

# Answers

# CHEMISTRY

## UNIT 3

## 2021

Student number:

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

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Name: \_\_\_\_\_

Teacher: \_\_\_\_\_

### 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

1. Write your answers in this Question/Answer booklet preferably using a blue/black pen. Do not use erasable or gel pens.
2. 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.

3. 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.
4. 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.
5. 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.

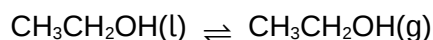
1. Which of the following factors would increase the reaction rate, by increasing the proportion of successful collisions between reactant particles?
- (a) Increasing the concentration of reactant species.
  - (b) Decreasing the volume of a gaseous system.
  - (c) Increasing the subdivision of a solid 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.

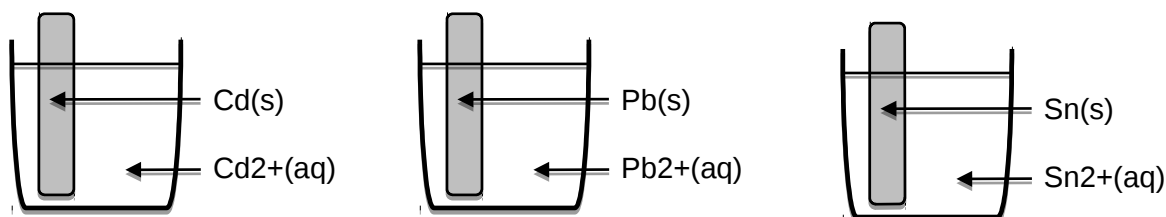
Consider the following physical equilibrium involving pure ethanol.



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?
- (a) Hydrochloric acid and sodium hydroxide.
  - (b) Sulfuric acid and barium hydroxide.**
  - (c) Ethanoic acid and ammonia.
  - (d) 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)?

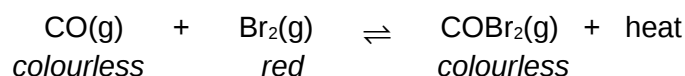
	<b>Oxidising agent</b>	<b>Reducing agent</b>
(a)	Cd	Pb <sup>2+</sup>
(b)	Pb	Cd <sup>2+</sup>
(c)	Cd <sup>2+</sup>	Pb
<b>(d)</b>	<b>Pb<sup>2+</sup></b>	<b>Cd</b>

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

7. Which piece of equipment would **not** be required?
- (a) Salt bridge
  - (b) Power pack**
  - (c) Wires
  - (d) 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?
- (a) 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
  - (b) 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
  - (c) 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
  - (d) 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.



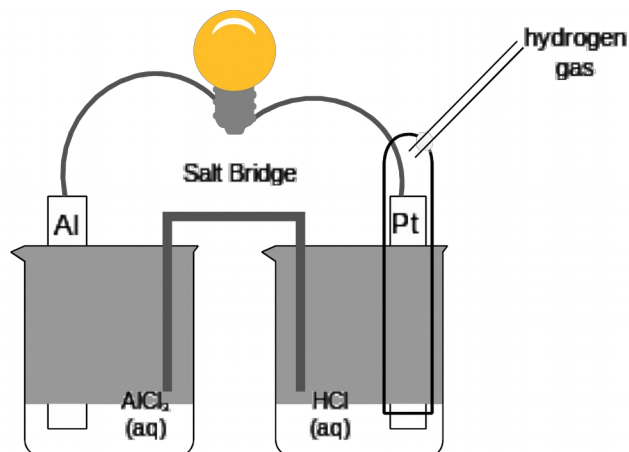
9. If the volume of the system was halved, it would be observed that
- (a) the red colour would gradually lighten.
  - (b) the red colour would gradually darken.
  - (c) the red colour would immediately darken and then gradually lighten.
  - (d) the red colour would immediately lighten and then gradually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

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

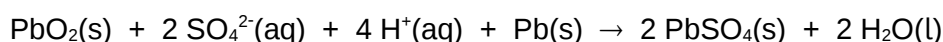
10. When compared to the system at 85 °C, at 35 °C the system would contain
- (a) a smaller mass of COBr<sub>2</sub>.
  - (b) a larger mass of COBr<sub>2</sub>.
  - (c) the same mass of COBr<sub>2</sub>.
  - (d) the comparative mass of COBr<sub>2</sub> cannot be predicted from this information.
11. Once 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
acidic	acidic	neutral	neutral
basic	basic	neutral	acidic
acidic	basic	basic	neutral
basic	acidic	basic	acidic

Questions 13 and 14 refer to the following diagram



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



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

- The oxidation number of Pb(s) changes by 2.
- The PbO<sub>2</sub>(s) electrode would have a positive polarity.
- The H<sup>+</sup>(aq) ions would migrate towards the PbO<sub>2</sub>(s) electrode.
- 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
$E_a(\text{forward})$ ( $\text{kJ mol}^{-1}$ )	551	<b>W</b>
$E_a(\text{reverse})$ ( $\text{kJ mol}^{-1}$ )	<b>X</b>	129
$\Delta H(\text{forward})$ ( $\text{kJ mol}^{-1}$ )	+373	<b>Y</b>
$\Delta H(\text{reverse})$ ( $\text{kJ mol}^{-1}$ )	<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>
<b>(a)</b>	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 have an equivalence point close to pH 7 by the addition of 1 mole of  $\text{NH}_3(\text{aq})$ ?

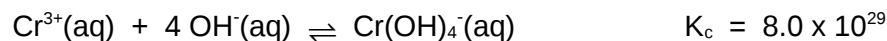
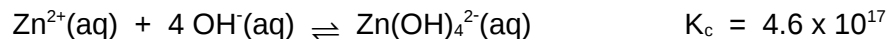
- (i) 1 mole of  $\text{CH}_3\text{COOH}(\text{aq})$
- (ii) 1 mole of  $\text{H}_2\text{SO}_4(\text{aq})$
- (iii) 1 mole of  $\text{HCl}(\text{aq})$
- (iv) 1 mole of  $\text{H}_2\text{CO}_3(\text{aq})$

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

**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.

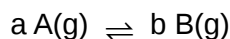
Ten drops of concentrated  $\text{NaOH}(\text{aq})$  was added to this mixture. The following equations relate to the subsequent equilibria that were established.



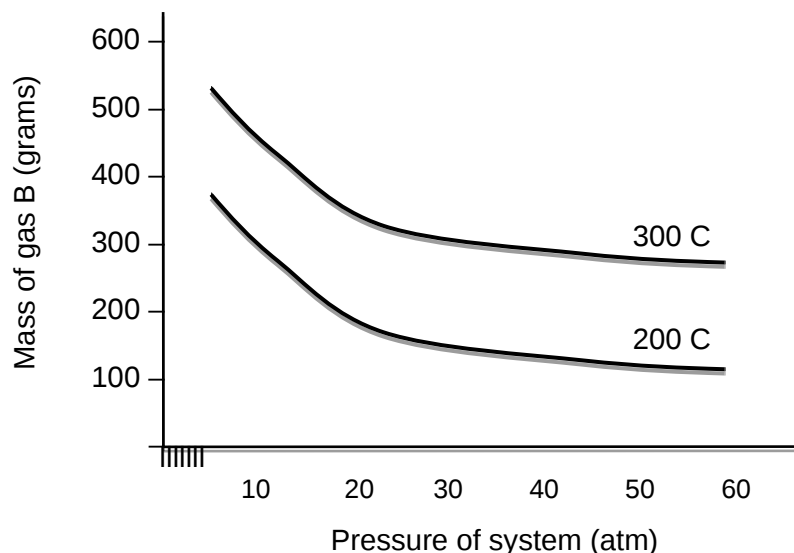
18. Whilst the system was moving to establish equilibrium, which of the following statements would be correct regarding the equilibria above?
- (a) The forward reaction rates were continually increasing.
  - (b) The reverse reaction rates were continually decreasing.
  - (c) The forward reaction rates 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;

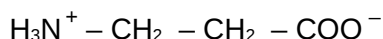


The graph below shows how the mass of gas B present at equilibrium changes with different conditions of temperature and pressure.



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

- (a)  $a > b$ ,  $\Delta H$  is positive.  
 (b)  $a > b$ ,  $\Delta H$  is negative.  
 (c)  $a < b$ ,  $\Delta H$  is positive.  
 (d)  $a < b$ ,  $\Delta H$  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**

# ROSSMOYNE SENIOR HIGH SCHOOL

## SEMESTER 1 EXAM 2021

### Multiple-choice Answer Sheet

Name: \_\_\_\_\_

### INSTRUCTIONS

For each question shade the box to indicate your answer.  
Use **only** a blue or black **pen** to shade the boxes.

For example, if b is your answer:

a ☐ b ☒ c ☐ d ☐

If you make a mistake, place a cross through that square and shade your new answer. **Do not** erase or use correction fluid/tape.

For example, if b is a mistake and d is your answer:

a ☐ b ☒ c ☐ d ☒

If you then want to use your first answer b, cross out d and then circle b.

a ☐ b ☒ c ☐ d ☒

Marks will **not** be deducted for incorrect answers.

**No marks** will be given if more than one answer is completed for any question.

1	a <input type="checkbox"/> b <input type="checkbox"/> c <input type="checkbox"/> d <input checked="" type="checkbox"/>	6	a <input type="checkbox"/> b <input type="checkbox"/> c <input type="checkbox"/> d <input checked="" type="checkbox"/>	11	a <input type="checkbox"/> b <input type="checkbox"/> c <input type="checkbox"/> d <input checked="" type="checkbox"/>
2	a <input type="checkbox"/> b <input type="checkbox"/> c <input checked="" type="checkbox"/> d <input type="checkbox"/>	7	a <input type="checkbox"/> b <input checked="" type="checkbox"/> c <input type="checkbox"/> d <input type="checkbox"/>	12	a <input type="checkbox"/> b <input type="checkbox"/> c <input checked="" type="checkbox"/> d <input type="checkbox"/>
3	a <input checked="" type="checkbox"/> b <input type="checkbox"/> c <input type="checkbox"/> d <input type="checkbox"/>	8	a <input type="checkbox"/> b <input type="checkbox"/> c <input type="checkbox"/> d <input checked="" type="checkbox"/>	13	a <input type="checkbox"/> b <input type="checkbox"/> c <input type="checkbox"/> d <input checked="" type="checkbox"/>
4	a <input type="checkbox"/> b <input type="checkbox"/> c <input type="checkbox"/> d <input checked="" type="checkbox"/>	9	a <input type="checkbox"/> b <input type="checkbox"/> c <input checked="" type="checkbox"/> d <input type="checkbox"/>	14	a <input type="checkbox"/> b <input type="checkbox"/> c <input checked="" type="checkbox"/> d <input type="checkbox"/>
5	a <input type="checkbox"/> b <input checked="" type="checkbox"/> c <input type="checkbox"/> d <input type="checkbox"/>	10	a <input type="checkbox"/> b <input checked="" type="checkbox"/> c <input type="checkbox"/> d <input type="checkbox"/>	15	a <input type="checkbox"/> b <input type="checkbox"/> c <input type="checkbox"/> d <input checked="" type="checkbox"/>
16	a <input checked="" type="checkbox"/> b <input type="checkbox"/> c <input type="checkbox"/> d <input type="checkbox"/>	21	a <input checked="" type="checkbox"/> b <input type="checkbox"/> c <input type="checkbox"/> d <input type="checkbox"/>		
17	a <input checked="" type="checkbox"/> b <input type="checkbox"/> c <input type="checkbox"/> d <input type="checkbox"/>	22	a <input type="checkbox"/> b <input type="checkbox"/> c <input checked="" type="checkbox"/> d <input type="checkbox"/>		
18	a <input type="checkbox"/> b <input type="checkbox"/> c <input checked="" type="checkbox"/> d <input type="checkbox"/>	23	a <input type="checkbox"/> b <input checked="" type="checkbox"/> c <input type="checkbox"/> d <input type="checkbox"/>		
19	a <input type="checkbox"/> b <input checked="" type="checkbox"/> c <input type="checkbox"/> d <input type="checkbox"/>	24	a <input type="checkbox"/> b <input type="checkbox"/> c <input type="checkbox"/> d <input checked="" type="checkbox"/>		
20	a <input type="checkbox"/> b <input type="checkbox"/> c <input checked="" type="checkbox"/> d <input type="checkbox"/>	25	a <input checked="" type="checkbox"/> b <input type="checkbox"/> c <input type="checkbox"/> d <input type="checkbox"/>		

**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) Write balanced chemical equations representing the combustion of ethane gas, in both excess and limited oxygen environments. (2 marks)

Description	Marks
Excess equation: $2 \text{C}_2\text{H}_6(\text{g}) + 7 \text{O}_2(\text{g}) \rightarrow 4 \text{CO}_2(\text{g}) + 6 \text{H}_2\text{O}(\text{g})$	
Balanced	1
Limited equation: $2 \text{C}_2\text{H}_6(\text{g}) + 5 \text{O}_2(\text{g}) \rightarrow 4 \text{CO}(\text{g}) + 6 \text{H}_2\text{O}(\text{g})$	
Balanced	1
<b>Total</b>	<b>2</b>

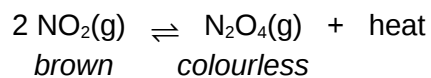
- (b) Use oxidation numbers to demonstrate which process results in the complete oxidation of ethane. (3 marks)

Description	Marks
Oxidation number of carbon changes from (-3) in $\text{C}_2\text{H}_6$ to (+4) in $\text{CO}_2$	1
Oxidation number of carbon changes from (-3) in $\text{C}_2\text{H}_6$ to (+2) in $\text{CO}$	1
Therefore complete oxidation takes place in excess oxygen since this produces carbon in a higher oxidation state (must be clear link between ON and conclusion)	1
<b>Total</b>	<b>3</b>

## 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.

Description			Marks
Rate of forward reaction:	increase	decrease	2
Position of equilibrium:	shift left	shift left	2
Concentration of $\text{NO}_2(\text{g})$ :	increase	decrease	2
Total			6

## 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)

Description	Marks
$\text{pH} = -\log 0.55 = 0.26$	1
<b>Total</b>	<b>1</b>

- (b) Calculate the pH of the mixture, after the 200 drops of nitric acid was added. (6 marks)  
Note: 1 drop = 0.05 mL.

Description	Marks
$n(\text{H}^+ \text{ in HCl}) = 0.55 \times 0.325$ $= 0.17875 \text{ mol}$	1
$V(\text{HNO}_3) = 200 \times 0.05$ $= 10 \text{ mL}$	1
$n(\text{H}^+ \text{ in HNO}_3) = 2 \times 0.01$ $= 0.02 \text{ mol}$	1
$n(\text{H}^+ \text{ total}) = 0.17875 + 0.02$ $= 0.19875 \text{ mol}$	1
$c(\text{H}^+ \text{ total}) = 0.19875 / 0.335$ $= 0.59328 \text{ mol L}^{-1}$	1
$\text{pH} = -\log(0.59328)$ $= 0.23$	1
<b>Total</b>	<b>6</b>

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, with reference to the results obtained. (2 marks)

Description	Marks
The solution is not a buffer because: there is no weak acid/weak conjugate base pair present <b>or</b> both acids are strong (ionised fully) and cannot be used to form a buffer, their negative ions are negligible bases. <b>or</b> a buffer must be formed from a weak acid and its conjugate base or a weak base and its weak conjugate acid	1
pH is a log scale, therefore at these low values a large amount of acid would be required to see a 'substantial' decrease in pH <b>or</b> pH is a log scale, therefore at these low values a small change in pH can represent a large change in [H <sup>+</sup> ]	1
<b>Total</b>	<b>2</b>

### 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.

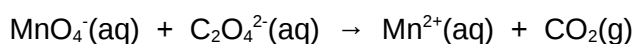
(a) Write the oxidation and reduction half equations, and the overall redox equation, for this reaction. State symbols are **not** required. (6 marks)

Oxidation half-equation	
$\text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}(\text{l}) \rightarrow \text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq}) + 5\text{e}^-$	
Reduction half-equation	
$\text{BiO}_3^-(\text{aq}) + 6\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{Bi}^{3+}(\text{aq}) + 3\text{H}_2\text{O}(\text{l})$	
Overall equation	
$2\text{Mn}^{2+}(\text{aq}) + 5\text{BiO}_3^-(\text{aq}) + 14\text{H}^+(\text{aq}) \rightarrow 2\text{MnO}_4^-(\text{aq}) + 5\text{Bi}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l})$	
Description	Marks
Oxidation half equation correct (One error e.g. incorrect balancing, incorrect formula)	2 (1)
Reduction half equation correct (One error e.g. incorrect balancing, incorrect formula)	2 (1)
Overall equation correct (One error e.g. incorrect balancing, incorrect formula, not simplest whole number ratio) If half equations are both incorrect and have some merit, but half equations multiplied correctly for number of electrons present –one mark.	2 (1)
<b>Total</b>	<b>6</b>

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

$\text{BiO}_3^- / \text{NaBiO}_3$

- (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)

Description	Marks
Statement / working showing that manganese oxidation number has changed from +7 to +2	1
Statement / working showing that carbon's oxidation number has changed from +3 to +4	1
Statement: Since manganese oxidation number has decreased, it ( $\text{MnO}_4^-$ ) has been reduced and since carbon's oxidation number increased, it ( $\text{C}_2\text{O}_4^{2-}$ ) has been oxidized...thus it is a redox reaction	1
<b>Total</b>	<b>3</b>

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### 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.

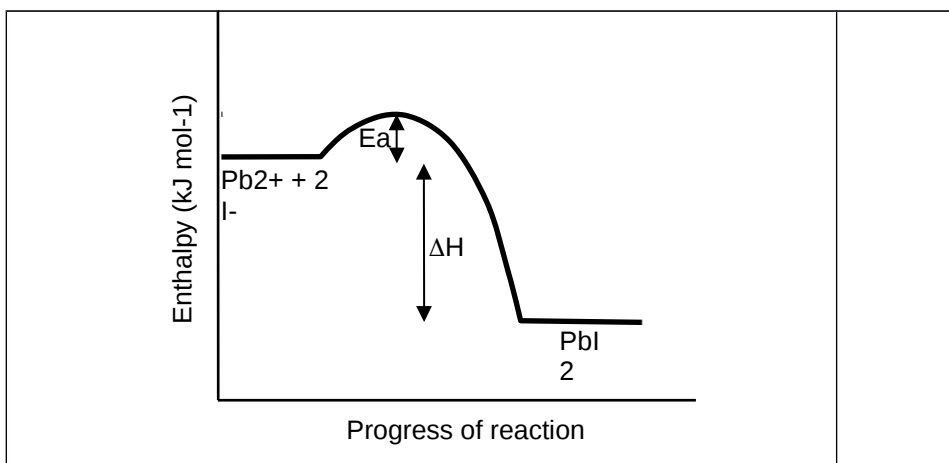
- (a) Write a balanced chemical equation for the reaction occurring. (2 marks)

Description	Marks
Equation: $\text{Pb}^{2+}(\text{aq}) + 2 \text{I}^-(\text{aq}) \rightarrow \text{PbI}_2(\text{s})$	
Correct reactants and products	1
Balanced	1
<b>Total</b>	<b>2</b>

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

Description	Marks
Reactants and products labelled	1
Activation energy labelled	1
Enthalpy change labelled	1
Exothermic curve	1
Shape of curve in (approximate) proportion with $E_a$ and $\Delta H$ values	1
<b>Total</b>	<b>5</b>
Example of a five mark response:	



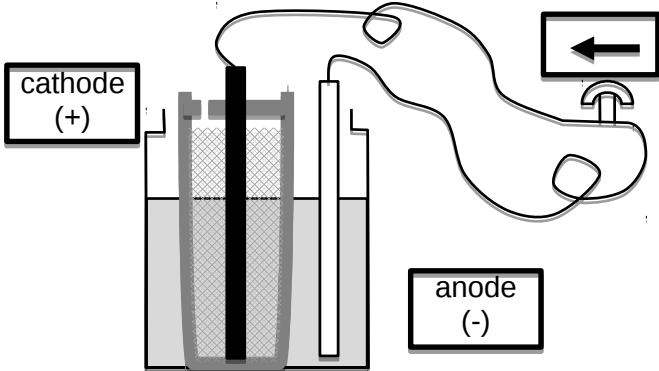


- (c) Comment, with justification, on the likely reversibility of this reaction at 25 °C. (2 marks)

Description	Marks
Not likely to be reversible	1
Large value of K <sub>c</sub> indicates PbI <sub>2</sub> product is very stable at this temperature or The reverse E <sub>a</sub> is large (four times greater) compared to the forward E <sub>a</sub> or PbI <sub>2</sub> is an insoluble salt, therefore unlikely to dissociate to any great extent	1
<b>Total</b>	<b>2</b>

**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.

Description	Marks
Cathode and anode labels	1
Polarity (+/-) labels	1
Direction of electron flow label	1
<b>Total</b>	<b>3</b>
<p>Example of a three mark response:</p> 	

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

(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)**

Description	Marks
$E^0(\text{red}) = + 0.64 \text{ V}$	1
$E^0(\text{ox}) = + 0.76 \text{ V}$	1
<b>Total</b>	<b>2</b>

(c) The porous pot is acting as the 'salt bridge'? Describe the functions of this component.

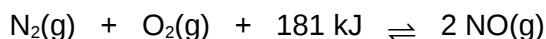
**(3 marks)**

Description	Marks
Any <b>three</b> of the following:	
<ul style="list-style-type: none"><li>allows ions to flow between half-cells</li><li>complete the electrical circuit</li><li>prevents reactants from coming into contact</li><li>maintains electrical neutrality</li></ul>	3
<b>Total</b>	<b>3</b>

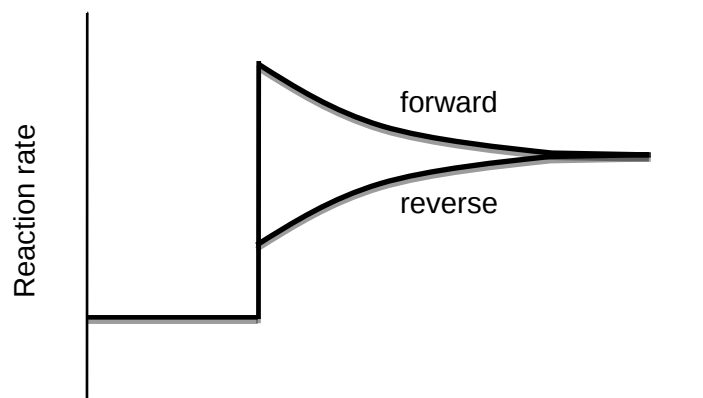
## Question 32

(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)

Description	Marks
'Increase in temperature of system' (circled)	1
<b>Total</b>	<b>1</b>

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

Description	Marks
The addition of nitrogen gas to the system would instantaneously increase the forward reaction rate only <b>or</b> The instantaneous increase seen in both forward and reverse reaction rates is not consistent with the addition of nitrogen gas / change in concentration	1
A decrease in total volume would increase the forward and reverse reaction rates equally (and would not shift the position of equilibrium) <b>or</b> The increase in forward reaction rate relative to reverse reaction rate is not consistent with a system that has a reactant to product ratio of 2:2 gas moles	1
<b>Total</b>	<b>2</b>

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

Description	Marks
A temperature increase would increase (both forward and reverse reaction rates, by increasing) the average kinetic energy of particles, resulting in an increase in the proportion and frequency of successful collisions	1
However the forward / endothermic reaction rate would increase more than the reverse reaction rate. ("temperature changes affect the endothermic reaction more----- optional point)	1
This would result in a shift to the right / the forward reaction being favoured	1
<b>Total</b>	<b>3</b>

or

Description	Marks
A temperature increase favours the reaction that absorbs heat. The forward reaction is endothermic	1
Both rates increase, however the forward / endothermic reaction rate would increase more than the reverse reaction rate	1
This would result in a shift to the right / the forward reaction being favoured	1
<b>Total</b>	<b>3</b>

**Question 33**

**(6 marks)**

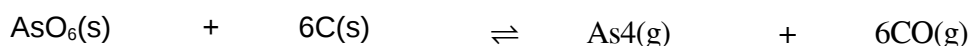
- (a) Write a balanced ionic equation for the chemical reaction that would occur when a solution of ethanoic acid is mixed with sodium carbonate solution. (2 marks)

Description	Marks
Equation: $2 \text{CH}_3\text{COOH}(\text{aq}) + \text{CO}_3^{2-}(\text{aq}) \rightarrow 2 \text{CH}_3\text{COO}^-(\text{aq}) + \text{CO}_2(\text{g}) + \text{H}_2\text{O}(\text{g})$	
Correct reactants and products	1
Balanced	1
<b>Total</b>	<b>2</b>
Note: one mark may be allocated for the correctly balanced molecular equation	

- (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)

Description	Marks
Orange and colourless solutions are mixed,	1
to form a brown solution	1
<b>Total</b>	<b>2</b>

- (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)



Description	Marks
$K = \frac{[\text{As}_4][\text{CO}]^6}{[\text{AsO}_6]}$	2
<b>Total</b>	<b>2</b>
Note: one mark may be allocated for minor error such as no 'K='	



## 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.

Trial	1	2	3	4	5
Initial reading	1.46 mL	17.46 mL	32.19 mL	1.65 mL	15.59 mL
Final reading	17.46 mL	32.19 mL	46.94 mL	16.59 mL	30.30 mL
Volume added	16.00	14.73	14.75	14.94	14.71

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

Description	Marks
Working shown using the four concordant values (trial 2,3 and 5) Average = $(14.73 + 14.75 + 14.71 + 14.94) / 4$	1
Average = 14.78 mL (must be to 2 dp)	1
<b>Total</b>	<b>2</b>

**Note: To be part of a concordant/consistent group of titre values all the values should be within a error of  $\pm 0.20 \text{ mL}$  (max range is 0.40 mL)**

- (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)

Description	Marks
$n(\text{H}_2\text{SO}_4) = cV = 0.0633 \text{ mol L}^{-1} \times 0.01478 \text{ L} = 9.356 \times 10^{-4} \text{ mol}$	1
$n(\text{NaOH})_{25\text{mL}} = 2 \times n(\text{H}_2\text{SO}_4) = 9.356 \times 10^{-4} \text{ mol} \times 2 = 1.871 \times 10^{-3} \text{ mol}$	1
$n(\text{NaOH})_{500\text{mL}} = 500/25 \times n(\text{NaOH})_{25\text{mL}} = 500/25 \times 0.001871 \text{ mol} = 3.742 \times 10^{-2} \text{ mol}$	1
$n(\text{NaOH})_{10\text{mL}} = n(\text{NaOH})_{500\text{mL}} = 0.03742 \text{ mol}$	1
$m(\text{NaOH})_{10\text{mL}} = n \times M = 0.03742 \text{ mol} \times 39.998 \text{ g mol}^{-1} = 1.497 \text{ g}$	1
$[\text{NaOH}]_{10\text{mL}} = m/V = 1.497 \text{ g} / 0.01 \text{ L} = 149.7 \text{ g L}^{-1}$	1
Appropriate number of significant figures – $1.50 \times 10^2 \text{ g L}^{-1}$ (3 significant figures) <b>Note 150 g has only 2 sf</b>	1
<b>Total</b>	<b>7</b>

or

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)

Description	Marks
$n(\text{H}_2\text{SO}_4) = cV = 0.0633 \text{ mol L}^{-1} \times 0.01478 \text{ L} = 9.356 \times 10^{-4} \text{ mol}$	1
$n(\text{NaOH})_{25\text{mL}} = 2 \times n(\text{H}_2\text{SO}_4) = 9.356 \times 10^{-4} \text{ mol} \times 2 = 1.871 \times 10^{-3} \text{ mol}$	1
$c(\text{NaOH})_{25 \text{ mL}/500\text{mL}} = n/V = 0.001871/0.025 = 0.07484 \text{ molL}^{-1}$	1
$c_o\text{Vo}(\text{NaOH})_{10 \text{ mL}} = c_2V_2(500\text{mL})$ $c_o(\text{NaOH}) = (500/10) \times 0.07484 = 3.742 \text{ molL}^{-1}$ mathematical error but correct method	2
$c(\text{NaOH})_{10\text{mL}} = 3.742 \text{ molL}^{-1} \times 39.998 \text{ g mol}^{-1} = 149.7 \text{ gL}^{-1}$	1
Appropriate number of significant figures – $1.50 \times 10^{-2} \text{ g L}^{-1}$ (3 significant figures) Note 150 g has only 2 sf	1
<b>Total</b>	<b>7</b>

- (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)

Description	Marks
1.5% of 155 g is 2.325 g ( $1.5/100 \times 155 = 2.325 \text{ g}$ )	1
$155 - 2.325 \text{ g} = 152.67 \text{ g}$ . Statement: The calculated concentration is below/outside the stated concentration minimum.	1
<b>Total</b>	<b>2</b>



- (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)

Description	Marks
The oven cleaner was not diluted enough. So the analysed sample is more concentrated/ There are the same moles of cleaner in smaller volume than it should be.	1
Thus the calculated concentration of the oven cleaner will be above the true value.	1
<b>Total</b>	<b>2</b>

- (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)

Description	Marks
Volume of sulfuric acid used was greater than it should have been. So the average titre is too large.	1
Calculated moles of acid is greater which means calculated moles of NaOH is also greater. Thus the calculated concentration of the oven cleaner will be greater than the true value.	1
<b>Total</b>	<b>2</b>

**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.

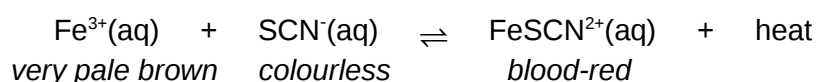
Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

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.

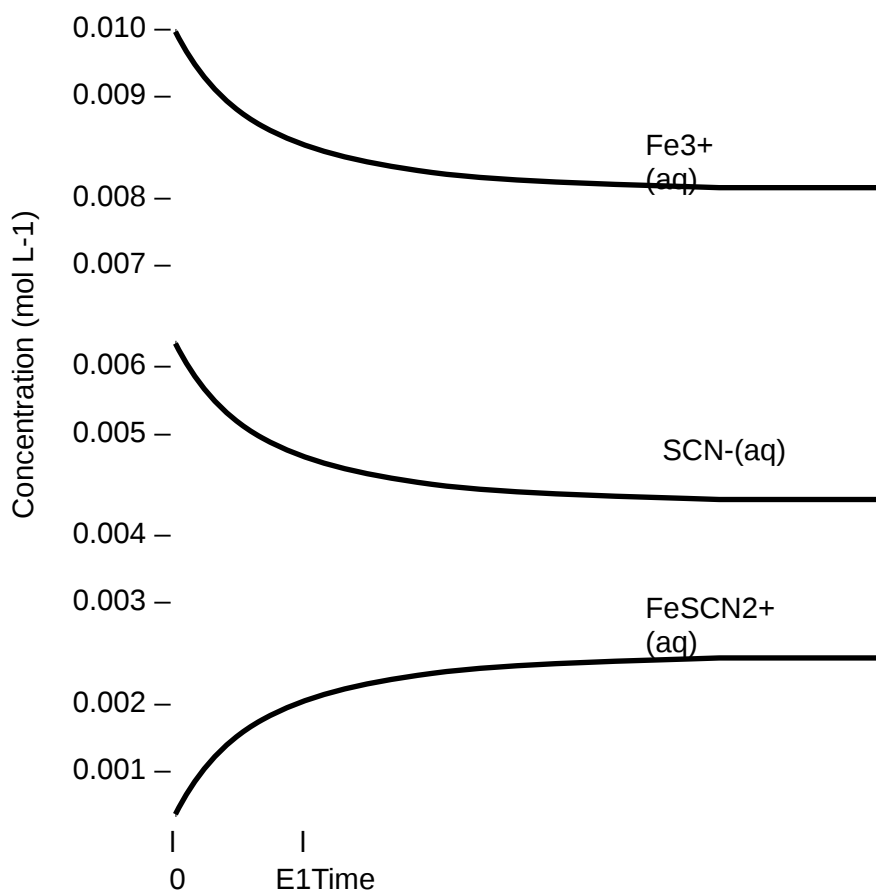
- (a) Determine the concentration of  $\text{FeSCN}^{2+}(\text{aq})$  present at equilibrium. (1 mark)

Description	Marks
0.002 [ or 0.00201 mol L <sup>-1</sup> (acceptable range 0.00198 - 0.00203)]	1
<b>Total</b>	<b>1</b>

- (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.

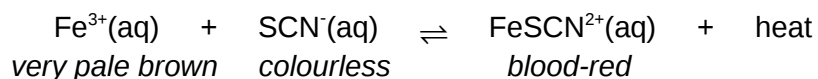
Description	Marks
$\text{Fe}^{3+}(\text{aq})$ concentration decreases from 0.01 to 0.008 mol L <sup>-1</sup>	1
$\text{SCN}^{-}(\text{aq})$ concentration decreases from 0.006 to 0.004 mol L <sup>-1</sup>	1
$\text{FeSCN}^{2+}(\text{aq})$ concentration increases from 0 to 0.002 mol L <sup>-1</sup>	1
Horizontal lines from E1 onwards	1
Labels on each of the three curves	1
<b>Total</b>	<b>5</b>

Example of a five mark response



(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)

Description	Marks
Addition of $\text{H}_3\text{O}^{+}$ :	
The $\text{H}_3\text{O}^{+}(\text{aq})$ added will react with $\text{SCN}^{-}(\text{aq})$ as shown in equation (ii)	1
The $\text{SCN}^{-}(\text{aq})$ concentration will therefore be lowered	1
The original equilibrium will therefore shift left to increase the concentration of $\text{SCN}^{-}(\text{aq})$	1
Addition of $\text{OH}^{-}$ :	
The $\text{OH}^{-}(\text{aq})$ added will react with $\text{Fe}^{3+}(\text{aq})$ as shown in equation (iii) to produce a solid	1
The $\text{Fe}^{3+}(\text{aq})$ concentration will therefore be lowered	1
The original equilibrium will therefore shift left to increase the concentration of $\text{Fe}^{3+}(\text{aq})$	1
<b>Total</b>	<b>6</b>

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

Description	Marks
Addition of $\text{OH}^-(\text{aq})$ would cause a pale brown precipitate to form	1
<b>Total</b>	<b>1</b>

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

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

Description	Marks
Adding $\text{KF}(\text{aq})$ would (increase the concentration of $\text{F}^-(\text{aq})$ which will react with, and) lower the concentration of $\text{Fe}^{3+}(\text{aq})$	1
This would initially only decrease the rate of the forward reaction. The rate of the reverse reaction is initially unaffected.	1
The reverse reaction rate is therefore larger than the rate of the forward reaction.	1
This would result in a shift to the left / the reverse reaction being favoured	1
<b>Total</b>	<b>4</b>

**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;

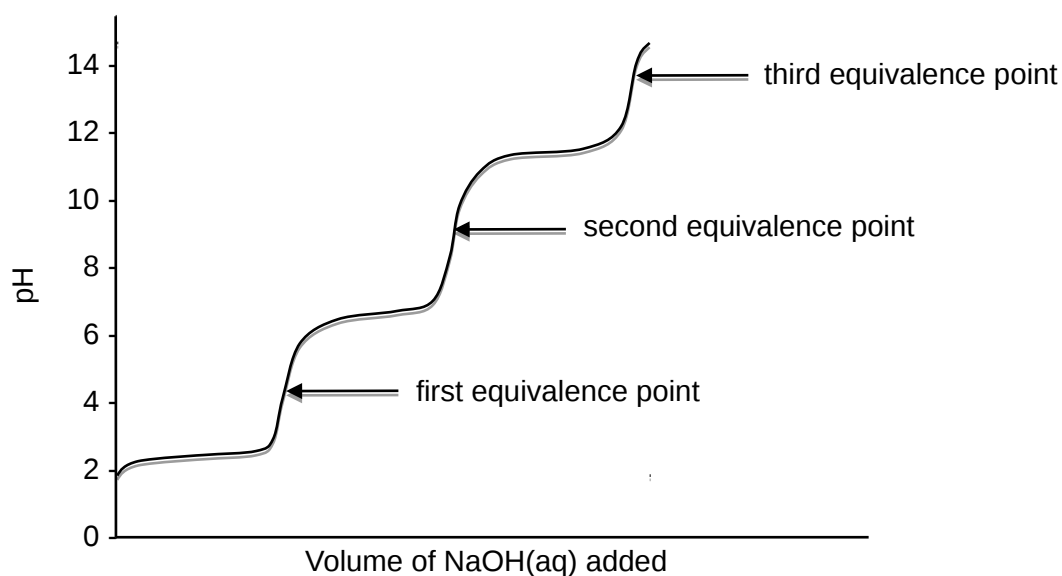
*Carbonated water, sugar, caffeine, phosphoric acid, caramel colour, natural flavourings.*

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.

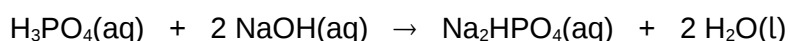
Research by the students led to the development of the following method;

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)

Description	Marks
At the first equivalence point:	
The salt produced ( $\text{NaH}_2\text{PO}_4$ ) is acidic due to the presence / hydrolysis of $\text{H}_2\text{PO}_4^-$ (aq) ions (which results in an excess of $\text{H}_3\text{O}^+$ ions)	1
$\text{H}_2\text{PO}_4^-(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{HPO}_4^{2-}(\text{aq}) + \text{H}_3\text{O}^+(\text{aq})$	1
<i>*Note* <math>\text{H}_2\text{PO}_4^-(\text{aq})</math> can act as both an acid and base, however, occurs to a larger extent as an acid.</i>	
At the second equivalence point:	
The salt produced ( $\text{Na}_2\text{HPO}_4$ ) is basic due to the presence / hydrolysis of $\text{HPO}_4^{2-}(\text{aq})$ ions (which results in an excess of $\text{OH}^-$ ions)	1
$\text{HPO}_4^{2-}(\text{aq}) + \text{H}_2\text{O}(\text{l}) \rightleftharpoons \text{H}_2\text{PO}_4^-(\text{aq}) + \text{OH}^-(\text{aq})$	1
<i>*Note* <math>\text{HPO}_4^{2-}(\text{aq})</math> can act as both an acid and base, however, occurs to a larger extent as a base.</i>	
<b>Total</b>	<b>4</b>

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

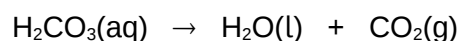
- (b) Calculate the milligrams of phosphorus present in a 375 mL can of Coca-Cola. (6 marks)

Description	Marks
$n(\text{NaOH}) = c \cdot V$ $= 0.1005 \times 0.01665$ $= 1.673 \times 10^{-3} \text{ mol}$	1
At equivalence point: $n(\text{H}_3\text{PO}_4) = \frac{1}{2} \cdot n(\text{NaOH})$ $= \frac{1}{2} \cdot 1.673 \times 10^{-3}$ $= 8.367 \times 10^{-4} \text{ mol}$	1
$c(\text{H}_3\text{PO}_4) = \frac{n}{N} = \frac{8.367 \times 10^{-4}}{150.0 \times 10^{-3}} = 5.578 \times 10^{-3} \text{ mol L}^{-1}$	1
Assume all Phosphorus in 375 mL can is as phosphoric acid: $n(\text{P}) = n(\text{H}_3\text{PO}_4) = c \cdot V = 5.578 \times 10^{-3} \times 375 \times 10^{-3}$ $= 2.092 \times 10^{-3} \text{ mol}$	1
$m(\text{P}) = n \cdot M$ $= 2.092 \times 10^{-3} \times 30.97$ $= 0.064778 \text{ g}$ $= 64.78 \text{ mg}$	1
<b>Total</b>	<b>6</b>

## OR (alternative)

Description	Marks
$n(\text{NaOH}) = c \cdot V$ $= 0.1005 \times 0.01665$ $= 1.673 \times 10^{-3} \text{ mol}$	1
At equivalence point: $n(\text{H}_3\text{PO}_4) = \frac{1}{2} \cdot n(\text{NaOH})$ $= \frac{1}{2} \cdot 1.673 \times 10^{-3}$ $= 8.367 \times 10^{-4} \text{ mol}$ $= n(\text{H}_3\text{PO}_4 \text{ in } 150 \text{ mL Coca-Cola})$	1
$n(\text{P in } 150 \text{ mL Coca-Cola}) = n(\text{H}_3\text{PO}_4 \text{ in } 150 \text{ mL Coca-Cola})$	1
$n(\text{P in } 375 \text{ mL can}) = 8.367 \times 10^{-4} \times (375 / 150)$ $= 2.092 \times 10^{-3} \text{ mol}$	1
$m(\text{P}) = n \cdot M$ $= 2.092 \times 10^{-3} \times 30.97$ $= 0.064778 \text{ g}$ $= 64.78 \text{ mg}$	1
<b>Total</b>	<b>6</b>

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)

Description	Marks
If $\text{H}_2\text{CO}_3$ is present, it will consume / react with some of the added $\text{OH}^-(\text{aq})$ in the titration	1
This would interfere with / inflate / give an invalid calculation of the concentration of $\text{H}_3\text{PO}_4$	1
<b>Total</b>	<b>2</b>

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)

Description	Marks
Systematic	1
This error would result in consistently higher titre values (due to some remaining carbonic acid)	1
The calculated Phosphorus content would be greater than the true value	1

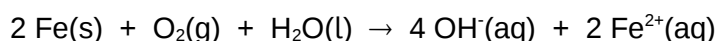


## Question 37

(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)

Description	Marks
Cathodic (left and right boxes)	1
Anodic (middle box)	1
Total	2

Example of a two mark response

Must have both cathodes labelled for that mark.

- (b) On the diagram above, label the direction of cation and anion flow. Your labels should indicate the **identity** of each ion. (2 marks)

Description	Marks
Cation ( $\text{Fe}^{2+}$ label and direction)	1
Anion ( $\text{OH}^-$ label and direction)	1
Total	2

Example of a two mark response

**NOTES: No follow through marks allocated. Must identify the ion to get the mark.**  
 Note: if ion flow is only labelled on one 'side' of the water droplet, allocate full marks

- (c) Demonstrate that this reaction is a redox process, using oxidation numbers to support your answer. (2 marks)

Description	Marks
Oxidation of iron atoms from (0) in Fe to (+2) in $\text{Fe}^{2+}$	1
Reduction of oxygen atoms from (0) in $\text{O}_2$ to (-2) in $\text{OH}^-$	1
<b>Total</b>	<b>2</b>

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)

Description	Marks
$\text{Fe}^{2+}(\text{aq}) + 2 \text{OH}^-(\text{aq}) \rightarrow \text{Fe}(\text{OH})_2(\text{s})$	1
<b>Total</b>	<b>1</b>

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)

Description	Marks
$m(\text{Fe reacted}) = 84.2 - 77.1$ $= 7.1 \text{ g}$	1
$n(\text{Fe}) = 7.1 / 55.85$ $= 0.12713 \text{ mol}$	1
$n(\text{O}_2) = 0.12713 / 2$ $= 0.063563 \text{ mol}$	1
$V(\text{O}_2) = (0.063563 \times 8.314 \times 292.45) / 21.2$ $= 7.29006 \text{ L}$	1
$= 7.29 \text{ L (3 SF)}$	1
<b>Total</b>	<b>5</b>

**NOTES: Many students used the loss of mass of Fe as the loss of mass of "rust" and applied values to:**  
 $2 \text{Fe}(\text{OH})_3(\text{s}) \rightarrow \text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}(\text{s}) + 2 \text{H}_2\text{O}(\text{l})$  instead of  
 $2 \text{Fe}(\text{s}) + \text{O}_2(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow 4 \text{OH}^-(\text{aq}) + 2 \text{Fe}^{2+}(\text{aq})$

**No follow through marks for this error.**

- (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)

Description	Marks
$n(\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}) = 0.12713 / 2$ $= 0.063563 \text{ mol}$	1
$m(\text{Fe}_2\text{O}_3 \cdot \text{H}_2\text{O}) = 0.063563 \times 177.716$ $= 11.3 \text{ g}$	1
<b>Total</b>	<b>2</b>

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)

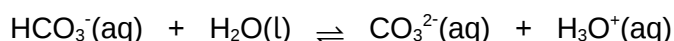
Description	Marks
The zinc coating acts as a sacrificial anode	1
This is because zinc has a higher oxidation potential / is more reactive than iron	1
Therefore the zinc coating will be preferentially oxidised	1
The iron is thus protected, and no evidence of corrosion is seen (until all of the Zn coating has been oxidised)	1
<b>Total</b>	<b>4</b>

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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)

Description	Marks
A solution containing a weak conjugate acid-base pair,	1
that can resist a change in pH when small amounts of acid or base are added to it	1
<b>Total</b>	<b>2</b>

- (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)

Description	Marks
Some of the excess atmospheric $\text{CO}_2(\text{g})$ dissolves into seawater,	1
which then forms carbonic acid	1
Carbonic acid then hydrolyses / ionises to produce $\text{H}_3\text{O}^+(\text{aq})$	1
<b>Total</b>	<b>3</b>

- (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)

Description	Marks
The increase in $\text{H}_3\text{O}^+(\text{aq})$ shifts the equilibrium to the left	1
This will partially counteract the change by decreasing the $\text{H}_3\text{O}^+(\text{aq})$ concentration / using up some of the extra $\text{H}_3\text{O}^+(\text{aq})$	1
<b>Total</b>	<b>2</b>

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)

Description	Marks
Any <b>two</b> of the following (or other relevant answers): must be two different answers.	
<ul style="list-style-type: none"> <li>may disrupt the food web</li> <li>species may be unable to reproduce</li> <li>species may become endangered / extinct</li> <li>reduced biodiversity of ecosystem (if endangered / extinct)</li> </ul>	2
<b>Total</b>	<b>2</b>

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

Description	Marks
Any <b>two</b> of the following (or other relevant answers): must be two different answers	
<ul style="list-style-type: none"><li>• reduce reliance on fossil fuels</li><li>• reduce car use / take public transport / ride bikes</li><li>• decrease use of electricity</li><li>• reduce consumption of meat</li><li>• reduce deforestation</li><li>• increase use of biofuels / renewable sources of energy</li></ul>	2
<b>Total</b>	<b>2</b>

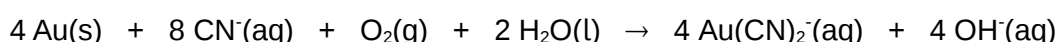
## Question 39

(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  $0.478 \text{ g L}^{-1}$ . After 48 hours, this had fallen to  $0.083 \text{ g L}^{-1}$ .

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

(6 marks)

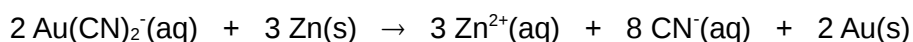
Description		Marks
m(NaCN initial)	$= 0.478 \times 25000$ $= 11950 \text{ g}$	1
m(NaCN final)	$= 0.083 \times 25000$ $= 2075 \text{ g}$	1
m(NaCN reacted)	$= 11950 - 2075$ $= 9875 \text{ g}$	1
n(NaCN)	$= 9875 / 49.01$ $= 201.4895 \text{ mol}$	1
n(Au)	$= (1/2) \times 201.4895$ $= 100.7447 \text{ mol}$	1
m(Au)	$= 100.7447 \times 197$ $= 19847 \text{ g} \quad (2.0 \times 10^4 \text{ g})$	1
Total		6

**NOTES:** Many students erroneously did their calculations based on the given concentrations in moles  $\text{L}^{-1}$  rather than  $\text{g L}^{-1}$ . Difficult to get follow through marks here.

- (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)

Description	Marks
$n(\text{OH}^-) = 100.7447 \text{ mol}$	1
$c(\text{OH}^-) = 100.7447 / 25000$ $= 0.0040298 \text{ mol L}^{-1}$	1
$[\text{H}^+] = (1.0 \times 10^{-14}) / 0.0040298$ $= 2.4815 \times 10^{-12} \text{ mol L}^{-1}$	1
$\text{pH} = -\log(2.4815 \times 10^{-12})$ $= 11.6 \quad (12)$	1
<b>Total</b>	<b>4</b>
Alternate working: $\text{pOH} = -\log(0.0040298)$ $= 2.3947$ $\text{pH} = 14 - 2.3947$ $= 11.6 \quad (12)$	

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)

Description	Marks
Oxidant: $\text{Au}(\text{CN})_2^-$	1
Reductant: $\text{Zn}$	1
<b>Total</b>	<b>2</b>

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

Description	Marks
The dust has a high surface area / high state of subdivision	1
This results in an increased frequency of collision,	1
and therefore a faster reaction rate	1
<b>Total</b>	<b>3</b>

Many students are still using “more” collisions rather than “more frequent” collisions. Students used “higher proportion” of collisions being successful. This only applies to the addition of a catalyst or increased temperature.



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)

Description	Marks
The cell potential / EMF for the reaction between Zn and $H^+$ is positive (+ 0.76 V)	1
The cell potential / EMF for the reaction between Au and $H^+$ is negative (- 1.50 V)	1
Therefore the reaction between Zn and the acid is spontaneous / the reaction between Au and the acid is non-spontaneous	1
This will result in the Zn dissolving in the acid, leaving behind solid Au (which can thus be separated)	1
<b>Total</b>	<b>4</b>

Many students stated the SRP value off the SRP table without reference to the  $H^+/H_2$  half reaction.

**End of questions**

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Question 35 (b)

