Science 122
Electrochemical Cells Worksheet

1. Calculate the standard cell potential produced by a galvanic cell consisting of a nickel electrode in contact with a solution of Ni\(^{2+}\) ions and a silver electrode in contact with a solution of Ag\(^{+}\) ions. Which is anode and which is the cathode?

2. What is the voltage produced by a galvanic cell consisting of an aluminum electrode in contact with a solution of Al\(^{3+}\) ions and an iron electrode in contact with a solution of Fe\(^{2+}\) ions. Which is anode and which is the cathode?

3. Calculate the standard cell potential produced by a galvanic cell consisting of a sodium electrode in contact with a solution of Na\(^{+}\) ions and a copper electrode in contact with a solution of Cu\(^{2+}\) ions. Which is anode and which is the cathode?

4. What is the voltage produced by a voltaic cell consisting of a calcium electrode in contact with a solution of Cu\(^{2+}\) ions. Which is anode and which is the cathode?

5. An electrochemical cell is constructed using electrodes based on the following half reactions:
   \[ \text{Pb}^{2+}(aq) + 2e^- \rightarrow \text{Pb}(s) \]
   \[ \text{Au}^{3+}(aq) + 3e^- \rightarrow \text{Au}(s) \]
   a) Which is the anode and which is the cathode in this cell?
   b) What is the standard cell potential?

6. Calculate the standard cell potential produced by a voltaic cell consisting of a nickel electrode in contact with a solution of Ni\(^{2+}\) ions and a copper electrode in contact with a solution of Cu\(^{2+}\) ions. Which is anode and which is the cathode?

7. A voltaic cell is constructed using electrodes based on the following half reactions:
   \[ \text{Mg}^{2+}(aq) + 2e^- \rightarrow \text{Mg}(s) \]
   \[ \text{Cu}^{2+}(aq) + 2e^- \rightarrow \text{Cu}(s) \]
   a) Which is the anode and which is the cathode in this cell?
   b) What is the standard cell potential?

8. What is the voltage produced by a voltaic cell consisting of a lead electrode in contact with a solution of Pb\(^{2+}\) ions and an iron electrode in contact with a solution of Fe\(^{2+}\)? Which is anode and which is the cathode?

9. What is the voltage produced by a voltaic cell consisting of a zinc electrode in contact with a solution of Zn\(^{2+}\) ions and a silver electrode in contact with a solution of Ag\(^{+}\) ions? Which is anode and which is the cathode?

10. Calculate the standard cell potential produced by a voltaic cell consisting of a gold electrode in contact with a solution of Au\(^{3+}\) ions and a silver electrode in contact with a solution of Ag\(^{+}\) ions. Which is the anode and which is the cathode?

11. Use half-reaction potentials to predict whether the following reactions are spontaneous or non-spontaneous in aqueous solutions.
   a) \[ \text{Ca}^{2+}(aq) + 2 \text{I}^- (aq) \rightarrow \text{Ca}(s) + 2 \text{I}_2(aq) \]
   b) \[ 2 \text{H}_2\text{S}(g) + \text{O}_2(g) \rightarrow 2 \text{H}_2\text{O}(l) + 2 \text{S}(s) \]
   c) \[ \text{SO}_2(g) + \text{MnO}_2(s) \rightarrow \text{Mn}^{2+}(aq) + \text{SO}_4^{2-}(aq) \]
   d) \[ 2 \text{H}^+(aq) + 2 \text{Br}^- (aq) \rightarrow \text{H}_2\text{I}(g) + \text{Br}_2(aq) \]
   e) \[ \text{Ce}^{4+}(aq) + \text{Fe}^{2+}(aq) \rightarrow \text{Ce}^{3+}(aq) + \text{Fe}^{3+}(aq) \]
   f) \[ \text{Cr}^{2+}(aq) + \text{Cu}^{2+}(aq) \rightarrow \text{Cr}^{3+}(aq) + \text{Cu}^+(aq) \]
1. Calculate the standard cell potential produced by a galvanic cell consisting of a nickel electrode in contact with a solution of Ni^{2+} ions and a silver electrode in contact with a solution of Ag^{+} ions. Which is anode and which is the cathode?

\[
\begin{align*}
\text{Ni}^{2+} (aq) + 2e^- &\rightarrow \text{Ni(s)} \quad E^\circ = -0.26 \text{ V (must be flipped)} \\
\text{Ag}^+ (aq) + e^- &\rightarrow \text{Ag(s)} \quad E^\circ = 0.80 \text{ V}
\end{align*}
\]

ANODE: \[\text{Ni(s)} \rightarrow \text{Ni}^{2+} (aq) + 2e^- \quad E^\circ = 0.26 \text{ V} \]

CATHODE: \[\text{Ag}^+ (aq) + e^- \rightarrow \text{Ag(s)} \quad E^\circ = 0.80 \text{ V} \]

\[E^\circ = 1.06 \text{ V}\]

2. What is the voltage produced by a galvanic cell consisting of an aluminum electrode in contact with a solution of Al^{3+} ions and an iron electrode in contact with a solution of Fe^{2+} ions. Which is anode and which is the cathode?

\[
\begin{align*}
\text{Al}^{3+} (aq) + 3e^- &\rightarrow \text{Al(s)} \quad E^\circ = -1.66 \text{ V (must be flipped)} \\
\text{Fe}^{2+} (aq) + 2e^- &\rightarrow \text{Fe(s)} \quad E^\circ = -0.44 \text{ V}
\end{align*}
\]

ANODE: \[\text{Al(s)} \rightarrow \text{Al}^{3+} (aq) + 3e^- \quad E^\circ = 1.66 \text{ V} \]

CATHODE: \[\text{Fe}^{2+} (aq) + 2e^- \rightarrow \text{Fe(s)} \quad E^\circ = 1.22 \text{ V} \]

3. Calculate the standard cell potential produced by a galvanic cell consisting of a sodium electrode in contact with a solution of Na^{+} ions and a copper electrode in contact with a solution of Cu^{2+} ions. Which is anode and which is the cathode?

\[
\begin{align*}
\text{Na}^+ (aq) + e^- &\rightarrow \text{Na(s)} \quad E^\circ = -2.71 \text{ V (must be flipped)} \\
\text{Cu}^{2+} (aq) + 2e^- &\rightarrow \text{Cu(s)} \quad E^\circ = 0.34 \text{ V}
\end{align*}
\]

ANODE: \[\text{Na(s)} \rightarrow \text{Na}^+ (aq) + e^- \quad E^\circ = 2.71 \text{ V} \]

CATHODE: \[\text{Cu}^{2+} (aq) + 2e^- \rightarrow \text{Cu(s)} \quad E^\circ = 3.05 \text{ V} \]

\[E^\circ = 3.05 \text{ V}\]

4. What is the voltage produced by a voltaic cell consisting of a calcium electrode in contact with a solution of Cu^{2+} ions. Which is anode and which is the cathode?

\[
\begin{align*}
\text{Ca}^{2+} (aq) + 2e^- &\rightarrow \text{Ca(s)} \quad E^\circ = -2.87 \text{ V (must be flipped)} \\
\text{Cu}^{2+} (aq) + 2e^- &\rightarrow \text{Cu(s)} \quad E^\circ = 0.34 \text{ V}
\end{align*}
\]

ANODE: \[\text{Ca(s)} \rightarrow \text{Ca}^{2+} (aq) + e^- \quad E^\circ = 2.87 \text{ V} \]

CATHODE: \[\text{Cu}^{2+} (aq) + 2e^- \rightarrow \text{Cu(s)} \quad E^\circ = 3.21 \text{ V} \]

\[E^\circ = 3.21 \text{ V}\]

5. An electrochemical cell is constructed using electrodes based on the following half reactions:

\[
\begin{align*}
\text{Pb}^{2+} (aq) + 2e^- &\rightarrow \text{Pb(s)} \\
\text{Au}^{3+} (aq) + 3e^- &\rightarrow \text{Au(s)}
\end{align*}
\]

a) Which is the anode and which is the cathode in this cell?

ANODE: \[\text{Pb} \rightarrow \text{Pb}^{2+} (aq) + 2e^- \quad E^\circ = 0.13 \text{ V} \]

CATHODE: \[\text{Au}^{3+} (aq) + 3e^- \rightarrow \text{Au(s)} \quad E^\circ = 1.50 \text{ V} \]

\[E^\circ = 1.63 \text{ V}\]

b) What is the standard cell potential?

ANODE: \[\text{Pb} (s) \rightarrow \text{Pb}^{2+} (aq) + 2e^- \quad E^\circ = 0.13 \text{ V} \]

CATHODE: \[\text{Au}^{3+} (aq) + 3e^- \rightarrow \text{Au(s)} \quad E^\circ = 1.50 \text{ V} \]

\[E^\circ = 1.63 \text{ V}\]
6. Calculate the standard cell potential produced by a voltaic cell consisting of a nickel electrode in contact with a solution of Ni\(^{2+}\) ions and a copper electrode in contact with a solution of Cu\(^{2+}\) ions. Which is anode and which is the cathode?

\[
\begin{align*}
\text{Ni}^{2+}(aq) + 2e^- &\rightleftharpoons \text{Ni}(s) \quad E^* = -0.26 \text{ V (must be flipped)} \\
\text{Cu}^{2+}(aq) + 2e^- &\rightleftharpoons \text{Cu}(s) \quad E^* = 0.34 \text{ V}
\end{align*}
\]

ANODE: \(\text{Ni}(s) \rightleftharpoons \text{Ni}^{2+}(aq) + 2e^- \quad E^* = 0.26 \text{ V} \)
CATHODE: \(\text{Cu}^{2+}(aq) + 2e^- \rightleftharpoons \text{Cu}(s) \quad E^* = 0.34 \text{ V} \)

\[E^* = 0.60 \text{ V}\]

7. A voltaic cell is constructed using electrodes based on the following half reactions:

\[
\begin{align*}
\text{Mg}^{2+}(aq) + 2e^- &\rightarrow \text{Mg}(s) \\
\text{Cu}^{2+}(aq) + 2e^- &\rightarrow \text{Cu}(s)
\end{align*}
\]

a) Which is the anode and which is the cathode in this cell?

ANODE: Mg \hspace{1cm} CATHODE: Cu

b) What is the standard cell potential?

\[
\begin{align*}
\text{Mg}^{2+}(aq) + 2e^- &\rightleftharpoons \text{Mg}(s) \quad E^* = -2.37 \text{ V (must be flipped)} \\
\text{Cu}^{2+}(aq) + 2e^- &\rightleftharpoons \text{Cu}(s) \quad E^* = 0.34 \text{ V}
\end{align*}
\]

ANODE: \(\text{Mg}(s) \rightleftharpoons \text{Mg}^{2+}(aq) + 2e^- \quad E^* = 2.37 \text{ V} \)
CATHODE: \(\text{Cu}^{2+}(aq) + 2e^- \rightleftharpoons \text{Cu}(s) \quad E^* = 0.34 \text{ V} \)

\[E^* = 2.71 \text{ V}\]

8. What is the voltage produced by a voltaic cell consisting of a lead electrode in contact with a solution of Pb\(^{2+}\) ions and an iron electrode in contact with a solution of Fe\(^{2+}\)? Which is anode and which is the cathode?

\[
\begin{align*}
Pb^{2+}(aq) + 2e^- &\rightleftharpoons Pb(s) \quad E^* = -0.13 \text{ V} \\
Fe^{2+}(aq) + 2e^- &\rightleftharpoons Fe(s) \quad E^* = -0.44 \text{ V (must be flipped)}
\end{align*}
\]

ANODE: \(\text{Fe}(s) \rightleftharpoons \text{Fe}^{2+}(aq) + 2e^- \quad E^* = 0.44 \text{ V} \)
CATHODE: \(\text{Pb}^{2+}(aq) + 2e^- \rightleftharpoons \text{Pb}(s) \quad E^* = 0.31 \text{ V} \)

9. What is the voltage produced by a voltaic cell consisting of a zinc electrode in contact with a solution of Zn\(^{2+}\) ions and a silver electrode in contact with a solution of Ag\(^+\) ions? Which is anode and which is the cathode?

\[
\begin{align*}
\text{Zn}^{2+}(aq) + 2e^- &\rightleftharpoons \text{Zn}(s) \quad E^* = -0.76 \text{ V (must be flipped)} \\
\text{Ag}^+(aq) + e^- &\rightleftharpoons \text{Ag}(s) \quad E^* = 0.80 \text{ V}
\end{align*}
\]

ANODE: \(\text{Zn}(s) \rightleftharpoons \text{Zn}^{2+}(aq) + 2e^- \quad E^* = 0.76 \text{ V} \)
CATHODE: \(\text{Ag}^+(aq) + e^- \rightleftharpoons \text{Ag}(s) \quad E^* = 0.80 \text{ V} \)

\[E^* = 1.56 \text{ V}\]

10. Calculate the standard cell potential produced by a voltaic cell consisting of a gold electrode in contact with a solution of Au\(^{3+}\) ions and a silver electrode in contact with a solution of Ag\(^+\) ions. Which is the anode and which is the cathode?

\[
\begin{align*}
\text{Au}^{3+}(aq) + 3e^- &\rightleftharpoons \text{Au}(s) \quad E^* = 1.50 \text{ V} \\
\text{Ag}^+(aq) + e^- &\rightleftharpoons \text{Ag}(s) \quad E^* = 0.80 \text{ V (must be flipped)}
\end{align*}
\]

ANODE: \(\text{Ag}(s) \rightleftharpoons \text{Ag}^+(aq) + e^- \quad E^* = -0.80 \text{ V} \)
CATHODE: \(\text{Au}^{3+}(aq) + 3e^- \rightleftharpoons \text{Au}(s) \quad E^* = 1.50 \text{ V} \)

\[E^* = 0.70 \text{ V}\]
11. Use half-reaction potentials to predict whether the following reactions are spontaneous or non-spontaneous in aqueous solutions.

a) \( \text{Ca}^{2+}(aq) + 2 \text{I}^-(aq) \rightarrow \text{Ca}(s) + \text{I}_2(aq) \)

ANODE: \( 2 \text{I}^-(aq) \rightleftharpoons \text{I}_2(aq) + 2\text{e}^- \quad E° = 0.54 \text{ V} \)

CATHODE: \( \text{Ca}^{2+}(aq) + 2\text{e}^- \rightleftharpoons \text{Ca}(s) \quad E° = -2.87 \text{ V} \)

\[
E° = -2.33 \text{ V}
\]

\( E° \) is negative, therefore the cell is non-spontaneous.

b) \( 2 \text{H}_2\text{S}(g) + \text{O}_2(g) \rightarrow 2 \text{H}_2\text{O}(l) + 2 \text{ S}(s) \)

ANODE: \( \text{H}_2\text{S}(g) \rightleftharpoons 2 \text{S}(s) + 2\text{H}^+(aq) + 2\text{e}^- \quad E° = -0.14 \text{ V} \)

CATHODE: \( \text{O}_2(g) + 4\text{H}^+(aq) + 4\text{e}^- \rightleftharpoons 2 \text{H}_2\text{O}(l) \quad E° = 1.23 \text{ V} \)

\[
E° = 1.09 \text{ V}
\]

\( E° \) is positive, therefore the cell is spontaneous.

c) \( \text{SO}_2(g) + \text{MnO}_2(s) \rightarrow \text{Mn}^{2+}(aq) + \text{SO}_4^{2-}(aq) \)

ANODE: \( \text{SO}_2(g) + 2\text{H}_2\text{O}(l) \rightleftharpoons \text{SO}_4^{2-}(aq) + 4\text{H}^+(aq) + 2\text{e}^- \quad E° = -0.18 \text{ V} \)

CATHODE: \( \text{MnO}_2(s) + 4\text{H}^+(aq) + 2\text{e}^- \rightleftharpoons \text{Mn}^{2+}(aq) + 2 \text{H}_2\text{O}(l) \quad E° = 1.22 \text{ V} \)

\[
E° = 1.04 \text{ V}
\]

\( E° \) is positive, therefore the cell is spontaneous.

d) \( 2 \text{H}^+(aq) + 2 \text{Br}^-(aq) \rightarrow \text{H}_2(g) + \text{Br}_2(aq) \)

ANODE: \( 2 \text{Br}^-(aq) \rightleftharpoons \text{Br}_2(l) + 2\text{e}^- \quad E° = -1.07 \text{ V} \)

CATHODE: \( 2\text{H}^+(aq) + 2\text{e}^- \rightleftharpoons \text{H}_2(g) \quad E° = 0.00 \text{ V} \)

\[
E° = -1.07 \text{ V}
\]

\( E° \) is negative, therefore the cell is non-spontaneous.

e) \( \text{Ce}^{4+}(aq) + \text{Fe}^{2+}(aq) \rightarrow \text{Ce}^{3+}(aq) + \text{Fe}^{3+}(aq) \)

ANODE: \( \text{Fe}^{2+}(aq) \rightleftharpoons \text{Fe}^{3+}(aq) + \text{e}^- \quad E° = -0.77 \text{ V} \)

CATHODE: \( \text{Ce}^{4+}(aq) + \text{e}^- \rightleftharpoons \text{Ce}^{3+}(aq) \quad E° = 1.61 \text{ V} \)

\[
E° = -2.38 \text{ V}
\]

\( E° \) is negative, therefore the cell is non-spontaneous.

f) \( \text{Cr}^{2+}(aq) + \text{Cu}^{2+}(aq) \rightarrow \text{Cr}^{3+}(aq) + \text{Cu}^+(aq) \)

ANODE: \( \text{Cr}^{2+}(aq) \rightleftharpoons \text{Cr}^{3+}(aq) + \text{e}^- \quad E° = 0.41 \text{ V} \)

CATHODE: \( \text{Cu}^{2+}(aq) + \text{e}^- \rightleftharpoons \text{Cu}^+(aq) \quad E° = 0.15 \text{ V} \)

\[
E° = 0.56 \text{ V}
\]

\( E° \) is positive, therefore the cell is spontaneous.