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VCE Chemistry ¾

Secondary Cells & Connected Cells [2.3]

Homework

Admin Info & Homework Outline:

Student Name	
Questions You Need Help For	
Compulsory Questions	Pg 2 - Pg 12
Supplementary Questions	Pg 13 - Pg 25

Section A: Compulsory Questions (45 Marks)

Sub-Section [2.3.1]: Write Discharge & Recharge Reactions in Secondary Cells & Redox Flow Batteries

Question 1 (3 marks)

Nickel hydroxide rechargeable batteries, commonly known as nickel-metal hydride (NiMH) batteries, utilise nickel hydroxide as the positive electrode material. These batteries offer a higher energy density compared to traditional nickel-cadmium batteries, making them popular choices for portable electronics and hybrid vehicles due to their improved performance and reduced environmental impact.

When the cell is being used, the electrode reactions are represented by the following equations during recharge:

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

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

a.

i. State the species found at the positive electrode during discharge. (0.5 marks)

_____

ii. Hence or otherwise, write the reaction occurring at the negative electrode during discharge. (1 mark)

_____

_____

b. Suggest a suitable electrolyte for the battery. (0.5 marks)

_____

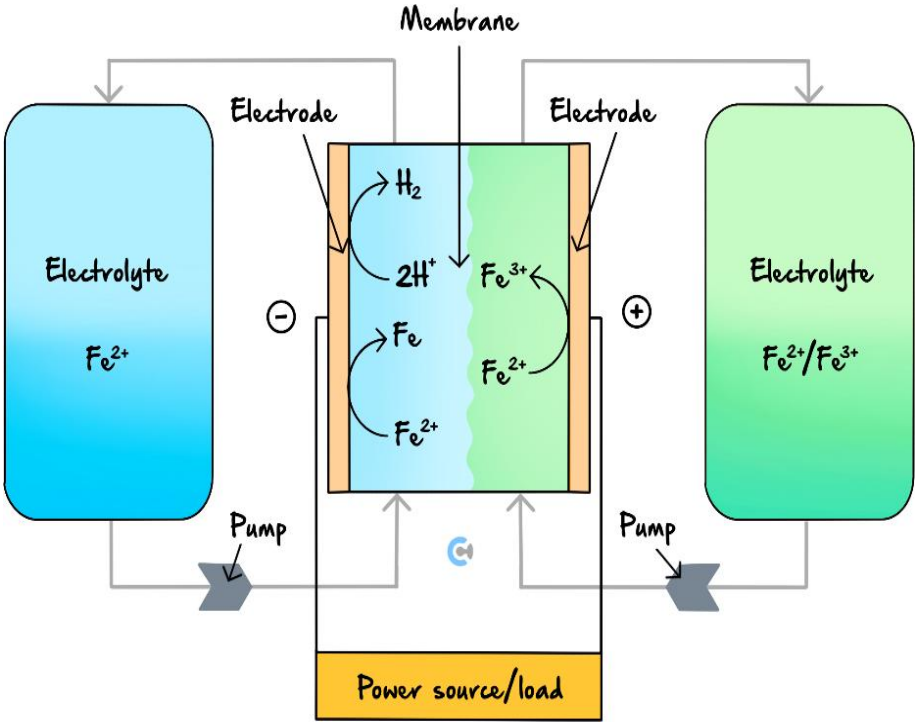
c. Determine whether this is a primary, secondary, or fuel cell and state why. (1 mark)

_____

Question 2 (4 marks)

A Fe-Fe redox flow battery is theorised to be able to produce high voltages in high temperatures, and as such have relevant applications in industrial machinery.

A theoretical diagram of a Fe-Fe redox flow battery is shown below.



a. Write the reaction occurring at the anode during the recharge of the Fe-Fe redox flow battery. (1 mark)

_____

b. When the cell is undergoing recharge and discharge, the location of the positive and negative polarities remains the same. Explain how the polarities remain the same, yet it swaps from anode to cathode, and cathode to anode. (3 marks)

_____

_____

_____

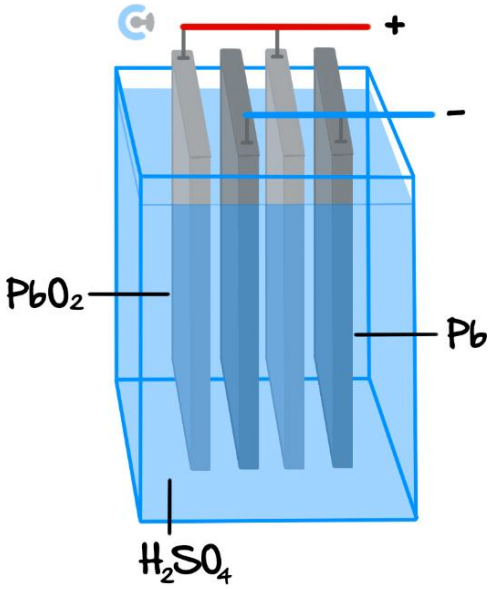
_____

_____

Question 3 (3 marks)

The most common battery in combustion-powered vehicles is the lead-acid accumulator. The reaction that occurs during discharge is shown below.

$$Pb(s) + PbO_2(s) + 2H_2SO_4(aq) \rightarrow 2PbSO_4(s) + 2H_2O(l)$$



a. Write the balanced half-equation occurring at the positive electrode when the cell is producing electrical energy. (1 mark)

_____

_____

b. Write the balanced half-equation occurring at each electrode as electrical energy is being inputted into the cell.

i. Positive electrode. (1 mark)

_____

_____

ii. Negative electrode. (1 mark)

_____

_____

Sub-Section [2.3.2]: Identify Factors which Affect Rechargeability & Compare Similarities/Differences Between Secondary Cells and Other Cells

Question 4 (2 marks)

a. A secondary cell requires: (1 mark)

A. A continuous supply of reactants.

B. Specific operational temperatures.

C. A positive anode and a negative cathode.

D. An external electrical power source.

b. Which of the following statements is correct about secondary cells? (1 mark)

A. Unlike fuel cells, secondary cells are able to discharge through non-spontaneous reactions.

B. Secondary cells require products of discharge to remain in contact with electrodes.

C. An example of a secondary cell is a non-rechargeable AA battery.

D. Secondary cells primarily undergo chemical to electrical energy conversions.

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Question 5 (2 marks)

a. Which of the following statements about the energy conversions in secondary cells is correct? (1 mark)

A. Secondary cells undergo fully efficient chemical to electrical-energy conversions whereby no thermal energy is produced.

B. Secondary cells remain electrically imbalanced throughout recharge by not discharge.

C. Secondary cells can be theoretically used indefinitely as chemical energy is reformed during recharge.

D. Secondary cells have minimal self-discharge reactions that produce electrical or thermal energy.

b. Which of the following is a benefit to using secondary cells over primary cells? (1 mark)

A. Primary cells are more expensive to produce due to specific reactive electrodes.

B. Secondary cells are more energy efficient.

C. Primary cells have to be discarded after use, which is unsustainable.

D. Secondary cells contain a lower amount of heavy metals than primary cells.

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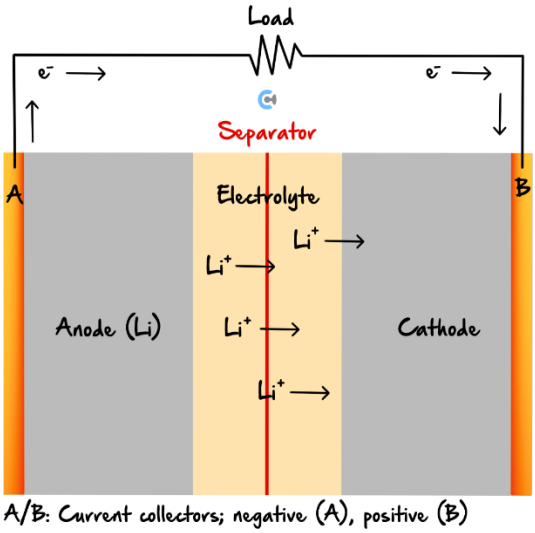
Question 6 (5 marks)

Lithium-ion batteries are used in modern-day phones as an extremely dense way of storing energy within batteries. A simplified lithium-ion battery is shown below.



a. Write the net ionic reaction occurring at the positive electrode during recharge. (1 mark)

_____

b. Electrode *B* is made up of an inert material.

i. During discharge, state the observation that will be seen at the electrode *B*, and hence explain the relationship between the mass of electrode *B* and the battery life of the cell. (2 marks)

_____

_____

_____

ii. Phones at very high temperatures can start to have a reduced battery life. Explain why this observation is seen. (2 marks)

_____

_____

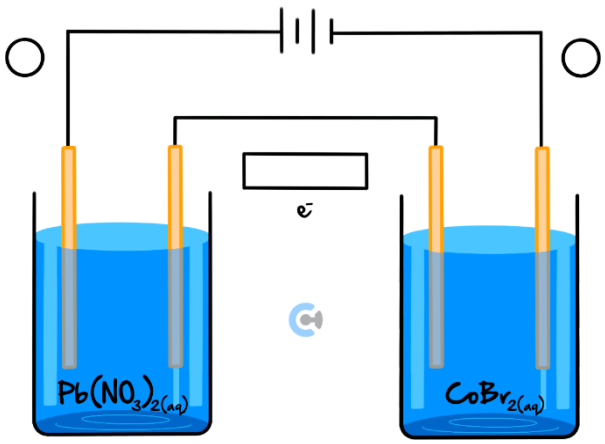
_____

_____

Sub-Section [2.3.3]: Find Reactions Occurring in Connected Cells

Question 7 (5 marks)

Two cells are connected together in series using a wire. Inert electrodes are used in both cells. A diagram of the connected cells is shown in the diagram below.



a. In the spaces provided above, label the polarities of the electrodes and the direction of electron flow. (1 mark)

b. Write the balanced half equations that occur in the cell containing $Pb(NO_3)_2$:

i. Reduction. (1 mark)

_____

ii. Oxidation. (1 mark)

_____

c. Write the balanced half-equation which occurs in the cell containing $CoBr_2$:

i. Reduction. (1 mark)

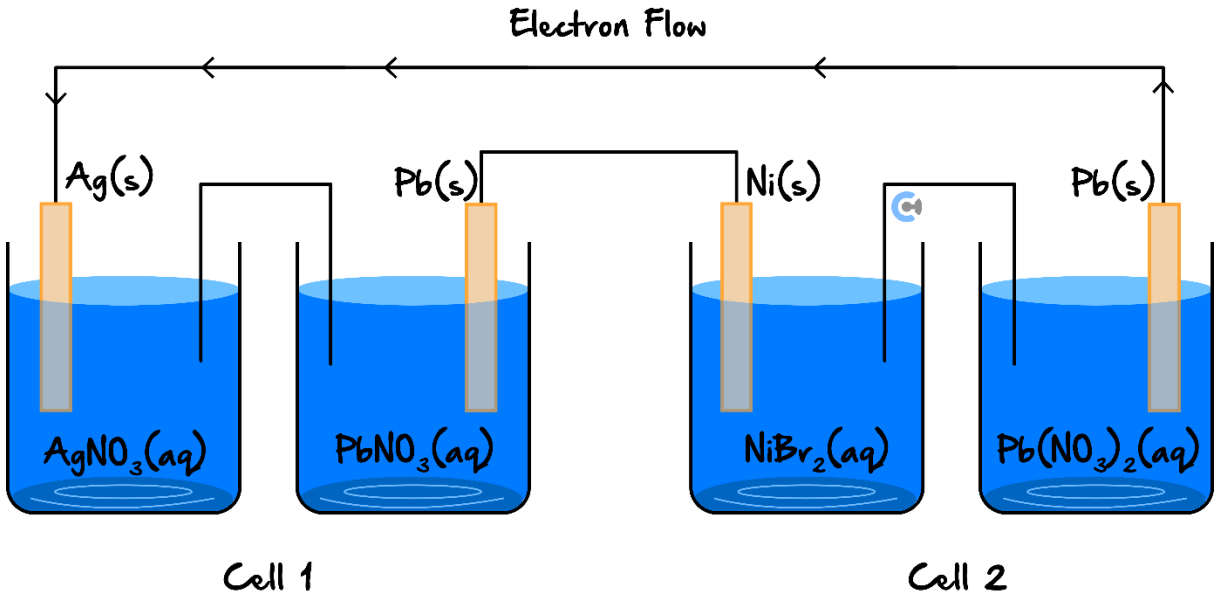
_____

ii. Oxidation. (1 mark)

_____

Question 8 (5 marks)

A diagram of a connected cell is shown below.



a.

i. State the energy conversions occurring in cell 2. (1 mark)

_____

ii. Hence or otherwise, write the overall reaction occurring in cell 1. (2 marks)

_____

_____

b. State and explain whether this cell would be able to be recharged. (2 marks)

_____

_____

_____

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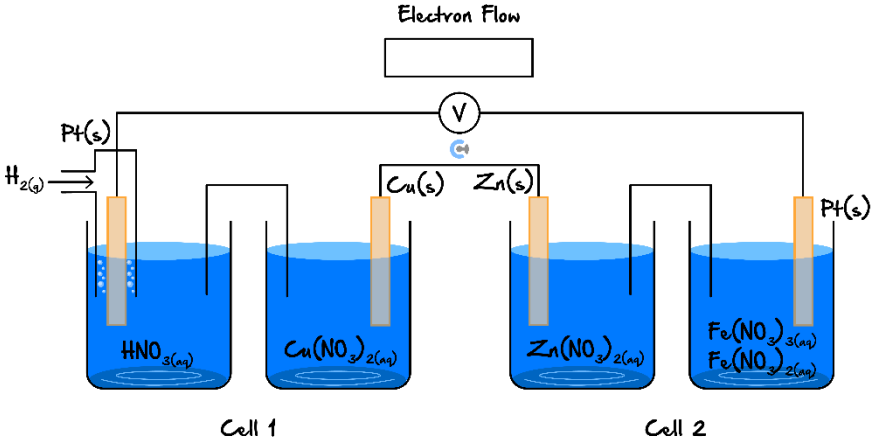
Question 9 (8 marks)

A connected galvanic cell is shown below, with each electrolyte containing 1.0 *M* of the substance shown at SLC.



a. In the box provided above, indicate the direction of electron flow. (1 mark)

b. Identify the copper electrode as the cathode or the anode. (1 mark)

_____

_____

c. Write the balanced half-equations which occur within cell 1. (2 marks)

Cathode: _____

Anode: _____

d. Write the balanced half-equations which occur within cell 2. (2 marks)

Positive electrode: _____

Negative electrode: _____

e. Find the theoretical maximum EMF produced. (2 marks)

_____

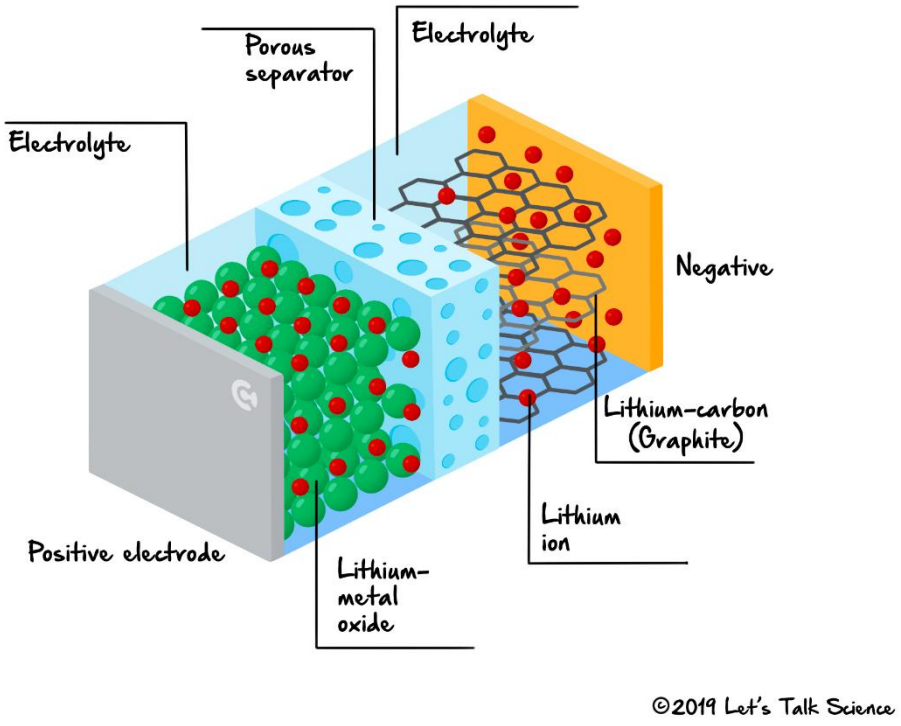
_____

_____

Sub-Section: The 'Final Boss'

Question 10 (8 marks)

Lithium-ion batteries are commonly used in electrical devices due to the high voltage they can produce. A diagram of one is shown below.



The following reactions occur within a lithium-ion battery during discharge:

$$LiC_6(s) \rightarrow C_6(s) + Li^+(aq) + e^-$$

$$CoO_2(s) + Li^+(aq) + e^- \rightarrow LiCoO_2(s)$$

a. Write the reaction occurring at the positive electrode during recharge. (2 marks)

_____

_____

b.

i. List 2 observations that will be seen during the recharge cycle. (2 marks)

_____

_____

ii. Explain why it is important that the products of discharge are solid. (2 marks)

_____

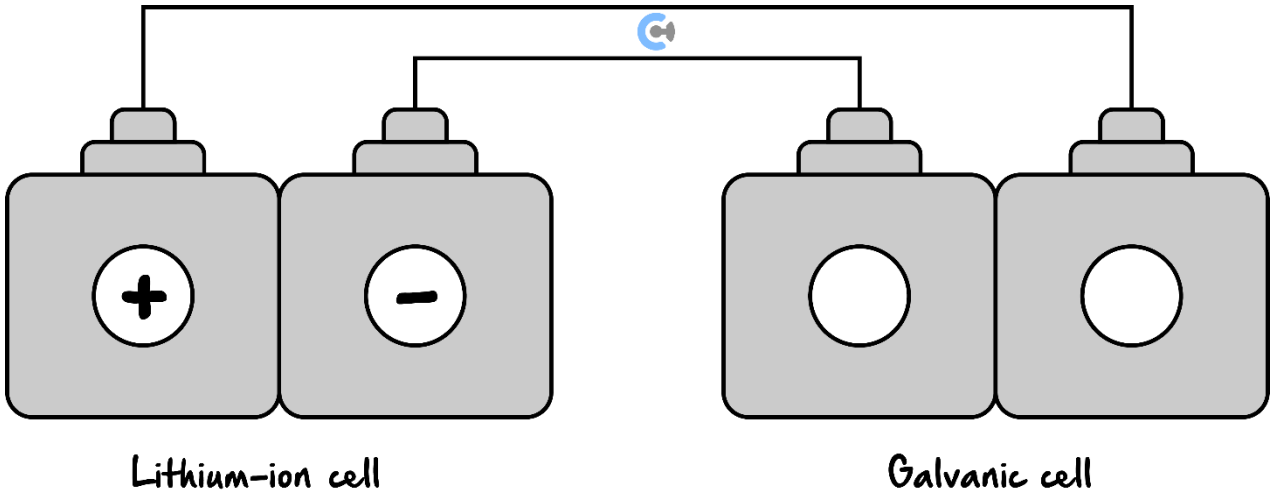
_____

_____

iii. $Li^+(aq)$ ions are not solid, suggesting what their role in the cell is. (1 mark)

_____

The lithium-ion battery is then recharged by connecting it to a galvanic cell, as shown below.



c. Label the polarities of the galvanic cell in the diagram above. (1 mark)

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Section B: Supplementary Questions (46 Marks)

Sub-Section [2.3.1]: Write Discharge & Recharge Reactions in Secondary Cells & Redox Flow Batteries

Question 11 (2 marks)

a. Zinc-bromine rechargeable batteries are commonly used within electric vehicles for efficient and quick releases of large amounts of energy.

The reactions occurring in a Zinc-Bromine cell during discharge are shown below.

$$Zn(s) + Br_2(l) \rightarrow ZnBr_2(s)$$

An observation noted during recharge will be: (1 mark)

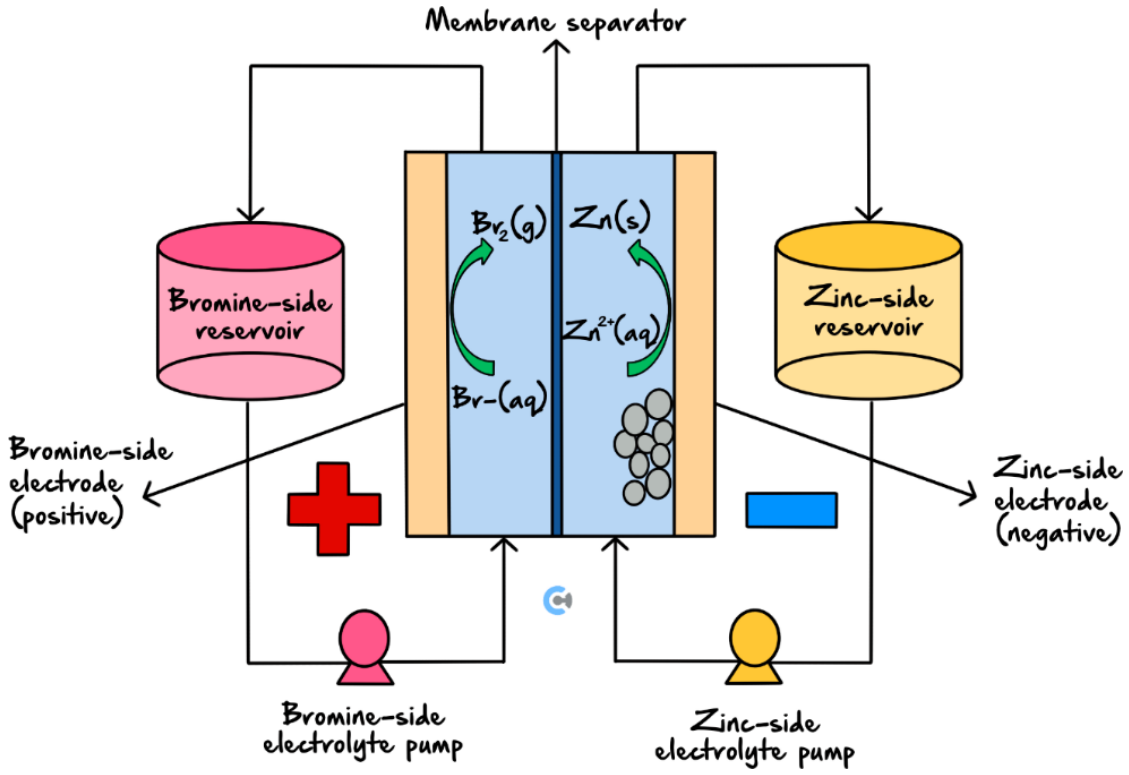
A. Decrease in mass of the cathode.

B. Increase in intensity of brown in the electrolyte.

C. Release of thermal energy.

D. A voltage produced of $+1.85\ V$.

b. An image of a Zinc-Bromine redox flow battery is shown below.



It can both discharge and recharge. The reactions that occur within the cell are shown below:

$$Br_2(l) + 2e^- \leftrightharpoons 2Br^-(aq) E^0 = +1.09\,V$$

$$Zn^{2+}(aq) + 2e^- \leftrightharpoons Zn(s) E^0 = -0.76\,V$$

An observation that would be made during the recharge of the cell would be: (1 mark)

A. Increase in mass at the bromine-side reservoir.

B. Decrease in mass at the zinc-side reservoir.

C. Brown bromine liquid being produced at the anode.

D. Zinc solid being produced at the anode.

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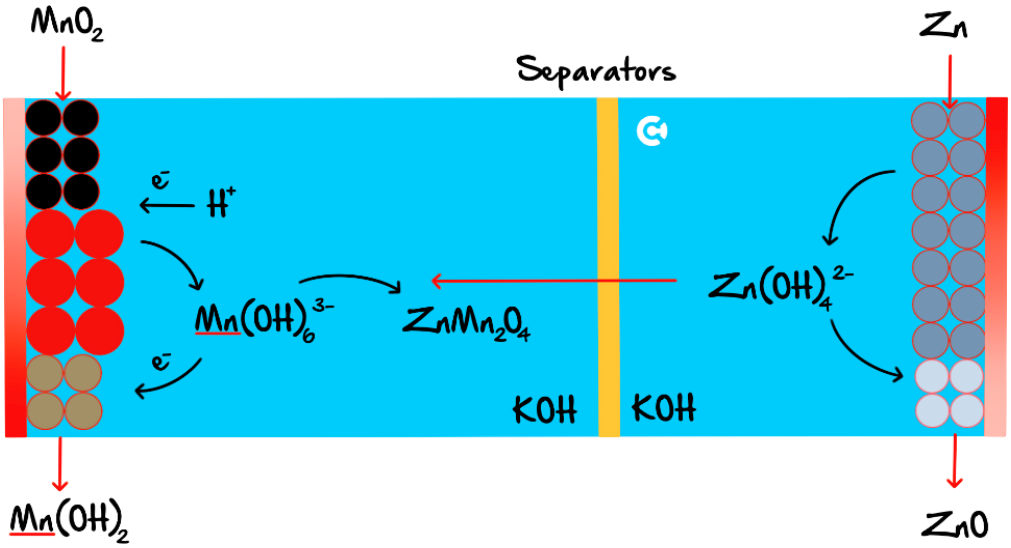
Question 12 (4 marks)

A manganese dioxide zinc half-cell is shown below. It uses multi-step reactions to both recharge and discharge.



The overall reaction occurring during discharge is shown below:

$$MnO_2(s) + Zn(s) + H_2O(l) \rightarrow ZnO(s) + Mn(OH)_2$$

a. Write the balanced equation for the reaction that occurs at the anode during discharge. (1 mark)

_____

_____

b. Write the balanced equation for the oxidation reaction occurring during recharge. (1 mark)

_____

_____

c. Explain the purpose of the separator in this secondary cell. (2 marks)

_____

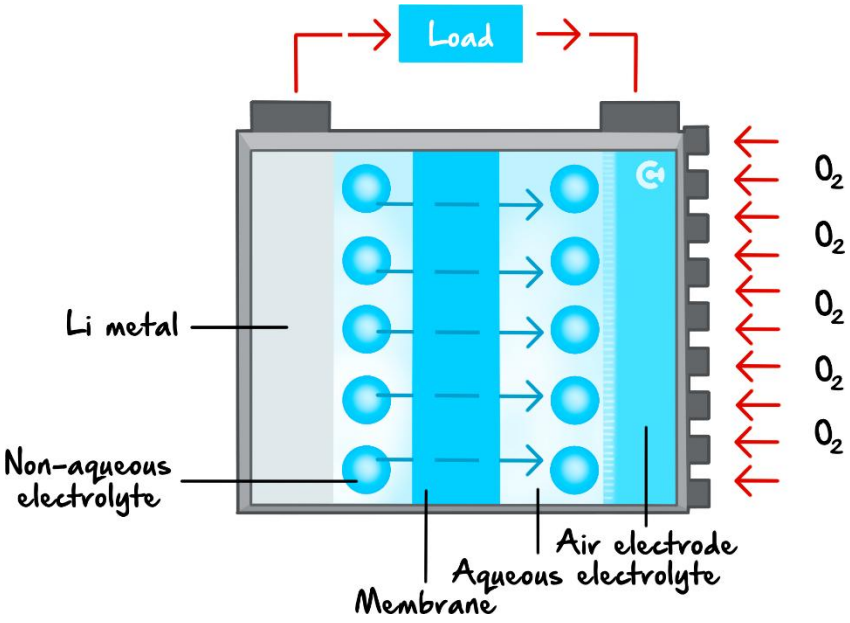
_____

_____

Question 13 (6 marks)

Lithium-air batteries, celebrated for their promising high energy density, hold potential as next-generation power sources in various applications.

A diagram of a lithium-air battery is shown below.



The following reaction occurs in an acidic electrolyte whilst the cell is undergoing discharge:

$$4Li(s) + O_2(g) + 4H^+(aq) \rightarrow 4Li^+(aq) + 2H_2O(l)$$

a.

i. Write the reaction occurring at the cathode as the cell is producing energy. (1 mark)

_____

ii. Hence or otherwise, identify the conjugate oxidant of the discharge reaction. (1 mark)

_____

b. Determine the voltage that must be inputted in order for the cell to be recharged. (1 mark)

_____

c. A non-aqueous electrolyte is used within some part of the cell. Explain a potential hazard in using an aqueous electrolyte throughout the entire cell. (3 marks)

_____

_____

_____

_____

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Sub-Section [2.3.2]: Identify Factors which Affect Rechargeability & Compare Similarities/Differences Between Secondary Cells and Other Cells

Question 14 (1 mark)

Secondary cells are used in phone batteries due to their rechargeability. Which of the following is a unique feature of the reactions in secondary cells?

A. The reactions both require the input of electrical energy in order to operate.

B. The products of discharge remain in contact with the electrodes.

C. The electrodes are inert and allow for theoretically indefinite rechargeability.

D. The discharge reactions of the cathode will occur at the other electrode during recharge.

Question 15 (2 marks)

a. Which of the following statements about secondary cells is correct? (1 mark)

A. Secondary cells can force electrons to travel against natural electrostatic forces to make the cathode negative.

B. Secondary cells minimise side reactions by always having a membrane between electrodes.

C. Secondary cells typically operate using porous electrodes in order to increase surface area and increase the rate of reaction.

D. Secondary cells allow electrons to always follow natural electrostatic forces.

b. Which of the following statements accurately describes a feature of secondary cells? (1 mark)

A. Exhibit minimal self-discharge rates compared to primary cells.

B. Predominantly used in low-drain devices due to their limited capacity.

C. Rely on non-reversible chemical reactions for energy conversion.

D. Typically operate optimally in extreme temperature conditions due to their robust design.

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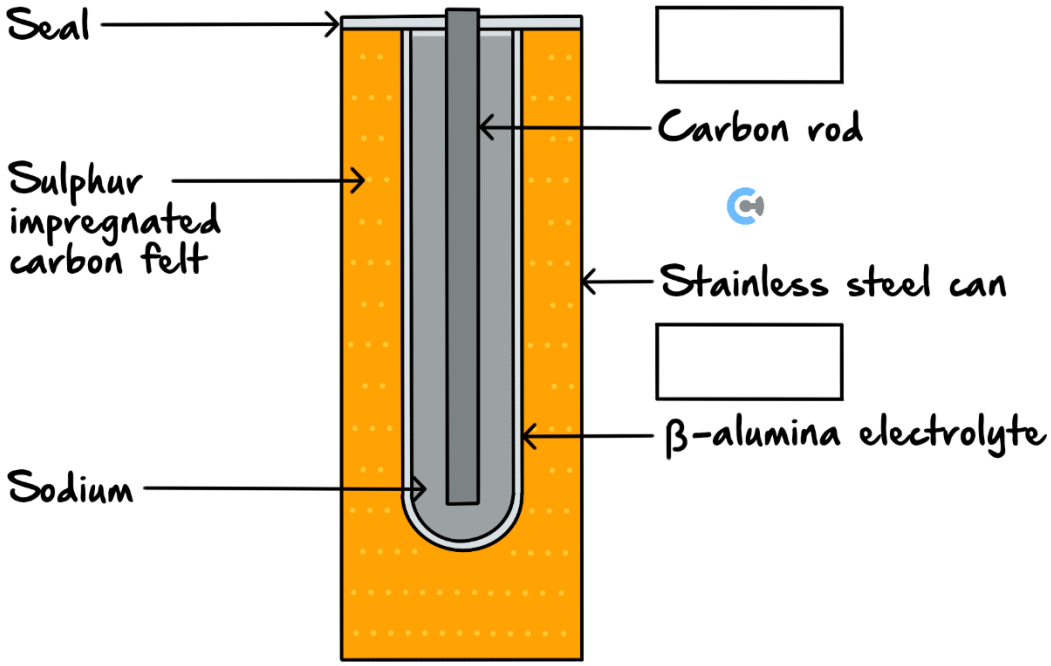
Question 16 (6 marks)

Sodium-sulphur batteries are used for large-scale energy production and storage due to their high energy density and long life cycle. This allows them to have applications in storing renewably generated energy from sources such as wind and solar. It utilised molten sodium and sulphur, with a solid β-alumina electrolyte. A diagram of a sodium-sulphur cell is shown below.



The overall reaction occurring within the cell during discharge is:

$$Na(l) + S(l) \rightarrow Na_2S(l)$$

a. In the boxes provided above, label the location of the anode and cathode during discharge. (1 mark)

b. Write the reaction for the reaction occurring at the positive electrode as energy is being produced. (1 mark)

_____

c.

i. β-alumina is added to the electrolyte for proper operation of the cell, it can be collected and reused after the reaction has been completed. Explain the role of the β-alumina within the cell. (2 marks)

_____

_____

_____

ii. There is a separator between either of the electrodes that allows for the flow of $Na^+(aq)$ ions. Explain two purposes for Na^+ions within the cell. (2 marks)

_____

_____

_____

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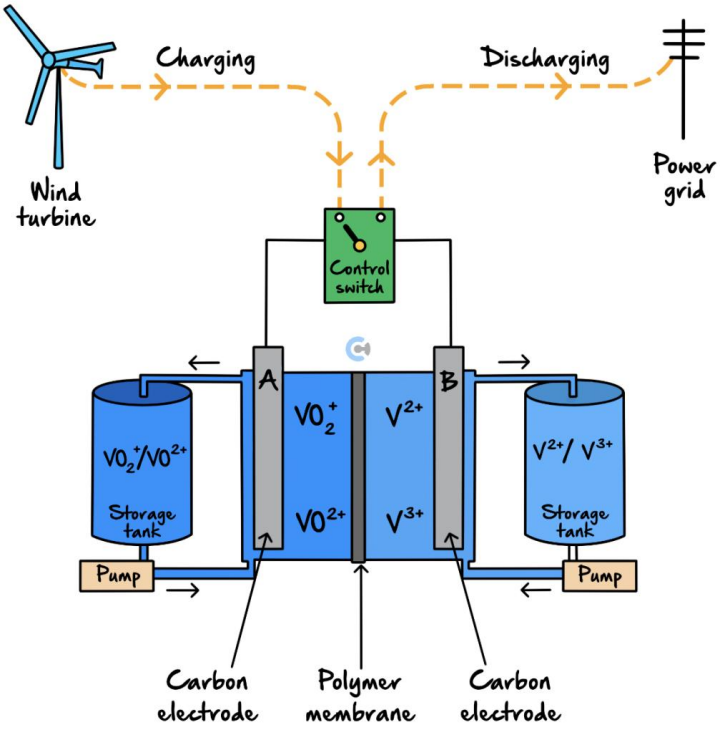
Question 17 (9 marks)

Vanadium redox flow batteries can be used as a means of adding energy generated by solar or wind energy to the power grid. An example of a typical vanadium redox flow battery is shown below.



a.

i. Given that electrode *B* is negative during discharge, state the reaction occurring at electrode *A* during recharge. (2 marks)

_____

_____

_____

ii. Hence or otherwise, explain why a polymer membrane must be added to the cell using relevant half-equations to support your response. (2 marks)

_____

_____

_____

_____

b. Explain how the control switch will allow for non-spontaneous reactions to occur when taking energy from the wind turbine. (3 marks)

_____

_____

_____

_____

_____

c. It can be claimed that the cell could be considered a fuel cell. Comment on the accuracy of this claim. (2 marks)

_____

_____

_____

_____

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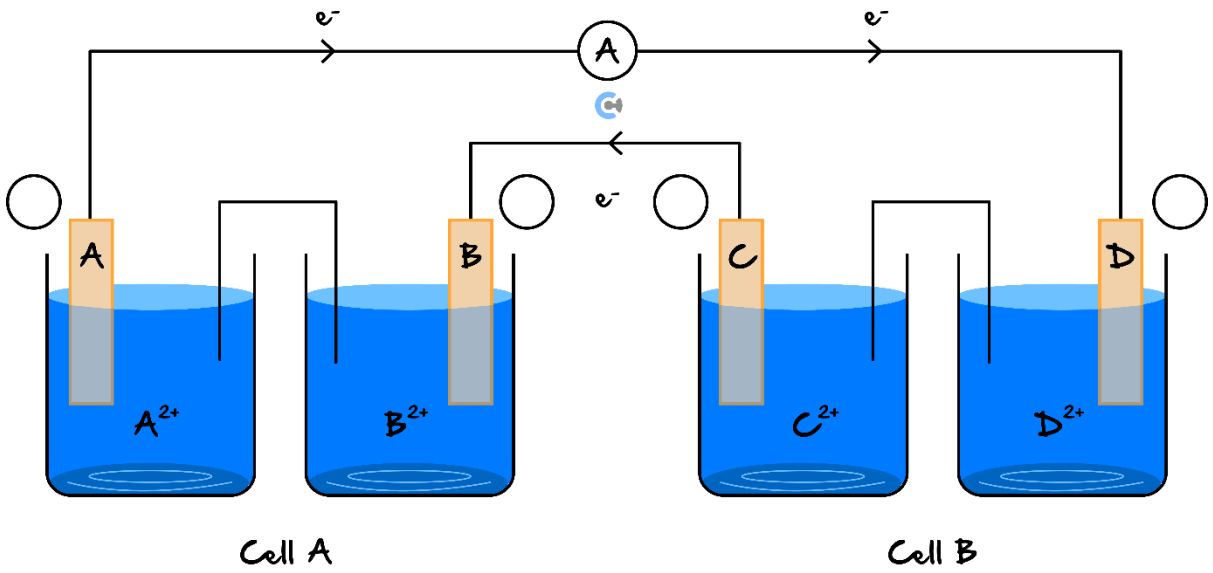
Sub-Section [2.3.3]: Find Reactions Occurring in Connected Cells

Question 18 (3 marks)

Two galvanic cells are connected together, as shown in the diagram.



a. Label the polarities of each electrode in the box provided above. (1 mark)

b. Write the half-equation which occurs at the following electrodes. States are not required.

i. Electrode *A*. (1 mark)

_____

ii. Electrode *D*. (1 mark)

_____

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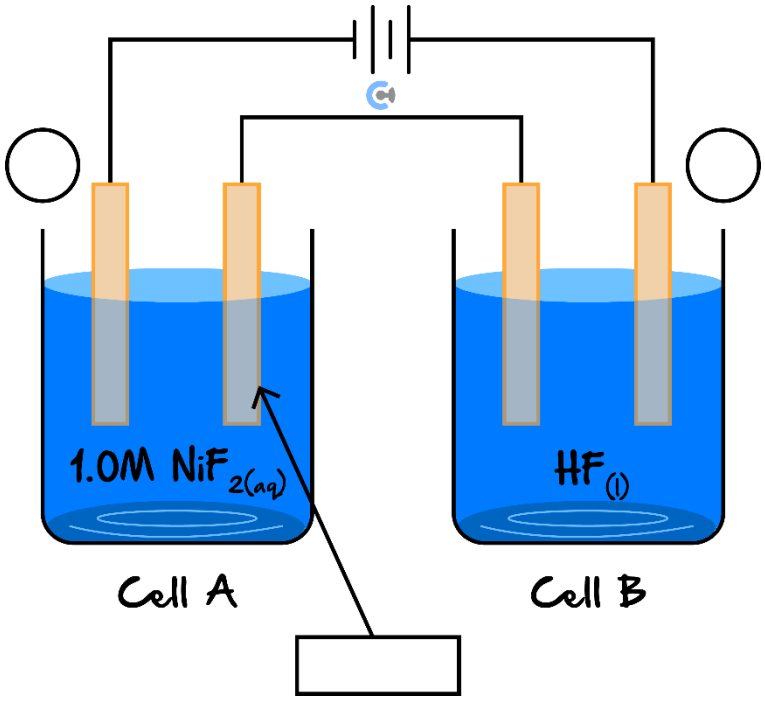
Question 19 (6 marks)

The following connected cell is constructed and is connected to a power source.



a. Write the polarities of the two electrodes in the circles provided above. (1 mark)

b. Label the electrode labelled in the diagram as the cathode or the anode. (1 mark)

c. Write the half-equations occurring at the anode of:

i. Cell *A*. (1 mark)

_____

ii. Cell *B*. (1 mark)

_____

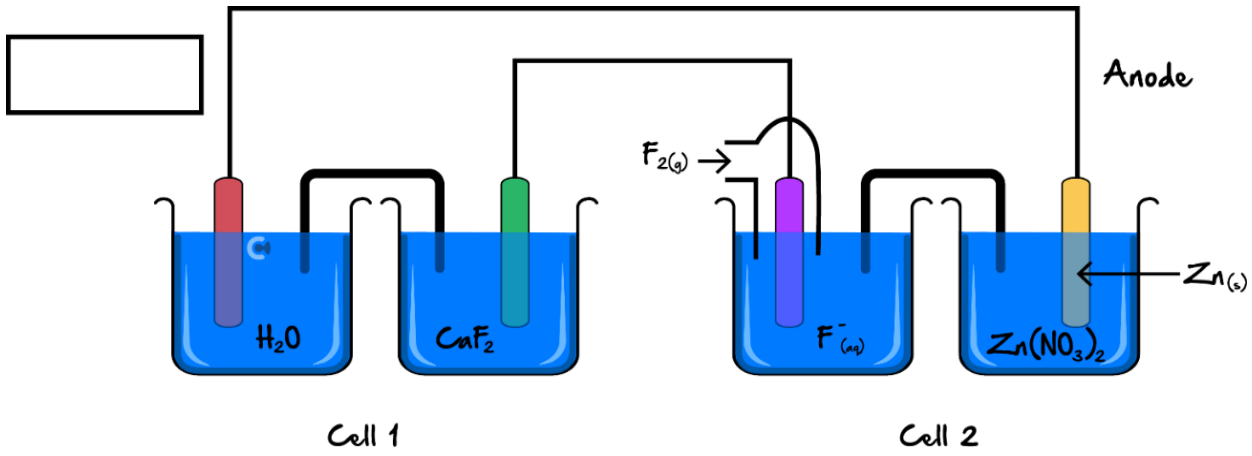
d. Find the total voltage that the power source must supply for the cell to operate. (2 marks)

_____

_____

_____

Question 20 (7 marks)



a. In the box provided above, label whether the electrode indicated is the anode or cathode. (1 mark)

b.

i. Using relevant half-equations, justify whether cell 2 is a galvanic or electrolytic cell. (2 marks)

_____

_____

_____

_____

ii. Hence or otherwise, determine the overall reaction occurring in cell 1. (1 mark)

_____

_____

iii. If the $F^-(aq)/F_2(g)$ half cell is swapped out for a $Cu^{2+}(aq)/Cu(s)$ half cell, explain whether the entire cell will operate. (3 marks)

_____

_____

_____

_____

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