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

Chemistry ¾ (Normal)

Question and Answer Book

VCE Examination (Term 1 Mock) – April 2025

- Reading time is **15 minutes.**
- Writing time is **2 hours 30 minutes.**

Materials Supplied

- Question and Answer Book of 40 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

Student's Full Name: _____

Student's Email: _____

Tutor's Name: _____

Marks (Tutor Only): _____

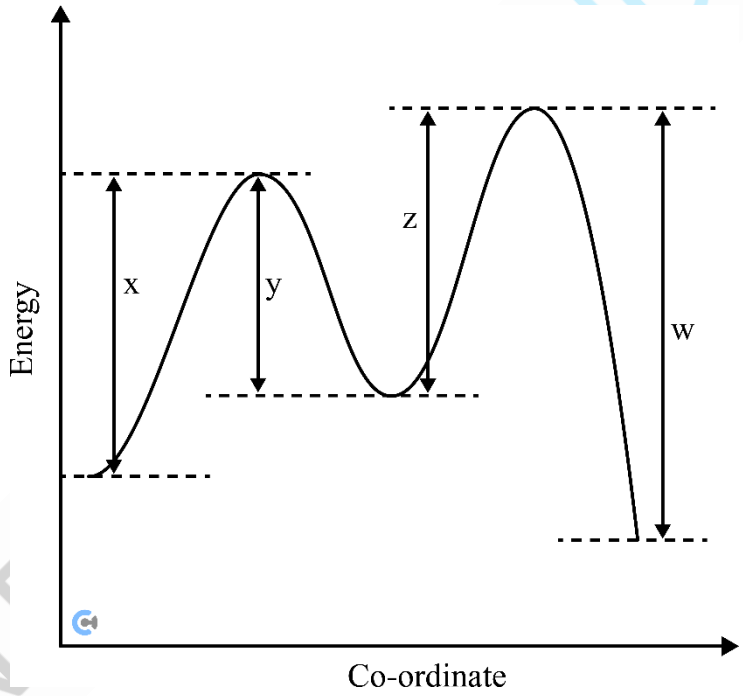
Section A

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 score 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

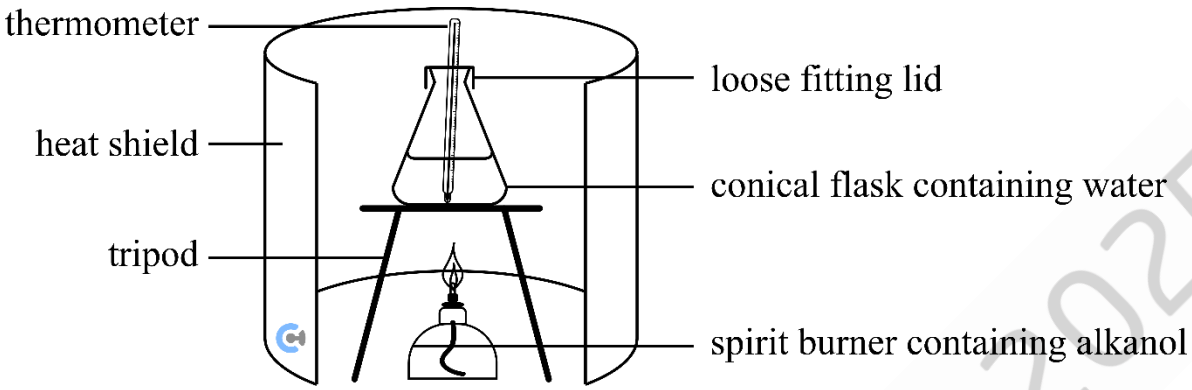
B. $w - x$

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. $2C_2H_6(g) + 7O_2(g) \rightarrow 4CO_2(g) + 6H_2O(g)$

B. $C_3H_8O(g) + 4O_2(g) \rightarrow CO_2(g) + CO(g) + 4H_2O(g)$

C. $2C_4H_{10}O(g) + 3O_2(g) \rightarrow 8C(s) + 2H_2(g) + 8H_2O(g)$

D. $2C_2H_6O(g) + 4O_2(g) \rightarrow 2CO_2(g) + 2C(s) + 6H_2O(g)$

Question 3

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

A. SO_3

B. HSO_4^-

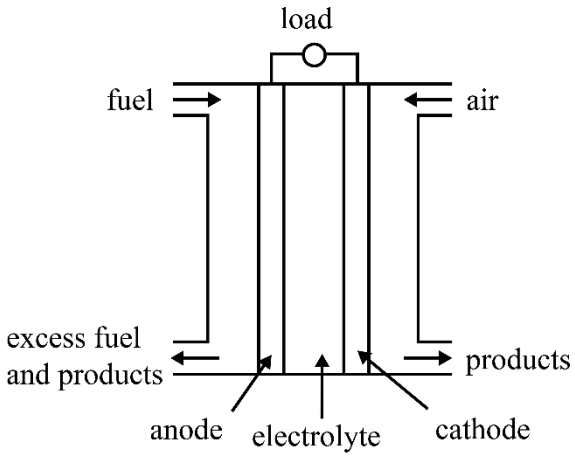
C. SO_2

D. Al_2S_3

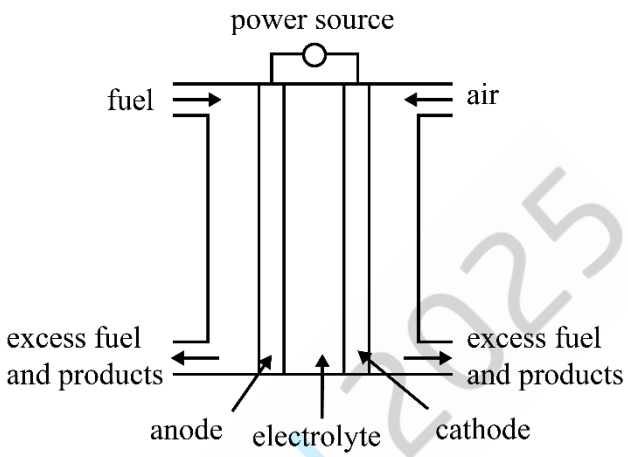
Question 4

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

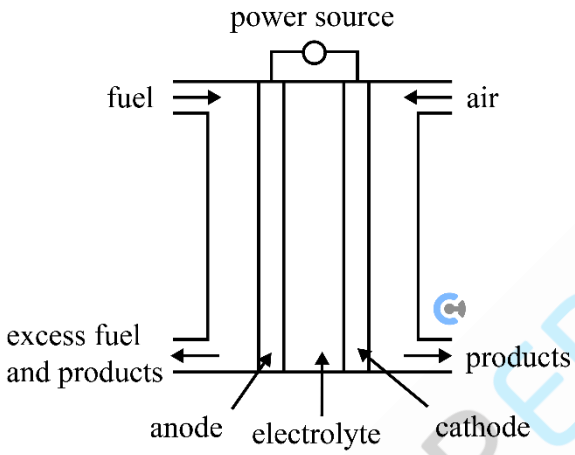
A.



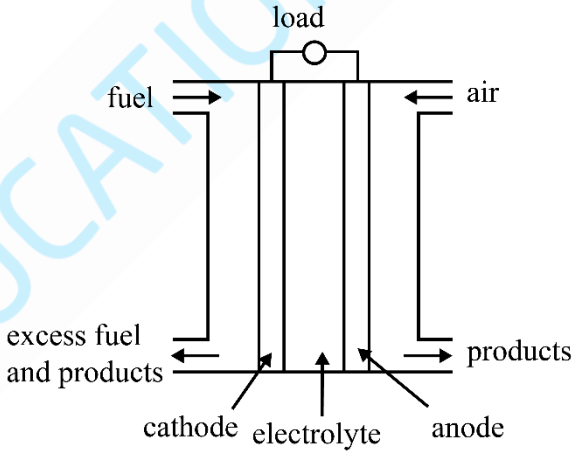
B.



C.



D.



The following information applies to the two questions that follow.

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 was 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.

$$2CO(g) + O_2(g) \rightarrow 2CO_2(g)$$

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

A. $40\ mL$ of CO_2 produced.

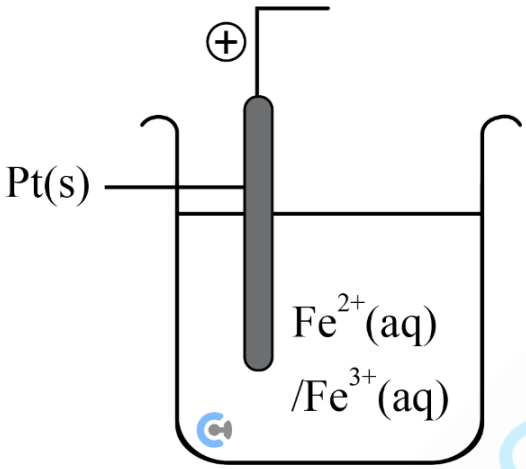
B. $20\ mL$ of CO_2 produced.

C. $10\ mL$ of CO unreacted.

D. $5\ mL$ of O_2 unreacted.

Question 8

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



A. $Ag^{+}(aq) + e^{-} \rightleftharpoons Ag(s)$

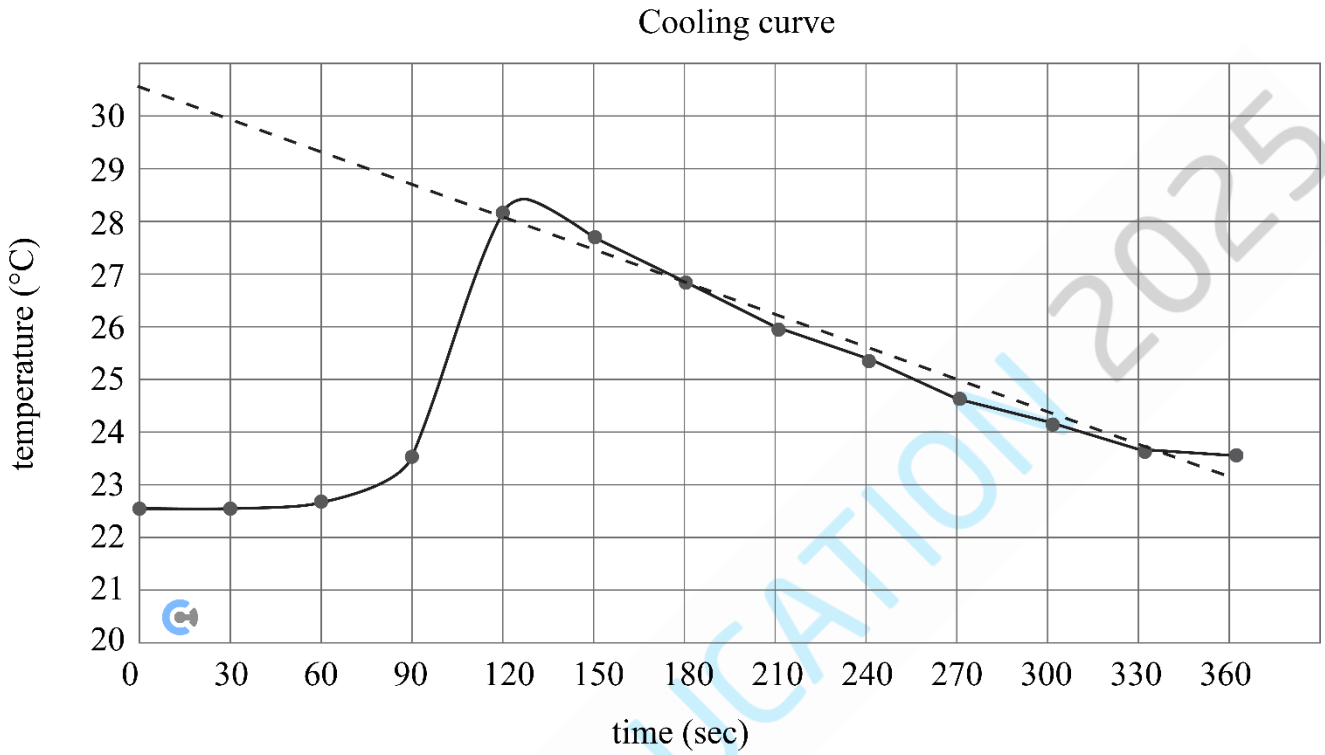
B. $Sn^{4+}(aq) + 2e^{-} \rightleftharpoons Sn^{2+}(aq)$

C. $F_2(g) + 2e^{-} \rightleftharpoons 2F^{-}(aq)$

D. $Cu^{2+}(aq) + 2e^{-} \rightleftharpoons Cu(s)$

Question 9

Consider the following temperature time graph of a calorimeter. Which of the following statements is incorrect?



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. $143\ J\ °C^{-1}$

B. $143\ kJ\ °C^{-1}$

C. $14.3\ J\ °C^{-1}$

D. $14.2\ kJ\ °C^{-1}$

Question 11

Which of the following statements is incorrect about biogas?

A. They contain only methane.

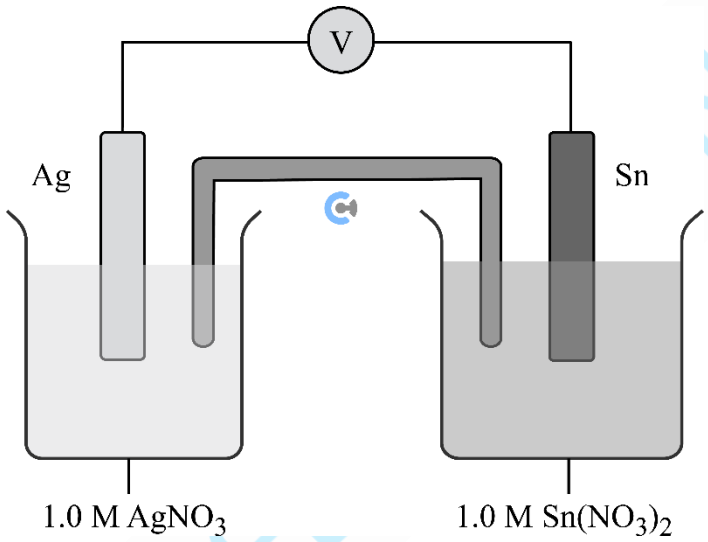
B. They are produced via anaerobic respiration by bacteria.

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 the two questions that follow.

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

Flask 1	Flask 2	Flask 3	Flask 4
$Cu(NO_3)_2(aq) + Sn$	$Ag^+(aq) + Sn$	$Fe^{3+}(aq) + NaCl(aq)$	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.

A. 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 to 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 the 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.

$$\mathrm{Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightleftharpoons 2Cr^{3+}(aq) + 7H_2O} \quad +1.36\ V$$

$$\mathrm{Cr^{3+}(aq) + e^- \rightleftharpoons Cr^{2+}(aq)} \quad -0.41\ V$$

$$\mathrm{Cr^{2+}(aq) + 2e^- \rightleftharpoons Cr\ (s)} \quad -0.91\ V$$

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. $\mathrm{F^-}$ 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.

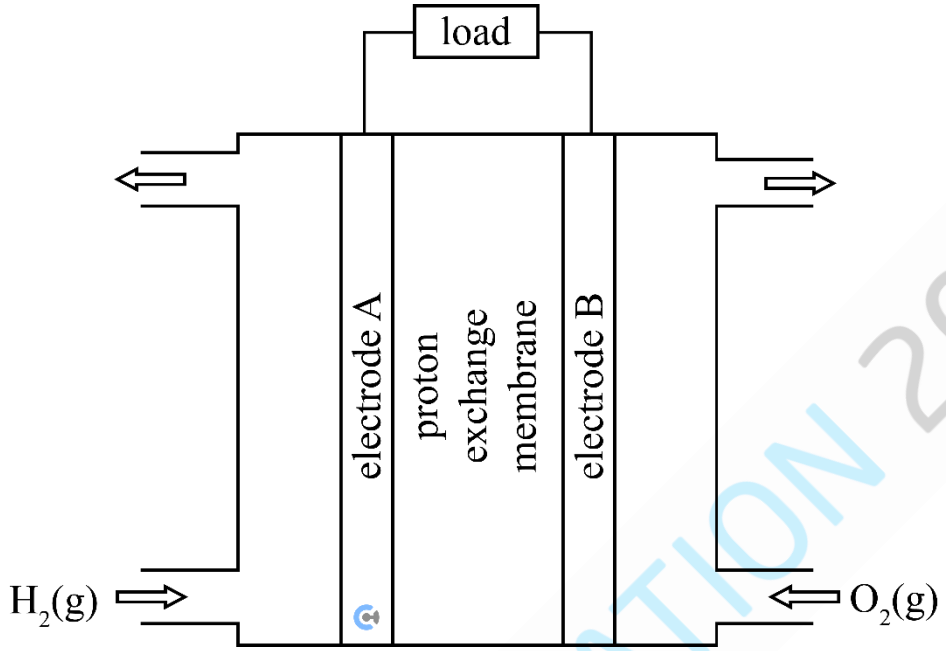
B. II only.

C. Both I and II.

D. Neither I and 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 are:

A. $+1$

B. $+2$

C. $+3$

D. $+4$

Question 19

A sample of a fuel is completely combusted, whereby $372\ J$ 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. $0.059\ ℃$

B. $0.248\ ℃$

C. $59℃$

D. $25.059℃$

Question 20

Which one of the following factors would have the **least** impact on the amount of chlorine gas produced during the electrolysis of $150.0\ mL$ of an aqueous $2.0\ M$ sodium chloride solution?

A. Length of time of electrolysis.

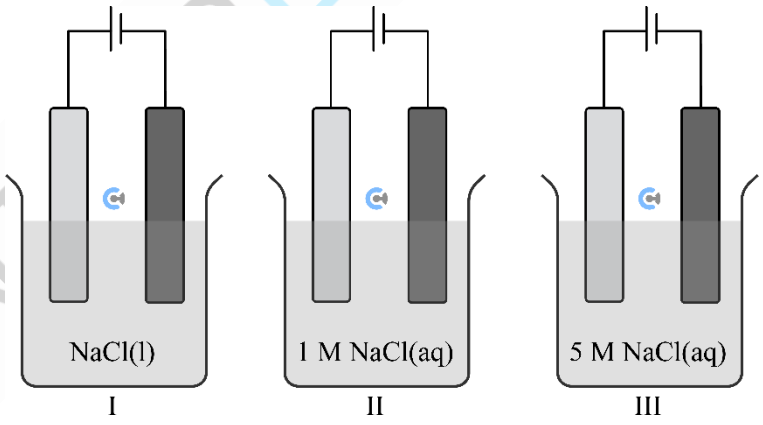
B. Current flowing.

C. Temperature of the electrolyte.

D. Volume of the electrolyte-containing vessel.

Question 21

Three electrolysis cells were constructed, each using a pair of graphite electrodes. Each cell contained sodium chloride as the electrolyte, but the state or concentration of the sodium chloride differed, as shown in the diagrams below.



For which cells would you expect to see the same chemical or chemicals initially produced at the anode when the electrolysis was performed?

A. I and II.

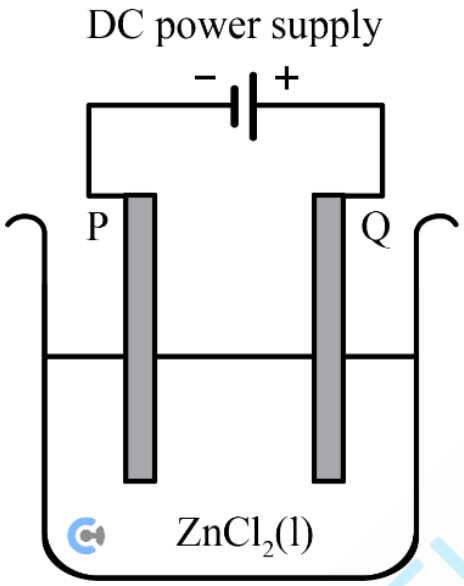
B. I and III.

C. II and III.

D. I, II and III.

Question 22

In the electrochemical cell represented below,



A. Oxygen gas forms at P.

B. Oxygen gas forms at Q.

C. Chloride gas forms at P.

D. Chloride gas forms at Q.

Question 23

An electrolytic cell is utilised with inert electrodes. Which of the following electrolytes will not result in the production of bubbles at either electrode?

A. Iron (II) nitrate solution $(\mathrm{Fe(NO_3)_2(aq)})$.

B. Sodium bromide solution $(\mathrm{NaBr(aq)})$.

C. Molten sodium chloride $(\mathrm{NaCl(l)})$.

D. Mixture of sodium hydroxide & cobalt iodide solutions (NaOH and $\mathrm{CoI_2}$).

Question 24

In the electrolysis of a dilute solution of $\mathrm{KNO_3}$, the nitrate ions are:

A. Attracted to the positive electrode where they are oxidised.

B. Attracted to the positive electrode where they are reduced.

C. Attracted to the positive electrode where they are neither reduced nor oxidised.

D. Not attracted to either electrode as they are spectator ions only.

Question 25

A solution containing tin (II) nitrate is to be electrolysed, whereby the positive terminal of the battery is connected to a silver electrode, and the negative terminal of the battery is connected to a lead electrode. After the cell runs for 5.00 minutes, the overall reaction that occurs is observed to have changed once from the initial reaction.

Which of the following is correct regarding the reactions which occur in the cell after 5.00 minutes?

A. The overall concentration of ions is decreasing.

B. Lead is deposited at the cathode.

C. The positive electrode decreases in mass.

D. There is no change in the mass of any electrode.

Question 26

An electric charge of $8042\ C$ is passed through a molten ionic solution. The product at the cathode could be:

A. $0.166\ mol$ of hydrogen gas.

B. $0.0833\ mol$ of magnesium metal.

C. $0.0417\ mol$ of sodium metal.

D. $0.0278\ mol$ of aluminium metal.

Question 27

The rechargeable nickel-cadmium cell is used to power small appliances. The following reactions occur when chemical energy is converted to electrical energy:

$$NiO_2(s) + 2H_2O(l) + 2e^- \rightarrow Ni(OH)_2(s) + 2OH^-(aq)$$

$$Cd(s) + 2OH^-(aq) \rightarrow Cd(OH)_2(s) + 2e^-$$

What is the half-reaction which occurs at the positive electrode when the cell is undergoing recharge?

A. $NiO_2(s) + 2H_2O(l) + 2e^- \rightarrow Ni(OH)_2(s) + 2OH^-(aq)$

B. $Ni(OH)_2(s) + 2OH^-(aq) \rightarrow NiO_2(s) + 2H_2O(l) + 2e^-$

C. $Cd(s) + 2OH^-(aq) \rightarrow Cd(OH)_2(s) + 2e^-$

D. $Cd(OH)_2(s) + 2e^- \rightarrow Cd(s) + 2OH^-(aq)$

Question 28

Iron metal is used to electroplate metal items to give them a lustrous coating. The item to be electroplated is placed into an electrolytic cell with an iron electrode and a solution of iron (II) ions, which are stirred constantly.

In the course of the electrolytic process:

A. Electrons will travel from cathode to anode.

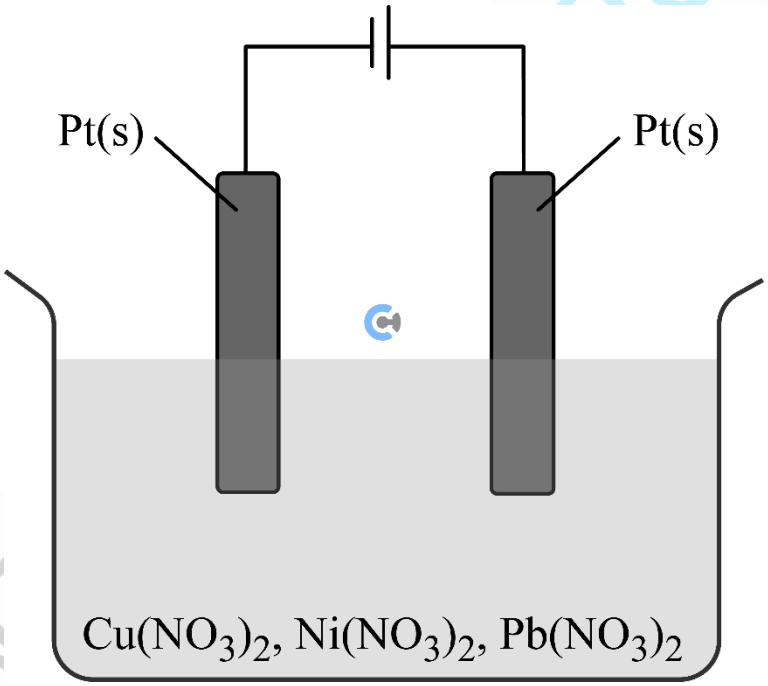
B. The mass of the anode will increase.

C. The concentration of iron ions in the electrolyte will decrease.

D. Iron ions will move towards the cathode.

Question 29

An electrolytic cell containing $0.20\ M$ of $\mathrm{Cu(NO_3)_2}, \mathrm{Ni(NO_3)_2}$ and $\mathrm{Pb(NO_3)_2}$ is electrolysed, as shown.



The reaction proceeds so that there are three layers of coating formed. The order of the coatings, from outside to inside are:

A. $\mathrm{Ni, Pb, Cu}$

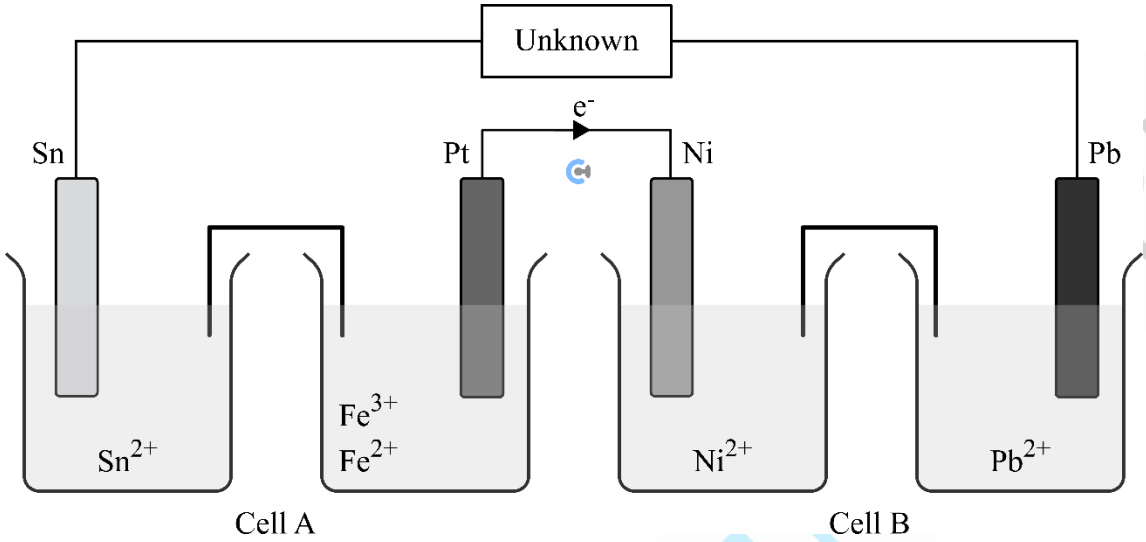
B. $\mathrm{Cu, Pb, Ni}$

C. $\mathrm{Cu, Ni, Pb}$

D. $\mathrm{Pb, Ni, Cu}$

Question 30

A connected cell is shown below, where it is unknown if they are connected to a power source, load or just connected by wires.



The energy transformation which occurs in each electrode are:

	Cell *A*	Cell *B*
A.	Chemical to electrical.	Chemical to electrical.
B.	Chemical to electrical.	Electrical to chemical.
C.	Electrical to chemical.	Chemical to electrical.
D.	Electrical to chemical.	Electrical to chemical.

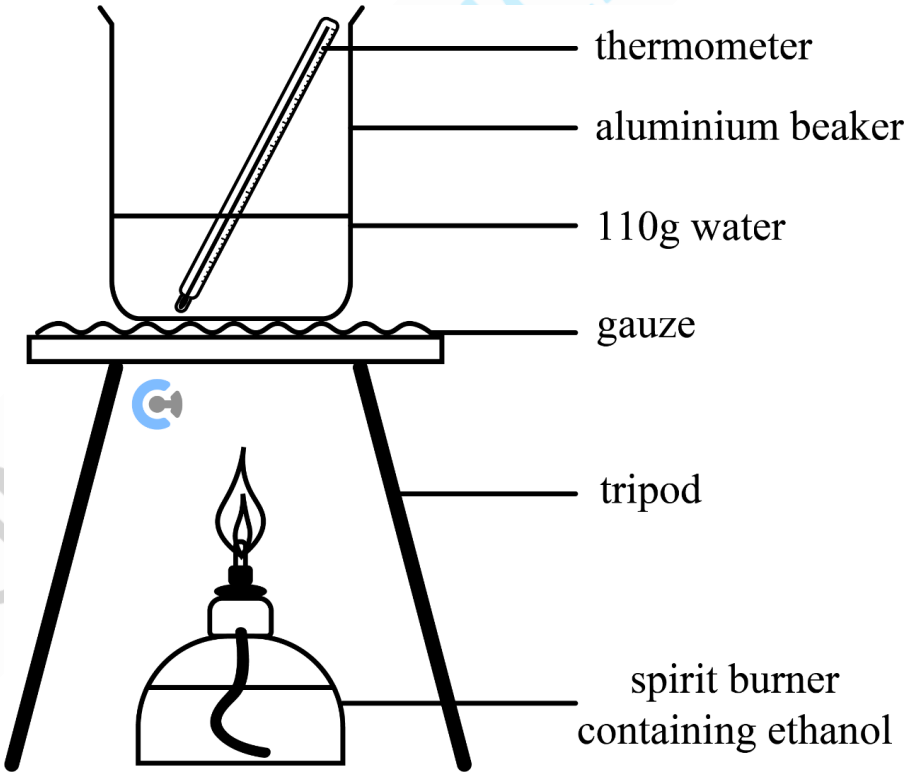
Section B

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, $H_2(g), NaCl(s)$.
- 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

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 $\mathrm{Ni(s)}$. To test this prediction, a strip of nickel metal is dipped into a solution containing $1.0\ M$ acidified hydrogen peroxide at $25℃$. 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.

$$O_3(g) + H_2O(l) + 2e^- \rightleftharpoons O_2(g) + 2OH^-(aq) \qquad E^0 = +1.24\,V$$

$$Y^{3+}(aq) + 3e^- \rightleftharpoons Y(s) \qquad E^0 = -2.37\,V$$

$$In^{3+}(aq) + 3e^- \rightleftharpoons In(s) \qquad E^0 = -0.34\,V$$

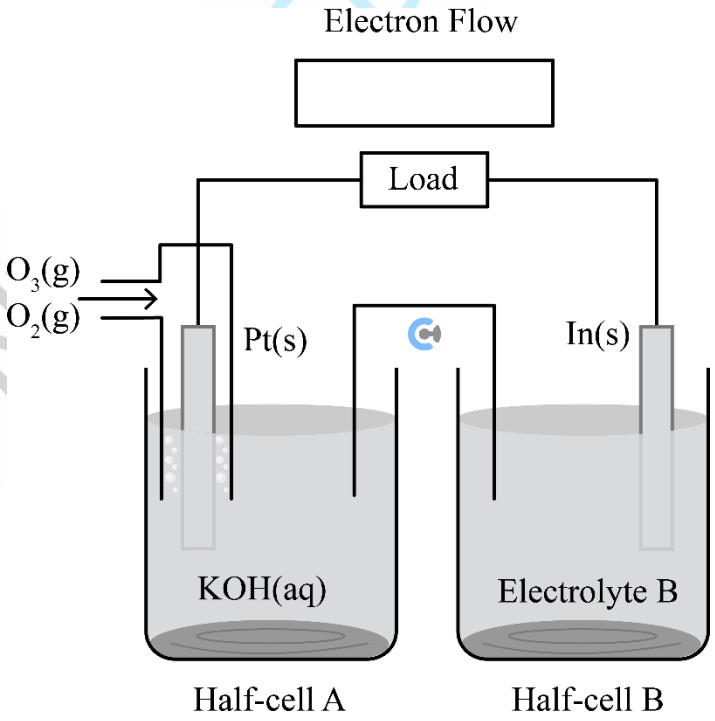
a. A strip of indium metal is dipped into $1.0\,M$ of $Y(NO_3)_3(aq)$ solution. Predict if a reaction is expected to occur. Justify your answer. 1 mark

_____

_____

_____

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

_____

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 $(\mathrm{Zn(s)})$ and manganese dioxide $(\mathrm{MnO_2(s)})$ which can produce zinc oxide $(\mathrm{ZnO(s)})$ and manganite $(\mathrm{MnOOH(s)})$.

a. Jayden now must 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 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 $2.5\ kJ\ °C^{-1}$.

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

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

_____

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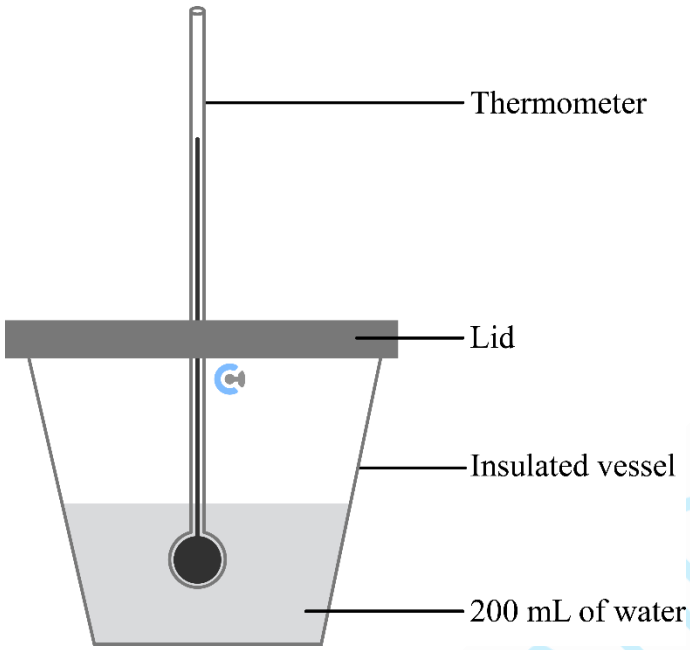
The original calorimeter with a calibration factor of $2.5\ kJ\ °C^{-1}$ which contains $200\ mL$ of water is shown below.



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 $2.5\ kJ\ °C^{-1}$. 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.

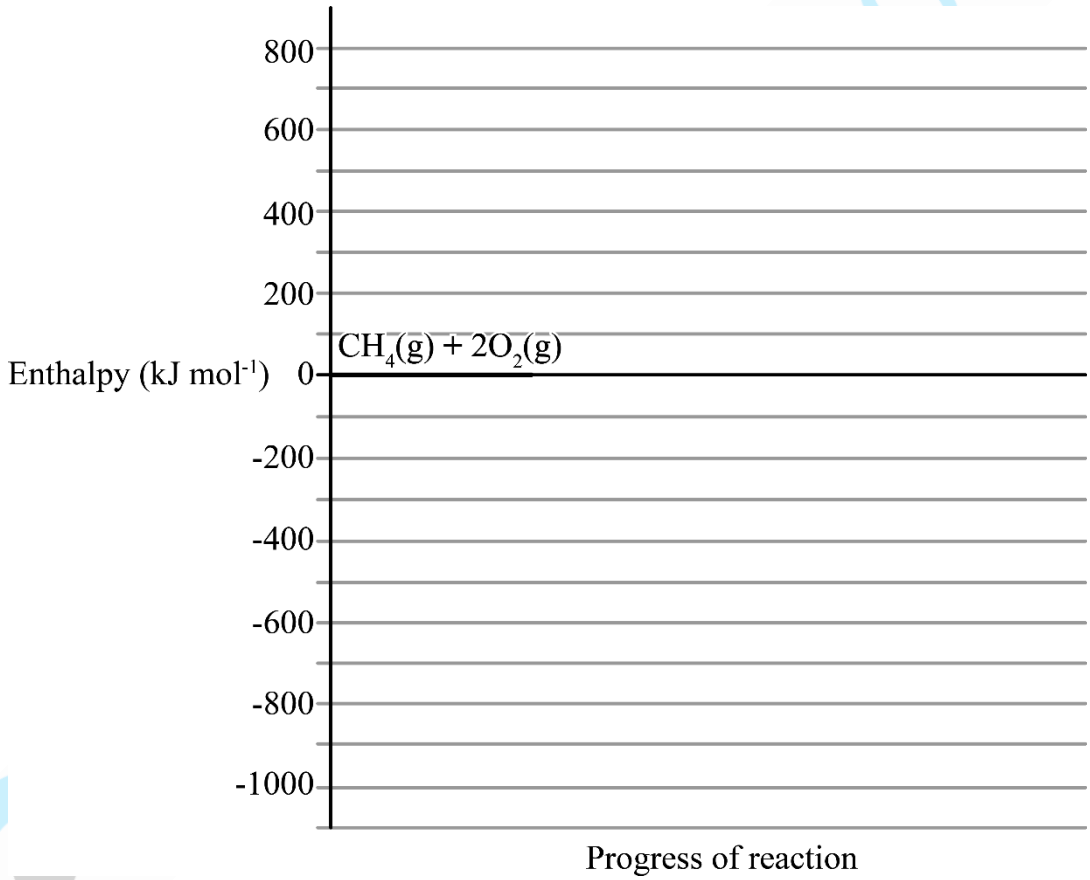
a. Write the thermochemical equation for the complete combustion of methane. 2 marks

_____

_____

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

_____

_____

_____

_____

_____

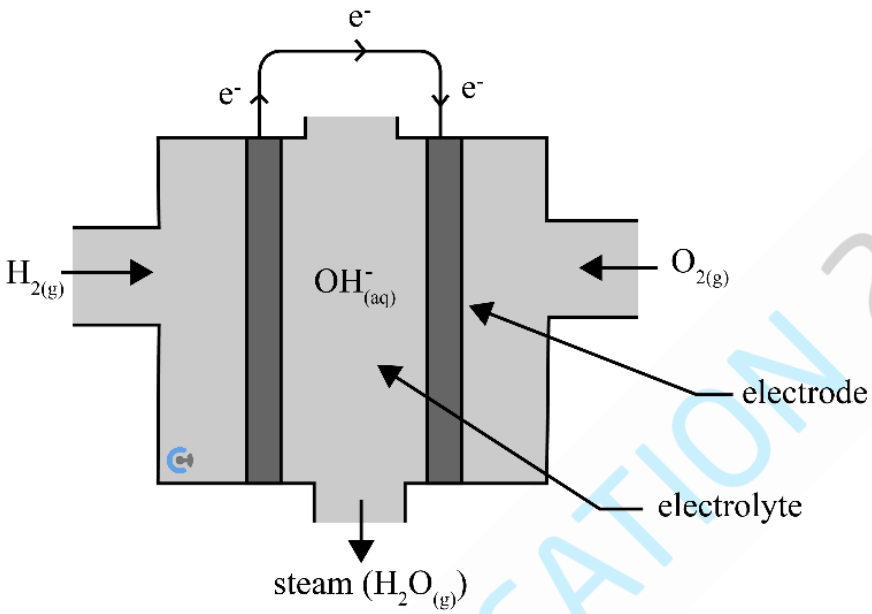
ii. In practice, the efficiency of the gas stove is 70%, find the amount of energy the experimental volume of LPG required to achieve the same amount of energy as **part e.i.** 1 mark

_____

_____

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 using hydrogen fuel cells to power cars over combustion engines fuelled by hydrogen, referring to one 'Green Chemistry Principle'. 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

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 the United Nations Sustainable Development Goal 2. Referning to answer UN Sustainability goal, suggest and explain another sustainability challenge. 2 marks

_____

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

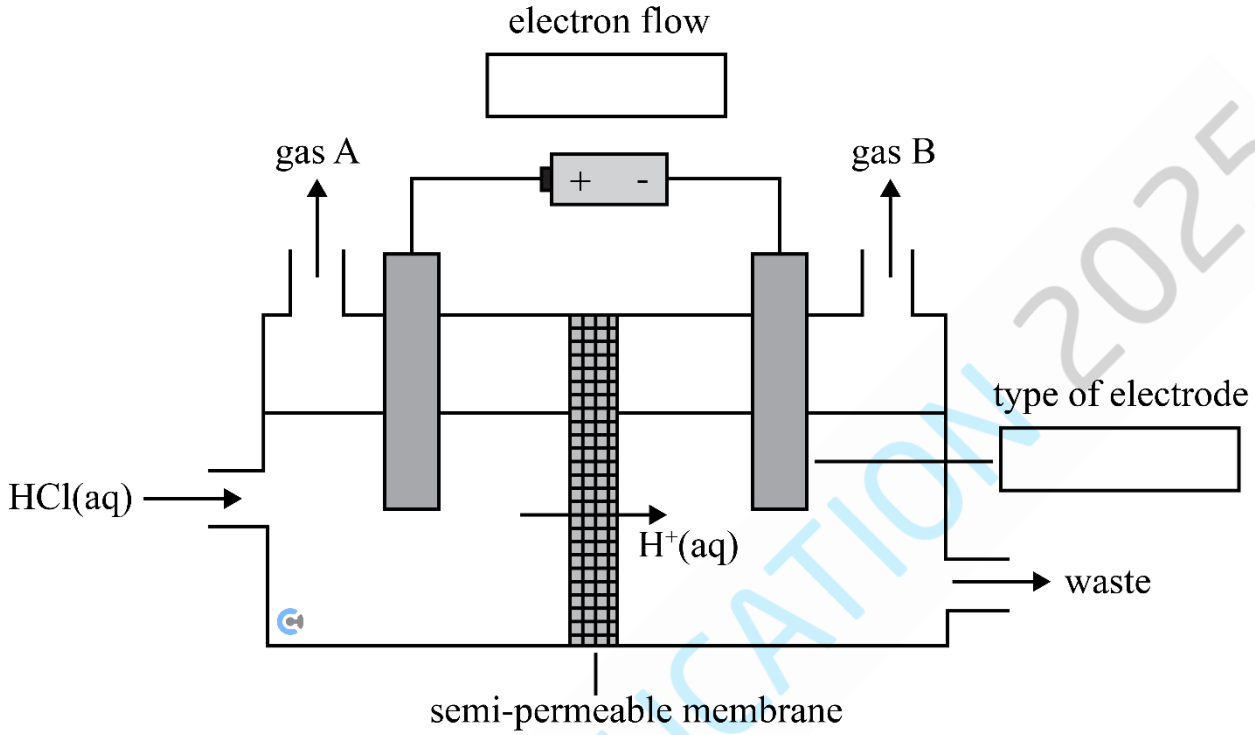
Composition	**Mass per 100 g of spinach (g)**
Water	91.40
Cellulose	2.20
Other Carbohydrates	0.42
Protein	2.86
Lipid	0.39
Other Minerals	2.73

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)

To allow 1.0 M hydrochloric acid to react, the following cell is used, which is powered by a battery, whereby two gases, gas A and gas B, are observed to be produced.



a. Inert electrodes are used.

i. Indicate whether the right electrode acts as the cathode or the anode in the box provided above. 1 mark

ii. Place an arrow to indicate the direction of electron flow in the box provided above. 1 mark

iii. Write the balanced half-equation which occurs at the electrode connected to the negative terminal of the battery. 1 mark

_____

iv. Identify gas A which is produced. 1 mark

_____

b. The cell is then altered, whereby high concentrations of hydrochloric acid of $5.0\ M$ are inserted into the cell instead. The equations at one of the electrodes are observed to change. 1 mark

Write the balanced half-equation for the reaction which occurs at this electrode.

_____

c. In the cell, a semi-permeable membrane is selected to only allow hydrogen ions to pass through. State **one** other function of the semi-permeable membrane. Justify your answer. 1 mark

_____

_____

d. The production of hydrogen in a 'green manner is to be investigated.

i. Propose **one** cell which can be used to produce 'green hydrogen.' 1 mark

_____

ii. Suggest **one** manner in which the proposed cell in **part d.i.** can aid with the United Nations Sustainable Development Goal 13. 1 mark

_____

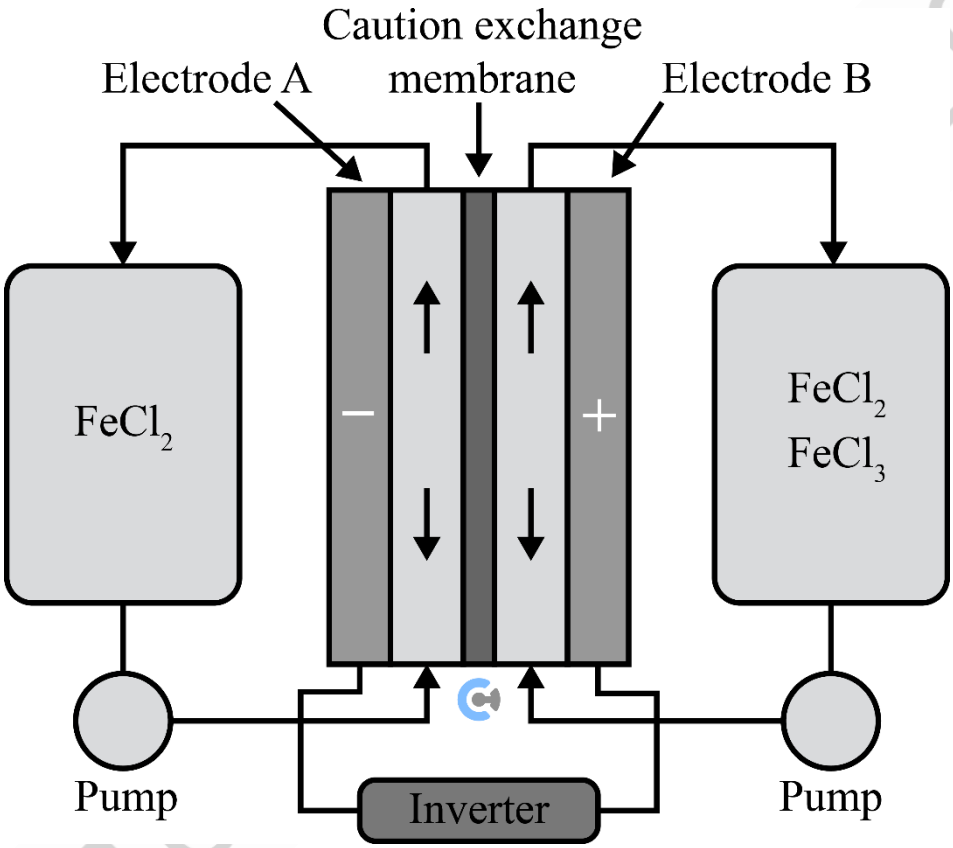
_____

Question 10 (6 marks)

An iron redox flow battery (IRFB) involves a reaction between the following relevant half-equations:

$$Fe^{3+}(aq) + e^- \rightleftharpoons Fe^{2+}(aq) \qquad E^0 = +0.77\ V$$
$$Fe^{2+}(aq) + 2e^- \rightleftharpoons Fe(s) \qquad E^0 = -0.44\ V$$

The cell is shown below, whereby the electrode A is made of iron metal, and electrode B is made of platinum metal.



a. Write the balanced overall reaction which occurs during the **discharge** cycle. 1 mark

_____

b. When the cell is **recharged**, write the balanced half-equation for the reaction occurring at the anode. 1 mark

_____

c. The IRFB is compared to a typical secondary cell. Compare IRFB to a typical secondary cell by stating **one** similarity and **one** difference. 2 marks

_____

_____

_____

_____

d. During discharge, electrode A acts as the negative electrode. Compare whether electrode A acts as cathode or anode, and whether it is the positive or negative electrode during the discharge and recharge reactions. Explain your answer. 2 marks

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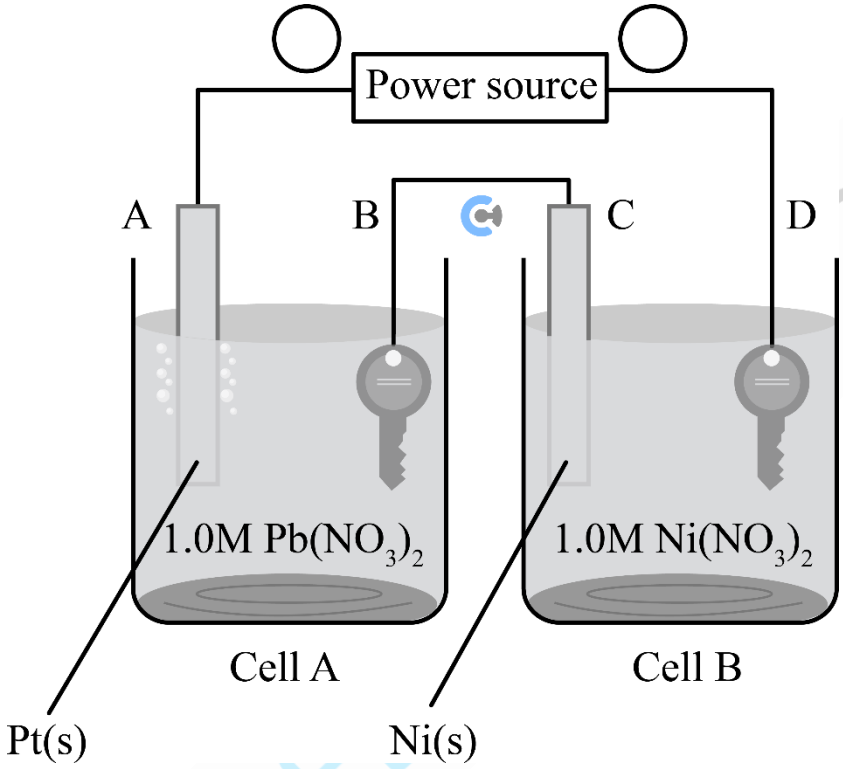
Question 11 (9 marks)

Two identical copper keys with identical mass are to be electroplated according to the connected cell below, whereby the electrode A is made of platinum metal, and electrode C is made of nickel metal. The electrolyte of Cell A contains $100\ mL$ of $1.0\ M\ \mathrm{Pb(NO_3)_2}$, whereas the electrolyte of Cell B contains $100\ mL$ of $1.0\ M\ \mathrm{Ni(NO_3)_2}$.



a. Label the polarities of the power source for the metals to be electroplated onto the respective keys in the circles provided above. 1 mark

b. Write the balanced half-equations for the reaction which occurs within cell B at the: 2 marks

Positive electrode: _____

Negative electrode: _____

c. After some time has elapsed, the concentration of $\mathrm{Pb}^{2+}(\mathrm{aq})$ ions in Cell A is seen to decrease, but the volume still remains at $100\ mL$.

i. State how the concentration of $\mathrm{Ni}^{2+}(\mathrm{aq})$ ions in Cell B will change. Explain your answer. 1 mark

ii. Find the initial amount of $\mathrm{Pb}^{2+}(\mathrm{aq})$ ions present in the solution before electrolysis occurred in moles. 1 mark

iii. Given that the power source provides a current of $2.20\ A$ for $20.0\ min$, find the final concentration of $\mathrm{Pb}^{2+}(\mathrm{aq})$ ions present. 4 marks

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 $4.44 \pm 0.02\ V$ at $25°\mathrm{C}$, 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. The 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 '$\mathrm{X}^+(\mathrm{aq})$' is to be placed in the electrochemical series in the following reaction:

$$\mathrm{X}^+(\mathrm{aq}) + \mathrm{e}^- \rightleftharpoons \mathrm{X}(\mathrm{s})$$

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

- **Reaction 1:** When placed directly in a beaker and $\mathrm{Zn}(\mathrm{s})$ is placed inside, the zinc begins to corrode.
- **Reaction 2:** When placed in a $2.0\ M\ \mathrm{KOH}$ solution, bubbles are produced.
- **Reaction 3:** When placed in a solution with $1.0\ M\ \mathrm{NaBr}$, 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 $\mathrm{X}^+(\mathrm{aq})$.

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

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