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VCE Chemistry ¾

AOS 2 Revision (Electrolysis) [2.0]

SAC 1 Solutions

50 Marks. 1 Minute Reading. 60 Minutes Writing.

Section A: Multiple Choice Questions (5 Marks)

Question 1 (1 mark) **[2.2.3] Identify key features, write reactions & relate to sustainability & green chemistry principles regarding production of green hydrogen (PEM & Artifical Photosynthesis)**

Meg is concerned about hydrogen gas being produced as a by-product in her cell for a school project. Does she have a reason to be worried, and if so, which of the following provides an appropriate measure she can adopt to prevent any risk?

A. Yes, as hydrogen gas is flammable, if it is ignited, it can explode. Increase ventilation to prevent this.

B. Yes, if hydrogen gas is accumulated and inhaled, it is toxic to the body. Operate the experiment in a fume hood to prevent this.

C. No, hydrogen gas isn't toxic to humans as it is tasteless.

D. Yes, as hydrogen gas is flammable, if it is ignited, it can explode. Combust released gas to prevent this.

Question 2 (1 mark) **[2.4.3] Apply Faraday's laws to electroplating calculations**

Athena trials multiple electroplating experiments with the following cations: Cr^{2+}, Mn^{2+}, Ag^{+}, Sn^{2+}. The same current is run through each electroplating circuit for the same amount of time. Which of the following is the correct order of elements, from smallest to greatest mass deposited at the cathode of the cell?

A. Cr, Mn, Sn, Ag

B. Mn, Cr, Sn, Ag

C. Ag, Sn, Mn, Cr

D. Mn, Cr, Ag, Sn

Question 3 (1 mark) **[2.2.2] Identify features of electrolytic cells & their purpose**

During electrolysis, the anode will/can be:

A. Negatively charged.

B. The site of reduction.

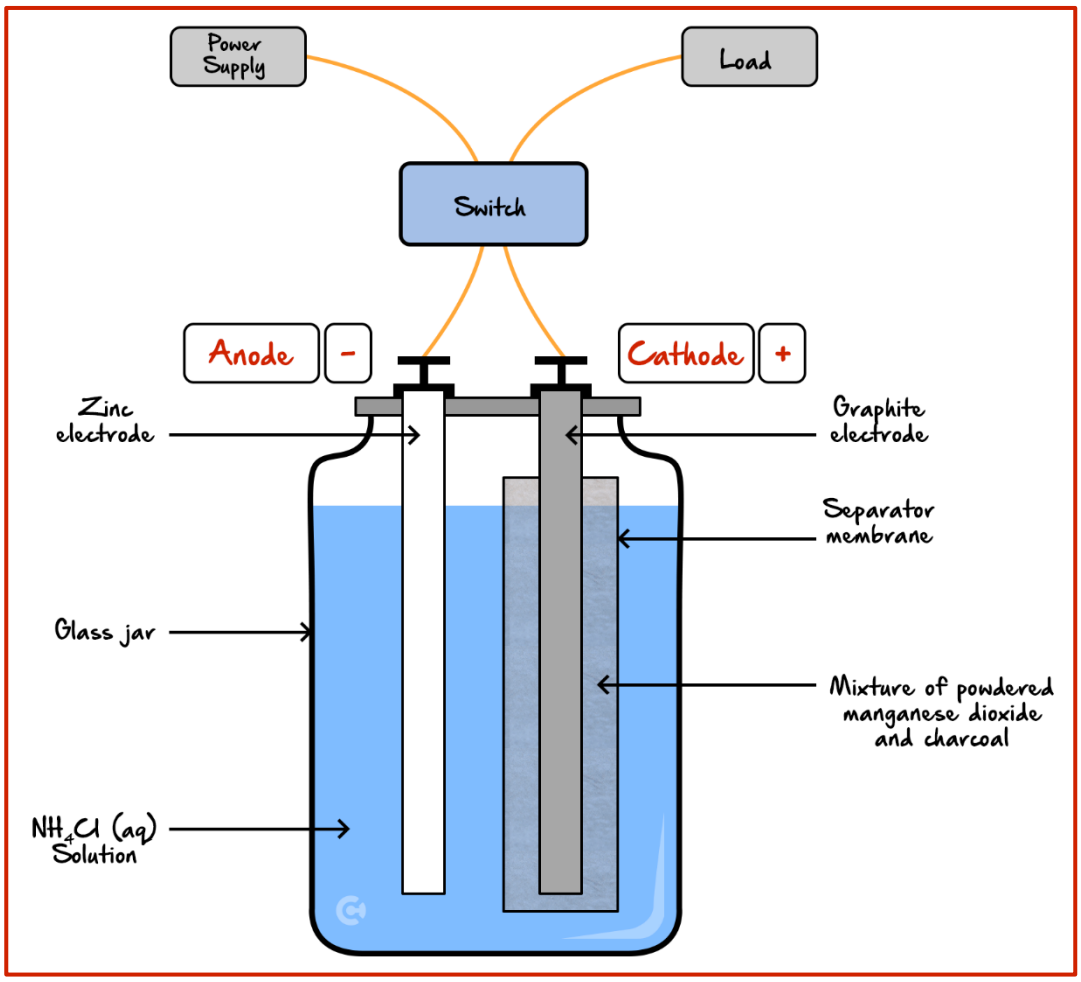
C. Always progressively reducing in size.

D. An inert electrode.

Section B: Short Answer Questions (45 Marks)

Question 4 (9 marks)

Taejus has replicated the Leclanche cell in a laboratory session. A diagram is shown below.



The half reactions are displayed below:

$$2MnO_2(s) + 2NH_4^+(aq) + 2e^- \rightleftharpoons Mn_2O_3(s) + 2NH_3(l) + H_2O(l) \qquad E_0 = 1.23\ V$$

$$ZnCl(aq) + 2e^- \rightleftharpoons Z$$

[2.1.1] Identify differences between galvanic & electrolysis for electrodes, energy conversions, electron flow

a. Assuming that the battery is undergoing **discharge** on the lines above, label the electrodes and their respective charges. (2 mar

[2.3.1] Write discharge & recharge reactions in secondary cells & redox flow batteries

b. Hence, write the full chemical reaction for the cell when it is converting electrical energy to chemical energy. (1 mark)

[2.3.1] Write discharge & recharge reactions in secondary cells & redox flow batteries

$$ZnCl(aq) + Mn_2O_3(s) + 2NH_3(l) + H_2O(l) \rightarrow 2MnO_2(s) + 2NH_4Cl(aq)$$

c. Calculate the voltage magnitude produced by the cell during discharge. (1 mark)

[2.1.2] Write equations & calculate EMF required for electrolytic reactions

$V_{out} = 1.23 - (-0.76) = 1.99\,V$

d. Explain the purpose of the separator membrane. (1 mark)

[2.3.2] Identify factors which affect rechargeability & compare similarities/differences between secondary cells and other cells

The separator membrane acts as a semi-permeable membrane, preventing reactants and products of each half reaction interacting with each other causing side reactions which would disrupt the cell function (1).

e. In the Leclanche cell although ammonia liquid is generally produced, if the cell overheats ammonia gas is produced. Suggest two issues with this. (2 marks)

[2.3.2] Identify factors which affect rechargeability & compare similarities/differences between secondary cells and other cells

- If ammonia gas is produced, it cannot remain in contact with the electrode after it is produced, preventing the backwards reaction from occurring during the recharge reaction.
- Pressure in the battery can increase causing it to burst.

f. Taejus discovers that the laboratory has run out of graphite electrodes. As a solution, Taejus decides to use an Iron electrode instead. Suggest and explain the impact which this change has on the cell. (2 marks)

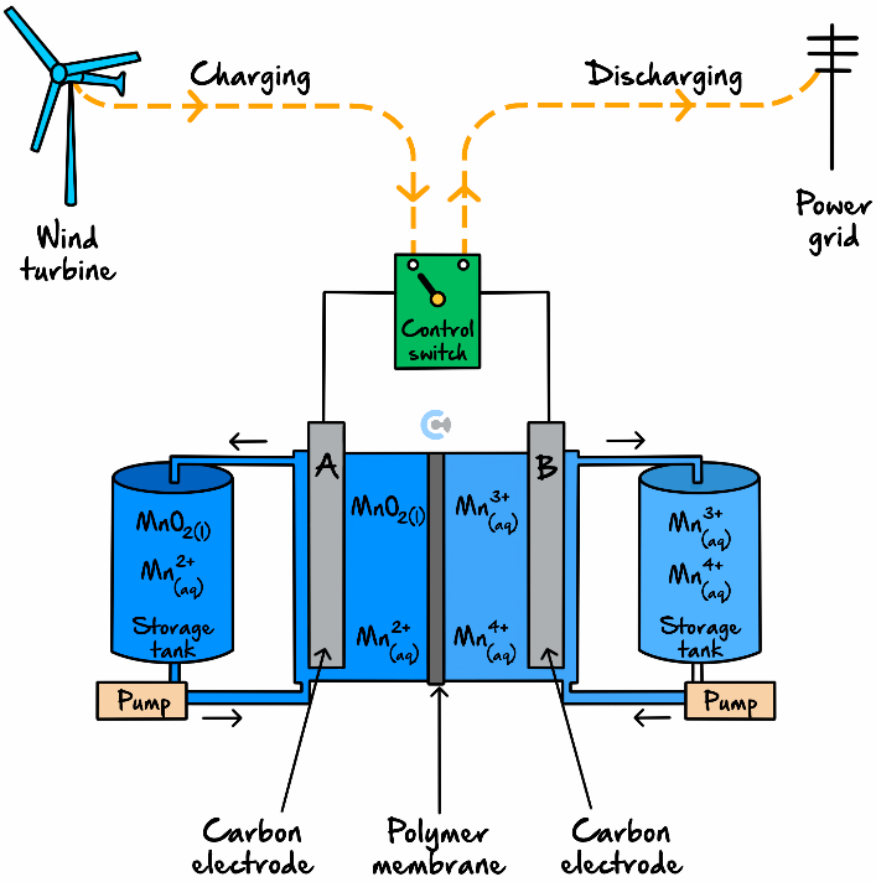
[2.2.1] Find electrolytic reactions in non-standard conditions (molten & high concentration)

$Fe(s)$ is a stronger reductant than $Mn_2O_3(s)$ and hence will oxidise in preference producing Fe^{2+} ions instead (1). This will result in manganese dioxide not being producing, disrupting cell function (2).

Space for Personal Notes

Question 5 (8 marks)

Anvi has created a brand new cell shown below, which is being used for commercial energy production in a nearby town. The cell operates in an alkaline medium.



a. Given that the E_0 value of the MnO_2/Mn^{2+} cell is $1.70\ V$ and E_0 value for Mn^{4+}/Mn^{3+} cell is $-0.85\ V$, write the oxidation and reduction half-reactions during discharge. (2 marks)

[2.3.1] Write discharge & recharge reactions in secondary cells & redox flow batteries

Reduction Half Reaction:

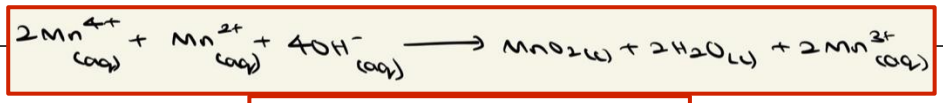
$2e^- + 2H_2O_{(l)} + MnO_{2(s)} \longrightarrow Mn^{2+}_{(aq)} + 4OH^-_{(aq)}$ $\quad E_0 = 1.70V$

Oxidation Half Reaction:

$Mn^{3+}_{(aq)} \longrightarrow Mn^{4+}_{(aq)} + e^-$ $\quad E_0 = -0.85V$

b. Hence, write the overall reaction for the cell during recharge, stating the polarities of electrode *A* and *B*. (2 marks)

[2.3.1] Write discharge & recharge reactions in secondary cells & redox flow batteries



Electrode *A* – Positively charged
Electrode *B* – Negatively charged

c. Calculate the energy required for the cell to function during recharge. (1 mark)

[2.1.2] Write equations & calculate EMF required for electrolytic reactions

$-0.85 - 1.70 = -2.55\text{V}$
Therefore, $> 2.55\text{V}$ required

d. Anvi is concerned about the concentrations of di

[2.2.1] Find electrolytic reactions in non-standard conditions (molten & high concentration)

i. Circle which species will be of the lowest concentration at the negatively charged electrode when all chemical energy in the battery has been consumed. (1 mark)

MnO_2 Mn^{2+} Mn^{4+} Mn^{3+}

ii. Explain your reasoning for **part i.** (2 marks)

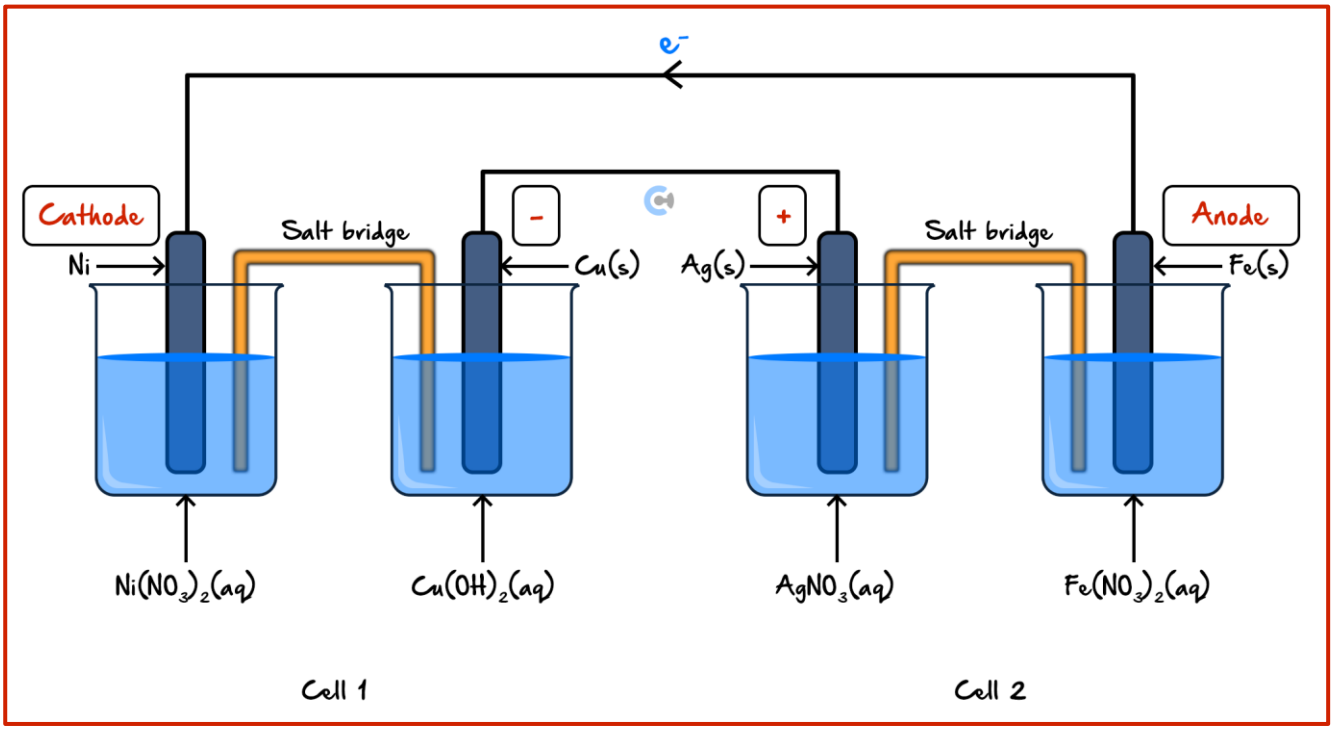
[2.2.1] Find electrolytic reactions in non-standard conditions (molten & high concentration)

When all chemical energy in the battery is consumed, the cell is still undergoing discharge (1). Hence, the negatively charged electrode will be the cathode, which is the site of reduction half reaction. As all chemical energy has been consumed, Mn^{3+} will be in lowest concentration (2).

Space for Personal Notes

Question 6 (18 marks)

Jacelynn is interested in the connected cell shown below. Jacelynn is also told that Nickel ions produce a distinct green colour.



a. On the diagram above, fill in the polarities of electrodes in the empty circles and label the electrode as cathode or anode on the empty lines. (2 marks)

[2.1.1] Identify differences between galvanic & electrolysis for electrodes, energy conversions, electron flow

b. Hence, or otherwise, prove that this cell can operate without an external power source. (2 marks)

Cell 1: Electrolytic cell

$E_o = -0.25 - (0.34)$

$= -0.59V$

(>0.59V required)

Cell 2: Galvanic cell

$E_o = 0.8 - (-0.44)$

$= 1.24V$

As Galvanic cell produces more than 0.59V, the cell can operate without an external power source.

[2.1.2] Write equations & calculate EMF required for electrolytic reactions

c. State the oxidation half reactions in cell 1 and cell 2. (1 mark)

[2.3.3] Find reactions occurring in connected cells

CELL 1:

$Cu_{(s)} \rightarrow Cu^{2+}_{(aq)} + 2e^-$

CELL 2:

$Fe_{(s)} \rightarrow Fe^{2+}_{(aq)} + 2e^-$

d. Her friend, Sai, suggests that the within cell 1, one half cell will increase in intensity of green, whereas the other half cell will decrease in intensity of blue. Evaluate and adjust this statement if necessary. (3 marks)

[2.3.3] Find reactions occurring in connected cells

Sai is incorrect (1). Nickel ions decrease in concentration as they are being reduced at the cathode, meaning that the green intensity will decrease (2). Copper ions will increase in concentration as copper solid is being oxidised at the anode, meaning that the blue intensity will increase (3).

e. After 30 minutes of the cell running, Jacelynn notices bubbling around the electrode in the nickel half cell of cell 1.

i. State the substance which is causing the bubbling. (1 mark)

[2.4.2] Find next order reactions during electrolysis

Hydrogen gas

ii. Hence, or otherwise, explain this observation. (3 marks)

[2.4.2] Find next order reactions during electrolysis

After 30 minutes, nickel ions present in the solution have been consumed (1). Hence, the next strongest oxidant in the half cell, water, will readily begin to reduce at the cathode (2). This produces hydrogen gas, causing bubbling at the electrode (3).

f. Jacelynn runs the cell for an hour.

[2.4.3] Apply Faraday's laws to electroplating calculations

i. Circle which electrode will gain the greatest mass at the end of the experiment. (1 mark)

Nickel Copper Silver Iron

ii. Explain your reasoning for **part f.i.** (2 marks)

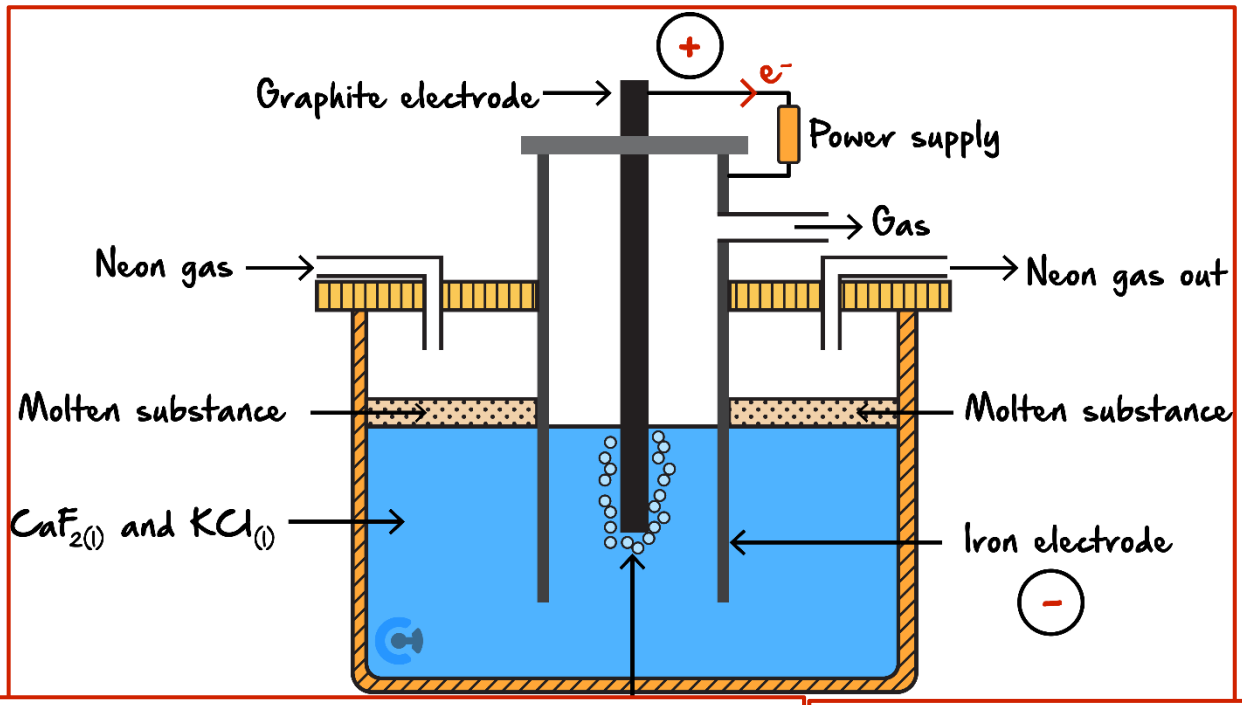
[2.4.3] Apply Faraday's laws to electroplating calculations

Copper and iron electrodes will decrease in mass as they are anodes (1). As silver has a larger m/z ratio (107.9) compared to nickel (58.7), silver electrode will have the greatest gain in mass (2).

Space for Personal Notes

Question 7 (10 marks)

Molten metals are used very commonly for thermal cooling and heating designs in modern homes. Eddie and Estella are exploring the cell below which is used to obtain some of these molten metals.



Gas bubbles accumulate around the graphite electrode. This suggests that Chloride ions have oxidised at this electrode to produce chlorine gas, indicating that this is the anode - positively charged.

[2.1.1] Identify differences between galvanic & electrolysis for electrodes, energy conversions, electron flow

a. Label the direction of electron flow, in addition to the polarities of the electrodes. (2 marks)

[2.2.2] Identify features of electrolytic cells & their purpose

b. Suggest and explain what molten substance will predominantly accumulate after 1 hour of the cell running. (2 marks)

[2.1.1] Identify differences between galvanic & electrolysis for electrodes, energy conversions, electron flow

Molten calcium will predominantly accumulate in the molten substance layer after 1 hour of the cell running (1). This is because Ca^{2+} is a stronger reductant than K^+ ions, meaning that these ions reduce in preference at the cathode to produce molten calcium (2).

c. Hence, write the oxidation and reduction half-reactions for this cell. (1 mark)

[2.2.1] Find electrolytic reactions in non-standard conditions (molten & high concentration)

Reduction Half Reaction:
$Ca^{2+}_{(l)} + 2e^- \rightarrow Ca_{(l)}$

Oxidation Half Reaction:
$2Cl^-_{(l)} \rightarrow Cl_{2(g)} + 2e^-$

d. When setting up a duplicate of this cell, Eddie realises that they have run out of graphite electrodes. As a solution, they decide to use iron metal for both electrodes instead. Whilst running the cell they notice that no bubbles are formed anymore. Explain this observation and its implications on the type of molten metals produced in the cell. (3 marks)

[2.1.2] Write equations & calculate EMF required for electrolytic reactions

If the graphite electrode is replaced with Iron, Iron will oxidise in preference to chlorine ions at the anode as it is a stronger reductant (1). This results in Iron cations produced at the anode instead of chlorine gas, which causes no bubbles to be produced (2). As iron cations are stronger oxidants than both Ca^{2+} and K^{+}, over time iron cations will reduce in preference producing a molten iron layer at the top of the cell (3).

e. Explain why Neon gas is actively pumped into the cell. (2 marks)

[2.2.2] Identify features of electrolytic cells & their purpose

Neon gas is an inert gas and will not react with the molten metal produced (1). By actively pumping it into the cell, it prevents oxygen from entering the cell and spontaneously reacting with the molten metal to produce Calcium oxide (2).

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