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Write your **student number** in the boxes above.

Letter

Chemistry $\frac{3}{4}$ (Flipped)

Question and Answer Book

VCE Examination (Term 1 Mock) – April 2025

- Reading time is **15 minutes**
- Writing time is **2 hours**

Materials Supplied

- Question and Answer Book of 44 pages.
- Multiple-Choice Answer Sheet.

Instructions

- Follow the instructions on your Multiple-Choice Answer Sheet.
- At the end of the examination, place your Multiple-Choice Answer Sheet inside the front cover of this book.

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

Contents

Pages

Section A (30 questions, 30 marks)

2–18

Section B (12 questions, 90 marks)

19–44

Student's Full Name: _____

Student's Email: _____

Tutor's Name: _____

Marks (Tutor Only): _____

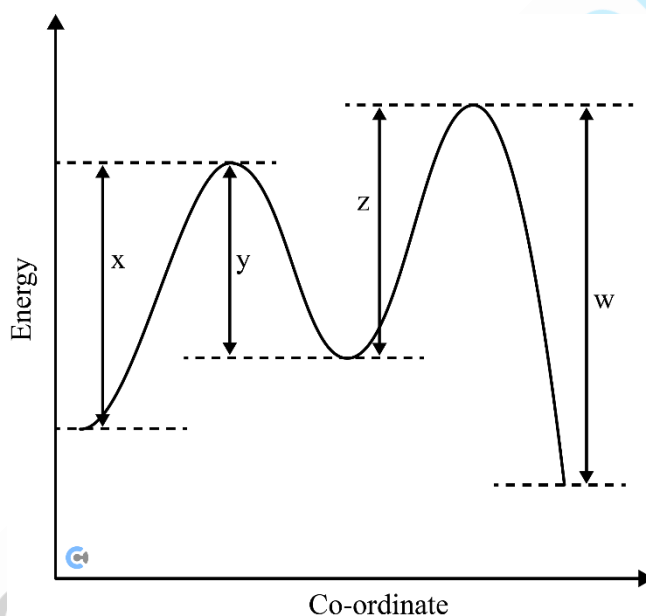
Section A

Instructions

- Answer **all** questions in pencil on the Multiple-Choice Answer Sheet.
- 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 book are not drawn to scale.

Question 1

The energy profile below represents the two steps in a reaction pathway from *A* to *E*.

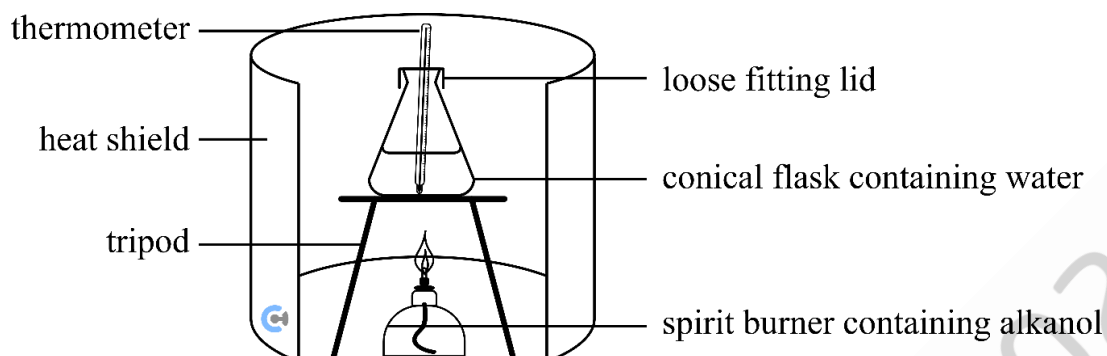


The overall energy change in the two-step process is:

- A. Endothermic
- B. $w - x$
- C. $x + z - w - y$
- D. $z - y - w$

Question 2

The following equipment was set up to measure the heat of combustion of an alkanol.



Black deposits were observed on the bottom of the conical flask and the heat of combustion measured was lower than the theoretical value. Which of the following equations could account for these observations?

- A. $2\text{C}_2\text{H}_6(\text{g}) + 7\text{O}_2(\text{g}) \rightarrow 4\text{CO}_2(\text{g}) + 6\text{H}_2\text{O}(\text{g})$
- B. $\text{C}_3\text{H}_8\text{O}(\text{g}) + 4\text{O}_2(\text{g}) \rightarrow \text{CO}_2(\text{g}) + \text{CO}(\text{g}) + 4\text{H}_2\text{O}(\text{g})$
- C. $2\text{C}_4\text{H}_{10}\text{O}(\text{g}) + 3\text{O}_2(\text{g}) \rightarrow 8\text{C}(\text{s}) + 2\text{H}_2(\text{g}) + 8\text{H}_2\text{O}(\text{g})$
- D. $2\text{C}_2\text{H}_6\text{O}(\text{g}) + 4\text{O}_2(\text{g}) \rightarrow 2\text{CO}_2(\text{g}) + 2\text{C}(\text{s}) + 6\text{H}_2\text{O}(\text{g})$

Question 3

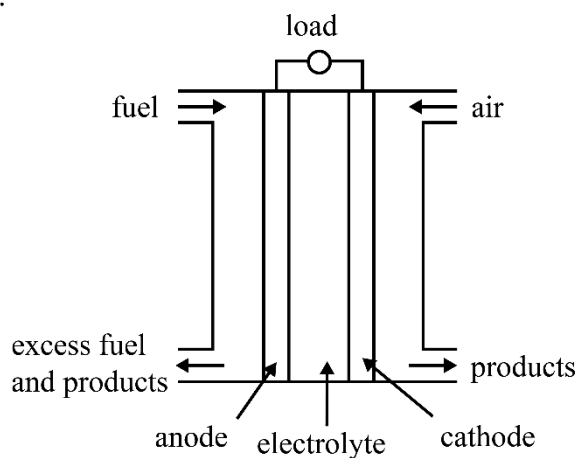
In which one of the following compounds is sulphur in its lowest oxidation state?

- A. SO_3
- B. HSO_4^-
- C. SO_2
- D. Al_2S_3

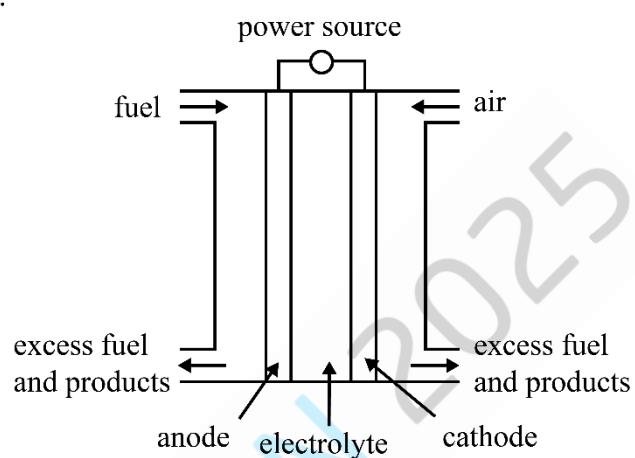
Question 4

Which of the following diagrams shows the common design features of a fuel cell?

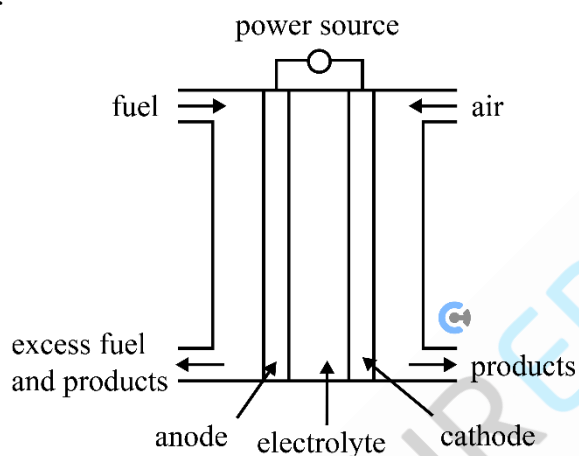
A.



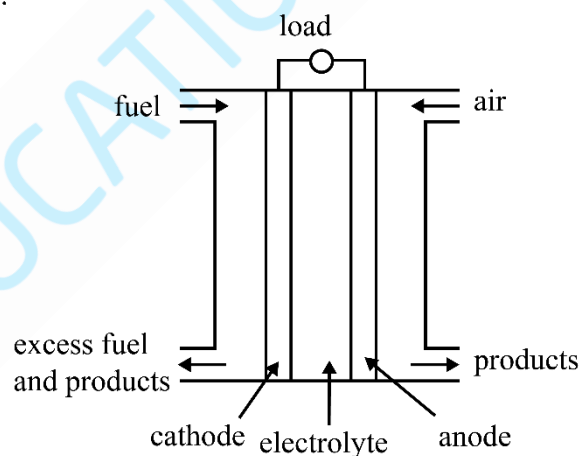
B.



C.



D.



Do not write in this area.

The following information applies to Questions 5 and 6

The complete combustion of 0.500 mol of a hydrocarbon produces 3.00 mol of carbon dioxide during complete combustion. The carbon dioxide is stored at SLC.

Question 5

The fuel could be:

- A. Butane
- B. Propane
- C. Hexane
- D. Methane

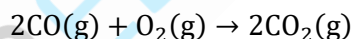
Question 6

If the complete 0.500 mol of this fuel were to be combusted, what would be the closest volume of water vapour which would be produced?

- A. 0.0 L
- B. 15 L
- C. 74 L
- D. 87 L

Question 7

Carbon monoxide can be oxidised to carbon dioxide.



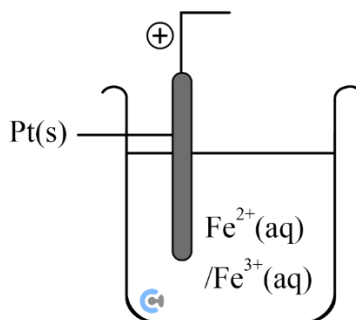
30 mL of CO and 20 mL of O_2 are mixed at SLC.

When the reaction is complete, there will be:

- A. 40 mL of CO_2 produced
- B. 20 mL of CO_2 produced.
- C. 10 mL of CO unreacted.
- D. 5 mL of O_2 unreacted.

Question 8

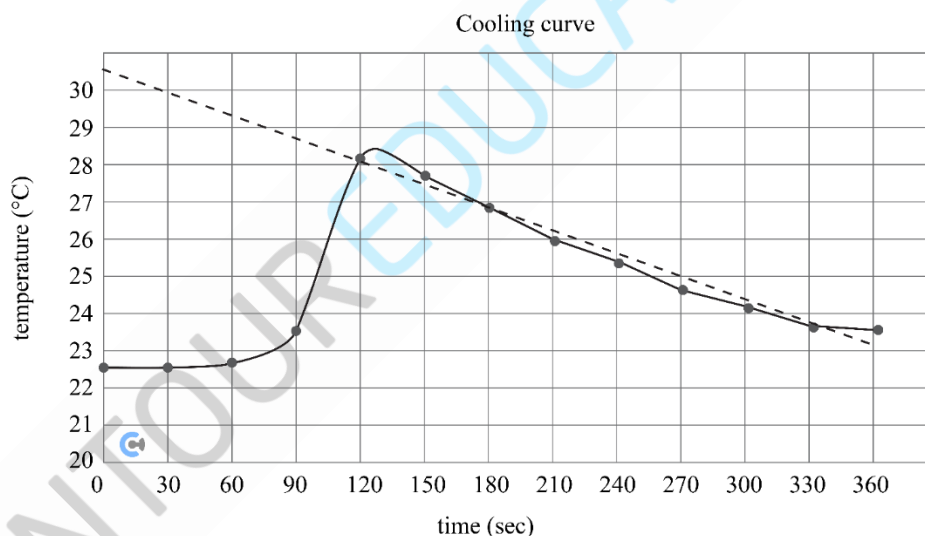
Consider a galvanic cell that consists of $\text{Fe}^{3+}(\text{aq}) / \text{Fe}^{2+}(\text{aq})$ cell as shown below. What should the other cell be to maximise the cell's theoretical EMF?



- A. $\text{Ag}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Ag}(\text{s})$
- B. $\text{Sn}^{4+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Sn}^{2+}(\text{aq})$
- C. $\text{F}_2(\text{g}) + 2\text{e}^- \rightleftharpoons 2\text{F}^-(\text{aq})$
- D. $\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Cu}(\text{s})$

Question 9

Consider the following temperature time graph of the electrical calibration of a calorimeter.



- A. Better insulation of the calorimeter would have resulted in a flatter dotted line.
- B. At time 90 seconds, carbon dioxide is being released from the calorimeter.
- C. After a long time, the graph will plateau at a constant value.
- D. Better insulation would result in a higher maximum temperature.

Question 10

A calorimeter is calibrated by passing 5.0 *amps* at 10 volts through a calorimeter for 60 seconds. The calorimeter increased in temperature from 24 to 45 degrees Celsius.

What is the calibration factor?

- A. $142 \text{ J } ^\circ\text{C}^{-1}$
- B. $142 \text{ kJ } ^\circ\text{C}^{-1}$
- C. $14.2 \text{ J } ^\circ\text{C}^{-1}$
- D. $14.2 \text{ kJ } ^\circ\text{C}^{-1}$

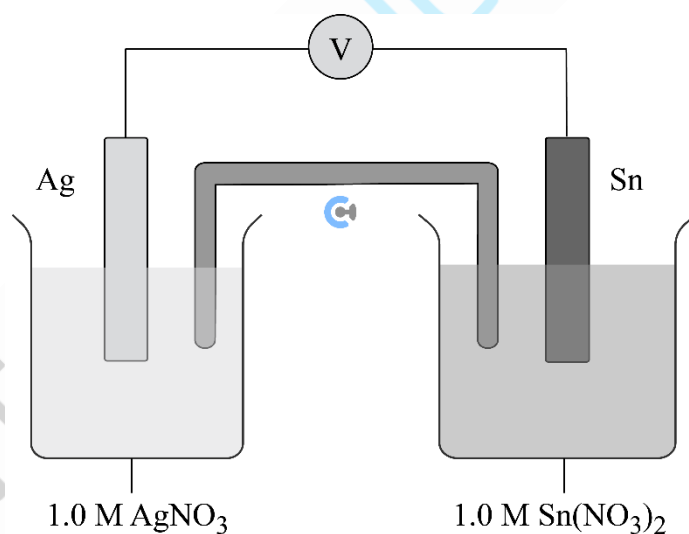
Question 11

Which of the following statements is incorrect about biogas?

- A. They contain only methane.
- B. They are produced via anaerobic respiration by bacteria.
- C. They have a lower energy density than pure methane.
- D. They can be produced by most organic matter.

Question 12

The diagram below shows a galvanic cell which is set up in a laboratory under standard conditions.



Which one of the following statements about the cell is correct when electrical energy is being produced?

- A. The mass loss of one electrode equals exactly the mass gain of the other electrode.
- B. Electrons travel from the positive Ag electrode to the Sn electrode.
- C. Positive ions travel towards the half-cell which contains the cathode.
- D. As the electrolytes are aqueous, gas bubbles will appear at each electrode surface.

The following information applies to Questions 13 and 14

Various reagents were mixed in separate flasks as shown in the table below.

Flask 1	Flask 2	Flask 3	Flask 4
$\text{Cu}(\text{NO}_3)_2(\text{aq}) + \text{Sn}$	$\text{Ag}^+(\text{aq}) + \text{Sn}$	$\text{Fe}^{3+}(\text{aq}) + \text{NaCl}(\text{aq})$	I_2 solution + Cu

Question 13

A reaction is likely to occur in:

- A. Flasks 1 and 2 but not in flask 3.
- B. Flasks 1 and 3 but not in flask 2.
- C. Flask 2 but not in flasks 1 and 3.
- D. Flask 3 but not in flasks 1 and 2.

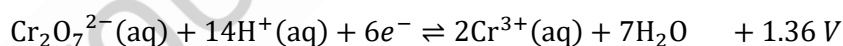
Question 14

Using the electrochemical series, a reaction is predicted to occur in flask 4. However, no reaction had occurred by the time any reactions took place in the other flasks. Which one of the following is the most likely reason to explain this?

- A. The iodine was in a different state than that shown in the electrochemical series.
- B. The enthalpy change for the reaction has a positive value.
- C. An alloy of copper and zinc was used mistakenly in place of pure copper metal.
- D. The products are formed much more slowly than products in the other reactions.

Question 15

The E^0 values for reduction reactions involving chromium are shown below.



The reaction begins with a solution of potassium dichromate. Which of the following could be used to reduce the potassium dichromate from an oxidation state of +6 to +2?

- A. Cu
- B. Al
- C. Zn
- D. F^- ions

Question 16

Consider the following situations:

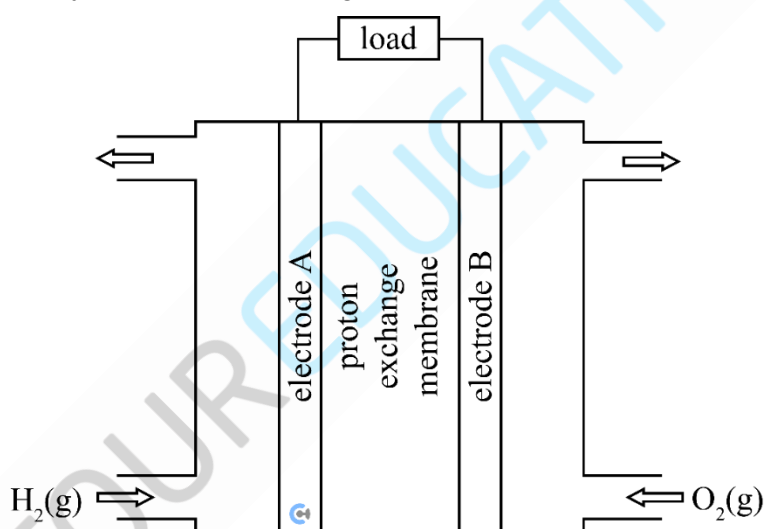
- I The volume of water surrounding the reaction chamber in the calorimeter was only 90% of the volume specified for the operation of the calorimeter.
- II The outer layer of insulation on the calorimeter was removed.

During the calibration of the calorimeter using benzoic acid combustion, which of the above situations would result in a calculated calibration factor which is greater than the actual value?

- A. I only.
- B. II only.
- C. Both I and II.
- D. Neither I nor II.

Question 17

The diagram below shows a typical proton exchange membrane fuel cell.



Which of the following would be correct when this fuel cell is releasing energy?

	Electrode A	Electrode B	Ion movement in the membrane
A.	Anode	Cathode	OH^- moving from the electrode B to electrode A.
B.	Cathode	Anode	H^+ moving from the electrode B to electrode A.
C.	Cathode	Anode	OH^- moving from the electrode A to electrode B.
D.	Anode	Cathode	H^+ moving from the electrode A to electrode B.

Question 18

In an experiment, the charge of vanadium ions is to be investigated. After 5000 C is passed through the cell, 0.88 g of vanadium is found to react.

The charge on the vanadium ions is:

- A. +1
- B. +2
- C. +3
- D. +4

Question 19

A sample of fuel is completely combusted, whereby 372 kJ of energy is released and is used to heat 1.50 L of water at SLC. What is the final temperature reached by the water?

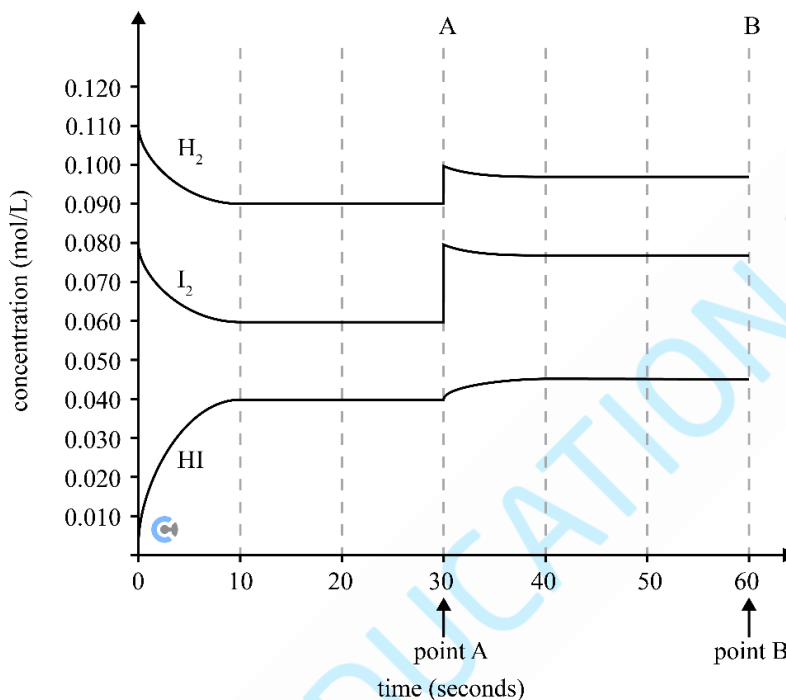
- A. 0.059°C
- B. 0.248°C
- C. 59°C
- D. 84°C

The following information applies to Questions 20 and 21

The reaction between $\text{H}_2(\text{g})$ and $\text{I}_2(\text{g})$ in a 1.0 L container was observed to be:



During the reaction, the temperature was kept at 200°C . The concentration versus time graph for this reaction was determined and is shown below.



Question 20

The value of K_c when the system first reaches equilibrium is closest to:

- A. 0.25
- B. 0.30
- C. 3.33
- D. 7.41

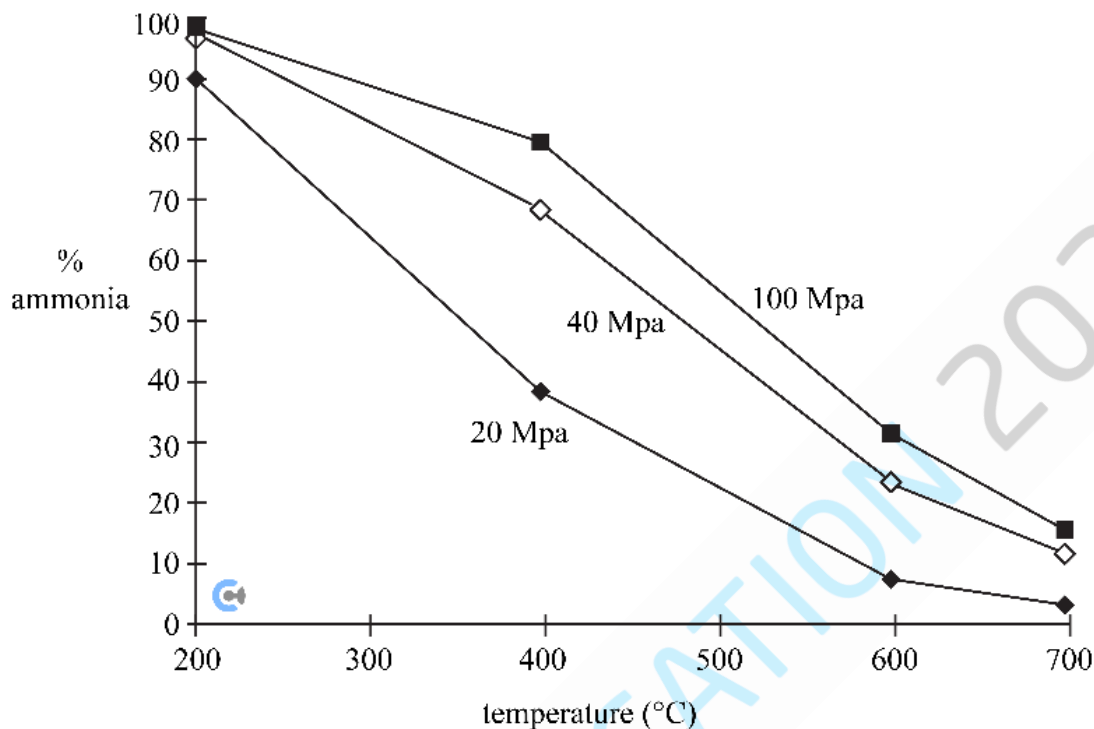
Question 21

What change occurred at Point A?

- A. The volume of the vessel was decreased, changing the value of K .
- B. The volume of the vessel was decreased, without a change in the value of K .
- C. $\text{H}_2(\text{g})$ and $\text{I}_2(\text{g})$ were added, changing the value of K .
- D. $\text{H}_2(\text{g})$ and $\text{I}_2(\text{g})$ were added, without a change in the value of K .

Question 22

The percentage of ammonia formed from its elements is plotted against temperature for three different pressures below.



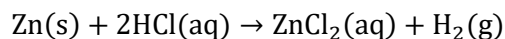
Which of the following conditions would not increase the yield of ammonia?

- A. High pressures.
- B. Low temperatures.
- C. Addition of a catalyst.
- D. Decreasing the volume of the vessel in which the reaction is occurring.

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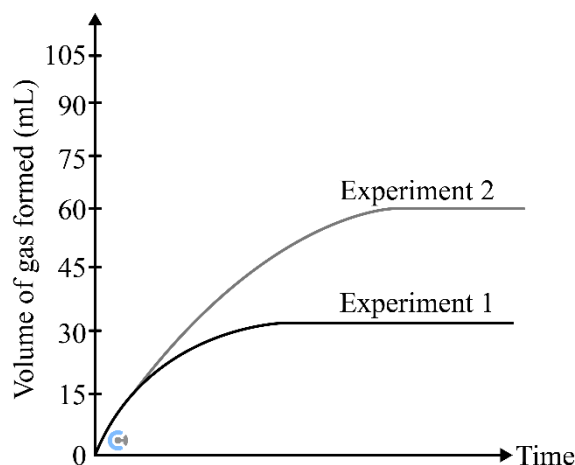
Question 23

Hydrochloric acid reacts with zinc metal according to the following reaction.



Two experiments are carried out. Experiment 1 involves 150 mL of 0.10 M hydrochloric acid with 2.50 g of solid strips of zinc metal at 25°C.

Some factors are changed in experiment 2. The volume of hydrogen gas evolved for both reactions is captured and measured, as shown in the graph below.

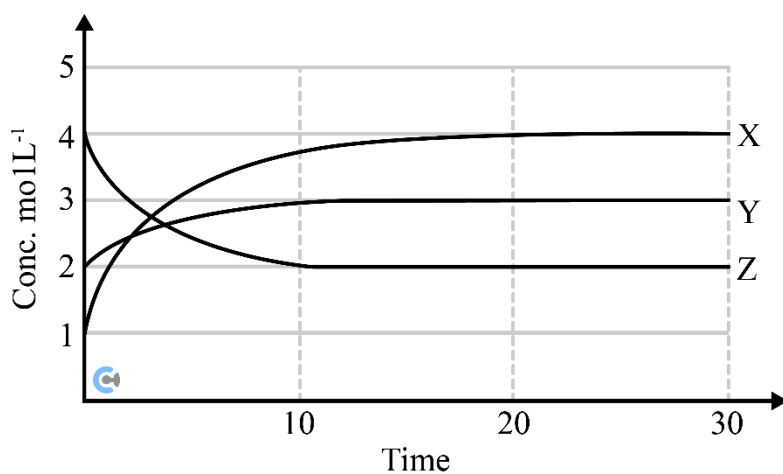


Which of the following factors could have been changed in experiment 2 to result in the results shown in the graph above?

- A. Concentration of hydrochloric acid is doubled from 0.10 M to 0.20 M in the same volume.
- B. Temperature is increased to 35°C.
- C. 300 mL of 0.10 M HCl is used instead.
- D. 5.0 g strips of zinc metal are finely divided into smaller pieces instead.

Question 24

The graph below shows the concentrations, as a function of time, for a mixture of gases, X, Y and Z reacting and achieving equilibrium in a 1 L. vessel.

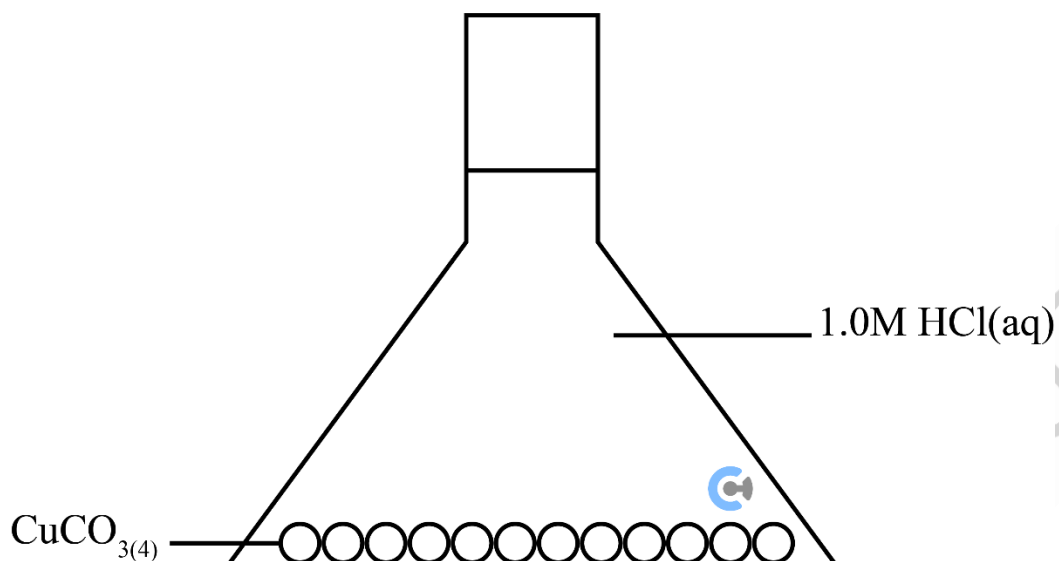


The equation describing the equilibrium system is:

- A. $X + Y \rightleftharpoons Z$
- B. $3X + Y \rightleftharpoons 2Z$
- C. $Z \rightleftharpoons X + Y$
- D. $4Z \rightleftharpoons X + 2Y$

Question 25

Which one of the following options will increase the rate of reaction?



- I Increase the surface area of the HCl solution.
- II Increase the surface area of copper carbonate.
- III Increase the pressure in the conical flask.
- IV Remove carbon dioxide gas.
- V Increase the concentration of HCl.

- A. I, II
- B. I, III
- C. II, V
- D. II, IV

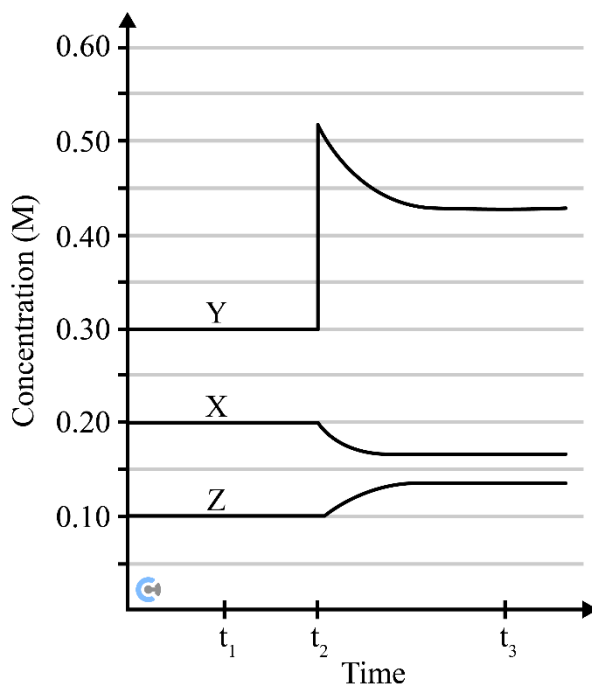
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Question 26

The gases X, Y, and Z were placed in an evacuated vessel and allowed to reach equilibrium according to the equation:



At time t_2 , a change was made, and the effect on the concentration of the gases was graphed, as shown below. The temperature remained constant throughout the experiment.

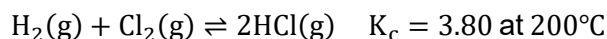


What occurred at t_2 ?

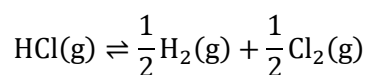
- A. More of Y was added.
- B. Volume was decreased.
- C. Catalyst was added.
- D. Temperature was increased.

The following information applies to Questions 27 and 28

The following reaction is considered.

**Question 27**

The equilibrium constant for the following equation is:



- A. 0.132
- B. 0.513
- C. 1.95
- D. -1.90

Question 28

It is found that chlorine gas has a greenish-yellow colour. How the intensity of the greenish-yellow colour will change if the following changes were made?

	Chlorine is removed	Volume is doubled
A.	Increase intensity	No change to intensity
B.	Increase intensity	Decrease intensity
C.	Decrease intensity	No change to intensity
D.	Decrease intensity	Decrease intensity

Question 29

The following reaction occurs:



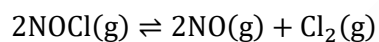
A change is made which causes the K_c value to decrease.

The change which was made is:

- A. Volume decreased.
- B. Catalyst was added.
- C. Temperature was increased.
- D. Temperature was decreased.

Question 30

Consider the following reaction, which has an endothermic forward reaction.



Chlorine gas is greenish-yellow in colour.

Which of the following changes will cause an increase in the intensity of the greenish-yellow colour?

- A. Decreasing temperature.
- B. Adding a small amount of nitrogen monoxide.
- C. Removing a small amount of chlorine gas.
- D. Decreasing volume.

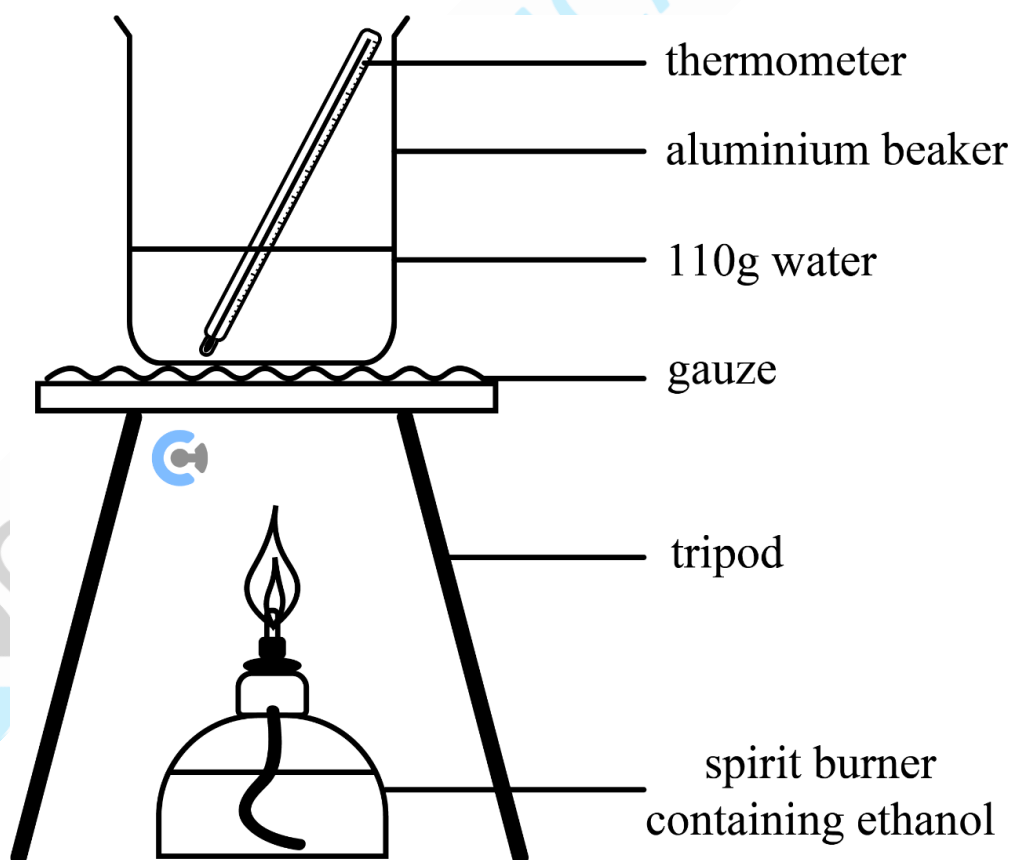
Section B

Instructions

- Answer all questions in the spaces provided.
- Write your responses in English.
- 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, $\text{H}_2(\text{g})$, $\text{NaCl}(\text{s})$.
- Unless otherwise indicated, the diagrams in this book are not drawn to scale.

Question 1 (7 marks)

The following apparatus was used in an experiment to determine the molar enthalpy of the combustion of ethanol.



- a. Calculate the experimental molar enthalpy of combustion (ΔH) of ethanol when 0.590 g ethanol was used to raise the water temperature from 12.5°C to 40.0°C. 4 marks

- b. Using your answer in **part a.**, find the % energy efficiency of the setup. 1 mark

- c. Explain one change that could be made to the experiment that would improve the accuracy of the obtained value. 2 marks

Do not write in this area.

Question 2 (4 marks)

Hydrogen peroxide is a common cleaning agent used in substances such as bleach.

a. Hydrogen peroxide is then mixed with fluorine gas.

- i. Use the information from the electrochemical series in the Data Book to write a balanced overall equation for the reaction which occurs. 2 marks

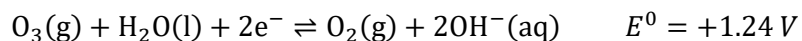
- ii. State the energy conversion which takes place as the reaction proceeds. 1 mark

- b. Using data from the electrochemical series, a student suggests that a reaction will occur between acidified hydrogen peroxide and Ni(s). To test this prediction, a strip of nickel metal is dipped into a solution containing 1.0 M acidified hydrogen peroxide at 25°C. No reaction was observed after 2 minutes. 1 mark

Provide one possible chemical reason that explains why the predicted reaction was not observed.

Question 3 (7 marks)

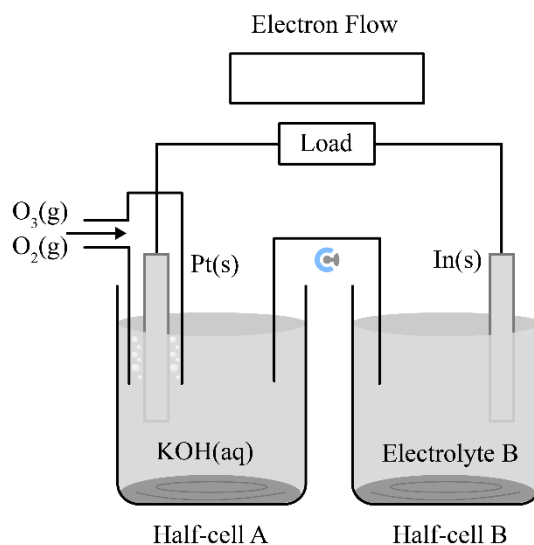
In an extended electrochemical series, the following half-equations are investigated.



- a. A strip of indium metal is dipped into 1.0 M of $\text{Y}(\text{NO}_3)_3(\text{aq})$ solution. Predict if a reaction is expected to occur. Justify your answer. 1 mark

Do not write in this area.

- b. A galvanic cell is constructed between the ozone/oxygen half-cell and $\text{In}^{3+}(\text{aq})/\text{In}(\text{s})$, as shown below.



- i. In the box provided above, label the direction of electron flow. 1 mark

- ii. Suggest a suitable substance for electrolyte B. 1 mark

- iii. Write the balanced equation for the overall reaction which takes place. 1 mark

- iv. A pH meter is inserted into the electrolyte of half-cell A. Explain what would happen to the pH as the reaction proceeds. 1 mark

c. In the salt bridge, potassium nitrate ions are present.

i. State **one** function of the salt bridge.

1 mark

ii. State **one** property of the potassium nitrate ions which helps with the operation of the cell.

1 mark

Do not write in this area.

Question 4 (3 marks)

Most batteries we use for household appliances are often categorised as alkaline batteries. Contour Industries is now trying to venture into the battery business, and Jayden is the lead researcher on batteries. The battery contains zinc metal (Zn(s)) and manganese dioxide ($\text{MnO}_2\text{(s)}$) which can produce zinc oxide (ZnO(s)) and manganite (MnOOH(s)).

a. Jayden must now figure out where to place these reactions in the alkaline battery.

i. Write the reaction occurring at the anode.

1 mark

ii. Write the reaction occurring at the cathode.

1 mark

b. A pacemaker is a small medical device placed in the chest to correct certain heart problems. While this type of battery is commonly used in appliances, it is not suitable for use in a pacemaker. Explain this phenomenon.

1 mark

Question 5 (6 marks)

A solution calorimeter was used to experimentally determine the heat of the solution of potassium nitrate when it is dissolved in water. The calorimeter is found to have had a calibration factor of $2.5 \text{ kJ } ^\circ\text{C}^{-1}$.

It is found that the experimental heat of the solution of potassium nitrate is $+35.0 \text{ kJ mol}^{-1}$.

- a. Write the balanced thermochemical equation for the dissolution reaction which occurs. 1 mark

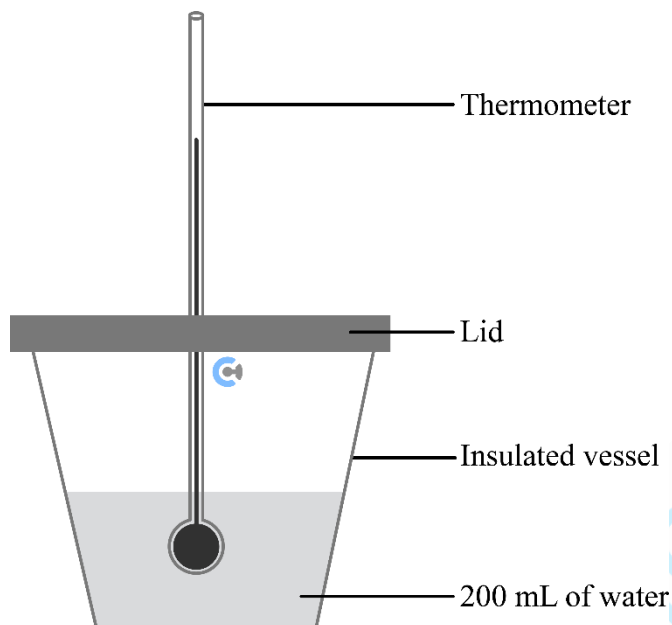
- b. A 30.0 g sample of the potassium nitrate is dissolved in water at SLC.

- i. Find the amount of energy, in kilojoules, which was absorbed by the reaction. 2 marks

- ii. Using the calibration factor given and your answer from **part b. i.**, find the final temperature reached, after the 30.0 g of potassium nitrate was completely dissolved into the water. 2 marks

Do not write in this area.

The original calorimeter with a calibration factor of $2.5 \text{ kJ } ^\circ\text{C}^{-1}$ which contains 200 mL of water is shown below.



The amount of water present in the calorimeter is increased to 250 mL , changing the calibration factor.

- c. State whether this new calibration factor will be higher or lower than $2.5 \text{ kJ } ^\circ\text{C}^{-1}$. Justify your answer. 1 mark

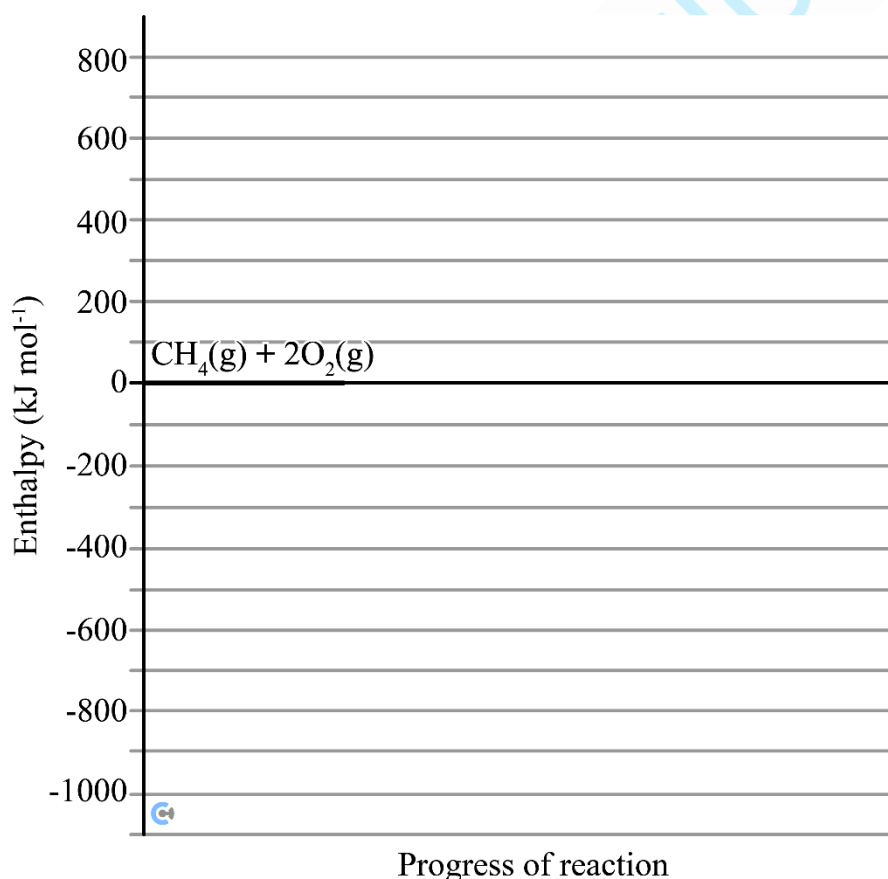
Question 6 (14 marks)

Contour Industries is an up-and-oncoming company looking to expand its outreach to the energy industry. They look for sources of methane.

- a. Write the thermochemical equation for the complete combustion of methane. 2 marks

- b. The activation energy for the combustion of methane is 280 kJ mol^{-1} .

- i. Complete the energy profile diagram on the axes provided below. 2 marks



- ii. State the activation energy for the reverse reaction. 1 mark

c. A surveyor decides whether to drill for natural gas or to obtain methane from biogas.

i. Explain how biogas is produced.

1 mark

ii. Noah says that 'natural gas is considered to be fossil fuels as it produces greenhouse gases which are harmful to the environment.'

2 marks

Evaluate Noah's statement, justifying your response.

d. Methane is used as a fuel over alternatives such as methanol. Methanol has a lower heat of combustion in kJ/mol . Explain the differences in the heat of combustion.

2 marks

e. Contour Industries is planning to expand into the domestic stove market with its own natural gas stove, the Burnout Mark IV. Methane is used at high pressure and low temperature, whereby it is compressed and turned into liquified petroleum gas, LPG.

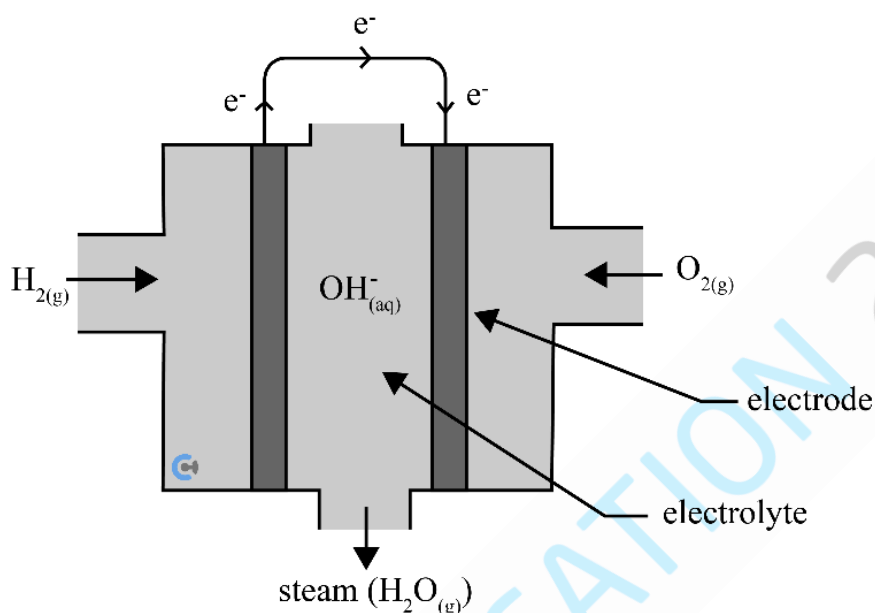
- i. Given that this LPG is only made of methane which has a density of 0.580 g mL^{-1} , find the theoretical volume of LPG, in mL , which is required to obtain 2.00 MJ of energy. 3 marks

- ii. In practice, the efficiency of the gas stove is 70%, find the amount of energy the experimental volume of LPG required to achieve the same amount of energy as part e. i. 1 mark

Do not write in this area.

Question 7 (11 marks)

With society moving to net zero carbon emissions by 2050, cars have started to be developed to be run on hydrogen gas as the main fuel rather than petrol. Some cars have begun development on a hydrogen/oxygen fuel cell, whereby a simplified version is shown below.



The fuel cell consists of two hydrogen gas that is inserted through the left pipe and oxygen gas through another. The two pipes are joined, and the alkaline electrolyte, KOH, passes through the centre of the cell.

- a. Write balanced ionic half-equations for the reactions occurring at the anode and cathode. 2 marks

Anode: _____

Cathode: _____

- b. The electrodes consist of a porous nickel alloy mesh. 2 marks

State **two** roles that the nickel electrodes play in the operation of the fuel cell.

- c. Explain one major advantage of the use of hydrogen fuel cells to power cars over combustion engines fuelled by hydrogen by referring to **one** 'Green Chemistry Principles'. Use item **26. ii.** of the Data Book. 3 marks

- d. This fuel cell creates a current of 5.60 A. Calculate the volume of hydrogen gas consumed at SLC, if the cell runs for 30.0 min. 4 marks

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Question 8 (8 marks)

Scientists help investigate how ethanol can be produced renewably. They decide to use spinach to produce ethanol.

- a. Write the equation for the reaction which takes place within the spinach plant to produce glucose. 1 mark

- b. They then use the glucose to produce ethanol via fermentation with the presence of yeast as a catalyst.

- i. Write the balanced equation for the reaction which takes place. 1 mark

- ii. The ethanol produced is dissolved in water. Propose a method to separate the ethanol and water. 1 mark

- c. Is the ethanol produced in this manner renewable? Justify your answer. 1 mark

- d. Suggest **one** sustainability challenge presented by the use of spinach plants to produce bioethanol in terms of United Nations Sustainable Development Goal 2. Explain your answer by referring to **one** other United Nations Sustainable Development Goal in your response. 2 marks

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They then repivot their focus and use the spinach for consumption instead. Spinach has the following composition:

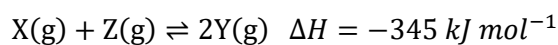
Composition	Mass per 100 <i>g</i> of spinach (<i>g</i>)
Water	91.40
Cellulose	2.20
Other Carbohydrates	0.42
Protein	2.86
Lipid	0.39
Other Minerals	2.73

Source: U.S. Department of Agriculture. (2019). FoodData Central.
Usda.gov. <https://fdc.nal.usda.gov/fdc-app.html#/food-details/168462/nutrients>

- e. Assuming the body does not obtain energy from the other minerals, calculate the energy present in 100 *g* of the spinach. 2 marks

Question 9 (8 marks)

The same amounts of reactants X and Z are placed in a 7.00 L sealed container and allowed to react according to the equation.



The equilibrium constant is known to be 0.650 at SLC.

- a. Determine whether the extent of reaction is low, moderate or high.

1 mark

- b. After some time, the amount of X is found to be 3.00 mol, and the amount of Y is found to be 5 mol.

- i. State the amount of Z present at this time.

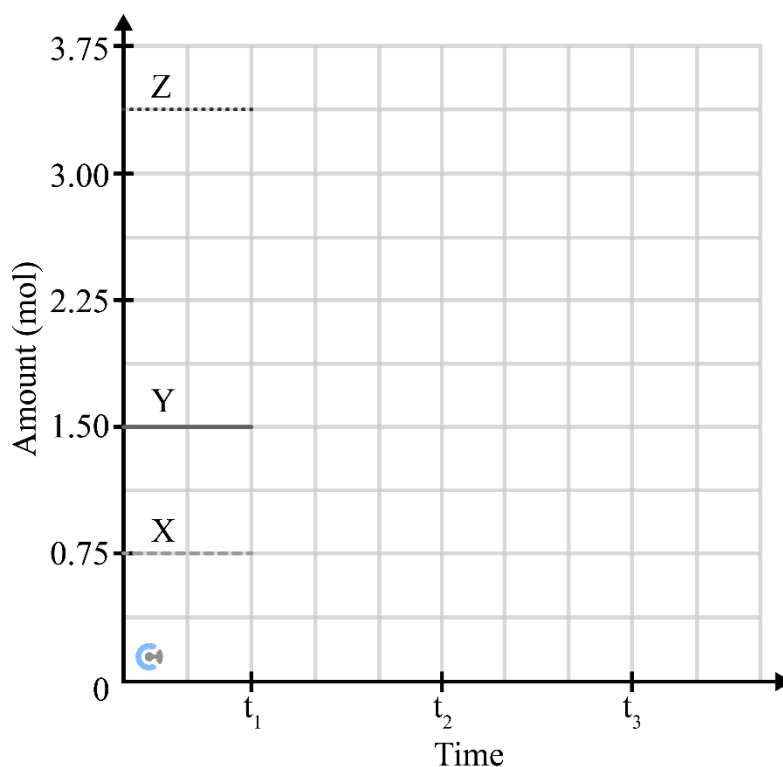
1 mark

- ii. Determine if the system is at equilibrium. Justify your answer.

2 marks

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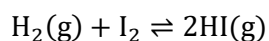
- c. In a different instance, a mixture of the three substances is initially at equilibrium, as shown below in the graph.



- i. At t_1 , 0.375 mol of Y is removed, whereby equilibrium is re-established at t_2 . 1 mark
Complete the graph above to show these changes.
- ii. At t_2 , the volume of the reaction vessel is increased from 7.00 L to 14.00 L . 1 mark
Complete the graph above to show these changes.
- d. To maximise the efficiency of the production of substance Y, both the rate of production and the equilibrium yield should be maximised. What temperature conditions should be used? Justify your answer. 2 marks

Question 10 (10 marks)

The equilibrium system with the following equation is investigated:



- a. Write the expression for the equilibrium constant.

1 mark

- b. In a 5.0 L container at equilibrium, the amounts of hydrogen and iodine gas are 2.00 mol each and the amount of the hydrogen iodide is 4.00 mol at 200°C. Find the value for the equilibrium constant.

1 mark

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c. The system is kept at the same temperature, but 2.00 mol of hydrogen gas is added.

- i. State the direction in which the equilibrium system will shift, justifying your response with reference to a specific principle. 2 marks

- ii. Find the final amount of hydrogen gas after the system has re-established equilibrium. 4 marks

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- d. The temperature of the system is then cooled to a lower temperature, whereby the amount of iodine gas is seen to increase. 2 marks

State whether the forward reaction is endothermic or exothermic, justifying your reasoning.

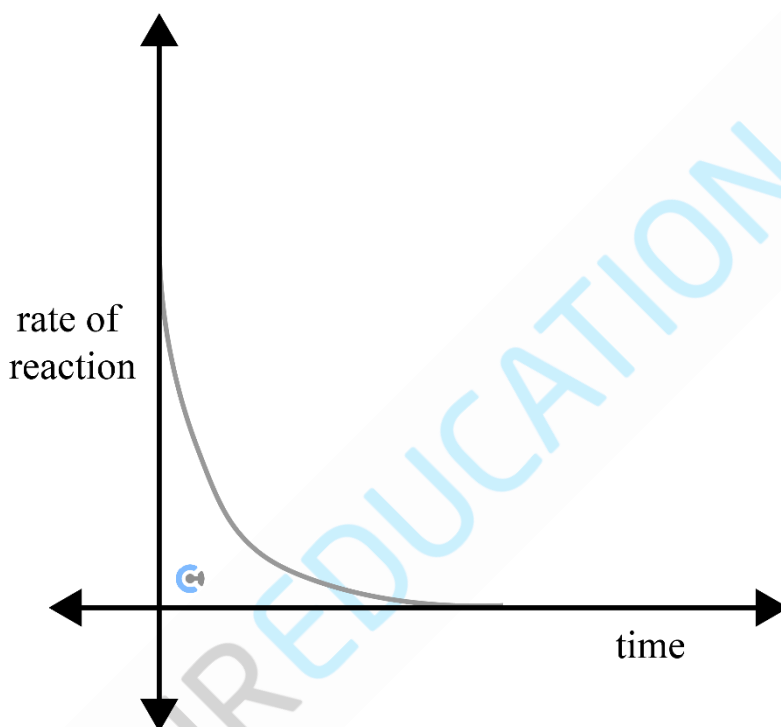
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Question 11 (5 marks)

A reaction similar to the baking soda and vinegar experiment is undertaken, with 2.0 g solid chunks of sodium bicarbonate, NaHCO_3 reacting with 1.0 M, 20 mL of ethanoic acid, CH_3COOH . The chemical reaction that occurs is as follows:



The following graph is recorded.



- a. On the same axes above, draw the new graph when powdered sodium bicarbonate is used instead. 1 mark
- b. Explain the effect on the rate of reaction of adding a suitable catalyst into the reaction beaker. 2 marks

- c. Explain the effect on the rate of reaction of adding 3 mL of liquid ethane, C_2H_6 into the reaction beaker. 2 marks

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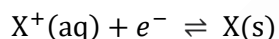
Question 12 (7 marks)

In electrochemistry, the standard hydrogen electrode (abbreviated SHE), is a redox electrode that forms the basis of the thermodynamic scale of oxidation-reduction potentials.

Its absolute electrode potential is estimated to be $4.44 \pm 0.02 \text{ V}$ at 25°C , but to form a basis for comparison with all other electrochemical reactions, hydrogen's standard electrode potential (E°) is declared to be zero volts at any temperature. Potentials of all other electrodes are compared with that of the standard hydrogen electrode at the same temperature.

Source: IUPAC, *Compendium of Chemical Terminology*, 2nd ed. (the "Gold Book") (1997). Online corrected version: (2006–) "standard hydrogen electrode". doi:10.1351/goldbook.S05917

An organic molecule ' $\text{X}^+(\text{aq})$ ' is to be placed in the electrochemical series in the following reaction:



The organic molecule ' $\text{X}^+(\text{aq})$ ' is then placed in a set of **three** reactions as detailed below.

- **Reaction 1:** When placed directly in a beaker and $\text{Zn}(\text{s})$ is placed inside, the zinc begins to corrode.
- **Reaction 2:** When placed in a 2.0 M KOH solution, bubbles are produced.
- **Reaction 3:** When placed in a solution with 1.0 M NaBr , no reaction takes place.

Explain the significance of each of the above reactions and observations to provide the range of possible E^0 values of the compound $X^+(aq)$.

In your response, for each of the three reactions, include:

- Any relevant half-equations
- Deduction for the E^0 value.

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