Insert School Logo

Semester One Examination 2023 Question/Answer booklet

CHEMISTRY UNIT 3

Name: ____

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	8	8	60	75	35
Section Three: Extended answer	5	5	70	89	40
				Total	100

Final percentage x 25 + x 35 + x 40 = %

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.

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. A piece of zinc metal is placed in a beaker containing excess 1.0 mol L^{-1} hydrochloric acid.

$$Zn(s) + 2\,H^{+}(aq) \rightarrow Zn^{2+}(aq) + H_2(g)$$

At first, a colourless gas is produced quickly, but the rate of effervescence slows over time, until no more gas is observed to form.

Which of the following statements does **not** contribute to an explanation of these observations?

(a) The frequency of reactant collisions decreases.
(b) The frequency of product collisions increases.
(c) The concentration of hydrochloric acid decreases.
(d) The zinc is eventually completely used up.

2. A piece of tin metal is placed in a solution of cadmium nitrate. Electrons would

(a) be transferred from Sn(s) to Cd^{2+}(aq).
(b) be transferred from Cd^{2+}(aq) to Sn(s).
(c) be transferred from Sn(s) to NO_3^-(aq).
(d) not be transferred.

3. A beaker contained a sample of aqueous sodium dihydrogenphosphate. Which of the following solutions, when added to this beaker, would **not** result in the formation of a buffer solution?

(a) H_3PO_4(aq).
(b) KH_2PO_4(aq).
(c) K_2HPO_4(aq).
(d) Na_2HPO_4 (aq).

4. Select the agent that can oxidise copper metal but not metallic gold.

(a) H^+(aq)/MnO_4^-(aq)
(b) H_2O_2(aq)
(c) Ag^+(aq)
(d) $H_2C_2O_4$(aq)

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

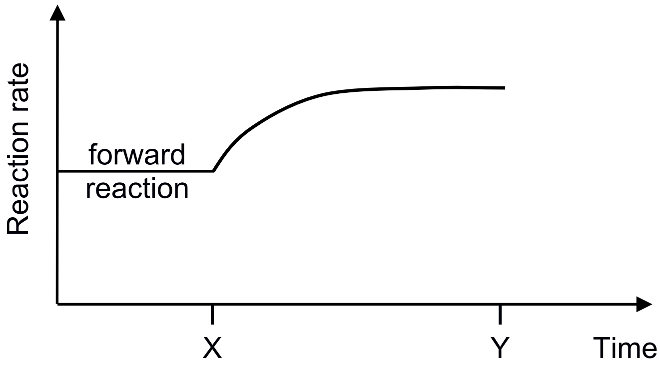
Consider the following system that had established equilibrium.

$$2\,N_2O(g) + O_2(g) \rightleftharpoons 4\,NO(g) \qquad K_c = 2.4 \times 10^{-8}$$

5. The value of K_c indicates, that at equilibrium

   (a) $[N_2O] = 2 \times [O_2]$.
   (b) $[NO] = 2 \times [N_2O]$.
   (c) $[N_2O] > [NO]$.
   (d) $[O_2] > [N_2O]$.

A change was imposed on the system at Time X, the result of which can be represented by the rate graph for the forward reaction below.

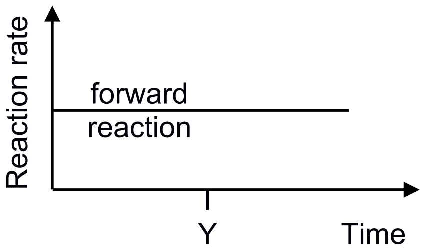


6. Which change could have been imposed at Time X?

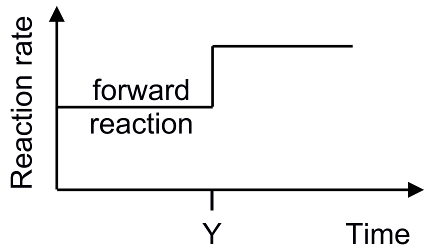
   (a) Some $N_2O(g)$ was injected into the system.
   (b) Some $O_2(g)$ was removed from the system.
   (c) Some NO(g) was injected into the system.
   (d) The total volume of the system was decreased.

7. An appropriate catalyst was added into the system at Time Y. Which of the following rate graphs correctly represents this change?

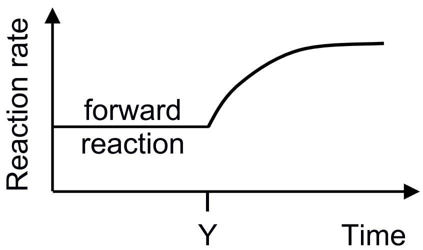
(a)



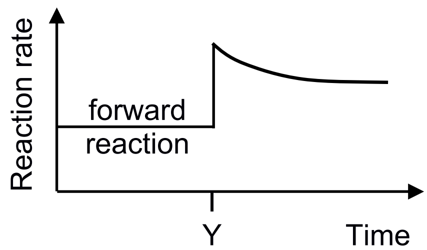
(b)



(c)



(d)



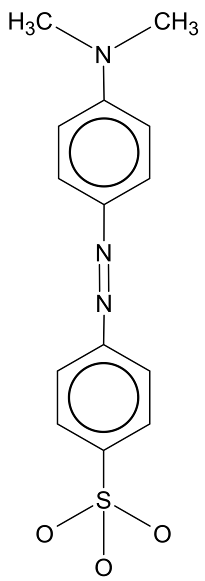
8. A salt bridge does **not**

(a) allow ion migration between half-cells.
(b) allow electron migration between half-cells.
(c) allow electricity to flow between half-cells.
(d) maintain the electrical neutrality of half-cells.

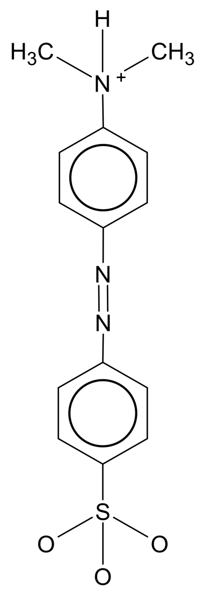
9. The indicator methyl orange has an end point of approximately pH 3.1 - 4.4. At pH values below 3.1 it appears red, whilst at pH values above 4.4 it is yellow.

The two different coloured forms of methyl orange are shown below.

Form A



Form B



A few drops of methyl orange were added to a test tube containing distilled water. Which of the options below, gives the correct colour and form that methyl orange would display in this situation?

	Colour	Form
(a)	red	A
(b)	red	B
(c)	yellow	A
(d)	yellow	B

10. An underground gas pipeline was prevented from corroding by the process of cathodic protection. Power sources were installed at regular intervals along the pipeline. At each location, one electrode was connected to the pipeline and the other was connected to a block of scrap iron.

When the power sources are switched on,

(a) electrons would flow towards the pipeline.
(b) the anode would have a negative polarity.
(c) the cathode would eventually need replacing.
(d) the pipeline would be acting as the anode.

See next page

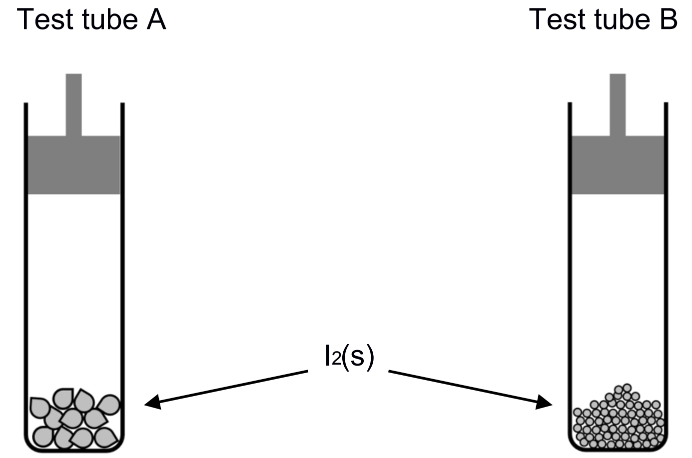
Questions 11 and 12 refer to the following equilibrium system.

Iodine (I_2) is a solid with a relatively high vapour pressure. When a sample of $I_2(s)$ is placed in a sealed tube, an equilibrium is established between grey iodine solid and purple iodine vapour.

$$I_2(s) \rightleftharpoons I_2(g)$$

grey solid   *purple vapour*

Two (2) glass tubes with syringe stoppers were set up; Test tube A contained 5.0 g of iodine crystals, and Test tube B contained 5.0 g of iodine powder. Equilibrium was allowed to establish in each.



11. Which of the following observations are correct, when comparing test tubes A and B?

Test tube B will

(i) establish equilibrium sooner.
(ii) have a higher $I_2(g)$ partial pressure at equilibrium.
(iii) have a greater mass of $I_2(s)$ present at equilibrium.
(iv) have a more deeply coloured purple vapour at equilibrium.

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

The stopper in test tube A was then pushed further down into the test tube, decreasing the volume of the system. Equilibrium was allowed to re-establish once again.

12. Which of the following observations are correct, when compared to the original equilibrium?

(i) The partial pressure of $I_2(g)$ would be higher.
(ii) The vapour would be a lighter shade of purple.
(iii) A greater mass of $I_2(s)$ would be present.

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

13. A titration was carried out between approximately 0.1 mol L^{-1} $CH_3COOH(aq)$, and 0.1033 mol L^{-1} NaOH(aq). At the equivalence point, which of the following species would be present at the lowest concentration?

(a) $H_2O(l)$.
(b) $Na^+(aq)$.
(c) CH_3COO^- (aq).
(d) $OH^-(aq)$.

Questions 14 and 15 refer to the combustion of ethane.

Compare the combustion of ethane (C_2H_6) in both limited and excess oxygen conditions.

14. For complete combustion of ethane to occur, the stoichiometric ratio of oxygen to ethane would need to be equal to or greater than

(a) 2.
(b) 2.5.
(c) 3.5.
(d) 7.

15. When ethane is combusted in the presence of limited oxygen, the oxidation number of the carbon atoms

(a) increases by more than when excess oxygen is present.
(b) increases by less than when excess oxygen is present.
(c) decreases by more than when excess oxygen is present.
(d) decreases by less than when excess oxygen is present.

16. The table below provides some information about three (3) monoprotic acids.

Name	Formula	K_a
Hydrofluoric acid	HF	7.2×10^{-4}
Benzoic acid	C_6H_5COOH	6.5×10^{-5}
Hypochlorous acid	HClO	3.5×10^{-8}

A 20.00 mL sample of each acid was placed in 3 separate beakers. All the acids had a concentration of 0.100 mol L^{-1}. A chemist wanted to neutralise each acid by adding 0.100 mol L^{-1} NaOH(aq).

Which of the following statements is correct?

(a) The HF(aq) sample would require the greatest volume of NaOH(aq) for neutralisation.
(b) The $C_6H_5COOH(aq)$ sample would require the greatest volume of NaOH(aq) for neutralisation.
(c) The HClO(aq) sample would require the greatest volume of NaOH(aq) for neutralisation.
(d) All the acid samples would require the same volume of NaOH(aq) for neutralisation.

Questions 17 and 18 refer to the following equilibrium system.

The following aqueous system was allowed to establish equilibrium.

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

orange *yellow*

A sample of this equilibrium mixture was placed in a test tube and gently warmed. It was observed that the colour of the solution became more yellow.

17. For the equation, it can therefore be concluded that

(a) the enthalpy of the reactants is higher than the enthalpy of the products.
(b) the sign of the enthalpy change is positive.
(c) the activation energy is relatively high.
(d) the reaction is likely to be difficult to reverse.

A second sample of the original equilibrium mixture was placed in a separate test tube. The volume of the solution was doubled by the addition of distilled water. Equilibrium was then allowed to re-establish.

18. In comparison to the original equilibrium, the new equilibrium mixture would contain

(a) a greater mass of $Cr_2O_7^{2-}(aq)$ present.
(b) a greater concentration of $Cr_2O_7^{2-}(aq)$ present.
(c) a greater mass of $CrO_4^{2-}(aq)$ present.
(d) a greater concentration of $CrO_4^{2-}(aq)$ present.

19. Which of the following is **not** a common feature of both primary and secondary cells?

(a) They involve redox reactions.
(b) They have an anode and a cathode.
(c) They can act as galvanic cells.
(d) They can act as electrolytic cells.

20. The autoionisation of water can be represented by the chemical equation below.

$$2\,H_2O(l) + \text{heat} \rightleftharpoons H_3O^+(aq) + OH^-(aq)$$

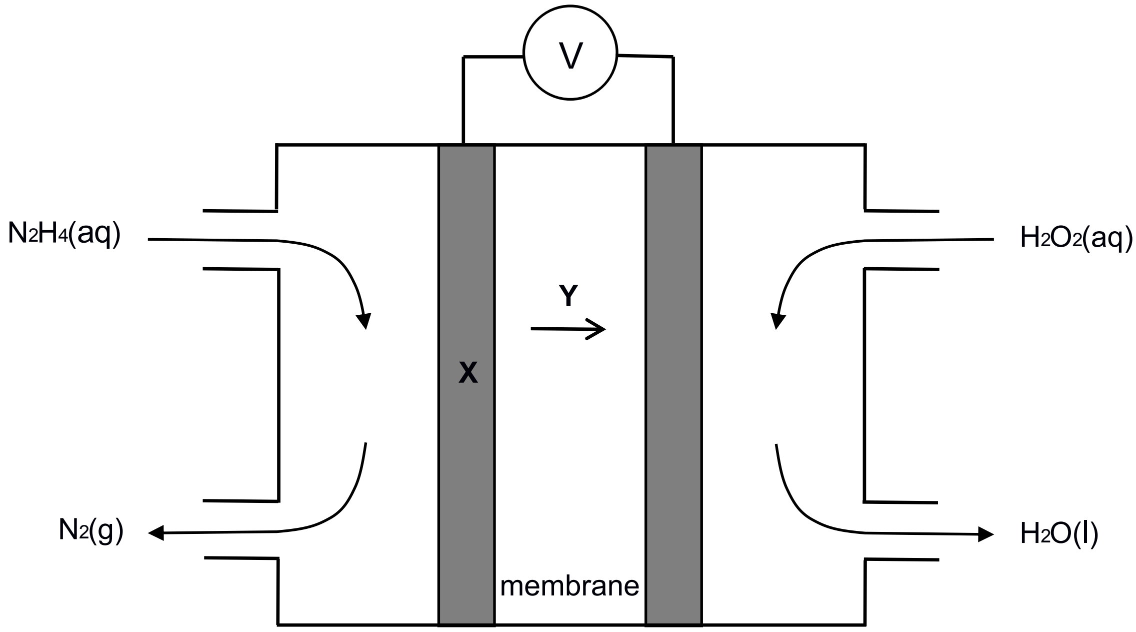
If a sample of pure water is heated to 70 °C, which of the following would be true?

(i) $[H_3O^+] > 1.0 \times 10^{-7}$ mol L^{-1}
(ii) $[H_3O^+] > [OH^-]$
(iii) $K_w > 1.0 \times 10^{-14}$
(iv) pH > 7

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

Questions 21 and 22 refer to the direct hydrazine fuel cell.

Direct hydrazine fuel cells are of interest because of their very high energy density. The diagram below shows the basic structure of such a cell, which utilises the reactants hydrazine (N_2H_4) and hydrogen peroxide (H_2O_2).



21. Which of the following gives the correct labels for X and Y?

	X	Y
(a)	anode	anions
(b)	anode	cations
(c)	cathode	anions
(d)	cathode	cations

22. This cell is classified as a fuel cell because it

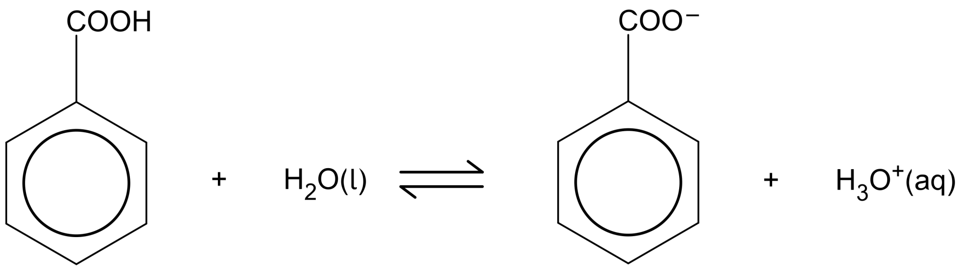
(a) does not produce any carbon emissions.
(b) produces a large amount of energy from a small amount of fuel.
(c) requires the continuous input of reactants.
(d) can easily be scaled down for use in portable devices.

23. A student set up a small-scale version of the industrial cell used in the electrolytic refining of copper. Which of the following substances would **not** be required to set up this cell?

(a) Sodium hydroxide solution.
(b) Sulfuric acid solution.
(c) Copper metal electrodes.
(d) Copper(II) sulfate solution.

Questions 24 and 25 refer to the following equilibrium system.

A student had a beaker containing 1.0 L of 1.0 mol L^{-1} benzoic acid solution, $C_6H_5COOH(aq)$, which ionises according to the equation below.



The K_a value of benzoic acid is 6.5 x 10^{-5} and the pH of the solution was 2.09.

The student then added 0.5 moles of sodium benzoate crystals, $C_6H_5COONa(s)$, to this solution and stirred.

24. As the crystals were dissolving, which of the following statements are true?

(i) The forward reaction rate was favoured.
(ii) The forward reaction rate was increasing.
(iii) The value of K_a was increasing.
(iv) The value of the pH was increasing.

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

Once all the crystals had dissolved, the student decided to test the buffering capacity of the resulting solution.

25. Based on your knowledge of chemical theory, which prediction is most likely to be correct?

(a) The solution will have higher buffering capacity upon addition of $H_3O^+(aq)$.
(b) The solution will have higher buffering capacity upon addition of $OH^-(aq)$.
(c) The solution will buffer the addition of $H_3O^+(aq)$ and $OH^-(aq)$ equally well.
(d) The solution will not act as a buffer.

End of Section One

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Section Two: Short answer **35% (75 marks)**

This section has 8 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.

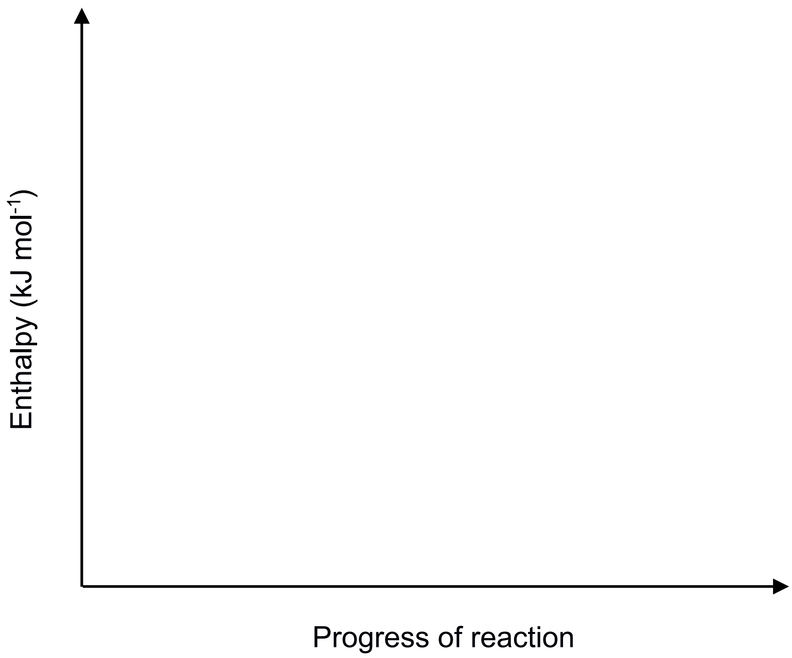
Question 26 **(11 marks)**

Consider the chemical equilibrium system represented by the following equation.

$$H_2(g) + Br_2(g) \rightleftharpoons 2\,HBr(g) + 72.9\text{ kJ}$$

colourless *red-brown* *colourless*

(a) On the axes below, sketch an energy profile diagram for this reaction. Label the reactants, products, activation energy and enthalpy change. (3 marks)



This reaction is usually carried out in the presence of a platinum catalyst.

(b) Explain, in terms of collision theory, how platinum increases the rate of this reaction. (2 marks)

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A chemist obtained a small sample of this equilibrium mixture in a sealed reaction chamber. The colour of the mixture was red-brown.

The chemist decided to investigate what factors would result in the colour of the mixture becoming darker red-brown, **whilst always maintaining a closed system**.

(c) Complete the tables below by;

- identifying two (2) changes that could be imposed on this system, which would result in a darker red-brown appearance, and
- justifying why this colour change occurs. (6 marks)

Imposed change 1 (1 mark)	
Justification (2 marks)	

Imposed change 2 (1 mark)	
Justification (2 marks)	

Question 27 **(10 marks)**

Permanganic acid, $HMnO_4$, is a **strong** acid with a deep purple colour.

Consider the process of permanganic acid ionising in water.

(a) Write an equation for this process that illustrates each the Arrhenius and Bronsted-Lowry behaviours of an acid. (3 marks)

Arrhenius	
Bronsted-Lowry	

Solutions of permanganic acid are unstable and decompose according to the following equation.

$$2\,HMnO_4(aq) \rightarrow 2\,MnO_2(s) + O_2(g) + H_2O_2(l)$$

(b) Demonstrate, with the use of oxidation numbers, that permanganic acid is both the oxidising and reducing agent in this reaction. (2 marks)

The rate of decomposition of permanganic acid can be accelerated by adding heat, light or other acids.

(c) Explain, in terms of collision theory, how adding heat or other acids can speed up this decomposition reaction. (3 marks)

Addition of heat (2 marks)	
Addition of other acids (1 mark)	

(d) What is the likely pH of sodium permanganate solution, $NaMnO_4(aq)$? Circle your choice below and justify your answer. (2 marks)

less than 7 7 greater than 7

___

___

___

___

Question 28 **(9 marks)**

Aqua regia means 'royal water' and is a very corrosive mixture of nitric acid (HNO_3) and hydrochloric acid (HCl). It is made by mixing nitric acid and hydrochloric acid in a 1:3 mole ratio respectively.

Aqua regia is always freshly prepared immediately before use because, upon mixing of the acids, the solution begins to decompose and form toxic yellow vapours.

A fresh sample of aqua regia was prepared by a chemist. A 5.00 mL aliquot of the aqua regia was placed in a 250.0 mL volumetric flask, and made up to the mark with distilled water.

Several 15.00 mL aliquots of the diluted solution were taken and titrated against standard 0.1778 mol L^{-1} NaOH(aq). The average titre was determined to be 17.28 mL.

(a) Calculate the concentration of hydrochloric acid (in mol L^{-1}) in the freshly prepared aqua regia sample. (6 marks)

(b) Describe why the concentration of hydrochloric acid calculated is likely to be lower than that used to prepare the original aqua regia solution. (1 mark)

(c) Identify two (2) safety risks the chemist should consider when performing this analysis. (2 marks)

1	
2	

Question 29 **(9 marks)**

(a) Write a balanced ionic equation for the reaction that would occur when 1.0 mol L^{-1} nitric acid is poured over powdered iron(III) carbonate. Include state symbols in your answer. (3 marks)

(b) Write observations for the reaction that would take place when chlorine gas is bubbled through sodium bromide solution. (2 marks)

(c) Write balanced oxidation and reduction half-equations for the reaction that would occur when a several pieces of chromium are placed in a tin(II) nitrate solution. (2 marks)

Oxidation half-equation	
Reduction half-equation	

(d) Prove whether the reaction below would occur spontaneously, under standard conditions. (2 marks)

$$2\,Fe^{2+}(aq) + O_2(g) + 2\,H^+(aq) \rightarrow 2\,Fe^{3+}(aq) + H_2O_2(aq)$$

Question 30 **(9 marks)**

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

$$2\ NH_3(g)\ +\ 4\ O_3(g)\ \rightleftharpoons\ NH_4NO_3(s)\ +\ 4\ O_2(g)\ +\ H_2O(g)$$

Consider the impact that each of the imposed changes in the table below would have on this equilibrium, **once equilibrium was allowed to re-establish**.

Complete the table, by stating the effect of each change on the;

- position of equilibrium
- rate of the reverse reaction, and
- concentration of $O_2(g)$.

Consider each change in isolation.

	Position of equilibrium (state 'left', 'right' or 'no change'	Rate of reverse reaction (state 'increased', 'decreased' or 'no change')	Concentration of $O_2(g)$ (state 'increased', 'decreased' or 'no change')
Addition of $H_2O(g)$ at constant volume			
Removal of $NH_3(g)$ at constant volume			
Decrease total volume of system			

Question 31 **(10 marks)**

Drinking water can be treated with ozone, $O_3(g)$, in order to remove iron and manganese ions. The iron and manganese ions are quickly oxidised by the ozone, forming insoluble precipitates that can be easily removed by filtration.

The following equations represent the chemical processes occurring in ozone water treatment.

$$2\,Fe^{2+}(aq) + O_3(g) + 5\,H_2O(l) \rightarrow 2\,Fe(OH)_3(s) + O_2(g) + 4\,H^+(aq)$$

$$2\,Mn^{2+}(aq) + 2\,O_3(g) + 4\,H_2O(l) \rightarrow 2\,MnO(OH)_2(s) + 2\,O_2(g) + 4\,H^+(aq)$$

A 455 L sample of water containing both iron ions, $Fe^{2+}(aq)$, and manganese ions, $Mn^{2+}(aq)$, was treated with excess ozone. The water sample was then filtered, and the total mass of the dried precipitate was 0.487 g. The original concentration of manganese ions in the water had been determined by previous analysis to be 0.120 mg L^{-1}.

Calculate the pH of the filtered water sample. You may assume the original pH of the untreated water was 7.

Question 32 **(8 marks)**

Consider the chemical equation below.

$$H_2PO_4^-(aq) + CO_3^{2-}(aq) \rightleftharpoons HCO_3^-(aq) + HPO_4^{2-}(aq)$$

(a) On the equation above, label and link the conjugate acid-base pairs. (2 marks)

The four (4) solutions below were prepared, to allow the pH of each species in this equation to be studied in isolation.

$NaH_2PO_4(aq)$ $Na_2CO_3(aq)$ $NaHCO_3(aq)$ $Na_2HPO_4(aq)$

(b) Identify one (1) solution above that would have a pH below 7, and support your choice with an appropriate chemical equation. (2 marks)

pH below 7	
Supporting equation	

(c) Identify one (1) solution above that would have a pH above 7, and support your choice with an appropriate chemical equation. (2 marks)

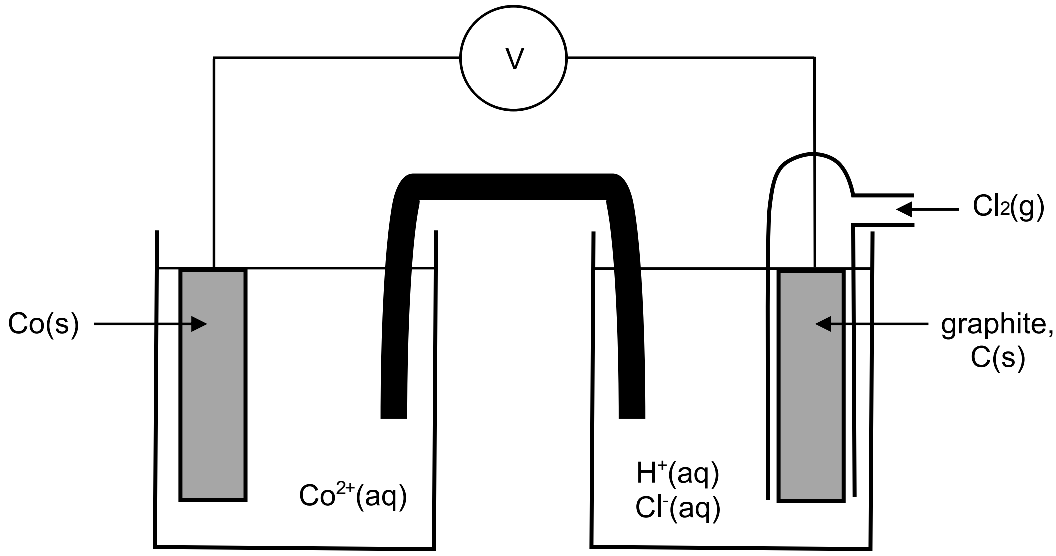
pH above 7	
Supporting equation	

All the species in the original equation above originate from phosphoric acid and carbonic acid, both of which are polyprotic.

(d) Define the term 'polyprotic' and name one (1) different polyprotic acid. (2 marks)

Question 33 **(9 marks)**

The diagram below illustrates the set-up of a galvanic cell, which was designed under standard conditions.



(a) Write balanced half-equations for the reactions occurring at each electrode. (3 marks)

Cathode	
Anode	

(b) Complete the following table. (3 marks)

State the original concentration of cobalt ions, $Co^{2+}(aq)$.	
State the original pressure of chlorine gas, $Cl_2(g)$.	
Calculate the maximum theoretical EMF produced.	

If the chlorine gas supply ran out, the cell would still be able to function. However, a different chemical reaction would then take place.

(c) Complete the following table, for this version of the cell. (3 marks)

State the polarity (sign) of the C(s) electrode.	
State the expected observations at the graphite, C(s), electrode.	
Calculate the maximum theoretical EMF of this cell if it was under standard conditions.	

End of Section Two

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See next page

Section Three: Extended answer **40% (89 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.

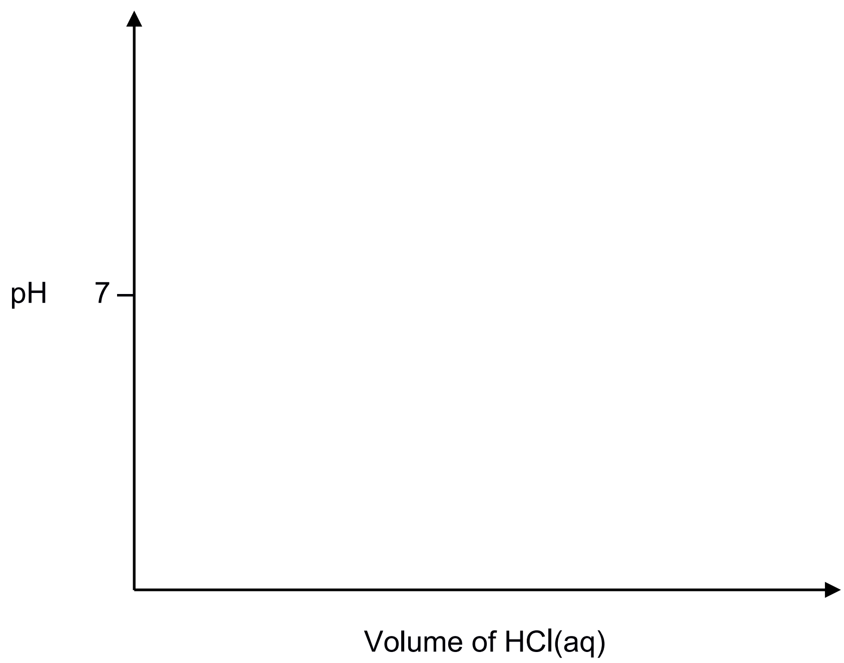
Question 34 **(16 marks)**

A chemistry professor prepared a standard solution by dissolving a sample of sodium borate decahydrate, $Na_2B_4O_7.10H_2O(s)$ in distilled water.

Sodium borate decahydrate is a weak base that is commonly used as a primary standard in volumetric analysis.

Three (3) students took a portion of the standard sodium borate solution and performed a series of titrations to determine the concentration of a sample of hydrochloric acid. The students placed aliquots of sodium borate in the conical flask, whilst the hydrochloric acid was in the burette.

(a) On the axes below, sketch a titration curve for this investigation. Label the equivalence point. (3 marks)



The results collected by each student are provided in the tables below.

Student A	Rough trial	1	2	3	4
Final (mL)	25.85	38.09	43.35	41.15	47.89
Initial (mL)	0.56	12.86	18.11	15.92	22.66
Titre (mL)	25.29	25.23	25.24	25.23	25.23

Student B	Rough trial	1	2	3	4
Final (mL)	25.11	47.25	25.31	47.91	46.67
Initial (mL)	1.89	25.11	2.36	25.31	24.88
Titre (mL)	23.22	22.14	22.95	22.60	21.79

Student C	Rough trial	1	2	3	4
Final (mL)	22.15	41.14	22.47	41.33	49.07
Initial (mL)	2.78	22.15	3.54	22.47	30.13
Titre (mL)	19.37	18.99	18.93	18.86	18.94

The professor also performed the same titration and obtained the results given below. The students were told to assume the professor's average titre to be the true value when evaluating their results.

Professor	Rough trial	1	2	3	4
Final (mL)	24.27	46.63	25.49	47.87	49.70
Initial (mL)	1.33	24.27	3.12	25.49	27.33
Titre (mL)	22.94	22.36	22.37	22.38	22.37

(b) Calculate the average titre using the professor's data. (1 mark)

(c) Which student obtained the most precise results? Justify your answer. (2 marks)

(d) Which student used phenolphthalein indicator (end point pH 8.8 - 10.1) in their titration? Justify your answer. (2 marks)

Even the professor's titration data showed some variation, illustrating that sources of random error can never be eliminated.

(e) Suggest two (2) sources of random error that may have affected the professor's results. (2 marks)

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2	

The original primary standard was produced when the professor dissolved 11.06 g of sodium borate decahydrate in distilled water, and made the solution up to 500.0 mL in a volumetric flask.

$$Na_2B_4O_7.10H_2O(s) \rightarrow 2\ Na^+(aq) + B_4O_7^{2-}(aq) + 10\ H_2O(l)$$

The titration was performed using 20.00 mL aliquots of sodium borate solution. The titration reaction can be represented by the chemical equation below.

$$B_4O_7^{2-}(aq) + 2\ H^+(aq) + 5\ H_2O(l) \rightarrow 4\ H_3BO_3(aq)$$

(f) Calculate the concentration of the hydrochloric acid solution, using the professor's results. State your answer to the appropriate number of significant figures. (6 marks)

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Question 35 **(16 marks)**

The corrosion of iron and iron-containing structures is an ongoing and expensive problem. The subsequent rust that forms on an iron structure as a result of corrosion is flaky and weak. Rust not only changes the appearance of the iron, but decreases its strength. The consequences of this are wide ranging and diverse, and largely depend on the function of the iron structure.

The chemical processes occurring during the initial stage of iron corrosion can be represented by the half-equations below.

Cathode: $O_2(g) + 2\ H_2O(l) + 4\ e^- \rightarrow 4\ OH^-(aq)$

Anode: $Fe(s) \rightarrow Fe^{2+}(aq) + 2\ e^-$

(a) Prove, using oxidation numbers, that oxygen and water react at the cathodic site. (2 marks)

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One common method which can prevent iron corrosion is the use of sacrificial anodes. These are often found in hot water tanks, where aluminium or zinc rods can be used to protect the iron tank.

In this situation, the cathode reaction remains the same, but the presence of a sacrificial anode prevents the iron from reacting.

(b) Explain why aluminium and zinc can be used as sacrificial anodes, but tin cannot. (3 marks)

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(c) Write a balanced chemical equation for the redox reaction occurring when an aluminium sacrificial anode is connected to the hot water tank. (2 marks)

A 545 g aluminium rod was connected to a hot water tank, to act as the sacrificial anode. It was known that, on average, 261 mL of oxygen gas would react each day.

(d) Calculate the number of years the hot water tank would be protected, before the aluminium rod would need replacing. Assume constant environmental conditions of 20.0 °C and 101.3 kPa. (5 marks)

(e) If a sacrificial zinc anode, of the same mass, had been used instead, would this provide longer lasting protection for the hot water tank? Support your answer with appropriate calculations. (4 marks)

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Question 36 **(20 marks)**

The following related chemical equilibria both involve aqueous copper(II) ions, $Cu^{2+}(aq)$.

Equilibrium 1: $Cu^{2+}(aq) + 2\ OH^{-}(aq) \rightleftharpoons Cu(OH)_2(s)$

Equilibrium 2: $Cu^{2+}(aq) + 4\ NH_3(aq) \rightleftharpoons Cu(NH_3)_4^{2+}(aq)$

(a) Classify these equilibria as 'homogeneous' or 'heterogeneous', and write the equilibrium constant expression for each. (4 marks)

	Equilibrium 1
Classify as 'homogeneous' or 'heterogeneous'	
Equilibrium constant (K) expression	

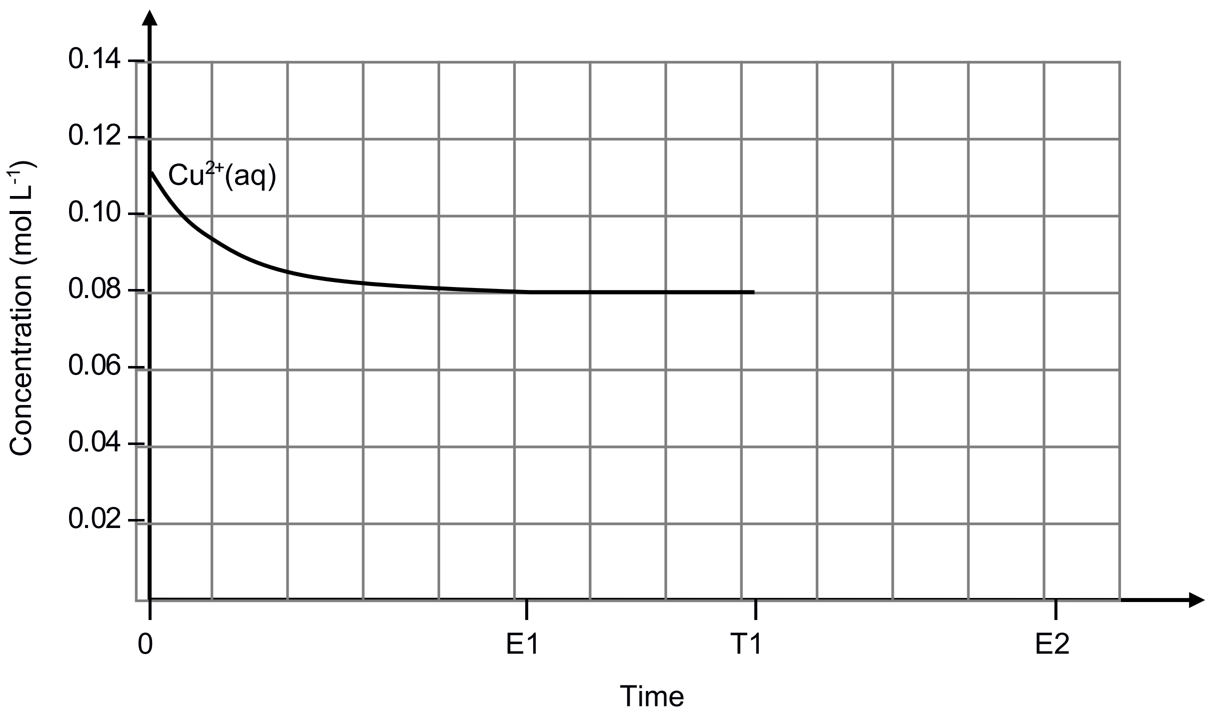
	Equilibrium 2
Classify as 'homogeneous' or 'heterogeneous'	
Equilibrium constant (K) expression	

The equations for both equilibria have been reproduced below for convenience.

Equilibrium 1: $Cu^{2+}(aq) + 2\ OH^-(aq) \rightleftharpoons Cu(OH)_2(s)$

Equilibrium 2: $Cu^{2+}(aq) + 4\ NH_3(aq) \rightleftharpoons Cu(NH_3)_4^{2+}(aq)$

A sample of **Equilibrium 1** was prepared by mixing 0.11 mol L^{-1} copper(II) nitrate, $Cu(NO_3)_2(aq)$, with 0.090 mol L^{-1} sodium hydroxide, NaOH(aq) at Time 0. The graph below illustrates the change in concentration of $Cu^{2+}(aq)$, from Time 0 until equilibrium was established at Time E1.



(b) Describe any observations that would have been made as equilibrium was established. (2 marks)

(c) On the graph above, add a curve showing the concentration changes for $OH^-(aq)$ ions, from Time 0 to E1. Continue your curve from Time E1 to T1. (3 marks)

(d) Explain why no curve can be plotted for $Cu(OH)_2(s)$. (1 mark)

(e) Explain, in terms of collision theory, what is happening to the rate of the forward reaction from Time 0 to Time E1. (3 marks)

At Time T1, a few drops of concentrated NH_3(aq) was added to the equilibrium system. This allowed **Equilibrium 2** to establish in the mixture, and resulted in the formation of a deep blue solution containing $Cu(NH_3)_4^{2+}$(aq) ions.

(f) On the same graph above, sketch a curve using a dotted line, showing the change in concentration for NH_3(aq) from Time T1 until equilibrium is established at Time E2. (2 marks)

At Time E2, there was much less $Cu(OH)_2$(s) present in the equilibrium mixture compared to Time E1.

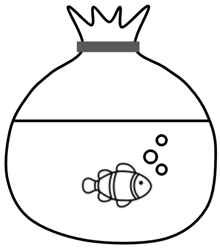
(g) Explain this observation, in terms of collision theory and reaction rates. (5 marks)

Question 37 **(19 marks)**

For fish to survive in an aquarium, water quality needs to be constantly monitored and adjusted.

One important factor affecting water quality is pH. The pH of aquarium water needs to be kept within a narrow range for fish to survive.

If there is poor water circulation, the pH may fall. For example, when fish are transported from the pet store to their aquarium, they are placed in a plastic bag, with only limited volumes of water and air.

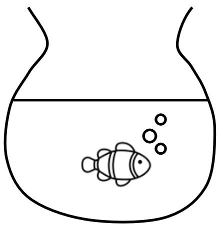


As carbon dioxide, $CO_2(aq)$, is produced by the fish, the pH of the water in the bag falls.

(a) Write a series of two (2) balanced chemical equations, showing how the production of $CO_2(aq)$ by the fish, results in a lowered water pH. (2 marks)

1.	
2.	

When the bag is opened, and the water is exposed to the air, the pH will rise again.



(b) Describe how this results in the formation of an 'open system'. (2 marks)

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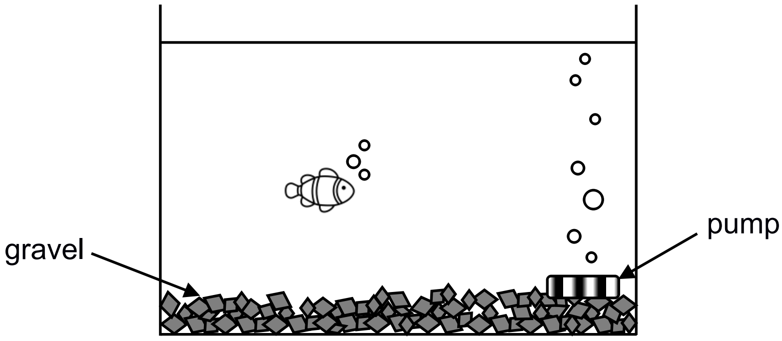
Once the fish are placed in their aquarium, a pump can be used to ensure the water continually circulates.



Certain types of gravel are also useful in maintaining the water pH. Materials like crushed coral or aragonite crystals contain calcium carbonate, $CaCO_3(s)$, which can increase the pH over time.

(c) Write a chemical equation showing how $CaCO_3(s)$ can result in an increased water pH. (2 marks)

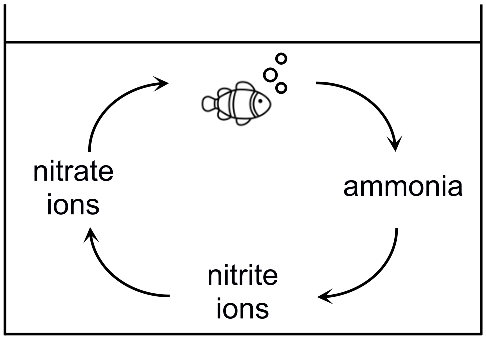
Due to the presence of species such as $CO_2(aq)$ and $CaCO_3(s)$ in the aquarium, the following buffer system is able to form in the water.

$$HCO_3^-(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CO_3^{2-}(aq)$$

When acidic species are produced by the fish, plants and bacteria in the aquarium, this buffer assists in stabilising the pH of the water.

(d) Explain how this buffer allows the pH of aquarium water to be maintained, as acids are produced. Use a chemical equation to support your answer. (4 marks)

Establishing a healthy nitrogen cycle is also key to maintaining aquarium water quality.



Fish excrete the waste product ammonia, which is very harmful to them. Nitrifying bacteria in the aquarium are able to convert this ammonia to nitrite ions, and then into nitrate ions, which are harmless to the fish.

(e) Write balanced half-equations, in acidic conditions, representing both processes performed by the nitrifying bacteria. (4 marks)

Ammonia to nitrite ions	
Nitrite ions to nitrate ions	

Fish such as *African Cichlids* prefer water with a pH of between 8.2 and 9.0.

A student attempted to replicate this pH in the laboratory. They had access to a fish tank with a 75.0 L capacity, a standard 0.02717 mol L^{-1} $NaOH(aq)$ solution, and distilled water.

(f) Describe how the student could prepare a full tank of water with a pH of 8.6. Support your answer with appropriate calculations. (5 marks)

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Question 38 **(18 marks)**

Nickel electroplating is performed on a wide variety of objects, such as bumpers, rims and exhaust pipes for cars and motorcycles, as well as many household fixtures such as taps, lights, door knobs and towel rails.

(a) What is 'metal electroplating'? (1 mark)

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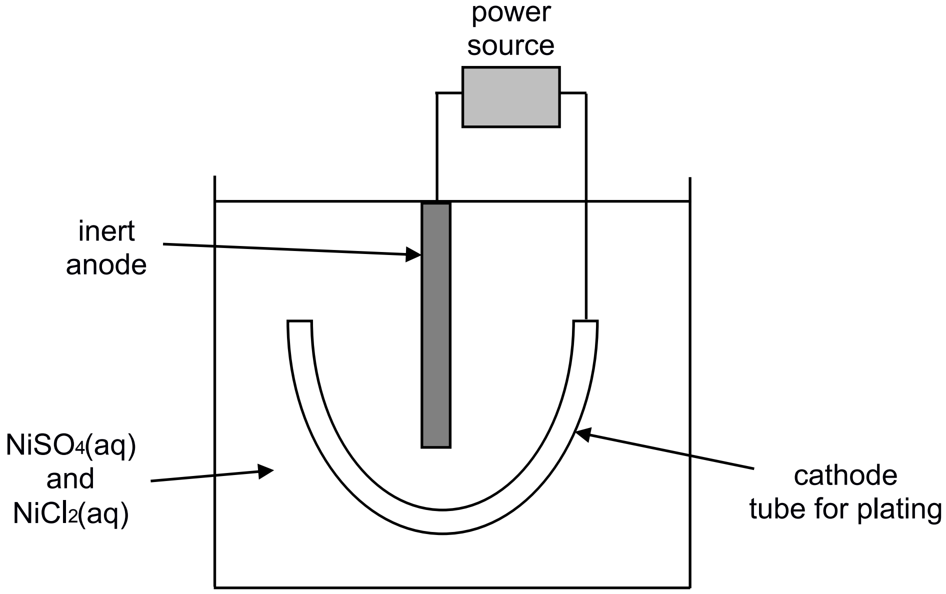
(b) Suggest two (2) reasons that it may be desirable to plate objects with nickel. (2 marks)

1.	
2.	

There are several different methods used for nickel electroplating. The most common involves a cell with an electrolyte containing both nickel sulfate, $NiSO_4(aq)$, and nickel chloride, $NiCl_2(aq)$. This electrolyte is maintained at a temperature of 40 - 60 °C and a pH of 3.5 - 4.5.

An inert anode of graphite is used for applications such as the internal plating of tubes. This results in water reacting at the anode to produce oxygen gas, $O_2(g)$.

The diagram below illustrates the set-up of such a cell.



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(c) Why is a power source required for the electroplating process? (1 mark)

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(d) On the diagram above, label the polarity (sign) of the electrodes. (1 mark)

(e) Explain why cations migrate towards the cathode in an electroplating cell. (2 marks)

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(f) Write half-equations representing the reactions occurring at the cathode and anode in this cell. (4 marks)

Cathode	
Anode	

(g) List two (2) observations that would be made as this cell operates. (2 marks)

1.	
2.	

The cell above was used to apply an internal plating of nickel to some tubes. The volume of the electrolyte was 1050 L and it contained 1.14 mol L^{-1} $NiSO_4(aq)$ and 0.337 mol L^{-1} $NiCl_2(aq)$. Each tube required 41.2 g of nickel to be sufficiently plated.

(h) Calculate the number of tubes that could be plated with nickel, before the electrolyte would need to be replenished. (5 marks)

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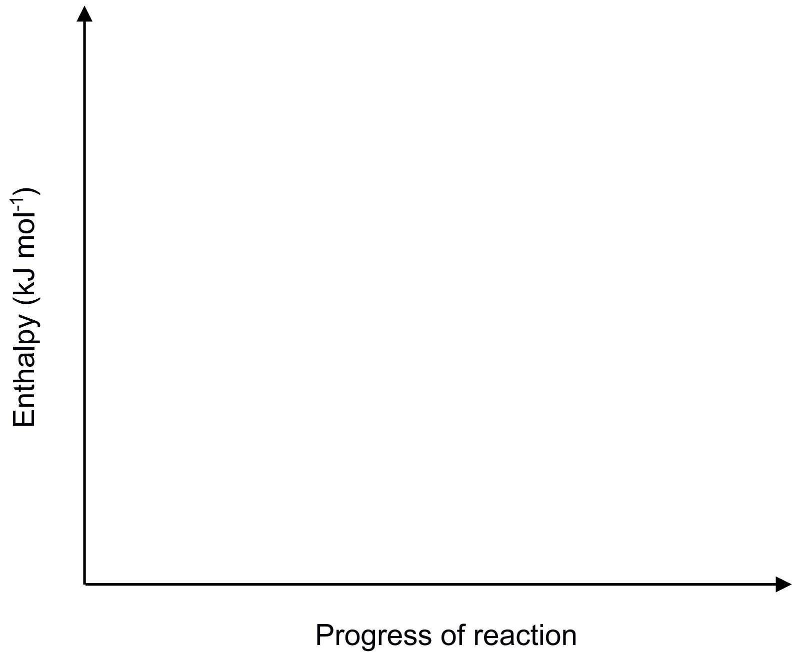
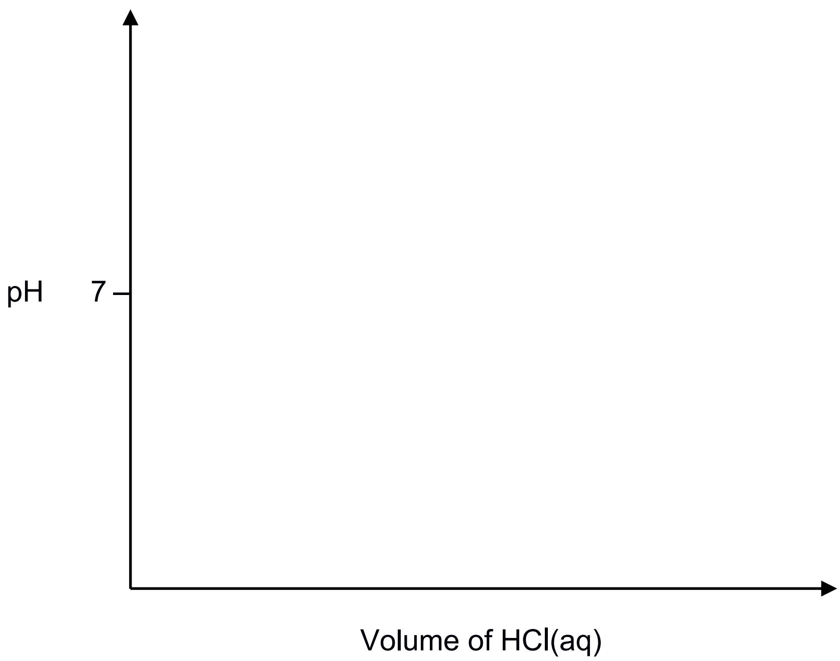
Question 26 (a)



Question 34 (a)



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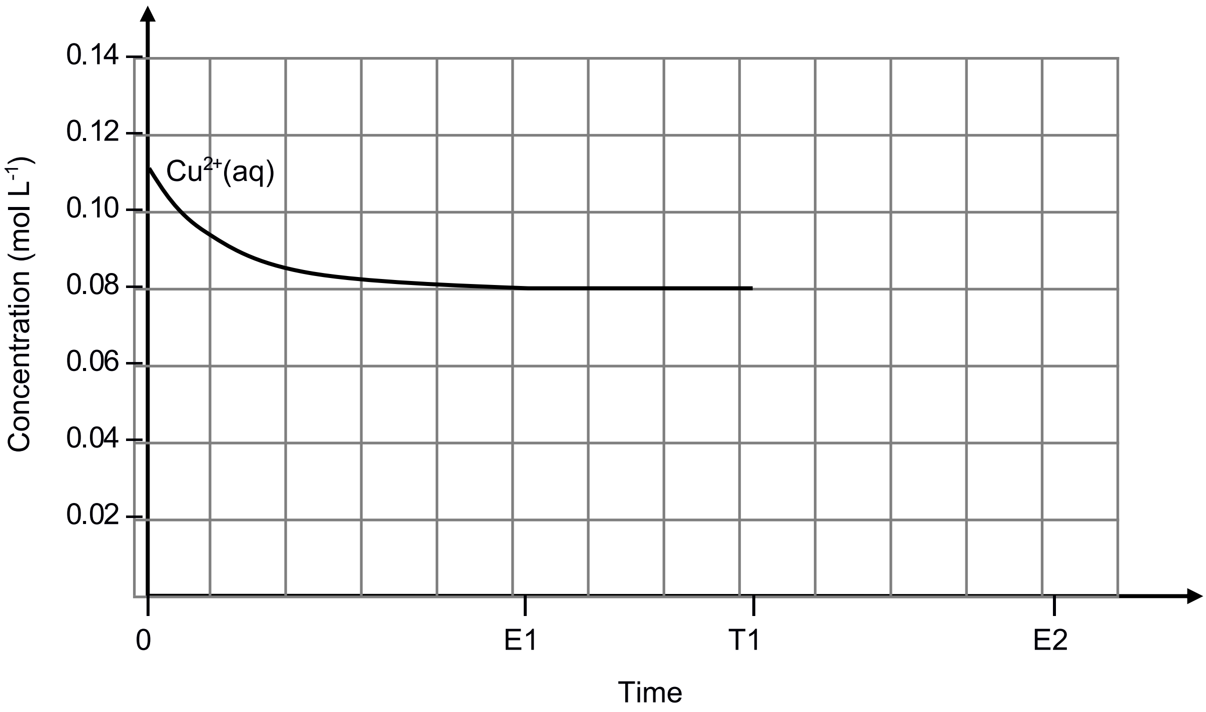
Question 36 (c), (f)



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