MATER DEI
COLLEGE
FAITH WITH COURAGE

# Semester One Examination 2022
# 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<br>Multiple-choice | 25 | 25 | 50 | 25 | 25 |
| Section Two<br>Short answer | 9 | 9 | 60 | 73 | 35 |
| Section Three<br>Extended answer | 5 | 5 | 70 | 85 | 40 |
| | | | | **Total** | 100 |

## 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.

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**Questions 1 and 2 refer to the following equilibrium system.**

A sample of nitrosyl chloride gas, NOCl(g), was injected into a fixed-volume and insulated canister, which did not allow heat to enter or exit. The NOCl(g) began to decompose and the system established equilibrium according to the chemical equation below.

$$2\,NOCl(g) \;+\; 77\,kJ \;\rightleftharpoons\; 2\,NO(g) \;+\; Cl_2(g)$$

1. How would the temperature and pressure readings inside the canister at equilibrium compare to the initial values (i.e. at the time the NOCl(g) was injected into the canister)?

| | **Temperature** | **Pressure** |
|---|---|---|
| (a) | lower | lower |
| (b) | lower | higher |
| (c) | higher | lower |
| (d) | higher | higher |

2. The addition of a suitable catalyst to this equilibrium system would

(a) shift the position of equilibrium to the right.
(b) increase the value of $K_c$.
(c) decrease the forward reaction rate.
(d) increase the reverse reaction rate.

3. Consider the following observations, noted in a student's laboratory book.

> *A white solid dissolves, producing a colourless solution and a colourless, odourless gas.*

Which of the following reactants would display these observations upon mixing?

(a) Solid barium hydroxide and hydrochloric acid solution.
(b) Copper(II) carbonate powder and nitric acid solution.
(c) Silver carbonate powder and hydrochloric acid solution.
(d) Magnesium carbonate chips and nitric acid solution.

4. In which of the following redox processes does the oxidation number of bromine change by a magnitude of 2?

(a) $Br_2 \rightarrow BrF_3$
(b) $FeBr_3 \rightarrow Br_2$
(c) $BrCl \rightarrow Br^-$
(d) $HOBr \rightarrow BrO_3^-$

5. The anode of an electrochemical cell is always

(i) the site where electrons are lost.
(ii) the negative electrode.
(iii) the target of anion migration.

Which of these statements are **true**?

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

6. Consider the chemical equations below.

Equation 1 $NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$
Equation 2 $HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$
Equation 3 $HNO_3(aq) + H_2O(l) \rightarrow NO_3^-(aq) + H_3O^+(aq)$
Equation 4 $KOH(aq) \rightarrow K^+(aq) + OH^-(aq)$

Which of these equations represents the behaviour of an Arrhenius base and a Br∅nsted-Lowry acid?

| | **Arrhenius base** | **Br∅nsted-Lowry acid** |
|---|---|---|
| (a) | Equation 1 | Equation 2 |
| (b) | Equation 4 | Equation 3 |
| (c) | Equation 1 | Equation 3 |
| (d) | Equation 4 | Equation 2 |

7. Which of the following is **not** a commitment that all 192 parties to the United Nations Kyoto Protocol have made?

(a) To take action to limit greenhouse gas emissions.
(b) To adhere to fixed greenhouse gas reduction targets.
(c) To monitor their greenhouse gas emission levels.
(d) To report on their greenhouse gas emissions periodically.

**Questions 8, 9 and 10 refer to the following experiment.**

A student weighed three 0.80 g samples of magnesium into three separate test tubes. A different acid was then added to each test tube. In each case, 20.00 mL of 1.0 mol $L^{-1}$ acid was added.

The student used a stopwatch to time how long it took for the magnesium to dissolve. The results collected by the student are summarised in the table below.

| | Acid A | Acid B | Acid C |
|---|---|---|---|
| Time taken for Mg(s) to dissolve | 4.1 s | 10.7 s | 3.2 s |

8. Which of the following lists contains variables which should be controlled to ensure the collection of valid data?

(a) State of subdivision of magnesium, type of acid, volume of acid.
(b) Mass of magnesium, initial temperature of acid, concentration of acid.
(c) Time for magnesium to dissolve, volume of acid, mass of magnesium.
(d) Initial temperature of acid, type of acid, state of subdivision of magnesium.

9. Correctly identify one source of random and one source of systematic error in this experiment.

| | **Random error** | **Systematic error** |
|---|---|---|
| (a) | Fluctuations in atmospheric pressure between each trial. | Measuring the volume of each acid from the top of the meniscus. |
| (b) | Uncalibrated scales that display the mass of each magnesium sample as 0.05 g higher than true. | Small differences in the time taken by the student to start the stopwatch. |
| (c) | Fluctuations in laboratory temperature between each trial. | Not performing repeat trials. |
| (d) | Not taring the scales before each use. | Leaving the jar of magnesium open, allowing a thin layer of magnesium oxide to form. |

10. Which of the 1.0 mol $L^{-1}$ acid samples had the lowest pH?

(a) Acid A.
(b) Acid B.
(c) Acid C.
(d) All three acids had the same pH.

11. The vanadium half-cell has the following standard electrode potential data.

$$V^{2+}(aq) + 2e^- \rightleftharpoons V(s) \qquad E^0 = -1.13\ V$$

If this half-cell was connected to a cobalt half-cell, $Co^{2+}(aq)/Co(s)$, under standard conditions, the maximum voltage produced by this cell would be

(a) +0.85 V.
(b) - 0.85 V.
(c) +1.41 V.
(d) - 1.41 V.

12. Chlorine gas was bubbled through a 1.0 mol $L^{-1}$ solution of sodium bromide. The oxidation half-equation for the reaction that would occur is

(a) $Cl_2(g) + 2e^- \rightarrow 2Cl^-(aq)$
(b) $2Cl^-(aq) \rightarrow Cl_2(g) + 2e^-$
(c) $Br_2(g) + 2e^- \rightarrow 2Br^-(aq)$
(d) $2Br^-(aq) \rightarrow Br_2(g) + 2e^-$

**Questions 13 and 14 refer to the following equilibrium system.**

The following aqueous equilibrium was set up in a beaker. Once equilibrium was established, the colour of the solution was a murky purple-green.

$$\underset{\text{green}}{Cr(H_2O)_6^{3+}(aq)} + 6NH_3(aq) \rightleftharpoons \underset{\text{purple}}{Cr(NH_3)_6^{3+}(aq)} + 6H_2O(l)$$

The contents of the beaker was then poured into two separate test tubes.

13. To the first test tube, a few drops of concentrated $NH_3(aq)$ was added, and the system was allowed to re-establish equilibrium.

Which of the following is **not** correct?

(a) The forward reaction rate would be increased.
(b) The reverse reaction rate would be increased.
(c) The equilibrium concentration of $NH_3(aq)$ would be increased.
(d) The value of $K_c$ would be increased.

14. The second test tube was left on the laboratory bench for one week, allowing some of the water to slowly evaporate.

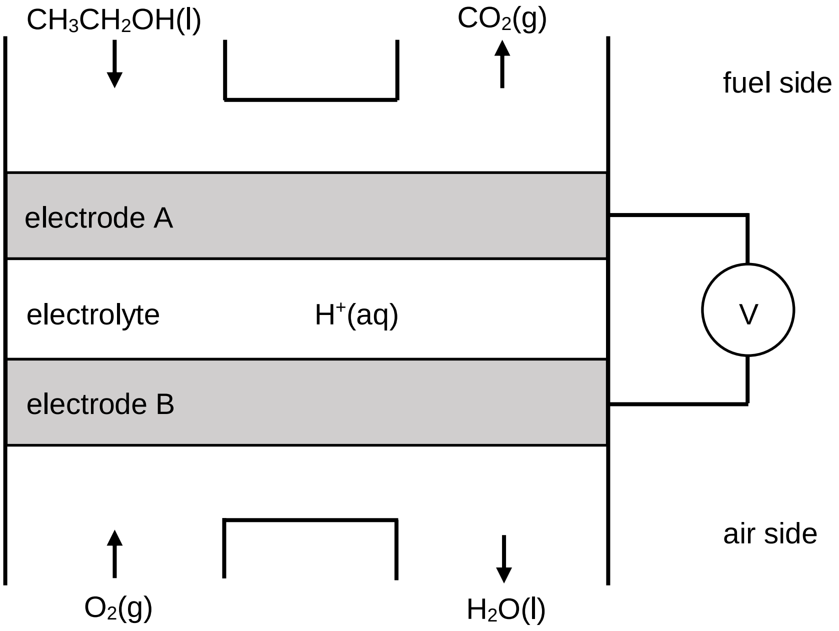
Classify this system as ‘open’ or ‘closed’, and describe how the colour of the solution would have changed.

| | **Type of system** | **Colour of equilibrium mixture** |
|---|---|---|
| (a) | closed | more purple |
| (b) | closed | more green |
| (c) | open | more purple |
| (d) | open | more green |

**Questions 15, 16 and 17 refer to the following information.**

The Nissan Motor Corporation has developed cars that are powered by direct ethanol fuel cells (DEFCs). These fuel cells use bioethanol, made from sugar cane and corn, to produce electricity.

As shown in the simplified diagram below, ethanol, $CH_3CH_2OH(l)$, enters the fuel cell and is converted to $CO_2(g)$ at electrode A. Air enters on the other side, and the $O_2(g)$ in the air is converted to $H_2O(l)$ at electrode B. These reactions take place in an acidic electrolyte.



15. This cell is classified as a fuel cell because

(a) it produces electrical energy from a spontaneous redox reaction.
(b) it has the potential to be branded as 'zero net $CO_2$ emission' technology.
(c) it utilises the stored chemical potential energy within reactants to do work.
(d) it requires the reactants to be continuously fed into the cell.

16. Which of the following correctly assigns the polarity of electrode A and the direction of hydrogen ion, $H^+(aq)$, movement in the electrolyte?

| | **Polarity of electrode A** | **Direction of $H^+(aq)$ movement** |
|---|---|---|
| (a) | positive | towards B |
| (b) | positive | towards A |
| (c) | negative | towards B |
| (d) | negative | towards A |

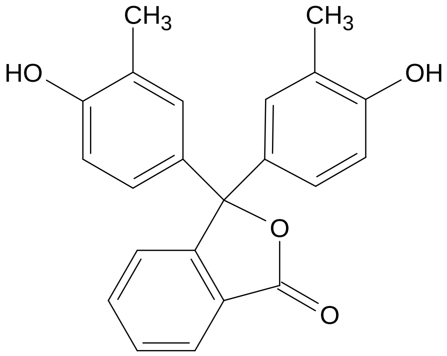
17. The correctly balanced half-equation for the reaction occurring at electrode A is;

(a) $CH_3CH_2OH(l) + H_2O(l) \rightarrow CO_2(g) + 8\ H^+(aq) + 8\ e^-$
(b) $CH_3CH_2OH(l) + 3\ H_2O(l) \rightarrow 2\ CO_2(g) + 12\ H^+(aq) + 12\ e^-$
(c) $CH_3CH_2OH(l) + H_2O(l) \rightarrow 2\ CO_2(g) + 8\ H^+(aq) + 8\ e^-$
(d) $CH_3CH_2OH(l) + 2\ H_2O(l) \rightarrow CO_2(g) + 10\ H^+(aq) + 10\ e^-$

**Questions 18 and 19 refer to the indicator o-cresolphthalein.**

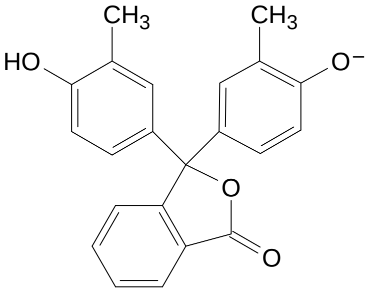
The indicator o-cresolphthalein is often used in acid-base titrations. Like most indicators, it exists in two forms, each displaying a different colour. The end point of o-cresolphthalein occurs at pH 8.2–9.8. At a pH lower than 8.2, the indicator appears colourless, whilst at a pH greater than 9.8, it appears purple.

The structure of o-cresolphthalein, as it exists in an acidic solution, is shown in the diagram to the right.

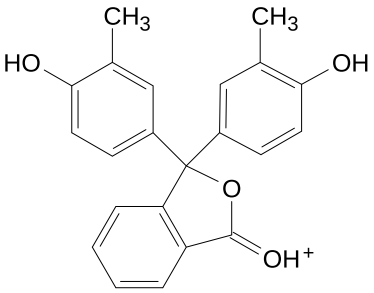


18. Which of the following correctly identifies the structure and colour of o-cresolphthalein as it would exist in a strongly basic solution?

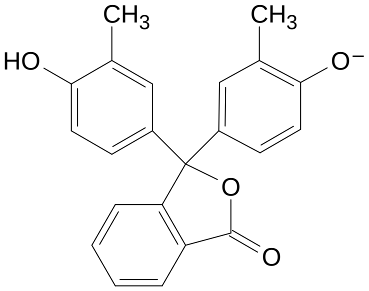
**Structure** **Colour**

(a)


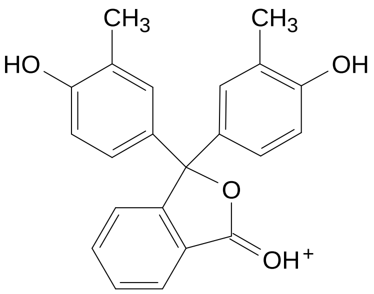
colourless

(b)


colourless

(c)


purple

(d)


purple

19. The indicator o-cresolphthalein would be suitable for a titration between

(a) $NaOH(aq)$ and $HF(aq)$.
(b) $Na_2CO_3(aq)$ and $HNO_3(aq)$.
(c) $KHCO_3(aq)$ and $HCl(aq)$.
(d) $NH_3(aq)$ and $CH_3COOH(aq)$.

20. Consider the system below, which has established equilibrium.

$$CH_4(g) + 2\ H_2S(g) \rightleftharpoons CS_2(g) + 4\ H_2(g) \qquad \Delta H = +253\ kJ\ mol^{-1}$$

Which of the following changes would increase the concentration of $H_2(g)$ in the equilibrium mixture?

(a) Increasing the total volume of the system.
(b) Decreasing the temperature of the system.
(c) Increasing the total pressure by injecting some $Ne(g)$.
(d) Decreasing the partial pressure of $CS_2(g)$.

21. Which of the following conjugate acid-base pairs could **not** form a buffer, when mixed in aqueous solution?

(a) $H_2SO_4$ / $HSO_4^-$
(b) $H_3PO_4$ / $H_2PO_4^-$
(c) $H_2CO_3$ / $HCO_3^-$
(d) $PO_4^{3-}$ / $HPO_4^{2-}$

22. A piece of nickel metal was placed into a beaker containing 1.0 mol $L^{-1}$ lead(II) nitrate solution. Which of the following would **not** be observed?

(a) A silver solid was placed into a colourless solution.
(b) The silver solid would dissolve.
(c) The green solution would decolorise.
(d) A new silver-grey solid would form.

23. A catalyst provides an alternate reaction pathway where the

(a) activation energy of the forward reaction is decreased more than the reverse reaction.
(b) activation energy of the endothermic reaction is decreased more than the exothermic reaction.
(c) activation energy of the forward and reverse reactions are decreased by the same proportion.
(d) activation energy of the endothermic and exothermic reactions are decreased by the same magnitude.

24. Liquid ammonia has the ability to autoionise in a manner similar to water. The chemical equation for this process, and the value of the equilibrium constant, are given below.

$$2\ NH_3 + \text{heat} \rightleftharpoons NH_4^+ + NH_2^- \qquad K_{am} = 5.1 \times 10^{-27} \text{ at } 25\ °C$$

Compare pure liquid samples of ammonia and water at 25 °C. How does the conductivity and pH of ammonia compare to that of water?

| | **Conductivity** | **pH** |
|---|---|---|
| (a) | lower than water | basic |
| (b) | lower than water | neutral |
| (c) | higher than water | neutral |
| (d) | higher than water | acidic |

25. A jeweller wanted to apply a thin coating of gold to a copper bangle using an electrolytic cell. When setting up this cell,

(a) the cathode should be solid gold.
(b) the bangle should be connected to the negative terminal of the power source.
(c) the electrolyte should be a solution containing copper(II) ions.
(d) the applied voltage should be as high as possible.

**End of Section One**

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

This section has 9 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.

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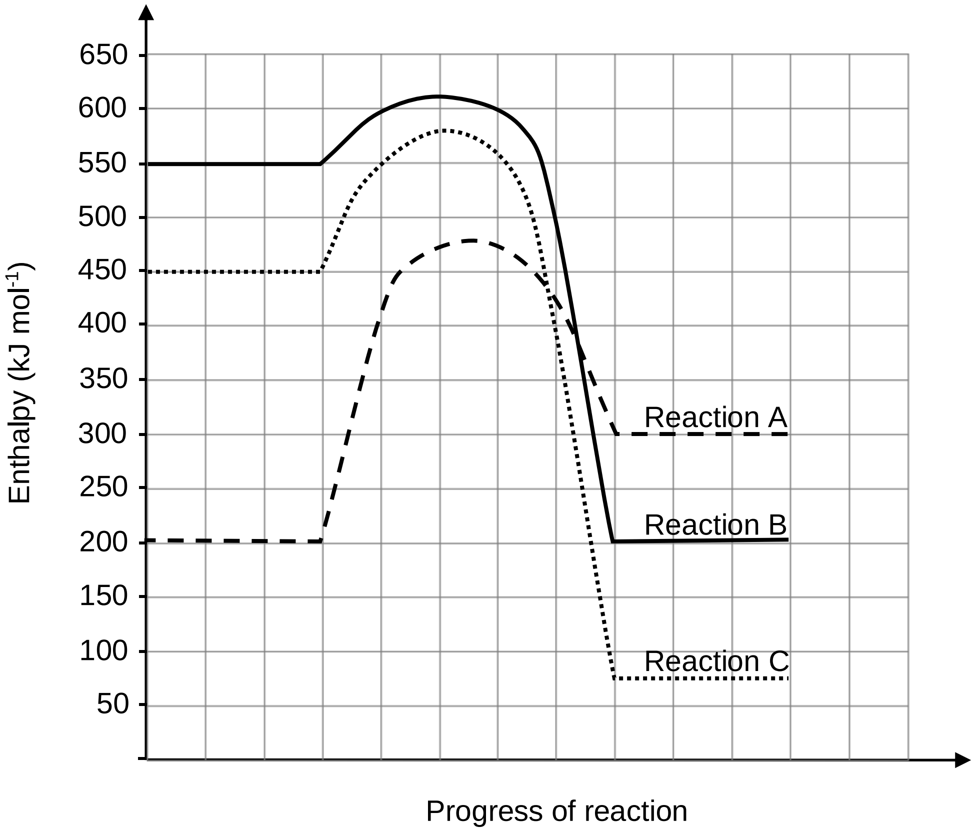
### Question 26 (8 marks)

Consider the three sketches on the energy profile diagram below.



Two of these curves represent the combustion reactions of different fuels. Both of the fuels have a similar energy content but differ in their ‘autoignition points’. The autoignition point of a fuel is defined as ‘the lowest temperature at which it will spontaneously ignite, in the absence of an external ignition source’.

Refer to the energy profile diagrams to answer the following questions.

(a) State the value, including appropriate units, of (2 marks)

(i) $\Delta H$ (reverse) for Reaction A ____________________

(ii) $E_a$ (forward) for Reaction C ____________________

(b) Which reaction (A, B or C) is **not** a combustion reaction? Justify your choice. (2 marks)

(c) Which reaction (A, B or C) represents combustion of the fuel with the lowest autoignition point? Justify your choice. (2 marks)

(d) Which reaction (A, B or C) is most likely to be reversible? Justify your choice. (2 marks)

**Question 27** **(10 marks)**

Lithium-ion batteries are the power source used in most portable electronic devices. Once discharged fully, they can be recycled to recover the valuable metals in them. These metals are present in the cathode material, in the form of lithium cobaltate, $LiCoO_2$.

In this recycling process, the lithium-ion batteries are crushed and processed to a particle size of less than 1 mm. Leaching solution is then added to this crushed material to form a slurry.

(a) Explain, in terms of the collision theory, why the batteries are crushed before being mixed with the leach solution. (3 marks)

A 5.00 g sample of crushed lithium-ion battery material was placed into a conical flask. The crushed battery material contained 48.6% $LiCoO_2$ by mass.

A 150 mL aliquot of leach solution was then added. The leach solution contained sulfuric acid, $H_2SO_4$, at a concentration of 2.0 mol $L^{-1}$ and hydrogen peroxide, $H_2O_2$, at a concentration of 0.60 mol $L^{-1}$. This mixture was gently swirled at 70 °C for 5 hours to ensure all the lithium and cobalt had been leached into solution (i.e. you may assume that both $H_2SO_4$(aq) and $H_2O_2$(aq) were present in excess).

The leaching process can be represented by the following chemical equation.

$$2\ LiCoO_2(s) + 3\ H_2SO_4(aq) + 3\ H_2O_2(aq) \rightarrow 2\ CoSO_4(aq) + Li_2SO_4(aq) + 6\ H_2O(l) + 2\ O_2(g)$$

(b) Calculate the concentration of hydrogen peroxide, in grams per litre, that would be present in the leach solution after 5 hours. (7 marks)

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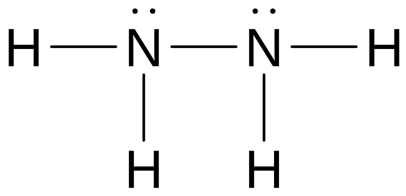
**Question 28** **(7 marks)**

Hydrazine ($N_2H_4$) is a colourless, flammable liquid, which is miscible with water. When in aqueous solution, it behaves as a weak BrØnsted-Lowry base. The Lewis structure of hydrazine is shown below.



(a) Identify the feature of the hydrazine molecule that allows it to behave as a BrØnsted-Lowry base. (1 mark)

___

___

(b) Amend the Lewis diagram above, to represent the conjugate acid of hydrazine, which is named 'hydrazinium'. (2 marks)

(c) Write a balanced chemical equation showing the reaction between hydrazine and nitric acid, to form the salt hydrazinium nitrate. (2 marks)

A pure sample of hydrazinium nitrate was isolated and dissolved in some distilled water.

(d) Predict whether the resulting solution would be acidic, basic or neutral (circle your choice). Use a chemical equation to support your answer. (2 marks)

acidic basic neutral

Equation

**Question 29** **(7 marks)**

In the process of developing photographic film, small crystals of silver bromide, AgBr(s), must be removed from the surface of the film. However, since silver bromide has a very low aqueous solubility, this cannot be done by washing the film with water alone.

A reagent called a 'fixer' is therefore used, which contains thiosulfate ions, $S_2O_3^{2-}(aq)$. The presence of this ion causes the silver bromide crystals to quickly dissolve.

The relevant chemical equations and equilibrium constants involved in these processes are given below.

Equation 1 $AgBr(s) \rightleftharpoons Ag^+(aq) + Br^-(aq)$ $K_c = 5.0 \times 10^{-13}$ at 20 °C

Equation 2 $Ag^+(aq) + S_2O_3^{2-}(aq) \rightleftharpoons [Ag(S_2O_3)_2]^{3-}(aq)$ $K_c = 4.7 \times 10^{13}$ at 20 °C

(a) Select a piece of data that supports the assertion 'AgBr(s) has a very low aqueous solubility'. Justify your answer. (2 marks)

(b) Use Le Chatelier's principle, to describe how the introduction of thiosulfate ions assists in removing the silver bromide crystals from the photographic film. (5 marks)

**Question 30** **(6 marks)**

Consider the information below, regarding selenic acid. Assume all the reactions described in the information refer to standard conditions.

Selenic acid, $H_2SeO_4$, is a strong, inorganic acid. It can be prepared by the oxidation of selenous acid, $H_2SeO_3$, with acidified potassium permanganate solution.

Selenic acid has similar structure and properties to sulfuric acid, although selenic acid is the stronger oxidising agent of the two. This can be confirmed experimentally, as selenic acid is capable of oxidising chloride ions into chlorine gas, whereas sulfuric acid is not. In this reaction, the selenic acid is reduced to selenous acid.

Use the information above, to infer the position of the selenic acid / selenous acid half-equation on the table of standard reduction potentials.

(a) Write a balanced equation for this half-reaction, and suggest a value for the associated standard reduction potential. (4 marks)

| Half-reaction | $E^0$ value |
|---|---|
| | |

(b) Justify whether selenic acid could be prepared by reacting acidified sodium dichromate solution with selenous acid, under standard conditions. (2 marks)

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**Question 31** **(9 marks)**

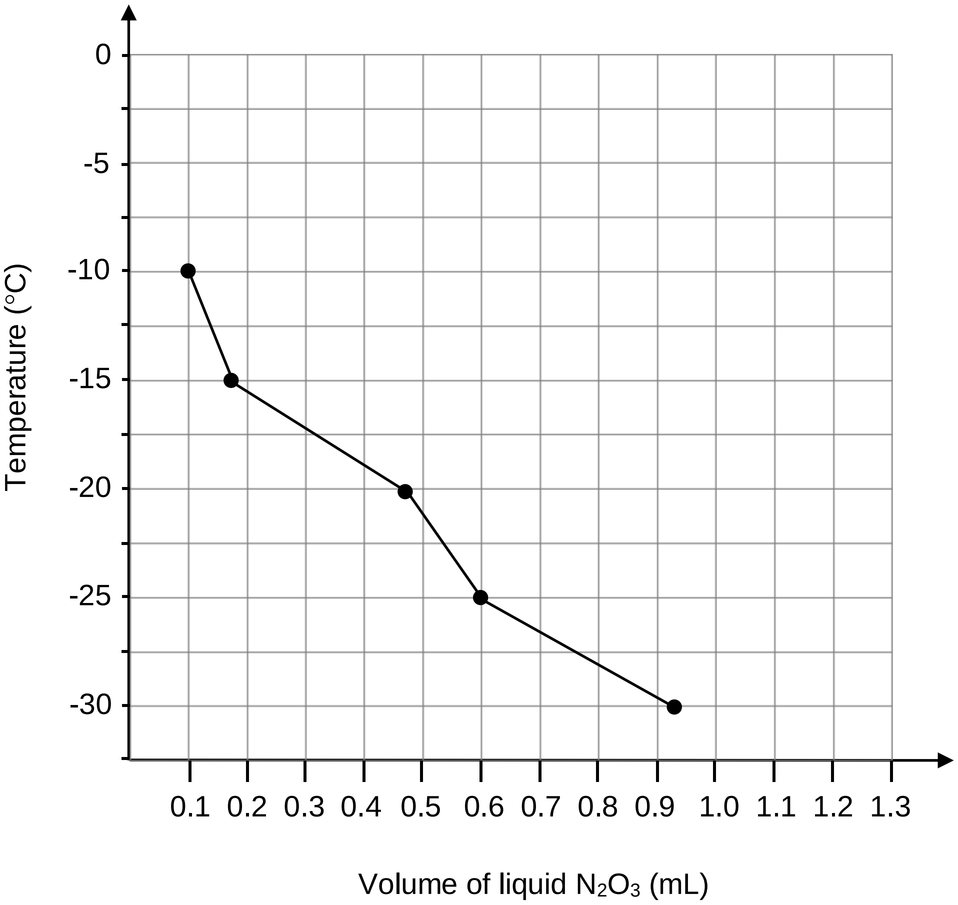
When a sample of liquid dinitrogen trioxide, $N_2O_3(l)$, is placed in a sealed vial at temperatures below 0 °C, the following equilibrium can be established.

$$N_2O_3(l) \rightleftharpoons NO(g) + NO_2(g)$$

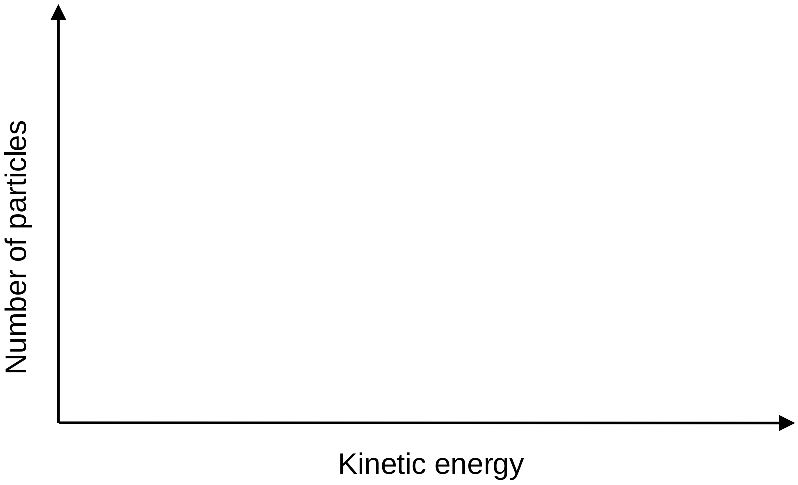
A group of chemistry students decided to investigate the effect of temperature on the equilibrium system.

The students placed several sealed vials, each containing the same mass of $N_2O_3(l)$, at different temperatures. They then waited for equilibrium to be established, and measured the final volume of $N_2O_3(l)$ present in each vial.

The students summarised the collated data in a graph, which is shown below.



(a) Explain why a decrease in temperature will decrease the rate of a reaction. Sketch a labelled kinetic energy distribution (Maxwell-Boltzmann) diagram to support your answer. (6 marks)



(b) Use the trend in the data to state the relationship between the variables. (1 mark)

(c) Identify two (2) problems with the way the students have presented the graph of their data. (2 marks)

| | |
|---|---|
| 1 | |
| 2 | |

**Question 32** **(9 marks)**

The process of dyeing textiles requires a controlled pH, to ensure the correct colour and performance of the dye. To achieve this, a buffer solution is often used to maintain this pH environment.

A common buffer is made from potassium hydrogenphosphate, $K_2HPO_4$, and potassium dihydrogenphosphate, $KH_2PO_4$. It has an excellent buffering capacity in the pH range 5.8–8.0.

The table below provides some information on how to prepare this buffer, depending on the pH desired. The data given represents the mass of $K_2HPO_4(s)$ and $KH_2PO_4(s)$ that should be dissolved in 1.0 L of distilled water, in order to produce a 0.1 mol $L^{-1}$ buffer solution.

| Preparation of 1.0 L of 0.1 mol $L^{-1}$ buffer solution | Buffer pH | $K_2HPO_4(s)$ | $KH_2PO_4(s)$ |
|---|---|---|---|
| Buffer A | 5.8 | 1.02 g | 12.8 g |
| Buffer B | 6.9 | 8.65 g | 6.85 g |
| Buffer C | 8 | 16.3 g | 0.888 g |

(a) Write the equation for the reaction that would occur when making buffer C. (2 marks)

(b) Which buffer (A, B or C) would demonstrate the highest buffering capacity if required to interact with both acidic and basic species? Justify your choice. (3 marks)

(c) Explain why Buffer A has the lowest pH. Use a relevant chemical equation to support your answer. (2 marks)

Equation

(d) Identify the spectator ion present in this buffer, and state why it has no effect on the pH of the buffer. (2 marks)

**Question 33** **(11 marks)**

Consider the following chemical reaction, which has established equilibrium in a closed system.

$$2\ BrF_5(g) \rightleftharpoons Br_2(g) + 5\ F_2(g)$$

| 2 $BrF_5$(g) | ⇌ | $Br_2$(g) | + | 5 $F_2$(g) |
|---|---|---|---|---|
| pale yellow | | reddish-brown | | pale yellow |

The colour of the system is determined by the concentration of bromine, since the other gases are too pale to significantly impact the overall appearance. The initial colour of the system was recorded as ‘light reddish-brown’.

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

The volume of the system was halved, and subsequent observations were recorded. Sufficient time was allowed for equilibrium to be re-established.

$$2\,BrF_5(g) \rightleftharpoons Br_2(g) + 5\,F_2(g)$$

| pale yellow | reddish-brown | pale yellow |
|---|---|---|

(b) Complete the following table, by predicting the observations for each time period. Provide a brief explanation for each observation. (9 marks)

| | Observations | Explanation |
|---|---|---|
| Initial<br>i.e. immediately following volume decrease<br>(2 marks) | | |
| During shift<br>i.e. during the re-establishment of equilibrium<br>(3 marks) | | |
| Final<br>i.e. once equilibrium had been re-established<br>(4 marks) | | |

**Question 34** **(6 marks)**

A chemistry class was discussing the best corrosion prevention strategy to protect steel pipes that were going to be used for an underground gas pipeline. Steel is an alloy composed largely of iron.

One group suggested powder coating the steel pipes, whilst another group suggested cathodic protection.

(a) Briefly describe the principles of cathodic protection. (3 marks)

Read the statement below.

> *"In the instance of below-ground pipelines, cathodic protection is a better corrosion prevention method than powder-coating."*

(b) By providing three (3) justifications, construct an argument that supports this statement. (3 marks)

| | |
|---|---|
| 1 | |
| 2 | |
| 3 | |

**End of Section Two**

## Section Three: Extended answer 40% (85 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.

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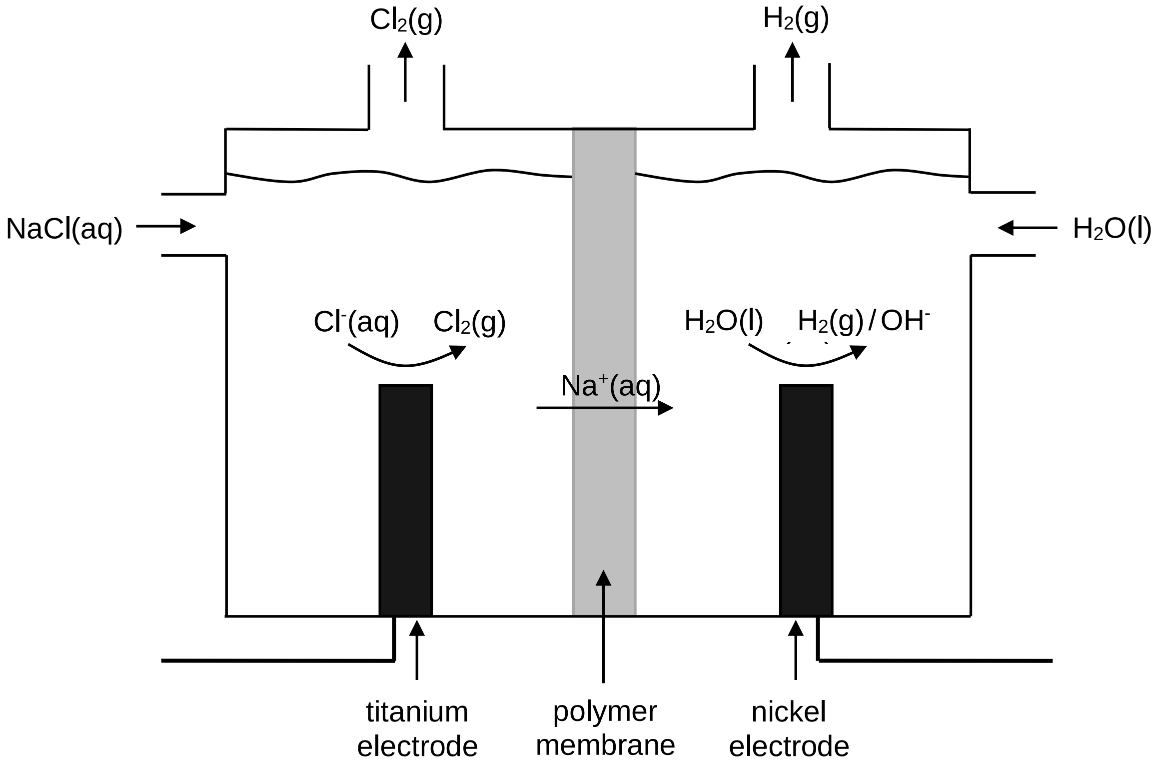
### Question 35 (19 marks)

The ‘chloralkali process’ refers to the electrolysis of sodium chloride solution, NaCl(aq). This is a valuable industrial process, as it produces the chemicals chlorine, $Cl_2(g)$, hydrogen, $H_2(g)$ and sodium hydroxide solution, NaOH(aq).

The diagram below shows a simplified, small-scale version of the membrane cell which can be used for this electrolytic process.



$Cl_2(g)$ is produced at the titanium electrode, whilst $H_2(g)$ and $OH^-(aq)$ are produced at the nickel electrode. The membrane is made from a polymer that allows only the positive $Na^+(aq)$ ions to pass through it. These $Na^+(aq)$ ions and $OH^-(aq)$ form a solution of sodium hydroxide.

(a) Identify one (1) safety risk associated with this cell and one (1) safety measure to reduce this risk. (2 marks)

| | |
|---|---|
| Safety risk | |
| Safety measure to reduce risk | |

(b) Complete the table below, regarding the titanium and nickel electrodes in the membrane cell. (2 marks)

| | Designation of electrode (anode or cathode) | Polarity (+ or –) |
|---|---|---|
| Titanium | | |
| Nickel | | |

(c) Provide a justification for the choice of titanium as the electrode material. (1 mark)

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

(d) Explain why electrical energy needs to be provided for this cell to function. (2 marks)

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

The overall ionic equation for the ‘chloralkali process’ is given below.

$$2\ Cl^-(aq)\ +\ 2\ H_2O(l)\ \rightarrow\ Cl_2(g)\ +\ H_2(g)\ +\ 2\ OH^-(aq)$$

Assume the membrane cell was initially filled with 12.0 L of NaCl(aq) at the titanium electrode and 12.0 L of distilled water at the nickel electrode. The cell was then run for a period of time, producing 66.5 L of chlorine gas, measured at 105 kPa and 25.0 °C.

(e) Calculate the final pH of the solution surrounding the nickel electrode. (5 marks)

The $Cl_2(g)$ produced in this cell is usually contaminated with oxygen gas, $O_2(g)$. When a higher concentration of NaCl(aq) is used at the titanium electrode, this contamination occurs to a lesser extent.

(f) Describe why this $O_2(g)$ forms, using a relevant chemical equation to support your answer. Propose a reason why the amount of $O_2(g)$ produced decreases, as the concentration of NaCl(aq) increases. (3 marks)

A related industrial method known as the ‘Downs process’ involves the electrolysis of **molten** sodium chloride.

(g) Name one (1) product of the Downs process that is the same, and one (1) product that is different, to those produced in the chloralkali process. (2 marks)

| | |
|---|---|
| Product formed in **both** Downs and chloralkali processes | |
| Product of Downs process **not** formed in chloralkali process | |

(h) Suggest two (2) reasons the Downs process requires a greater energy input than the chloralkali process. (2 marks)

| | |
|---|---|
| 1 | |
| 2 | |

**Question 36** **(18 marks)**

A group of chemistry students was investigating the water quality in the Swan River. The students developed an aim to measure the 'total alkalinity' of the river water by performing a titration.

Total alkalinity can be defined as;

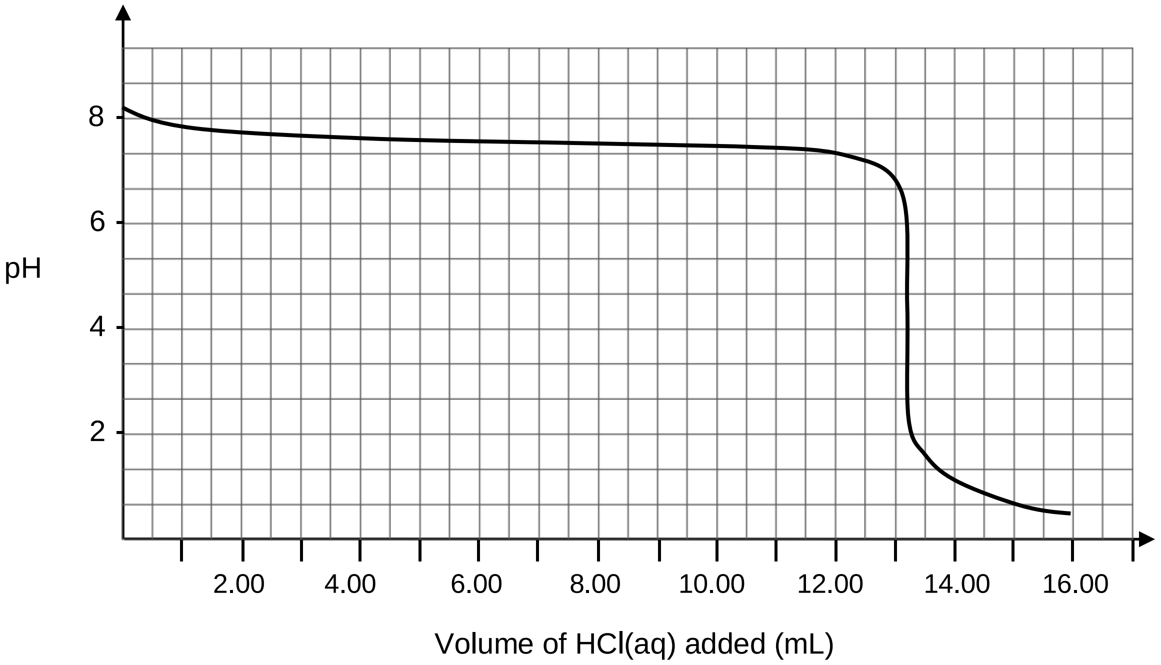
> 'The quantity of hydrogen ions, in millimoles (mmol), required to neutralise the weak bases present in 1 kilogram of water.'

There are many species present in river and sea water that contribute to its total alkalinity, including $HCO_3^-$(aq), $CO_3^{2-}$(aq), $B(OH)_4^-$(aq) and $PO_4^{3-}$(aq).

(a) Explain, with the use of an equation, how the phosphate ion, $PO_4^{3-}$(aq), contributes to the alkalinity of the water. (3 marks)

Equation

The students collected a 100.0 mL sample of river water from Elizabeth Quay. The sample was placed in a conical flask, and transported back to the laboratory where it was titrated against 0.01565 mol $L^{-1}$ hydrochloric acid, HCl(aq). The titration curve is shown below.



(b) Calculate the ‘total alkalinity’ of the river water sample, if the density of the river water was determined to be 1.024 kg $L^{-1}$. (5 marks)

The students concluded that they had accurately determined the total alkalinity of the Swan River water, and reported their calculated value to a local environmental group, who monitor water quality.

(c) Identify three (3) ways the students could increase the validity of their reported total alkalinity value. (3 marks)

| | |
|---|---|
| 1 | |
| 2 | |
| 3 | |

The indicator bromothymol blue has an end point range of 6.0–7.6.

(d) Explain why bromothymol blue would **not** be an appropriate indicator choice for this titration. (2 marks)

(e) If the students had incorrectly rinsed the burette with water; (2 marks)

(i) On the grid on the previous page, sketch the effect this would have on the titration curve.

(ii) State the effect this would have on the students' calculated total alkalinity value. (circle your choice)

too high too low no effect

Total alkalinity can provide an indication of the chemical composition of river or sea water, in particular its carbonate content. The following equations show how carbonate and hydrogencarbonate ions are produced from the calcium carbonate found in sediment, shells and coral reefs.

1. $CaCO_3(s) \rightleftharpoons Ca^{2+}(aq) + CO_3^{2-}(aq)$
2. $CO_3^{2-}(aq) + H_2O(l) \rightleftharpoons HCO_3^{-}(aq) + OH^{-}(aq)$
3. $HCO_3^{-}(aq) + H_2O(l) \rightleftharpoons H_2CO_3(aq) + OH^{-}(aq)$

(f) Increased atmospheric $CO_2(g)$ levels result in sea water having a lower total alkalinity. By referring to the equations above, justify why lower total alkalinity corresponds to a decrease in carbonate ion concentration. (3 marks)

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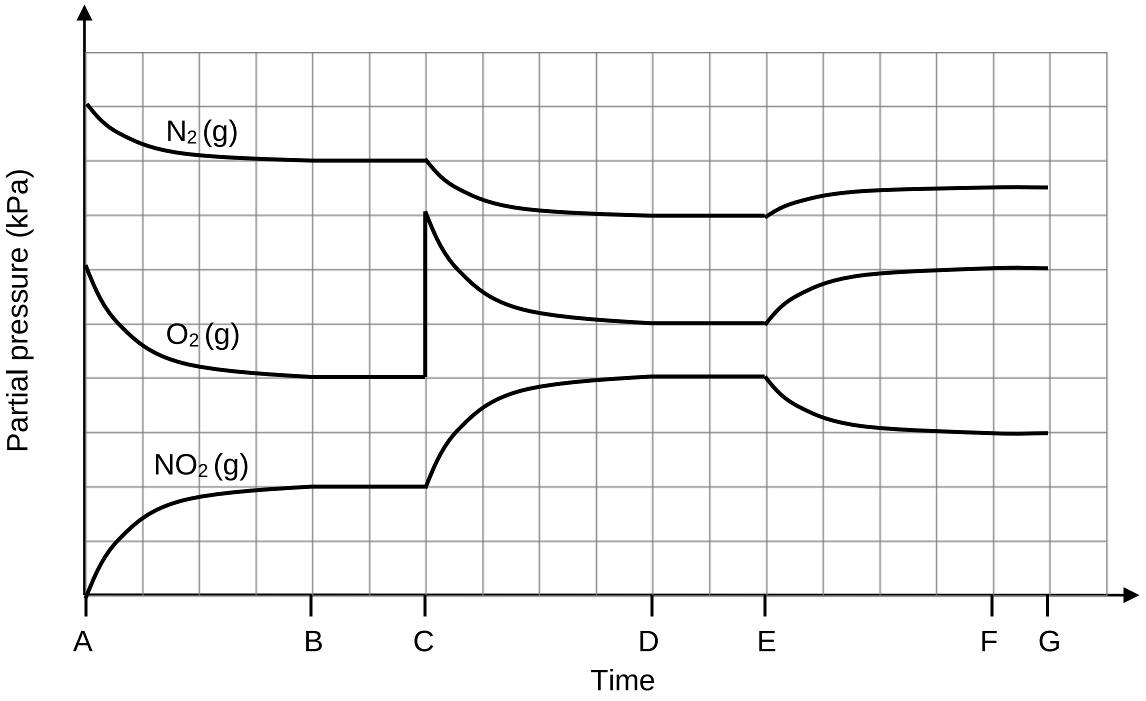
**Question 37** **(18 marks)**

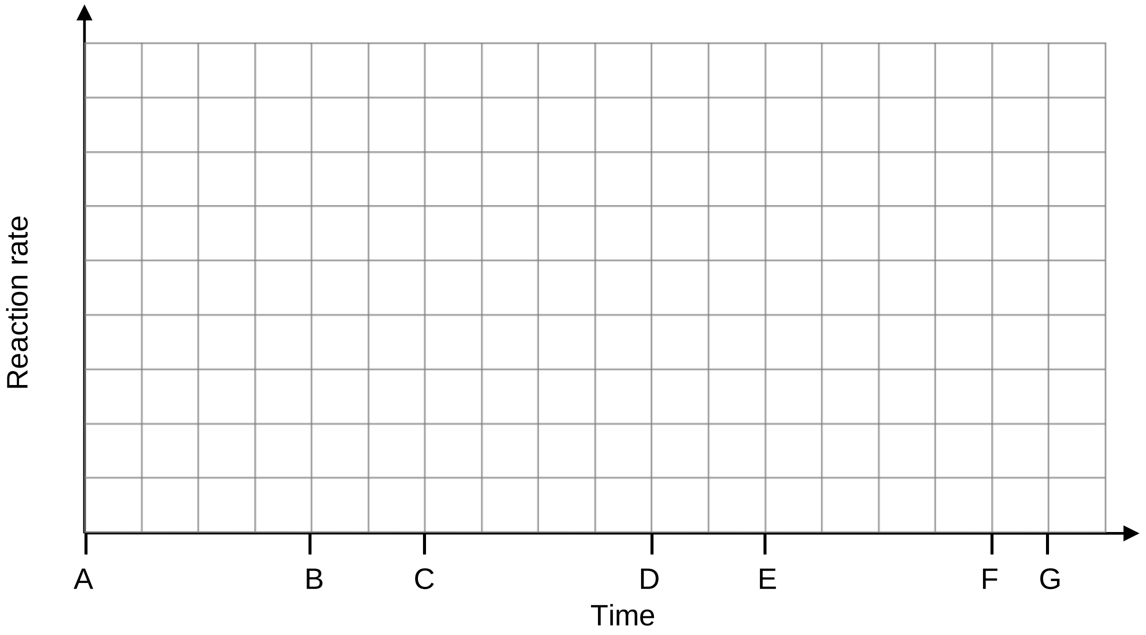
Nitrogen dioxide, $NO_2(g)$, is a brown gas which is used in the production of nitric acid. The reversible reaction between nitrogen and oxygen gases to form nitrogen dioxide can be represented by the chemical equation below.

$$N_2(g) + 2\,O_2(g) \rightleftharpoons 2\,NO_2(g)$$

Samples of nitrogen and oxygen gases were injected into a sealed, empty flask at Time A, and equilibrium was established at Time B.

Various changes were then imposed, in order to study the behaviour of the system. The results were recorded on the graph below.





(a) Explain the difference in gradient between the $N_2$(g) and $O_2$(g) curves, from Time A to B. (2 marks)

(b) Identify the change that occurred at Time C. (1 mark)

(c) At Time E, the temperature of the system was decreased. Is the reaction endothermic or exothermic as written? Justify your answer. (4 marks)

(d) On the blank grid on the previous page, sketch a graph illustrating the changes in both the forward and reverse reaction rates that occurred in this system from Time A to G. Use a solid line (——) to represent the forward reaction rate and a dashed line (- - -) to represent the reverse reaction rate. (8 marks)

The value of $K_c$ for this reaction at room temperature is $9.09 \times 10^6$. Air contains a significant proportion of both nitrogen and oxygen gases, however the rate of reaction between these gases is extremely slow at room temperature.

(e) Provide a justification for the lack of reactivity between $N_2(g)$ and $O_2(g)$ at room temperature, given that the $K_c$ value for this reaction is large. (3 marks)

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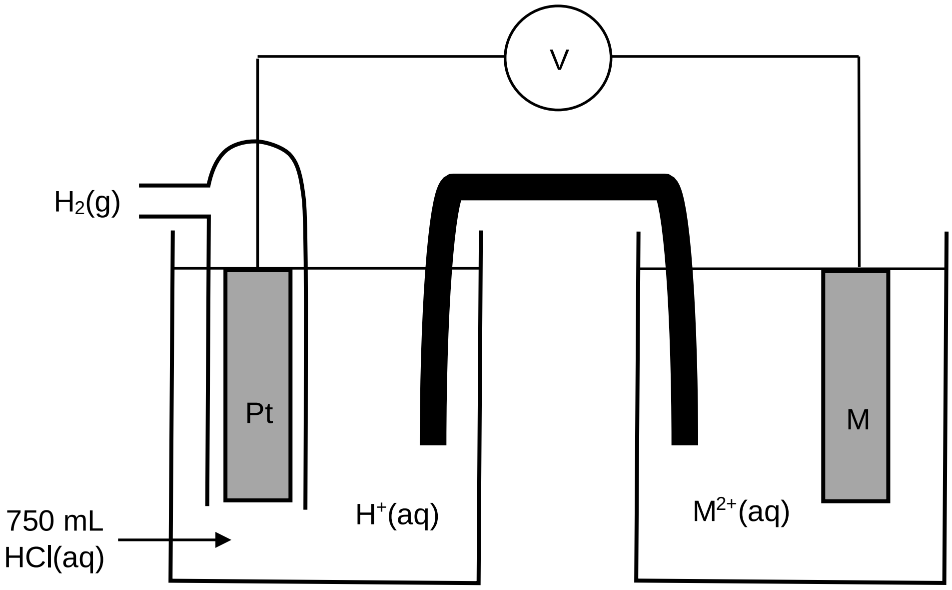
**Question 38** **(16 marks)**

A galvanic cell was constructed using a hydrogen half-cell connected to a half-cell of unknown identity. The unknown half-cell consisted of a metallic electrode, M(s), submerged in a solution of metallic ions, $M^{2+}$(aq). Both half-cells met the requirements for standard conditions.

The set-up of the galvanic cell is shown in the diagram below.



Before the half-cells were connected with wires, the pH of the electrolyte in the hydrogen half-cell was recorded using a digital pH meter. The mass of the unknown electrode was also recorded.

Wires were then attached, and the cell was allowed to run for 45 minutes before being disconnected. The same readings were then taken again.

The data collected is summarised in the table below.

| | pH of 750 mL HCl(aq) solution | Mass of M(s) electrode |
|---|---|---|
| Initial | 0.000 | 91.3 g |
| Final | 0.422 | 65.2 g |

(a) Is M(s) the anode or cathode in this cell? Justify your answer. (3 marks)

(b) Write balanced half-equations for the reactions occurring in this cell. (2 marks)

| | |
|---|---|
| anode | |
| cathode | |

(c) List two (2) quantitative pieces of data, that would allow the hydrogen half-cell to conform to ‘standard conditions’. (2 marks)

| | |
|---|---|
| 1. | |
| 2. | |

(d) Determine the identity of M(s). Show all workings. (9 marks)

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**Question 39** **(15 marks)**

Gold is a precious metal that humankind has used for thousands of years. Over the centuries there have been many methods used to extract gold from its ore. Whilst it is a relatively unreactive metal, it does dissolve in alkaline solutions of cyanide. This discovery, in 1783, lead to the development of the ‘gold cyanidation’ process, which is widely used today.

In the extraction of gold, the ore is first ground and crushed. Water and sodium cyanide solution, $NaCN(aq)$, are then added to form a slurry. This mixture is then left for 16 - 48 hours with a stream of oxygen gas passing through the mixture. During this time ‘gold leaching’ occurs. This process results in the gold being oxidised to the (+1) oxidation state and dissolving into solution to form the aurocyanide ion.

This process can be represented by the ‘Elsner equation’.

$$4\ Au(s) + 8\ CN^-(aq) + O_2(g) + 2\ H_2O(l) \rightarrow 4\ Au(CN)_2^-(aq) + 4\ OH^-(aq)$$

A sample of gold-bearing ore was crushed and placed in a tank, along with 25 kL of leaching solution. The initial concentration of $NaCN(aq)$ in the leach solution was $0.478\ g\ L^{-1}$. After 48 hours, this had fallen to $0.083\ g\ L^{-1}$.

(a) Calculate the mass of gold that was leached into solution. (6 marks)

(b) Calculate the final pH of the leaching solution. (You may assume that only the $OH^-(aq)$ ions produced are contributing to pH). (4 marks)

There are several techniques used to separate the gold from the leaching solution, one of which is the Merill-Crowe process. Once the slurry has been filtered, zinc dust is then added to the leaching solution to precipitate the gold. The Merill-Crowe process can be represented by the following chemical equation.

$$2\ Au(CN)_2^-(aq) + 3\ Zn(s) \rightarrow 3\ Zn^{2+}(aq) + 8\ CN^-(aq) + 2\ Au(s)$$

(c) State the oxidant and the reductant in this process. (2 marks)

(d) Explain, in terms of the collision theory, why zinc **dust** is used to precipitate the gold out of solution. (3 marks)

End of questions

**Additional working space**

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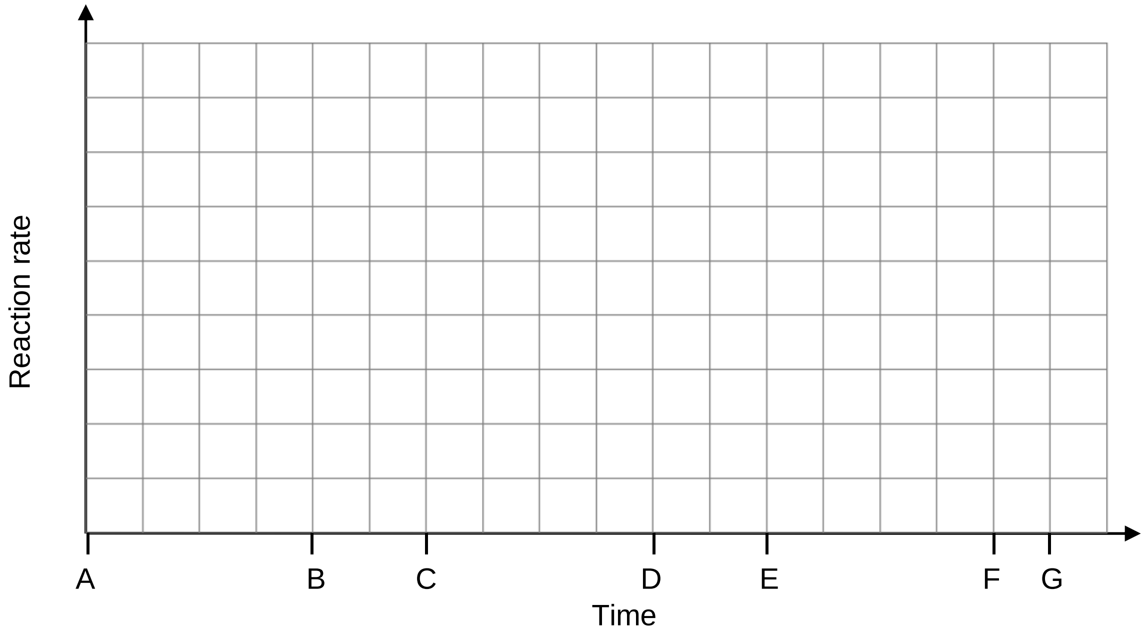

## Additional working space

Question number(s): ……………………

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