

**ROSSMOYNE  
SENIOR  
HIGH SCHOOL**

**CHEMISTRY  
•  
UNIT 3  
2021**

Student number:

In words \_\_\_\_\_  
\_\_\_\_\_

Circle your Teacher's 

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 Name

Mr Lloyd

Dr Barnes

Mr Wallace

Mr Dhue

Mr Venter

Mr Faulkner

**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 Book

***To be provided by the candidate:***

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

Special items: up to three calculators, which do not have the capacity to create or store programmes or text, are permitted in this ATAR course 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	Percentage of examination
Section One Multiple-choice	25	25	50	/ 25	/ 25
Section Two Short answer	9	9	60	/ 74	/ 35
Section Three Extended answer	5	5	70	/ 80	/ 40
					/ 100

### Instructions to candidates

- Write your answers in this Question/Answer booklet preferably using a blue/black pen. Do not use erasable or gel pens.
- 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.

- 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.
- 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.
- 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.

6. The Chemistry Data Book is not to be 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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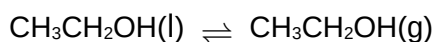
1. Which of the following factors would increase the reaction rate, by increasing the proportion of successful collisions between reactant particles?
- (a) Increasing the concentration of reactant species.
  - (b) Decreasing the volume of a gaseous system.
  - (c) Increasing the subdivision of a solid reactant.
  - (d) Increasing the temperature of a reacting system.
2. A 500 mL sample of a 1.0 mol L<sup>-1</sup> solution must meet the following criteria;
- (i) Have a pH below 7.
  - (ii) Can be completely neutralised by the addition of 0.5 moles of NaOH(s).
  - (iii) Have a K<sub>a</sub> value less than 1.

The solution could be

- (a) NH<sub>3</sub>(aq).
- (b) HCl(aq).
- (c) CH<sub>3</sub>COOH(aq).
- (d) H<sub>2</sub>SO<sub>3</sub>(aq).

**Questions 3 and 4 refer to the equilibrium below.**

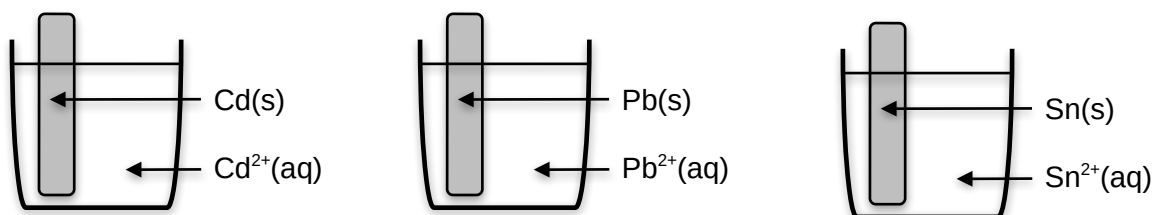
Consider the following physical equilibrium involving pure ethanol.



3. If this system had established equilibrium, which of the following would be correct?
- (a) The rate of evaporation would equal the rate of condensation.
  - (b) The rate of evaporation would be greater than the rate of condensation.
  - (c) The rate of condensation would be greater than the rate of evaporation.
  - (d) The rate of evaporation and condensation would be zero.
4. If the temperature of this system was increased by 5 °C, this would
- (a) have no effect on the position of equilibrium.
  - (b) decrease the rate of condensation.
  - (c) decrease the rate of evaporation.
  - (d) increase the value of K<sub>c</sub>.
-

5. In which of the following acid-base titrations, would the reaction mixture **not** be a good conductor of electricity at the equivalence point?
- Hydrochloric acid and sodium hydroxide.
  - Sulfuric acid and barium hydroxide.
  - Ethanoic acid and ammonia.
  - All of the above.

Questions 6 and 7 refer to the three (3) half-cells pictured below, which were set up under standard conditions.



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

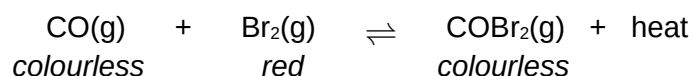
	Oxidising agent	Reducing agent
(a)	Cd	Pb <sup>2+</sup>
(b)	Pb	Cd <sup>2+</sup>
(c)	Cd <sup>2+</sup>	Pb
(d)	Pb <sup>2+</sup>	Cd

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

7. Which piece of equipment would **not** be required?
- Salt bridge
  - Power pack
  - Wires
  - Electrical load (e.g. globe, voltmeter, resistor)
8. Which one of the following mixtures will have the **greatest** ability to resist change in pH when a small quantity of concentrated acid or base is added to it?
- 50.00 mL of 0.10 mol L<sup>-1</sup> NH<sub>3</sub> and 50.00 mL of 0.10 mol L<sup>-1</sup> HCl
  - 25.00 mL of 0.50 mol L<sup>-1</sup> NaOH and 25.00 mL of 0.50 mol L<sup>-1</sup> HCl
  - 25.00 mL of 0.10 mol L<sup>-1</sup> NH<sub>3</sub> and 25.00 mL of 0.10 mol L<sup>-1</sup> NH<sub>4</sub>Cl
  - 25.00 mL of 0.50 mol L<sup>-1</sup> NH<sub>3</sub> and 25.00 mL of 0.50 mol L<sup>-1</sup> NH<sub>4</sub>Cl

Questions 9, 10 and 11 refer to the following equilibrium system.

Consider the following gaseous system, which has established equilibrium at 85 °C.



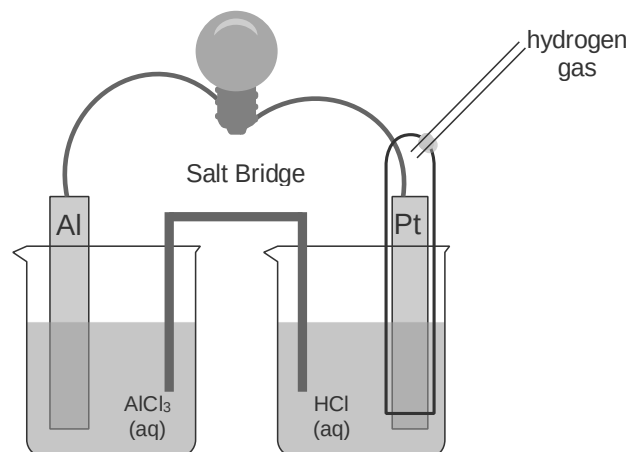
9. If the volume of the system was halved, it would be observed that
- (a) the red colour would gradually lighten.
  - (b) the red colour would gradually darken.
  - (c) the red colour would immediately darken and then gradually lighten.
  - (d) the red colour would immediately lighten and then gradually darken.

The reacting system was then cooled from 85 °C to 35 °C, to **condense** the COBr<sub>2</sub>.

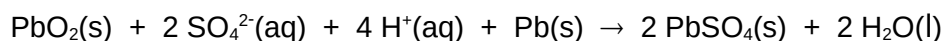
10. When compared to the system at 85 °C, at 35 °C the system would contain
- (a) a smaller mass of COBr<sub>2</sub>.
  - (b) a larger mass of COBr<sub>2</sub>.
  - (c) the same mass of COBr<sub>2</sub>.
  - (d) the comparative mass of COBr<sub>2</sub> cannot be predicted from this information.
11. Once the system had been cooled to 35 °C, it was then classified as
- (a) an open system, because some of the COBr<sub>2</sub> had condensed.
  - (b) an open system, because there were fewer gas particles.
  - (c) a closed system, because the position of equilibrium had not changed.
  - (d) a closed system, because the number of atoms in the system had not changed.
12. Which of the following rows correctly describes the acidity/basicity of the specified compounds when dissolved in distilled water?

	ammonium nitrate	potassium fluoride	barium hydroxide	calcium chloride
(a)	acidic	acidic	neutral	neutral
(b)	basic	basic	neutral	acidic
(c)	acidic	basic	basic	neutral
(d)	basic	acidic	basic	acidic

Questions 13 and 14 refer to the following diagram



13. For the galvanic cell above
- (a) a greenish–yellow gas will form at the aluminium electrode.
  - (b) the aluminium electrode will be the positive electrode.
  - (c) the concentration of aluminium ions in solution will decrease during discharge.
  - (d) electrons will flow from the aluminium to the hydrogen half–cell.
14. The reaction occurring at the platinum electrode is
- (a)  $\text{Cl}_2(\text{g}) + 2\text{e}^- \rightarrow 2\text{Cl}^-(\text{aq})$ .
  - (b)  $2\text{Cl}^-(\text{aq}) \rightarrow \text{Cl}_2(\text{g}) + 2\text{e}^-$ .
  - (c)  $2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g})$ .
  - (d)  $2\text{H}_2\text{O}(\text{l}) + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g}) + 2\text{OH}^-(\text{aq})$ .
15. The following equation represents the discharge reaction occurring in a lead-acid accumulator.



Which statement regarding this chemical process is **not** correct?

- (a) The oxidation number of Pb(s) changes by 2.
- (b) The PbO<sub>2</sub>(s) electrode would have a positive polarity.
- (c) The H<sup>+</sup>(aq) ions would migrate towards the PbO<sub>2</sub>(s) electrode.
- (d) The Pb(s) electrode acts as the oxidising agent.

16. 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	<b>W</b>
$E_a(\text{reverse}) \text{ (kJ mol}^{-1}\text{)}$	<b>X</b>	129
$H(\text{forward}) \text{ (kJ mol}^{-1}\text{)}$	+373	<b>Y</b>
$H(\text{reverse}) \text{ (kJ mol}^{-1}\text{)}$	<b>Z</b>	

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

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

17. Which of the acidic solutions below could produce an equivalence point close to pH 7 by the addition of **1 mole of  $\text{NH}_3(\text{aq})$**  to the substances below, that have previously been dissolved in equal amounts of distilled water?

- (i) 1 mole of  $\text{CH}_3\text{COOH}$
- (ii) 1 mole of  $\text{H}_2\text{SO}_4(\text{aq})$
- (iii) 1 mole of  $\text{HCl}(\text{aq})$
- (iv) 1 mole of  $\text{H}_2\text{CO}_3(\text{aq})$

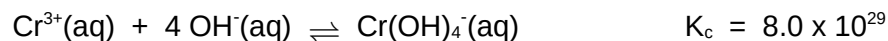
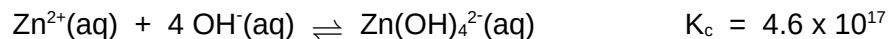
- (a) (i) only.
  - (b) (iii) only.
  - (c) (i) and (iii) only.
  - (d) (ii) and (iv) only.
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**Questions 18 and 19 refer to the information below.**

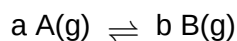
An aqueous solution was formed by dissolving an equal number of moles of  $\text{Zn}(\text{NO}_3)_2(\text{s})$  and  $\text{Cr}(\text{NO}_3)_3(\text{s})$  into water.

Ten drops of concentrated  $\text{NaOH}(\text{aq})$  was added to this mixture. The following equations relate to the subsequent equilibria that were established.

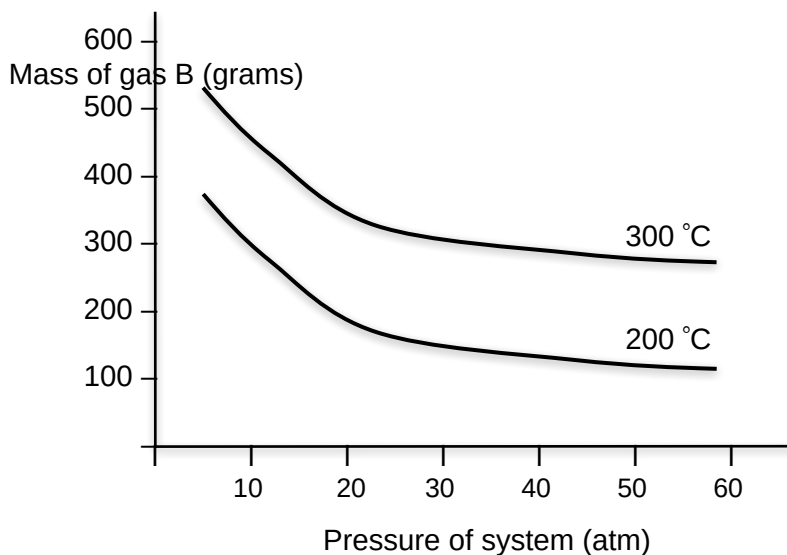


18. Whilst the system was moving to establish equilibrium, which of the following statements would be correct regarding the equilibria above?
- (a) The forward reaction rates were continually increasing.
  - (b) The reverse reaction rates were continually decreasing.
  - (c) The forward reaction rates were faster than their respective reverse reaction rates.
  - (d) The reverse reaction rates were faster than their respective forward reaction rates.
19. Once all equilibria had been established, which of the following would be correct?
- (a)  $[\text{Zn}^{2+}(\text{aq})] < [\text{Cr}^{3+}(\text{aq})]$
  - (b)  $[\text{Zn}(\text{OH})_4^{2-}(\text{aq})] < [\text{Cr}(\text{OH})_4^{-}(\text{aq})]$
  - (c)  $[\text{Zn}(\text{OH})_4^{2-}(\text{aq})] = \frac{1}{4} \times [\text{OH}^{-}(\text{aq})]$
  - (d) None of the above

20. A particular gaseous equilibrium can be represented by the following equation;

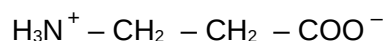


The graph below shows how the mass of gas B present at equilibrium changes with different conditions of temperature and pressure.



Using the data provided in this graph, which of the following must be true for this reaction?

- (a)  $a > b$ ,  $H$  is positive.
  - (b)  $a > b$ ,  $H$  is negative.
  - (c)  $a < b$ ,  $H$  is positive.
  - (d)  $a < b$ ,  $H$  is negative.
21. Consider the following substance which can act as an acid or a base;



Select the correct conjugate species for this substance.

Conjugate acid	Conjugate base
(a) $\text{H}_3\text{N}^+ - \text{CH}_2 - \text{CH}_2 - \text{COOH}$	$\text{H}_2\text{N} - \text{CH}_2 - \text{CH}_2 - \text{COO}^-$
(b) $\text{H}_2\text{N} - \text{CH}_2 - \text{CH}_2 - \text{COO}^-$	$\text{H}_3\text{N}^+ - \text{CH}_2 - \text{CH}_2 - \text{COOH}$
(c) $\text{H}_2\text{N} - \text{CH}_2 - \text{CH}_2 - \text{COOH}$	$\text{HN}^- - \text{CH}_2 - \text{CH}_2 - \text{COO}^-$
(d) $\text{H}_3\text{N}^+ - \text{CH}_2 - \text{CH}_2 - \text{COOH}_2^+$	$\text{H}_2\text{N} - \text{CH}_2 - \text{CH}_2 - \text{COOH}$

22. Phosphoric acid is a weak acid. Which one of the following species will be in the **lowest** concentration in a dilute solution of  $\text{H}_3\text{PO}_4$ ?

- (a)  $\text{H}_2\text{PO}_4^-(\text{aq})$
- (b)  $\text{HPO}_4^{2-}(\text{aq})$
- (c)  $\text{PO}_4^{3-}(\text{aq})$
- (d)  $\text{H}_3\text{PO}_4(\text{aq})$

23. Increased deforestation and continual burning of fossil fuels have caused an increase in the partial pressure of carbon dioxide in the atmosphere. This is causing which one of following changes in the ocean?
- (a)  $[\text{CO}_3^{2-}(\text{aq})]$  increasing
  - (b)  $[\text{HCO}_3^-(\text{aq})]$  increasing
  - (c)  $[\text{H}^+(\text{aq})]$  decreasing
  - (d)  $[\text{CO}_2(\text{aq})]$  decreasing

**Questions 24 and 25 refer to the following chemicals.**

Consider the four (4) pairs of chemicals listed below.

- (i) Pb(s) and  $\text{Cd}(\text{NO}_3)_2(\text{aq})$
- (ii) Sn(s) and  $\text{Ni}(\text{NO}_3)_2(\text{aq})$
- (iii) Ni(s) and  $\text{Pb}(\text{NO}_3)_2(\text{aq})$
- (iv) Cd(s) and  $\text{Sn}(\text{NO}_3)_2(\text{aq})$

24. If these chemical combinations were mixed in separate beakers, which would result in a metal displacement reaction?
- (a) (i) and (ii) only.
  - (b) (i) and (iii) only.
  - (c) (ii) and (iv) only.
  - (d) (iii) and (iv) only.

Four (4) separate galvanic cells were then set up, using the chemicals listed above.

25. Which combination of chemicals would have produced the galvanic cell with the highest EMF under standard conditions?
- (a) Pb(s) /  $\text{Pb}^{2+}(\text{aq})$  and Cd(s) /  $\text{Cd}^{2+}(\text{aq})$
  - (b) Sn(s) /  $\text{Sn}^{2+}(\text{aq})$  and Ni(s) /  $\text{Ni}^{2+}(\text{aq})$
  - (c) Ni(s) /  $\text{Ni}^{2+}(\text{aq})$  and Pb(s) /  $\text{Pb}^{2+}(\text{aq})$
  - (d) Cd(s) /  $\text{Cd}^{2+}(\text{aq})$  and Sn(s) /  $\text{Sn}^{2+}(\text{aq})$

**End of Section One**

**Section Two: Short answer****35% (74 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.

**Question 26****(5 marks)**

Consider the combustion of ethane gas,  $\text{C}_2\text{H}_6(\text{g})$ .

- (a) Balance the following chemical equations representing the combustion of ethane gas, in both excess, to  $\text{CO}_2$  and limited oxygen, to CO environments. (2 marks)

Excess oxygen	$\text{C}_2\text{H}_6(\text{g}) + \text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{g})$
Limited oxygen	$\text{C}_2\text{H}_6(\text{g}) + \text{O}_2(\text{g}) \rightarrow \text{CO}(\text{g}) + \text{H}_2\text{O}(\text{g})$

- (b) Use oxidation numbers to demonstrate which process results in the complete oxidation of ethane. (3 marks)

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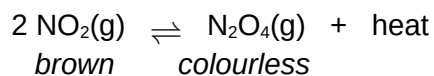
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## Question 27

(6 marks)

Consider the following gaseous equilibrium system.



Complete the following table by stating how each of the imposed changes would affect;

- (i) the rate of the forward reaction,
- (ii) the position of equilibrium, and
- (iii) the concentration of  $\text{NO}_2(\text{g})$ .

Note: consider the effect of each imposed change in isolation.

	Increase in temperature of system	Increase in volume of system
Rate of forward reaction  (increase, decrease, no change)		
Position of equilibrium  (shift left, shift right, no change)		
Concentration of $\text{NO}_2(\text{g})$  (increase, decrease, no change)		

**Question 28****(9 marks)**

A chemistry student poured 325 mL of 0.55 mol L<sup>-1</sup> hydrochloric acid, HCl(aq), into a beaker. They then added 200 drops of 2.0 mol L<sup>-1</sup> nitric acid, HNO<sub>3</sub>(aq), whilst measuring the pH of the mixture throughout.

- (a) Calculate the initial pH of the hydrochloric acid solution. (1 mark)

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- (b) Calculate the pH of the mixture, after the 200 drops of nitric acid was added. (6 marks)  
Note: 1 drop = 0.050 mL.

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The student concluded that the solution was a buffer, since the pH change caused by the additional 200 drops of nitric acid had been minimal. However, their teacher said this was incorrect, and the solution was **not** a buffer.

- (c) Use relevant chemical theory to justify the teacher's statement (2 marks)

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**Question 29**

**(10 marks)**

When a few drops of concentrated sodium bismuthate solution,  $\text{NaBiO}_3(\text{aq})$ , are added to a small volume of manganese(II) chloride solution, a deep purple solution is formed. The purple colour of the solution suggests that manganese is transformed to the permanganate ion,  $\text{MnO}_4^-$ . The colourless bismuth ion,  $\text{Bi}^{3+}(\text{aq})$ , is also formed.

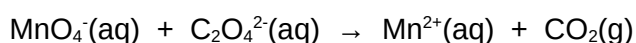
(a) Write the oxidation and reduction half equations, and the overall redox equation, for this reaction. State symbols are **not** required. (6 marks)

Oxidation half-equation
Reduction half-equation
Overall equation

(b) Write the formula of the oxidant in the box below. (1 mark)

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(c) Another reaction involving the permanganate ion is given below.



Use oxidation numbers to show that this reaction is classified as a redox reaction. (3 marks)


**Question 30****(9 marks)**

Consider the information provided in the table below, which relates to a particular reaction that is taking place at 25 °C.

$E_a$	=	8 kJ
$H$	=	-33 kJ mol <sup>-1</sup>
$K$	=	$\frac{1}{[\text{Pb}^{2+}][\text{I}^-]^2}$
$K_c$	=	$2.27 \times 10^8$

- (a) Write a balanced chemical equation for the reaction occurring. (2 marks)

- (b) Sketch an energy profile diagram for this reaction on the axes below. Label the activation energy and change in enthalpy. (5 marks)



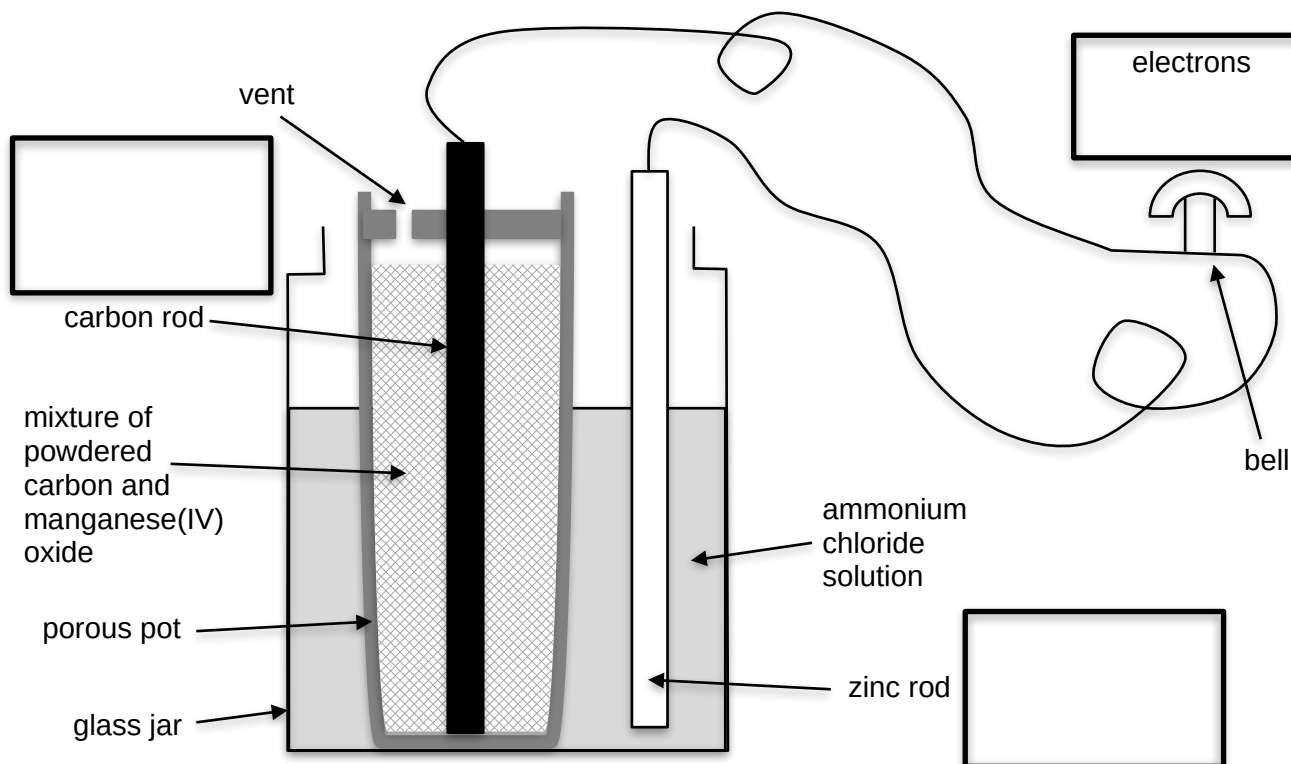
- (c) Comment, with justification, on the likely reversibility of this reaction at 25 °C. (2 marks)



## Question 31

(8 marks)

The Leclanché cell was invented and patented in 1866. It was a primary cell, that was later developed into the dry cell. The Leclanché cell was very successful and quickly became used to power early telephones and electric bells. The diagram below shows the original Leclanché design.



The relevant half-equations are given in the table below.

$\text{MnO}_2(\text{s}) + 2 \text{NH}_4^+(\text{aq}) + 2 \text{e}^- \rightarrow \text{Mn}_2\text{O}_3(\text{s}) + 2 \text{NH}_3(\text{aq}) + \text{H}_2\text{O}(\text{l})$	$E^0(\text{red}) =$
$\text{Zn}(\text{s}) \rightarrow \text{Zn}^{2+}(\text{aq}) + 2 \text{e}^-$	$E^0(\text{ox}) =$

(a) In the boxes on the diagram above, label the

- anode and cathode,
- polarity of each electrode, and
- direction of electron flow.

(3 marks)

- (b) The Leclanché cell provides an EMF of +1.4 V. If this EMF was produced under standard conditions, complete the table above by adding in the  $E^0$  values. (2 marks)
- (c) The porous pot is acting as the 'salt bridge'? Describe the functions of this component. (3 marks)

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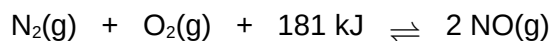
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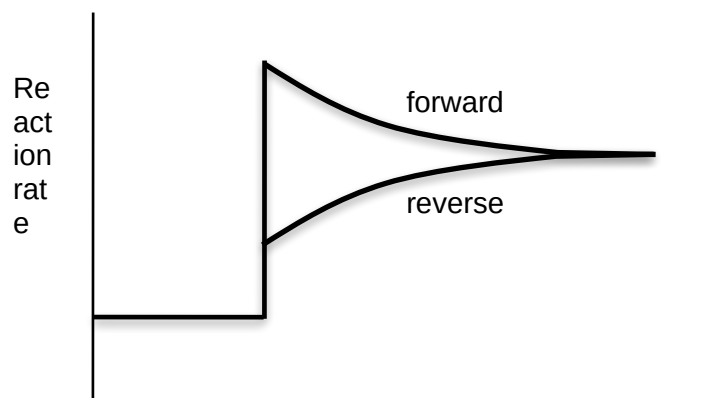
## Question 32

(6 marks)

The following gaseous system had established equilibrium.



A change was then imposed on the system, the effect of which is represented by the graph below.



- (a) Which of the changes below was imposed on the system? (circle your choice) (1 mark)

addition of nitrogen gas  
to the system

decrease in total volume  
of the system

increase in temperature  
of the system

- (b) Justify why you **did not choose** the two remaining options. (2 marks)

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- (c) Explain the direction of the resultant equilibrium shift that was observed. (3 marks)

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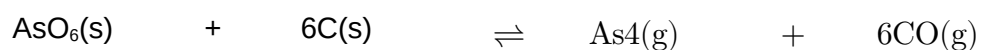
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**Question 33****(6 marks)**

- (a) Write a balanced ionic equation for the chemical reaction that would occur when a solution of ethanoic acid is mixed with sodium carbonate solution. (2 marks)

- (b) State all observations that would be noted, when several drops of bromine water are added to a beaker containing a solution of potassium iodide. Potassium iodide is the excess reagent. (2 marks)

- (c) Write the equilibrium constant for the following reaction that occurs when arsenic is extracted from its oxide by reacting it with carbon according to the following equation. (2 marks)



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**Question 34****(15 marks)**

A brand of oven cleaner contains sodium hydroxide as its primary cleaning agent. The brand claims that it contains sodium hydroxide at a concentration of  $155 \text{ g L}^{-1} \pm 1.5\%$ .

A 10.00 mL sample of the oven cleaner was diluted to 500.0 mL in a volumetric flask. Using a pipette 25.00 mL samples of the diluted cleaner were then titrated against a  $0.0633 \text{ mol L}^{-1}$  standard solution of sulfuric acid. The results of these titrations are shown below.

<b>Trial</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
<b>Initial reading</b>	1.46 mL	17.46 mL	32.19 mL	1.65 mL	15.59 mL
<b>Final reading</b>	17.46 mL	32.19 mL	46.94 mL	16.59 mL	30.30 mL
<b>Volume added</b>					

- (a) Calculate the average titre for this titration. Show your working. (2 marks)

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- (b) Use the data above to calculate the concentration of NaOH in the oven cleaner in grams per litre. (State your answer to the appropriate number of significant figures) (7 marks)

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- (c) Does the oven cleaner contain sodium hydroxide at a concentration of  $155 \text{ g L}^{-1} \pm 1.5\%$  as claimed by the manufacturer? Show your working. (2 marks)

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- (d) If the following errors occurred during the titrations predict and explain how the calculated concentration of NaOH in the oven cleaner would be affected.

- (i) When the 500.0 mL volumetric flask was filled to the mark with water, the bottom of the meniscus was below the line. (2 marks)

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**Question 34 Continued**

- (ii) The determination of the end point was incorrect because the intensity of the final colour was darker and thus the end point was identified later than it should have been. (2 marks)

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**End of Section Two**



**Section Three: Extended answer****40% (80 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.

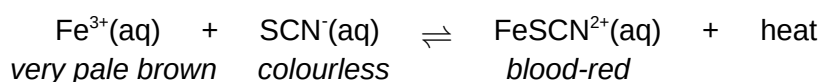
Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 70 minutes.

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**Question 35****(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.



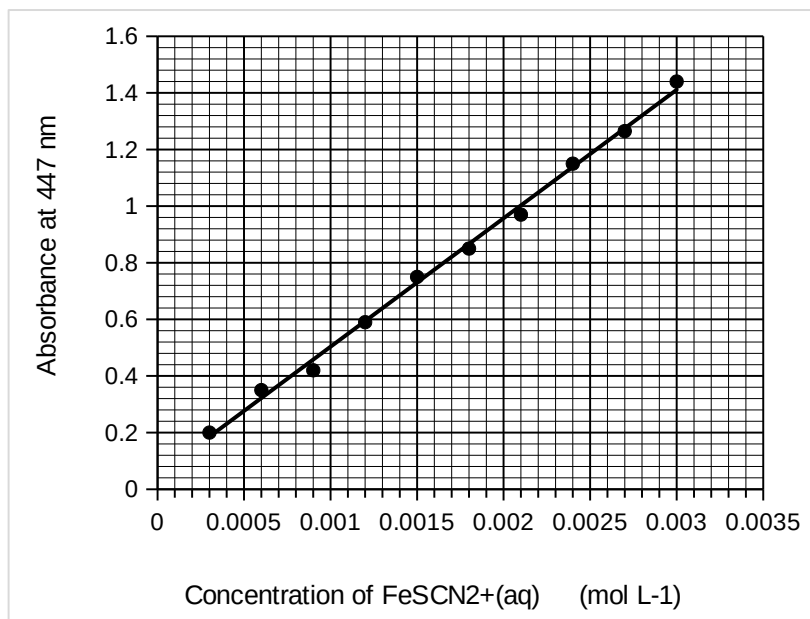
The appearance of the equilibrium mixture is determined by the concentration of  $\text{FeSCN}^{2+}(\text{aq})$ , which displays a characteristic blood-red colour.

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;

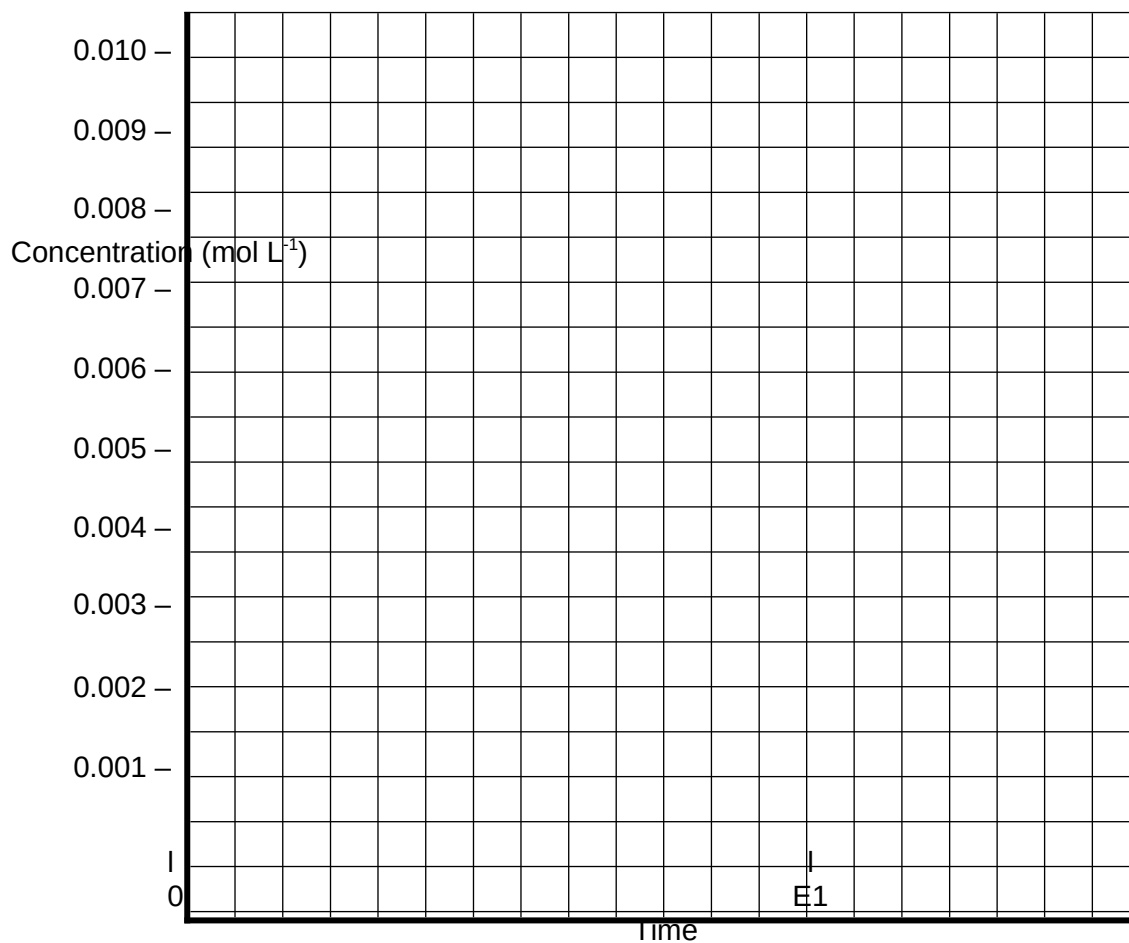
1. Samples of  $\text{Fe}(\text{NO}_3)_3(\text{aq})$  and  $\text{KSCN}(\text{aq})$  were prepared.
2. Aliquots of each solution were then combined so that, once mixed, the initial concentrations were  $0.01 \text{ mol L}^{-1}$  and  $0.006 \text{ mol L}^{-1}$  respectively.
3. The mixture was allowed 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.

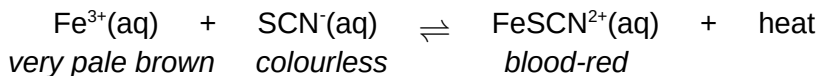


- (a) Determine the concentration of  $\text{FeSCN}^{2+}(\text{aq})$  present at equilibrium. (1 mark)

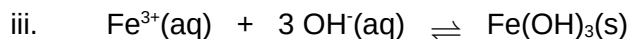
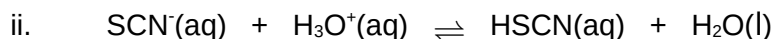
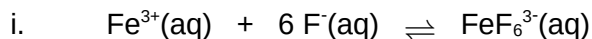
- (b) Sketch a graph, including all relevant species, showing the establishment of equilibrium, from Time 0 where the reactants were mixed, to Time E1, where equilibrium was established and maintained. (5 marks)



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.



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)

[illegible]

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

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To a separate beaker containing a sample of the iron thiocyanate equilibrium, the students added a few drops of concentrated potassium fluoride,  $\text{KF(aq)}$ .

- (e) Explain, in terms of reaction rates in the iron thiocyanate equilibrium, how the changes caused by the addition of  $\text{KF(aq)}$  affected those reaction rates and the equilibrium position of iron thiocyanate equilibrium. (4 marks)

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## Question 36

(15 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;

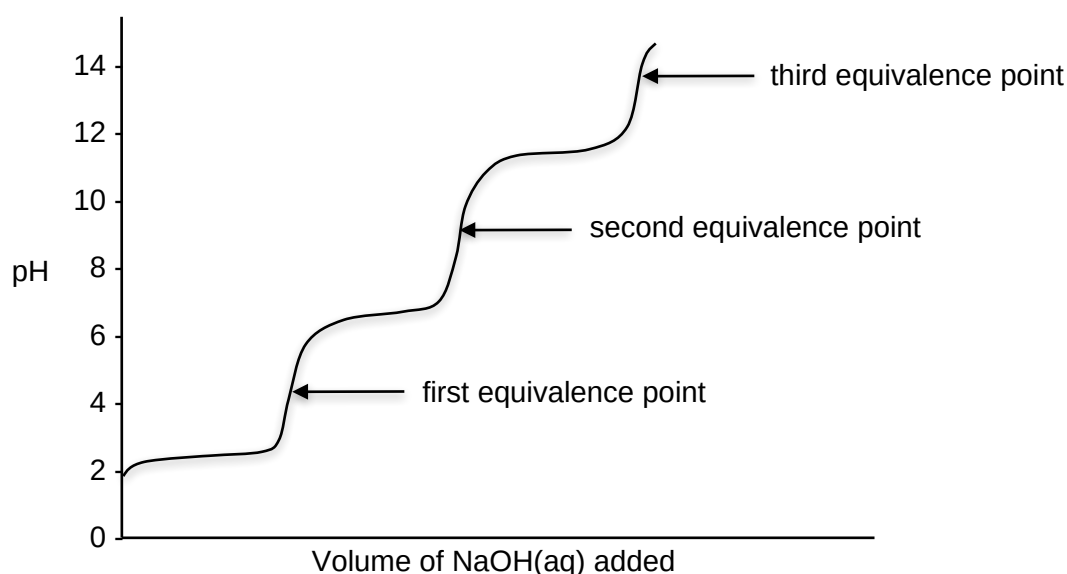
*Carbonated water, sugar, caffeine, phosphoric acid, caramel colour, natural flavourings.*

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.

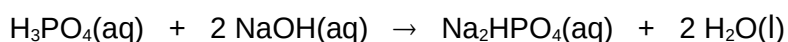
Research by the students led to the development of the following method;

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)

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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.

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

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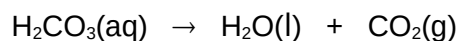
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In Step 2 and 3 of the method, the Coca-Cola is heated and cooled. This causes the following reaction to occur, which removes the carbonic acid present in the soft drink.



- (c) Justify why this step is important for the **validity** of the experiment. (2 marks)

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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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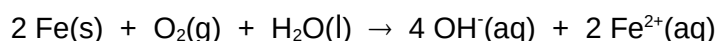
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## Question 37

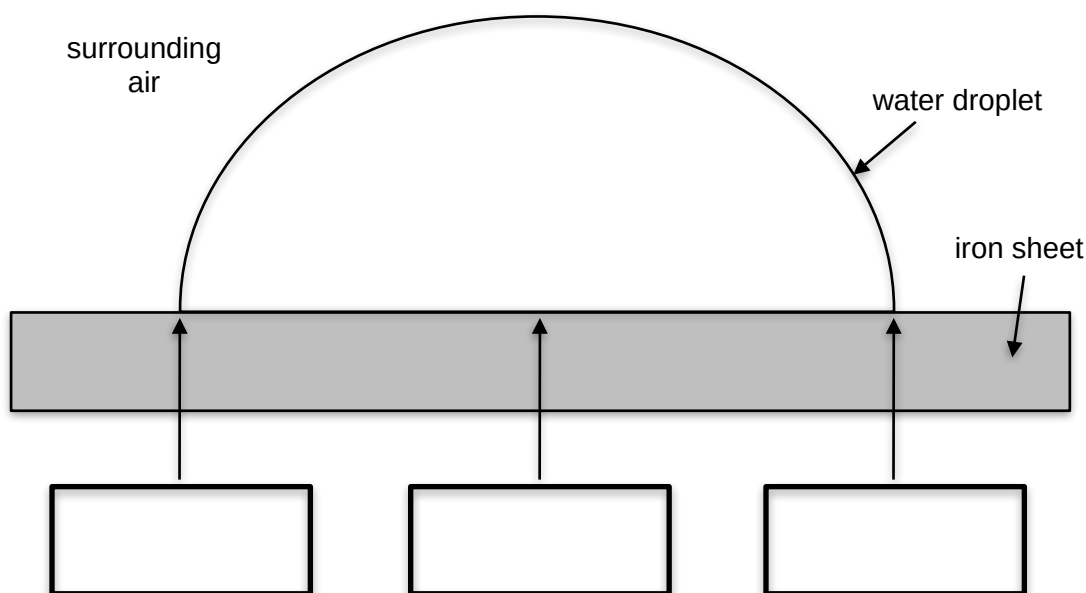
(18 marks)

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

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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

- (d) 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.  
 { Hint: Moles formula's including  $PV = nRT$  are in the data sheet } (5 marks)

- (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)

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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. (4 marks)

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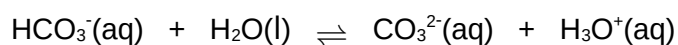
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**Question 38****(11 marks)**

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)

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(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)

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(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)

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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.

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

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

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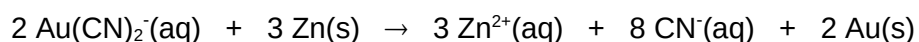
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There are several techniques used to separate the gold from the leaching solution, one of which is the Merrill-Crowe process. Once the slurry has been filtered, zinc dust is then added to the leaching solution to precipitate the gold. The Merrill-Crowe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



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

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

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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)

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**End of questions**

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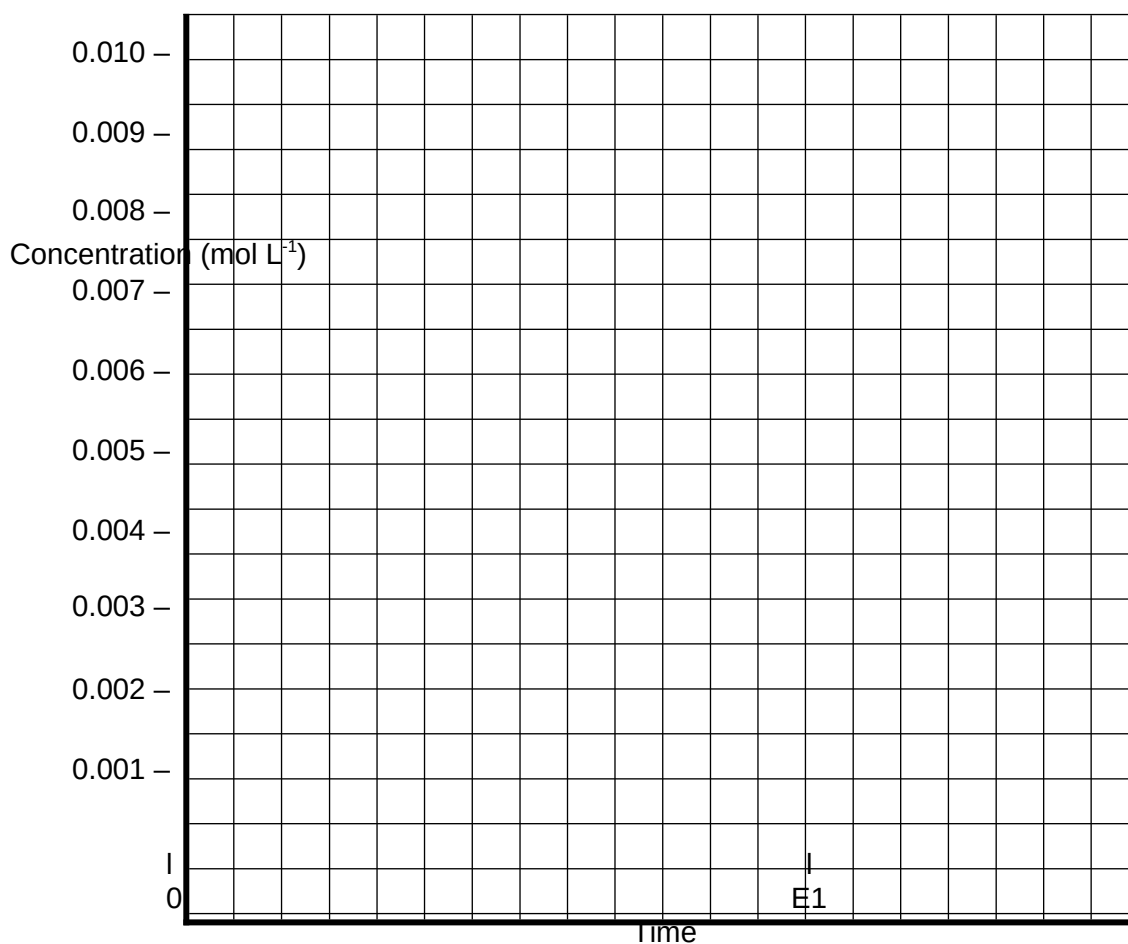
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Question 35 (b)



Marker	Question	Mark	Section Mark	% 2 d.p
	MC		/50	25
AB	26			
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TF	28			
TF	29			
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TW	31			
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BL	33			
TF	34		/74	35
BL	35			
MD	36			
JV	37			
AB	38			
JV	39		/80	40
			TOTAL	