{pH} = -\log_{10}[\text{H}^+]$$

Avogadro constant, N_A $6.022 \times 10^{23} \text{ mol}^{-1}$

Volume of 1 mole ideal gas: at 100 kPa and

at 0°C (273.15 K) 22.71 L

at 25°C (298.15 K) 24.79 L

Gas constant $8.314 \text{ J mol}^{-1} \text{ K}^{-1}$

Ionisation constant for water at 25°C (298.15 K), K_w 1.0×10^{-14}

Specific heat capacity of water $4.18 \times 10^3 \text{ J kg}^{-1} \text{ K}^{-1}$

DATA SHEET

Solubility constants at 25°C


Compound	K_{sp}	Compound	K_{sp}
Barium carbonate	2.58×10^{-9}	Lead(II) bromide	6.60×10^{-6}
Barium hydroxide	2.55×10^{-4}	Lead(II) chloride	1.70×10^{-5}
Barium phosphate	1.3×10^{-29}	Lead(II) iodide	9.8×10^{-9}
Barium sulfate	1.08×10^{-10}	Lead(II) carbonate	7.40×10^{-14}
Calcium carbonate	3.36×10^{-9}	Lead(II) hydroxide	1.43×10^{-15}
Calcium hydroxide	5.02×10^{-6}	Lead(II) phosphate	8.0×10^{-43}
Calcium phosphate	2.07×10^{-29}	Lead(II) sulfate	2.53×10^{-8}
Calcium sulfate	4.93×10^{-5}	Magnesium carbonate	6.82×10^{-6}
Copper(II) carbonate	1.4×10^{-10}	Magnesium hydroxide	5.61×10^{-12}
Copper(II) hydroxide	2.2×10^{-20}	Magnesium phosphate	1.04×10^{-24}
Copper(II) phosphate	1.40×10^{-37}	Silver bromide	5.35×10^{-13}
Iron(II) carbonate	3.13×10^{-11}	Silver chloride	1.77×10^{-10}
Iron(II) hydroxide	4.87×10^{-17}	Silver carbonate	8.46×10^{-12}
Iron(III) hydroxide	2.79×10^{-39}	Silver hydroxide	2.0×10^{-8}
Iron(III) phosphate	9.91×10^{-16}	Silver iodide	8.52×10^{-17}
		Silver phosphate	8.89×10^{-17}
		Silver sulfate	1.20×10^{-5}

Aylward and Findlay, *SI Chemical Data* (5th Edition) is the principal source of data for this examination paper. Some data may have been modified for examination purposes.

Infrared absorption data

Bond	Wavenumber/cm ⁻¹
N—H (amines)	3300–3500
O—H (alcohols)	3230–3550 (broad)
C—H	2850–3300
O—H (acids)	2500–3000 (very broad)
C≡N	2220–2260
C=O	1680–1750
C=C	1620–1680
C—O	1000–1300
C—C	750–1100

¹³C NMR chemical shift data

Type of carbon	δ/ppm
$\begin{array}{c} \quad \\ -C-C- \\ \quad \end{array}$	5–40
$\begin{array}{c} \\ R-C-Cl \text{ or } Br \\ \end{array}$	10–70
$\begin{array}{c} \\ R-C-C- \\ \quad \\ O \end{array}$	20–50
$\begin{array}{c} \\ R-C-N \\ \end{array}$	25–60
$\begin{array}{c} \\ -C-O- \\ \end{array}$ alcohols, ethers or esters	50–90
$\begin{array}{c} \diagup \quad \diagdown \\ C=C \\ \diagdown \quad \diagup \end{array}$	90–150
$R-C \equiv N$	110–125
	110–160
$\begin{array}{c} R-C- \\ \\ O \end{array}$ esters or acids	160–185
$\begin{array}{c} R-C- \\ \\ O \end{array}$ aldehydes or ketones	190–220

UV absorption

(This is not a definitive list and is approximate.)

Chromophore	λ_{max} (nm)
C—H	122
C=C	135
C=C	162

Chromophore	λ_{max} (nm)
C≡C	173 178 196 222
C—Cl	173
C—Br	208

Some standard potentials

$\text{K}^+ + \text{e}^-$	\rightleftharpoons	$\text{K}(s)$	-2.94 V
$\text{Ba}^{2+} + 2\text{e}^-$	\rightleftharpoons	$\text{Ba}(s)$	-2.91 V
$\text{Ca}^{2+} + 2\text{e}^-$	\rightleftharpoons	$\text{Ca}(s)$	-2.87 V
$\text{Na}^+ + \text{e}^-$	\rightleftharpoons	$\text{Na}(s)$	-2.71 V
$\text{Mg}^{2+} + 2\text{e}^-$	\rightleftharpoons	$\text{Mg}(s)$	-2.36 V
$\text{Al}^{3+} + 3\text{e}^-$	\rightleftharpoons	$\text{Al}(s)$	-1.68 V
$\text{Mn}^{2+} + 2\text{e}^-$	\rightleftharpoons	$\text{Mn}(s)$	-1.18 V
$\text{H}_2\text{O} + \text{e}^-$	\rightleftharpoons	$\frac{1}{2}\text{H}_2(g) + \text{OH}^-$	-0.83 V
$\text{Zn}^{2+} + 2\text{e}^-$	\rightleftharpoons	$\text{Zn}(s)$	-0.76 V
$\text{Fe}^{2+} + 2\text{e}^-$	\rightleftharpoons	$\text{Fe}(s)$	-0.44 V
$\text{Ni}^{2+} + 2\text{e}^-$	\rightleftharpoons	$\text{Ni}(s)$	-0.24 V
$\text{Sn}^{2+} + 2\text{e}^-$	\rightleftharpoons	$\text{Sn}(s)$	-0.14 V
$\text{Pb}^{2+} + 2\text{e}^-$	\rightleftharpoons	$\text{Pb}(s)$	-0.13 V
$\text{H}^+ + \text{e}^-$	\rightleftharpoons	$\frac{1}{2}\text{H}_2(g)$	0.00 V
$\text{SO}_4^{2-} + 4\text{H}^+ + 2\text{e}^-$	\rightleftharpoons	$\text{SO}_2(aq) + 2\text{H}_2\text{O}$	0.16 V
$\text{Cu}^{2+} + 2\text{e}^-$	\rightleftharpoons	$\text{Cu}(s)$	0.34 V
$\frac{1}{2}\text{O}_2(g) + \text{H}_2\text{O} + 2\text{e}^-$	\rightleftharpoons	2OH^-	0.40 V
$\text{Cu}^+ + \text{e}^-$	\rightleftharpoons	$\text{Cu}(s)$	0.52 V
$\frac{1}{2}\text{I}_2(s) + \text{e}^-$	\rightleftharpoons	I^-	0.54 V
$\frac{1}{2}\text{I}_2(aq) + \text{e}^-$	\rightleftharpoons	I^-	0.62 V
$\text{Fe}^{3+} + \text{e}^-$	\rightleftharpoons	Fe^{2+}	0.77 V
$\text{Ag}^+ + \text{e}^-$	\rightleftharpoons	$\text{Ag}(s)$	0.80 V
$\frac{1}{2}\text{Br}_2(l) + \text{e}^-$	\rightleftharpoons	Br^-	1.08 V
$\frac{1}{2}\text{Br}_2(aq) + \text{e}^-$	\rightleftharpoons	Br^-	1.10 V
$\frac{1}{2}\text{O}_2(g) + 2\text{H}^+ + 2\text{e}^-$	\rightleftharpoons	H_2O	1.23 V
$\frac{1}{2}\text{Cl}_2(g) + \text{e}^-$	\rightleftharpoons	Cl^-	1.36 V
$\frac{1}{2}\text{Cr}_2\text{O}_7^{2-} + 7\text{H}^+ + 3\text{e}^-$	\rightleftharpoons	$\text{Cr}^{3+} + \frac{7}{2}\text{H}_2\text{O}$	1.36 V
$\frac{1}{2}\text{Cl}_2(aq) + \text{e}^-$	\rightleftharpoons	Cl^-	1.40 V
$\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^-$	\rightleftharpoons	$\text{Mn}^{2+} + 4\text{H}_2\text{O}$	1.51 V
$\frac{1}{2}\text{F}_2(g) + \text{e}^-$	\rightleftharpoons	F^-	2.89 V

PERIODIC TABLE OF THE ELEMENTS

PERIODIC TABLE OF THE ELEMENTS																	
				KEY													
		Atomic Number Symbol		Standard Atomic Weight		Name											
1	4	3	2	5	6	7	8	9	10	11	12	13	14	15	16	17	18
H 1.008 Hydrogen	He 4.003 Helium	Li 6.941 Lithium	Be 9.012 Beryllium	B 10.81 Boron	C 12.01 Carbon	N 14.01 Nitrogen	O 16.00 Oxygen	F 19.00 Fluorine	Ne 20.18 Neon	Na 22.99 Sodium	Mg 24.31 Magnesium	Al 26.98 Aluminum	Si 28.09 Silicon	P 30.97 Phosphorus	S 32.07 Sulfur	Cl 35.45 Chlorine	Ar 39.95 Argon
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
K 39.10 Potassium	Ca 40.08 Calcium	Sc 44.96 Scandium	Ti 47.87 Titanium	V 50.94 Vanadium	Cr 52.00 Chromium	Mn 54.94 Manganese	Fe 55.85 Iron	Co 58.93 Cobalt	Ni 58.69 Nickel	Cu 63.55 Copper	Zn 65.38 Zinc	Ga 69.72 Gallium	Ge 72.64 Germanium	As 74.92 Arsenic	Se 78.96 Selenium	Br 79.90 Bromine	Kr 83.80 Krypton
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb 85.47 Rubidium	Sr 87.61 Strontium	Y 88.91 Yttrium	Zr 91.22 Zirconium	Nb 92.91 Niobium	Mo 95.96 Molybdenum	Tc 99.44 Technetium	Ru 101.1 Ruthenium	Rh 102.9 Rhodium	Pd 106.4 Palladium	Ag 107.9 Silver	Cd 112.4 Cadmium	In 114.8 Indium	Sn 118.7 Tin	Sb 121.8 Antimony	Te 127.6 Tellurium	I 126.9 Iodine	Xe 131.3 Xenon
55	56	57-71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Cs 132.9 Cesium	Ba 137.3 Barium	Lanthanoids	Hf 178.5 Hafnium	Ta 180.9 Tantalum	W 183.9 Tungsten	Re 186.2 Rhenium	Os 190.2 Osmium	Ir 192.2 Iridium	Pt 195.1 Platinum	Au 197.0 Gold	Hg 200.6 Mercury	Tl 204.4 Thallium	Pb 207.2 Lead	Bi 209.0 Bismuth	Po 209.0 Polonium	At 210.0 Astatine	Rn 222.0 Radon
87	88	89-103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118
Fr 223.0 Francium	Ra 226.0 Radium	Actinoids	Rf 261.0 Rutherfordium	Db 262.0 Dubnium	Sg 266.0 Seaborgium	Bh 264.0 Bohrium	Hs 277.0 Hassium	Mt 268.0 Meitnerium	Ds 285.0 Darmstadtium	Rg 289.0 Roentgenium	Cn 285.0 Copernicium	Uut 288.0 Ununtrium	Fl 289.0 Flerovium	Uup 289.0 Ununpentium	Lv 293.0 Livermorium	Uus 294.0 Ununseptium	Uuo 294.0 Ununoctium

Lanthanoids

57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
138.9	140.1	140.9	144.2		150.4	152.0	157.3	158.9	162.5	164.9	167.3	168.9	173.1	175.0
Lanthanum	Cerium	Praseodymium	Neodymium	Promethium	Samarium	Europium	Gadolinium	Terbium	Dysprosium	Holmium	Erbium	Thulium	Ytterbium	Lutetium

Actinoids

89	90	91	92	93	94	95	96	97	98	99	100	101	102	103
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr
	232.0	231.0	238.0											
Actinium	Thorium	Protactinium	Uranium	Neptunium	Plutonium	Americium	Curium	Berkelium	Californium	Einsteinium	Fermium	Mendelevium	Nobelium	Lawrencium

Standard atomic weights are abridged to four significant figures.

Elements with no reported values in the table have no stable nuclides.

Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (January 2016 version). The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of all other data. Some data may have been modified.

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2023 HIGHER SCHOOL CERTIFICATE CHEMISTRY EXAMINATION

MARKING GUIDELINES & ADVICE FOR TEACHERS

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2023-CHE-NSW-Y12-NA-EXGL-QATS

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2023 Higher School Certificate Trial Examination Chemistry

Marking Guidelines

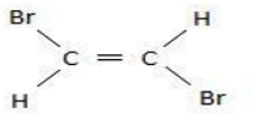
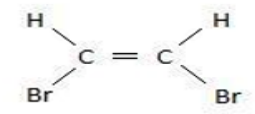
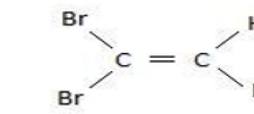
Section I Multiple-Choice (20 marks)

Question	Answer
1	A
2	C
3	D
4	D
5	B
6	A
7	B
8	B
9	A
10	B
11	C
12	D
13	D
14	C
15	A
16	A
17	B
18	D
19	C

20	A
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Explanations for Multiple-Choice (20 marks)	
1	<p>A</p> <p>When 100 mL solution is cooled from 40°C to 10°C, the mass of precipitate forming = 50 – 20 = 30 g</p> <p>When 20 mL solution is cooled through the same temperature range, then $20/100 \times 30 = 6$ g of precipitate forms.</p>
2	<p>C</p> <p>The only bases are Ca(OH)_2 and NaCH_3COO. Of these, Ca(OH)_2 is the stronger as it ionises completely to form OH^-. Hence the pH will be close to 14.</p>
3	<p>D</p> <p>The combination will form Cu(OH)_2 which is classified as insoluble and hence will form a precipitate in water. All nitrates are soluble, so precipitates cannot form in any of the other alternative answers.</p>
4	<p>D</p> <p>The compound with the strongest intermolecular forces will have the highest boiling point. Ethane, C_2H_6, has only weak dispersion forces/temporary dipole-dipole forces, fluoromethane is polar, so has permanent dipole-dipole forces (stronger than temporary dipole-dipole forces) and methanol has hydrogen bonding between adjacent molecules. This is the strongest of the 3 types of intermolecular forces. So the order of BP is $\text{C}_2\text{H}_6 < \text{CH}_3\text{F} < \text{CH}_3\text{OH}$.</p>
5	<p>B</p> <p>No. of moles of the molecule = $0.105 \text{ g/MM} = 0.105/304.5 = 0.000345$ moles of the molecule</p> <p>Moles of ICl used = $0.224 \text{ g/MM} = 0.224/(126.9 + 35.45) = 0.224/162.35$ moles ICl</p> <p>= 0.00138 moles ICl = moles double bonds</p> <p>No. of double bonds per molecule = No. of moles of double bonds/No. of moles of molecules = $0.00138/0.000345 = 4$</p> <p>Hence there must be 4 double bonds per molecule</p>
6	<p>A</p> <p>Only statement I is correct. The forward reaction is endothermic, so an increase in temperature will favour the forward reaction and produce a higher yield of PCl_5. Increasing the volume decreases the pressure, so the equilibrium shifts to the side with a greater no. of molecules. This is the LHS of the equation. So increasing the volume favours the backward reaction, not the production of PCl_5.</p>

7	<p>B</p> <p>Benzoic acid is a weak acid</p> $K_a \text{ C}_6\text{H}_5\text{COOH} = 6.5 \times 10^{-5}$ <p>So $K_b \text{ C}_6\text{H}_5\text{COO}^- = 1.0 \times 10^{-14} / 6.5 \times 10^{-5} = 1.54 \times 10^{-10}$</p> <p>$\text{C}_6\text{H}_5\text{COO}^-$ reacts with water to form OH^-</p> <p>Let $[\text{OH}^-] = x$</p> $K_b = [x] [x] / (0.2 - x) = 1.54 \times 10^{-10}$ $x^2 = 1.54 \times 10^{-10} \times 0.2 = 3.08 \times 10^{-11}$ $x = \sqrt{(3.08 \times 10^{-11})} = 5.55 \times 10^{-6}$ $\text{pOH} = -\log_{10} (5.55 \times 10^{-6}) = 5.26$ $\text{pH} = 14 - 5.26 = 8.74$
8	<p>B</p> $K_{sp} \text{ AgCl} = 1.8 \times 10^{-10}$ <p>If solubility of $\text{AgCl} = x$</p> <p>Then $x^2 = 1.8 \times 10^{-10}$</p> $x = 1.34 \times 10^{-5} \text{ mol/L}$ <p>Hence mass AgCl dissolving per litre = $1.34 \times 10^{-5} \times 143.4 = 0.00193 \text{ g} = 1.9 \text{ mg}$</p>
9	<p>A</p> $K_p = [\text{SO}_3] / [\text{SO}_2] [\text{O}_2]^{1/2} = 0.332 / (0.562 \times \sqrt{0.101}) = 0.332 / (0.562 \times 0.318) = 1.86$
10	<p>B</p> <p>On a ^1H NMR spectrum</p> <p>Single peak – no H atom on an adjacent C atom</p> <p>Doublet – one H atom on an adjacent C atom</p> <p>Septet – 6 equivalent H atoms on two adjacent C atoms.</p> <p>The presence of three significant peaks on the ^1H NMR spectrum indicates that the compound has three different hydrogen environments on its molecules.</p> <p>A. $(\text{CH}_3)_2\text{CHCH}_2\text{COOH}$ – 4 peaks</p> <p>B. $(\text{CH}_3)_2\text{CHCOOH}$ – 3 peaks – doublet, septet, singlet</p> <p>C. $(\text{CH}_3)_2\text{CClCH}_3$ – 1 peak</p> <p>D. $(\text{CH}_3)_2\text{CClCH}_2\text{Cl}$ – 2 peaks</p>

11	<p>C</p> <p>There are 3 isomers, including the <i>cis</i>-1,2-dibromoethene and <i>trans</i>-1,2-dibromoethene and 1,1-dibromoethene.</p> <div style="display: flex; justify-content: space-around; align-items: flex-end; text-align: center;"> <div data-bbox="279 324 534 526">  <p>1,2-dibromoethene trans-isomer</p> </div> <div data-bbox="630 324 885 526">  <p>1,2-dibromoethene cis-isomer</p> </div> <div data-bbox="981 324 1236 526">  <p>1,1-dibromoethene</p> </div> </div>
12	<p>D</p> <p>A is incorrect as ethanoic acid and ethanol would form an ester. It is an alcohol.</p> <p>B is incorrect as ethanoic acid and ethylamine form $\text{CH}_3\text{CONHCH}_2\text{CH}_3$ (not $\text{CH}_3\text{CH}_2\text{CONHCH}_3$).</p> <p>C does not react with ethanoic acid.</p> <p>D is correct as $\text{CH}_3\text{COOH} + \text{CH}_3\text{NH}_2 \rightarrow \text{CH}_3\text{CONHCH}_3$ as shown = Y</p>
13	<p>D</p> <p>The graph is typical of a weak acid reacting with a strong base. The conductance is initially low as the weak acid is only partially ionised. The conductance increases as ethanoate ions form. At the equivalence point all the ethanoic acid molecules have been neutralised, so no molecules apart from water are in the solution. After the equivalence point the conductivity increases as there is an excess of the strong base, containing K^+ and OH^- ions.</p>
14	<p>C</p> <p>Biofuels are those produced from renewable resources, not from fossil fuels. Biofuels are derived from living, or recently living, organisms and they are used to produce energy. Ethanol from biomass is identical to that produced from fossil fuels, so produces the same amount of carbon dioxide per mole and can be used in the same way. Biomass material has recently been made during photosynthesis which has removed carbon dioxide from the atmosphere.</p>
15	<p>A</p> <p>The $-\text{OH}$ group has higher priority than an $-\text{NH}_2$ group. Hence $-\text{OH}$ is on C-1 of the 4-C chain with $-\text{NH}_2$ group on C-3.</p>
16	<p>A</p> <p>Since the compound reacts with base, it must be either $\text{CH}_3\text{CH}_2\text{CH}_2\text{COOH}$ or $(\text{CH}_3)_2\text{CHCOOH}$. While (COOH^+) and $(\text{CH}_3\text{CH}_2\text{O}^+)$ are both consistent with $m/z = 45$, only (COOH^+) is consistent with the compound being an acid.</p>

17	<p>B</p> <p>Since E_{a2} is lower than E_{a1}, a catalyst (which lowers the activation energy) must have been added. The lower activation energy causes an increase in the proportion of total collisions that are successful. A catalyst does not increase the speed of particles.</p>
18	<p>D</p> <p>100 mL of 0.4 M HNO_3 contains $(100/1000) \times 0.4$ moles $\text{H}^+ = 0.04$ moles H^+ 100 mL of 0.1 M $\text{Ba}(\text{OH})_2$ contains $(100/1000) \times 0.1 \times 2$ moles $\text{OH}^- = 0.02$ moles OH^-</p> <p>There are 0.02 moles H^+ excess (after neutralisation) in 200 mL solution. Hence $(1000/200) \times 0.02 = 0.10$ moles excess H^+ per litre of final solution.</p> <p>$[\text{H}^+] = 0.1 \text{ M}$ So $\text{pH} = 1.0$</p>
19	<p>C</p> <p>The ^{13}C NMR spectrum indicates that there are 3 carbon environments.</p> <p>The IR spectrum supports the presence of $\text{C}=\text{O}$ and the lack of $\text{O}-\text{H}$ (acid) or $\text{O}-\text{H}$ (alcohol). $\text{CH}_3\text{COOCH}_3$ (option C) is the only option. CH_3COCH_3 (option D) is incorrect as this has only 2 C environments.</p>
20	<p>A</p> <p>$n(\text{KOH})$ in 20 mL titre $= 0.102 \times 20 \times 10^{-3} = 0.00204 \text{ mol}$ $n(\text{CH}_3\text{COOH})$ in 20 mL diluted $= 0.00204 \text{ mol}$ $m(\text{CH}_3\text{COOH})$ in 100 mL $= 5 \times 0.00204 \times 60 = 0.612 \text{ g}$ in 100 mL; i.e. 0.612% m/V So, vinegar has to be diluted by a factor of $3.16 / 0.612 = 5.2$ This can be achieved by diluting 20 mL original sample to 100 mL.</p>

Section II – Short responses (80 marks)

Question 21 (5 marks)

21 (a) (1 mark)

Criteria	Mark
<ul style="list-style-type: none">Identifies the change as the addition of extra oxygen, O_2, into the container.	1

Sample answer

Extra oxygen, O_2 , was added into the container.

21 (b) (1 mark)

Criteria	Mark
<ul style="list-style-type: none">Identifies $SO_3(g)$ as X and $SO_2(g)$ as Y.	1

Sample answer

$X = SO_3(g)$

$Y = SO_2(g)$

21 (c) (3 marks)

Criteria	Marks
<ul style="list-style-type: none">Explains or defines Le Chatelier's principle.Explains the changes in $[SO_3(g)]$, $[SO_2(g)]$ and $[O_2(g)]$ between 10 and 20 minutes.Explains that a new equilibrium is achieved at 20 minutes and that the concentrations of all 3 gases will remain constant (at their 20-minute values) after 20 minutes.	3
<ul style="list-style-type: none">TWO of the above.	2
<ul style="list-style-type: none">ONE of the above.	1

Sample answer

When a system is at equilibrium and a change (concentration, pressure, volume, temperature) is imposed on the system, the equilibrium will shift in a direction to compensate for, or counteract, that imposed change.

Upon addition of O_2 at 10 minutes, there is an immediate spike in the concentration of oxygen only. To compensate for this extra oxygen, the position of equilibrium moves to the right. Hence the amount of SO_3 (or X) will increase and the amount of SO_2 (or Y) will decrease. Because the forward reaction rate has temporarily increased, some (but not all) of the added O_2 will be consumed in the reaction to form additional SO_3 . Hence $[O_2(g)]$ will fall after the spike. The falls in $[O_2(g)]$ and $[SO_2(g)]$ and the increase in $[SO_3(g)]$ continue until a new equilibrium is reached at 20 minutes. This new equilibrium will have the same K_{eq} as previously but different proportions of all 3 gases.

After 20 minutes, if no further change is imposed on the equilibrium mixture, the concentrations of all 3 gases will remain at their values at 20 minutes. The lines representing the concentrations of the 3 gases will be parallel to the x-axis (time axis).

(Note: a new graph does not need to be drawn.)

Question 22 (9 marks)

22 (a) (1 mark)

Criteria	Mark
<ul style="list-style-type: none"> The forward reaction is endothermic. 	1

Sample answer*Endothermic.*

22 (b) (2 marks)

Criteria	Marks
<ul style="list-style-type: none"> Refers to the trend in the graph which shows that the concentration of ozone increases as temperature increases. <p style="text-align: center;">AND</p> <ul style="list-style-type: none"> Indicates the forward reaction must be endothermic, as a temperature increase favours the reaction which takes in heat (as an increase in temperature has a greater impact on the proportion of collisions overcoming the activation energy of the endothermic reaction than the exothermic reaction). 	2
<ul style="list-style-type: none"> Refers to the trend in the graph which shows that the concentration of ozone increases as temperature increases. <p style="text-align: center;">OR</p> <ul style="list-style-type: none"> Indicates the forward reaction must be endothermic as, by Le Chatelier's principle, a temperature increase favours the reaction which takes in heat (OR an increase in temperature has a greater impact on the proportion of collisions overcoming the activation energy of the endothermic reaction than the exothermic reaction). 	1

Sample answer

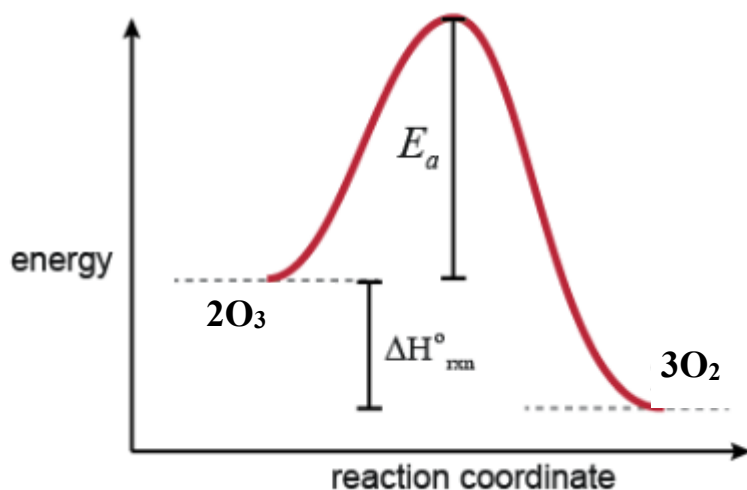
The graph shows that the concentration of ozone increases as temperature increases. The forward reaction must be endothermic as, by Le Chatelier's principle, a temperature increase favours the reaction which takes in heat. The rate of the endothermic reaction is increased more than the rate of the backward reaction when heat is added. An increase in temperature will favour the reaction that cools the reaction vessel (the endothermic reaction).

Also, an increase in temperature has a greater impact on the proportion of collisions overcoming the activation energy of the endothermic reaction than the exothermic reaction. The endothermic reaction has a greater activation energy than the reverse exothermic reaction. By collision theory, raising the temperature from 10°C to 45°C for a reaction with a higher activation energy has a greater impact on the fraction of collisions with enough energy to react. The same increase in temperature for a reaction with a lower activation energy produces only a smaller increase in the fraction of collisions with enough energy to react.

22 (c) (1 mark)

Criteria	Mark
<ul style="list-style-type: none"> Draws an energy profile for an exothermic reaction. 	1

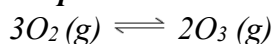
Sample answer



22 (d) (5 marks)

Criteria	Marks
<ul style="list-style-type: none"> Correct answer. 	5
<ul style="list-style-type: none"> Incorrect answer with correct reasoning but mathematical error. 	4
<ul style="list-style-type: none"> Correct calculation of concentrations of both gases at equilibrium. 	3
<ul style="list-style-type: none"> Correct calculation of moles of both gases at equilibrium. 	2
<ul style="list-style-type: none"> Evidence of some correct reasoning. 	1

Sample answer



	O_2	O_3
Initial (mol)	7.50×10^{-2}	0
Change (mol)	$-\{(3/2) \times (1.56 \times 10^{-7})\}$ $= -2.34 \times 10^{-7}$	$+1.56 \times 10^{-7}$
Equilibrium (mol)	7.50×10^{-2}	1.56×10^{-7}
Equilibrium (mol/L)	$(7.50 \times 10^{-2}) / 3 = 0.0250$	$(1.56 \times 10^{-7}) / 3 = 5.20 \times 10^{-8}$

$$K_{\text{eq}} = [\text{O}_3]^2 / [\text{O}_2]^3 = (5.20 \times 10^{-8})^2 / (0.0250)^3 = 2.704 \times 10^{-15} / 1.563 \times 10^{-5} = 1.73 \times 10^{-10}$$

Question 23 (8 marks)

23 (a) (2 marks)

Criteria	Marks
<ul style="list-style-type: none"> Estimates that the $[\text{Ba}^{2+}]$ is 19 mg/L (from graph). Calculates that mass of Ba^{2+} in 10 mL is 0.19 mg. 	2
<ul style="list-style-type: none"> Estimates that the $[\text{Ba}^{2+}]$ is 19 mg/L (from graph). 	1

Sample answer

From the graph, $[Ba^{2+}]$ remaining = 19 mg L^{-1}

$$\text{Mass Ba}^{2+} \text{ in } 10.00 \text{ mL} = (19 / 1000) \times 10 \text{ mg} = 0.19 \text{ mg}$$

23 (b) (2 marks)

Criteria	Marks
<ul style="list-style-type: none"> Calculates the no. of moles of Ba^{2+} that reacted to produce the barium sulfate precipitate. 	2
<ul style="list-style-type: none"> Calculates the mass of Ba^{2+} that reacted to produce the barium sulfate precipitate. 	1

Sample answer

$$\text{mass Ba}^{2+} \text{ added to volumetric flask} = (2.00 / 1000) \times 200 = 0.400 \text{ mg}$$

mass Ba^{2+} remaining in volumetric flask = 0.19 mg

$$\text{mass Ba}^{2+} \text{ reacted} = 0.400 - 0.19 = 0.21 \text{ mg} = 0.00021 \text{ g}$$
$$\text{No. of moles Ba}^{2+} \text{ reacted} = 0.21 \times 10^{-3} / 137.3 = 1.5 \times 10^{-6} \text{ mol}$$

23 (c) (2 marks)

Criteria	Marks
<ul style="list-style-type: none"> Calculates the no. of moles of sulfur in 25 mL surfactant. <p style="text-align: center;">AND</p> <ul style="list-style-type: none"> Calculates the mass of sulfur, in mg, on the 100.0 g of grapes. 	2
<ul style="list-style-type: none"> Calculates the no. of moles of sulfur in 25 mL surfactant. 	1

Sample answer

$$\begin{aligned} n(S) \text{ in } 25 \text{ mL surfactant} &= n(\text{BaSO}_4) \text{ precipitated in volumetric flask} \\ &= n(\text{Ba}^{2+}) \text{ reacted} = 1.5 \times 10^{-6} \text{ mol} \end{aligned}$$
$$n(S) \text{ in } 100.0 \text{ g of grapes} = n(S) \text{ in } 100 \text{ mL surfactant} = 4 \times 1.5 \times 10^{-6} = 6.0 \times 10^{-6} \text{ mol}$$
$$m(S) \text{ in } 100.0 \text{ g of grapes} = 6.0 \times 10^{-6} \times 32.1 = 1.9 \times 10^{-4} \text{ g} = 0.19 \text{ mg}$$

23 (d) (2 marks)

Criteria	Marks
<ul style="list-style-type: none">Explains TWO reasons why AAS is a better way of determining the amount of S left on grapes than gravimetric analysis.	2
<ul style="list-style-type: none">Explains ONE reason why AAS is a better way of determining the amount of S left on grapes than gravimetric analysis.	1

Sample answer

Gravimetric analysis is less accurate than AAS when very small quantities are to be precipitated and weighed.

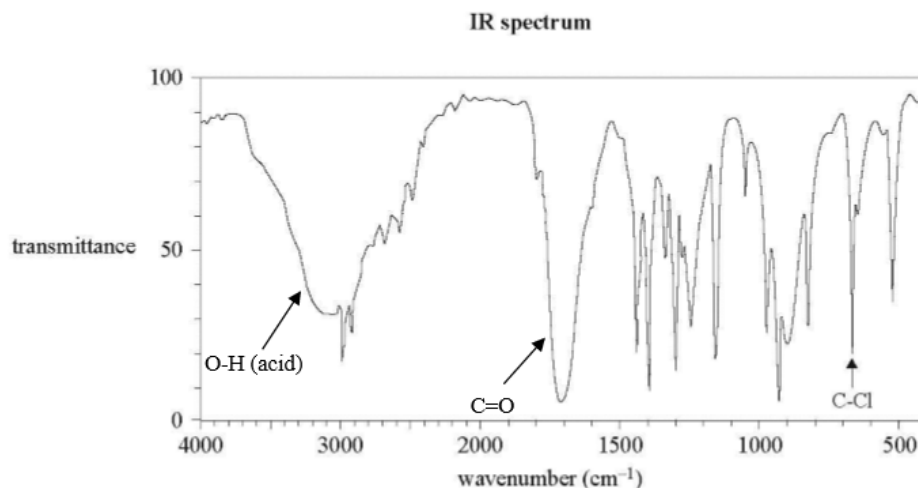
The percentage error due to loss of solid during precipitation, filtering, weighing and drying is likely to be greater in gravimetric analysis than in an instrumental analysis which is very sensitive, in that small concentrations can be detected and measured against standards.

A large mass of grapes is needed for effective gravimetric analysis, whereas only a small but representative sample is needed for AAS analysis.

Question 24 (8 marks)

24 (a) (1 mark)

Criteria	Mark
<ul style="list-style-type: none"> Identifies correctly 2 peaks on the infrared spectrum as an –OH from an acid AND a carbonyl group (C=O). 	1

Sample answer

24 (b) (1 mark)

Criteria	Mark
<ul style="list-style-type: none"> Identifies the compound as acidic <p style="text-align: center;">OR</p> <ul style="list-style-type: none"> Concludes that the compound contains a –COOH group. 	1

Sample answer

The compound forms an acidic solution, so probably contains a –COOH group.

24 (c) (1 mark)

Criteria	Mark
<ul style="list-style-type: none"> Identifies that the molecular mass is approximately 110 because of the m/z ratio of the parent peak(s). 	1

Sample answer

The mass spectrum indicates that there are 2 parent peaks, at m/z ratios of 108 and 110 – hence the molecular mass will be 108 or 110 depending on which chlorine isotope is present.

24 (d) (2 marks)

Criteria	Marks
<ul style="list-style-type: none"> Indicates there are three hydrogen environments in the molecule. <p style="text-align: center;">AND</p> <ul style="list-style-type: none"> Indicates (from the splitting patterns) that <ul style="list-style-type: none"> one hydrogen environment has three neighbouring H atoms, one hydrogen environment has one neighbouring H atom, and one hydrogen environment has no neighbouring H atoms. 	2
<ul style="list-style-type: none"> Indicates there are three hydrogen environments in the molecule. 	1

Sample answer

There are 3 different hydrogen environments on the molecule, one with three neighbouring H, one with one neighbouring H and one with no neighbouring H atoms.

NMR provides information on how many hydrogen neighbours exist for a particular hydrogen or group of equivalent hydrogens. In general, an NMR resonance will be split into $N + 1$ peaks where N = number of hydrogens on the adjacent atom or atoms.

If there are **no hydrogens** on the adjacent atoms, then the resonance will remain a single peak, a **singlet**.

If there is **one hydrogen** on the adjacent atoms, the resonance will be split into two peaks of equal size, a **doublet**.

Two hydrogens on the adjacent atoms will split the resonance into three peaks with an area in the ratio of **1:2:1**, a **triplet**.

If there are **3 hydrogens** on the adjacent atoms, the resonance will be split into four peaks with an area in the ratio of **1:3:3:1**, a **quartet**.

Hence, 2 of the three hydrogen environments are CH_3 and CH ; the third is COOH .

24 (e) (2 marks)

Criteria	Marks
<ul style="list-style-type: none"> Uses the data from the mass spectrum, ^1H NMR spectrum and the ^{13}C NMR spectrum to conclude that there are 3 carbon atoms, 5 hydrogen atoms (and 1 chlorine atom) in the molecule. 	2
<ul style="list-style-type: none"> Uses the data from the spectra to make a correct conclusion about either the number of carbons or the number of hydrogen atoms. 	1

Sample answer

Since the molecular mass is approximately 109 and assuming only 1 chlorine is present, the total mass of carbon and hydrogen is close to 74.

The chlorine atom must be attached to a carbon atom (see IR spectrum).

This would correspond to 3 carbons, 2 oxygens and 5 hydrogens ($36 + 32 + 5$)

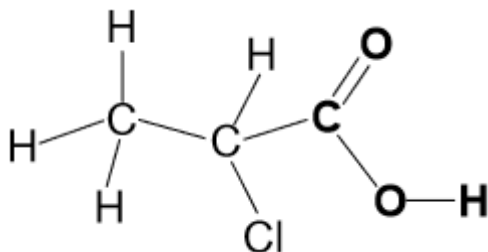
The conclusion from part (b) is that the compound is an acid.

The conclusions from the ^{13}C NMR and ^1H NMR spectra and splitting patterns is that there are 3 carbons and 5 hydrogens. A chlorine is attached to the carbon of the $-\text{CH}$ group.

24 (f) (1 mark)

Criteria	Mark
<ul style="list-style-type: none"> Draws a molecular formula that corresponds to the conclusion in part (e). 	1

Sample answer



Question 25 (11 marks)

25 (a) (2 marks)

Criteria	Marks
<ul style="list-style-type: none"> Correctly identifies all 4 liquids. 	2
<ul style="list-style-type: none"> Correctly identifies 2 liquids. 	1

Sample answer

A = hex-3-ene

B = ethanoic acid

C = ethanol

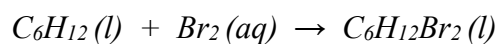
D = pentane

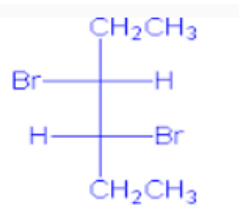
25 (b) (3 marks)

Criteria	Marks
<ul style="list-style-type: none"> Identifies the reaction between A and bromine as an addition reaction. Writes a balanced equation. Draws the structure of the compound formed 3,4-dibromohexane. 	3
<ul style="list-style-type: none"> TWO of the above. 	2
<ul style="list-style-type: none"> ONE of the above. 	1

Sample answer

The reaction between hex-3-ene and bromine solution is addition.



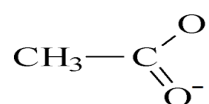
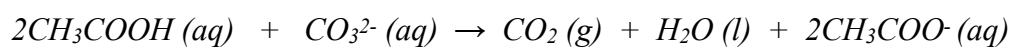


25 (c) (3 marks)

Criteria	Marks
<ul style="list-style-type: none">Identifies the reaction between B and sodium carbonate solution as an acid-base reaction.Writes a balanced equation.Draws the structure of the ethanoate ion.	3
<ul style="list-style-type: none">TWO of the above.	2
<ul style="list-style-type: none">ONE of the above.	1

Sample answer

An acid-base reaction occurs.



25 (d) (3 marks)

Criteria	Marks
<ul style="list-style-type: none"> Discusses the solubilities of the 4 substances in water by correctly identifying: <ul style="list-style-type: none"> the structures and polarity of each of the 4 substances <p style="text-align: center;">AND</p> <ul style="list-style-type: none"> the strength of the intermolecular (or ionic) forces between the substances and water. 	3
<ul style="list-style-type: none"> Discusses the solubilities of 3 of the 4 substances in water by correctly identifying: <ul style="list-style-type: none"> the structures and polarity of each of the 3 substances <p style="text-align: center;">AND</p> <ul style="list-style-type: none"> the strength of the intermolecular (or ionic) forces between the substances and water. 	2
<ul style="list-style-type: none"> Discusses some correct information about the solubility of carbon compounds in water. 	1

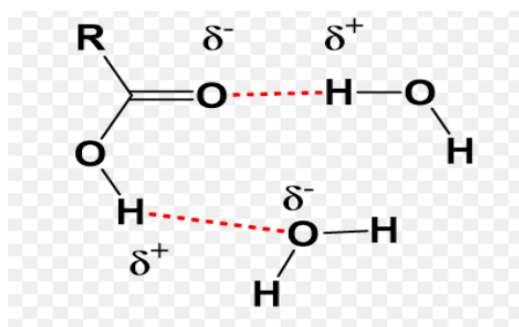
Sample answer

A = hex-3-ene

This is a non-polar covalently bonded molecule, while water is polar. The liquids do not form a solution as the water molecules are strongly attracted to other water molecules by hydrogen bonding. These strong intermolecular forces mean that water and hex-3-ene form immiscible layers. Hex-3-ene molecules are only attracted to each other by weak temporary dipole-dipole forces/dispersion forces.

B = ethanoic acid

This covalently bonded molecule dissolves in water because the polar part of the molecule, the -COOH group, is attracted to water by strong intermolecular hydrogen bonding between the H of the -COOH group (which has a δ^+ charge due to the polar bond with oxygen of the -OH group) and the O of water.

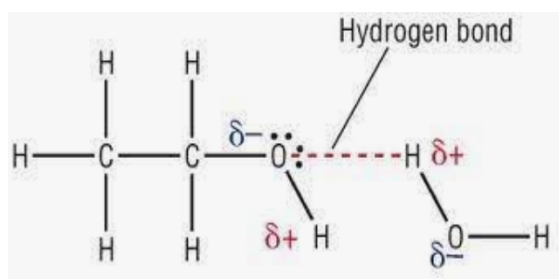


In addition, ethanoic acid is a weak acid and partially ionises in water to form hydronium and ethanoate ions. These dissolve in water due to the attraction between the charged ions and polar water molecules. As a result, ethanoic acid dissolves readily in water and does not form layers.

The response continues on the next page

C = ethanol

Ethanol is a polar molecule. It is described as having a “dual” nature, as it has both polar and non-polar parts to the molecule. The polar –OH end of the molecule forms strong hydrogen bonding, allowing ethanol to be totally miscible in water. No layers form. The strength of hydrogen bonding and the small hydrocarbon chain (which has no attraction for water) means that the net result is ethanol and water are completely miscible.



D = pentane

This is a non-polar covalently bonded molecule, while water is polar. The liquids do not form a solution as the water molecules are strongly attracted to other water molecules by hydrogen bonding. These strong intermolecular forces mean that water and pentane form immiscible layers. Pentane molecules are only attracted to each other by weak temporary dipole-dipole forces/dispersion forces.

Question 26 (13 marks)

26 (a) (4 marks)

Criteria	Marks
<ul style="list-style-type: none"> Justifies the statement. Correctly outlines the theories of Arrhenius and Brønsted-Lowry. Provides examples of acids and bases which illustrate each theory. Provides examples of substances which are classified as acids or bases by one but not the other of these theories. 	4
<ul style="list-style-type: none"> Correctly outlines the theories of Arrhenius and Brønsted-Lowry. Provides examples of acids and bases which illustrate each theory. Provides examples of substances which are classified as acids or bases by one but not the other of these theories. 	3
<ul style="list-style-type: none"> Correctly outlines the theories of Arrhenius and Brønsted-Lowry. Provides examples of acids and bases which illustrate each theory <p style="text-align: center;">OR</p> <ul style="list-style-type: none"> Provides examples of substances which are classified as acids or bases by one but not the other of these theories. 	2
<ul style="list-style-type: none"> Correctly outlines the theory of Arrhenius OR Brønsted-Lowry. 	1

Sample answer

Swedish scientist, Svante Arrhenius (in 1887) described acids as compounds which produced hydrogen ions (we would now say hydronium ions) as the only positive ions in an aqueous solution. Hence the solvent is water and substances such as ammonium ion or iron (III) chloride solution could not be described as acids, even though they do result in solutions with a $pH < 7$.

The Brønsted-Lowry theory (1923) defines acids and bases by their structures. A Brønsted-Lowry acid is capable of donating a proton, regardless of its state or the nature of the solvent.

Arrhenius described bases as the hydroxides of alkali and alkaline earth metals. These bases are known as alkalis. These include sodium hydroxide, potassium hydroxide, barium hydroxide and calcium hydroxide.

Brønsted-Lowry bases are capable of accepting a proton. This is irrespective of state and the reaction does not need to be occurring in water. Ammonia gas accepts a proton from hydrogen chloride gas, forming a solid salt.

Even before the times of Arrhenius, Brønsted and Lowry, other scientists such as Lavoisier (1777) and Davy (1810) had put forward theories, based on experiments, that claimed that oxygen and hydrogen (respectively) were common in all acids.

Hence the statement is correct. Acids and bases have been defined differently by scientists over several centuries.

26 (b) (3 marks)

Criteria	Marks
<ul style="list-style-type: none"> Correct pH values calculated for both acids, with working. 	3
<ul style="list-style-type: none"> Correct pH value for ONE of the TWO acids, with a mathematical error in the other calculation. 	2
<ul style="list-style-type: none"> ONE correct pH value calculated. 	1

Sample answer

For 0.001 M HCl

$$pH = \log_{10} [H^+] = \log_{10}(0.001) = 3$$

For 0.001 M HOCl

$$K_a = [H^+] [OCl^-] / [HOCl] = 3.0 \times 10^{-8}$$

Let x moles HOCl ionise

$$x^2 = 3.0 \times 10^{-8} \times 0.001$$

$$[H^+] = \sqrt{(3.0 \times 10^{-11})} = 0.0000054 = 5.4 \times 10^{-6} \text{ mol/L}$$

$$pH = \log_{10} [H^+] = \log_{10}(5.4 \times 10^{-6}) = 5.27$$

26 (c) (2 marks)

Criteria	Marks
<ul style="list-style-type: none"> Accounts for the difference in pH values for the acids HCl and HOCl, in terms of the degrees of dissociation. 	2
<ul style="list-style-type: none"> Outlines that HCl is a strong acid and HOCl is a weak acid. 	1

Sample answer

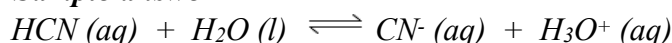
HCl is a strong acid so all the molecules are completely dissociated in water. No equilibrium exists. The $[H^+]$ is the same as the concentration of the acid.

HOCl is a weak acid. It only partially ionises in water, so the proportion of molecules converted to ions is small. Significantly less than 100% of molecules are converted into ions, so the $[H^+]$ is much smaller than for HCl. Hence the pH is much higher.

26 (d) (4 marks)

Criteria	Marks
<ul style="list-style-type: none"> Calculates the pH to 2 s.f. Explains why this mixture is classified as a buffer. 	4
<ul style="list-style-type: none"> Calculates the pH with correct steps but a mathematical error. Explains why this mixture is classified as a buffer. 	3
<ul style="list-style-type: none"> Determines the $[H_3O^+]$ in the buffer <p style="text-align: center;">AND</p> <ul style="list-style-type: none"> Explains why this mixture is classified as a buffer. 	2
<ul style="list-style-type: none"> Determines the $[H_3O^+]$ in the buffer <p style="text-align: center;">OR</p> <ul style="list-style-type: none"> Explains why this mixture is classified as a buffer. 	1

Sample answer



$$K_a HCN = \frac{[CN^-][H_3O^+]}{[HCN]} = 4.9 \times 10^{-10}$$

On mixing, the volume is 100 mL

$$\text{Initial } [HCN] = 0.010 \text{ mol/L}$$

$$\text{Initial } [CN^-] = 0.055 \text{ g} / 100 \text{ mL} = (0.055 / 49.01) \text{ mol} / 100 \text{ mL} = 0.001122 \text{ mol} / 100 \text{ mL} = 0.01122 \text{ mol/L}$$

Let x mol/L HCN ionise at equilibrium.

At equilibrium

$$[HCN] = (0.010 - x) \text{ mol/L}$$

$$[CN^-] = (0.01122 + x) \text{ mol/L}$$

$$[H_3O^+] = x \text{ mol/L}$$

$$K_a HCN = \frac{[CN^-][H_3O^+]}{[HCN]} = 4.9 \times 10^{-10} = \frac{(0.01122 + x)(x)}{(0.010 - x)}$$

Assume x is small by comparison with 0.01122 and with 0.010 mol/L

$$K_a HCN = \frac{[CN^-][H_3O^+]}{[HCN]} = 4.9 \times 10^{-10} = \frac{(0.01122)(x)}{(0.010)}$$

$$[H_3O^+] = x = 4.367 \times 10^{-10} \text{ mol/L}$$

$$pH = 9.36$$

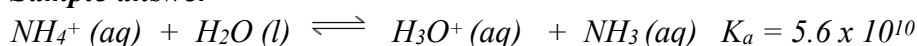
A buffer solution is one which will maintain an almost constant pH, even if small quantities of strong acid or base are added to it. As long as there are close to equal moles of equal concentration solutions making up the buffer mixture, and the acid and base are both only

moderately strong as acids and bases, the solution will stay at close to the pH value 9.36, as calculated above. By Le Chatelier's Principle, if $[x]$ is small by comparison with the concentrations of the acid and base, if the concentration of H^+ in the buffer mixture changes slightly, the proportions of HCN and CN^- will change to keep the pH close to 9.36.

Question 27 (6 marks)

27 (a) (3 marks)

Criteria	Marks
• Correctly calculates the K_{sp} of ammonium chloride, including all working and reasoning.	3
• Incorrect answer due to mathematical error but with correct method and reasoning.	2
• Some evidence of correct method and reasoning.	1

Sample answer

In a saturated solution of NH_4Cl , at $25^\circ C$, the $pH = 4.67$

$$\text{Hence } [H^+] = 10^{-4.67} = 0.00002138 = 2.138 \times 10^{-5} \text{ mol/L}$$

Substituting into the acid dissociation constant equilibrium constant expression

$$K_{eq} = [H_3O^+][NH_3] / [NH_4^+] = 5.6 \times 10^{-10}$$

$$\text{If } [H_3O^+] = 2.138 \times 10^{-5}, \text{ then } [NH_3] = 2.138 \times 10^{-5}$$

$$\text{Thus } [NH_4^+] = (2.138 \times 10^{-5})^2 / 5.6 \times 10^{-10} = 0.816 \text{ mol/L}$$

$$\text{Hence } K_{sp} NH_4Cl = [NH_4^+][Cl^-] = (0.816)^2 = 0.67$$

27 (b) (1 mark)

Criteria	Mark
• Correctly calculates the solubility of ammonium chloride at $25^\circ C$.	1

Sample answer

Let solubility of $NH_4Cl = x$

$$K_{sp} = [NH_4^+][Cl^-] = x^2$$

$$x = \sqrt{0.67} = 0.82 \text{ mol/L}$$

27 (c) (2 marks)

Criteria	Marks
• Determines that precipitation of $AgCl$ will occur, by showing $Q > K_{sp}$ $AgCl$.	2
• Shows some correct working and reasoning.	1

Sample answer

When ammonium chloride solution is saturated, at $25^\circ C$, $[Cl^-] = 0.82 \text{ mol/L}$

$$= 0.082 \text{ mol/100 mL}$$

$$\text{Moles of } Ag^+ \text{ added} = (0.1/1000) \times 2.0 \times 10^{-5} = 2.0 \times 10^{-9}$$

$$\text{Total volume of solution} = 100.1 \text{ mL}$$

$$[\text{Cl}^-] = 0.82 \text{ mol/L}$$

$$[\text{Ag}^+] = 2.0 \times 10^{-9} \text{ mole per } 100.1 \text{ mL} = 2.0 \times 10^{-8} \text{ mol/L}$$

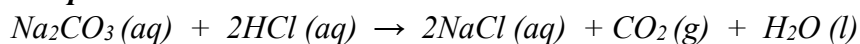
$$Q = [\text{Ag}^+] [\text{Cl}^-] = 0.82 \times 2.0 \times 10^{-8} = 1.64 \times 10^{-8}$$

Since Q is greater than 1.77×10^{-10} (the K_{sp} AgCl),
then precipitation of AgCl will occur.

Question 28 (8 marks)

28 (a) (1 mark)

Criteria	Mark
<ul style="list-style-type: none"> Correct answer. 	1

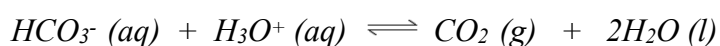
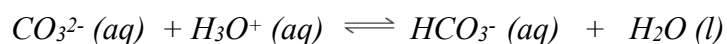
Sample answer

28 (b) (3 marks)

Criteria	Marks
<ul style="list-style-type: none"> Explains that the overall reaction occurs in 2 steps, as the carbonate ion is dibasic (can react with 2 hydrogen ions) with each step having an equivalence point. Writes TWO correct equations for the reactions corresponding to the TWO steps. 	3
<ul style="list-style-type: none"> Explains that the overall reaction occurs in 2 steps, with each step having an equivalence point. Writes ONE correct equation for the reactions corresponding to ONE of the steps. 	2
<ul style="list-style-type: none"> ONE of the above. 	1

Sample answer

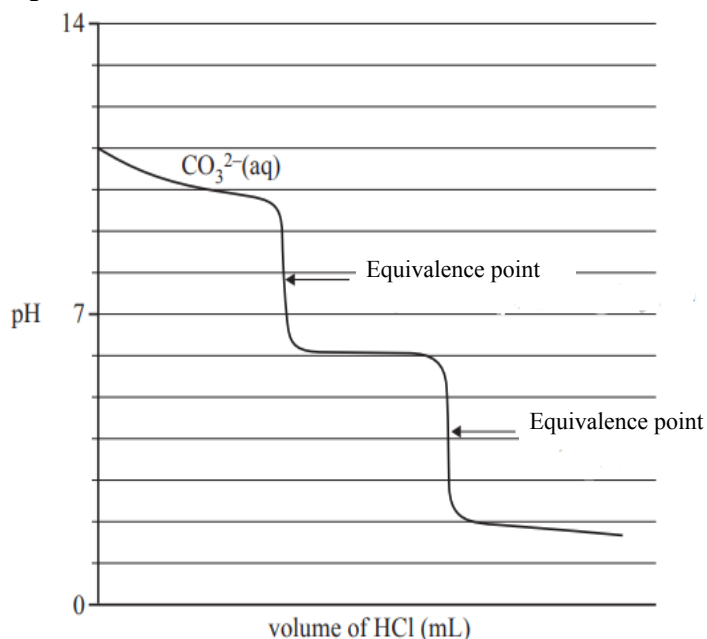
The overall reaction occurs in 2 steps, as the carbonate ion is dibasic (can react with 2 hydrogen ions), with each step having an equivalence point.



28 (c) (2 marks)

Criteria	Marks
<ul style="list-style-type: none"> Sketches a graph of the correct shape, showing 2 equivalence points at the correct pH values. 	2
<ul style="list-style-type: none"> Sketches a graph of the correct shape. 	1

Sample answer



28 (d) (1 mark)

Criteria	Mark
<ul style="list-style-type: none"> Identifies the predominant species at pH 8. 	1

Sample answer

Hydronium ions, H_3O^+ , chloride ions, Cl^- , hydrogen carbonate ions, HCO_3^- , sodium ions, Na^+ , (CO_3^{2-} and OH^- in very low concentration)

28 (e) (1 mark)

Criteria	Mark
<ul style="list-style-type: none"> Identifies 2 indicators, one that changes colour at pH 8 and the other at pH 3-4. 	1

Sample answer

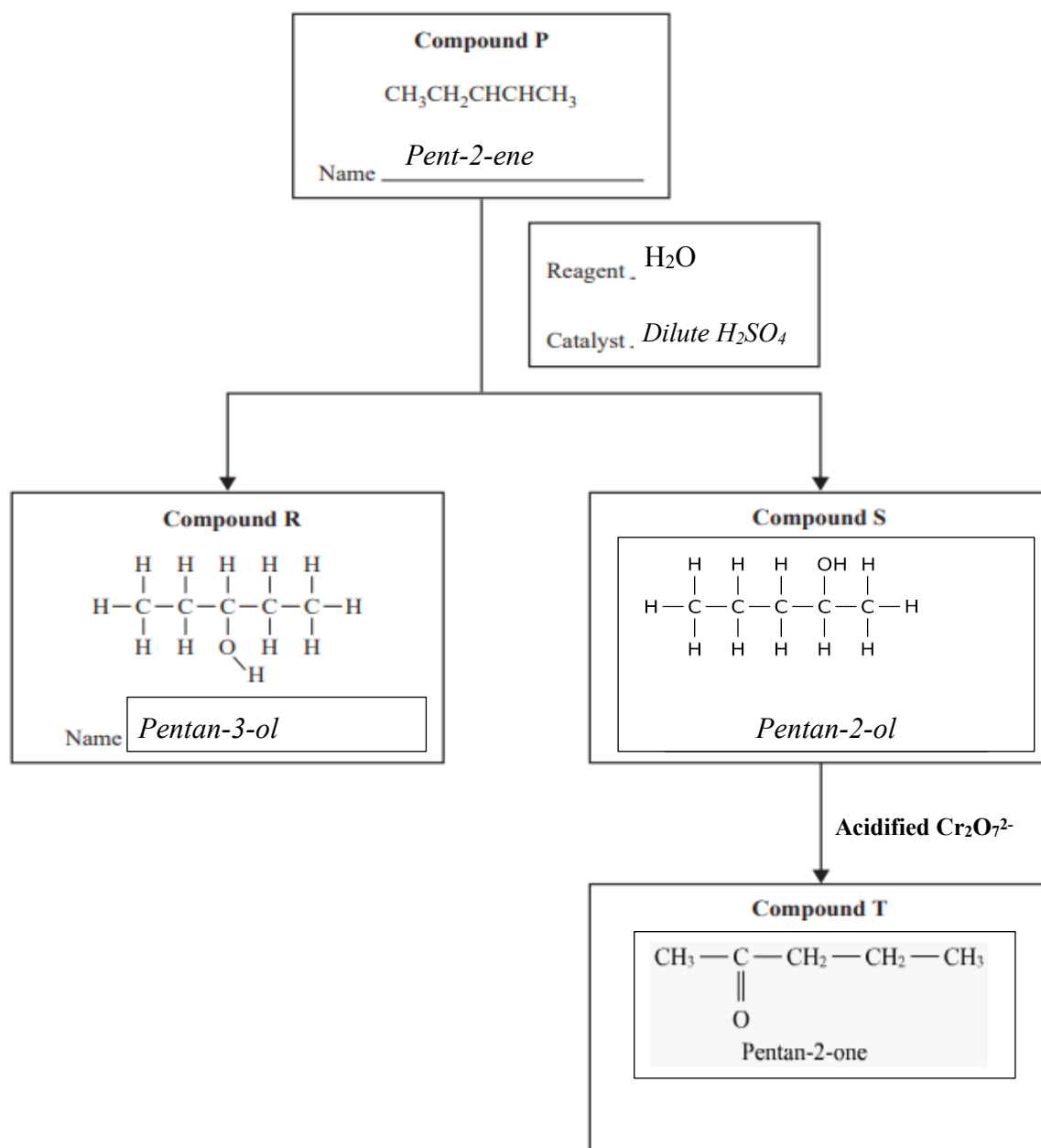
Phenolphthalein will change colour at the first equivalence point (pH 8) – from pink to colourless.

Methyl orange will change colour at the second equivalence point (pH 3–4) – from yellow to red.

Question 29 (8 marks)

Criteria	Marks
• 8 correct answers.	8
• 7 correct answers.	7
• 6 correct answers.	6
• 5 correct answers.	5
• 4 correct answers.	4
• 3 correct answers.	3
• 2 correct answers.	2
• 1 correct answer.	1

Sample answer



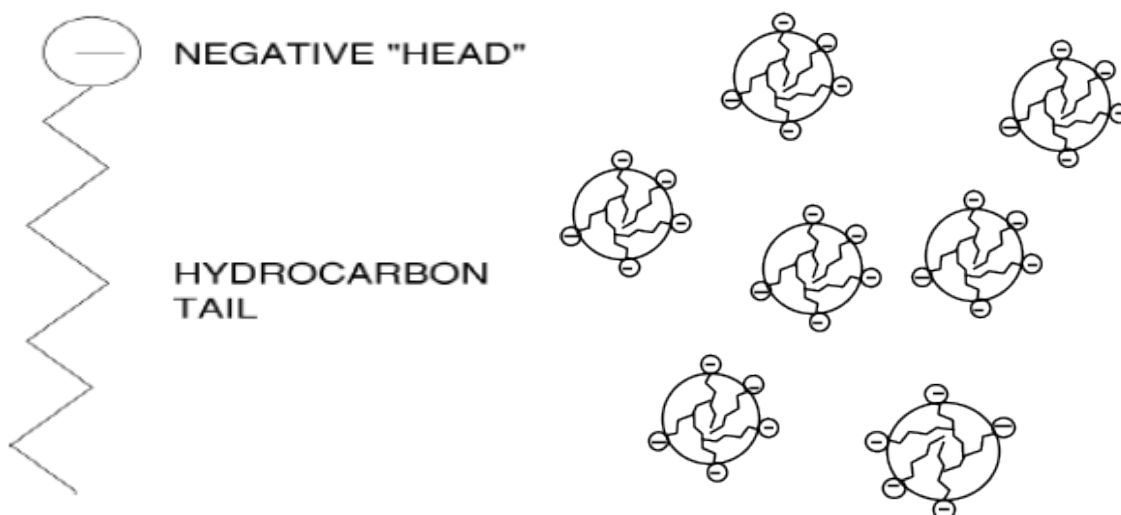
Question 30 (4 marks)

30 (a) (2 marks)

Criteria	Marks
<ul style="list-style-type: none">Describes how the recovery process requires a surfactant which will remove the oil <p style="text-align: center;">AND</p> <ul style="list-style-type: none">Uses a diagram to show the hydrophobic and hydrophilic parts of a soap molecule and explains the cleaning process.	2
<ul style="list-style-type: none">Describes how the recovery process requires a surfactant which will remove the oil <p style="text-align: center;">OR</p> <ul style="list-style-type: none">Uses a diagram to show the hydrophobic and hydrophilic parts of a soap molecule and explains the cleaning process.	1

Sample answer

A surfactant is a substance that disperses dirt and grease as small particles throughout the water. Soap is the sodium or potassium salt of a long-chain fatty acid. It has a hydrophobic (hydrocarbon) tail which is attracted to oil or grease, and a negatively charged hydrophilic head, which is attracted to water. The small spherical particles are called micelles. The oil is represented by the circle. The hydrophobic tails are attracted to the oil, while the anionic heads are on the outer surface of the micelle, closest to the water. The ions in the water will be attracted to the outer surface of the micelles. When the surfactant is washed away from the object, the oil and some of the ions go with the water.

SOAP ION

30 (b) (2 marks)

Criteria	Marks
<ul style="list-style-type: none">Compares the process of removal of ions embedded in an object from the ocean with the leaching of toxins from food, noting the similarity between the 2 processes.	2
<ul style="list-style-type: none">Recognises that both processes are related to discarding a saturated solution and replacing it with pure water, allowing new dissolution until the solution again becomes saturated.	1

Sample answer

In a saturated solution there is an equilibrium, as ions are constantly leaving the surface of the solid and returning to the surface at the same rate. If the solid is removed from a saturated solution and more water added, the solid will dissolve until the solution is again saturated (or all the solid has been converted to ions if the solubility has not been reached).

When an object is recovered from the ocean, salts are usually embedded within the object. To restore the artefact, a process of leaching is used. This involves placing the artefact in water including surfactant for an extended period so that the salts can dissolve. Once the water becomes saturated with the ions from the salt, no further removal of salt from the artefact can occur. If the saturated solution is discarded and replaced with water including surfactant, new dissolution will occur until the solution again becomes saturated. This process is repeated with pure water until the solution contains a minimal concentration of ions in solution.

In removing the toxicity from foods, a similar repeated process of leaching and discarding the saturated solution occurs. The food, such as seeds from cycad plants, is crushed and left over time for the toxic chemicals to be dissolved. Once the solution is saturated, the solution is discarded and replaced by pure water. Once the majority of the toxicity has been removed by this leaching process, the food is then baked to bring about chemical changes and destroy any remnants of the toxic chemical.

**2023 Higher School Certificate
Trial Examination
Chemistry**

Section 1 Mapping Grid

Question	Marks	Content	Syllabus Outcomes
1	1	Mod 5: Solution Equilibria	12–4, 12–6, 12–12
2	1	Mod 6: Using Brønsted-Lowry Theory	12–6, 12–13
3	1	Mod 8: Analysis of Inorganic Substances	12–5, 12–15
4	1	Mod 7: Hydrocarbons; Alcohols; Products of Reaction involving Hydrocarbons	12–6, 12–14
5	1	Mod 7: Products of Reaction involving Hydrocarbons	12–6, 12–14
6	1	Mod 5: Factors that Affect Equilibrium	12–5, 12–12
7	1	Mod 6: Quantitative Analysis	12–6, 12–13
8	1	Mod 5: Solution Equilibria	12–4, 12–6, 12–12
9	1	Mod 5: Calculating the Equilibrium Constant	12–6, 12–12
10	1	Mod 8: Analysis of Organic Substances	12–6, 12–15
11	1	Mod 7: Nomenclature	12–5, 12–14
12	1	Mod 7: Reactions of Organic Acids and Bases	12–5, 12–14
13	1	Mod 6: Quantitative Analysis	12–6, 12–13
14	1	Mod 7: Alcohols	12–7, 12–14
15	1	Mod 7: Nomenclature	12–7, 12–14
16	1	Mod 8: Analysis of Organic Substances	12–5, 12–15
17	1	Mod 5: Factors that Affect Equilibrium	12–5, 12–12
18	1	Mod 6: Using the Brønsted-Lowry Theory	12–5, 12–13
19	1	Mod 8: Analysis of Organic Substances	12–5, 12–15
20	1	Mod 6: Quantitative Analysis	12–6, 12–13

Section II Mapping Grid

Question	Marks	Content	Syllabus Outcomes
21 (a)	1	Mod 5: Factors that Affect Equilibrium	12-4, 12-5, 12-7, 12-12
21 (b)	1	Mod 5: Factors that Affect Equilibrium	12-4, 12-5, 12-7, 12-12
21 (c)	3	Mod 5: Factors that Affect Equilibrium	12-4, 12-7, 12-12
22 (a)	1	Mod 5: Factors that Affect Equilibrium	12-4, 12-5, 12-7, 12-12
22 (b)	2	Mod 5: Factors that Affect Equilibrium	12-4, 12-7, 12-12
22 (c)	1	Mod 5: Factors that Affect Equilibrium	12-4, 12-7, 12-12
22 (d)	5	Mod 5: Calculating the Equilibrium Constant	12-6, 12-12
23 (a)	2	Mod 8: Analysis of Inorganic Substances	12-5, 12-6, 12-15
23 (b)	2	Mod 8: Analysis of Inorganic Substances	12-5, 12-6, 12-15
23 (c)	2	Mod 8: Analysis of Inorganic Substances	12-5, 12-6, 12-15
23 (d)	2	Mod 8: Analysis of Inorganic Substances	12-7, 12-15
24 (a)	1	Mod 8: Analysis of Organic Substances	12-5, 12-6, 12-7, 12-15
24 (b)	1	Mod 8: Analysis of Organic Substances	12-5, 12-15
24 (c)	1	Mod 8: Analysis of Organic Substances	12-5, 12-15
24 (d)	2	Mod 8: Analysis of Organic Substances	12-5, 12-15
24 (e)	2	Mod 8: Analysis of Organic Substances	12-6, 12-7, 12-15
24 (f)	1	Mod 8: Analysis of Organic Substances	12-7, 12-15
25 (a)	2	Mod 8: Analysis of Organic Substances	12-5, 12-6, 12-14, 12-15
25 (b)	3	Mod 7: Hydrocarbons	12-5, 12-7, 12-14
25 (c)	3	Mod 7: Reactions of Organic Acids and Bases	12-6, 12-7, 12-14
25 (d)	3	Mod 7: Hydrocarbons, Alcohols, Reactions of Organic Acids and Bases	12-7, 12-14, 12-15
26 (a)	4	Mod 6: Properties of Acids and Bases	12-7, 12-13
26 (b)	3	Mod 6: Quantitative Analysis	12-6, 12-13
26 (c)	2	Mod 6: Using the Brønsted-Lowry Theory	12-7, 12-13
26 (d)	4	Mod 6: Quantitative Analysis	12-6, 12-13
27 (a)	3	Mod 6: Quantitative Analysis Mod 5: Solution Equilibria	12-6, 12-12, 12-13
27 (b)	1	Mod 5: Solution Equilibria	12-6, 12-12
27 (c)	2	Mod 5: Solution Equilibria	12-6, 12-12
28 (a)	1	Mod 6: Properties of Acids and Bases	12-7, 12-13
28 (b)	3	Mod 6: Quantitative Analysis	12-7, 12-13
28 (c)	2	Mod 6: Quantitative Analysis	12-4, 12-7, 12-13, 12-14

28 (d)	1	Mod 6: Quantitative Analysis	12–7, 12–13
28 (e)	1	Mod 6: Quantitative Analysis	12–7, 12–13
29	8	Mod 8: Analysis of Organic Substances	12–5, 12–7, 12–15
30 (a)	2	Mod 7: Reactions of Organic Acids and Bases	12–7, 12–14
30 (b)	2	Mod 5: Solution Equilibria	12–7, 12–12