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 ell 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 Cu²⁺ 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 Cu²⁺ ions. Which is anode and which is the cathode?
- 5. An electrochemical cell is constructed using electrodes based on the following half reactions:

$$Pb^{2+}_{(aq)} + 2e^{-} \rightarrow Pb_{(s)}$$
 $Au^{3+}_{(aq)} + 3e^{-} \rightarrow Au_{(s)}$

- 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 Ni²⁺ ions and a copper electrode in contact with a solution of Cu²⁺ ions . Which is anode and which is the cathode?
- 7. A voltaic cell is constructed using electrodes based on the following half reactions:

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

- 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 Fe²⁺? 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 Au³⁺ 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) $\operatorname{Ca}^{2+}_{(aq)} + 2 \operatorname{I}_{(aq)} \xrightarrow{} \operatorname{Ca}_{(s)} + \operatorname{I}_{2(aq)}$
 - b) 2 $H_2S_{(g)} + O_{2(g)} \rightarrow 2 H_2O_{(I)} + 2 S_{(s)}$
 - c) $SO_{2(g)} + MnO_{2(s)} \rightarrow Mn^{2+}_{(aq)} + SO_{4-}^{2-}_{(aq)}$

 - $\begin{array}{ll} \text{d)} & 2 \ \text{H}^{+}_{(aq)} \ + 2 \ \text{Br}_{(aq)} \ \rightarrow \ \text{H}_{2(g)} \ + \ \text{Br}_{2(aq)} \\ \text{e)} & \text{Ce}^{4+}_{(aq)} \ + \ \text{Fe}^{2+}_{(aq)} \ \rightarrow \ \text{Ce}^{3+}_{(aq)} \ + \ \text{Fe}^{3+}_{(aq)} \\ \text{f)} & \text{Cr}^{2+}_{(aq)} \ + \ \text{Cu}^{2+}_{(aq)} \ \rightarrow \ \text{Cr}^{3+}_{(aq)} \ + \ \text{Cu}^{+}_{(aq)} \\ \end{array}$

Science 122 Electrochemical Cells Worksheet - Key

 Calculate the standard cell potential produced by a galvanic cell consisting of a nickel electrode in contact with a solution of Ni²⁺ ions and a silver electrode in contact with a solution of Ag⁺ ions. Which is anode and which is the cathode?

 $Ni^{2+}_{(aq)} + 2e^{-} \Rightarrow Ni_{(s)}$ $E^{\circ} = -0.26 V \text{ (must be flipped)}$ $Ag^{+}_{(aq)} + e^{-} \Rightarrow Ag_{(s)}$ $E^{\circ} = 0.80 V$

ANODE: $Ni_{(s)} \rightleftharpoons Ni^{2+}_{(aq)} + 2e^{-}$ $E^{\circ} = 0.26 V$ CATHODE: $Ag^{+}_{(aq)} + e^{-} \rightleftharpoons Ag_{(s)}$ $\underline{E^{\circ} = 0.80 V}$ $E^{\circ} = 1.06 V$

2. What is the voltage produced by a galvanic ell consisting of an aluminum electrode in contact with a solution of Al³⁺ ions and an iron electrode in contact with a solution of Fe²⁺ ions. Which is anode and which is the cathode?

$$Al^{3+}_{(aq)} + 3e^{-} \rightleftharpoons Al_{(s)}$$
 $E^{\circ} = -1.66 V \text{ (must be flipped)}$ $Fe^{2+}_{(aq)} + 2e^{-} \rightleftharpoons Fe_{(s)}$ $E^{\circ} = -0.44 V$

ANODE:	$AI_{(s)} \rightleftharpoons AI_{(aq)}^{3+} + 3e^{-}$	E° = 1.66 V
CATHODE:	$Fe^{2+}_{(aq)} + 2e^{-} \Rightarrow Fe_{(s)}$	E° = -0.44 V
		E° = 1.22 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 Cu²⁺ ions. Which is anode and which is the cathode?

$$Na^{+}_{(aq)} + e^{-} \Rightarrow Na_{(s)}$$
 $E^{\circ} = -2.71 V (must be flipped)$ $Cu^{2+}_{(aq)} + 2e^{-} \Rightarrow Cu_{(s)}$ $E^{\circ} = 0.34 V$

ANODE: $Na_{(s)} \rightleftharpoons Na^{+}_{(aq)} + e^{-}$ $E^{\circ} = 2.71 V$ CATHODE: $Cu^{2+}_{(aq)} + 2e^{-} \rightleftharpoons Cu_{(s)}$ $\underline{E^{\circ} = 0.34 V}_{E^{\circ} = 3.05 V}$

4. What is the voltage produced by a voltaic cell consisting of a calcium electrode in contact with a solution of Cu²⁺ ions. Which is anode and which is the cathode?

 $Ca^{2+}_{(aq)} + 2e^{-} \rightleftharpoons Ca_{(s)}$ $E^{\circ} = -2.87 \text{ V} \text{ (must be flipped)}$ $Cu^{2+}_{(aq)} + 2e^{-} \rightleftharpoons Cu_{(s)}$ $E^{\circ} = 0.34 \text{ V}$

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

$$Pb^{2^+}{}_{(aq)} + 2e^- \rightarrow Pb_{(s)}$$
 $Au^{3^+}{}_{(aq)} + 3e^- \rightarrow Au_{(s)}$
a) Which is the anode and which is the cathode in this cell?

ANODE: Pb CATHODE: Au

b) What is the standard cell potential?

ANODE: $Pb_{(s)} \rightleftharpoons Pb^{2+}_{(aq)} + 2e^{-} E^{\circ} = 0.13 V$ CATHODE: $Au^{3+}_{(aq)} + 3e^{-} \rightleftharpoons Au_{(s)} \underline{E^{\circ} = 1.50 V}_{E^{\circ} = 1.63 V}$ 6. Calculate the standard cell potential produced by a voltaic cell consisting of a nickel electrode in contact with a solution of Ni²⁺ ions and a copper electrode in contact with a solution of Cu²⁺ ions. Which is anode and which is the cathode?

 $Ni^{2+}_{(aq)} + 2e^{-} \Rightarrow Ni_{(s)}$ $E^{\circ} = -0.26 V \text{ (must be flipped)}$ $Cu^{2+}_{(aq)} + 2e^{-} \Rightarrow Cu_{(s)}$ $E^{\circ} = 0.34 V$

ANODE: $Ni_{(s)} \rightleftharpoons Ni^{2+}_{(aq)} + 2e^{-}$ $E^{\circ} = 0.26 V$ CATHODE: $Cu^{2+}_{(aq)} + 2e^{-} \rightleftharpoons Cu_{(s)}$ $\underline{E^{\circ} = 0.34 V}_{E^{\circ} = 0.60 V}$

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

 $\label{eq:mg2+} \begin{array}{ll} Mg^{2+}_{(aq)} + 2e^{\bar{}} \rightarrow Mg_{(s)} & Cu^{2+}_{(aq)} + 2e^{\bar{}} \rightarrow Cu_{(s)} \end{array}$ a) Which is the anode and which is the cathode in this cell? ANODE: Mg CATHODE: Cu

b) What is the standard cell potential? $Mg^{2+}_{(aq)} + 2e^{-} \Rightarrow Mg_{(s)}$ $E^{\circ} = -2.37 V$ (must be flipped) $Cu^{2+}_{(aq)} + 2e^{-} \Rightarrow Cu_{(s)}$ $E^{\circ} = 0.34 V$

ANODE: $Mg_{(s)} \rightleftharpoons Mg^{2+}_{(aq)} + 2e^{-} E^{\circ} = 2.37 V$ CATHODE: $Cu^{2+}_{(aq)} + 2e^{-} \rightleftharpoons Cu_{(s)} \frac{E^{\circ} = 0.34 V}{E^{\circ} = 2.71 V}$

8. What is the voltage produced by a voltaic cell consisting of a lead electrode in contact with a solution of Pb²⁺ ions and an iron electrode in contact with a solution of Fe²⁺? Which is anode and which is the cathode?

 $Pb^{2+}_{(aq)} + 2e^{-} \Rightarrow Pb_{(s)}$ $E^{\circ} = -0.13 V$ $Fe^{2+}_{(aq)} + 2e^{-} \Rightarrow Fe_{(s)}$ $E^{\circ} = -0.44 V$ (must be flipped)

ANODE:	$Fe_{(s)} \rightleftharpoons Fe^{2+}_{(aq)} + 2e^{-}$	E° = 0.44 V
CATHODE:	$Pb^{2+}_{(aq)} + 2e^{-} \Rightarrow Pb_{(s)}$	E° = -0.13 V
		E° = 0.31 V

9. What is the voltage produced by a voltaic cell consisting of a zinc electrode in contact with a solution of Zn²⁺ ions and a silver electrode in contact with a solution of Ag⁺ ions? Which is anode and which is the cathode?

 $Zn^{2+}_{(aq)} + 2e^{-} \rightleftharpoons Zn_{(s)}$ $E^{\circ} = -0.76 V \text{ (must be flipped)}$ $Ag^{+}_{(aq)} + e^{-} \rightleftharpoons Ag_{(s)}$ $E^{\circ} = 0.80 V$

ANODE:	$Zn_{(s)} \rightleftharpoons Zn^{2+}_{(aq)} + 2e^{-}$	E° = 0.76 V
CATHODE:	$Ag^{+}_{(aq)} + e^{-} \Rightarrow Ag_{(s)}$	E° = 0.80 V
		E° = 1.56 V

10. Calculate the standard cell potential produced by a voltaic cell consisting of a gold electrode in contact with a solution of Au³⁺ 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) $Ca^{2+}_{(aq)} + 2I_{(aq)} \rightarrow Ca_{(s)} + I_{2(aq)}$ ANODE: $2I_{(aq)} \rightleftharpoons I_{2(aq)} + 2e^{-}$ $E^{\circ} = 0.54 \text{ V}$ CATHODE: $Ca^{2+}_{(aq)} + 2e^{-} \rightleftharpoons Ca_{(s)}$ $E^{\circ} = -2.87 \text{ V}$ $E^{\circ} = -2.33 \text{ V}$

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

b) 2 $H_2S_{(g)} + O_{2(g)} \rightarrow 2 H_2O_{(I)} + 2 S_{(s)}$ ANODE: $H_2S_{(g)} \rightleftharpoons 2 S_{(s)} + 2H^+_{(aq)} + 2e^ E^\circ = -0.14 V$ CATHODE: $O_{2(g)} + 4H^+_{(aq)} + 4e^- \rightleftharpoons 2 H_2O_{(I)}$ $E^\circ = 1.23 V$ $E^\circ = 1.09 V$

E° is positive, therefore the cell is spontaneous.

c) SO _{2(g)} +	$- MnO_{2(s)} \rightarrow Mn^{2+}_{(aq)} + SO_4^{2-}_{(aq)}$	
ANODE:	$SO_{2(g)} + 2 H_2O_{(I)} \Rightarrow SO_4^{2-}(aq) + 4H^{+}(aq) + 2e^{-}$	E° = -0.18 V
CATHODE:	$MnO_{2(s)} + 4H^{+}_{(aq)} + 2e^{-} \rightleftharpoons Mn^{2+}_{(aq)} + 2H_2O_{(l)}$	E° = 1.22 V
		E° = 1.04 V

E° is positive, therefore the cell is spontaneous.

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

ANODE: $2 Br^{-}_{(aq)} \rightleftharpoons Br_{2(l)} + 2e^{-} E^{\circ} = -1.07 V$
CATHODE: $2H^{+}_{(aq)} + 2e^{-} \rightleftharpoons H_{2(g)} \qquad E^{\circ} = 0.00 V$
 $E^{\circ} = -1.07 V$

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

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

ANODE: $Fe^{2_{+}}_{(aq)} \rightleftharpoons Fe^{3_{+}}_{(aq)} + e^{-} \qquad E^{\circ} = -0.77 \text{ V}$
CATHODE: $Ce^{4_{+}}_{(aq)} + e^{-} \rightleftharpoons Ce^{3_{+}}_{(aq)} \qquad \underline{E^{\circ} = 1.61 \text{ V}}_{E^{\circ} = -2.38 \text{ V}}$

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

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

ANODE: $Cr^{2+}_{(aq)} \rightleftharpoons Cr^{3+}_{(aq)} + e^{-} = E^{\circ} = 0.41 \text{ V}$
CATHODE: $Cu^{2+}_{(aq)} + e^{-} \rightleftharpoons Cu^{+}_{(aq)}$
 $E^{\circ} = 0.15 \text{ V}$
 $E^{\circ} = 0.56 \text{ V}$

E° is positive, therefore the cell is spontaneous.