1. What is the oxidizing agent in the following reaction?

\[ \text{Pb} + \text{PbO}_2 + 2 \text{H}_2\text{SO}_4 \rightarrow 2 \text{PbSO}_4 + 2 \text{H}_2\text{O} \]

2. How many electrons are transferred in the following reaction?

\[ 2 \text{Cr}^{3+} + 3 \text{SO}_4^{2-} + 4 \text{H}_2\text{O} \rightarrow \text{Cr}_2\text{O}_7^{2-} + 3 \text{H}_2\text{SO}_3 + 2 \text{H}^+ \]

3. Which of the following is the strongest oxidizing agent?

\[
\begin{align*}
\text{Zn}^{2+} + 2\text{e}^- & \rightarrow \text{Zn} \quad -0.76 \text{ V} \\
2\text{H}_2\text{O} + 2\text{e}^- & \rightarrow \text{H}_2 + 2\text{OH}^- \quad -0.83 \text{ V} \\
\text{Mn}^{2+} + 2\text{e}^- & \rightarrow \text{Mn} \quad -1.18 \text{ V}
\end{align*}
\]

4. What would be the standard cell potential at 298K if the energy of the following reaction could be harnessed as a Galvanic cell?

\[ 4 \text{P} + 5 \text{O}_2 \rightarrow 2 \text{P}_2\text{O}_5 \quad \Delta G^0 = -2698 \text{ kJ} \]

5. Write the half reaction that will take place at the anode of a Galvanic cell based on the following data?

\[
\begin{align*}
\text{Cl}_2 + 2\text{e}^- & \rightarrow 2\text{Cl}^- \quad 1.36 \text{ V} \\
\text{I}_2 + 2\text{e}^- & \rightarrow 2\text{I}^- \quad 0.54 \text{ V}
\end{align*}
\]

6. A Galvanic cell is described as follows:

\[ \text{Pt} | \text{H}_2 (1.0 \text{ atm}) | \text{H}^+ (1.0 \text{M}) || \text{Fe}^{3+} (1.0 \text{ M}), \text{Fe}^{2+} (1.0 \text{ M}) | \text{Pt} \]

Write the half reactions that occur at the anode and cathode.

7. Consider a Galvanic cell constructed using a solid silver electrode immersed in a 1.0 M Ag\(^+\) solution and a solid nickel electrode immersed in a 1.0 M Ni\(^{2+}\) solution. Which direction will the electrons flow?

\[
\begin{align*}
\text{Ag}^+ + \text{e}^- & \rightarrow \text{Ag} \quad 0.80 \text{ V} \\
\text{Ni}^{2+} + 2\text{e}^- & \rightarrow \text{Ni} \quad -0.23 \text{ V}
\end{align*}
\]

8. Determine the standard potential for the following reaction at 298K: \( \text{PbS} \leftrightharpoons \text{Pb}^{2+} + \text{S}^{2-} \quad K = 8.0 \times 10^{-28} \)

Based on your answer; determine the standard reduction potential for the following half reaction:

\[ \text{PbS} + 2\text{e}^- \rightarrow \text{Pb} + \text{S}^{2-} \quad E^0 = ??? \]

Note: \( \text{Pb}^{2+} + 2\text{e}^- \rightarrow \text{Pb} \quad E^0 = -0.13 \text{ V} \)

9. What can silver spontaneously reduce based on the following data?

\[
\begin{align*}
\text{Cl}_2 + 2\text{e}^- & \rightarrow 2\text{Cl}^- \quad 1.36 \text{ V} \\
\text{Br}_2 + 2\text{e}^- & \rightarrow 2\text{Br}^- \quad 1.09 \text{ V} \\
\text{Ag}^+ + \text{e}^- & \rightarrow \text{Ag} \quad 0.80 \text{ V} \\
\text{Fe}^{3+} + \text{e}^- & \rightarrow \text{Fe}^{2+} \quad 0.77 \text{ V} \\
\text{Zn}^{2+} + 2\text{e}^- & \rightarrow \text{Zn} \quad -0.76 \text{ V}
\end{align*}
\]

10. Will solid lead dissolve in a 1.0M solution of NiCl\(_2\)?

\[
\begin{align*}
\text{Cl}_2 + 2\text{e}^- & \rightarrow 2\text{Cl}^- \quad 1.36 \text{ V} \\
\text{Pb}^{2+} + 2\text{e}^- & \rightarrow \text{Pb} \quad -0.13 \text{ V} \\
\text{Ni}^{2+} + 2\text{e}^- & \rightarrow \text{Ni} \quad -0.23 \text{ V}
\end{align*}
\]
11. Predict what will happen when a piece of Sn (s) is placed in an aqueous solution of FeCl₂.

\[
\begin{align*}
\text{Cl}_2 + 2e^- & \rightarrow 2\text{Cl}^- & \text{1.36 V} \\
\text{Sn}^{2+} + 2e^- & \rightarrow \text{Sn} & \text{-0.44 V} \\
\text{Fe}^{2+} + 2e^- & \rightarrow \text{Fe} & \text{-0.14 V}
\end{align*}
\]

a. Sn²⁺ will be produced  
 b. Cl₂ will be produced  
 c. Fe will be produced  
 d. No reaction will occur  
 e. More than one of these will occur

12. You want to plate out nickel from a nickel (II) nitrate solution by inserting a piece of metal. Should you use copper, zinc, either copper or zinc, neither copper or zinc will plate out nickel.

\[
\begin{align*}
\text{Cu}^{2+} + 2e^- & \rightarrow \text{Cu} & \text{0.34 V} \\
\text{Ni}^{2+} + 2e^- & \rightarrow \text{Ni} & \text{-0.23 V} \\
\text{Zn}^{2+} + 2e^- & \rightarrow \text{Zn} & \text{-0.76 V}
\end{align*}
\]

13. Based on the following information, what can reduce Ni²⁺ but not Al³⁺?

\[
\begin{align*}
\text{Cu}^{2+} + 2e^- & \rightarrow \text{Cu} & \text{0.34 V} \\
\text{Ni}^{2+} + 2e^- & \rightarrow \text{Ni} & \text{-0.23 V} \\
\text{Fe}^{2+} + 2e^- & \rightarrow \text{Fe} & \text{-0.44 V} \\
2\text{H}_2\text{O} + 2e^- & \rightarrow \text{H}_2 + 2\text{OH}^- & \text{-0.83 V} \\
\text{Al}^{3+} + 3e^- & \rightarrow \text{Al} & \text{-1.66 V} \\
\text{Na}^+ + e^- & \rightarrow \text{Na} & \text{-2.71 V}
\end{align*}
\]

14. Consider a Galvanic cell based on the following half reactions:

\[
\begin{align*}
\text{Pb}^{2+} + 2e^- & \rightarrow \text{Pb} & \text{-0.13 V} \\
\text{Cr}^{3+} + 3e^- & \rightarrow \text{Cr} & \text{-0.73 V}
\end{align*}
\]

Determine what will happen to the cell potential for the following if initially [Pb²⁺] = 1.0M and [Cr³⁺] = 1.0M.

a. Water is added to both sides causing the volume to double in each compartment.
 b. Sodium hydroxide is added to the chromium half cell causing Cr(OH)₃ to precipitate.
 c. The mass of the lead electrode is doubled.

15. Consider the Galvanic cell at 25 °C described as follows:

\[
X | X^{2+} || Y^{3+} | Y
\]

Where X and Y are unknown metals. Given the standard reduction potential for Y³⁺ is 1.5 V and that K for the overall reaction in this Galvanic cell is 1.2 x 10⁻²⁰ what is the standard reduction potential of X²⁺?

16. Calculate the potential for the following galvanic cell at 320K.
17. Consider the Galvanic cell below to answer the following:

Initially the masses of the aluminum electrode and the zinc electrode are 116 g and 150 g respectively. Assuming the reaction goes to completion calculate the final mass of the aluminum electrode.

18. Calculate $\Delta G$ for the following electrochemical cell at 298K.

$$
\text{Mg} \mid \text{Mg}^{2+} \ (2.3 \text{ M}) \ || \ \text{Cr}^{3+} \ (0.16\text{ M}) \mid \text{Cr}
$$

- $\text{Cr}^{3+} + 3e^- \rightarrow \text{Cr} \quad -0.73 \text{ V}
- $\text{Mg}^{2+} + 2e^- \rightarrow \text{Mg} \quad -2.37 \text{ V}$

19. Consider the following cell: $\text{Al} \mid \text{Al}^{3+} \ (1.0 \text{ M}) \ || \ \text{Pb}^{2+} \ (1.0 \text{ M}) \mid \text{Pb}\ (s)$

- $\text{Pb}^{2+} + 2e^- \rightarrow \text{Pb} \quad -0.13 \text{ V}
- $\text{Al}^{3+} + 3e^- \rightarrow \text{Al} \quad -1.66 \text{ V}$

Calculate the cell potential for the reaction when the $[\text{Al}^{3+}]$ has changed by 0.66 M at 25 °C.

20. A concentration cell is created using copper electrodes and aqueous Cu$^{2+}$ solutions. Which of the following will cause a positive cell potential if the concentration of copper (II) ion is 1.0 M at the cathode?

- $\text{Cu}^{2+} + 2e^- \rightarrow \text{Cu} \quad 0.34 \text{ V}$
  a. The concentration of the copper (II) ion at the anode must be less than 1.0 M
  b. The concentration of the copper (II) ion at the anode must be greater than 1.0 M
  c. The concentration of the copper (II) ion at the anode must be equal to 1.0 M
  d. The cell potential will be zero regardless of the concentration of the copper (II) ion

21. A concentration cell is constructed in which one half cell contains a Cr (s) electrode immersed in a 0.21 M Cr$^{3+}$ solution and the other half cell contains a Cr (s) electrode immersed in a 1.8 M Cr$^{3+}$ solution. Which direction will the potassium ions flow if the salt bridge is composed of KNO$_3$ solution?
22. Consider the following concentration cell at 298K: \( \text{Fe} \mid \text{Fe}^{2+} (0.001 \text{ M}) \mid \text{Fe}^{2+} (0.1 \text{ M}) \mid \text{Fe} \) 
Calculate the cell potential if the standard reduction potential for \( \text{Fe}^{2+} \) is -0.44 V.

23. Three separate solutions are electrolyzed using the same current to plate out solid metals. Which of the following will take the longest amount of time?
   a. Plating 5 grams of solid Al from an \( \text{Al}^{3+} \) solution
   b. Plating 15 grams of solid Ca from a \( \text{Ca}^{2+} \) solution
   c. Plating 40 grams of solid Rb from a \( \text{Rb}^{+} \) solution
   d. All three processes take the same amount of time

24. How long will it take (in min) to plate out 10.0 g of Bi from a solution of \( \text{Bi}^{3+} \) using a current of 25.0 A?

25. In an electrolysis experiment, a student passes the same current through two electrolytic cells for the same amount of time. One cell contains \( \text{Ag}^{+} \) ion and the other contains \( \text{Mn}^{2+} \). Determine the value of \( x \) if 7.6 grams of Ag and 0.77 grams of Mn were plated out.

26. To determine the molar mass of an unknown metal \( M \), the metal is plated out from a solution containing \( M^{3+} \) ions. Determine the molar mass of the metal if 61.8 grams of \( M \) is plated out after electrolyzing the solution with a current of 25.1 A for 85 minutes.

27. Consider an electrochemical cell described as follows: \( \text{Mg(s)} \mid \text{Mg}^{2+} (0.85 \text{ M}) \mid \text{Al}^{3+} (0.85 \text{ M}) \mid \text{Al(s)} \) 
   If each compartment has a volume of 1.0L, what will be the concentration of the \( \text{Al}^{3+} \) after the cell delivers 0.22 A of current for 31.6 hr?

28. A solution of \( \text{NaCl} \) is electrolyzed to produce \( \text{Cl}_2 \) gas. What volume of \( \text{Cl}_2 \) at 298 K and 1 atm is generated if the solution is exposed to a current of 54 A for 13 minutes?