

Name(s): \_\_\_\_\_

***Electrochemistry Worksheet II***

Use the following table of standard reduction potentials as necessary in answering the questions in this workshop.

<u>Half-cell Reaction</u>	<u>Standard Reduction Potential, E° (V)</u>
$\text{K}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{K}(\text{s})$	-2.92
$\text{Al}^{3+}(\text{aq}) + 3 \text{e}^- \rightleftharpoons \text{Al}(\text{s})$	-1.69
$2 \text{NO}_3^-(\text{aq}) + 2 \text{H}_2\text{O}(\ell) + 2 \text{e}^- \rightleftharpoons \text{N}_2\text{O}_4(\text{g}) + 4 \text{OH}^-(\text{aq})$	-0.85
$2 \text{H}_2\text{O}(\ell) + 2 \text{e}^- \rightleftharpoons \text{H}_2(\text{g}) + 2 \text{OH}^-(\text{aq})$	-0.83
$\text{Zn}^{2+}(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{Zn}(\text{s})$	-0.76
$\text{C}_4\text{H}_4\text{O}_2(\text{aq}) + 2 \text{H}^+(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{C}_4\text{H}_6\text{O}_2(\text{aq})$	-0.15
$2 \text{H}^+(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{H}_2(\text{g})$	0.00
$\text{AgBr}(\text{s}) + \text{e}^- \rightleftharpoons \text{Ag}(\text{s}) + \text{Br}^-(\text{aq})$	0.071
$\text{Cu}^{2+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{Cu}^+(\text{aq})$	0.16
$\text{Cu}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Cu}(\text{s})$	0.51
$\text{Ag}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Ag}(\text{s})$	0.77
$\text{O}_2(\text{g}) + 4 \text{H}^+(\text{aq}) + 4 \text{e}^- \rightleftharpoons 2 \text{H}_2\text{O}(\ell)$	1.23

1. Answer the following questions without using a calculator. In each case, explain the reasoning you used to arrive at your answer.
  - a) Which is the stronger oxidizing agent,  $\text{Ag}^+(\text{aq})$  or  $\text{O}_2(\text{g})$ ?
  - b) Which is the stronger reducing agent,  $\text{Al}(\text{s})$  or  $\text{Zn}(\text{s})$ ?
  - c) What is the potential for the half reaction  $\text{Ag}(\text{s}) \rightleftharpoons \text{Ag}^+(\text{aq}) + \text{e}^-$  ?
  - d) What is the potential for the half reaction  $\frac{1}{2} \text{O}_2(\text{g}) + 2 \text{H}^+(\text{aq}) + 2 \text{e}^- \rightleftharpoons \text{H}_2\text{O}(\ell)$ ?

*Recall that  $\Delta G^\circ$  is a state function and therefore path independent. The relationship between  $\Delta G^\circ$  and  $E^\circ$  is given by  $\Delta G^\circ = -nFE^\circ$ , where  $n$  is the number of moles of electrons transferred.*

2. Given two half reactions with potentials  $E^{\circ}_1$  and  $E^{\circ}_2$ ,

$$\Delta G^{\circ}_1 + \Delta G^{\circ}_2 = -nFE^{\circ}_1 - nFE^{\circ}_2$$

- a) What is the free energy change for the reduction of 0.50 mol of oxygen? for 1.00 mol of oxygen?
- b) Determine the potential and the free energy change for the following reactions:
- solid silver and aqueous hydrogen ion
  - liquid water and potassium metal
  - aqueous hydrogen ion and potassium metal
- c) Will zinc metal spontaneously react with either water or 1.00 M HCl? Explain.
3. a) Write the Nernst equation expression for the reaction of  $\text{Cu}^{2+}(\text{aq})$  in the cathodic cell and  $\text{Ni}^{2+}(\text{aq})$  in the anodic cell.

b) What is the potential of a cell with 0.10 M  $\text{Cu}^{2+}(\text{aq})$  in the cathodic cell and 0.010 M  $\text{Ni}^{2+}(\text{aq})$  in the anodic cell?

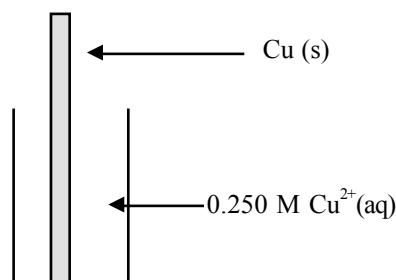
4. Write the Nernst equation for the reaction  
 $\text{Ag}(\text{s}) + \text{AgBr}(\text{s}) \rightleftharpoons \text{Ag}^+(\text{aq}) + \text{Br}^-(\text{aq})$ .

5. When the potential for a cell is zero, there is no net tendency for electrons to flow. At equilibrium, the Nernst equation becomes

$$0 = E^{\circ} - \frac{0.0592}{n} \log K_{\text{eq}}$$

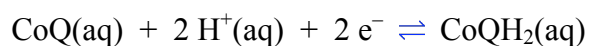
- a) Why is  $K_{\text{eq}}$  used in place of the reaction quotient?
- b) Determine the value of the equilibrium constant for the reaction of potassium metal and water.
- c) Calculate the equilibrium constant for the reaction  
 $\text{Cu}(\text{s}) + \text{Cu}^{2+}(\text{aq}) \rightleftharpoons 2 \text{Cu}^+(\text{aq})$

d) A cell is initially at the conditions illustrated below. What will be the final conditions?



6. An electrolytic cell passes  $2.0 \times 10^4$  coulombs of charge in reducing aluminum ion to aluminum metal. How many grams of aluminum metal are produced?
7. Normal physiological pH is about seven. Although it is not widely discussed, normal physiological redox potential is about  $-0.1$  V. This means that the human body maintains a very slightly reducing environment. There is some evidence that redox potential is related to human health. For instance, many antioxidants (what is the common electrochemical term for antioxidant?), such as vitamins C and E, are known to serve important functions.

Living organisms utilize redox reactions to transfer electrons. Ubiquinones, also called coenzyme Q (abbreviated CoQ), are abundant in biological systems and serve as electron-transport molecules. The reduction half reaction for coenzyme Q is

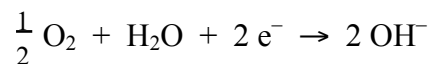


Since biochemical systems have pH values near seven, biochemists use  $\text{pH} = 7$  as their standard state. The standard reduction potential,  $E^{\circ'}$ , where the prime indicates biochemical standard state, for the coenzyme Q reduction half reaction is  $0.04$  V.

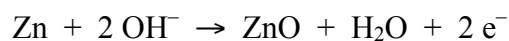
- a) Write the Nernst equation for this reaction coupled with the nickel half reaction as the anodic reaction.
- b) What is the biochemical standard potential for this reaction?
- c) What is the standard potential for this reaction? (*Hint*: What is the standard state concentration of  $\text{H}^+(\text{aq})$ ?)



9. A zinc-air fuel cell was reported in the American Chemical Society's magazine, *Chemical and Engineering News*. A fuel cell is a galvanic cell in which one of the components needs to be constantly replenished. Oxygen is the component which must be replenished in the zinc air fuel cell. The cathodic reaction is



and the anodic reaction is



- What is the standard cell potential for this reaction?
- When the cell is recharged, the reaction runs in reverse. How many moles of oxygen are released when 2.00 g ZnO is reacted while recharging?
- What STP volume of oxygen is released when 2.00 g ZnO is reacted while recharging?
- How many coulombs of charge are needed for the reaction of 2.00 g ZnO?