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VCE Chemistry ¾

AOS 2 Revision (Electrolysis) [2.0]

SAC 2 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 & Artificial Photosynthesis)

Which of the following is not a method of safely handling hydrogen gas?

A. Using a well-ventilated area.

B. Storing under high pressure (and low temperature).

C. Storing in cool and wet areas.

D. Installing detection devices near the storage of hydrogen gas.

Question 2 (1 mark)

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

Emma is experimenting with half-reactions shown below, in a secondary cell.

$$2Cr^{3+}(aq) + 7H_2O(l) \rightarrow Cr_2O_7{}^{2-} + 14H^+(aq) + 6e^- \qquad E_0 = -0.81\,V$$

$$Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^- \qquad E_0 = 1.12\,V$$

What is the overall reaction and the voltage produced during discharge?

A. $1.93\,V;\ 14H^+(aq) + 6Fe^{2+}(aq) + Cr_2O_7{}^{2-}(aq) \rightarrow 6Fe^{3+} + 2Cr^{3+}(aq) + 7H_2O(l)$

B. $0.31\,V;\ 14H^+(aq) + 6Fe^{2+}(aq) + Cr_2O_7{}^{2-}(aq) \rightarrow 6Fe^{3+} + 2Cr^{3+}(aq) + 7H_2O(l)$

C. $1.93\,V;\ 6Fe^{2+}(aq) + 2Cr^{3+}(aq) + 7H_2O(l) \rightarrow Cr_2O_7{}^{2-}(aq) + 6Fe^{3+}(aq) + 14H^+(aq)$

D. $0.31\,V;\ 6Fe^{2+}(aq) + 2Cr^{3+}(aq) + 7H_2O(l) \rightarrow Cr_2O_7{}^{2-}(aq) + 6Fe^{3+}(aq) + 14H^+(aq)$

Question 3 (1 mark)

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

Which of the following is least likely to be a significant reason for the decreasing battery life of a phone battery?

A. Overheating of the battery.

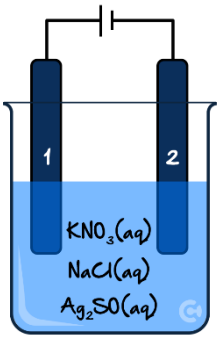
B. Excessive force exerted on the phone.

C. Side reactions occurring within the battery cells.

D. Battery is only partially charged during recharge.

Question 4 (1 mark) **[2.2.1] Find electrolytic reactions in non-standard conditions (molten & high concentration)**

Neha is operating the cell shown below with concentrated reagents. Which of the following describes the products produced at each electrode correctly?



A. Electrode 1: $H_2O(l)$, Electrode 2: $Ag(s)$

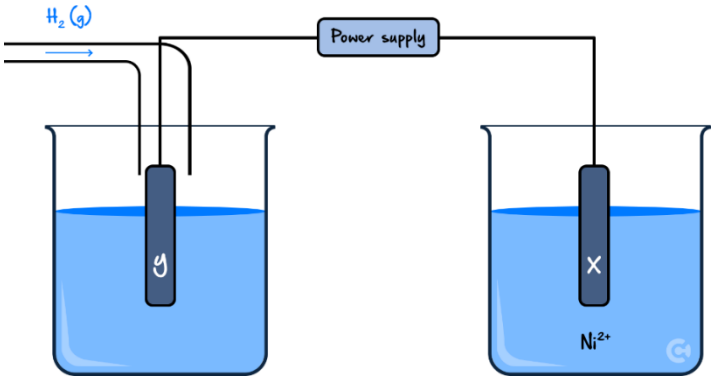
B. Electrode 1: $Cl_2(g)$, Electrode 2: $Ag(s)$

C. Electrode 1: $H_2O(l)$, Electrode 2: $H_2(g)$

D. Electrode 1: $Cl_2(g)$, Electrode 2: $K(s)$

Question 5 (1 mark) **[2.2.2] Identify features of electrolytic cells & their purpose**

Jayden is interested in the electrolytic cell shown below, where $H_2(g)$ is reacted with $Ni^{2+}(aq)$. Which of the following materials for electrodes *X* and *Y* would ensure the cell functions optimally?



A. *Y* - Lead, *X* - Nickel metal

B. *Y* - Platinum, *X* - Nickel metal

C. *Y* - Lead, *X* - Lead

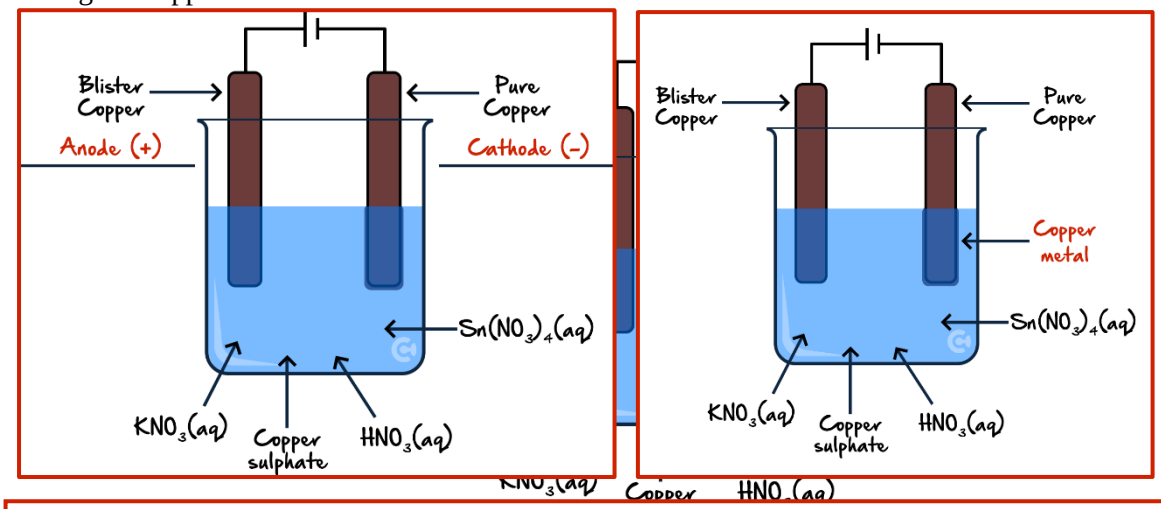
D. *Y* - Lead, *X* - Platinum

$Ni^{2+}(aq)$ will react with $Pb(s)$ in preference to $H_2(g)$, meaning the function of the electrolytic cell is disrupted. Hence, electrode Y must be platinum as it is inert.

Section B: Short Answer Questions (45 Marks)

Question 6 (27 marks)

Leviana is running an experiment to obtain pure copper from blister copper in the electrolytic cell shown below. Her lab technician tells her that the blister copper contains metal impurities such as silver and gold. Current runs through the apparatus at 4.00 *A*.



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

a. On the lines provided, label the cathode and anode with their respective polarities. (2 marks)

b. Draw the product/s formed at the cathode. (1 mar

[2.4.1] Identify the electroplating setup (location of object) & find the electroplating reactions

c. State the oxidation and reduction half-reactions occurring immediately when Leviana turns the cell on. (1 mark)

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

Oxidation Half Reaction:

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

Reduction Half Reaction:

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

d. Leviana runs the cell for 1.50 hours and finds that 4.74 g of metal has deposited on an electrode.

i. Given that 4.74 g of metal is deposited at the electrode, find the charge of the copper ion used in this reaction. (4 marks)

[2.4.3] Apply Faraday's laws to electroplating calculations

$Q = (1.5 \times 60 \times 60) \times 4$
$= 21600$
$n(e) = \frac{21600}{96500}$
$= 0.2238$
$n(Cu) = \frac{4.74}{63.5}$
$= 0.07461$

∴ Let 'x' represent the charge of copper ion

∴ $0.2238 = x \times 0.07461$
$x \approx 3$
Cu^{3+}

ii. Leviana's friend tells her that "The 4.74 g of metal deposited on the electrode is a combination of potassium and copper." Evaluate this statement. (4 marks)

[2.4.2] Find next order reactions during electrolysis

Leviana's friend is incorrect (1). Copper ions are the strongest oxidant in the electrolyte and hence will reduce most readily on the electrode (2). As water is a stronger oxidant than potassium ions, water will preferentially reduce at the cathode until the electrolyte is no longer in contact with the electrode (3). Hence, the potassium ions are no longer to reduce on the electrode and hence will not contribute to the final mass of the electrode at the end of the experiment (4).

e. In another trial, Leviana runs the cell at the same current but finds that the 6.98 *g* of metal has deposited on the cathode. Calculate the duration, in hours, for which the circuit was running, based on your answer for **part d. i.** (3 marks)

[2.4.3] Apply Faraday's laws to electroplating calculations

$n(Cu) = \frac{6.98}{63.5} = 0.109921$

$\therefore n(e) = 3 \times 0.109921$

$= 0.32976$

$\therefore Q = 0.32976 \times 96500$

$= 31822.20472$

$\therefore t = \frac{31822.20472}{4}$

$t = 7955.55$

≈ 2.21 hours

f. Explain the purpose of the electrolyte containing $HNO_3(aq)$. (3 marks)

[2.2.2] Identify features of electrolytic cells & their purpose
[2.4.2] Find next order reactions during electrolysis

HNO_3 when in the electrolyte will dissociate into H^+ ions which are stronger oxidants than Sn^{4+} ions but weaker than copper ions (1). In doing so, when there is an insufficient supply of copper ions at the cathode due to a decrease in the rate of oxidation of copper at the anode, the H^+ ions will readily reduce producing hydrogen gas bubbling (2). This provides a visual indication to Leviana to stop the cell from running before Sn^{4+} begins to readily reduce (3).

g. Leviana notices that for the first thirty minutes, the intensity of the blue of the electrolyte remains constant. Explain this observation. (3 marks)

[2.4.1] Identify the electroplating setup (location of object) & find the electroplating reactions
[2.1.2] Write equations & calculate EMF required for electrolytic reactions

For the first thirty minutes, Copper is oxidised at the anode, producing copper ions and these ions are consumed at the cathode to reduce into solid copper (1). Hence, the copper ion concentration remains constant (2). As copper ions correspond to the blue colour of the solution, the blue intensity of the solution will remain relatively constant (3).

h. As the experiment progresses, Leviana notices that a sludge-like substance forms under the anode. Explain this observation. (2 marks)

[2.4.2] Find next order reactions during electrolysis

The blister copper is known to also contain impurities of Ag and Au. As both of these substances are weaker reductants than copper, they will not readily oxidise (1). Hence, as copper in the anode oxidises, the impurity substances will fall off the electrode and accumulate below as sludge (2).

i. State two commercial applications of electroplating blister copper. (2 marks)

[2.4.1] Identify the electroplating setup (location of object) & find the electroplating reactions

- To separate valuable metal impurities (Ag/Au) (1).
- To obtain pure solid copper (2).

j. Explain why electroplating blister copper in this way may be preferred to traditional industrial processes. Traditional methods utilise different melting points of metals to purify copper. (2 marks)

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

Traditional methods are often dangerous, require a lot of energy and can be expensive because of the need to melt copper (1). Electrolytic methods don't melt the copper and so are far cheaper, safer and more energy efficient (2).

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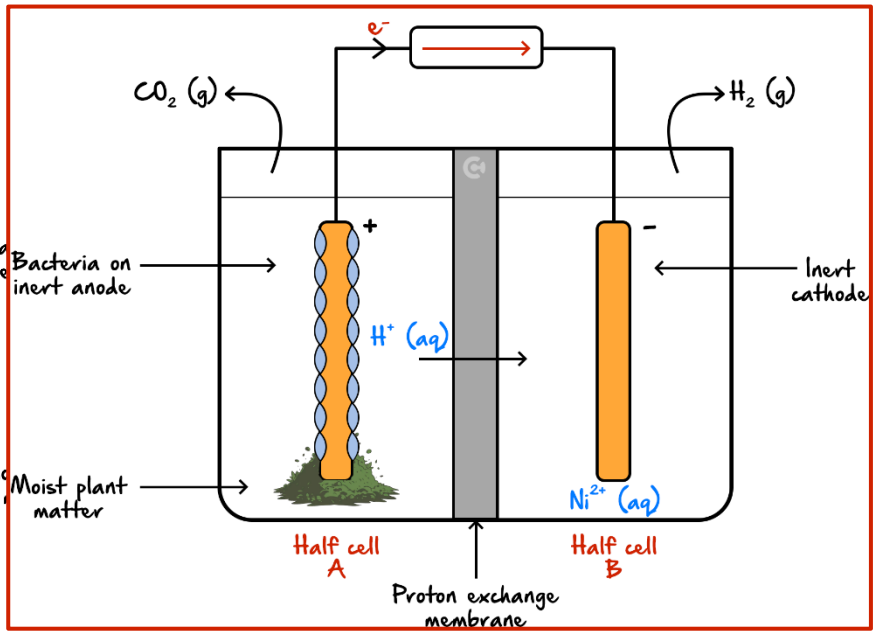
Question 7 (18 marks)

Jody and Dawn are investigating the cell below where the moist plant matter will ferment into ethanoic acid, which is consumed by the bacteria on the inert anode.



a. Complete the following half-equations:

i. Anode Reaction. (1 mark)

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

$CH_3COOH_{(aq)} + 2H_2O_{(l)} \rightarrow 2CO_{2(g)} + 8H^+_{(aq)} + 8e^-$

ii. Cathode Reaction. (1 mark)

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

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

iii. Hence, or otherwise, determine if the cell is electrolytic or galvanic and write in the box above whether the cell is attached to a power supply or a load, providing a reason why. (2 marks)

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

Electrolytic cell (0.5). As the anode is positively charged, the cell must be electrolytic and hence be connected to a power supply (1). (0.5 for correct label as power supply in the box on the diagram.)

iv. Draw the direction of electron flow on the diagram above. (1 mark)

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

b. Given that the E_0 value $= 1.05\ V$ for the anode reaction, calculate the voltage input required to run the cell. (1 mark)

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

$$V(\text{cell}) = 1.05 - 0$$
$$> 1.05\ V$$

c. After 30 minutes of the cell running, Jody notices that the intensity of green is decreasing in half-cell *B* and bubbling occurring at the anode in half-cell *A*.

i. Suggest what has caused the intensity of green in the half-cell to decrease. (2 marks)

[2.2.2] Identify features of electrolytic cells & their purpose

Ni^{2+} ions contained in the cell cause the green colour (1). As the intensity has decreased, the Nickel ions have been consumed at the cathode (2).

ii. Hence, explain both observations in relation to the redox reactions occurring with both half-cells. (4 marks)

[2.2.1] Find electrolytic reactions in non-standard conditions (molten & high concentration)
[2.4.2] Find next order reactions during electrolysis

As nickel ions are being consumed at the cathode, nickel ions are being preferentially reduced (1). Although H^+ ions are a stronger oxidant than Ni^{2+}, this suggests that the concentration of H^+ ions within half-cell *B* have decreased (2). Hence, the plant matter has likely all been fermented resulting in all the ethanoic acid being consumed, thereby meaning no H^+ ions are produced at the anode (3). Instead, water is being oxidised at the anode, Ni(s) is produced at the cathode (4).

d. Dawn notices that the cell produces large amounts of carbon dioxide and hydrogen gas. Explain why large accumulations of both gases can be dangerous and suggest a method to mitigate this situation. (2 marks)

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

Large accumulations of carbon dioxide and hydrogen gas can be toxic if inhaled (1). To avoid this issue, ensuring good ventilation is present in the room is important (2).

e. Hydrogen gas is used commonly as a fuel, such as in vehicles.

i. State a benefit of using hydrogen gas as a fuel in vehicles. (1 mark)

When hydrogen gas is combusted, no carbon dioxide emissions are produced (1).

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

ii. State two distinct disadvantages of using hydrogen gas as a fuel in vehicles. (2 marks)

- Hydrogen gas is extremely flammable/explosive (1).
- A large tank is required to store the hydrogen gas in the vehicle (2).

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

iii. Hydrogen detection equipment is often found near industrial hydrogen storage tanks. Explain why hydrogen gas is very hard to detect. (1 mark)

Hydrogen gas is invisible, doesn't emit an odour, and is tasteless making it difficult to detect (1).

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

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