Semester One
Examination 2024
Question/Answer Booklet

CHEMISTRY
UNIT 3

Name: MARKING KEY

Teacher: _____

TIME ALLOWED FOR THIS PAPER

Reading time before commencing work:	Ten minutes
Working time for the paper:	Three hours

MATERIALS REQUIRED/RECOMMENDED FOR THIS PAPER

To be provided by the supervisor:
This Question/Answer Booklet
Multiple-choice Answer Sheet
Chemistry Data Book

To be provided by the candidate:

Standard items:	pens, pencils, eraser or correction fluid, ruler, highlighter.
Special items:	calculators satisfying the conditions set by the SCSA for this subject.

IMPORTANT NOTE TO CANDIDATES
No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Multiple-choice	25	25	50	_____ / 25	_____ / 25
Section Two: Short answer	10	10	60	_____ / 73	_____ / 35
Section Three: Extended answer	5	5	70	_____ / 86	_____ / 40
				Total	%

Instructions to candidates

1. Answer the questions according to the following instructions.

   Section One: Answer all questions on the separate Multiple-choice Answer Sheet provided. For each question shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

   Sections Two and Three: Write your answers in this Question/Answer Booklet.

2. When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.

3. You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.

4. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
   - Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
   - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

5. The Chemistry Data Book is **not** handed in with your Question/Answer Booklet.

See next page

Section One: Multiple-choice **25% (25 marks)**

This section has **25** questions. Answer **all** questions on the separate Multiple-choice Answer Sheet provided. For each question, shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time: 50 minutes.

1. Increased levels of atmospheric carbon dioxide gas have an indirect effect on marine organisms who depend on the process of calcification for survival. The following equation represents one of the many carbon-related equilibria in the ocean.

$$CaCO_3(s) + H_2O(l) + CO_2(g) \rightleftharpoons Ca^{2+}(aq) + 2\,HCO_3^-(aq)$$

Increased levels of atmospheric $CO_2(g)$ would **not** result in

(a) an increased concentration of $HCO_3^-(aq)$.
(b) an increased rate of decalcification.
(c) a decreased concentration of $CO_2(aq)$.
(d) a decreased quantity of $CaCO_3(s)$.

2. A 10.00 mL aliquot of KOH(aq) was placed in a flask and 90.00 mL of distilled water was added. When compared to the original undiluted aliquot, the pH of the diluted solution would be

(a) one unit higher.
(b) one unit lower.
(c) unchanged.
(d) unable to be determined.

3. In the following list of compounds, how many **different** oxidation states are displayed by the element manganese?

$KMnO_4$ MnO_2 $MnCl_2$ Mn_2O_7 $MnCO_3$

(a) 2
(b) 3
(c) 4
(d) 5

4. Identify the reducing agent in the following chemical equation.

$$2\,HNO_2(aq) + 4\,H^+(aq) + 4\,Ag(s) + 2\,SO_4^{2-}(aq) \rightarrow N_2O(g) + 2\,Ag_2SO_4(s) + 3\,H_2O(l)$$

(a) $HNO_2(aq)$
(b) $H^+(aq)$
(c) $Ag(s)$
(d) $SO_4^{2-}(aq)$

See next page

Questions 5, 6 and 7 refer to the equilibrium system below.

Consider the following reversible reaction that has established equilibrium.

$$CH_4(g) + H_2O(g) \rightleftharpoons CH_3OH(g) + H_2(g) \qquad K_c = 2.8 \times 10^{-21}$$

5. Identify the effect, on both the forward and reverse reaction rates, if the volume of this system was doubled.

	Forward reaction rate	Reverse reaction rate
(a)	increased	increased
(b)	decreased	decreased
(c)	no change	no change
(d)	increased	decreased

6. Identify the effect, on both the forward and reverse reaction rates, if an appropriate catalyst was added to this system.

	Forward reaction rate	Reverse reaction rate
(a)	increased	increased
(b)	decreased	decreased
(c)	no change	no change
(d)	increased	decreased

7. The value of K_c indicates that

(i) The reaction reaches equilibrium quickly.
(ii) The reaction reaches equilibrium slowly.
(iii) The equilibrium mixture contains predominantly reactants.
(iv) The equilibrium mixture contains predominantly products.

(a) (i) and (iii) only.
(b) (ii) and (iii) only.
(c) (i) and (iv) only.
(d) (iii) only.

8. Which of the following statements is true, under standard conditions?

(a) Acidified permanganate solution is a stronger reducing agent than acidified dichromate solution.
(b) Sodium metal is a stronger reducing agent than potassium metal.
(c) Lead(II) ions are a stronger oxidising agent than iron(II) ions.
(d) Manganese metal is a stronger oxidising agent than chromium metal.

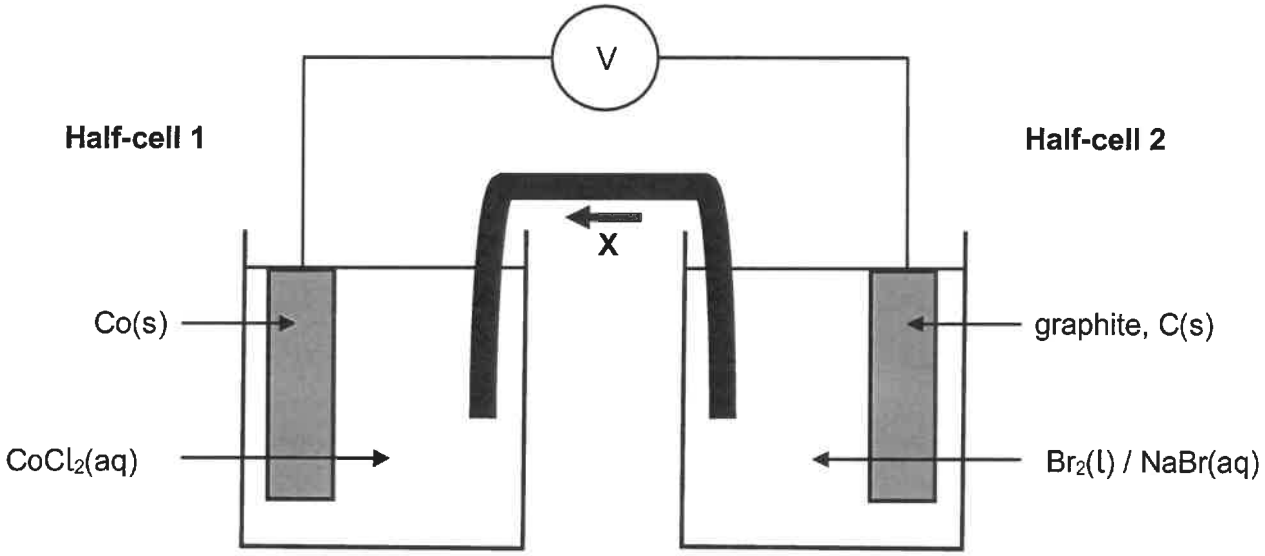
9. Which of the following is **not** a reaction that takes place at the anode of a cell, during the electrolytic refining of copper?

(a) $Cu(s) \rightarrow Cu^{2+}(aq) + 2\,e^-$
(b) $Fe(s) \rightarrow Fe^{2+}(aq) + 2\,e^-$
(c) $Au(s) \rightarrow Au^{3+}(aq) + 3\,e^-$
(d) $Ni(s) \rightarrow Ni^{2+}(aq) + 2\,e^-$

See next page

Questions 10 and 11 refer to the following diagram.

Consider the galvanic cell in the diagram below.



10. Select the option which correctly identifies the direction of electron flow, and the EMF that would be produced by this cell, when operating under standard conditions.

	Electrons flow from half-cell	EMF produced
(a)	1 to 2	+1.36 V
(b)	1 to 2	+0.80 V
(c)	2 to 1	+1.36 V
(d)	2 to 1	+0.80 V

11. The movement of which electrolyte ion is represented by X?

(a) $Co^{2+}(aq)$.
(b) $Cl^{-}(aq)$.
(c) $Na^{+}(aq)$.
(d) $Br^{-}(aq)$.

12. Consider the following system which has established equilibrium in a sealed flask.

$$CaO(s) + SO_2(g) \rightleftharpoons CaSO_3(s) + \text{heat}$$

The position of equilibrium would **not** be disturbed if

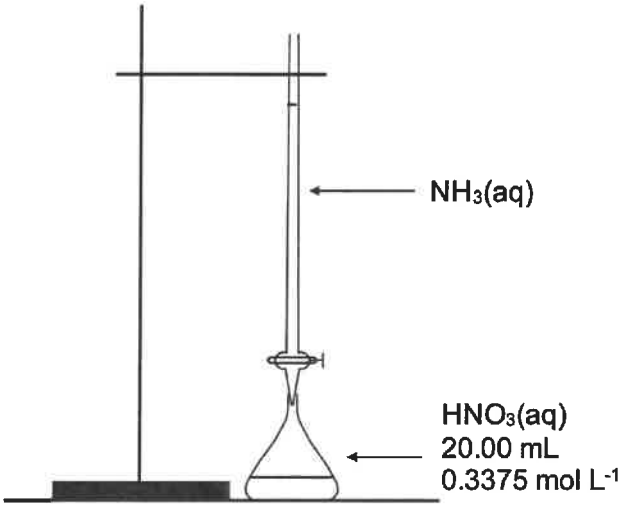
(a) the flask was opened.
(b) the temperature was increased.
(c) some CaO(s) was added.
(d) some $SO_2(g)$ was removed.

See next page

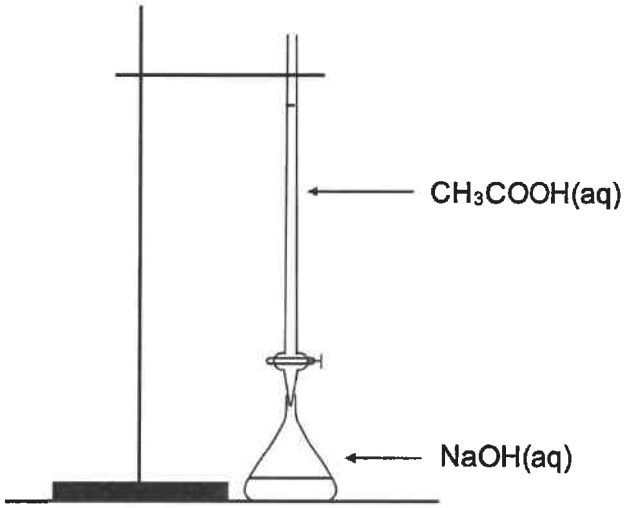
Questions 13, 14 and 15 refer to the titrations described below.

Consider the information provided in the diagrams below, regarding the set-up of two different titrations, A and B.

Titration A



Titration B



13. In Titration A, the

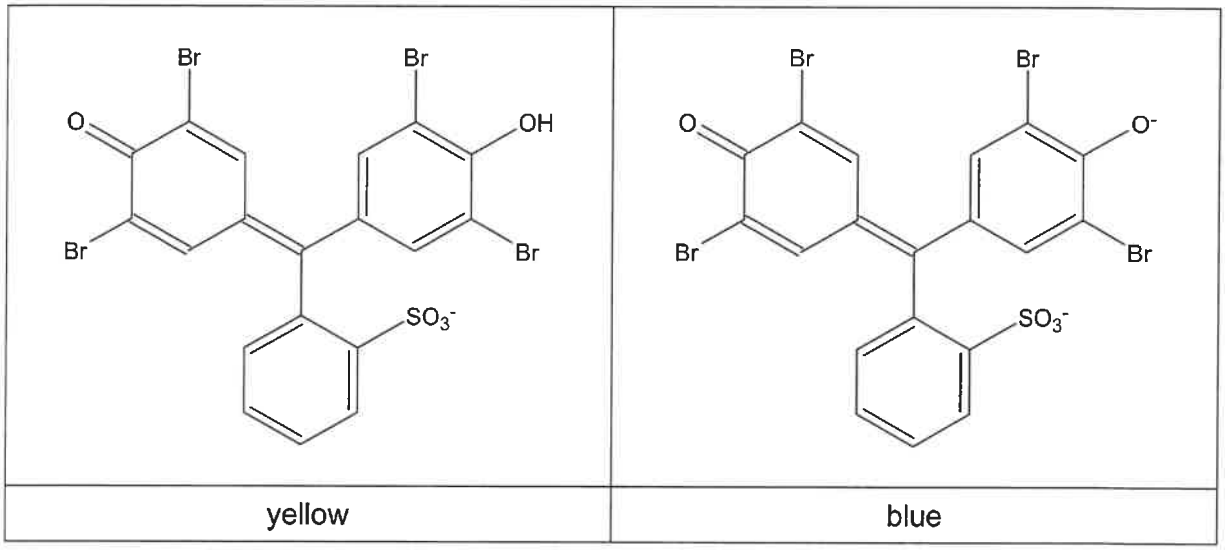
(a) nitric acid is the primary standard.
(b) nitric acid is the standard solution.
(c) pH of the solution in the conical flask will decrease as the titration proceeds.
(d) end point occurs when an equal number of moles of $NH_3(aq)$ and $HNO_3(aq)$ have reacted.

14. In Titration B, which of the following correctly identifies an error, along with its correct classification as random or systematic?

	Error	Random or systematic
(a)	Rinsing the pipette with distilled water prior to titration.	systematic
(b)	Rinsing the conical flask with distilled water prior to titration.	systematic
(c)	Rinsing the burette with distilled water prior to titration.	random
(d)	Washing down the sides of the conical flask with distilled water during the titration.	random

See next page

The indicator bromophenol blue has an end point between 3.0 – 4.6. The acidic and basic forms of bromophenol blue, along with their corresponding colours, are shown below.



yellow	blue

15. Identify for which titration this indicator would be suitable, as well as the associated colour change that would be observed during the titration.

	Titration	Colour change
(a)	A	yellow to blue
(b)	A	blue to yellow
(c)	B	yellow to blue
(d)	B	blue to yellow

16. A sample of distilled water was held in a sealed flask, where the temperature was maintained at 25 °C. Over time, an equilibrium was established between liquid water and water vapour.

$$H_2O(l) \rightleftharpoons H_2O(g)$$

A small aliquot of tritiated liquid water was then injected into the flask. Tritiated water is a radioactive form of water. The addition of the tritiated water **did not** cause a shift in the equilibrium position.

The flask was then left for one (1) hour, where the temperature continued to be maintained at 25 °C.

Identify any change in the rate of evaporation, and the level of radioactivity in the water vapour, after 1 hour.

	Rate of evaporation	Radioactivity level in $H_2O(g)$
(a)	increased	increased
(b)	increased	unchanged
(c)	unchanged	increased
(d)	unchanged	unchanged

See next page

Questions 17 and 18 refer to the following information.

Consider the conjugate acid-base pairs, of which some have been incorrectly classified, listed below.

	Acid	Conjugate base
(i)	CO_3^{2-}	HCO_3^-
(ii)	H_2O	OH^-
(iii)	NH_3	NH_4^+
(iv)	HCl	Cl^-
(v)	HSO_4^-	SO_4^{2-}

17. In which of these pairs, have the acid and conjugate base species been **correctly** classified?

(a) (i) and (iii) only.
(b) (ii) and (v) only.
(c) (i), (iii) and (v) only.
(d) (ii), (iv) and (v) only.

18. Which of these pairs, when dissolved in aqueous solution, would form a buffer?

(a) (i), (iii) and (iv) only.
(b) (i), (iii) and (v) only.
(c) (ii), (iv) and (v) only.
(d) All of (i), (ii), (iii), (iv) and (v).

19. Which of the following statements regarding primary and secondary cells is correct?

Both primary and secondary cells

(i) involve a redox reaction.
(ii) involve a spontaneous redox reaction.
(iii) involve a non-spontaneous redox reaction.

(a) (i) only.
(b) (i) and (ii) only.
(c) (i) and (iii) only.
(d) All of (i), (ii) and (iii).

20. A few drops of $K_2CO_3(aq)$ were added to a beaker containing distilled water, at 25 °C.

Which of the following statements regarding the resulting solution is **not** correct?

(a) The $[OH^-]$ would be greater than 1.0×10^{-7} mol L^{-1}.
(b) The $[H_3O^+]$ would be less than 1.0×10^{-7} mol L^{-1}.
(c) The value of K_w would be greater than 1.0×10^{-14}.
(d) The pH would be greater than 7.

See next page

Questions 21, 22 and 23 refer to the following information.

Propane-oxygen fuel cells have shown promise as a flexible power option, due to their dependability and low maintenance requirements.

The equation for the chemical reaction occurring in this fuel cell is identical to that for the combustion of propane. The **unbalanced** equation is shown below.

$$\_\_\_ C_3H_8(g) + \_\_\_ O_2(g) \rightarrow \_\_\_ CO_2(g) + \_\_\_ H_2O(g)$$

21. When correctly balanced, the coefficients would be;

(a) 1, 4, 3, 2
(b) 1, 5, 3, 4
(c) 2, 9, 6, 6
(d) 2, 10, 6, 4

22. For this fuel cell to operate correctly, propane needs to

(a) enter at the cathode.
(b) undergo reduction.
(c) be ignited.
(d) be continuously fed into the cell.

One current use of propane-oxygen fuel cells is for the cathodic protection of liquid and gas pipelines. The fuel cell provides the external voltage required for the cathodic protection process.

23. When implementing cathodic protection, the pipeline should

(a) be the cathode.
(b) be connected to the cathode of the fuel cell.
(c) be coated with a more reactive cathode.
(d) be connected to a more reactive cathode.

See next page

Questions 24 and 25 refer to the following equilibrium system.

The following reaction had established equilibrium.

$$2\,NO(g) + O_2(g) \rightleftharpoons 2\,NO_2(g)$$

colourless colourless brown

The volume of the system was then decreased, and equilibrium was allowed to re-establish.

24. When compared to the original equilibrium, identify which gases would have a higher concentration at the new equilibrium.

(a) $NO_2(g)$ only.
(b) $NO(g)$ and $O_2(g)$ only.
(c) $NO(g)$ and $NO_2(g)$ only.
(d) All of $NO(g)$, $O_2(g)$ and $NO_2(g)$.

25. Which of the following statements is true, for the new equilibrium?

(a) The colour of the equilibrium mixture would be the same as the original equilibrium.
(b) The total pressure within the system would be the same as the original equilibrium.
(c) The value of K_c would be the same as the original equilibrium.
(d) The rate of the forward and reverse reactions would be the same as the original equilibrium.

End of Section One

See next page

Section Two: Short answer **35% (73 marks)**

This section has **ten (10)** questions. Answer **all** questions. Write your answers in the spaces provided.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 60 minutes.

Question 26 **(6 marks)**

Write a balanced ionic equation for any reactions occurring between the following substances and state any observations that would be noted as the reaction takes place.

(a) Excess 1 mol L^{-1} nitric acid is poured into a beaker containing chromium(III) carbonate powder. (3 marks)

Equation $Cr_2(CO_3)_{3(s)} + 6H^+_{(aq)} \rightarrow 2Cr^{3+}_{(aq)} + 3CO_{2(g)} + 3H_2O_{(l)}$

1 mark - Correct species 1 mark - Correct balancing

Observations

1 mark A green powder is added to a colourless solution and it dissolves/decreases in mass. The solution turns green and a colourless, odourless gas is produced.

(b) Bromine water is mixed with a solution of 0.1 mol L^{-1} potassium iodide, and shaken. (3 marks)

Equation $Br_{2(aq)} + 2I^-_{(aq)} \rightarrow 2Br^-_{(aq)} + I_{2(aq)}$

1 mark

Observations

1 mark - An orange solution is added to a colourless solution

1 mark - and a brown solution is produced

See next page

Question 27 **(8 marks)**

Consider the following data regarding three (3) different chemical reactions.

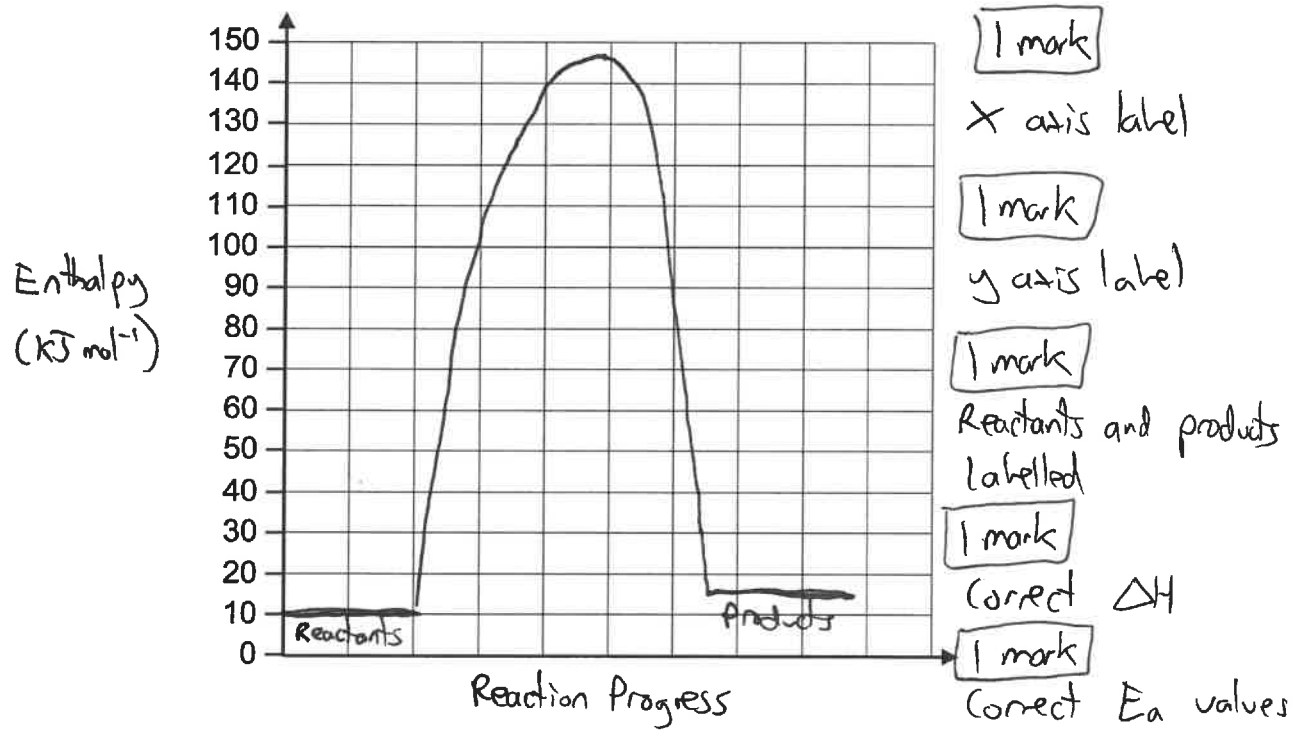
	Reaction A	Reaction B	Reaction C
K_c	5.22×10^{-7}	1.45×10^{4}	2.13×10^{-3}
E_a(forward) (kJ mol^{-1})	137	13	17
E_a(reverse) (kJ mol^{-1})	133	142	23
ΔH (kJ mol^{-1})	+4	-129	-6

(a) Identify and justify which reaction is most likely to be reversible. (2 marks)

1 mark - Reaction C

1 mark - It has the smallest E_a for both the forward and reverse reactions.

(b) Draw an energy profile diagram for Reaction A. Label the axes, reactants and products. (5 marks)



(c) If a catalyst was added to Reaction A, which of the following pieces of data would be affected? Circle any appropriate response/s. (1 mark)

1 mark (need both)

K_c E_a(forward) E_a(reverse) ΔH

See next page

Question 28 **(6 marks)**

Calculate the pH of the following.

(a) A 10.00 mL aliquot of 0.05119 mol L^{-1} NaOH(aq) was transferred to a 250.0 mL volumetric flask, and made up to the mark with distilled water. The flask was stoppered and inverted several times. (4 marks)

$n(NaOH) = cV$

$= 0.05119 \times 0.01$

$= 5.119 \times 10^{-4}$ mol [1 mark]

$c(NaOH)_{dilute} = \frac{n}{V} = \frac{5.119 \times 10^{-4}}{0.25}$

$= 2.0476 \times 10^{-3}$ mol L^{-1} [1 mark]

$[H^+] = \frac{1.0 \times 10^{-14}}{2.0476 \times 10^{-3}}$

$= 4.8838 \times 10^{-12}$ [1 mark]

$pH = -\log 4.8838 \times 10^{-12}$

$= 11.3112$ [1 mark]

(b) A sample of distilled water is heated to 75 °C. The value of K_w is 1.955×10^{-13} at this temperature. (2 marks)

$[H^+] = \sqrt{1.955 \times 10^{-13}}$

$= 4.4215 \times 10^{-7}$ mol L^{-1} [1 mark]

$pH = -\log 4.4215 \times 10^{-7}$

$= 6.3544$ [1 mark]

See next page

Question 29 **(6 marks)**

When phosphorus trihydride gas is bubbled through chlorous acid, $HClO_2(aq)$, this forms solid phosphorus, P(s), in a solution of hydrochloric acid.

Write balanced oxidation and reduction half-equations, as well as the overall redox equation, representing this reaction.

Oxidation half-equation (2 marks)	$PH_{3(g)} \rightarrow P_{(s)} + 3H^+ + 3e^-$
Reduction half-equation (2 marks)	$HClO_{2(aq)} + 3H^+_{(aq)} + 4e^- \rightarrow Cl^-_{(aq)} + 2H_2O_{(l)}$
Overall equation (2 marks)	$4PH_{3(g)} + 3HClO_{2(aq)} \rightarrow 4P_{(s)} + 3H^+_{(aq)} + 3Cl^-_{(aq)} + 6H_2O_{(l)}$

See next page

Question 30 **(8 marks)**

A chemical reaction was allowed to establish equilibrium according to the equation below.

$$OCl^-(aq) + H_2O(l) \rightleftharpoons HOCl(aq) + OH^-(aq)$$

(a) Write the equilibrium constant expression for this reaction. (2 marks)

$K = \dfrac{[HOCl][OH^-]}{[OCl^-]}$ 2 marks

(b) Consider the effect of the following imposed changes on this system, once equilibrium was allowed to re-establish.

Complete the table, by stating the effect of each change on the;
- rate of forward reaction
- position of equilibrium, and
- final pH of the mixture.

Consider each change in isolation. (6 marks)

	Rate of forward reaction (state 'increased', 'decreased' or 'no change')	Position of equilibrium (state 'shift left', 'shift right' or 'no change')	Final pH of mixture (state 'increased', 'decreased' or 'no change')
Several drops of 2 mol L^{-1} NaOCl(aq) was added.	Increased 1 mark	Right 1 mark	Increased 1 mark
A 50 mL aliquot of distilled water was added.	Decreased 1 mark	Right 1 mark	Decreased 1 mark

See next page

Question 31 **(9 marks)**

One of the chemicals used in the process of leather tanning is sodium formate, NaHCOO. It acts as a pH regulator and a preservative.

Sodium formate is added to the tanning solution, where the crystals dissolve and react with the sulfuric acid present from previous steps. This neutralises the sulfuric acid, whilst producing formic acid.

$$H_2SO_4(aq) + 2\,NaHCOO(s) \rightarrow 2\,HCOOH(aq) + Na_2SO_4(aq)$$

sodium formate *formic acid*

The aim is to add excess sodium formate to the tanning solution, so that all the sulfuric acid is neutralised, and the remaining sodium formate forms a buffer solution with the newly produced formic acid.

Consider a 285 L batch of tanning solution containing 0.135 mol L^{-1} $H_2SO_4(aq)$. The leathermakers wish to produce a final solution containing an equal number of moles of formic acid and sodium formate.

(a) Calculate the mass of sodium formate that should be dissolved in the tanning solution. Assume no change in final volume. (4 marks)

$n(H_2SO_4) = cV$

$= 0.135 \times 285$

$= 38.475\ mol$ 1 mark

$n(NaHCOO)_{required} = 4 \times n(H_2SO_4)$

$= 153.9\ mol$

2 marks

(1 mark if only $\times 2$)

need $2 \times n(H_2SO_4)$

then another $2 \times n(H_2SO_4)$

to ensure you have enough excess to match the $n(HCOOH)$

$m(NaHCOO) = n \times M$

$= 153.9 \times 68.008$

$= 10466\ g$

1 mark

See next page

(b) Write the chemical equation for the buffer system that would be formed in the tanning solution. (2 marks)

$HCOOH + H_2O \rightleftharpoons HCOO^- + H_3O^+$

OR

$HCOOH + OH^- \rightleftharpoons HCOO^- + H_2O$

1 mark – Equation

1 mark – Double Arrows

(c) If the amount of sodium formate added was **greater than** that calculated in part (a), explain the effect this would have on the buffering capacity of the tanning solution. Include a definition of buffering capacity in your answer. (3 marks)

1 mark – Buffering capacity is the extent to which a buffer can maintain the pH of a solution when small amounts of an acid or base are added.

1 mark – If more sodium formate was added, there would be an increased concentration of the conjugate base.

1 mark – This would increase the ability of the buffer to resist pH change when an acid was added.

See next page

Question 32 **(8 marks)**

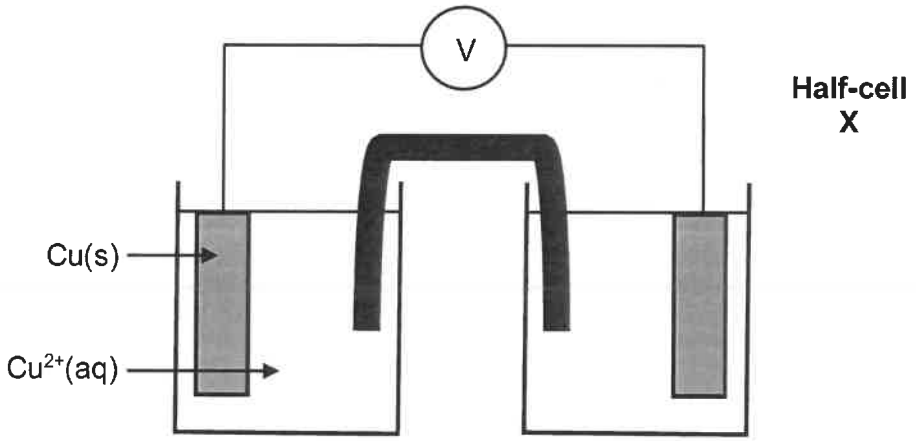
Consider the galvanic cells below, both of which involve a $Cu(s)/Cu^{2+}(aq)$ half-cell, connected to a half-cell of unknown identity.

Half-cells X and Y are identical in appearance, consisting of a silver-coloured electrode submerged in a colourless electrolyte solution.

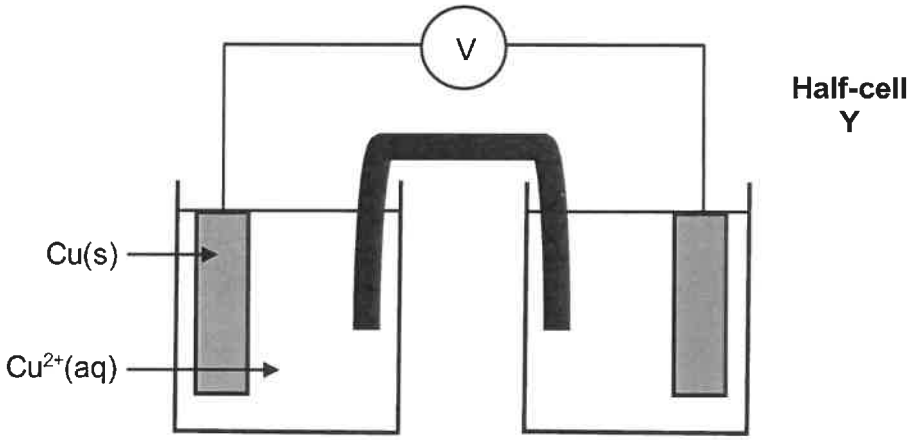
When a voltmeter was connected, both galvanic cells produced a similar reading of approximately 0.45 V.

The only difference noted, was the change in appearance of the $Cu(s)/Cu^{2+}(aq)$ half-cell. These observations are noted below each cell diagram.

You may assume both cells were constructed under standard conditions.



Observations for $Cu(s)/Cu^{2+}(aq)$ half-cell:
The electrode increased in size and the blue solution became paler as the cell operated.



Observations for $Cu(s)/Cu^{2+}(aq)$ half-cell:
The electrode decreased in size and the blue solution became darker as the cell operated.

See next page

(a) Complete the following table for half-cells X and Y. (6 marks)

	Half-cell X	Half-cell Y
Identity of half-cell (2 marks)	Pb/Pb^{2+} OR Sn/Sn^{2+} 1 mark	Ag/Ag^{+} 1 mark
Designation of electrode ('anode' or 'cathode') (1 mark)	Anode 1 mark	Cathode
Polarity of electrode ('positive' or 'negative') (1 mark)	Negative 1 mark	positive
Half-equation for reaction occurring at electrode (2 marks)	$Pb_{(s)} \rightarrow Pb^{2+}_{(aq)} + 2e^-$ OR 1 mark $Sn_{(s)} \rightarrow Sn^{2+}_{(aq)} + 2e^-$	$Ag^{+}_{(aq)} + e^- \rightarrow Ag_{(s)}$ 1 mark

(b) Explain why galvanic cells must utilise a spontaneous redox reaction. (2 marks)

1 mark - Galvanic cells convert chemical energy into electrical energy OR Galvanic cells are designed to produce electricity.

1 mark - This requires a transfer of electrons between the electrodes

See next page

Question 33 **(7 marks)**

A student was investigating the rate of reaction between zinc metal and hydrochloric acid.

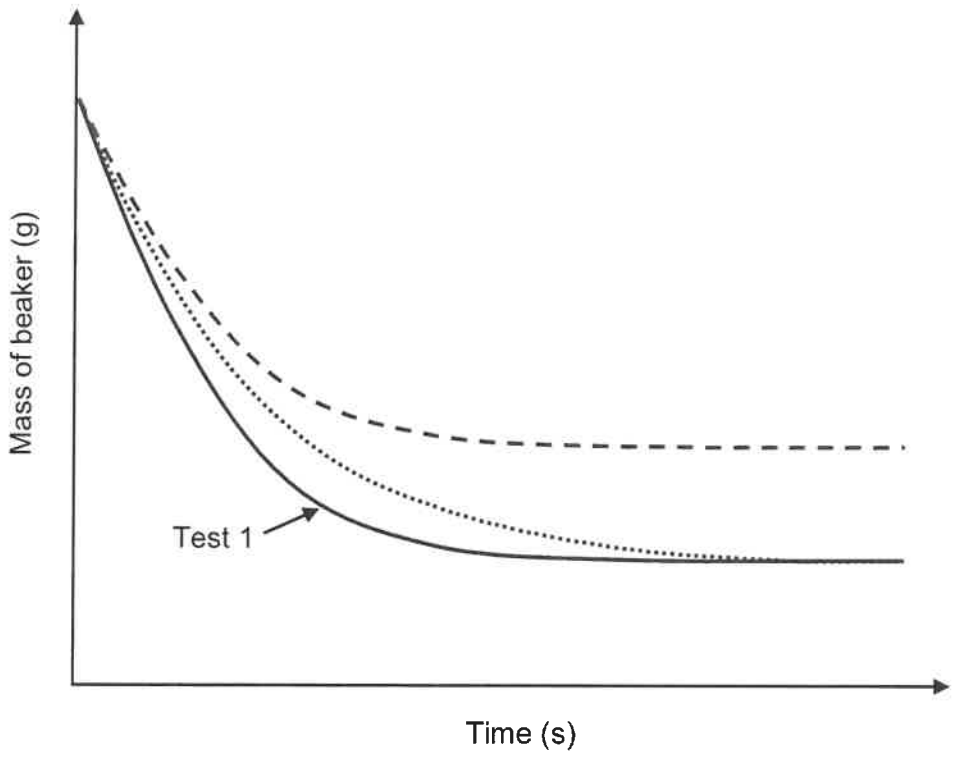
$$Zn(s) + 2\,HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

The student performed three (3) different tests, which are summarised below.

Test 1	20 g of Zn(s) was ground into small pieces, and was then mixed with 50 mL of 0.2 mol L^{-1} HCl(aq)
Test 2	20 g of Zn(s) in large chunks, was mixed with 50 mL of 0.2 mol L^{-1} HCl(aq)
Test 3	20 g of Zn(s) was ground into small pieces, and was then mixed with 50 mL of 0.1 mol L^{-1} HCl(aq)

In each test, the zinc was present in excess.

The data collected by the student involved monitoring the mass of the beaker upon mixing of the reactants. The results of the 3 tests are displayed on the graph below.



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Consider the curve labelled **Test 1**.

(a) Explain, in terms of collision theory, what information the **shape** of this curve provides, regarding the rate of reaction. (4 marks)

1 mark - The rate of reaction decreases over time.

1 mark - This is due to a decrease in the concentration of HCl (more space between reactant particle),

1 mark - which decreases the frequency of collisions.

1 mark - When the HCl runs out, the rate of reaction becomes zero / the reaction stops (indicated by the flat part of the curve)

(b) On the graph above, label the other curves to indicate which represents **Test 2** and which represents **Test 3**. (1 mark)

..... Test 2
– – – Test 3

1 mark

(c) Justify the choices you made in part (b). (2 marks)

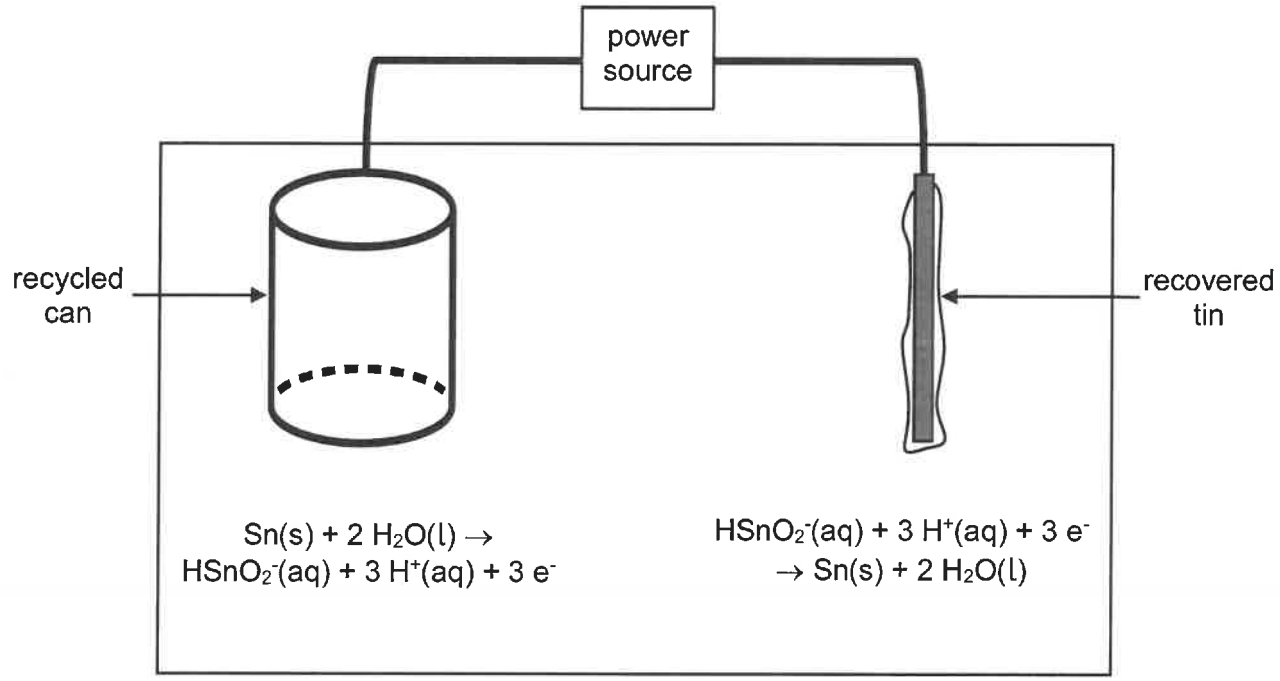
1 mark - Test 2 has the same number of moles of reactants so will end up with the same amount of products (and therefore the same final mass as Test 1).

1 mark - Test 3 has fewer moles of HCl, so will produce less products (therefore a smaller change in final mass)

Question 34 **(8 marks)**

Cans that are used for storing food are made by electroplating a thin layer of tin onto iron. Once the food has been emptied and the cans have been disposed of, the tin coating is recovered during recycling.

The diagram below illustrates the electrolytic processes involved in recovering the tin from used food cans.



(a) Briefly define an electrolytic cell. (2 marks)

1 mark - A cell that uses an external power source OR A cell that converts electrical energy into chemical energy.

1 mark - By forcing a non-spontaneous redox reaction to occur.

(b) Demonstrate, using oxidation numbers to support your answer, that the recycled can is the anode in this cell. (2 marks)

1 mark - Tin is oxidised from 0 to +2

1 mark - Oxidation always occurs at the anode

See next page

The tin layer prevents the food from coming into contact with the iron, thus preventing its corrosion.

(c) Briefly define corrosion, in the context of iron metal. (2 marks)

1 mark - It is the oxidation of iron

1 mark - due to a reaction with oxygen and water

(d) Justify whether the tin coating has the ability to act as a sacrificial anode. (2 marks)

1 mark - No

1 mark - The oxidation potential of tin (+0.14V) is lower than that of iron (+0.44V)

OR - The reduction potential of tin (-0.14V) is higher than that of iron (-0.44V)

OR - Iron is more easily oxidised than tin

OR - A sacrificial anode must have an oxidation potential higher than iron and tin doesn't.

Question 35 **(7 marks)**

Sodium hydrogenphosphate, Na_2HPO_4, is a soluble ionic compound. When dissolved in water, it dissociates into its component ions.

(a) Identify which ion does **not** affect the pH of the resulting solution. (1 mark)

1 mark - $Na^+_{(aq)}$

The other ion has the ability to undergo two (2) different hydrolysis reactions.

(b) Write balanced chemical equations showing both possible hydrolysis reactions. (3 marks)

1	$HPO_4^{2-} + H_2O \rightleftharpoons H_2PO_4^- + OH^-$	1 mark
2	$HPO_4^{2-} + H_2O \rightleftharpoons PO_4^{3-} + H_3O^+$	1 mark

1 mark - Both equations with double arrows

Sodium fluoride, NaF, is another soluble ionic compound. The pH of NaF(aq) and Na_2HPO_4(aq) solutions are very similar.

(c) State whether the solution of Na_2HPO_4(aq) is acidic, basic or neutral, and explain what information this provides regarding the equations in part (b). (3 marks)

1 mark - Basic

1 mark - The hydrolysis equation producing OH^- occurs to a greater extent

1 mark - This means that $[OH^-] > [H_3O^+]$

End of Section Two

See next page

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See next page

Section Three: Extended answer **40% (86 marks)**

This section contains **five (5)** questions. You must answer **all** questions. Write your answers in the spaces provided below.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression. Lists or dot points are unlikely to gain full marks.

Final answers to calculations should be expressed to the appropriate number of significant figures.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 70 minutes.

Question 36 **(15 marks)**

Sulfuric (H_2SO_4) and sulfurous (H_2SO_3) acids are closely related in terms of their chemical composition, however they display different chemical properties and consequently have very different uses.

Both acids are polyprotic, and the acidity constants for each are provided in the table below.

	H_2SO_4	H_2SO_3
K_{a1}	1.0×10^{3}	1.4×10^{-2}
K_{a2}	1.2×10^{-2}	1.0×10^{-7}

(a) Define the term polyprotic. (1 mark)

1 mark - Capable of donating more than one proton OR Contains more than one ionisable hydrogen per molecule

(b) Define the term 'acidity constant' and state what information the value of an acidity constant provides about the strength of an acid. (2 marks)

1 mark - It is the degree to which the acid ionises

1 mark - A greater Ka value indicates a stronger acid

See next page

Compare 1 mol L^{-1} solutions of $H_2SO_4(aq)$ and $H_2SO_3(aq)$.

(c) State which solution would have the higher pH. Include a definition of pH, and use the K_a data provided, to justify your answer. (4 marks)

1 mark - H_2SO_3

1 mark - pH is a measure of hydrogen ion concentration

OR $pH = -\log [H^+]$

1 mark - H_2SO_3 has smaller K_a values

1 mark - Indicating it ionises to a smaller extent producing a lower concentration of H^+ (and thus a higher pH).

(d) Define an acid, according to the Arrhenius theory. Write successive ionisation equations showing **sulfuric** acid behaving as an Arrhenius acid. (4 marks)

1 mark - Acids ionise to produce H^+ ions in solution according to Arrhenius

1 mark - $H_2SO_4 \rightarrow H^+ + HSO_4^-$

1 mark - $HSO_4^- \rightleftarrows H^+ + SO_4^{2-}$

1 mark - use of single arrows or single then double arrows in equation.

(e) Define an acid, according to the Bronsted-Lowry theory. Write successive ionisation equations showing **sulfurous** acid behaving as a Bronsted-Lowry acid in aqueous solution. (4 marks)

1 mark - Acids are proton donors according to Bronsted Lowry

1 mark - $H_2SO_3 + H_2O \rightleftarrows H_3O^+ + HSO_3^-$

1 mark $HSO_3^- + H_2O \rightleftarrows H_3O^+ + SO_3^{2-}$

1 mark - Double arrows for both equations

See next page

Question 37 **(16 marks)**

A chemistry student was investigating the following equilibrium.

$$Ni^{2+}(aq) + 2\,OH^-(aq) \rightleftharpoons Ni(OH)_2(s)$$

To produce this equilibrium system, they first placed 125 mL of 0.10 mol L^{-1} $Ni(NO_3)_2(aq)$ into a beaker. To this, 10 drops of 7.5 mol L^{-1} NaOH(aq) was added. The mixture was then left until equilibrium had established.

(a) Describe the observations that would have been noted as equilibrium was established. (2 marks)

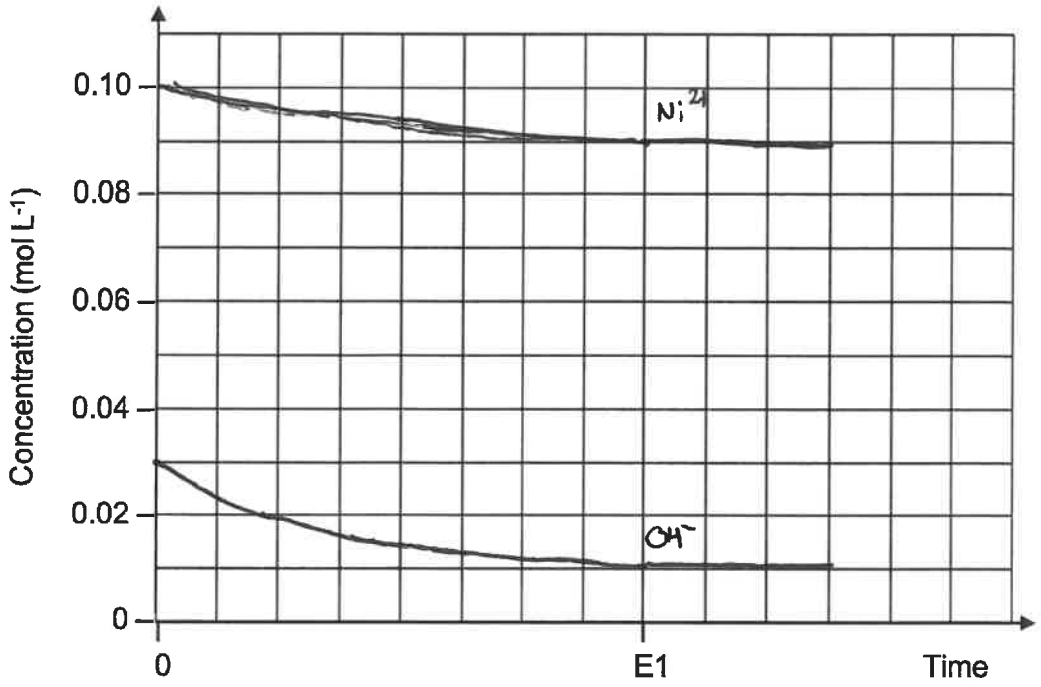
1 mark - A green solid forms

1 mark - A green solution starts to fade

The student wanted to produce a concentration graph on the grid below, showing the changes that occurred as equilibrium was being established.

However, in order to do this, they needed to complete the table below.

	$Ni^{2+}(aq)$	$OH^-(aq)$
Initial concentration (mol L^{-1})	0.10	0.03
Equilibrium concentration (mol L^{-1})	0.09	0.01



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(b) Calculate the initial concentration of $OH^-(aq)$ that would have been present instantaneously in the reaction mixture (i.e. before any reaction has taken place), upon addition of the 10 drops of NaOH(aq) to the beaker. (3 marks)

You may assume;

- The volume of 1 drop = 0.05 mL.
- The final volume of the mixture remained 125 mL.

$V(NaOH) = 0.05 \times 10 \times 10^{-3}$

$= 5.0 \times 10^{-4} L$ 1 mark

$n(NaOH) = cV$

$= 7.5 \times 5.0 \times 10^{-4}$

$= 3.75 \times 10^{-3}$ mol

1 mark

$c(NaOH) = \frac{n}{V} = \frac{3.75 \times 10^{-3}}{0.125}$

$= 0.03$ mol L^{-1}

1 mark

Once equilibrium had been established, the student took the equilibrium mixture and poured it through a funnel lined with filter paper. The $Ni(OH)_2(s)$ residue was washed, dried, and found to have a mass of 0.1159 g. The filtrate contained the remaining aqueous equilibrium mixture.

(c) Calculate the final concentrations of $Ni^{2+}(aq)$ and $OH^-(aq)$ that would have been present in this equilibrium mixture. (7 marks)

$n(Ni(OH)_2) = \frac{m}{M} = \frac{0.1159}{92.706}$

$= 1.2502 \times 10^{-3}$ mol 1 mark

(ie amount removed from solution)

$n(Ni^{2+})_{original} = cV$

$= 0.1 \times 0.125$

$= 0.0125$ mol 1 mark

$n(Ni^{2+})_{remaining} = 0.0125 - 1.2502 \times 10^{-3}$

$= 0.01125$ mol 1 mark

$c(Ni^{2+})_{remaining} = \frac{0.01125}{0.125}$

$= 0.09$ mol L^{-1} 1 mark

$n(OH^-) = 3.75 \times 10^{-3}$ mol 1 mark

(from part b)

$n(OH^-)_{remaining} = 3.75 \times 10^{-3} - (2 \times 1.2502 \times 10^{-3})$

$= 1.2496 \times 10^{-3}$ mol 1 mark

$c(OH^-) = \frac{1.2496 \times 10^{-3}}{0.125}$

$= 0.01$ mol L^{-1} 1 mark

See next page

The student thought, that by filtering and removing the $Ni(OH)_2(s)$, this would have caused a shift in the equilibrium position. However, they observed no evidence of this.

(d) Justify this observation. (1 mark)

1 mark - Changing the amount of a solid has no effect on equilibrium position.

(e) Transfer your calculated values into the table and use this data to draw a corresponding concentration graph on the grid provided (both table and grid are on page 28). Your graph should show the change in concentration of $Ni^{2+}(aq)$ and $OH^-(aq)$ from Time 0 until equilibrium is established at Time E1. Continue your curves past Time E1. (3 marks)

(If you were unable to complete the calculations, use your knowledge of equilibrium to sketch a possible representation of this scenario.)

1 mark - Correct shape (ushy correct values)

1 mark - OH^- changes by twice as much as Ni^{2+}

1 mark - Reach equilibrium at E, and straight line after.

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See next page

Question 38 **(12 marks)**

A chemistry student was given four (4) unlabelled beakers, each containing a colourless solution.

They were told that the identities of the solutions were;

- 0.1 mol L^{-1} $Sn(NO_3)_2(aq)$
- 0.1 mol L^{-1} $Zn(NO_3)_2(aq)$
- 0.1 mol L^{-1} $AgNO_3(aq)$
- 0.1 mol L^{-1} $Cd(NO_3)_2(aq)$

The student's task was to label each beaker with its identity.

In order to do this, the student was provided with;

- test tubes
- a jar containing small pieces of copper, Cu(s)
- a jar containing small pieces of iron, Fe(s)
- a jar containing small pieces of nickel, Ni(s)
- a Data Booklet

Describe how the student could identify each of the solutions in the beakers, using a sequence of chemical tests. Relevant observations and ionic equations should be included for each step.

The first step carried out by the student is given, and your answer should be continued below.

Note: There are multiple ways to answer the question that could attract marks that are different to below.

Samples of the 4 solutions were placed into separate test tubes, and a piece of Cu(s) was added into each.

1 mark - Only the $AgNO_3$ will react.

1 mark - Observation:
- A salmon pink solid dissolves
- Silver/grey solid forms
- Blue solution forms

} not all required

1 mark - Equation: $2Ag^+_{(aq)} + Cu_{(s)} \rightarrow 2Ag_{(s)} + Cu^{2+}_{(aq)}$

See next page

1 mark - Samples of remaining solutions were placed into separate test tubes and a piece of Ni was added to each.

1 mark - Only the $Sn(NO_3)_2$ will react

1 mark - Observation:
- Silver/grey solid dissolves
- New silver grey solid forms
- Green solution forms

} not all required

1 mark - Equation: $Sn^{2+}_{(aq)} + Ni_{(s)} \rightarrow Sn_{(s)} + Ni^{2+}_{(aq)}$

1 mark - Samples of the remaining solutions were placed into separate test tubes and a piece of Fe was added to each.

1 mark - Only the $Cd(NO_3)_2$ will react

1 mark - Observation:
- Silver/grey solid dissolves
- New silver solid forms
- pale green solution forms

} not all required

1 mark - Reaction: $Cd^{2+}_{(aq)} + Fe_{(s)} \rightarrow Cd_{(s)} + Fe^{2+}_{(aq)}$

1 mark - The remaining solution is $Zn(NO_3)_2$

See next page

Question 39 **(29 marks)**

Barium hydroxide solution, $Ba(OH)_2(aq)$, is also known as 'baryta water'. It is used primarily in analytical chemistry, but also for certain organic synthesis processes.

A chemist wanted to use a sample of 'baryta water' to analyse the $CO_2(g)$ content of air. However, the concentration of $Ba(OH)_2(aq)$ had to first be determined by titration.

The 'baryta water' was titrated against a standard solution of potassium hydrogenphthalate, $KHC_8H_4O_4(aq)$. Potassium hydrogenphthalate is a weak, monoprotic acid, which is commonly used as a primary standard.

(a) Briefly describe why each of the following are important characteristics of a primary standard. (2 marks)

High molar mass	1 mark – Minimises weighing errors / Reduces the impact of weighing errors
Not deliquescent or hygroscopic	1 mark – Prevents an incorrect mass / concentration from being used when substance is measured.

A standard 0.1282 mol L^{-1} $KHC_8H_4O_4(aq)$ solution was made by dissolving $KHC_8H_4O_4(s)$ in distilled water, and making it up to 500.0 mL in a volumetric flask.

(b) Calculate the mass of $KHC_8H_4O_4(s)$ that was dissolved to prepare a 500.0 mL solution of the primary standard. (3 marks)

$n(KHC_8H_4O_4) = cV = 0.1282 \times 0.5$

$= 0.0641$ mol 1 mark

$m(KHC_8H_4O_4) = n \times M$ 1 mark

$= 0.0641 \times 204.22$

$= 13.09$ g

1 mark

See next page

A 20.00 mL sample of 'baryta water' was diluted to 100.0 mL in a volumetric flask. The diluted solution was then used to fill a burette. A few drops of phenolphthalein were added to a conical flask containing 15.00 mL of 0.1282 mol L^{-1} $KHC_8H_4O_4$(aq). After several trials, the chemist determined an average titre of 18.38 mL.

The chemical equation for the titration reaction is as follows;

$$HC_8H_4O_4^-(aq) + OH^-(aq) \rightarrow C_8H_4O_4^{2-}(aq) + H_2O(l)$$

(c) Explain why phenolphthalein is a suitable indicator for this titration. Support your answer with a relevant chemical equation. (4 marks)

1 mark - The equivalence point for this reaction is basic.

1 mark - This is due to the presence of the basic ion $HC_8H_4O_4^-$. It hydrolyses with water as follows:

1 mark - $C_8H_4O_4^{2-} + H_2O \rightleftharpoons HC_8H_4O_4^- + OH^-$ producing OH^- ions

1 mark - Phenolphthalein changes colour in the basic range therefore results in a titration end point that matches the equivalence point.

(d) Calculate the concentration of the undiluted 'baryta water'. State your answer to the appropriate number of significant figures. (7 marks)

$n(KHC_8H_4O_4) = cV$

$= 0.1282 \times 0.015$

$= 0.001923$ mol 1 mark

$n(OH^-) = \frac{1}{1} \times n(KHC_8H_4O_4)$

Burette $= 0.001923$ mol 1 mark

$n(Ba(OH)_2) = \frac{1}{2} \times n(OH^-)$

Burette $= 9.615 \times 10^{-4}$ mol

1 mark

$n(Ba(OH)_2) = \frac{100}{18.38} \times 9.615 \times 10^{-4}$

100mL dilute $= 5.2312 \times 10^{-3}$ mol 1 mark

$\therefore n(Ba(OH)_2) = 5.2312 \times 10^{-3}$ mol

original 20mL 1 mark

$c(Ba(OH)_2) = \frac{n}{V} = \frac{5.2312 \times 10^{-3}}{0.02}$

in Baryta water $= 0.26156$ mol L^{-1}

1 mark

4 sig figs 1 mark

See next page

Once the 'baryta water' was standardised, the chemist was able to carry out their analysis to determine the concentration of $CO_2(g)$ in a sample of air.

When $CO_2(g)$ comes into contact with 'baryta water' a film of white barium carbonate powder, as well as water, forms.

(e) Write a balanced ionic equation for this reaction, including state symbols. (3 marks)

$$CO_{2(g)} + Ba^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow BaCO_{3(s)} + H_2O_{(l)}$$

1 mark – Species; 1 mark – Balancing; 1 mark – State Symbols

The chemist had a 1.00 L sample of air contained in a sealed gas cylinder with an inlet valve. A sample of 'baryta water' was injected through the valve. The gas cylinder was gently swirled, and enough time was allowed for any reaction to complete.

(f) If the global average concentration of atmospheric $CO_2(g)$ is 421 ppm, calculate the mass of barium carbonate powder that should form in the 'baryta water'. (6 marks)

You may assume;

- The 'baryta water' is in excess.
- All the $CO_2(g)$ reacts.
- The density of air is 1.225 g L^{-1}.

$m(air) = 1.225 \times 1$

$= 1.225$ g — 1 mark

$m(CO_2) = \frac{421 \times 1.225}{10^6}$ — 2 marks

$= 5.157 \times 10^{-4}$ g

$n(CO_2) = \frac{m}{M} = \frac{5.157 \times 10^{-4}}{44.01}$

$= 1.1718 \times 10^{-5}$ mol — 1 mark

$n(BaCO_3) = \frac{1}{1} \times n(CO_2)$

$= 1.1718 \times 10^{-5}$ mol — 1 mark

$m(BaCO_3) = n \times M$

$= 1.1718 \times 10^{-5} \times 197.31$

$= 2.312 \times 10^{-3}$ g

or 2.31 mg — 1 mark

See next page

(g) Justify, **without** the use of chemical equations, the effect of increased atmospheric $CO_2(g)$ concentration on the pH of Earth's oceans. (4 marks)

1 mark - Increased $CO_{2(g)}$ in the atmosphere leads to increased dissolved $CO_{2(aq)}$ in our oceans.

1 mark - This CO_2 combines with water to form Carbonic acid H_2CO_3.

1 mark - H_2CO_3 partially ionises in solution to form H^+ ions

1 mark - The increased concentration of H^+ decreases the pH of our oceans (due to $pH = -\log[H^+]$).

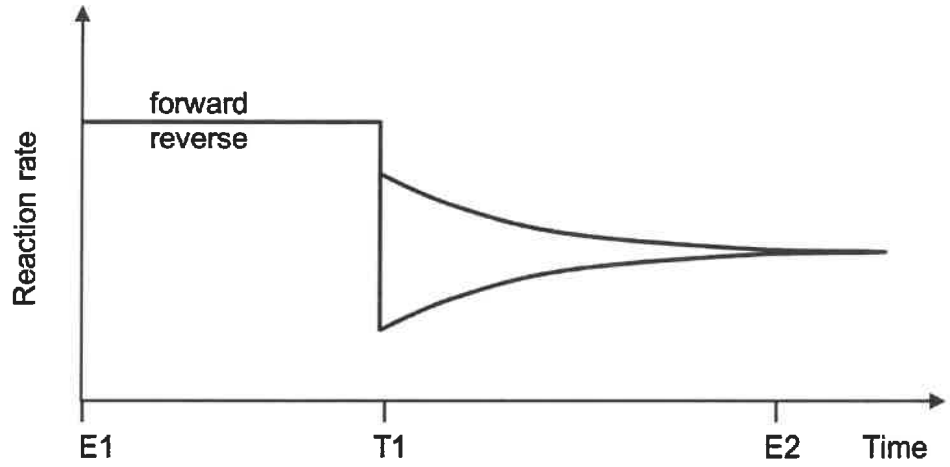
See next page

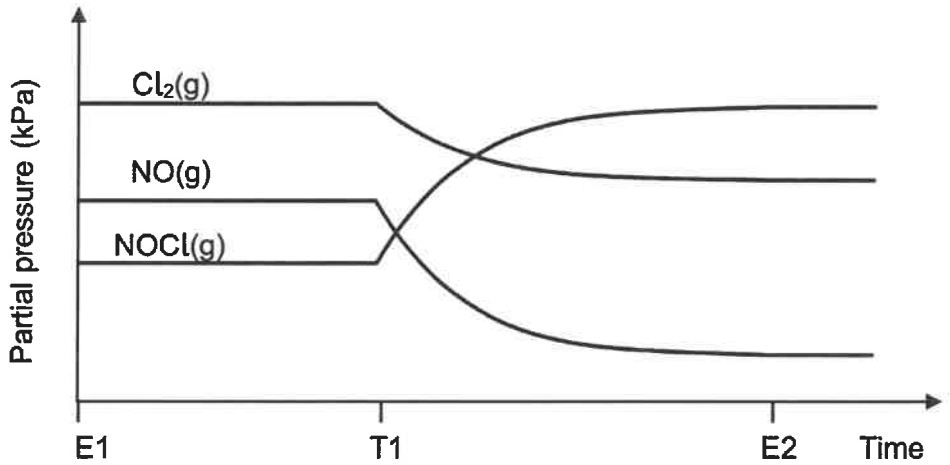
Question 40 **(14 marks)**

Consider the following reversible system, that has been allowed to establish equilibrium.

$$\underset{\textit{colourless}}{2\,NO(g)} + \underset{\textit{greenish-yellow}}{Cl_2(g)} \rightleftharpoons \underset{\textit{yellow}}{2\,NOCl(g)}$$

A change was imposed on this system at Time T1. The subsequent effects of this change are illustrated by both the rate and concentration graphs below.





Between Time E1 and Time T1, the system was in equilibrium.

(a) Describe the information provided by each of the graphs above, which supports the assertion that the system was in equilibrium. (2 marks)

1 mark - The rate of the forward and reverse reactions were equal.

1 mark - The partial pressure/concentration of all gases were constant.

See next page

At Time T1, a change was imposed on the system.

(b) Describe the change in appearance of the system between Time T1 and Time E2. (1 mark)

1 mark - The colour of the gas mixture becomes more yellow.

(c) Identify the change imposed on the system at Time T1. Explain your answer, using evidence from the graphs above, and referring to collision theory. (5 marks)

1 mark - Temperature decreases

1 mark - There are no instantaneous concentration changes at T1 indicating it cannot be a concentration or volume change.

1 mark - Both reaction rates decreased indicating it must have been a temperature decrease.

1 mark - This happened as there would have been a decreased average kinetic energy of reacting species (and a smaller proportion having sufficient energy to react).

1 mark - This results in a decreased frequency of successful collisions.

(d) Identify the sign of the enthalpy change for the forward reaction. Justify your answer, using evidence from the graphs above, and referring to Le Chatelier's principle. (4 marks)

1 mark - ΔH will be negative

1 mark - Since the concentration of NOCl increases, this indicates that the forward reaction is favoured.

1 mark - LCP predicts that a decreased temperature will favour the exothermic reaction (reaction that produces heat).

1 mark - Indicating that the forward reaction is exothermic

See next page

(e) Compare the values of K_c at Time E1 and Time E2. Justify your answer. (2 marks)

1 mark - K will be higher at E2

1 mark - Since a greater proportion of products is present / The ratio of products to reactants is greater

End of questions