AP Chemistry
2000 Student Samples

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2. Answer the following questions that relate to electrochemical reactions.

(a) Under standard conditions at 25°C, Zn(s) reacts with Co^{2+}(aq) to produce Co(s).

(i) Write the balanced equation for the oxidation half reaction.

(ii) Write the balanced net-ionic equation for the overall reaction.

(iii) Calculate the standard potential, \( E^\circ \), for the overall reaction at 25°C.

(b) At 25°C, \( \text{H}_2\text{O}_2 \) decomposes according to the following equation.

\[
2 \text{H}_2\text{O}_2(aq) \rightarrow 2 \text{H}_2\text{O}(l) + \text{O}_2(g) \quad E^\circ = 0.55 \text{ V}
\]

(i) Determine the value of the standard free energy change, \( \Delta G^\circ \), for the reaction at 25°C.

(ii) Determine the value of the equilibrium constant, \( K_eq \), for the reaction at 25°C.

(iii) The standard reduction potential, \( E^\circ \), for the half reaction \( \text{O}_2(g) + 4 \text{H}^+(aq) + 4 \text{e}^- \rightarrow 2 \text{H}_2\text{O}(l) \) has a value of 1.23 V. Using this information in addition to the information given above, determine the value of the standard reduction potential, \( E^\circ \), for the half reaction below.

\[
\text{O}_2(g) + 2 \text{H}^+(aq) + 2 \text{e}^- \rightarrow \text{H}_2\text{O}_2(aq)
\]

(c) In an electrolytic cell, Cu(s) is produced by the electrolysis of \( \text{CuSO}_4(aq) \). Calculate the maximum mass of Cu(s) that can be deposited by a direct current of 100. amperes passed through 5.00 L of 2.00 \( M \) \( \text{CuSO}_4(aq) \) for a period of 1.00 hour.
B. \[ 2 \text{H}_2\text{O}_2 \rightarrow 2 \text{H}_2\text{O} + \text{O}_2 \] \( \varepsilon^o = 0.55 \text{ V} \)

i. \( \Delta G = -n \gamma \varepsilon^o \)
\[ = - (2 \text{ mol e}^-)(96485 \text{ mol e}^- \text{ V}) \]
\[ = -106150 \text{ J} \]
\( \Delta G = -110 \text{ KJ} \)

ii. \( \Delta G = -RT \ln K \)
\[ K_{eq} = e^{\frac{-
\[ = e^{\frac{-106150}{8.315 \times 1 \times 298.15}} \]
\[ K_{eq} = 4.03 \times 10^{18} \]

iii. \[ \text{O}_2 + 4 \text{H}^+ + 4 \text{e}^- \rightarrow \text{H}_2\text{O} \] \( \varepsilon^o = 1.23 \text{ V} \)

\[ \text{H}_2\text{O} + \text{O}_2 \rightarrow 2 \text{H}_2\text{O}_2 \] \( \varepsilon^o = -0.55 \text{ V} \)

\[ \text{O}_2 + 2 \text{H}^+ + 2 \text{e}^- \rightarrow \text{H}_2\text{O}_2 \]

\[ 2 \text{O}_2 + 4 \text{H}^+ + 4 \text{e}^- \rightarrow 2 \text{H}_2\text{O}_2 \]

\[ \varepsilon^o_{\text{rxn}} = 1.23 \text{ V} + (-0.55 \text{ V}) \]
\[ \varepsilon^o_{\text{rxn}} = 0.68 \text{ V} \]

C. \[ \text{Cu}^{2+} + 2 \text{e}^- \rightarrow \text{Cu}^{0} \]
\[ 2.00 \text{ mol} \]
\[ \frac{\text{Cu}^{2+}}{\text{L}}(5.00 \text{ L}) = 10.0 \text{ mol} \text{Cu}^{2+} \]
\[ A = \frac{\text{Cu}^{2+}}{\text{sec}} \]

\[ g \text{ Cu} = 63.55 \text{ g Cu} \]
\[ 1 \text{ mol Cu} \]
\[ 1 \text{ mol e}^- \]
\[ 100 \text{ C} \]
\[ 60 \text{ sec} \]
\[ 1.00 \text{ hr} \]
\[ 1 \text{ min} \]
\[ 1 \text{ hr} \]

\[ = 119 \text{ g Cu} \]

GO ON TO THE NEXT PAGE.
2. Answer the following questions that relate to electrochemical reactions.

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(i) Write the balanced equation for the oxidation half reaction.

(ii) Write the balanced net-ionic equation for the overall reaction.

(iii) Calculate the standard potential, \( E^\circ \), for the overall reaction at 25°C.

(b) At 25°C, \( \text{H}_2\text{O}_2 \) decomposes according to the following equation.

\[
2 \text{H}_2\text{O}_2(aq) \rightarrow 2 \text{H}_2\text{O}(l) + \text{O}_2(g) \quad E^\circ = 0.55 \text{ V}
\]

(i) Determine the value of the standard free energy change, \( \Delta G^\circ \), for the reaction at 25°C.

(ii) Determine the value of the equilibrium constant, \( K_{eq} \), for the reaction at 25°C.

(iii) The standard reduction potential, \( E^\circ \), for the half reaction \( \text{O}_2(g) + 4 \text{H}^+(aq) + 4 e^- \rightarrow 2 \text{H}_2\text{O}(l) \) has a value of 1.23 V. Using this information in addition to the information given above, determine the value of the standard reduction potential, \( E^\circ \), for the half reaction below.

\[
\text{O}_2(g) + 2 \text{H}^+(aq) + 2 e^- \rightarrow \text{H}_2\text{O}_2(aq)
\]

(c) In an electrolytic cell, \( \text{Cu}(s) \) is produced by the electrolysis of \( \text{CuSO}_4(aq) \). Calculate the maximum mass of \( \text{Cu}(s) \) that can be deposited by a direct current of 100 amperes passed through 5.00 L of 2.00 M \( \text{CuSO}_4(aq) \) for a period of 1.00 hour.

\begin{align*}
3) & \; 1) \quad \text{Zn} \rightarrow \text{Zn}^{2+} + 2e^- \\
& \; ii) \quad \text{Zn} + \text{Co}^{2+} \rightarrow \text{Zn}^{2+} + \text{Co} \\
& \; iii) \quad E^\circ_{\text{Zn}} = 0.76 \\
& \quad E^\circ_{\text{red Co}} = -0.28 \\
& \quad E^\circ = 0.76 + (-0.28) = 0.48 \text{ V} \\
2) & \; 1) \quad \Delta G^\circ = -nFE^\circ \\
& \quad \Delta G^\circ = -(1)(96500)(0.55) \\
& \quad = -53075 \\
& \; ii) \quad \Delta G^\circ = -230.3 k \text{cal} \\
& \quad -53075 = -2303 \left( 5.31 \right) \log \text{k} \\
& \quad \log \text{k} = 9.306 \\
& \quad k = 2.02 \times 10^9
\end{align*}

GO ON TO THE NEXT PAGE.
\[ E^\circ = 1.23 + (-0.55) = 0.68 \text{ V} \]

c) \[ \frac{Mx}{V} = \frac{63.55}{96.50} \]

\[ 2.00 \text{ mol} \]

\[ \frac{mol}{S} \]

\[ 10 \text{ mol} + 20e^- \]

GO ON TO THE NEXT PAGE.
Answer EITHER Question 2 below OR Question 3 printed on page 12. Only one of these two questions will be graded. If you start both questions, be sure to cross out the question you do not want graded. The Section II score weighting for the question you choose is 20 percent.

2. Answer the following questions that relate to electrochemical reactions.

(a) Under standard conditions at 25°C, Zn(s) reacts with Co^{2+}(aq) to produce Co(s).
   (i) Write the balanced equation for the oxidation half reaction.
   (ii) Write the balanced net-ionic equation for the overall reaction.
   (iii) Calculate the standard potential, $E^\circ$, for the overall reaction at 25°C.

(b) At 25°C, $H_2O_2$ decomposes according to the following equation.
   \[ 2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g) \quad E^\circ = 0.55 \text{ V} \]
   (i) Determine the value of the standard free energy change, $\Delta G^\circ$, for the reaction at 25°C.
   (ii) Determine the value of the equilibrium constant, $K_{eq}$, for the reaction at 25°C.
   (iii) The standard reduction potential, $E^\circ$, for the half reaction $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(l)$ has a value of 1.23 V. Using this information in addition to the information given above, determine the value of the standard reduction potential, $E^\circ$, for the half reaction below.
   \[ O_2(g) + 2H^+(aq) + 2e^- \rightarrow H_2O_2(aq) \]

(c) In an electrolytic cell, Cu(s) is produced by the electrolysis of CuSO$_4$(aq). Calculate the maximum mass of Cu(s) that can be deposited by a direct current of 100. amperes passed through 5.00 L of 2.00 M CuSO$_4$(aq) for a period of 1.00 hour.
b.) i.) \( \Delta G = -n FE^o \)
\( = -2 (96,500 \text{ C/mol})(0.55 \text{ V}) \)
\( \Delta G = -1.06 \times 10^5 \)

ii.) \( K_{eq} = \frac{[H_2O]^2 [O_2]}{[H_2O_2]^2} \)

iii.) \( O_2 + 2H^+ + 2e^- \rightarrow H_2O_2 \)
\( E^o = \frac{1}{2} (1.23) = 0.615 \text{ V} \)

C.)