



Semester 1, 2021 Examination

Question/Answer booklet

CHEMISTRY ATAR Year 12 Unit 3

Student Name: _____

Teacher Name: _____

Time allowed for this paper

Reading time before commencing work: ten minutes
Working time: three hours

Materials required/recommended for this paper

To be provided by the supervisor

This Question/Answer booklet
Multiple-choice answer sheet
Chemistry Data booklet

To be provided by the candidate

Standard items: pens (blue/black preferred), pencils (including coloured), sharpener,
correction fluid/tape, eraser, ruler, highlighters

Special items: non-programmable calculators approved for use in this examination

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 material. 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	Your mark
Section One Multiple-choice	25	25	50	25	
Section Two Short answer	9	9	60	80	
Section Three Extended answer	5	5	70	88	
Total					
					<hr/> 193
					%

Instructions to candidates

1. The rules for the conduct of ATAR course examinations are detailed in the *Year 12 Information Handbook 2021*. Sitting this examination implies that you agree to abide by these rules.
2. Write your answers in this Question/Answer booklet preferably using a blue/black pen. Do not use erasable or gel pens.
3. 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. Do not use erasable or gel pens. 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.

4. When calculating numerical answers, show your working or reasoning clearly. Your working should be in sufficient detail to allow your answers to be checked readily and for marks to be awarded for reasoning. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.
5. 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.
6. 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.
7. The Chemistry Data booklet is not to be handed in with your Question/Answer booklet.

Section One: Multiple-choice**(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. Do not use erasable or gel pens. 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

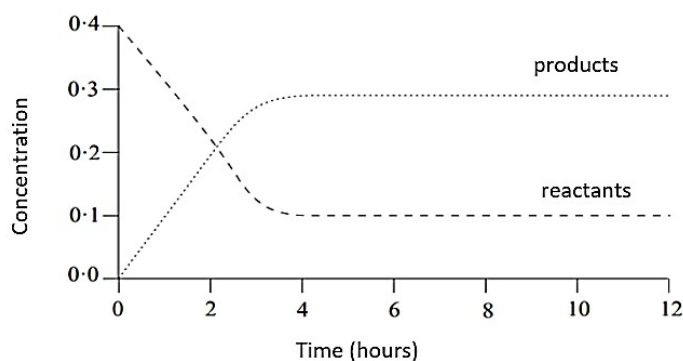
1. Consider the data shown in the table below, which relates to a particular reversible reaction.

	Uncatalysed reaction	Catalysed reaction
$E_a(\text{forward}) \text{ (kJ mol}^{-1}\text{)}$	551	W
$E_a(\text{reverse}) \text{ (kJ mol}^{-1}\text{)}$	X	129
$H(\text{forward}) \text{ (kJ mol}^{-1}\text{)}$	+373	Y
$H(\text{reverse}) \text{ (kJ mol}^{-1}\text{)}$	Z	

The correct values of W, X, Y and Z are

	W	X	Y	Z
(a)	502	178	+373	- 373
(b)	924	178	- 373	+373
(c)	244	924	- 422	- 373
(d)	502	422	+373	+924

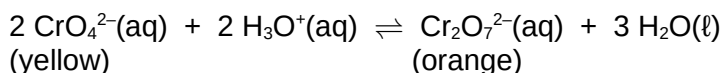
2. The graph below shows the changes in concentration of reactants and products over time for a reversible aqueous reaction.



Which one of the following statements is correct about this graph?

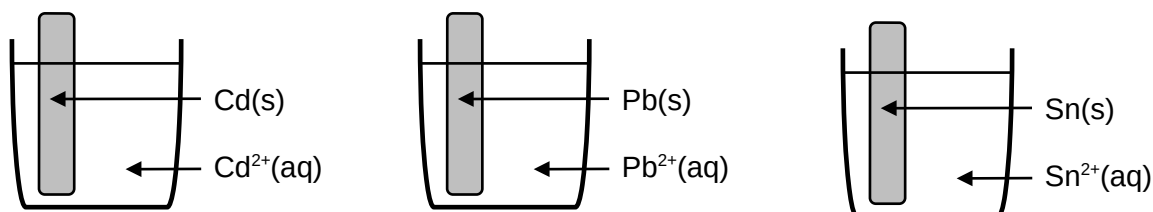
- (a) Equilibrium was reached after 4 hours and $K < 1$.
- (b) Equilibrium was reached after 2 hours and $K > 1$.
- (c) Equilibrium was reached after 4 hours and $K > 1$.
- (d) Equilibrium was reached after 2 hours and $K < 1$.

Questions 3 & 4 refer to the following reaction at equilibrium.



- Which one of the following solutions, when added to the equilibrium mixture, will turn the mixture more yellow?
 - $\text{KNO}_3(\text{aq})$
 - $\text{NaOH}(\text{aq})$
 - $\text{NH}_4\text{NO}_3(\text{aq})$
 - $\text{CH}_3\text{COOH}(\text{aq})$
- Which one of the following best describes the change in reaction rates produced by the addition of a small amount of concentrated sodium hydroxide solution?
 - The reverse reaction decreases more than the forward reaction.
 - The reverse reaction increases more than the forward reaction.
 - The forward reaction increases more than the reverse reaction.
 - The forward reaction decreases more than the reverse reaction.

Questions 5 and 6 refer to the three (3) half-cells pictured below, which were set up under standard conditions.



5. Which of the species in the half-cells above represent the strongest oxidising and reducing agents (oxidant and reductant)?

	Oxidising agent	Reducing agent
(a)	Cd	Pb ²⁺
(b)	Pb	Cd ²⁺
(c)	Cd ²⁺	Pb
(d)	Pb ²⁺	Cd

Two of these half-cells are connected to form a functioning galvanic cell.

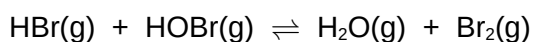
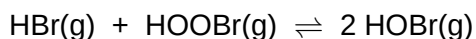
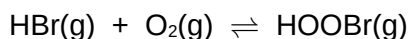
6. Which piece of equipment would **not** be required?
- (a) Salt bridge
 - (b) Power pack
 - (c) Wires
 - (d) Electrical load (e.g. globe, voltmeter, resistor)

7. Which one of the following will have the greatest initial reaction rate with a piece of zinc?

- (a) $\text{CH}_3\text{COOH}(\text{aq})$ $K_a = 1.7 \times 10^{-5}$
- (b) $\text{NaHSO}_4(\text{aq})$ $K_a = 1.0 \times 10^{-2}$
- (c) $\text{H}_3\text{PO}_4(\text{aq})$ $K_a = 7.1 \times 10^{-3}$
- (d) $\text{H}_2\text{CO}_3(\text{aq})$ $K_a = 4.5 \times 10^{-7}$

Questions 8 and 9 refer to the information below

Consider the following multistep reaction.



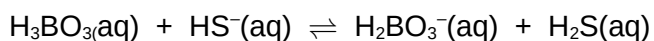
8. Which one of the following statements is correct?

- (a) HBr is a final product.
- (b) HOBr is a reaction intermediate.
- (c) HOBr acts as a catalyst.
- (d) Br atoms are reduced in this reaction sequence.

9. Which one of the following is the overall equation for this reaction?

- (a) $3 \text{HBr}(\text{g}) \rightleftharpoons \text{HOBr}(\text{g}) + \text{H}_2\text{O}(\text{g}) + \text{Br}_2(\text{g})$
- (b) $\text{HBr}(\text{g}) + \text{HOBr}(\text{g}) \rightleftharpoons \text{H}_2\text{O}(\text{g}) + \text{Br}_2(\text{g})$
- (c) $4 \text{HBr}(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons 2 \text{H}_2\text{O}(\text{g}) + 2 \text{Br}_2(\text{g})$
- (d) $3 \text{HBr}(\text{g}) + \text{O}_2(\text{g}) \rightleftharpoons \text{H}_2\text{O}(\text{g}) + \text{Br}_2(\text{g})$

10. Consider this equation.



Which one of the following classifies the Brønsted–Lowry acids and bases in the order shown in the equation?

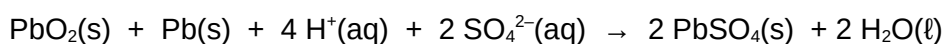
- (a) acid, base, base, acid
- (b) base, acid, acid, base
- (c) acid, base, acid, base
- (d) base, acid, base, acid

11. Which of the following is/are correct about the addition of a catalyst to a reaction?

- (i) The heat of reaction decreases.
 - (ii) A new reaction pathway is available.
 - (iii) The equilibrium constant increases.
 - (iv) Catalysts do not take part in the reaction.
- (a) i only
 - (b) ii only
 - (c) ii and iv only
 - (d) i, iii and iv only

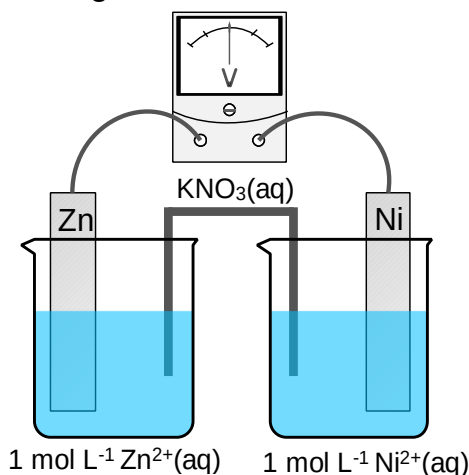
Questions 12, 13 and 14 refer to the information below.

Consider the overall reaction of the rechargeable lead–acid cell.



12. Which one of the following occurs during discharge of the cell?
- (a) Lead atoms are both oxidised and reduced.
 - (b) Lead is reduced and hydrogen oxidised.
 - (c) Lead is oxidised and hydrogen reduced.
 - (d) Lead is oxidised and sulfur reduced.
13. Which one of the following is re-formed at the anode during recharging?
- (a) PbSO_4
 - (b) PbO_2
 - (c) Pb
 - (d) Pb^{2+}
14. Used lead acid batteries must be disposed of carefully as they contain hazardous waste. Which of the following statements correctly states why the waste is hazardous?
- (i) Lead compounds only are toxic.
 - (ii) Lead metal and lead compounds are toxic.
 - (iii) The sulfuric acid electrolyte is corrosive.
 - (iv) Lead metal only is toxic.
- (a) i only
 - (b) ii and iii only
 - (c) iv only
 - (d) iii and iv only

Questions 15 and 16 refer to the diagram below.



15. Which one of the following occurs as this cell operates?
- the zinc electrode is reduced and increases in mass.
 - the zinc electrode is reduced and decreases in mass.
 - the zinc electrode is oxidised and increases in mass.
 - the zinc electrode is oxidised and decreases in mass.
16. Which one of the following shows the overall equation and voltage generated by this cell under standard conditions?

Equation	Voltage
(a) $\text{Zn}^{2+}(\text{aq}) + \text{Ni}(\text{s}) \rightarrow \text{Zn}(\text{s}) + \text{Ni}^{2+}(\text{aq})$	0.52 V
(b) $\text{Ni}^{2+}(\text{aq}) + \text{Zn}(\text{s}) \rightarrow \text{Ni}(\text{s}) + \text{Zn}^{2+}(\text{aq})$	1.0 V
(c) $\text{Ni}^{2+}(\text{aq}) + \text{Zn}(\text{s}) \rightarrow \text{Ni}(\text{s}) + \text{Zn}^{2+}(\text{aq})$	0.52 V
(d) $\text{Zn}^{2+}(\text{aq}) + \text{Ni}(\text{s}) \rightarrow \text{Zn}(\text{s}) + \text{Ni}^{2+}(\text{aq})$	1.0 V

17. Which one of the following is correct about the species $\text{HCO}_3^-(\text{aq})$?

$\text{HCO}_3^-(\text{aq})$ is the conjugate

- base of $\text{H}_2\text{CO}_3(\text{aq})$.
- base of $\text{CO}_3^{2-}(\text{aq})$.
- acid of $\text{H}_2\text{CO}_3(\text{aq})$.
- base of $\text{CO}_2(\text{aq})$.

18. Which one of the following is the most important property of a base of known concentration to be used in a titration to determine the concentration of a weak acid?

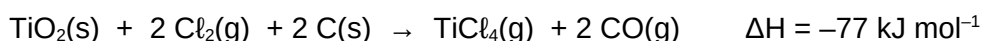
It should be

- (a) weak.
- (b) strong.
- (c) a primary standard.
- (d) concentrated.

Questions 19 and 20 refer to the following information.

Consider the following factors which might affect the rate and or yield of the reaction shown below.

- (i) increase temperature
- (ii) decrease pressure in a closed vessel
- (iii) grind the $\text{TiO}_2(\text{s})$ and $\text{C}(\text{s})$ into smaller pieces.



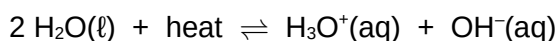
19. Which of the above will increase the rate of this reaction?

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

20. Which of the above will increase both the rate and yield of this reaction?

- (a) i only
- (b) ii only
- (c) i, and iii only
- (d) none of the above

21. In the equilibrium system shown below, which one of the following changes will cause the pH to increase and K_w to decrease?



- (a) Add a strong acid.
- (b) Add a strong base.
- (c) Increase the temperature.
- (d) Decrease the temperature.

22. A chemistry student attempted to identify a 0.5 mol L^{-1} salt solution by performing several chemical tests.
- (i) A few drops of universal indicator were added to a sample of the solution, and the mixture turned blue.
 - (ii) A few drops of $2 \text{ mol L}^{-1} \text{ HCl(aq)}$ were added to a separate sample of the solution, and this resulted in bubbles of colourless, odourless gas forming.

The identity of the salt solution could be

- (a) $\text{NaCH}_3\text{COO(aq)}$.
 - (b) $\text{KHCO}_3\text{(aq)}$.
 - (c) LiF(aq) .
 - (d) $\text{NH}_4\text{NO}_3\text{(aq)}$.
23. Which one of the following statements is correct about equal volumes and concentrations of hydrochloric and ethanoic acids?
- Both solutions
- (a) will produce the same number of H_3O^+ ions.
 - (b) have the same pH.
 - (c) require the same number of moles of sodium hydroxide to reach equivalence point.
 - (d) will be at the same pH when the equivalence point with sodium hydroxide is reached.
24. The rate of a gas reaction in a closed container doubles when the temperature is increased from 10 to 20°C . Which one of these best explains why this occurs?
- (a) The activation energy has doubled.
 - (b) The average kinetic energy of the molecules has doubled.
 - (c) The frequency of collisions between molecules has doubled.
 - (d) The proportion of molecules with collision energy $\geq E_a$ has doubled.
25. Which one of the following is a reason methyl orange is recommended when titrating hydrochloric acid with sodium carbonate solution?
- (a) Using phenolphthalein will produce a systematic error.
 - (b) The end point will be acidic.
 - (c) Neither of these chemicals reacts with the indicator.
 - (d) The equivalence point will be basic.

End of section 1

Section Two: Short answer**(80 Marks)**

This section has **nine** 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.

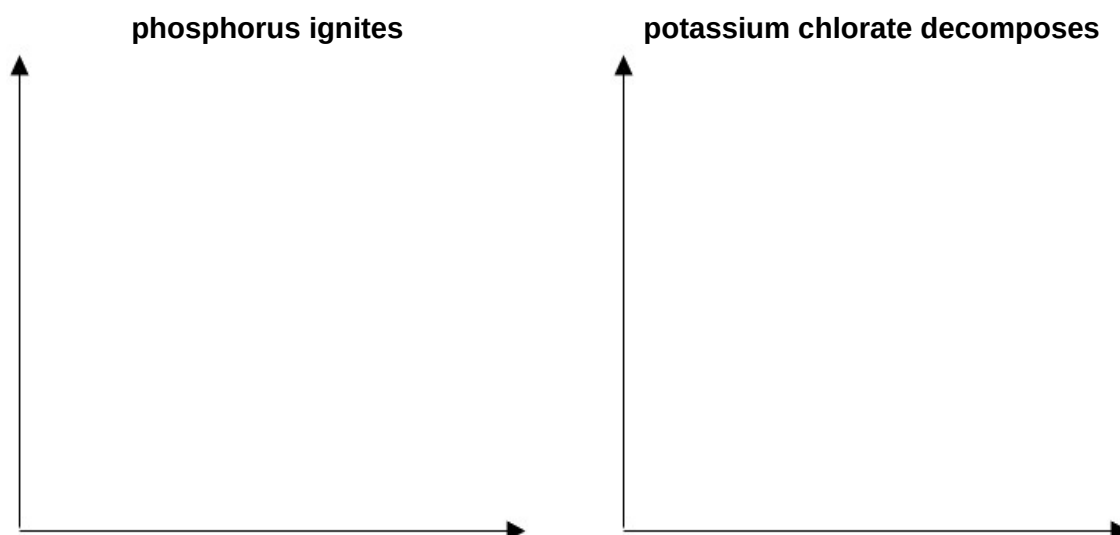
Suggested working time: 60 minutes

Question 26**(7 marks)**

Safety matches have a small amount of stable red phosphorus on the striking surface. The friction from rubbing the match-head against the striking surface causes unstable white phosphorus to form which ignites spontaneously in air at a temperature of at least 40 °C to form various phosphorus oxides.

The head of the match contains potassium chlorate ($\text{KClO}_3(\text{s})$) which, when heated to at least 300 °C by the ignition of white phosphorus, decomposes exothermically to form oxygen gas and potassium chloride.

- (a) Sketch energy profile diagrams for each of these reactions. (3 marks)



- (b) Write a balanced equation for the decomposition of potassium chlorate including the heat of reaction and state symbols. $\Delta H = -98.56 \text{ kJ}$ (3 marks)

- (c) State one reason why the experimental value obtained is lower than the theoretical value. (1 mark)

Question 27

(4 marks)

Using ethanoic acid as an example, distinguish between the definition of the term 'acid' in the Davy and the Brønsted–Lowry models. Include relevant equations in your answer.

Question 28**(8 marks)**

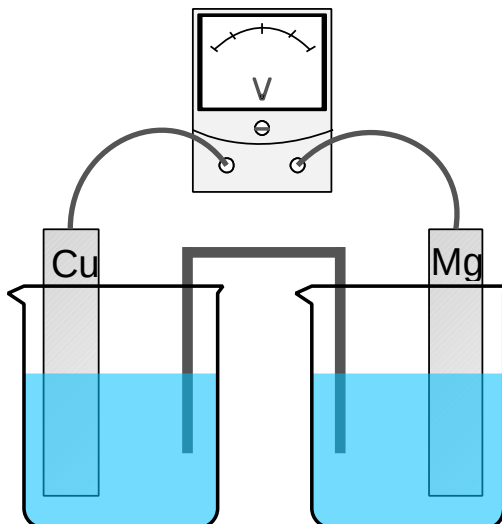
The sulfur cycle involves the transformation of sulfur atoms through various oxidation states. Hydrogen sulfide (H_2S) released from hydrothermal vents can be converted to elemental sulfur (S_8) by photosynthetic green and purple bacteria. The elemental sulfur is then converted to sulfate (SO_4^{2-}). Another type of bacteria transforms the sulfate into sulfite (SO_3^{2-}), and then finally back into hydrogen sulfide, where the cycle can begin again.

Write four (4) half-equations representing the steps in the sulfur cycle described above, assuming acidic conditions. Classify each step as a reduction (R) or oxidation (O) process.

	Half-equation	R / O
1		
2		
3		
4		

Question 29**(15 marks)**

An investigation into the oxidising strength of various metals was set up as shown below initially comparing copper and magnesium.



(a) Label the anode and cathode. (1 mark)

(b) Write the overall redox equation and calculate the cell voltage under standard conditions. (2 marks)

(c) Name suitable electrolyte solutions for each beaker. (2 marks)

Copper electrode beaker _____

Magnesium electrode beaker _____

The voltage measured was initially higher than predicted then slowly decreased.

(d) Explain this observation. (2 marks)

- (e) State two observations for the copper half-cell as the reaction proceeds. (2 marks)

As part of the experiment the student weighed both electrodes before and after the experiment and found one electrode increased by 0.253 g.

- (f) Calculate the mass change in the other electrode. (3 marks)

The equipment shown above compares the oxidising strength of copper and magnesium.

- (g) How could the oxidising strength of zinc be determined using this equipment? (3 marks)

Question 30**(6 marks)**

Write balanced equations for reactions occurring between the following substances and describe observations during the reaction and the contents of the flask at the end of the reaction.

- (a) A small amount of aqueous chlorine is added to some potassium iodide solution.

(3 marks)

Equation_____

Observations during the reaction_____

Observations of contents of flask when reaction finished_____

- (b) A large volume of sodium hydroxide solution is added to a small volume of sulfuric acid containing a few drops of phenolphthalein.

(3 marks)

Equation_____

Observations during the reaction_____

Observations of contents of flask when reaction finished_____

Question 31**(15 marks)**

Limestone is defined as a rock that contains at least 50% calcium carbonate.

An excess of $0.5030 \text{ mol L}^{-1} \text{ HCl(aq)}$ (200.0 mL) is added to completely react with a 3.75 g sample of a rock containing calcium carbonate. A volume of 30.0 mL of $2.004 \text{ mol L}^{-1} \text{ NaOH(aq)}$ is required to then neutralise the excess hydrochloric acid. Assume no other chemicals in the rock can react with the acid or base.

- (a) Determine by calculation if this sample of rock should be considered limestone. (8 marks)

The equation for the decomposition of calcium carbonate is shown below.



- (b) Explain how this reaction will behave differently if it is carried out in an open container compared with a closed container. (2 marks)

- (c) Write the equilibrium expression for this reaction. (1 mark)

At 800°C $K = 2.5 \times 10^{-3}$

- (d) Compare the relative amounts of products and reactants at equilibrium. (1 mark)

- (e) Predict the effect on K of reducing the temperature. Justify your answer. (3 marks)

Question 32**(7 marks)**

The K_a values (at 25 °C) for the ionisation of phosphoric acid are shown below.

$$K_{a1} = 6.9 \times 10^{-3}$$

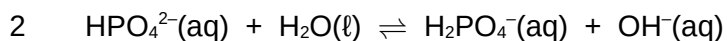
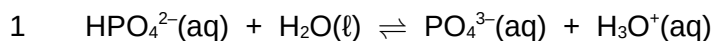
$$K_{a2} = 6.2 \times 10^{-8}$$

$$K_{a3} = 4.8 \times 10^{-13}$$

- (a) Write the equation for the reaction of the dihydrogen phosphate ion with water. (2 marks)

- (b) Which one of the following reactions will be more likely to take place? Explain your answer by referring to the relative strength of the conjugate acids and bases present.

(5 marks)



Question 33**(10 marks)**

The equation describing one of the buffering systems found in the human body is shown below. It maintains blood at pH 7.4.



During exercise more oxygen is used by the body and more carbon dioxide is produced. Intense exercise also produces lactic acid ($\text{CH}_3\text{CH}(\text{OH})\text{COOH}$) which can cause muscle pain and tiredness.

- (a) Describe the initial effect of lactic acid on the pH of blood. (2 marks)

- (b) Explain, using collision theory, how the buffer acts to reduce the impact of lactic acid. (4 marks)

b

During periods of intense exercise, the buffer alone may not be able to maintain pH. The lungs remove excess $\text{CO}_2(\text{aq})$ and the kidneys remove excess $\text{HCO}_3^-(\text{aq})$.

- (c) Explain how both these processes can help maintain normal pH. (4 marks)

Question 34**(8 marks)**

- (a) Calculate the mass of barium hydroxide solid required to neutralise 45.0 mL of a hydrochloric acid solution at pH = 1.52. (6 marks)

- (b) Discuss the effect, if any, on the mass of barium hydroxide required if the original solution was sulfuric acid. (2 marks)

End of section two

Section Three: Extended answer**(88 Marks)**

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

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.

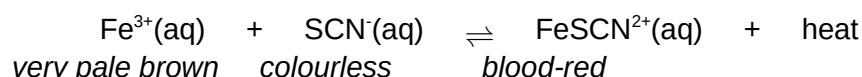
Final answers to calculations should be expressed to the appropriate number of significant figures and include appropriate units where applicable.

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 question where the answer is continued, i.e. give the page number.

Suggested working time: 70 minutes

Question 35**(17 marks)**

When solutions of iron(III) nitrate and potassium thiocyanate are mixed, the iron thiocyanate complex ion, $\text{FeSCN}^{2+}(\text{aq})$ is formed, and an aqueous equilibrium system is established as shown below.



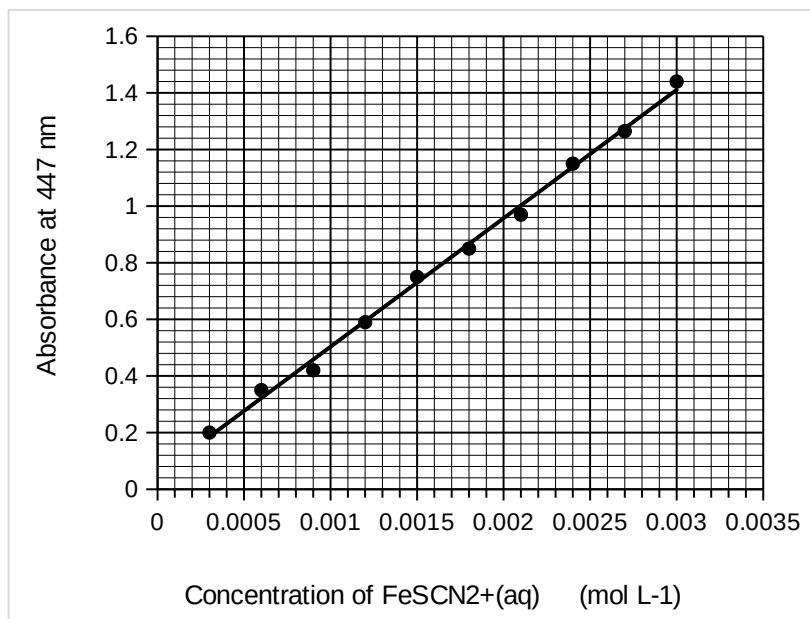
The appearance of the equilibrium mixture is determined by the concentration of $\text{FeSCN}^{2+}(\text{aq})$, which displays a characteristic blood-red colour.

Due to the presence of this colour, the concentration of $\text{FeSCN}^{2+}(\text{aq})$ can be quantified by measuring the absorbance. A sample of the equilibrium mixture can be taken, and the absorbance is measured using light at 447 nm. This absorbance value is then compared to a calibration curve to determine the concentration of $\text{FeSCN}^{2+}(\text{aq})$.

A group of chemistry students set up this equilibrium as described;

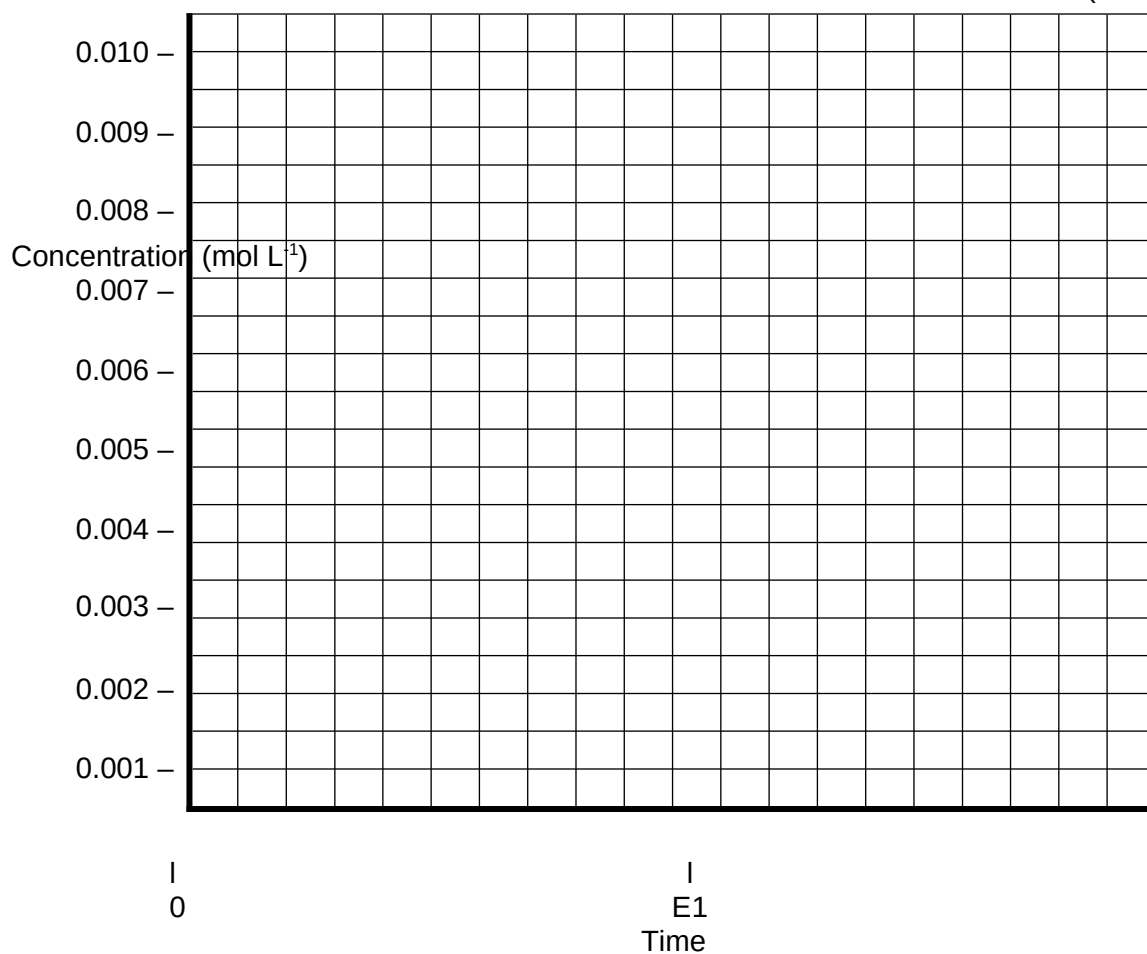
1. Samples of $\text{Fe}(\text{NO}_3)_3(\text{aq})$ and $\text{KSCN}(\text{aq})$ were prepared.
2. Aliquots of each solution were then combined so that, once mixed, the initial concentrations were 0.01 mol L^{-1} and 0.006 mol L^{-1} respectively.
3. The mixture was allowed to sit for 10 minutes so equilibrium could be established.
4. A sample of the equilibrium mixture was then taken, and the absorbance was measured at 447 nm using a spectrophotometer.
5. The absorbance was determined to be 0.96.

The calibration curve for $\text{FeSCN}^{2+}(\text{aq})$ is shown below.

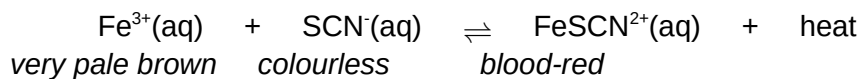


- (a) Determine the concentration of $\text{FeSCN}^{2+}(\text{aq})$ present at equilibrium. (1 mark)

- (b) Sketch a graph, including all relevant species, showing the establishment of equilibrium, from Time 0 where the reactants were mixed, to Time E1, where equilibrium was established and maintained. (5 marks)



The students then decided to split their equilibrium mixture into several different beakers, and impose various changes on the system to examine the results. The equilibrium equation is provided again below, for convenience.



The students' research had also provided them with the following chemical equations, related to the iron thiocyanate equilibrium.

- i. $\text{Fe}^{3+}(\text{aq}) + 6 \text{F}^{-}(\text{aq}) \rightleftharpoons \text{FeF}_6^{3-}(\text{aq})$
- ii. $\text{SCN}^{-}(\text{aq}) + \text{H}_3\text{O}^{+}(\text{aq}) \rightleftharpoons \text{HSCN}(\text{aq}) + \text{H}_2\text{O}(\text{l})$
- iii. $\text{Fe}^{3+}(\text{aq}) + 3 \text{OH}^{-}(\text{aq}) \rightleftharpoons \text{Fe}(\text{OH})_3(\text{s})$

Firstly, the students used two beakers to investigate the effect of adding acid, $\text{H}_3\text{O}^{+}(\text{aq})$ and base, $\text{OH}^{-}(\text{aq})$ to the original iron thiocyanate equilibrium. They found that in both cases, this shifted the position of the equilibrium to the left.

- (c) Justify these results by using Le Chatelier's principle and making reference to any appropriate equations provided. (6 marks)

- (d) Describe the observation that would have distinguished between the addition of acid and base to the equilibrium system. (1 mark)

In a separate beaker, the students added a few drops of concentrated potassium fluoride, KF(aq) , to the system.

- (e) Explain, in terms of reaction rates, the effect this would have on the equilibrium position. (4 marks)

Question 36**(14 marks)**

Coca-Cola was first released in 1886 in the USA. It's current formula still remains a trade secret, but the listed ingredients are;

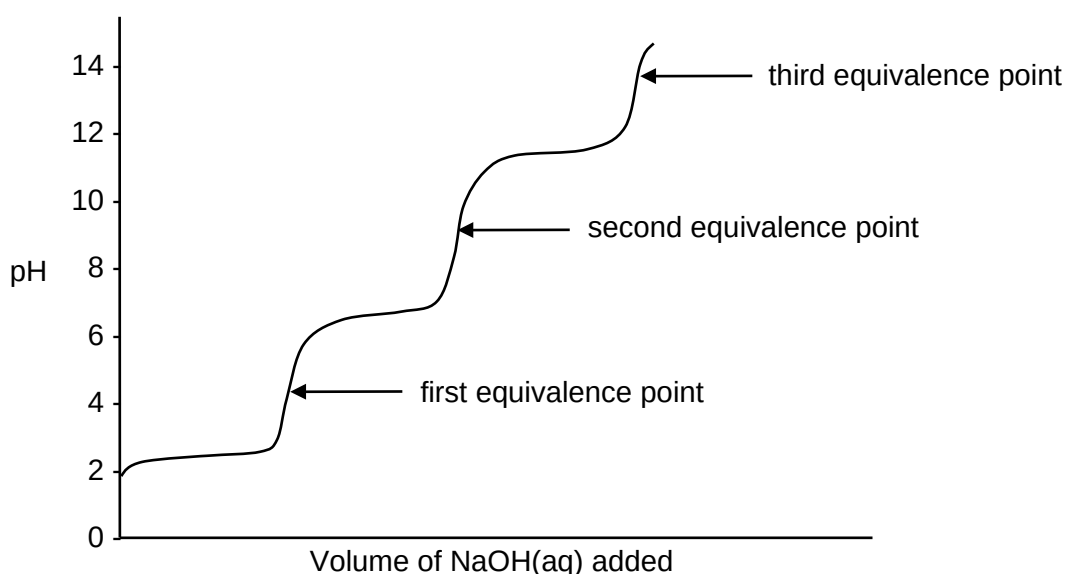
Carbonated water, sugar, caffeine, phosphoric acid, caramel colour, natural flavourings.

Phosphoric acid adds a tangy taste to the Coca-Cola. A chemistry class was assigned the task of determining the concentration of phosphoric acid, $\text{H}_3\text{PO}_4(\text{aq})$, in Coca-Cola and using this **to determine the phosphorus content** of the soft drink.

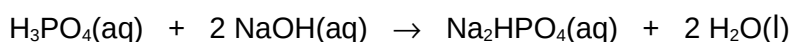
Research by the students led to the development of the following method;

1. Take a 150.0 mL aliquot of Coca-Cola.
2. Heat for 20 minutes, to just below the boiling point.
3. Allow to cool.
4. Insert a pH meter into the solution.
5. Titrate against a $0.1005 \text{ mol L}^{-1} \text{ NaOH}(\text{aq})$ standard solution, until a pH of 9.5 is reached.

Phosphoric acid is a weak, triprotic acid. This means there are three different equivalence points for the titration reaction. The titration curve for this reaction is shown below.



The pH at the third equivalence point is too basic to titrate accurately, and so the titration is performed to the **second equivalence point**, according to the following equation;



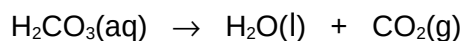
- (a) Explain why the pH at the first equivalence point is acidic, whilst the pH at the second equivalence point is basic. Include relevant chemical equations in your answer. (4 marks)

- (b) Suggest one practical reason a pH meter is used to detect the equivalence point, instead of the indicator phenolphthalein. (1 mark)

The students performed the titration and found an average titre of 16.65 mL of NaOH(aq) was required to reach the second equivalence point.

- (c) Calculate the milligrams of phosphorus present in a 375 mL can of Coca-Cola. (6 marks)

In Step 2 and 3 of the method, the Coca-Cola is heated and cooled. This causes the following reaction to occur, which removes the carbonic acid present in the soft drink.



One group of students only heated their Coca-Cola samples for 5 minutes, before performing each titration.

- (d) Classify this error as random or systematic. Justify your choice and state the likely effect this would have on the students' calculated phosphorus content. (3 marks)

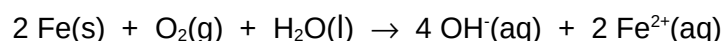
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Question 37

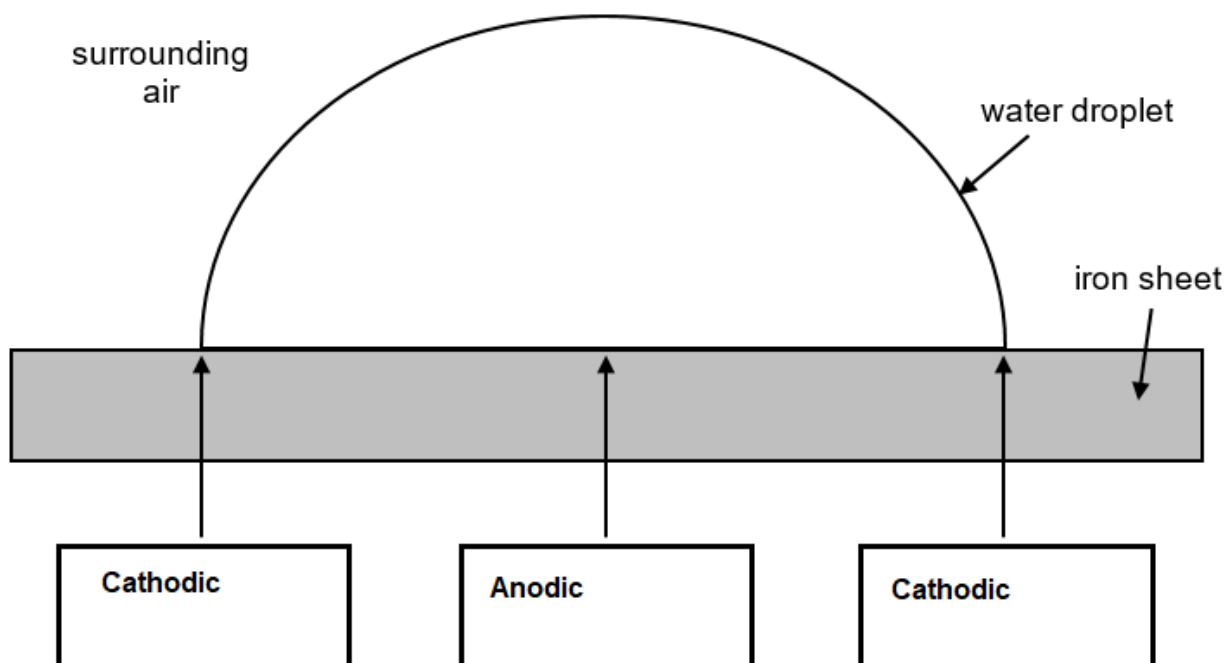
(18 marks)

Iron is used widely in modern society, in structures such as bridges and buildings, in reinforced concrete as well as piping, and to manufacture cars and ships. The corrosion of iron to form rust is a costly and potentially dangerous problem, and a great deal of money is spent trying to prevent, reduce and repair the damage caused by the corrosion of iron.

The corrosion of iron to form rust involves a sequence of reactions. The process generally begins when iron comes into contact with water and oxygen. The overall equation for the initial redox reaction involved in the corrosion of iron can be represented by the following chemical equation.



The diagram below shows a close-up view of a water droplet on a sheet of iron.



- (a) On the diagram above, label the direction of cation and anion flow. Your labels should indicate the **identity** of each ion. (2 marks)
- (b) Demonstrate that this reaction is a redox process, using oxidation numbers to support your answer. (2 marks)

Consider the following statement made by a student in response to a question on corrosion.

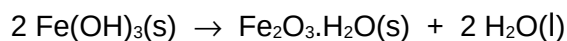
'Corrosion of iron is a very slow process so the reaction will have a small equilibrium constant.'

- (c) Comment on this statement by discussing both rate of reaction and equilibrium. (4 marks)

The next step in the reaction sequence to form rust, involves the formation of a precipitate.

- (d) Write a balanced ionic equation for this step. (1 mark)

The product of this precipitation reaction is further oxidised to solid iron(III) hydroxide, which then dehydrates to form orange-brown rust, $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}(\text{s})$. This is illustrated in the chemical equation below.



The mass of a sample of iron sheet was recorded. After a period of time, rust formed on the surface of the iron. All traces of the rust were then scraped off, and the new mass of the iron sheet was recorded. The results are shown in the table below.

Initial mass of iron (g)	84.2 g
Final mass of iron (g)	77.1 g

- (e) Calculate the volume of $\text{O}_2(\text{g})$ that would have reacted to produce this rust. The partial pressure of $\text{O}_2(\text{g})$ in air is 21.2 kPa and the temperature of the air was 19.3 °C. State your answer to the appropriate number of significant figures. (5 marks)

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- (f) Calculate the maximum mass of rust, $\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}(\text{s})$, that would have formed from this corrosion. (2 marks)

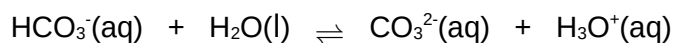
This experiment was repeated with a galvanised iron sheet (i.e. an iron sheet coated in zinc), which was exposed to identical conditions, for the same period of time. The galvanised iron sheet showed no signs of rust.

(g) Explain these observations. (2 marks)

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Question 38**(20 marks)**

The buffering capacity of seawater results from the presence of hydrogencarbonate, $\text{HCO}_3^-(\text{aq})$ and carbonate, $\text{CO}_3^{2-}(\text{aq})$ ions. The chemical equation for this buffer is given below.



- (a) Define a buffer. (2 marks)

- (b) Describe how the large increase in atmospheric $\text{CO}_2(\text{g})$ caused by human activity, results in a higher $\text{H}_3\text{O}^+(\text{aq})$ concentration in seawater. (Note: chemical equations are **not** required in your answer). (3 marks)

- (c) Justify, using Le Chatelier's principle, how the hydrogencarbonate / carbonate buffer system in seawater responds to this increase in $\text{H}_3\text{O}^+(\text{aq})$. (2 marks)

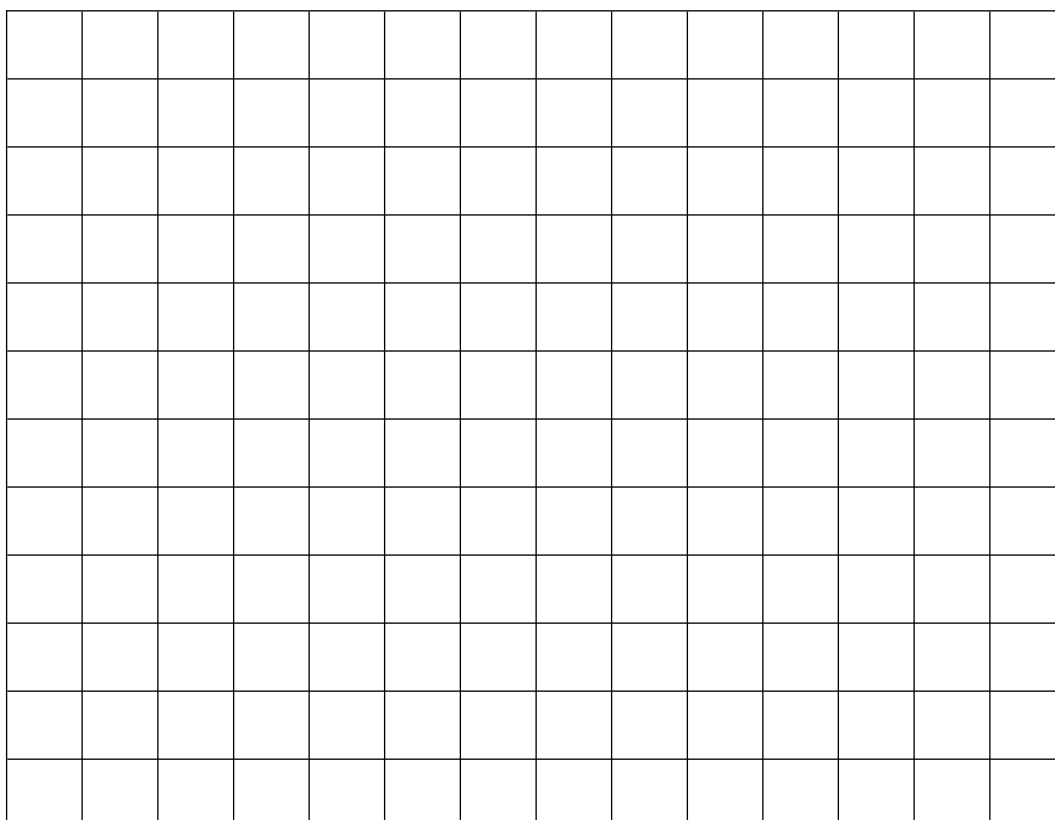
A group of chemistry students collected a sample of seawater and decided to investigate its buffering capacity. They placed two 100 mL samples of the seawater into separate beakers and measured the initial pH.

To one beaker they added 0.005 mol L⁻¹ HCl(aq) in 1 mL aliquots, whilst measuring the pH. To the other beaker, they added 0.005 mol L⁻¹ NaOH(aq) in 1 mL aliquots, whilst measuring the pH.

Their results are shown in the table below.

		Volume of acid / base added (mL)										
Solution added		0	1	2	3	4	5	6	7	8	9	10
pH	HCl(aq)	8.2	8.2	8.1	8.1	8.0	7.8	7.5	7.0	6.2	5.0	3.0
	NaOH(aq)	8.2	8.2	8.3	8.3	8.4	8.4	8.5	8.5	8.6	8.7	8.9

- (d) Plot this data on the same set of axes, using the grid below. (5 marks)



- (e) Does seawater contain a higher concentration of $\text{HCO}_3^-(\text{aq})$ or $\text{CO}_3^{2-}(\text{aq})$? Justify your answer, by referring to the data collected in this investigation. (4 marks)

In addition to an increased $\text{H}_3\text{O}^+(\text{aq})$ ion concentration, the increase in atmospheric $\text{CO}_2(\text{g})$ also has a negative impact on many marine calcifying species, such as cuttlefish.

- (f) State two (2) negative consequences associated with the cuttlefish not being able to form its internal calcium carbonate shell. (2 marks)

- (g) Suggest two (2) ways humans can reduce their production of $\text{CO}_2(\text{g})$. (2 marks)

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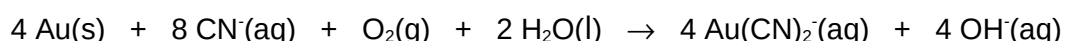
Question 39

(19 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, led 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'.



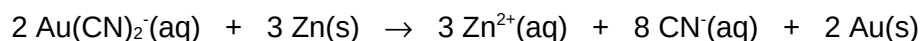
A sample of gold-bearing ore was crushed and placed in a tank, along with 25 kL of leaching solution. The initial concentration of NaCN(aq) in the leach solution was 0.478 g L^{-1} . After 48 hours, this had fallen to 0.083 g L^{-1} .

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

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- (b) Calculate the final pH of the leaching solution. (You may assume that only the $\text{OH}^-(\text{aq})$ 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 Merrill-Crowe process. Once the slurry has been filtered, zinc dust is then added to the leaching solution to precipitate the gold. The Merrill-Crowe process can be represented by the following chemical equation.



- (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)

Once the gold has been precipitated, filtration is again used to separate the reaction mixture. This results in a solid filtrate composed of Au(s) as well as excess Zn(s).

A solution of sulfuric acid is then added to this Au(s) / Zn(s) mixture.

- (e) Explain how this would allow separation of the two metals to occur. Use data from your standard reduction potential table to support your answer. (4 marks)

End of questions

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