Electrochemistry Problems

1) **Given the E° for the following half-reactions:**

$Cu^{+} + e^{-} \rightarrow Cu°$ $\quad$ $E°_{red} = 0.52\ V$

$Cu^{2+} + 2e^{-} \rightarrow Cu°$ $\quad$ $E°_{red} = 0.34\ V$

What is E° for the reaction:

$Cu^{+} \rightarrow Cu^{2+} + e^{-}$

2) **How many Faradays are required to produce 21.58 g of silver from a silver nitrate solution?**

3) **A current of 2.75 amperes is used to electrolyze a solution of copper(II) sulfate. How long will it take to deposit 10.47 grams of copper?**

4) **A voltaic cell consists of a copper electrode in a solution of copper(II) ions and a palladium electrode in a solution of palladium(II) ions. The palladium is the cathode and its reduction potential is 0.951 V.**

   (a) **Write the half-reaction that occurs at the anode.**

   (b) **If E° is 0.609 V, what is the potential for the oxidation half-reaction?**

   (c) **What is K_{eq} for this reaction?**

5) **5.77 g of zinc is deposited at the cathode when a current of 7.1 amperes passes through an electrolytic cell for 40. minutes. What is the oxidation state of the zinc in the aqueous solution?**

6) **For each pair of species, choose the better reducing agent.**

(a) **Ag(s) or Sn(s), given:**

$Ag^{+}(aq) + e^{-} \rightarrow Ag(s)$ $E°_{red} = 0.799\ V$

$Sn^{2+}(aq) + 2e^{-} \rightarrow Sn(s)$ $E°_{red} = -0.136\ V$

(b) **$Br^{-}(aq)$ or $Cl^{-}(aq)$, given:**

$Br_2(l) + 2e^{-} \rightarrow 2Br^{-}(aq)$ $E°_{red} = 1.065\ V$

$Cl_2(g) + 2e^{-} \rightarrow 2Cl^{-}(aq)$ $E°_{red} = 1.359\ V$

(c) **Zn(s) or Co(s), given:**

$Zn^{2+}(aq) + 2e^{-} \rightarrow Zn(s)$ $E°_{red} = -0.763\ V$

$Co^{2+}(aq) + 2e^{-} \rightarrow Co(s)$ $E°_{red} = -0.277\ V$

(d) **Au(s) or $I^{-}(aq)$, given:**

$Au^{3+}(aq) + 3e^{-} \rightarrow Au(s)$ $E°_{red} = 1.420\ V$

$I_2(s) + 2e^{-} \rightarrow 2I^{-}(aq)$ $E°_{red} = 0.540\ V$

Solutions

1) **reduction:** $Cu^{+} + e^{-} \rightarrow Cu°$ $E°_{red} = 0.52\ V$

oxidation: $Cu° \rightarrow Cu^{2+} + 2e^{-}$ $E°_{ox} = -0.34\ V$

$Cu^{+} + \cancel{e^{-}} \rightarrow \cancel{Cu°}$ $E°_{red} = 0.52\ V$

$\cancel{Cu°} \rightarrow Cu^{2+} + \cancel{2}e^{-}$ $E°_{ox} = -0.34\ V$

$Cu^{+} \rightarrow Cu^{2+} + e^{-}$ $E°_{cell} = 0.18\ V$

2) **m = 21.58 g Ag**

1 F = 1 mol e^{-}

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

$n_F = 21.58\ \cancel{g\ Ag} \times 1\ \cancel{mol\ Ag}/107.90\ \cancel{g\ Ag} \times 1\ \cancel{mol\ e^{-}}/1\ \cancel{mol\ Ag} \times 1\ F/1\ \cancel{mol\ e^{-}}$

$n_F = 0.200\ F$

3) **I = 2.75 A = 2.75 C/s**

m = 10.47 g Cu

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

$10.47\ \cancel{g\ Cu} = 2.75\ \cancel{C}/s \times t \times 1\ \cancel{mol\ Cu}/2\ \cancel{mol\ e^{-}} \times 1\ \cancel{mol\ e^{-}}/96500\ \cancel{C} \times$

$63.55\ \cancel{g\ Cu}/1\ \cancel{mol\ Cu}$

$t = 11600\ s \times 1\ hr/3600\ s = 3.22\ hr$

4) (a) $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$

(b) $Pd^{2+} + \cancel{2e^-} \rightarrow Pd$ $\qquad E°_{red} = 0.951\ V$

$Cu \rightarrow Cu^{2+} + \cancel{2e^-}$ $\qquad E°_{ox} = ?$

$Pd^{2+}(aq) + Cu(s) \rightarrow Pd(s) + Cu^{2+}(aq)$ $\qquad E°_{cell} = 0.609\ V$

$E°_{cell} = E°_{red} + E°_{ox}$

$0.609\ V = 0.951\ V + E°_{ox}$

$E°_{ox} = -0.340\ V$

(c) $\log K_{eq} = n \times E°/0.0592$

$\log K_{eq} = 2 \times 0.609\ V/0.0592 = 20.6$

$K_{eq} = 10^{20.6} = 3.98 \times 10^{20}$

5) m = 5.77 g Zn

I = 7.1 A = 7.1 C/s

t = 40. ~~min~~ x 60 s/1 ~~min~~ = 2.4×10^3 s

$Zn^{x+}(aq) + xe^- \rightarrow Zn(s)$

$5.77\ \cancel{g\ Zn} = 7.1\ \cancel{C}/s \cdot 2.4 \times 10^3\ s \cdot 1\ \cancel{mol\ Zn}/x\ \cancel{mol\ e^-} \cdot 1\ \cancel{mol\ e^-}/96500\ \cancel{C}$

$\cdot\ 65.39\ \cancel{g\ Zn}/1\ \cancel{mol\ Zn}$

x = 2, therefore $Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$

6) **(a)** **Sn(s) because it is more difficult to reduce than Ag(s).**

The more difficult it is to reduce a species, the more readily its products are oxidized. This inverse relationship between reducing and oxidizing agents is similar to the inverse relationship between the strengths of conjugate acids and bases.

(b) **Br^-(aq) because Cl^-(aq) is the better oxidizing agent making Br^-(aq) the better reducing agent.**

(c) **Zn(s) because it is a weaker oxidizing agent than Co(s).**

(d) **Au(s) is the better oxidizing agent, therefore I^-(aq) is the better reducing agent.**