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VCE Chemistry ¾
AOS 1 Revision II [1.12]
Contour Check

Contour Checklist

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Section A: [1.6] – Introduction to Redox (Checkpoints) (43 Marks)

Sub-Section [1.6.1]: Apply Oxidation Numbers to Find Oxidant & Reductant

Question 1 (4 marks)

State the oxidation number for the element specified in the molecule/ion provided.

a. Oxidation number of chromium in CrO_4^{2-}. (1 mark)

_____

_____

b. Oxidation number of sulphur in SO_3^{2-}. (1 mark)

_____

_____

c. Oxidation number of phosphorus in $H_2PO_4^-$. (1 mark)

_____

_____

d. Oxidation number of nitrogen in NO_3^-. (1 mark)

_____

_____

Space for Personal Notes

Question 2 (4 marks)

Natalie is investigating the following chemical reaction:

$$ZnO(s) + C(s) \rightarrow Zn(s) + CO_2(g)$$

a. Find the oxidation numbers for all atoms in the following molecules:

i. C. (1 mark)

_____

ii. CO_2. (1 mark)

_____

_____

b. Hence, determine and justify whether C (carbon) is a reductant or an oxidant. (2 marks)

_____

_____

_____

_____

Space for Personal Notes

Question 3 (4 marks)

Kanta is observing the following reaction occurring at school:

$$2Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6I^-(aq) \rightarrow 2Cr^{3+}(aq) + 3I_2(g) + 7H_2O(l)$$

His friend explains that the reducing agent in this reaction is $Cr_2O_7^{2-}$. Evaluate Kanta's friend's statement, using calculations as justification.

Question 4

In an acidic solution, ascorbic acid ($C_6H_8O_6$) reacts with dichromate ions ($Cr_2O_7^{2-}$), resulting in the formation of chromium (III) ions (Cr^{3+}) and dehydroascorbic acid ($C_6H_6O_6$).

$$C_6H_8O_6(aq) + Cr_2O_7^{2-}(aq) + 8H^+(aq) \rightarrow C_6H_6O_6(aq) + 2Cr^{3+}(aq) + 4H_2O(l)$$

A friend claims that $\mathbf{C_6H_8O_6}$ is the reducing agent in this reaction. Evaluate this claim and justify your response with the relevant calculations.

Sub-Section [1.6.2]: Apply KOHES to Write Balanced Half-Equations in Acidic & Basic Conditions

Question 5 (2 marks)

Perchlorate ions (ClO_4^-) turn into chlorine gas (Cl_2) in a laboratory.

a. Write the half-equation in acidic conditions. (1 mark)

b. Write the half-equation in alkaline conditions. (1 mark)

Question 6 (4 marks)

Complete the balanced half-equation for each of the following, and state whether it is a reduction or oxidation reaction.

a. Copper (II) ions turning into copper solid. (1 mark)

b. Silver oxide (Ag_2O) turning into silver solid. (1 mark)

c. Butanol (C_4H_9OH) turning into butanoic acid ($C_4H_8O_2$). (1 mark)

_____

_____

d. Nitrous oxide (N_2O) turning into nitrogen gas (N_2). (1 mark)

_____

_____

Question 7 (4 marks)

In acidic conditions, potassium permanganate ($KMnO_4$) can react and turn into manganese ions (Mn^{2+}).

a. Write a balanced half-equation for this process. (1 mark)

_____

_____

b. State whether this is an oxidation or reduction reaction and justify why. (2 marks)

_____

_____

_____

_____

c. Hence or otherwise, is Mn^{2+} an oxidant or reductant? (1 mark)

_____

_____

Question 8 (4 marks)

In acidic conditions, potassium dichromate ($K_2Cr_2O_7$) reacts and turns into chromium (III) ions (Cr^{3+}).

a. Write a balanced half-equation for the reduction of potassium dichromate to chromium (III) ions in acidic conditions. (1 mark)

_____

_____

b. State whether this is an oxidation or reduction reaction and justify why. (2 marks)

_____

_____

_____

_____

c. Hence or otherwise, is Cr^{3+} an oxidant or reductant? (1 mark)

_____

_____

Space for Personal Notes

Sub-Section [1.6.3]: Apply KOHES to Write Balanced Half-Equations and Overall Equations in Acidic & Basic Conditions

Question 9 (4 marks)

Express the overall equation using the half-equations provided.

a. Oxidation half-equation: (2 marks)

$$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^{-}$$

Reduction half-equation:

$$Cr_2O_7{}^{2-}(aq) + 14H^{+}(aq) + 6e^{-} \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$$

b. Oxidation half-equation: (2 marks)

$$2Cl^{-}(aq) \rightarrow Cl_2(g) + 2e^{-}$$

Reduction half-equation:

$$2H^{+}(aq) + 2e^{-} \rightarrow H_2(g)$$

Space for Personal Notes

Question 10 (4 marks)

Zinc (II) Zn^{2+} can be formed from zinc solid, Zn, when reacted with dichromate ions ($Cr_2O_7^{2-}$). Cr^{3+} ions are formed in the process.

Write the balanced equation for:

a. The oxidation reaction. (1 mark)

_____

_____

b. The reduction reaction. (1 mark)

_____

_____

c. The overall reaction. (2 marks)

_____

_____

_____

_____

Space for Personal Notes

Question 11 (4 marks)

Sodium (Na) reacts with water in an alkaline environment to form sodium hydroxide and hydrogen gas.

Write the balanced equation for:

a. The oxidation reaction. (1 mark)

_____

_____

b. The reduction reaction. (1 mark)

_____

_____

c. The overall reaction. (2 marks)

_____

_____

_____

_____

Space for Personal Notes

Question 12 (5 marks)

In the paper industry, bleaching is a crucial process to eliminate colour from pulp, ensuring the production of high-quality paper. Chlorine or chlorine compounds are commonly used in redox reactions to oxidise and remove impurities, enhancing the paper's brightness and quality.

a. Chlorine gas is used in a reaction with water. This purifies pulp and produces Hydrochloric acid(HCl) and hypochlorous acid (HOCl).

Write a balanced equation for the:

i. Oxidation reaction. (1 mark)

_____

ii. Reduction reaction. (1 mark)

_____

iii. Overall reaction. (1 mark)

_____

_____

b. Hydrochloric acid (HCl) is also often used as an alternative to using chlorine gas. HCl can undergo the following reaction:

$$HCl(aq) + NaOH(aq) \rightarrow H_2O(l) + NaCl(aq)$$

State and explain whether the above reaction is a redox reaction. (2 marks)

_____

_____

_____

_____

Space for Personal Notes

Section B: [1.7] – Spontaneous Redox Reactions (Checkpoints) (34 Marks)

Sub-Section [1.7.1]: Apply the ECS to Predict Spontaneous Reactions

Question 13 (3 marks)

Write the (i) oxidation and (ii) half equations for each of the following spontaneous reactions.

a. Sarah reacts magnesium metal (Mg) with hydrochloric acid (HCl) in an aqueous solution.

i. Oxidation half equation. (0.5 marks)

_____

ii. Reduction half equation. (0.5 marks)

_____

b. Liam reacts aluminium metal (Al) with iron (III) chloride ($FeCl_3$) in aqueous solution.

i. Oxidation half equation. (0.5 marks)

_____

ii. Reduction half equation. (0.5 marks)

_____

c. Emma reacts lead (II) nitrate ($Pb(NO_3)_2$) with solid zinc (Zn).

i. Oxidation half equation. (0.5 marks)

_____

ii. Reduction half equation. (0.5 marks)

_____

Question 14 (3 marks)

Write the (i) oxidation and (ii) half equations for each of the following spontaneous reactions.

a. Rebecca reacts tin (II) chloride ($SnCl_2$) with iron (III) nitrate ($Fe(NO_3)_3$) in an aqueous solution.

i. Oxidation half equation. (0.5 marks)

_____

ii. Reduction half equation. (0.5 marks)

_____

b. Kevin reacts hydrogen peroxide (H_2O_2) with permanganate ions (MnO_4^-) in an aqueous solution.

i. Oxidation half equation. (0.5 marks)

_____

ii. Reduction Half equation. (0.5 marks)

_____

Space for Personal Notes

Question 15 (4 marks)

Write the (i) oxidation and (ii) half equations for each of the following spontaneous reactions.

a. Sophia adds tin (II) chloride ($SnCl_2$) to a solution containing potassium dichromate ($K_2Cr_2O_7$) and hydrogen peroxide (H_2O_2) in aqueous conditions.

i. Oxidation half equation. (1 mark)

_____

_____

ii. Reduction half equation. (1 mark)

_____

_____

b. Angela adds iron (III) chloride ($FeCl_3$), hydrogen peroxide (H_2O_2), and sulphuric acid (H_2SO_4) in aqueous medium.

i. Oxidation half equation. (1 mark)

_____

_____

ii. Reduction half equation. (1 mark)

_____

_____

Space for Personal Notes

Question 16 (2 marks)

Vivek is given the following electrochemical series for some reactions that are not occurring at SLC.

$Sn^{4+}(aq) + 2e^- \rightleftharpoons Sn^{2+}(aq)$	$+0.1$
$Cu^{2+}(aq) + 2e^- \rightleftharpoons Cu(s)$	$+0.25$
$I_2(s) + 2e^- \rightleftharpoons 2I^-(aq)$	$+0.69$
$Zn^{2+}(aq) + 2e^- \rightleftharpoons Zn(s)$	-0.90

Vivek adds copper (II), iodide, and tin (IV) ions to a beaker. Following this, he adds a strip of zinc metal.

Predict the half equations of the reaction occurring.

a. Oxidation reaction. (1 mark)

_____

b. Reduction reaction. (1 mark)

_____

Space for Personal Notes

Sub-Section [1.7.2]: Identify Differences Between Direct & Indirect Redox Reactions, & Features of ECS

Question 17 (4 marks)

Betty is analysing a reaction between oxygen gas (O_2) and iron metal (Fe).

a. State and justify using chemical equations whether the reaction is spontaneous. (2 marks)

b. When Betty sets up this reaction in the laboratory, she notices no reaction occurring. Provide a justification for this observation. (1 mark)

c. Provide a physical application of this chemical reaction. (1 mark)

Space for Personal Notes

Question 18 (2 marks)

Precious adds a strip of magnesium (Mg) to a beaker containing a 1.0 *M* aqueous solution of aluminium phosphate ($AlPO_4$).

a. Predict the half-reactions occurring in the beaker.

i. Oxidation reaction. (0.5 marks)

_____

_____

ii. Reduction reaction. (0.5 marks)

_____

_____

b. State the type of energy conversion occurring in this chemical reaction. (1 mark)

_____

Question 19 (2 marks)

State the role of the Standard Hydrogen Electrode (SHE) in the electrochemical series.

_____

_____

_____

_____

Space for Personal Notes

Question 20 (3 marks)

Discuss the limitations of the electrochemical series when applied to real-world chemical reactions.

Space for Personal Notes

Sub-Section [1.7.3]: Find the Strongest Oxidants/Reductants by Constructing Your Own ECS

Question 21 (4 marks)

a. There are three unknown substances J, K, and L. The following half-equations are given, but their $E°$ values are not given.

Reaction
$J^{2+}(aq) + 2e^- \rightarrow J(s)$
$K^{2+}(aq) + 2e^- \rightarrow K(s)$
$L^{2+}(aq) + 2e^- \rightarrow L(s)$

It is known that when J is mixed into a solution of L^{2+}, a reaction begins to occur.

It is also known that when K is mixed into a solution of L^{2+}, no reaction occurs.

Rank the three metals in terms of their decreasing oxidant strength. (2 marks)

_____

_____

_____

_____

b. There are three unknown substances A, B, and C. The following half-equations are given, but their $E°$ values are not given.

Reaction
$A^{2+}(aq) + 2e^- \rightarrow A(s)$
$B^{2+}(aq) + 2e^- \rightarrow B(s)$
$C^{2+}(aq) + 2e^- \rightarrow C(s)$

i. A plastic rod coated in metal A reacts vigorously with a solution of $B(NO_3)_2$ and CSO_4.

ii. Metal C is able to react with B^{2+} but not with A^{2+}.

Rank the three metals in terms of their decreasing oxidant strength. (2 marks)

_____

_____

_____

_____

Space for Personal Notes

Question 22 (3 marks)

Four unknown substances P, Q, R, and S are present. The half-equations are provided without $E°$ values.

$$P^{2+}(aq) + 2e^- \rightarrow P(s)$$

$$Q^{+}(aq) + e^- \rightarrow Q(g)$$

$$R^{3+}(aq) + 3e^- \rightarrow R(s)$$

$$S^{+}(aq) + e^- \rightarrow S(l)$$

The following observations are recorded:

1. When Q^+ is added to P , no reaction occurs.
2. When R^{3+} is added to P, the beaker becomes warmer.
3. However, no reaction is observed when S^+ is added to P.

Rank the four substances in increasing reductant strength.

Space for Personal Notes

Question 23 (4 marks)

A scientist is given five metals and 1 *M* solutions of their nitrates.

The metals are labelled A, B, C, D, and E and the solutions are labelled A^{2+}, B^{2+}, C^{2+}, D^{2+}, and E^{2+}.

The scientist carries out several experiments, and the results obtained are as follows:

1. When metal A is dipped into all solutions, it reacts vigorously with D^{2+} and E^{2+}, but no reaction occurs with B^{2+} or C^{2+}.
2. When metal D is dipped into all solutions, it reacts only with E^{2+}.
3. Metal C, when dipped into solutions, reacts with A^{2+} but not with B^{2+}.

a. State the strongest oxidant and reductant. (2 marks)

_____

_____

b. Rank the metals in terms of decreasing $E°$ values. (2 marks)

_____

_____

_____

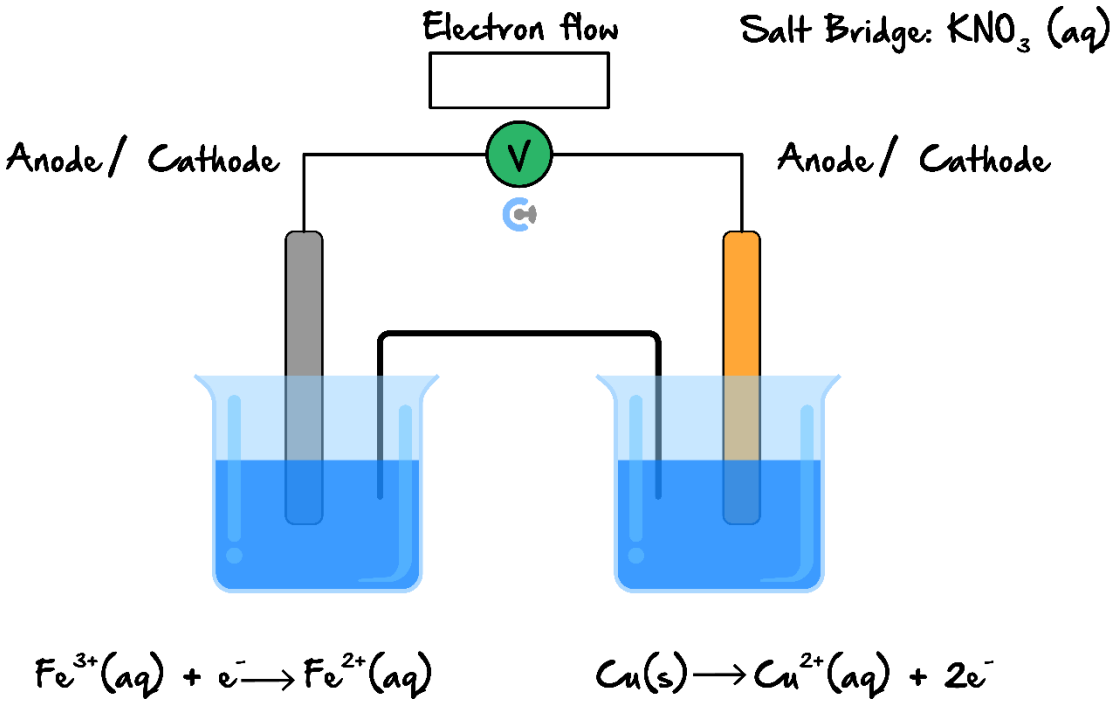
_____

Space for Personal Notes

Section C: [1.8] – Galvanic Cells (Checkpoints) (26 Marks)

Sub-Section [1.8.1]: Identify Electrodes, Salt Bridge/Electron Movement during Galvanic

Question 24 (3 marks)

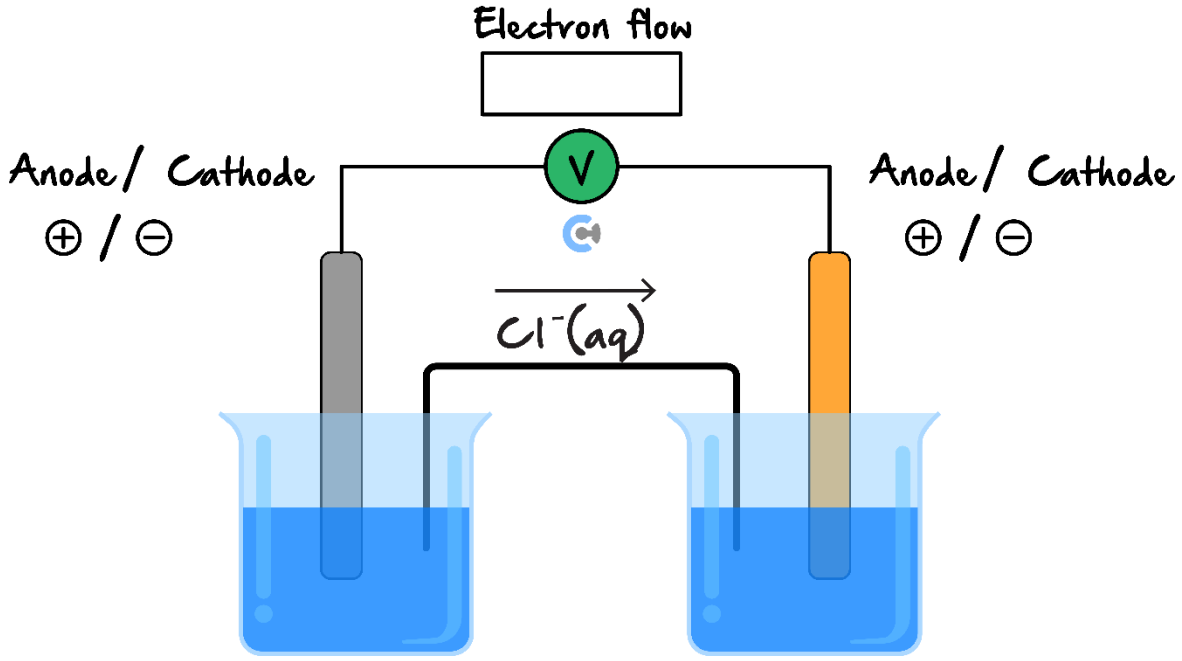


Use the provided diagram of a galvanic cell, and label the cathode, anode, electron flow and ion movement in the salt bridge.

Space for Personal Notes

Question 25 (3 marks)

Use the provided galvanic cell diagram to label the cathode, anode, electrode polarities and electron flow.



Space for Personal Notes

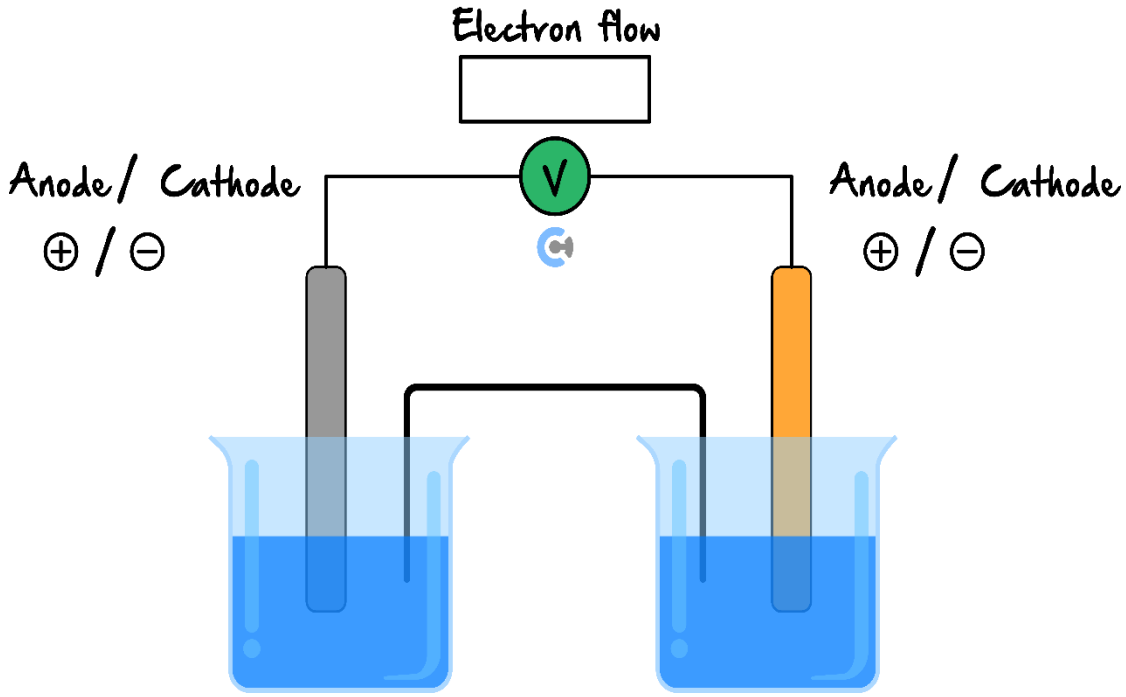
Question 26 (3 marks)

Use the provided half-equations:

$$\mathbf{Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-}$$

$$\mathbf{Sn^{2+}(aq) + 2e^- \rightarrow Cu(s)}$$

Draw the galvanic cell, labelling the anode, cathode, electron flow, ion movement in the salt bridge and electrode polarities.

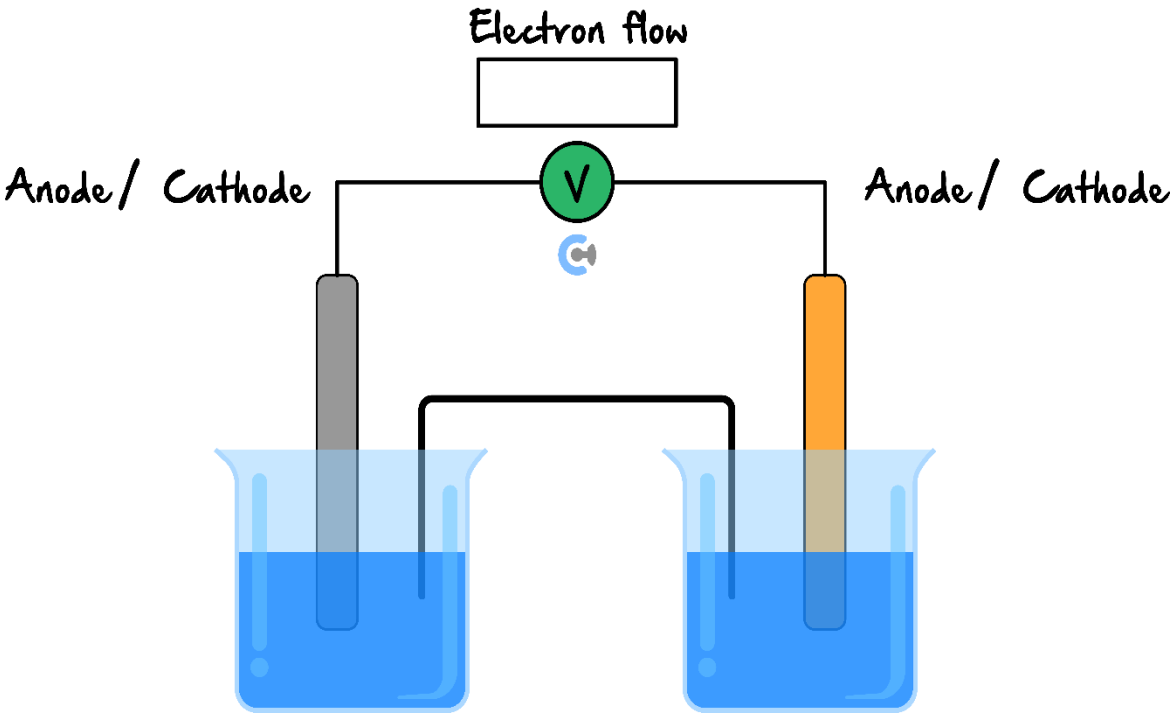


Space for Personal Notes

Sub-Section [1.8.2]: Write Reactions in Galvanic Cells & Calculate the Maximum EMF Produced

Question 27 (5 marks)

Matthias is interested in the Sn-Sn^{4+}(aq) galvanic cell.



a. Write the half-equations for this cell. (2 marks)

_____

_____

_____

b. Label the cathode, anode, their polarities and electron flow in the diagram above. (3 marks)

Space for Personal Notes

Question 28 (7 marks)

Angel is curious about the Cu^{2+}/Cu^{+} and Cr^{3+}/Cr^{2+} half-cell. The half-equation for the cells and their relative $E°$ values are provided.

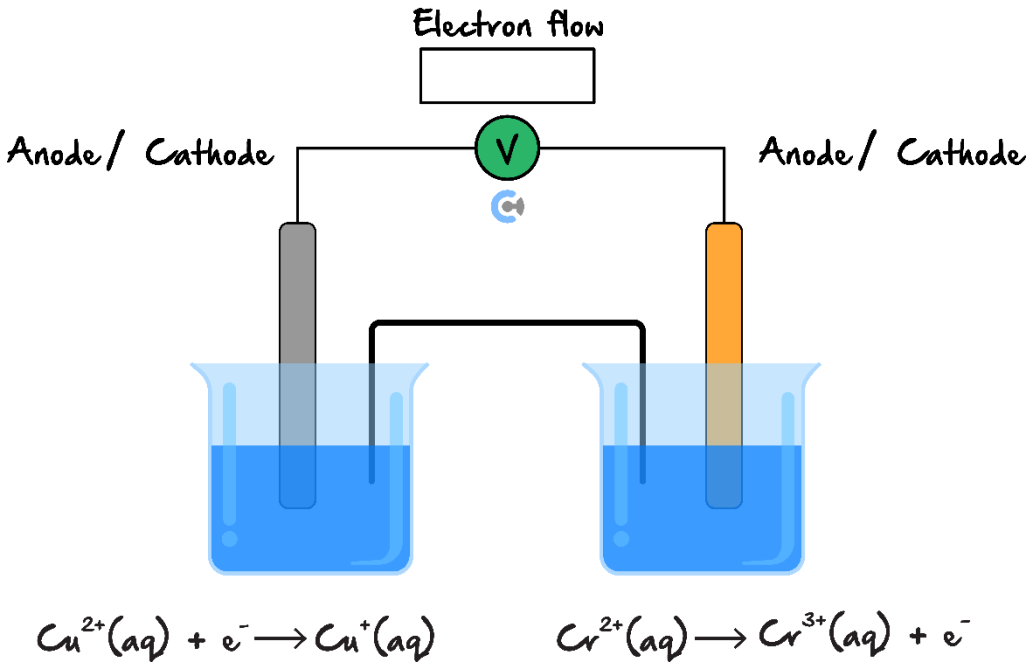
$$Cr^{3+}(aq) + e^{-} \rightarrow Cr^{2+}(aq) \quad E° = -0.41\,V$$

$$Cu^{2+}(aq) + e^{-} \rightarrow Cu^{+}(aq) \quad E° = +0.15\,V$$

a. Write the half-equations for the galvanic cell. (2 marks)

b. Calculate the EMF of the cell. (2 marks)

c. Label the galvanic cell in Angel's experiment. (3 marks)

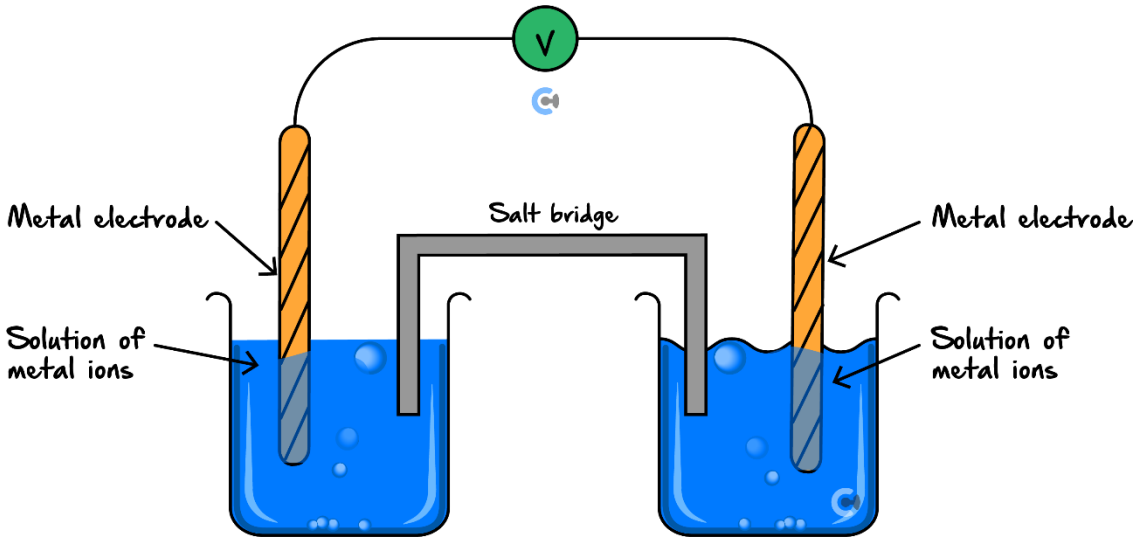


Question 29 (1 mark)

Four half-cells are constructed as follows.

- **Half-cell I:** An electrode of metal X in a 1.0 *M* solution of X^+ ions.
- **Half-cell II:** An electrode of metal Y in a 1.0 *M* solution of Y^+ ions.
- **Half-cell III:** An electrode of metal Z in a 1.0 *M* solution of Z^+ ions.
- **Half-cell IV:** An electrode of W metal in a 1.0 *M* solution of W^{2+} ions.

The half-cells are connected in pairs as shown below to form a series of galvanic cells.



Half-Cells Used	Positive Electrode	Negative Electrode	Voltage Produced (*V*)
I and IV	X	W	0.35
II and IV	W	Y	0.45
III and IV	W	Z	1.20
II and III	Y	Z	0.65

Which of the following alternatives lists the metals in order of increasing strength as reductants?

A. Z, Y, W, X

B. X, W, Y, Z

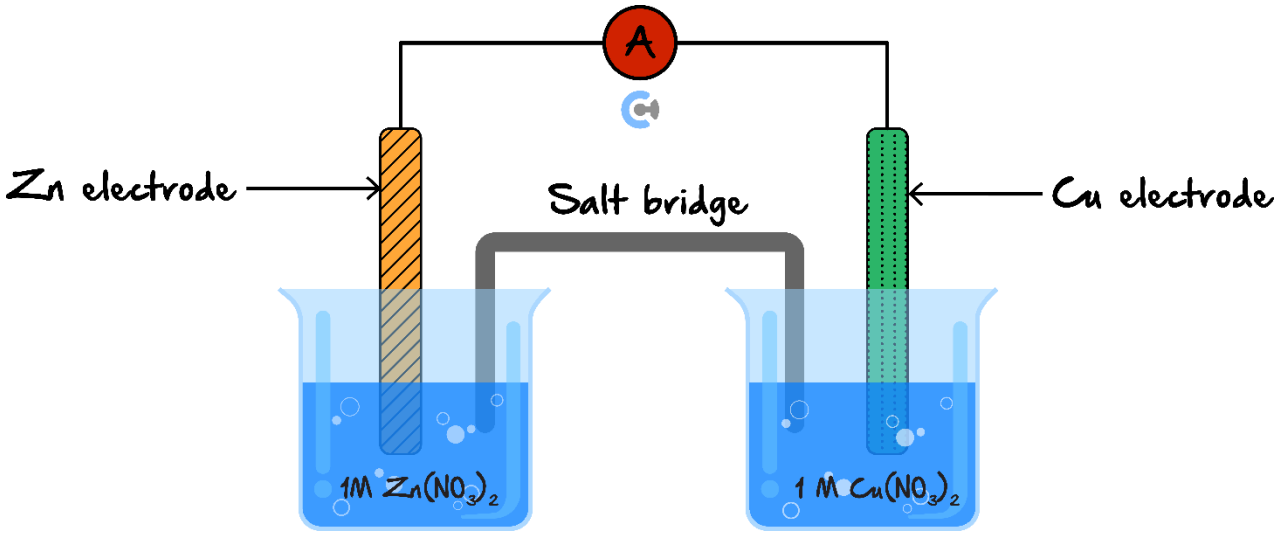
C. W, X, Z, Y

D. Z, W, X, Y

Sub-Section [1.8.3]: Identify & Explain Observations during Operation of Galvanic Cells

Question 30 (1 mark)

A galvanic cell is set up as shown in the diagram below with Zn/Zn^{2+} and Cu/Cu^{2+} half-cells.



When this cell is operating:

A. A gas forms at the Zn electrode.

B. The mass of the Cu electrode increases.

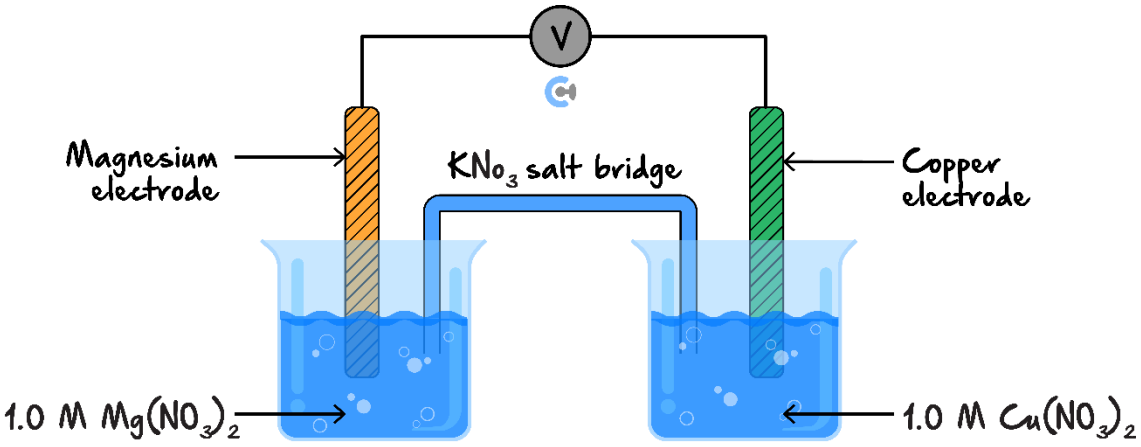
C. Zn^{2+} ions move towards the salt bridge.

D. Electrons move from the Cu electrode to the Zn electrode.

Space for Personal Notes

Question 31 (2 marks)

The following diagram is relevant to the two questions below.



a. Which one of the following statements about the cell above is true as the cell discharges? (1 mark)

A. The copper electrode is the anode.

B. The concentration of Mg^{2+} ions will increase.

C. The maximum voltage delivered by this cell will be 2.71 V.

D. Electrons in the external circuit will flow from the magnesium electrode to the copper electrode.

b. What should be observed at the magnesium electrode as the cell discharges? (1 mark)

A. No change will be observed at this electrode.

B. The electrode will become thinner as magnesium dissolves into the solution.

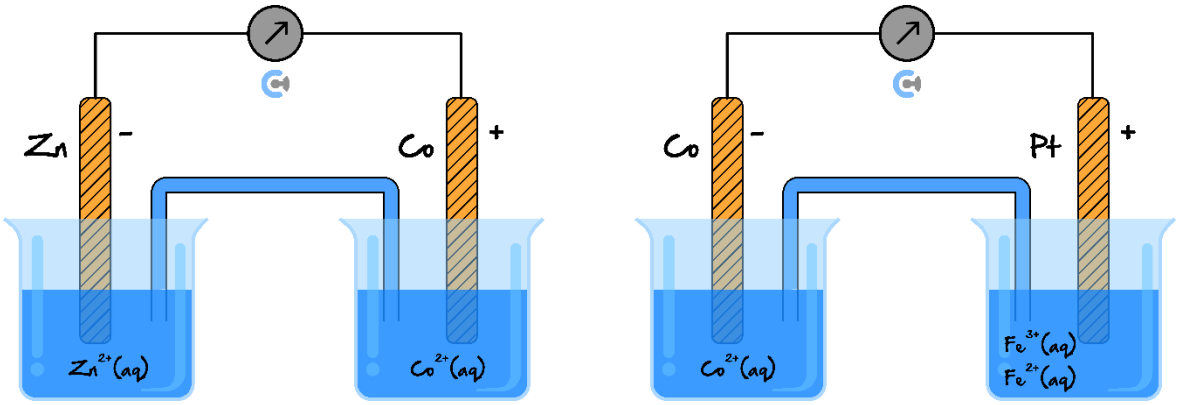
C. Crystals will form over the surface of the electrode.

D. Bubbles of gas will form over the surface of the electrode.

Space for Personal Notes

Question 32 (1 mark)

Two standard galvanic cells are shown below.



On the basis of the polarity of the electrodes shown above, which one of the following reactions would **not** be expected to occur spontaneously? (1 mark)

A. $Co^{2+}(aq) + Zn(s) \rightarrow Co(s) + Zn^{2+}(aq)$

B. $2Fe^{3+}(aq) + Co(s) \rightarrow 2Fe^{2+}(aq) + Co^{2+}(aq)$

C. $2Fe^{3+}(aq) + Zn(s) \rightarrow 2Fe^{2+}(aq) + Zn^{2+}(aq)$

D. $2Fe^{2+}(aq) + Co^{2+}(aq) \rightarrow 2Fe^{3+}(aq) + Co(s)$

Space for Personal Notes

Section D: [1.9] – Fuel Cells (Checkpoints) (62 Marks)

Sub-Section [1.9.1]: Write Fuel Cell Half & Overall Reactions in Acidic Conditions

Question 33 (2 marks)

Consider a fuel cell between hydrogen gas, as the fuel, and oxygen gas. Remember to include states in your answer.

a. Hydrogen gas. (1 mark)

_____

b. Oxygen gas. (1 mark)

_____

Question 34 (3 marks)

For each of the following, write the balanced half-equation for the reaction occurring at the anode in acidic conditions. Assume that carbon dioxide is produced.

a. A fuel cell involving ethanol as a reactant. (1 mark)

_____

b. A fuel cell involving ethane as a reactant. (1 mark)

_____

c. A fuel cell involving propanol as a reactant. (1 mark)

_____

Question 35 (4 marks)

Write the half-equations for the fuel cell reaction involving butanol and oxygen gas.

a. Reduction half-equation. (1 mark)

_____

b. Oxidation half-equation. (2 marks)

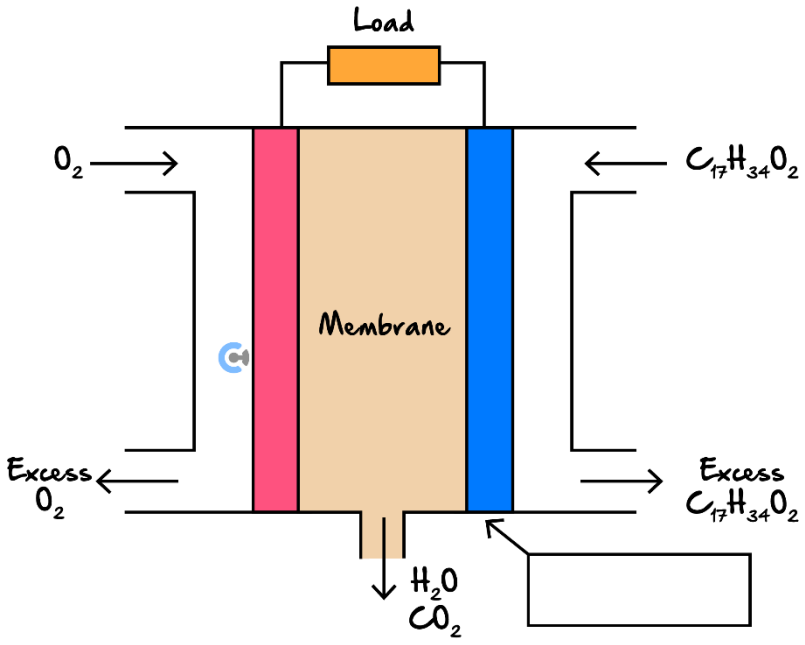
_____

c. Overall reaction. (1 mark)

_____

Question 36 (7 marks)

Biodiesel is an example of a renewable fuel. Some farming equipment manufacturers have tried to make a fuel cell in order to more efficiently use leftover livestock feed. A diagram of an acidic biodiesel fuel cell is shown below.



a. Identify the electrode as either the cathode or the anode in the box provided in the diagram above. (1 mark)

b. Write the half-equation for the reaction occurring at the anode. (2 marks)

_____

c. Write a balanced equation for the overall reaction which takes place at SLC. (2 marks)

_____

d. Explain whether this cell would be considered renewable or not. (2 marks)

_____

_____

_____

_____

Space for Personal Notes

Sub-Section [1.9.2]: Identify Key Features of Fuel Cells Including Continuous Supply, Electrolyte Movement, and Properties of Electrodes

Question 37 (2 marks)

Explain the key characteristics of a fuel cell.

_____

_____

Question 38 (3 marks)

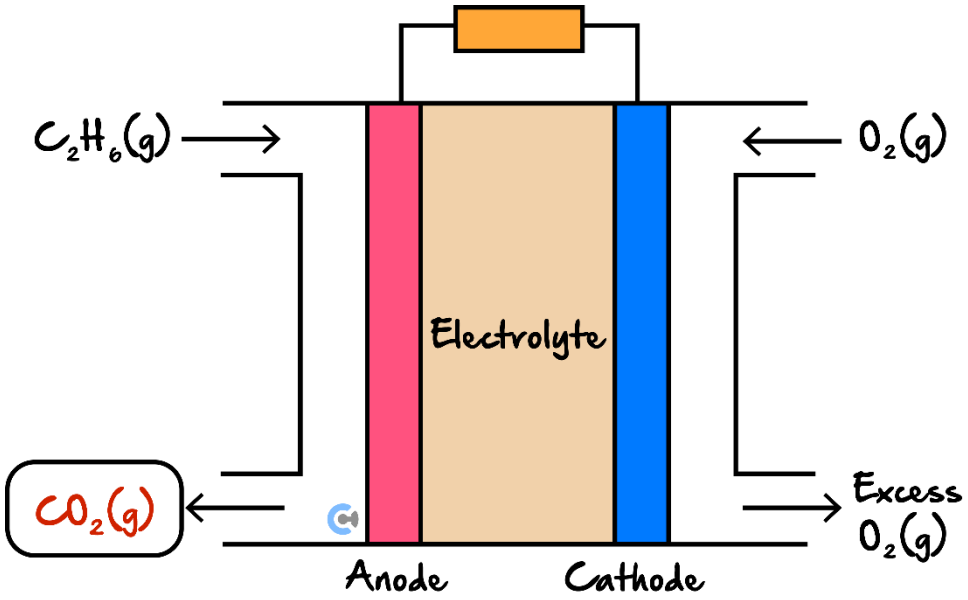
For the following table, mark each statement as either True or False, with regards to a fuel cell involving methane and oxygen gas in acidic conditions.

Statement	True	False
a. The overall reaction is the same as combustion.		
b. Electrons flow from the anode to the cathode.		
c. Oxygen reacts at the anode.		
d. Electrodes must always be inert.		
e. The energy conversion is direct.		

Space for Personal Notes

Question 39 (5 marks)

Ethane is a common fuel used in fuel cells.



a. Write the balanced redox reaction for:

i. The half-reaction occurring at the anode. (1 mark)

_____

ii. Label the main product in the blank box provided above. (1 mark)

b. State three different qualities electrodes in fuel cells must possess. (3 marks)

_____

_____

_____

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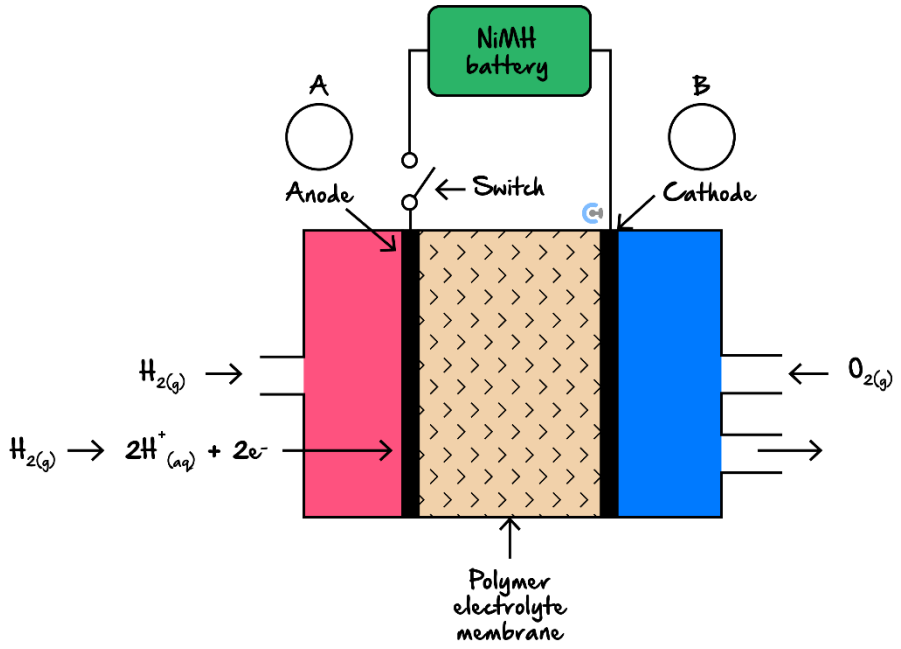
Question 40 (6 marks)

An example of the real-life design of a hydrogen fuel cell is shown below.



a. On the diagram above, indicate the polarity of the anode and cathode in circles *A* and *B*. (1 mark)

b. Write the overall reaction occurring in the cell. (1 mark)

_____

c. Explain the function of the polymer electrolyte membrane in the operation of the cell. (2 marks)

_____

_____

_____

d. State and explain whether this cell is more efficient than a typical combustion engine. (2 marks)

_____

_____

_____

Sub-Section [1.9.3]: Explain Advantages & Disadvantages of Fuel Cells with Reference to Green Chemistry Principles

Question 41 (2 marks)

State and explain one reason why we would use a fuel cell over a galvanic cell.

Question 42 (2 marks)

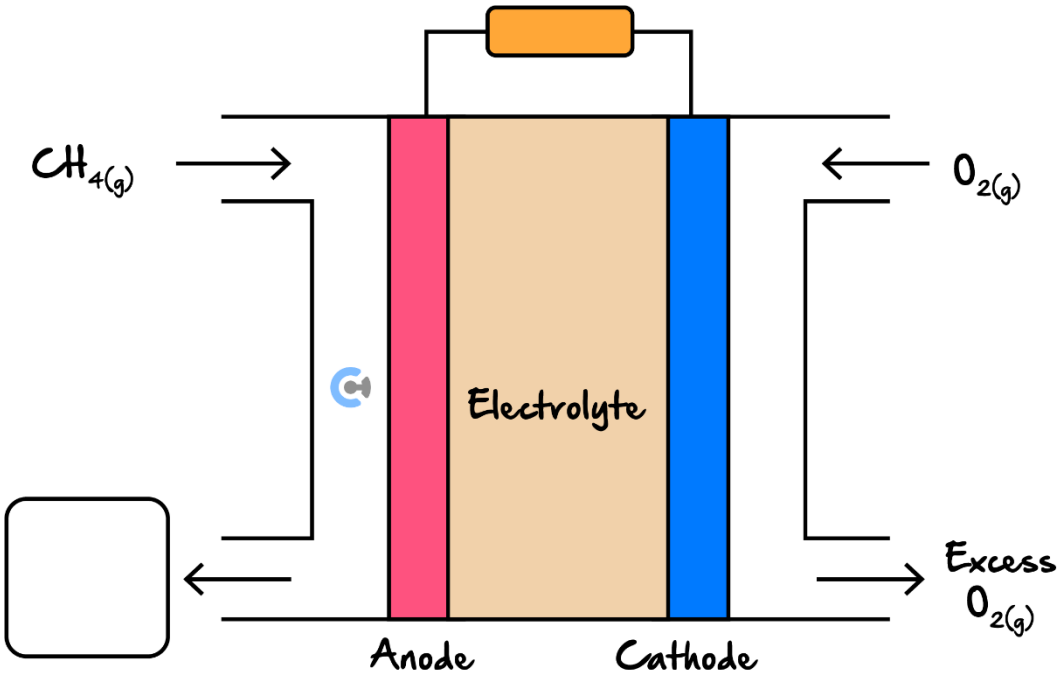
One environmental advantage of using hydrogen fuel cells instead of gas-powered engines is the reduction of greenhouse gas emissions. State one other environmental advantage, referencing green chemistry principles.

Question 43 (3 marks)

State two limitations of hydrogen fuel cells in practical applications.

Question 44 (7 marks)

Methane can be a source of energy in combustion engines. A fuel cell involving methane is shown below.



a. Write the balanced half-equations for the reactions occurring at the:

i. Anode. (1 mark)

_____

ii. Cathode. (1 mark)

_____

b. In the diagram above, label the expected product(s) at the anode. (1 mark)

c. Compare the efficiency and viability of a combustion engine as opposed to a fuel cell, referencing green chemistry principles. (2 marks)

_____

_____

_____

d. A scientist is aiming to produce an engine that can produce mass amounts of energy at a single time. Explain whether he should use a fuel cell or an internal combustion engine. (2 marks)

_____

_____

_____

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Sub-Section [1.9.4]: Write Fuel Cell Equations in Non-Acidic Conditions

Question 45 (1 mark)

Write the balanced oxidation half-equation in basic conditions of methane oxidising into carbon dioxide.

_____

Question 46 (3 marks)

For each of the following, write the balanced oxidation half-equation in basic conditions. Assume CO_2 is the only carbon product formed.

a. A fuel cell involving ethane as a reactant. (1 mark)

_____

_____

b. A fuel cell involving propanol as a reactant. (1 mark)

_____

_____

c. A fuel cell involving methanol as a reactant. (1 mark)

_____

_____

Space for Personal Notes

Question 47 (5 marks)

The overall equation for an unknown fuel cell is shown below, in alkaline conditions.

$$X(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$$

a. What is the equation for the reaction that occurs at the cathode? (1 mark)

_____

b. If the fuel itself was an alkane, what could its identity be? (2 marks)

_____

c. Hence, write the half-equation for the reaction that would occur at the anode. (2 marks)

_____

_____

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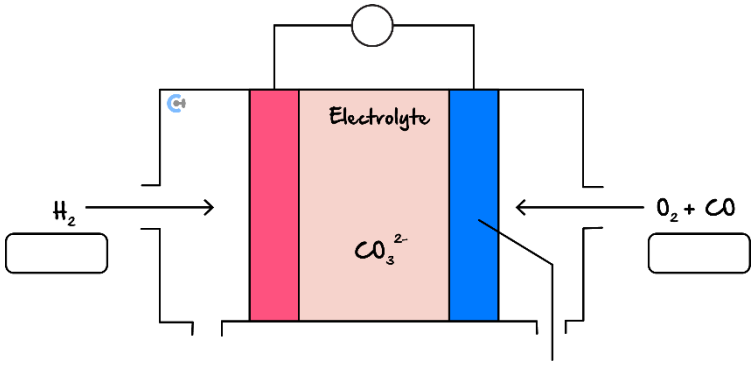
Question 48 (7 marks)

A simplified diagram of a molten carbonate fuel cell (MCFC) is shown below.



In this MCFC, hydrogen is being used as a reactant alongside $O_2(g)$ in order to produce energy. The main carbon-containing product of the cell is carbon monoxide.

a. On the diagram above, label the:

i. Anode and cathode along with the polarities of either electrode. (1 mark)

ii. The direction of electron flow in the external circuit. (1 mark)

b. Write a balanced half-equation for the cathode. (1 mark)

_____

c. Write the balanced half-equation for the anode. (2 marks)

_____

d. Explain one property of the electrodes in this fuel cell. (2 marks)

_____

_____

_____

Space for Personal Notes

Section E: [1.10] – Primary Cells & Faraday's Laws (Checkpoints) (25 Marks)

Sub-Section [1.10.1]: Identify Features of Primary Cells & How They Operate

Question 49 (3 marks)

Sodium metal is commonly used in batteries, especially in alkaline and sodium-carbon cells for daily consumer use.

a. By referring to information provided in the Data Book, give one reason why sodium is used as a reactant in these galvanic cells. (1 mark)

_____

_____

b. When sodium comes into contact with water, an explosion is observed. Using the half equations, explain this observation. (2 marks)

_____

_____

_____

_____

_____

_____

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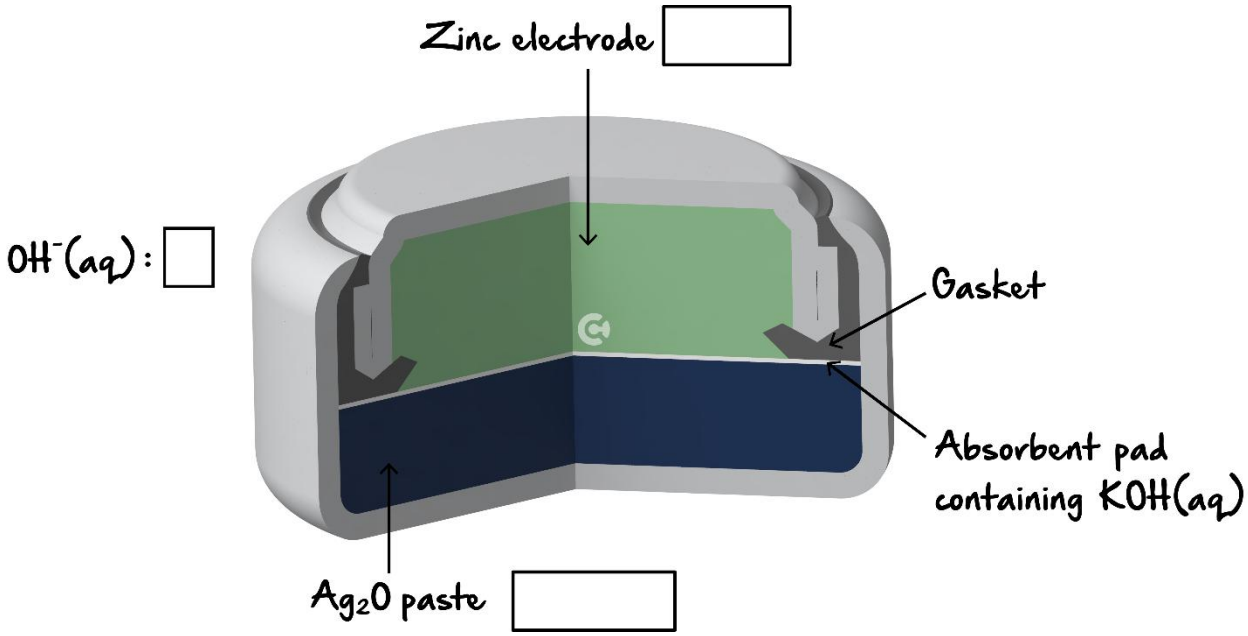
Question 50 (2 marks)

Zinc-mercury oxide batteries are commonly used commercially due to their long battery life and durability. A diagram of the cell has been provided below.



The half equations for the cell have also been provided below:

$$Zn(s) + 2OH^-(aq) \rightarrow ZnO(s) + H_2O(l) + 2e^-$$

$$HgO(s) + H_2O(l) + 2e^- \rightarrow Hg(l) + 2OH^-(aq)$$

a. Label the anode and the cathode in the boxes provided above. (1 mark)

b. Label the direction of movement of the electrolyte in the cell in the box provided above. (1 mark)

Space for Personal Notes

Question 51 (2 marks)

a. What is a key feature of primary cells that allows for their commercial usage over fuel cells? (1 mark)

A. Greater efficiency in the production of energy.

B. Cheaper electrodes that reduce the overall cost of the battery.

C. Separation of reactants into two half-cells is cheaper than a constant supply of reactants.

D. Less specific electrodes that are easier to source.

b. Which of the following outlines the properties required for electrodes in primary cells? (1 mark)

A. Porous, inert, catalytic, conduct electricity.

B. Reactive, catalytic, porous.

C. Conductive of electrons.

D. Porous, inert, conductive.

Space for Personal Notes

Sub-Section [1.10.2]: Apply Faraday's First & Second Law and $Q = It$ & $Q = n(e)F$ to Calculations

Question 52 (4 marks)

Answer the following questions regarding three separate galvanic cells.

a. In a galvanic cell, 250 C of electric charge passes through the circuit in 20 minutes. Calculate the current, in A, running through the cell. (1 mark)

b. In another galvanic cell, 1.46 A of current runs through the cell during a 10.0-minute period. Calculate the moles of electrons produced in the cell. (1 mark)

c. Calculate the moles of zinc (Zn) produced in a cell, when 5.42 A of current is running through the circuit for 35 minutes. The half equation for zinc has been provided below: (2 marks)

$$Zn^{2+}(aq) + 2e^{-} \rightarrow Zn(s)$$

Space for Personal Notes

Question 53 (3 marks)

Joanne has set up a copper-nickel galvanic cell for a school experiment.

a. Write the half equations for the galvanic cell. (1 mark)

_____

_____

b. Joanne ran the cell for 19.5 minutes and found that 8.75 A of current passed through the cell. Calculate the mass of metal deposited on the electrode. (2 marks)

_____

_____

_____

_____

c. The setup is reset and the experiment is run again and Joanne notices 4.55 g of copper produced. Given that 2.45 A of current was passed through the cell, calculate the time (in seconds) for which the cell was running.

_____

_____

_____

_____

_____

_____

Space for Personal Notes

Question 54 (2 marks)

Scott sets up a galvanic cell where chromium metal oxidises to form chromium (III) ions. Given that the change in mass of chromium was 2.55 g and the cell ran for 350 seconds, calculate the current running through the cell.

Space for Personal Notes

Sub-Section [1.10.3]: Calculate the Charge of a Metal

Question 55 (1 mark)

Kevin runs a galvanic cell where 9.54 mol of iron is formed on the cathode. Given that the moles of electrons running through the cell is 3.18 mol, calculate the charge of the iron ions in the cell.

Question 56 (2 marks)

Shiven sets up a galvanic cell in the school laboratory and notes that 27.6 g of manganese metal deposits on the electrode. Given that the amount of electrons running through the cell is 1.01 mol, calculate the charge of the manganese ions in the cell.

Space for Personal Notes

Question 57 (3 marks)

A solution of titanium ions is reduced at a cathode, whereby it is found that a current of 2.75 A is produced over 9.75 hours. It is found that 15.9 g of titanium metal is deposited at the cathode. Find the charge of the titanium ions.

Question 58 (3 marks)

A solution of iodine ions is reduced at a cathode, whereby it is found that a current of 5.80 A is produced over 4.04 hours. It is found that 22.2 g of iodine metal is deposited at the cathode. Find the charge of the iodine ions.

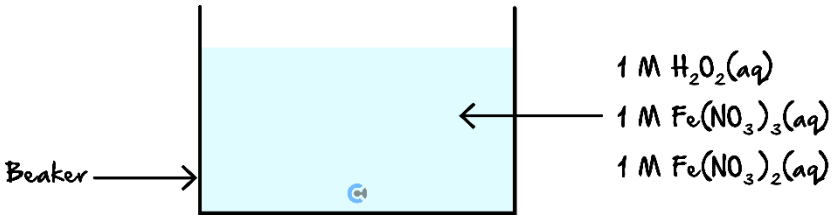
Space for Personal Notes

Section F: [1.6 – 1.10] – Overall (VCAA Qs) (75 Marks)

Question 59 (1 mark)

Inspired from VCAA Chemistry Exam 2023
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2023/2023chemistry-w.pdf

At standard conditions, solutions of hydrogen peroxide, H_2O_2, iron(III) nitrate, $Fe(NO_3)_3$, and iron(II) nitrate, $Fe(NO_3)_2$, were added to a beaker. The initial concentrations of H_2O_2, $Fe(NO_3)_3$ and $Fe(NO_3)_2$ in the beaker were all 1 M.



Which one of the following statements is correct?

A. Iron, Fe, is deposited at the bottom of the beaker.

B. The two half-reactions in the beaker immediately produce 1.09 V.

C. The concentration of $H_2O_2(aq)$ decreases immediately since it is the strongest reducing agent.

D. The temperature of the contents in the beaker decreases immediately when $Fe(NO_3)_3(aq)$ reacts with $H_2O_2(aq)$.

Space for Personal Notes

Question 60 (1 mark)

Inspired by VCAA Chemistry Exam 2020
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2020/2020chem-w.pdf

Consider the following half-equation.

$$ClO_2(g) + e^- \rightleftharpoons ClO_2^-(aq)$$

It is also known that:

- $ClO_2(g)$ will oxidise $HI(aq)$, but not $HCl(aq)$.
- $Fe^{3+}(aq)$ will oxidise $HI(aq)$, but not $NaClO_2(aq)$.

Based on this information, $Fe^{2+}(aq)$ can be oxidised by:

A. $Cl_2(g)$ and $I_2(aq)$.

B. $Cl_2(g)$, but not $ClO_2(g)$

C. $ClO_2(g)$and $Cl_2(g)$, but not $I_2(aq)$.

D. $Cl_2(g)$, $ClO_2(g)$and $I_2(aq)$.

Question 61 (1 mark)

Inspired by VCAA Chemistry Exam 2015
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2015/2015chem-w.pdf

The reaction between hydrogen peroxide and ammonium ions is represented by the following equation.

$$3H_2O_2(aq) + 2NH_4^+(aq) \rightarrow N_2(g) + 2H^+(aq) + 6H_2O(l)$$

Which one of the following is the correct half-equation for the reduction reaction?

A. $H_2O_2(aq) + 2H^+(aq) + 2e^- \rightarrow 2H_2O(l)$

B. $2NH_4^+(aq) \rightarrow N_2(g) + 8H^+(aq) + 6e^-$

C. $2NH_4^+(aq) + 2e^- \rightarrow N_2(g) + 4H_2(g)$

D. $H_2O_2(aq) + 2H_2O(l) \rightarrow 2O_2(g) + 6H^+(aq) + 6e^-$

Question 62 (1 mark)

Inspired by VCAA Chemistry Exam 2020
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2020/2020chem-w.pdf

Hydrogen, H_2, fuel cells and H_2-powered combustion engines can both be used to power cars. Three statements about H_2 fuel cells and H_2-powered combustion engines are given below:

I. Neither H_2 fuel cells nor H_2-powered combustion engines produce greenhouse gases.
II. Less H_2 is required per kilometre travelled when using an H_2-powered combustion engine than when using H_2 fuel cells.
III. More heat per kilogram of H_2 is generated in an H_2-powered combustion engine than in H_2 fuel cells.

Which of the statements above is correct?

A. II only

B. I and II only

C. III only

D. I and III only

Question 63 (1 mark)

Inspired by VCAA Chemistry Exam 2016
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2016/2016chem-amd-w.pdf

Hydrogen peroxide solutions are commercially available and have a range of uses. The active ingredient, hydrogen peroxide, H_2O_2, undergoes decomposition in the presence of a suitable catalyst according to the reaction:

$$2H_2O_2(l) \rightarrow 2H_2O(l) + O_2(g)$$

In this reaction, oxygen:

A. Only undergoes oxidation.

B. Only undergoes reduction.

C. Undergoes both oxidation and reduction.

D. Undergoes neither oxidation nor reduction.

Space for Personal Notes

Question 64 (1 mark)

The following two unbalanced equations represent processes which are part of the nitrogen cycle.

I. $NH_3(aq) \rightarrow NH_4^+(aq)$
II. $NH_4^+(aq) \rightarrow NO_3^-(aq)$

Which one of the following alternatives correctly describes the reactants in each of these processes?

	In process I, $NH_3(aq)$ is	**In process II, the $NH_4^+(aq)$ ion is**
A.	an acid	reduced
B.	a base	reduced
C.	an acid	oxidised
D.	a base	oxidised

Space for Personal Notes

Question 65 (1 mark)

Inspired by VCAA Chemistry Exam 2023
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2023/2023chemistry-w.pdf

Consider the half-cell equations and their half-cell potentials in the table below.

Half-Cell Equations	Standard Electrode Potential ($E°$) in volts at 25℃
$Mn^{3+}(aq) + e^- \rightleftharpoons Mn^{2+}(aq)$	$+1.56$
$SO_3^{2-}(aq) + 3H_2O(l) + 4e^- \rightleftharpoons S_2O_3^{2-}(aq) + 6OH^-(aq)$	-0.57
$SO_4^{2-}(aq) + H_2O(l) + 2e^- \rightleftharpoons SO_3^{2-}(aq) + 2OH^-(aq)$	-0.94
$Mn^{2+}(aq) + 2e^- \rightleftharpoons Mn(s)$	-1.18

A galvanic cell contains $S_2O_3^{2-}(aq)$, $SO_3^{2-}(aq)$ and $OH^-(aq)$ with a platinum electrode in the first half-cell and $Mn^{3+}(aq)$ and $Mn^{2+}(aq)$ in the second half-cell. All solutions are IM solutions and the cell is at SLC.

The galvanic cell will deliver:

A. 2.50 V if the electrode in the second half-cell is $Mn(s)$.

B. 2.50 V if the electrode in the second half-cell is $Pt(s)$.

C. 1.75 V if the electrode in the second half-cell is $Mn(s)$.

D. 1.75 V if the electrode in the second half-cell is $Pt(s)$.

Space for Personal Notes

Question 66 (1 mark)

Inspired by VCAA Chemistry Exam 2022
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2022/2022chem-w.pdf

A student wants to investigate a galvanic cell consisting of Sn^{4+}/Sn^{2+} and Ag^{+}/Ag half-cells.

Which one of the following combinations of electrodes and solutions will produce an operational galvanic cell?

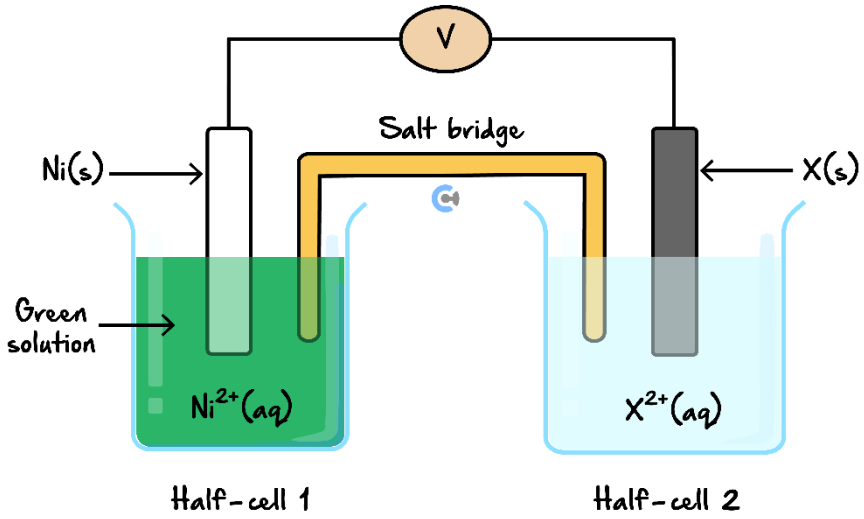
	Sn^{4+}/Sn^{2+} Half-Cell		**Ag^{+}/Ag Half-Cell**	
	Electrode	**Solution(s)**	**Electrode**	**Solution**
A.	Sn	1 M $Sn(NO_3)_2$	Graphite	1 M $AgNO_3$
B.	Sn	1 M $Sn(NO_3)_4$, 1 M $Sn(NO_3)_2$	Graphite	1 M $AgNO_3$
C.	Graphite	1 M $Sn(NO_3)_4$, 1 M $Sn(NO_3)_2$	Ag	1 M $AgNO_3$
D.	Graphite	1 M $Sn(NO_3)_4$	Ag	1 M $AgNO_3$

Space for Personal Notes

Question 67 (1 mark)

Inspired by VCAA Chemistry Exam 2019
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2019/2019chem-w.pdf

At the start of the day, a student set up a galvanic cell using two electrodes: nickel, Ni, and metal *X*. This setup is shown in the diagram below.



Consider the following alternative metals that could be used to replace metal *X*:

1. Zinc, Zn
2. Lead, Pb
3. Cadmium, Cd
4. Copper, Cu

At the end of the day, the student checked the colour of the solution in half-cell 1 and observed that the solution was a darker green colour.

Which of the alternative metals could cause the colour of half-cell 1 to become a darker green?

A. Metals 1 and 3

B. Metals 2 and 4

C. Metals 1, 2 and 3

D. Metals 3 and 4

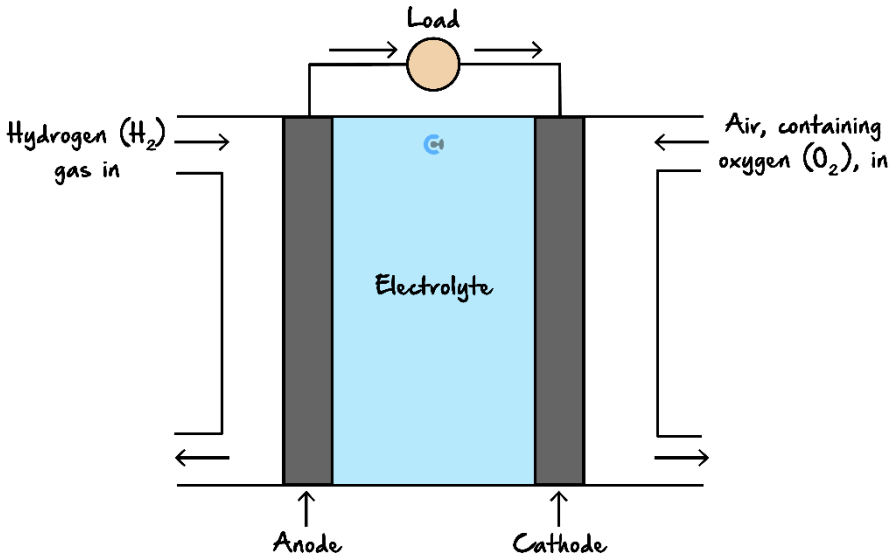
Space for Personal Notes

Question 68 (8 marks)

Inspired from VCAA Chemistry Exam 2017
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2017/2017chem-w.pdf#page=26

Submarines operate both on the surface and underwater. When operating underwater, the submarine acts as a closed system, where there is no interaction with the atmosphere. Most types of submarines use both batteries and diesel engines to provide their energy requirements. A new type of submarine uses proton exchange membrane (PEM) fuel cells and diesel engines.

Below is a diagram of a PEM fuel cell.



a.

i. State the function of the electrolyte in a fuel cell. (1 mark)

_____

_____

ii. Write the balanced overall redox reaction that occurs in this PEM fuel cell. (1 mark)

_____

iii. Give **two** safety considerations for the safe storage of hydrogen, H_2, gas on a submarine. (2 marks)

_____

_____

b.

i. State **two** advantages of using a PEM fuel cell compared to a diesel engine when a submarine is underwater. (2 marks)

_____

_____

_____

_____

ii. Most submarines generate more H_2 gas for their fuel cells when travelling on the surface.

Explain how the H_2 gas could be generated. (2 marks)

_____

_____

_____

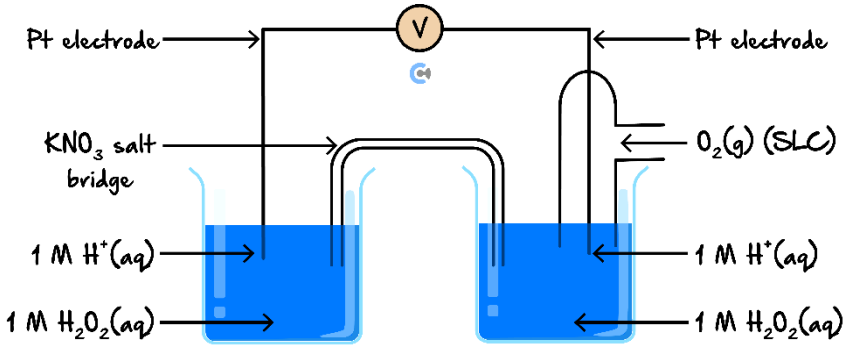
_____

Space for Personal Notes

Question 69 (1 mark)

Inspired by VCAA Chemistry Exam 2013
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2013/2013chem-w.pdf

A student constructs the following galvanic cell.



The student predicts that the following overall reaction will occur:

$$2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$$

However, no reaction is observed.

This is most likely because:

A. The difference between the $E°$ values is too small for a reaction to occur.

B. Hydrogen peroxide will oxidise water in preference to itself.

C. The student did not construct standard half-cells.

D. The rate of the reaction is extremely slow.

Question 70 (1 mark)

Inspired by VCAA Chemistry Exam 2023
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2023/2023chemistry-w.pdf

Which one of the following statements about acidic propan-1-ol fuel cells is correct?

A. Positive ions flow through the membrane to the cathode.

B. The voltage decreases since the reactants are used up in the half-cell reactions.

C. H_2O is formed at the negative electrode and CO_2 is formed at the positive electrode.

D. Since it is a gas, O_2 is the only reactant that must have direct contact with the electrode.

Use the following information to answer the two questions that follow.

Inspired by VCAA Chemistry Exam 2013
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2013/2013chem-w.pdf

Four standard galvanic cells are set up as indicated below.

Cell I: A Br_2/Br^- standard half-cell connected to a Cu^{2+}/Cu standard half-cell
Cell II: An Sn^{2+}/Sn standard half-cell connected to a Zn^{2+}/Zn standard half-cell
Cell III: A Br_2/Br^- standard half-cell connected to an I_2/I^- standard half-cell
Cell IV: A Co^{2+}/Co standard half-cell connected to an Fe^{3+}/Fe^{2+} standard half-cell

Question 71 (1 mark)

Which cell would be expected to develop the largest potential difference?

A. I

B. II

C. III

D. IV

Question 72 (1 mark)

The reaction occurring at the cathode as cell IV is discharged is:

A. $Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$

B. $Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$

C. $Co(s) \rightarrow Co^{2+}(aq) + 2e^-$

D. $Co^{2+}(aq) + 2e^- \rightarrow Co(s)$

Space for Personal Notes

Question 73 (1 mark)

Inspired by VCAA Chemistry Exam 2011
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2011chem2-w.pdf

An ornament was coated with a metal, M, by electrolysis of a solution of the metal ion, M^{x+}. During the electrolysis, a current of 1.50 amperes was applied for 180 seconds. The ornament was coated in 0.0014 mol of metal.

The value of x in M^{x+} is:

A. 1

B. 2

C. 3

D. 4

Question 74 (1 mark)

Inspired by VCAA Chemistry Exam 2013
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2013/2013chem-w.pdf

The main reason an aqueous solution of potassium nitrate, KNO_3, is used in salt bridges is:

A.	$K^+(aq)$ is a strong oxidant.	$NO_3^-(aq)$ is a weak reductant.
B.	$K^+(aq)$ is a weak reductant.	$NO_3^-(aq)$ is a strong oxidant.
C.	$K^+(aq)$ salts are soluble in water.	$NO_3^-(aq)$ salts are soluble in water.
D.	$K^+(aq)$ ions will migrate to the anode half-cell.	$NO_3^-(aq)$ ions will migrate to the cathode half-cell.

Space for Personal Notes

Question 75 (1 mark)

Inspired by VCAA Chemistry Exam 2023
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2023/2023chemistry-w.pdf

Consider two types of drones: petrol-powered and hydrogen-fuel-cell-powered.

Which one of the following statements is correct about petrol-powered drones and hydrogen-fuel-cell-powered drones?

A. They both produce greenhouse gases.

B. Only petrol-powered drones produce heat.

C. They both have the same energy transformations.

D. The overall reactions in hydrogen-fuel-cell-powered drones are endothermic.

Question 76 (1 mark)

Inspired by VCAA Chemistry Exam 2009
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2009chem2-w.pdf

Corrosion of an iron pipe can be prevented by connecting it to a magnesium bar buried in the ground. The magnesium corrodes in preference to the iron.

If the average current flowing between the two metals is $2.0 \times 10^{-6}\ A$, the amount of magnesium metal, in mol, reacting each second, would be:

A. 1.0×10^{-11}

B. 2.1×10^{-11}

C. 4.1×10^{-11}

D. 0.19

Question 77 (1 mark)

Inspired by VCAA Chemistry Exam 2023
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2023/2023chemistry-w.pdf

Methane, CH_4, and methanol, CH_3OH, can both be used to power fuel cells.

Methane and methanol fuel cells produce:

A. The same amount of greenhouse gases and the same number of electrons per mol of fuel reacted.

B. The same amount of greenhouse gases and a different number of electrons per mol of fuel reacted.

C. A different amount of greenhouse gases and the same number of electrons per mol of fuel reacted.

D. A different amount of greenhouse gases and a different number of electrons per mol of fuel reacted.

Question 78 (1 mark)

Inspired by VCAA Chemistry Exam 2004
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/chem22004.pdf

A student is planning to set up a demonstration of a galvanic cell using half-cells constructed as follows.

- Half cell 1: a calcium electrode in a beaker containing an aqueous solution of Ca^{2+} ions
- Half cell 2: a platinum electrode in a beaker containing an aqueous solution of a mixture of Sn^{4+} and Sn^{2+} ions

A salt bridge would connect the two beakers. The electrodes would be attached to a voltmeter.

This particular cell is impractical because:

A. Solid calcium (Ca) will react directly to reduce water to hydrogen gas.

B. There is no solid tin (Sn) in the half-cell containing $Sn^{4+}(aq)$ and $Sn^{2+}(aq)$.

C. There are no known ionic compounds of calcium that are soluble in water.

D. $Sn^{4+}(aq)$ will be in contact with Ca and will oxidise it to $Ca^{2+}(aq)$.

Space for Personal Notes

Question 79 (10 marks)

Inspired from VCAA Chemistry Exam 2018
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2018/2018chem-w.pdf#page=28

Redox reactions occur in the human body as well as in electrochemical cells.

a. Nicotinamide adenine dinucleotide (NAD) is a vital coenzyme for energy production in the human body. It exists in two forms: an oxidised form, NAD^+, and a reduced form, NADH.

NAD is involved in the conversion of ethanol, CH_3CH_2OH, to ethanal, CH_3CHO, in the human body. The overall equation for this redox reaction is

$$CH_3CH_2OH + NAD^+ \rightarrow CH_3CHO + NADH + H^+$$

i. Write the two half-equations for this redox reaction. States are not required. (2 marks)

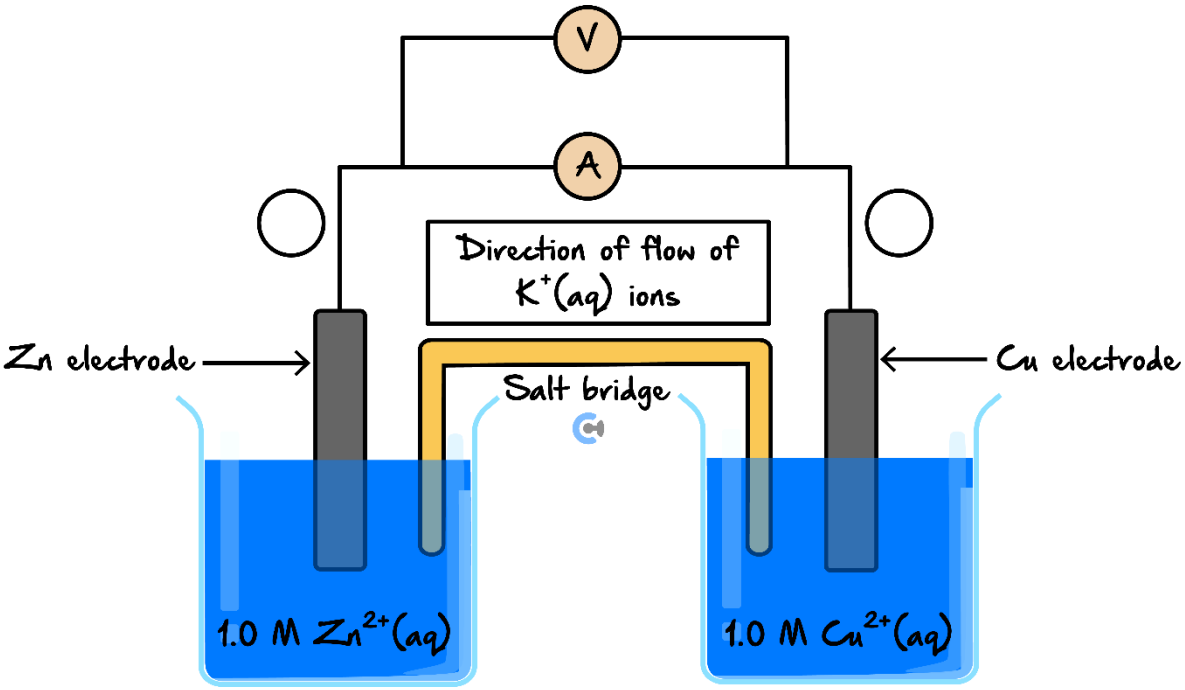
Oxidation half-equation _____

Reduction half-equation _____

ii. Identify the reducing agent in this redox reaction. (1 mark)

_____

b. The Daniell cell, a type of galvanic cell, was first constructed in the mid-1800s and this type of cell is still in use today. A diagram of the Daniell cell is shown below.



i. Label the polarity of the electrodes by placing a positive (+) or negative (−) sign in each of the circles next to the electrodes on the diagram above. (1 mark)

ii. Use the electrochemical series to determine the theoretical voltage of this cell. (1 mark)

_____

iii. The electrolyte in the salt bridge is a potassium nitrate solution, $KNO_3(aq)$.

In the box above the salt bridge, use an arrow to indicate the direction of flow of $K^+(aq)$ ions. (1 mark)

iv. List **two** visible changes that are likely to be observed when the Daniell cell has been operating for some time. (2 marks)

_____

_____

_____

c. What design features of the Daniell cell structure would allow it to produce electrical energy? (2 marks)

_____

_____

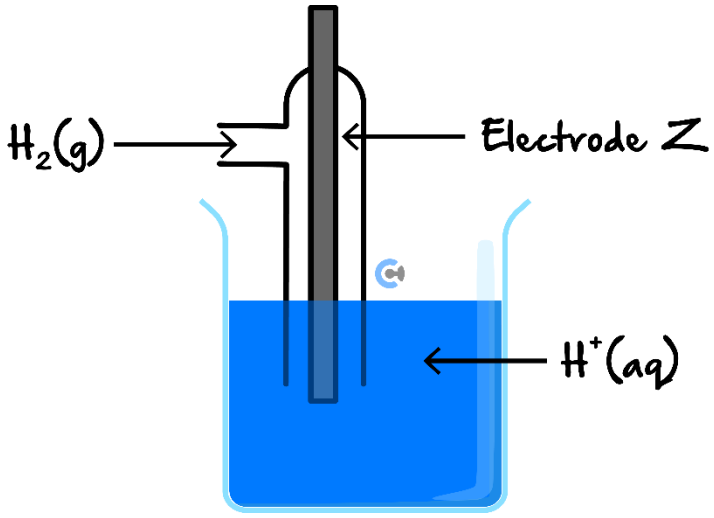
_____

Question 80 (11 marks)

Inspired from VCAA Chemistry Exam 2007
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2007chem2.pdf#page=18

The following diagram represents a $H^+(aq)/H_2(g)$ half cell for the reaction:

$$2H^+(aq) + 2e^- \rightleftharpoons H_2(g)$$



a.

i. For this half cell, identify an appropriate material for electrode Z. (1 mark)

_____

ii. For this half cell to be a **standard** half cell, state: (2 marks)

- The temperature at which it must operate _____
- The required **pH** of the solution of $H^+(aq)$ ions _____

b. A galvanic cell consists of the following half cells which have been set up under standard conditions.

- Half cell 1: the $H^+(aq)/H_2(g)$ half cell described in **part a.**
- Half cell 2: an iron (Fe) electrode in a solution containing $Fe^{2+}(aq)$.

After some time, the pH in half cell 1 has increased. Use this information to identify the species in this galvanic cell which is the stronger reductant and explain how you reached this conclusion. (2 marks)

The stronger reductant is _____

Explanation _____

_____

_____

_____

The stronger reductant is Fe(s)

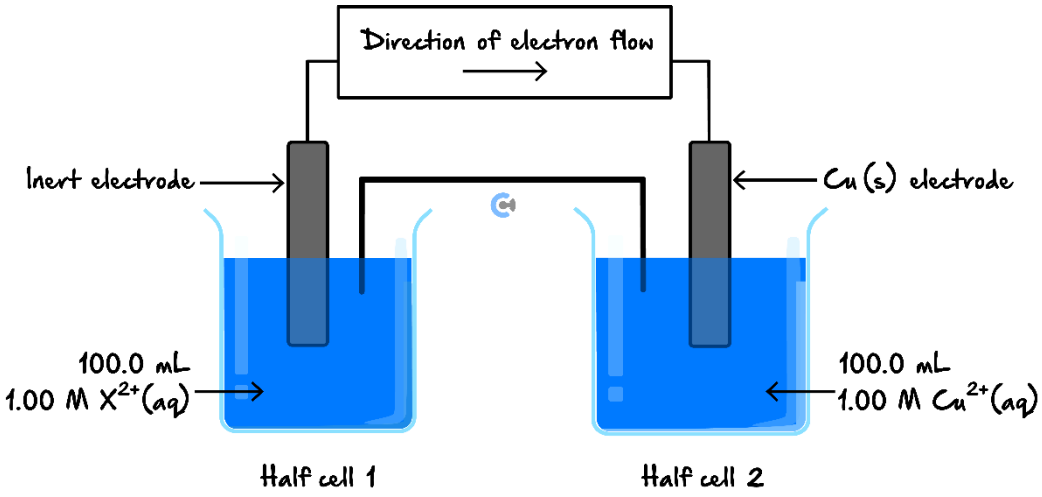
Explanation As cell #1 is increasing in pH, this indicates $H^+_{(aq)}$ is being used up. Thus, $H^+_{(aq)}$ is reducing according to $2H^+_{(aq)} + 2e^- \rightarrow H_{2(g)}$. Therefore, Fe(s) is the stronger reductant since it causes $H^+_{(aq)}$ to be reduced.

(1): $H^+_{(aq)}$ has been reduced so it must have been reduced by Cd(s)

c. A second galvanic cell consists of the following half-cells.

- Half cell 1: an inert electrode in 100.0 mL solution of 1.00 M $X^{2+}(aq)$.
- Half cell 2: an electrode of $Cu(s)$ in 100.0 mL solution of 1.00 M $Cu^{2+}(aq)$.

This galvanic cell is shown in the diagram below.



After discharging 2654 C of electricity, the concentration of the $X^{2+}(aq)$ in solution in half cell 1 was found to be 0.725 M. The volume of the solutions in the two half cells had not changed.

i. Calculate the amount, in mol, of $X^{2+}(aq)$ that reacted in half cell 1. (2 marks)

ii. Calculate the ratio of $n(X^{2+})$ reacted to $n(e^-)$ that passed through the cell. That is, calculate: $n(X^{2+})_{reacted}$: $n(e^-)$. (2 marks)

iii. State the oxidation state of the product of the half-reaction in half cell 1. (1 mark)

_____

iv. Write an equation for the half-reaction that occurred at the electrode of half cell 1. (1 mark)

_____

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Question 81 (4 marks)

Inspired from VCAA Chemistry Exam 2010
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2010chem2-w.pdf

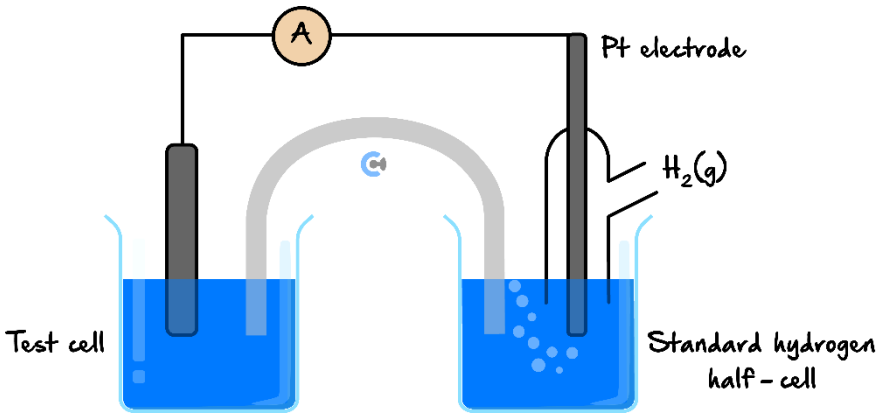
In a problem-solving activity, a student is given the following information regarding three half-equations.

However, although the three numerical values of $E°$ are correct, they have been incorrectly assigned to the three half-equations.

Half-Equation	$E°$
$AgCl(s) + e \rightleftharpoons Ag(s) + Cl^-(aq)$	$-0.40\ V$
$Cd^{2+}(aq) + 2e \rightleftharpoons Cd(s)$	$-0.36\ V$
$PbSO_4(s) + 2e \rightleftharpoons Pb(s) + SO_4^{2-}(aq)$	$+0.22\ V$

The objective of this task is to correctly assign the $E°$ values to the corresponding half-equation.

To do this, the student constructs standard half-cells for each of the above half-reactions. These half-cells are connected, one at a time, to a standard hydrogen half-cell as indicated in the diagram below.



The following observations were made either during or after the electrochemical cell discharged electricity for several minutes.

Experiment	Half-Cell Reaction Being Investigated	Experimental Notes
1	$AgCl(s) + e \rightleftharpoons Ag(s) + Cl^-(aq)$	Electron flow was detected passing from the standard hydrogen half-cell to the half-cell containing the silver electrode.
2	$Cd^{2+}(aq) + 2e \rightleftharpoons Cd(s)$	The mass of the cadmium electrode decreased.
3	$PbSO_4(s) + 2e \rightleftharpoons Pb(s) + SO_4^{2-}(aq)$	The pH of the solution in the standard hydrogen half-cell increased.

a. The above information can only be used to assign **one** of the $E°$ values to its corresponding half-equation. Identify this half-equation by placing the correct $E°$ value next to its corresponding half-equation in the table below. (2 marks)

Half-Equation	***E*°**
$AgCl(s) + e \rightleftharpoons Ag(s) + Cl^-(aq)$	
$Cd^{2+}(aq) + 2e \rightleftharpoons Cd(s)$	
$PbSO_4(s) + 2e \rightleftharpoons Pb(s) + SO_4^{2-}(aq)$	

b. Explain why the other two $E°$ values cannot be correctly assigned to their half-equations. (1 mark)

_____

_____

c. Explain why the pH of the solution in the standard hydrogen half-cell increased in experiment 3. (1 mark)

_____

_____

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Question 82 (10 marks)

Inspired from VCAA Chemistry Exam 2023
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2023/NHT/2023chem-nht-w.pdf#page=20

A galvanic cell can be constructed from a $Ni^{2+}(aq)/\ Ni(s)$ half-cell and an $Ag^{+}(aq)/Ag(s)$ half-cell.

a. State the maximum cell voltage, under standard conditions, of the $Ag^{+}(aq)/Ag(s)//Ni^{2+}(aq)/\ Ni(s)$ galvanic cell. (1 mark)

_____

b. Write the overall equation for the $Ag^{+}(aq)/Ag(s)//Ni^{2+}(aq)/\ Ni(s)$ galvanic cell. (1 mark)

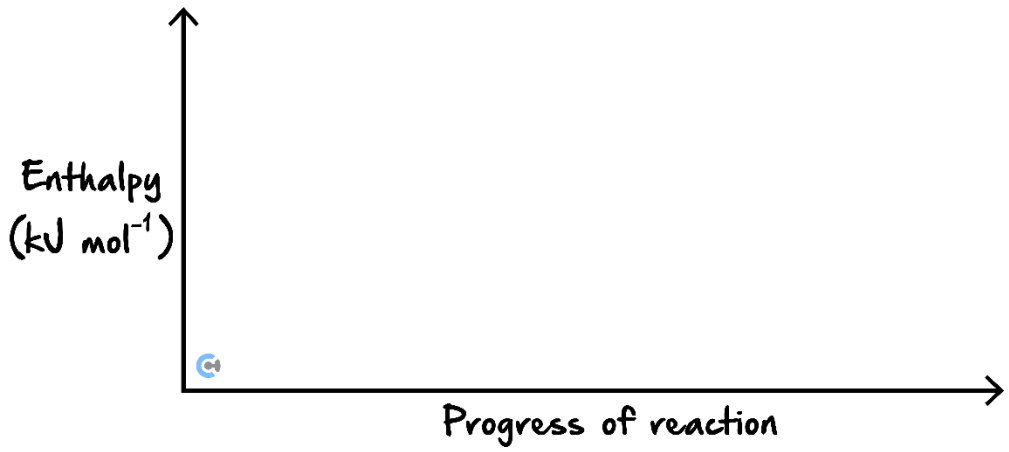
_____

c. Microbial fuel cells, MFCs, use bacteria to metabolise biomass. In an MFC, the bacteria decompose biomass, in the absence of oxygen, through a process called anaerobic cellular respiration.

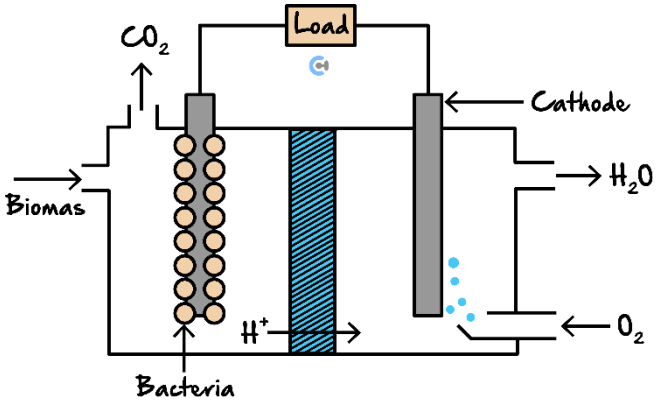
i. Write the equation for respiration that occurs in the cells of the human body. (1 mark)

_____

ii. On the axes below, sketch the energy profile diagram for respiration. (1 mark)



The MFC anode has bacteria growing on it. The bacteria decompose organic matter and produce H^+ ions and electrons. The bacteria transfer electrons directly to the anode. One half-cell has oxygen bubbled into it. In the other half-cell, oxygen is excluded. A diagram of an MFC is given below.



d. Write the balanced half-equation for the reaction occurring at the cathode. (1 mark)

_____

e. Explain why the two half-cells are separated. (2 marks)

_____

_____

_____

_____

f. For the cell shown in the diagram above, state the feature that causes the overall movement of H^+ ions across the membrane. Explain your answer. (2 marks)

_____

_____

_____

_____

g. State an advantage of an MFC over the $Ag^+(aq)/Ag(s)//Ni^{2+}(aq)/\ Ni(s)$ galvanic cell. (1 mark)

_____

Question 83 (7 marks)

Inspired from VCAA Chemistry Exam 2005
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2005chem2.pdf#page=18

One type of 'breathalyser' instrument used by police for the measurement of the concentration of alcohol in a driver's breath is a fuel cell. An acidic electrolyte is used. Ethanol is oxidised to ethanoic acid at one electrode and oxygen from the air is converted to water at the other.

The overall equation for this reaction is:

$$C_2H_2OH(aq) + O_2(g) \rightarrow CH_3COOH(aq) + H_2O(l)$$

a. Write the equation for the half-reaction at the anode. (2 marks)

_____

_____

b. A motorist who has consumed alcohol blows into the fuel cell. If the breath entering the cell provides alcohol at the rate of $3.0 \times 10^{-5}\ g$ per second, calculate the maximum current, in amps, that the cell would produce. (3 marks)

_____

_____

_____

_____

c. The nature of the electrodes in the cell is essential to the effective operation of the breathalyser. State **two** important functions that the electrodes must perform. (2 marks)

Function 1 _____

Function 2 _____

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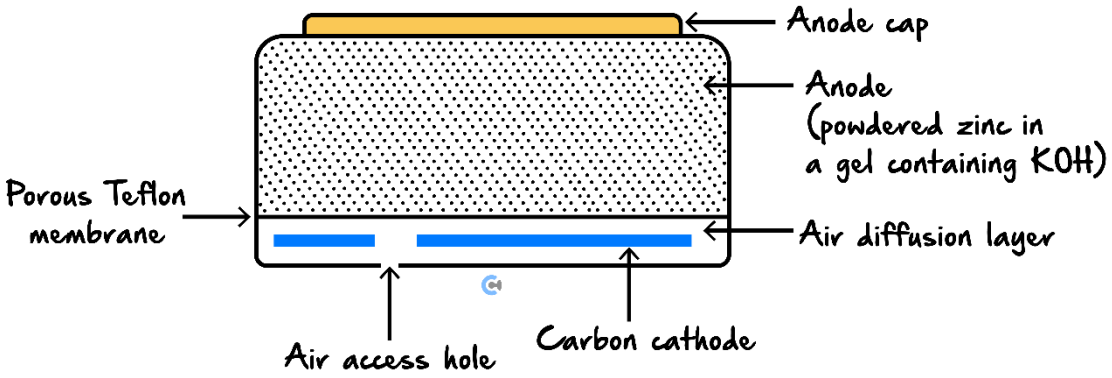
Question 84 (6 marks)

Inspired from VCAA Chemistry Exam 2014
https://www.vcaa.vic.edu.au/Documents/exams/chemistry/2014/2014chem-amd-w.pdf#page=38

The following diagram shows a cross-section of a small zinc-air button cell, a button cell that is used in hearing aids.



The zinc acts as the anode. It is in the form of a powder dispersed in a gel (a jelly-like substance) that also contains potassium hydroxide. The cathode consists of a carbon disc. Oxygen enters the cell via a porous Teflon membrane. This membrane also prevents any chemicals from leaking out.

The following reaction takes place as the cell discharges.

$$2Zn(s) + O_2(g) + 2H_2O(l) \rightarrow 2Zn(OH)_2(s)$$

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

_____

b. Suggest **one** role of potassium hydroxide in this cell. (1 mark)

_____

_____

c. A zinc-air button cell is run for 10 hours at a steady current of 2.36 mA.

What mass of zinc metal reacts to form zinc hydroxide? (3 marks)

_____

_____

_____

_____

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_____

d. A hydrogen-oxygen fuel cell can operate with an alkaline electrolyte such as potassium hydroxide. In this cell, the reaction at the cathode is the same as that in the zinc-air cell. A porous carbon cathode is used.

Write the half-equation for the reaction that occurs at the anode in a hydrogen-oxygen cell with an alkaline electrolyte. (1 mark)

_____

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