



**ALL SAINTS'**  
**COLLEGE**

**Semester Two Examination, 2016**

**Question/Answer Booklet**

## **CHEMISTRY**

Student Name

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Student Number:

In figures

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In words

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\_\_\_\_\_

### **Time allowed for this paper**

Reading time before commencing work: ten minutes

Working time for paper: three hours

### **Material required/recommended for this paper**

#### ***To be provided by the supervisor***

This Question/Answer booklet

Multiple-choice Answer sheet

Chemistry Data sheet

#### ***To be provided by the candidate***

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

Special items: up to three non-programmable calculators approved for use in the WACE examinations

Section	Marks
1	/25
	<b>/50</b>
2	<b>/70</b>
3	<b>/80</b>
total	<b>/200</b>
	<b>%</b>

**Important note to candidates**

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

## Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Multiple-choice	25	25	50	25	25
Section Two: Short answer	9	9	60	70	35
Section Three: Extended answer	5	5	70	80	40
Total					100

## Instructions to candidates

1. The rules for the conduct of Western Australian external examinations are detailed in the *Year 12 Information Handbook 2016*. Sitting this examination implies that you agree to abide by these rules.
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. If you make a mistake, place a cross through that square, and 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. 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. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.
  - Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
  - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of question that you are continuing to answer at the top of the page.
6. The Chemistry Data Sheet is **not** handed in with your Question/Answer Booklet.

See next page

## Section One: Multiple-choice

25% (25 marks)

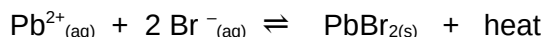
This section has **25** questions. Answer **all** questions on the separate Multiple-choice Answer Sheet provided. For each question shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square, then shade your new answer. 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 one of the following substances is the strongest acid?
  - (a) HF
  - (b) HNO<sub>3</sub>
  - (c) H<sub>3</sub>PO<sub>4</sub>
  - (d) CH<sub>3</sub>COOH
2. Which one of the following substances is the strongest reducing agent?
  - (a) Au
  - (b) Sr
  - (c) FeI<sub>3</sub>
  - (d) H<sub>2</sub>O<sub>2</sub>

3. Consider the following system at equilibrium.



Which one of the following changes would cause the concentration of lead(II) ions to be lowered (compared to the original concentration) once equilibrium is re-established?

- (a) Adding potassium iodide solution.
  - (b) Stirring the mixture.
  - (c) Warming the system.
  - (d) Adding solid lead(II) bromide to the system.
4. Which one of the following 1.0 mol L<sup>-1</sup> solutions will have the lowest pH?
  - (a) sodium hydrogencarbonate
  - (b) ammonium chloride
  - (c) sodium ethanoate
  - (d) sodium hydrogenphosphate
5. In which one of the following reactions is the carbon-containing species acting as a Brønsted-Lowry acid?
  - (a)  $\text{NaHCO}_{3(\text{s})} + \text{H}^{+}_{(\text{aq})} \rightarrow \text{Na}^{+}_{(\text{aq})} + \text{H}_2\text{O}_{(\text{l})} + \text{CO}_{2(\text{g})}$
  - (b)  $\text{CO}_{2(\text{g})} + \text{H}_2\text{O}_{(\text{l})} \rightarrow \text{H}_2\text{CO}_{3(\text{aq})}$
  - (c)  $\text{H}_2\text{CO}_{3(\text{aq})} + \text{NaOH}_{(\text{aq})} \rightarrow \text{NaHCO}_{3(\text{aq})} + \text{H}_2\text{O}_{(\text{l})}$
  - (d)  $\text{CO}_3^{2-}_{(\text{aq})} + \text{Ca}^{2+}_{(\text{aq})} \rightarrow \text{CaCO}_{3(\text{s})}$

See next page

6. Which of the following combinations will form a buffer solution?

- i.  $\text{NH}_{3(\text{aq})} / \text{NH}_4\text{Cl}_{(\text{aq})}$
  - ii.  $\text{NH}_{3(\text{aq})} / \text{HCl}_{(\text{aq})}$
  - iii.  $\text{HCl}_{(\text{aq})} / \text{NH}_4\text{Cl}_{(\text{aq})}$
  - iv.  $\text{H}_2\text{PO}_4^{-}{}_{(\text{aq})} / \text{HPO}_4^{2-}{}_{(\text{aq})}$
  - v.  $\text{H}_2\text{SO}_{4(\text{aq})} / \text{HSO}_4^{-}{}_{(\text{aq})}$
- (a) i and iv only
  - (b) i, iv and v only
  - (c) i, ii and iv only
  - (d) iv only

**Question 7 and 8 relate the following equation:**

One of the processes involved in the acidification of the oceans caused by increasing carbon dioxide levels is shown below:



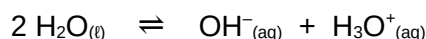
7. Which one of the following statements is true?

- (a)  $\text{HCO}_3^{-}$  is the conjugate base of the  $\text{CO}_3^{2-}$  ion.
- (b) The  $\text{HCO}_3^{-}$  ion is the conjugate acid of the  $\text{H}^{+}$  ion.
- (c)  $\text{HCO}_3^{-}$  is the conjugate acid of the  $\text{CO}_3^{2-}$  ion.
- (d)  $\text{H}^{+}$  is the conjugate acid of the  $\text{HCO}_3^{-}$  ion.

8. Using this process and your knowledge of other chemical processes occurring in the ocean, which one of the following will reduce the acidity of the oceans?

- (a) increased amount of sediments and shells that contain calcium carbonate.
- (b) Increased concentration of carbon dioxide in the atmosphere
- (c) Addition of more hydrogencarbonate ions into the ocean
- (d) Increased extreme weather conditions causing wind and waves in the ocean

9. Water ionises according to the following reaction.

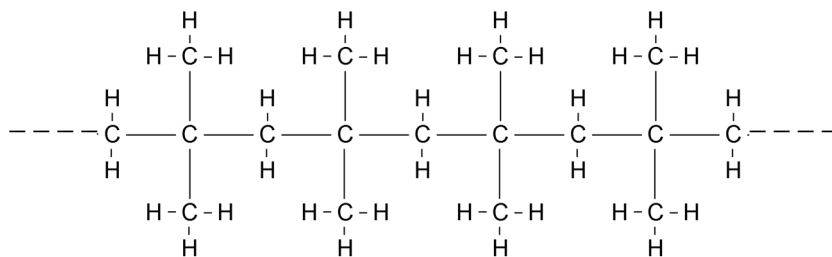


At 25 °C the concentration of  $\text{H}^{+}$  is  $10^{-7} \text{ mol L}^{-1}$  and the pH of pure water is 7.0. When the temperature is increased, the pH of water reduces. Which of the following statements below is correct?

- (a) The forward reaction is endothermic.
- (b) The concentration of  $\text{OH}^{-}{}_{(\text{aq})}$  reduces, making the water more acidic.
- (c) The water is no longer neutral, so the pH of water reduces.
- (d) The concentration of the  $\text{H}_3\text{O}^{+}{}_{(\text{aq})}$  reduces.

**See next page**

10. Consider the section of the polymer below.

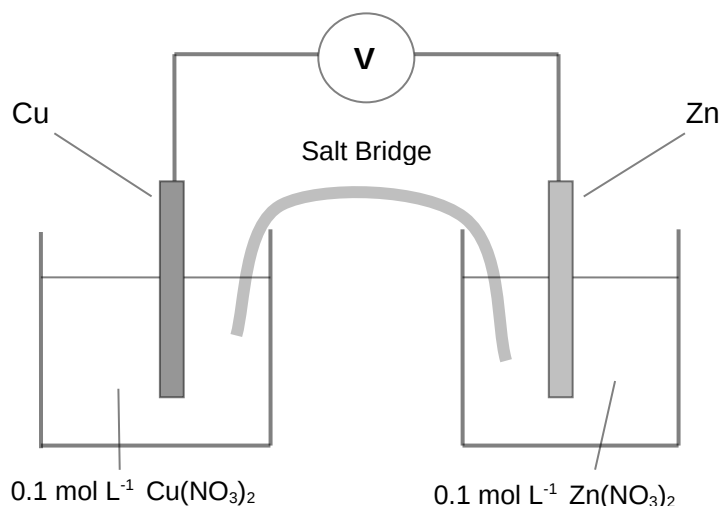


Which one of the following is correct name for the monomer used to synthesise this polymer?

- (a) but-1-ene
  - (b) but-2-ene
  - (c) 2-methylpropene
  - (d) 2,2-dimethylethene
11. In which of the following processes is chlorine being oxidised?
- i.  $\text{PCl}_3 + \text{Cl}_2 \rightarrow \text{PCl}_5$
  - ii.  $\text{Cl}_2 + \text{H}_2\text{O} \rightarrow \text{Cl}^- + \text{HClO} + \text{H}^+$
  - iii.  $2 \text{Cl}^- \rightarrow \text{Cl}_2 + 2 \text{e}^-$
  - iv.  $\text{HClO}_3 + \text{H}_2\text{O}_2 \rightarrow \text{HClO}_4 + \text{H}_2\text{O}$
- (a) i, ii and iv only
  - (b) ii, iii and iv only
  - (c) i, ii, iii and iv
  - (d) ii and iv only

The following diagram relates to questions 12 and 13

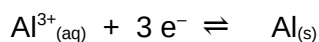
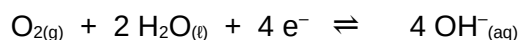
The following galvanic cell was set up.



12. Which one of the following is the purpose of the salt bridge?
- To increase the concentration of the ions in order to speed up the rate of the reaction.
  - To allow the flow of electrons between the two electrodes.
  - To complete the circuit to allow ions to flow between the two half-cells.
  - To copper ions to flow to the zinc electrode
13. Which one of the following statements is **false**?
- The zinc electrode is the anode.
  - The electrons in the wire move towards the copper electrode.
  - The mass of the copper electrode will increase.
  - Positive ions in the salt bridge move towards the zinc electrode.
14. Which of the following reactions will occur spontaneously?
- $2 \text{I}^-_{(\text{aq})} + \text{Br}_{2(\text{aq})} \rightarrow 2 \text{Br}^-_{(\text{aq})} + \text{I}_{2(\text{aq})}$
  - $\text{Cu}_{(\text{s})} + 2 \text{HCl}_{(\text{aq})} \rightarrow \text{CuCl}_{2(\text{aq})} + \text{H}_{2(\text{aq})}$
  - $\text{Sn}_{(\text{s})} + \text{Cd}^{2+}_{(\text{aq})} \rightarrow \text{Sn}^{2+}_{(\text{aq})} + \text{Cd}_{(\text{s})}$
  - $\text{H}_2\text{O}_{2(\text{aq})} + \text{Ni}^{2+}_{(\text{aq})} \rightarrow \text{O}_{2(\text{g})} + 2 \text{H}^+_{(\text{aq})} + \text{Ni}_{(\text{s})}$
- i and iv only
  - i only
  - iii and iv
  - iv only

**Question 15, 16 and 17 relate to the following information**

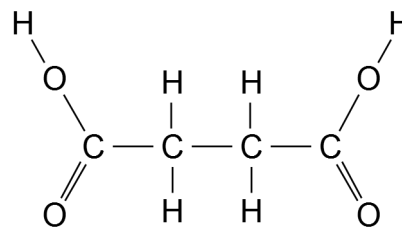
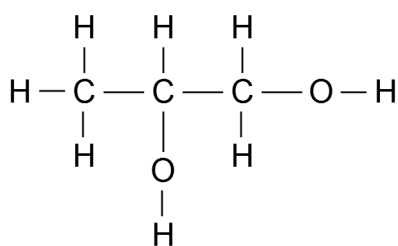
An aluminium-air battery is a fuel cell that involves aluminium reacting with oxygen in the air. The relevant half-equations are shown below.



15. This cell is described as a fuel cell because
- (a) it is a sustainable power source that can be used to replace fossil fuels.
  - (b) both half-reactions are reversible so the cell can be recharged.
  - (c) it involves a gas as a reactant at one of the electrodes.
  - (d) it requires the reactants to be supplied to the cell during operation.
16. Which one of the following is the overall equation for the cell?
- (a)  $\text{Al}_{(\text{s})} + \text{O}_{2(\text{g})} + 2 \text{H}_2\text{O}_{(\text{l})} \rightarrow \text{OH}^-_{(\text{aq})} + \text{Al}^{3+}_{(\text{aq})}$
  - (b)  $4 \text{Al}^{3+}_{(\text{aq})} + 3 \text{O}_{2(\text{g})} + 6 \text{H}_2\text{O}_{(\text{l})} \rightarrow 12 \text{OH}^-_{(\text{aq})} + 4 \text{Al}_{(\text{s})}$
  - (c)  $\text{Al}^{3+}_{(\text{aq})} + \text{O}_{2(\text{g})} + 2 \text{H}_2\text{O}_{(\text{l})} \rightarrow 4 \text{OH}^-_{(\text{aq})} + \text{Al}_{(\text{s})}$
  - (d)  $4 \text{Al}_{(\text{s})} + 3 \text{O}_{2(\text{g})} + 6 \text{H}_2\text{O}_{(\text{l})} \rightarrow 12 \text{OH}^-_{(\text{aq})} + 4 \text{Al}^{3+}_{(\text{aq})}$
17. The theoretical voltage obtainable from this cell is
- (a) 1.88 V.
  - (b) 2.08 V.
  - (c) 2.91 V.
  - (d) 5.52 V.
18. Substance **X** has an empirical formula of  $\text{C}_2\text{H}_4\text{O}$ . Which one of the following could **not** be substance **X**?
- (a) butanoic acid
  - (b) ethyl ethanoate
  - (c) methyl methanoate
  - (d) methyl propanoate
19. Which one of the following compounds will be readily oxidised to form a carboxylic acid?
- (a)  $\text{CH}_3\text{CH}_2\text{C}(\text{OH})\text{CH}_3$
  - (b)  $\text{HOC}(\text{CH}_3)_3$
  - (c)  $\text{CH}_3\text{CH}_2\text{COOCH}_3$
  - (d)  $\text{CH}_3\text{CH}_2\text{CHO}$



20. The following two substances were reacted together:



Which one of the following would be the type of product produced?

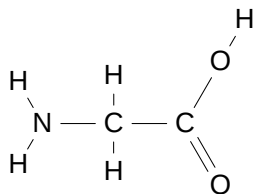
- (a) a soap  
 (b) a fatty acid  
 (c) a polyester  
 (d) a protein
21. Which one of the following pairs of compounds would form methyl propanoate when warmed with concentrated sulfuric acid?
- (a)  $\text{CH}_4$  and  $\text{CH}_3\text{CH}_2\text{COOH}$   
 (b)  $\text{CH}_3\text{OH}$  and  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$   
 (c)  $\text{CH}_3\text{OH}$  and  $\text{CH}_3\text{CH}_2\text{COOH}$   
 (d)  $\text{HCOOH}$  and  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
22. Consider the dipeptide below.



Use your data sheet to identify which pair of amino acids below would form this dipeptide.

- (a) alanine and valine  
 (b) valine and threonine  
 (c) glycine and serine  
 (d) serine and alanine

23. Consider the molecule below.



Which one of the following will this molecule **not** react with?

- (a) dilute hydrochloric acid
  - (b) sodium hydrogencarbonate solution
  - (c) sodium chloride solution
  - (d) sodium hydroxide solution
24. Which one of the following are **not** bonds between sections of a protein that contribute to the tertiary structure of the protein?
- (a) C=O bonds
  - (b) hydrogen bonds
  - (c) S–S bonds
  - (d) dispersion forces
25. Which one of the following is **not** an aim of the Protein Data bank? (PDB)?
- (a) Standardising the way protein structures are represented.
  - (b) Allowing companies to patent new discoveries of protein structures.
  - (c) Informing medical research such as development of the use of antibodies.
  - (d) Sharing knowledge of protein structures from scientists across the world.

**End of Section One**

**See next page**

**Section Two: Short answer****35% (70 Marks)**

This section has **ten (10)** questions. Answer **all** questions. Write your answers in the spaces provided.

When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question that you are continuing to answer at the top of the page.

Suggested working time: 60 minutes.

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

(a) Calculate the pH of a solution of  $0.500 \text{ mol L}^{-1}$  hydrochloric acid.

**(2 marks)**

(b) A student was asked to dilute  $50.0 \text{ mL}$  of this solution to produce a solution of hydrochloric acid with a pH of  $2.00$ . Calculate the volume of distilled water that she would need to add.

**(3 marks)**

## Question 27

(6 marks)

The alcohol butan-2-ol can be oxidised with acidified potassium dichromate solution.

- (a) Draw the structural formula and name the organic product formed. (2 marks)



Name \_\_\_\_\_

- (b) (i) Draw and name an isomer of butan-2-ol that will react with the potassium dichromate solution to produce a carboxylic acid. (2 marks)



Name \_\_\_\_\_

- (ii) Write a balanced redox equation for this reaction. (2 marks)

## Question 28

(10 marks)

Swimming Pool maintenance uses sodium hypochlorite ( $\text{NaClO}$ ), to control algae and bacteria. The swimming pool water can be considered as an equilibrium system as shown below, where hypochlorite ions are converted in to hypochlorous acid ( $\text{HClO}$ ).



For best results, the concentration of the hypochlorous acid should be kept above 1.00 ppm.

- (a) Complete the table by using Le Châtelier's principle to predict, with reasoning, the effect of the following changes on the concentration of the hypochlorous acid ( $\text{HClO}$ ) in the swimming pool. (6 marks)

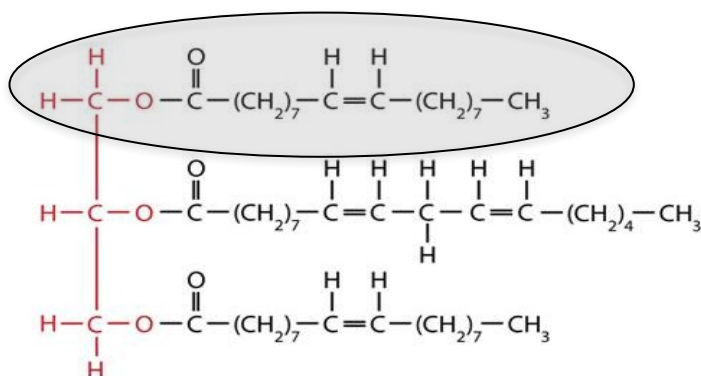
Imposed change	Prediction for any change to the concentration of $\text{HClO}$	Brief reasoning for prediction
Increasing the pH of the pool		
Increasing the temperature of the pool		

- (b) (i) If the concentration is 1.50 ppm, calculate the mass of hypochlorous acid in a pool that has a capacity of 120 000 litres. (density of pool water is  $1.00 \text{ kg L}^{-1}$ ) (1 mark)
- (ii) Assuming 60% conversion of sodium hypochlorite to hypochlorous acid, calculate the mass of sodium hypochlorite that would be required provide this mass of hypochlorous acid. (3 marks)

## Question 29

(5 marks)

Biodiesel is a fuel that can be synthesised from natural oils and fats. The molecule below is a triglyceride present in vegetable oil that can be used for this process.



Biodiesel can be synthesised using a base-catalysed reaction with methanol. The triglyceride breaks down into fatty acids and these undergo esterification with methanol to form methyl esters. The methyl esters are the main components of biodiesel.

- (a) State why the compound above is described as an unsaturated oil. (1 mark)

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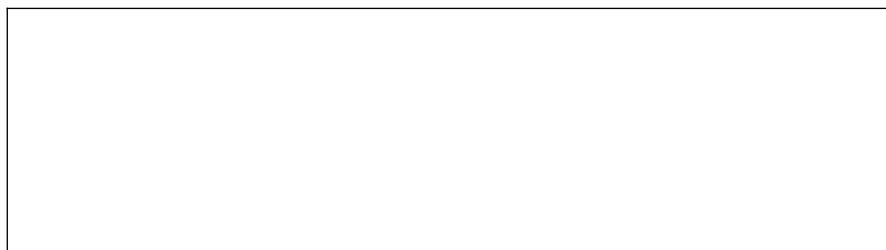
- (b) Draw the structural formula of the methyl ester formed from the section of the molecule circled in the above diagram. (1 marks)



- (c) Name a catalyst that can be used in this process. (1 mark)

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- (d) As well as the methyl esters (the biodiesel), there is one other product of this reaction. Name and draw the structural formula of this product. (2 marks)



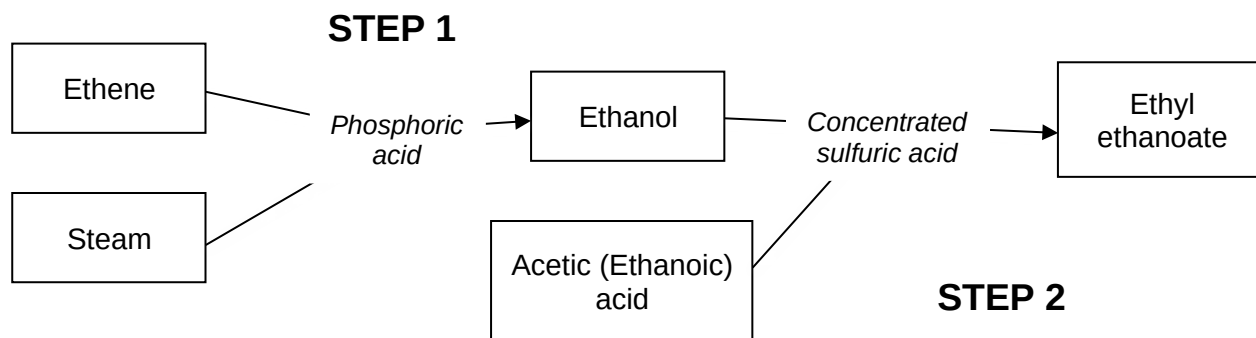
Name \_\_\_\_\_

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## Question 30

(13 marks)

The following reaction sequence can be used to synthesise ethyl ethanoate.



- (a) Explain, using **collision theory**, how catalysts function in this reaction sequence. (2 marks)

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- (b) Consider Step 1 and Step 2 in this reaction sequence.

- (i) Write the equation for Step 1 and explain why it is described as an addition reaction. (2 marks)

- (ii) Write the equation for Step 2 and explain why it is described as a condensation reaction. (2 marks)

- (c) In Step 1, 458 kg of ethene was reacted with excess steam and 48.5 kg of ethanol was produced. Calculate the percentage yield of this reaction. (4 marks)

- (d) Ethanol can also be produced via the fermentation process. Biomass provides glucose ( $C_6H_{12}O_6$ ) which is fermented.

- (i) Write an equation showing the conversion of glucose to ethanol. (1 mark)

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- (ii) In this process, the reaction is catalysed by enzymes. Describe two characteristics of enzymes that makes them different from catalysts such as phosphoric acid and sulfuric acid. (2 marks)

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## Question 31

(9 marks)

Sodium stearate ( $\text{CH}_3(\text{CH}_2)_{16}\text{COONa}$ ) is a soap.

- (a) Using a diagram, and your knowledge of intermolecular forces, explain how the polarity of the stearate ion enables it to act as a soap. (4 marks)

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- (b) In hard water, soaps can form a precipitate of calcium stearate (scum).

- (i) Write an ionic equation, including state symbols, showing this process. (3 marks)

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- (ii) Describe two problems caused by the formation of scum. (2 marks)

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## Question 32

(7 marks)

A group of students was investigating the equilibrium between dichromate and chromate ions. The equation for the system is shown below:

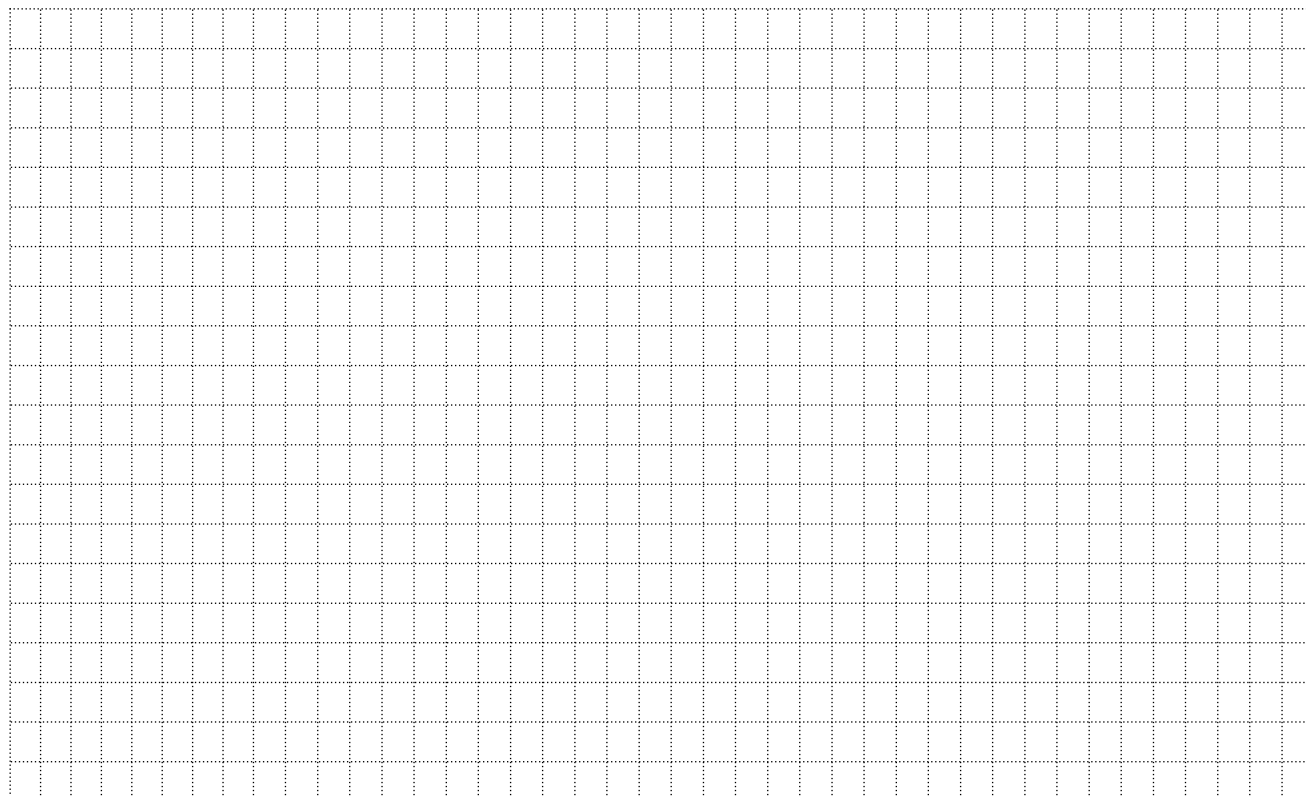


They started with 50.0 mL of a solution of 0.10 mol L<sup>-1</sup> potassium chromate, and gradually added hydrochloric acid to the solution. They recorded the colour of the solution and the pH using a pH probe. Their results are shown below.

Table 1. Colour of a solution of potassium chromate on addition of 1.0 mol L<sup>-1</sup> hydrochloric acid

Measurement	Volume of HCl <sub>(aq)</sub> (mL)	pH	Colour of solution
1	0.0	10	green/yellow
2	0.5	9.9	green/yellow
3	1.0	9.8	green/yellow
4	1.5	9.7	green/yellow
5	2.0	7.3	yellow
6	2.5	6.5	orange
7	3.0	4.5	orange
8	3.5	3.4	orange
9	4.0	2.1	orange

- (a) Plot a graph on the grid below showing the variation of pH against volume of hydrochloric acid added. (a spare grid is provided at the end of the questions if required) (4 marks)



See next page

- (b) Suggest why there is no significant change in pH for the first four measurements. (1 mark)

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- (c) Based on these results, the students concluded that potassium chromate could be used as an indicator in an acid-base titration. Evaluate this conclusion. (2 marks)

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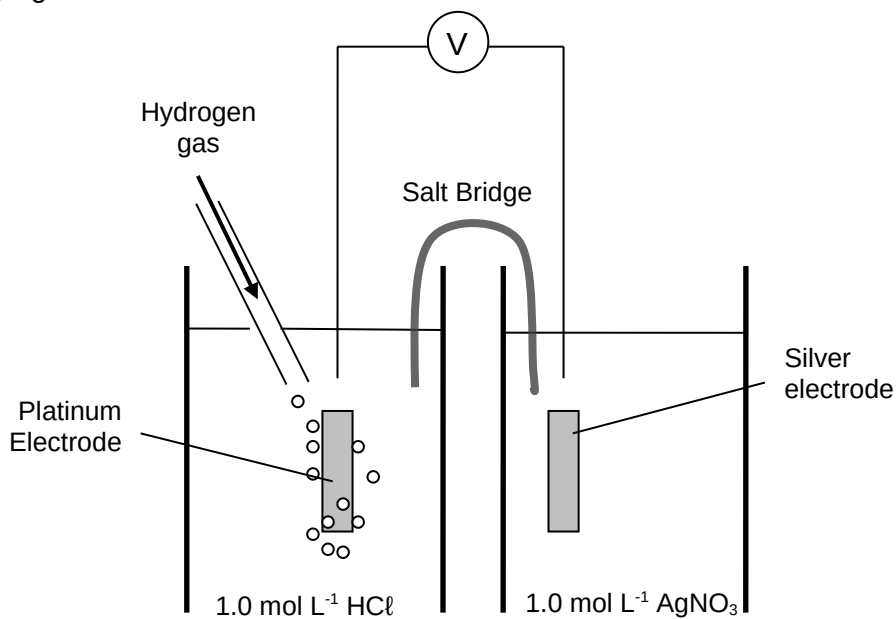
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## Question 33

(8 marks)

Below is a representation of an electrochemical cell used to measure the standard reduction potential for the  $\text{Ag}/\text{Ag}^+$  half-cell.



- (a) Give the half-equation for the reactions occurring at the anode and cathode and write an overall redox equation for the reaction occurring in the cell. (3 marks)

Anode half-equation:

Cathode half-equation:

Overall equation:

- (b) Use an arrow to show the movement of electrons on the diagram above. (1 mark)
- (c) Explain why  $1.0 \text{ mol L}^{-1}$  sulfuric acid is not used as the electrolyte in the hydrogen half-cell. (2 marks)

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- (d) Apart from the concentrations of the solutions, state two other conditions required to achieve an accurate measurement of the standard reduction potential for the  $\text{Ag}^+/\text{Ag}$  half-cell. (2 marks)

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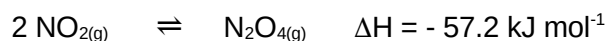
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## Question 34

(7 marks)

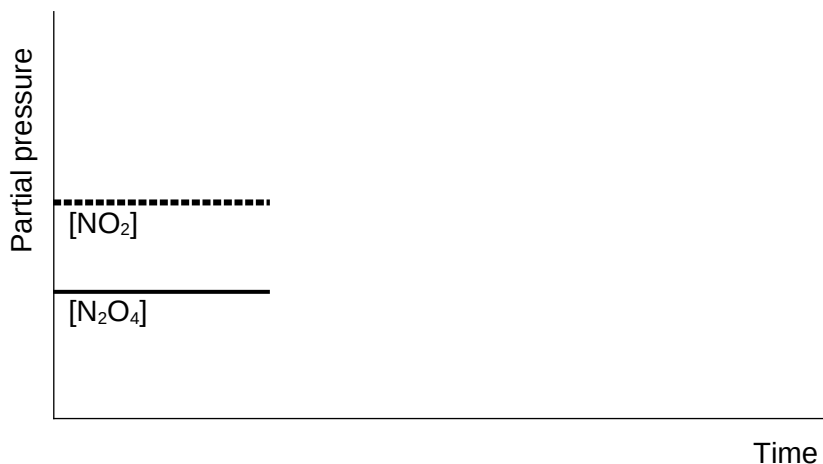
A student was investigating the equilibrium between the brown gas, nitrogen dioxide ( $\text{NO}_2$ ) and the colourless gas dinitrogen tetroxide ( $\text{N}_2\text{O}_4$ ). The gases were contained in a syringe. The syringe was suddenly squeezed to reduce the volume of the system. The temperature of the system was not changed. The equation for the equilibrium is shown below.



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

K =

- (b) Complete the following graph to show what happens to the partial pressures of nitrogen dioxide and dinitrogen tetroxide as the syringe is squeezed and the system responds to the change by re-establishing equilibrium. (3 marks)



- (c) Explain, with reference to reaction rates and collision theory, the shape of the graph drawn in part (b). (3 marks)

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## 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.

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.

Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

- Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
- Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question that you are continuing to answer at the top of the page.

Suggested working time: 70 minutes.

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Question 35

(21 marks)

Aspartic acid ( $\text{C}_4\text{H}_7\text{O}_4\text{N}$ ) is a diprotic  $\alpha$ -amino acid. Aspartic acid has solubility of  $4.5 \text{ g L}^{-1}$  at  $25^\circ\text{C}$  and a  $K_a$  value of  $1.26 \times 10^{-4}$ . Aspartic acid increases resistance to fatigue and is often found in food supplements, especially those used by athletes and body builders.

A chemist was asked to analyse the contents of a food supplement to check the manufacturer's claims that it contained **97.0%** aspartic acid by mass. To check this claim, the following experiment was carried out. (It can be assumed that aspartic acid is the only active ingredient in the supplement)

1. 1.546 g of the supplement powder was weighed and dissolved in warmed distilled water in a beaker.
2. The solution is transferred to a 500.0 mL volumetric flask and was made up to the mark with distilled water.
3. 25.00 mL aliquots of the resulting solution were titrated, using phenolphthalein indicator, against  $0.0570 \text{ mol L}^{-1}$  sodium hydroxide solution.

See next page

The results obtained are shown below.

Burette readings (mL)	Titrations			
	1	2	3	4
Final volume	20.30	40.05	19.80	39.50
Initial volume	0.00	20.30	0.00	19.80
Titration volume (titre)				

- (a) Calculate the percentage purity of the supplement. (7 marks)

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(b) Consider the method used in this experiment.

(i) In Step 1, suggest why the distilled water was warmed. (1 mark)

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(ii) In Step 2, the solution was transferred from a beaker into the volumetric flask. Explain why this process could be a source of systematic error. (2 marks)

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(iii) Phenolphthalein changes colour at between pH 9 –10. Methyl orange changes colour at between pH 4 –5. In Step 3, predict and explain the effect on the final result if methyl orange was used as the indicator instead of phenolphthalein. (3 marks)

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- (c) (i) Due to the low solubility of the aspartic acid, it was suggested to the student that they use a 'back titration'. This would require the addition of a known amount of sodium hydroxide (in excess) to the aspartic acid and the titration of the unreacted hydroxide against a standard solution of acid.

Sodium hydroxide solution with a concentration of  $0.978 \text{ mol L}^{-1}$  is used and there is a standard solution of  $0.100 \text{ mol L}^{-1}$  hydrochloric acid available.

There are three pipettes to choose from (20.00 mL, 25.00 mL or 50.00 mL) for adding sodium hydroxide solution to the 1.546 g of the supplement powder.

Calculate which volume pipette the student should use to add the sodium hydroxide in order to get a titration volume (titre) of approximately 20 mL of the hydrochloric acid. (6 marks)

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- (ii) Explain why having a titre of less than 20 mL could increase the random error in this experiment. (2 marks)

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**Question 36****(14 marks)**

Proteins comprise of up to 2000  $\alpha$ -amino acid molecules joined to form a polymer. The structure of 20 commonly occurring  $\alpha$ -amino acids are given on your data sheet.

- (a) Draw a diagram of glutamic acid in zwitterion form and use this example to explain what a zwitterion is.

(2 marks)

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- (b) Draw the structure of glutamic acid in a solution that has a pH of 10.

(1 mark)

The structure of proteins can be defined on a series of levels. Compare the primary, secondary and tertiary structure of proteins by

- (c) drawing the primary structure of the section of a protein represented by:

– Gly – Ala – Val –

(show all atoms in your diagram)

(2 marks)

- (d) using a diagram to show how hydrogen bonding occurs between two parts of a protein molecule which contributes to the **secondary structure** of a protein.

(3 marks)

- (e) using diagrams to predict and explain the type of bonding which contribute to the **tertiary structure** of the protein that would be formed between the side groups of the following pairs of amino acids in proteins.

- o glutamic acid (Glu) and lysine (Lys)
- o leucine (Leu) and isoleucine (Ile)
- o two cysteine (Cys) molecules

(6 marks)

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## Question 37

(19 marks)

In Mount Isa, Queensland, one of the world's most productive mines produces lead, silver, zinc and copper ore. One of the minerals extracted at Mount Isa is chalcopyrite ( $\text{CuFeS}_2$ ), and the reaction used to smelt this compound is shown below.

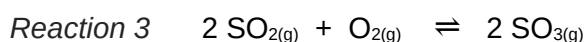


The copper-containing compound is then reacted with more oxygen as shown below:



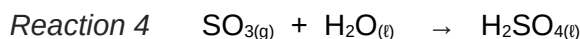
There is also a sulfuric acid plant at Mount Isa, which collects, then cleans sulphur dioxide before converting it to sulfuric acid via the Contact process.

The Contact process includes the following exothermic reaction, which has a yield of 87.0%



The conditions used in Reaction 3 are a moderately high temperature of  $450^\circ\text{C}$ , a pressure close to normal atmospheric pressure and a catalyst of vanadium(V) oxide.

The sulfur trioxide produced is then added to water to produce sulfuric acid with a purity of 98%. This is a two-stage process which can be summarized as:



- (a) Assuming Reaction 1 and 2 are 100% efficient; calculate the mass of chalcopyrite required to produce 1.00 tonne of copper metal. (1.00 tonne =  $1.00 \times 10^6 \text{ g}$ ) (3 marks)

- (b) Calculate the total number of moles of sulfur dioxide generated in the production of 1.00 tonne of copper. (2 marks)

- (c) In 2012 the Mount Isa mine was producing 280 tonnes of copper per day from chalcopyrite and the sulfuric acid plant had to be closed down for maintenance and repair. Sulfur dioxide that would have been processed by the sulfuric acid plant was released to the atmosphere. Calculate the mass of sulfur dioxide in tonnes, released to the atmosphere each day during this time. (2 marks)
- (d) Calculate the mass of sulfur trioxide produced in Reaction 3 from each 1.00 tonne of sulfur dioxide. (3 marks)
- (e) The sulfuric acid plant at Mount Isa has the capacity to produce 3,700 tonnes of 98% sulfuric acid per day. At full capacity, calculate the volume of water required by the sulfuric acid plant each day. (1.00 kg of water has a volume of 1.00 L) (5 marks)

(h) Explain, in terms of green chemistry,

(i) Two benefits of the two plants operating together at the Mount Isa site.

(2 marks)

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(ii) Why a catalyst, and not a higher temperature, is used in Reaction 3.

(2 marks)

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A third sample weighing 0.401 g was vaporised and the gas produced was found to occupy a volume of 162 mL at 150 °C at 67.0 kPa.

- (b) From this information, prove that the empirical formula of the ester is the same as the molecular formula. (3 marks)

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- (c) This ester can be synthesised from an alcohol and a carboxylic acid. The alcohol required is 3-methylbutan-1-ol.

- (i) Name the carboxylic acid required to produce the ester. (1 mark)

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- (ii) Draw the structural formula of the ester present in banana oil. (1 mark)

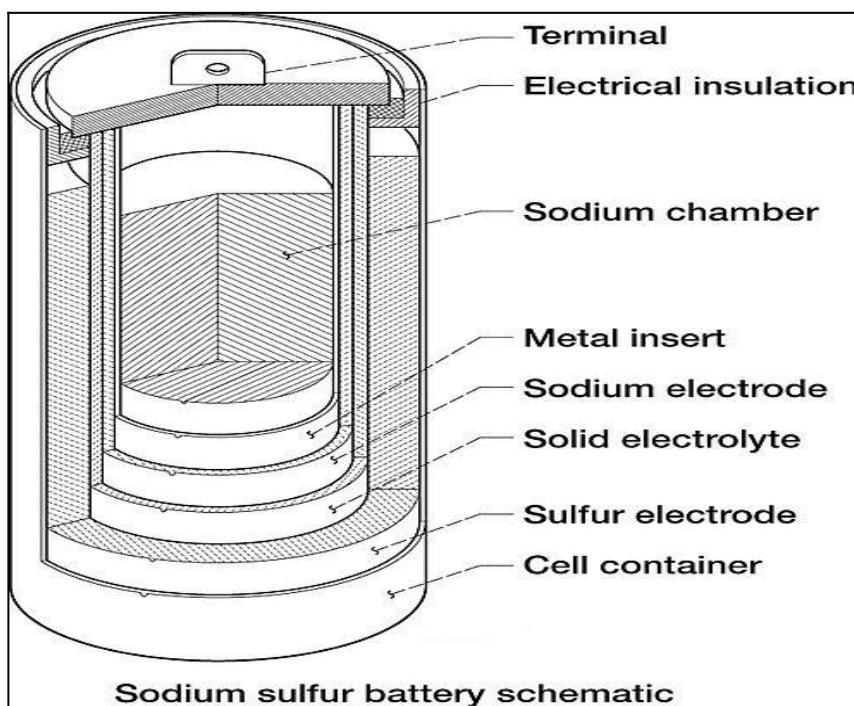
## Question 39

(15 marks)

This question refers to the following information about a type of large scale secondary storage cell used as a backup for power grids:

### Anatomy of the sodium-sulfur cell

The battery has a sodium (Na) anode and a sulfur (S) cathode. The electrolyte is the ceramic, sodium beta alumina (approx. 11 parts aluminium oxide  $\text{Al}_2\text{O}_3$  and 1 part sodium oxide  $\text{Na}_2\text{O}$ ) which has ion transmitting qualities.



For the cell to work, both the sodium and the sulfur must be liquid and the electrolyte must be at a temperature at which it can work as an ionic conductor. Sodium melts at  $98^\circ\text{C}$  and sulfur at  $113^\circ\text{C}$  but the electrolyte does not operate effectively until the temperature reaches around  $350^\circ\text{C}$ . This then is the operating temperature of the battery. The electrolyte remains solid at this temperature as its melting point is  $2100^\circ\text{C}$  yet it has **ion transmitting qualities**. The cells are commonly constructed as a pair of concentric tubes in which the inner tube made of the electrolyte contains one electrode while the outer tube made of a metal such as aluminium, contains the other electrode. The cell is completely enclosed and does not give off any gases. The cell actually has a very high electrical efficiency of the order of 85%.

The electrolyte is very brittle and thus the sodium sulfur cell does suffer from poor shock resistance. It also suffers from thermal cycling problems although this is not an issue if the temperature is maintained. The poor shock resistance is less of a problem in stationary applications but it is a serious problem in the transport market. The overall chemistry of the cell is represented below. Reduction of elemental sulfur gives polysulfides, which consist of 2 sulfur atoms in a chain terminated with  $\text{S}^-$  ionic centres. The product is known as sodium polysulfide.



\*Structure of the polysulfide ion ( $^-\text{S} - \text{S} - \text{S} - \text{S}^-$ )

See next page

- (a) The product of the overall cell chemistry is known as sodium polysulfide ( $\text{Na}_2\text{S}_4$ ). Given that **sodium** is an alkali metal with only one valence shell electron, what oxidation state **must** it exhibit in its most stable ion?

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(1 mark)

- (b) Give a half equation for the anode chemistry in this cell.

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(1 mark)

- (c) Given the structure of the polysulfide ion what **two different** oxidation states does sulfur have in a polysulfide ion ( $\text{S}_4^{2-}$ )?

i. 

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ii. 

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(2 mark)

- (d) Draw a possible electron – dot structure for the polysulfide ion ( $\text{S}_4^{2-}$ ).

(1 mark)

- (e) Write a half equation for the cathode process.

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(1 mark)

- (f) Show the addition of the anode and cathode half equations to show how the overall cell reaction ( $2\text{Na} + 4\text{S} \rightarrow \text{Na}_2\text{S}_4$ ) is arrived at.

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(1 mark)

- (g) Given the information contained on your data chart determine the approximate reduction potential for the reaction at the cathode.

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(1 mark)

- (h) The values used and determined for the electrode potentials are not completely accurate. Give the major reason for this lack of accuracy.

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(1 mark)

- (i) If there is a breach in this cell and the sulfur is exposed to the air it may oxidise to form sulfur dioxide. Give a molecular equation for this reaction.

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(1 mark)

- (k) Describe a major safety hazard associated with this type of battery other than the release of sulfur dioxide into the environment.

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(1 mark)

- (l) If this battery receives an input of 250 MJ (mega joules) of energy then how much energy, given its efficiency, can be transformed into useful output?

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(1 mark)

- (m) What is meant by the term "secondary cell"?

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See next page

(1 mark)

- (n) Explain in a paragraph in terms of chemical bonding why the electrolyte used in this cell is very brittle and why this leads to poor shock resistance.

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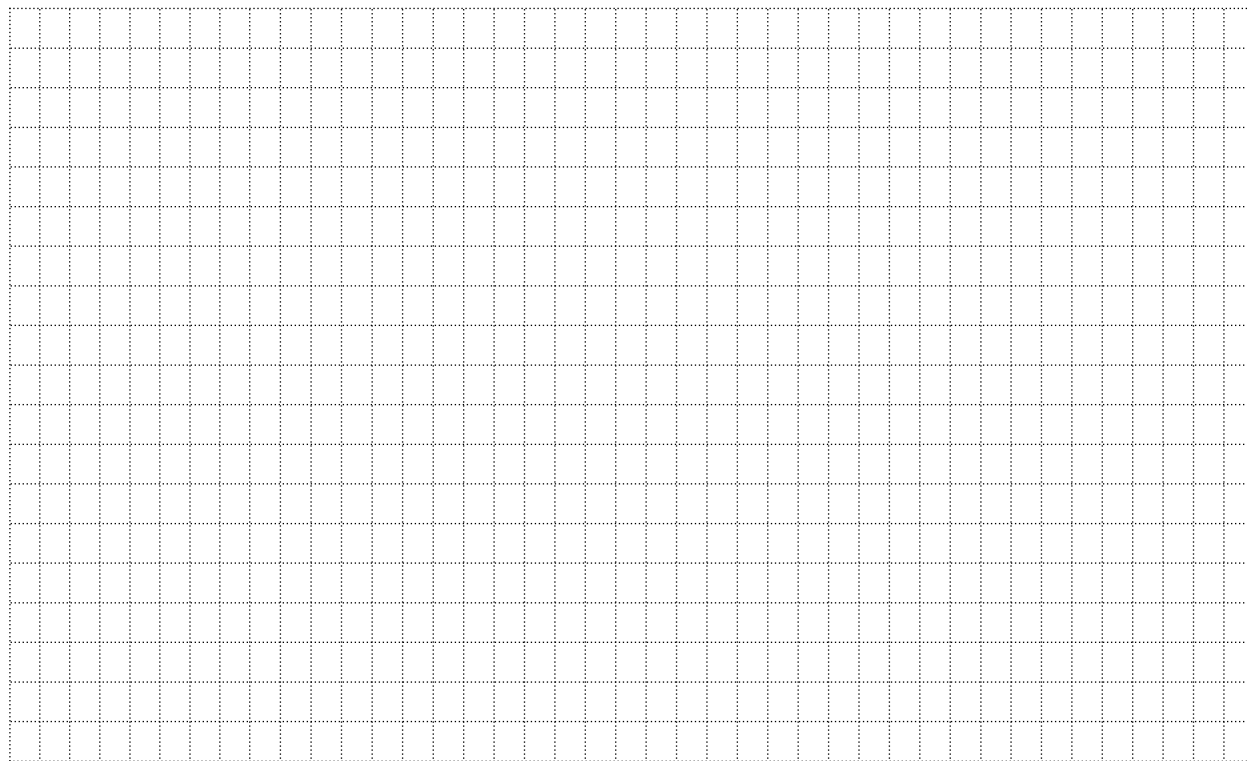
(2 marks)

**End of questions****See next page**

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*Spare graph paper for Question 33*



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Spare answer page



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