Neap

VCE Chemistry Unit 3

Question and Answer Booklet

2024 Trial Examination

Reading time: 15 minutes

Writing time: 1 hour 30 minutes

Student's Name: _____

Teacher's Name: _____

Approved materials

- Pens, pencils, highlighters, erasers, sharpeners, rulers and one scientific calculator

Materials supplied

- Question and Answer Booklet of 21 pages
- Data Booklet
- Answer Sheet for multiple-choice questions

Instructions

- Write your responses in English.
- Write **your name** and your **teacher's name** in the space provided above on this page.
- Place the Answer Sheet for multiple-choice questions inside the front cover of this booklet after the examination.
- You may keep the Data Booklet after the examination.

Students are **not** permitted to bring mobile phones and/or any unauthorised electronic devices into the examination room.

Contents pages

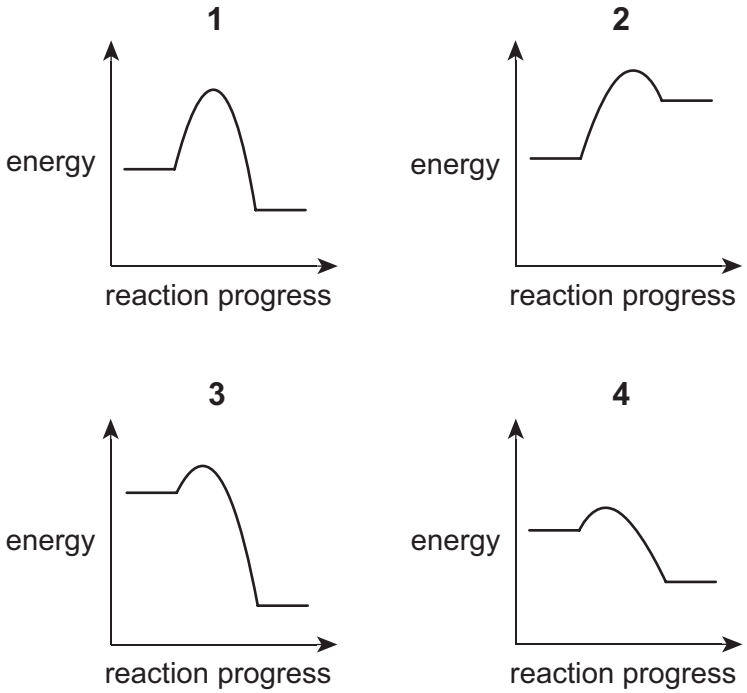
Students are advised that this is a trial examination only and cannot in any way guarantee the content or the format of the 2024 VCE Chemistry Units 3&4 Written Examination.

Section A – Multiple-choice questions

- Answer **all** questions in pencil on the Answer Sheet provided for multiple-choice questions.
- Choose the response that is **correct** or that **best answers** the question.
- A correct answer scores 1; an incorrect answer scores 0.
- Marks will **not** be deducted for incorrect answers.
- No marks will be given if more than one answer is completed for any question.
- Unless otherwise indicated, the diagrams in this booklet are **not** drawn to scale.

Question 1

The energy profile diagrams, labelled 1–4, for four different reactions are shown below.



Which energy profile best represents the combustion of a fuel?

A. 1

B. 2

C. 3

D. 4

Use the following information to answer Questions 2 and 3.

Four equilibrium systems are listed below.

I. $SO_2(g) + Cl_2(g) \rightleftharpoons SO_2Cl_2(g)$

II. $CH_4(g) + H_2O(g) \rightleftharpoons 3H_2(g) + CO(g)$

III. $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$

IV. $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

Question 2

For which equilibrium system is it possible to calculate the equilibrium constant (*K*) without knowing the volume of the reaction vessel?

A. I

B. II

C. III

D. IV

Question 3

If the volume of each equilibrium system was decreased while maintaining a constant temperature, which equilibrium systems would have an increase in the yield?

A. I and II only

B. I and IV only

C. II and III only

D. III and IV only

Question 4

Which one of the following statements about the salt bridge in a galvanic cell is correct?

A. The ionic compound chosen for the salt bridge must be insoluble in water.

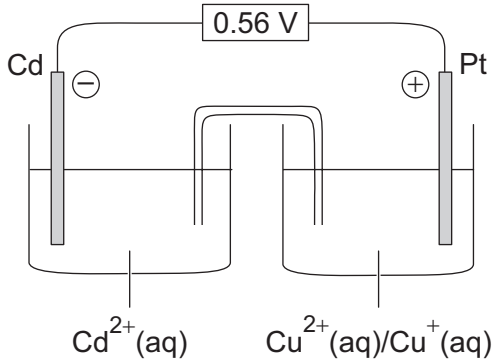
B. The ionic compound chosen for the salt bridge must contain either a strong reductant or a strong oxidant.

C. The salt bridge enables electrons to flow from the cathode to the anode.

D. The salt bridge enables anions to flow from the cathode to the anode.

Question 5

A galvanic cell is set up as shown in the following diagram.



Which one of the following statements about the cell is correct?

A. The cell can be recharged by applying a voltage of 0.56 V using a power supply.

B. In the overall cell reaction, copper(II) ions are reduced to copper(I) ions.

C. When the cell is producing electrical energy, the oxidant is the cadmium ion.

D. To recharge the cell, the positive terminal of the power supply is connected to the negative electrode of the cell and the negative terminal is connected to the positive electrode.

Use the following information to answer Questions 6 and 7.

Secondary cells play an important role in providing electrical energy for a range of common devices.

Question 6

In a secondary cell,

A. chemical energy is converted to electrical energy only.

B. an electrolytic reaction occurs during the operation of the cell.

C. the electrodes have a catalytic role.

D. new reactants are added to the cell from outside.

Question 7

Which one of the following statements is true for a secondary cell but not true for a primary cell?

A. All products of the reaction maintain contact with the electrodes.

B. Electrons move towards the positive electrode.

C. Reactions involving conjugate redox pairs occur.

D. Oxidation occurs at the anode.

Question 8

A deposit of 0.318 g of vanadium metal forms when a solution of vanadium chloride, $VCl_3(aq)$, is electrolysed using a current of 0.598 A.

The duration of the electrolysis reaction is closest to

A. 17 minutes.

B. 25 minutes.

C. 50 minutes.

D. 67 minutes.

Use the following information to answer Questions 9 and 10.

Iodine gas and bromine gas react according to the following equation.

$$I_2(g) + Br_2(g) \rightleftharpoons 2IBr(g) \qquad K = 120 \text{ at } 150°C$$

Question 9

Based on the information provided, which one of the following statements is correct?

A. At 200°C, the value of *K* is likely to be greater than 120.

B. At 200°C, the value of *K* is likely to be less than 120.

C. At 200°C, the value of *K* will be exactly 120.

D. A valid estimation of the value of *K* at 200°C cannot be made.

Question 10

The following reaction occurs at 150°C.

$$IBr(g) \rightleftharpoons \frac{1}{2}I_2(g) + \frac{1}{2}Br_2(g)$$

What is the value of *K*?

A. 4.17×10^{-3}

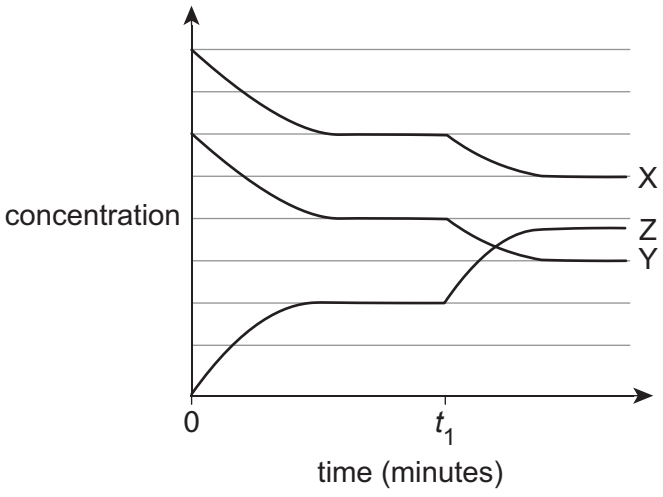
B. 8.33×10^{-3}

C. 9.13×10^{-2}

D. 3.02×10^{-1}

Question 11

Three gases, X, Y and Z, form an equilibrium mixture as shown in the graph below. At time t_1, the equilibrium mixture was heated.



Which one of the following shows the equation of the equilibrium reaction and identifies the type of reaction occuring?

	Chemical equation	Type of reaction
A.	$X + Y \rightleftharpoons Z$	endothermic
B.	$X \rightleftharpoons Y + Z$	exothermic
C.	$X \rightleftharpoons Y + Z$	endothermic
D.	$X + Y \rightleftharpoons Z$	exothermic

Use the following information to answer Questions 12 and 13.

Bioethanol is produced by the fermentation of glucose. It can be added to petrol to form a fuel known as E10 that can be used in modern cars. Some specially designed cars can use pure bioethanol as a fuel without it being mixed with petrol.

Question 12

Which one of the following processes is used soon after fermentation to produce a more sustainable transport fuel?

A. respiration

B. electrolysis

C. catalysis

D. distillation

Question 13

When compared to ethanol produced from compounds derived from fossil fuels, bioethanol has

A. a lower energy content per gram of fuel.

B. the same energy content per gram of fuel.

C. a higher energy content per gram of fuel.

D. a higher or lower energy content per gram of fuel, depending on the source of glucose.

Question 14

The energy profile of a particular catalysed reaction has the following features.

- maximum potential energy = 130 kJ mol^{-1}
- potential energy of products = 105 kJ mol^{-1}
- potential energy of reactants = 10 kJ mol^{-1}

Which one of the following identifies the activation energy and enthalpy change (ΔH) for the **uncatalysed** reaction?

	Activation energy (kJ mol^{-1})	**ΔH (kJ mol^{-1})**
A.	115	+95
B.	130	+95
C.	140	+125
D.	140	+235

Question 15

Part of the nutritional information panel of a 100 g can of baked beans is shown in the table below.

Nutrient	Average quantity per 100 g
protein	4.9 g
fats, total	0.5 g
carbohydrate	14.3 g
dietary fibre	4.2 g
sodium	358 mg

The energy content of the can of baked beans is closest to

A. 5 kJ g^{-1}

B. 10 kJ g^{-1}

C. 30 kJ g^{-1}

D. 300 kJ g^{-1}

Question 16

In an experiment, a metal can with 300 g of water was heated using a fuel burner. The can was placed directly above the flame, and 0.40 g of methanol was burnt in the fuel burner. The temperature of the water rose by 7.30°C, indicating that 9.15 kJ of energy had been transferred to the water.

Which one of the following statements best explains the result of the experiment?

A. Ethanol was used in place of methanol.

B. Some heat was lost to the surroundings.

C. The combustion of the fuel was not complete.

D. Part of the energy released was used to heat the metal can.

Question 17

A dilute solution of sodium chloride, NaCl, and a dilute solution of potassium bromide, KBr, each undergo electrolysis under standard conditions.

Which one of the following statements about the initial results of the electrolysis in both cells is correct?

A. The same products are produced at both electrodes in both cells.

B. The same products are produced at the positive electrode in both cells, but different products are produced at the negative electrode in each cell.

C. The same products are produced at the negative electrode in both cells, but different products are produced at the positive electrode in each cell.

D. The products at the four electrodes in the cells are all different from each other.

Question 18

In which one of the following compounds does manganese, Mn, have the lowest oxidation number?

A. Mn_3O_4

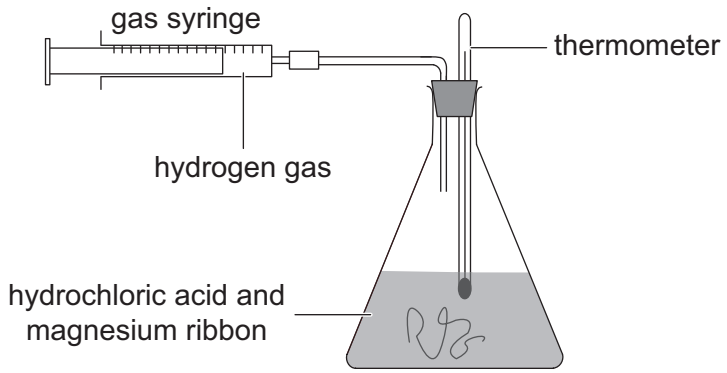
B. $KMnO_4$

C. Mn_2O_3

D. MnO_2

Question 19

An experiment was conducted to determine the rate of reaction of hydrochloric acid and magnesium by collecting the hydrogen gas produced in the reaction. The set-up of the experiment is shown in the diagram below.



A systematic error would occur in this experiment if the experimenter

A. used approximate masses of magnesium that are all slightly different.

B. estimated the syringe volume when the plunger stops between two graduations.

C. used 0.10 M nitric acid in the reaction rather than 0.10 M hydrochloric acid.

D. used hydrochloric acid that was labelled as 0.10 M but was actually 0.11 M.

Question 20

What is the enthalpy change, ΔH, for the complete combustion of ethane when using the simplest whole number coefficients in the equation?

A. –3120 kJ

B. –1560 kJ

C. +1560 kJ

D. +3120 kJ

End of Section A

Section B

- Answer **all** questions in the spaces provided.
- Give simplified answers to all numerical questions, with an appropriate number of significant figures; unsimplified answers will not be given full marks.
- Show all working in your answers to numerical questions; no marks will be given for an incorrect answer unless it is accompanied by details of the working.
- Ensure chemical equations are balanced and that the formulas for individual substances include an indication of state, for example, $H_2(g)$, NaCl(s).
- Unless otherwise indicated, the diagrams in this booklet are **not** drawn to scale.

Question 1 (10 marks)

Petrol and diesel are the most commonly used transport fuels worldwide. Both fuels are classified as blended fuels because they contain a number of different hydrocarbon compounds.

a. The main component of petrol is octane. When octane is burnt in a restricted supply of oxygen, carbon monoxide, CO, is produced in addition to carbon dioxide, CO_2, and water, H_2O.

Write a balanced equation for the incomplete combustion of octane at standard laboratory conditions (SLC). 2 marks

b. Petrol can be mixed with bioethanol to produce a fuel known as E10, which contains 10% ethanol.

i. Outline **two** benefits of adding bioethanol to petrol. 2 marks

ii. Bioethanol is produced by the fermentation of glucose.

Write a balanced equation for the production of bioethanol by fermentation. 2 marks

c. Diesel fuel derived from crude oil, which is also known as petrodiesel, is being increasingly replaced by biodiesel.

The energy content of a particular sample of biodiesel is 36.5 MJ kg^{-1}.

i. Under what circumstances could the unit MJ mol^{-1} be used for the energy content of a sample of biodiesel? 1 mark

ii. The density of the sample of biodiesel is 0.91 kg L^{-1}.

How many litres of biodiesel must be fully burnt to heat 2.56 kg of water to 65°C at standard laboratory conditions (SLC)? 3 marks

Question 2 (10 marks)

Oxalic acid, $C_2H_2O_4$, converts purple-coloured permanganate ions, MnO_4^-, into almost colourless manganese(II) ions, Mn^{2+}, according to the following equation.

$$2MnO_4^-(aq) + 5C_2H_2O_4(aq) + 6H_3O^+(aq) \rightarrow 2Mn^{2+}(aq) + 10CO_2(g) + 14H_2O(l)$$

a. Rhubarb is a plant with long, roughly cylindrical stalks that contains oxalic acid naturally. In an experiment, three 50 mm lengths were cut from one rhubarb stalk. Each piece of stalk was treated in a particular way and then placed in a separate beaker, as described in the following table.

Beaker 1	Beaker 2	Beaker 3
stalk cut in half lengthways	stalk cut in half lengthways and then sliced across to produce six evenly sized pieces	stalk left intact with no slicing or cutting

50 mL of 0.10 M acidified potassium permanganate, $KMnO_4$, solution was poured into each beaker and stirred constantly. The time it took for each solution to decolourise was measured.

i. Identify the order, from slowest to fastest, in which the solution in each beaker decolourised. 1 mark

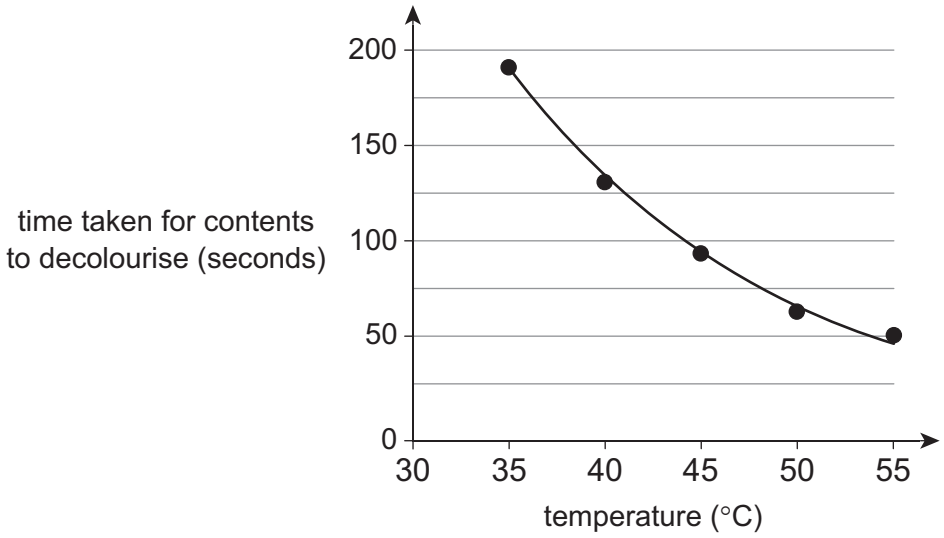
ii. Use collision theory to explain the order identified in **part a.i.** 3 marks

iii. Why were the three 50 mm sections cut from one stalk rather than from three different stalks? 1 mark

b. In a second experiment, the reaction was used to determine the rate of reaction at different temperatures. The method of the experiment involved the following steps.

1. 0.750 M $C_2H_2O_4$ and 0.0650 M $KMnO_4$ solutions were prepared.
2. 10.00 mL of each solution was placed in separate beakers.
3. The two beakers were placed in a water bath until each solution reached 35°C.
4. The $C_2H_2O_4$ solution was poured into the beaker containing the $KMnO_4$ solution while being stirred continuously.
5. The time taken for the contents of the beaker to decolourise completely was recorded.
6. Steps 2–5 were repeated at each of the following temperatures: 40°C, 45°C, 50°C and 55°C.

The results of the experiment are shown in the following graph.



i. Calculate the number of moles of MnO_4^- in 10.00 mL of the 0.0650 M $KMnO_4$ solution. 1 mark

ii. For the data presented, calculate the greatest average rate of reaction. Give your answer in moles of MnO_4^- used per minute. 2 marks

c. There are other methods by which the rate of reaction could be measured, including by collecting the carbon dioxide gas in a gas syringe and determining the volume produced over time.

Describe **one** additional method that has not been mentioned that could have been used to determine the rate of reaction. 2 marks

Question 3 (7 marks)

An important chemical reaction in the manufacture of sulfuric acid is the oxidation of sulfur dioxide, SO_2, which occurs according to the following equation.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -197 \text{ kJ}$$

At 1000 K, $K = 81 \text{ M}^{-1}$.

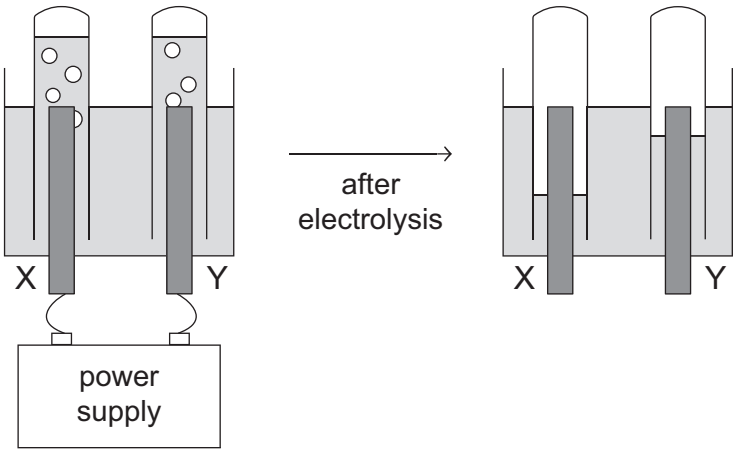
a. In a laboratory experiment conducted at 1000 K, a sealed 2.00 L vessel contained 1.00 mol of SO_2 and 2.00 mol of O_2 in an equilibrium mixture.

How many moles of SO_3 were present? 3 marks

b. Explain **one** advantage and **one** disadvantage of using a high temperature, such as 1000 K, when oxidising SO_2 during the manufacture of sulfuric acid. 4 marks

Question 4 (8 marks)

a. An experiment involving the electrolysis of water was conducted as shown in the following diagram.



i. Explain why a small amount of potassium nitrate, KNO_3, was added to the water before electrolysis. 1 mark

ii. Write a balanced half-equation for the reaction occurring at electrode X during electrolysis. 1 mark

iii. Write a balanced half-equation for the reaction occurring at electrode Y during electrolysis. 1 mark

iv. One of the products of the electrolysis is hydrogen gas.

Under what circumstances could the gas be classified as green hydrogen? 1 mark

b. An innovation in the production of hydrogen gas involves artificial photosynthesis using water oxidation to generate hydrogen ions as one product, and then using a proton reduction system

i. Write a balanced half-equation for the proton reduction reaction. 1 mark

ii. The proton reduction reaction occurs in the presence of a special protein known as hydrogenase.

What is the role of hydrogenase in the proton reduction reaction? 1 mark

iii. Outline **one** advantage of using hydrogen gas as a fuel. 1 mark

iv. Outline **one** disadvantage of using hydrogen gas as a fuel. 1 mark

Question 5 (10 marks)

a. A primary galvanic cell is constructed under standard conditions using two half-reactions from the electrochemical series. The following information about the galvanic cell is known.

- Both half-reactions have a positive standard electrode potential (E^0).
- The conjugate redox pair in one half-cell is composed of metal ions.
- The conjugate redox pair in the other half-cell is a metal and a metal ion.
- A cell voltage of 0.65 V is recorded.

i. Write a balanced equation for the cell reaction. 2 marks

ii. Write a balanced half-equation for the reaction occurring at the anode. 1 mark

iii. Write a balanced half-equation for the reaction occurring at the positive electrode. 1 mark

b. In a solid oxide fuel cell (SOFC), a special ceramic material is used as the electrolyte to allow oxide ions, O^{2-}, to move from one electrode to the other. Methane gas, CH_4, can be used as the fuel in a cell reaction that is identical to the combustion reaction. The reactions at the electrodes occur according to the following equations.

$$CH_4(g) + 4O^{2-}\text{ (in ceramic)} \rightarrow CO_2(g) + 2H_2O(g) + 8e^-$$

$$O_2(g) + 4e^- \rightarrow 2O^{2-}\text{ (in ceramic)}$$

i. Like many fuel cells, the SOFC has porous electrodes.
Explain how these porous electrodes increase the efficiency of the fuel cell. 2 marks

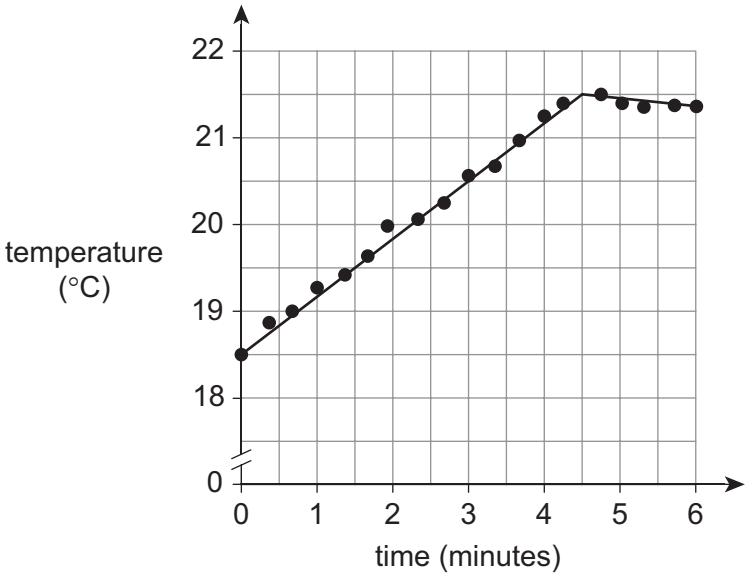
ii. If the SOFC operates for 2.0 hours at a current of 0.49 A, what is the minimum mass of CH_4 required? 3 marks

iii. State **one** difference (other than the porous electrodes) between a fuel cell and a primary galvanic cell. 1 mark

Question 6 (10 marks)

A Chemistry student noticed that when a sample of solid potassium nitrate dissolved in water, the temperature of the mixture decreased. They decided to investigate this observation using calorimetry.

a. The student electrically calibrated a calorimeter by heating 100.0 mL of water using a current of 1.5 A at 5.5 V for 180 seconds. The temperature of the water was recorded every 20 seconds during heating and during an additional 180 seconds after heating. The student used the data collected to plot the following graph.



i. Why is it necessary to calibrate a calorimeter? 1 mark

ii. Why did the temperature of the water continue to rise after heating had ceased? 1 mark

iii. Explain which feature of the graph indicates that the calorimeter was insulated effectively. 1 mark

iv. Using the results of the calibration, show that the calibration factor of the calorimeter is 495 $J°C^{-1}$. 2 marks

b. After calibration, the student used the calorimeter to determine the enthalpy change, ΔH, for the dissolution of solid potassium nitrate, KNO_3, which occurs according to the following equation.

$$KNO_3(s) \xrightarrow{H_2O} K^+(aq) + NO_3^-(aq)$$

The student poured 100.0 mL of water into the calorimeter and monitored the temperature until it remained constant. They added 2.50 g of solid KNO_3 to the water and stirred continuously. The change in the temperature of the water was found to be 1.2°C.

i. Why did the student use 100.0 mL as the volume in which to dissolve the solid? 1 mark

ii. Calculate ΔH, in kJ mol^{-1}, for the dissolution of $KNO_3(s)$ in water. 3 marks

iii. The accepted value of ΔH for the dissolution of $KNO_3(s)$ in water is 35 kJ mol^{-1}.

Suggest **one** reason why the value calculated in **part c.ii.** differs from the accepted value. 1 mark

End of Question and Answer Booklet