Week 10 Electrochemistry

QUESTION 1

An incomplete voltaic cell is shown in the figure below.

a. As shown, will the cell produce a current? If not, what else is needed for current to flow?
b. What are the half-cell potentials in each compartment?
c. Which electrode is the cathode? Which one is the anode?
d. When the cell is completed and current flows in this cell, which direction will the electrons flow?
e. What is the direction of the flow of the ions in solution?
f. What is the balanced overall reaction for this cell? How many electrons are transferred?
g. When current flows in this cell, what will the standard cell potential be?

QUESTION 2

The purpose of the salt bridge in an electrochemical cell is to__________.

A. maintain electrical neutrality in the half-cells via migration of ions.
B. provide a source of ions to react at the anode and cathode.
C. provide oxygen to facilitate oxidation at the anode.
D. provide a means for electrons to travel from the anode to the cathode.
E. provide a means for electrons to travel from the cathode to the anode.

QUESTION 3

Calculate $E^\circ$ (in volts) for a cell in which the overall reaction is shown below:

$$\text{Pb(s)} + 2 \text{Ag}^+(aq) \rightarrow \text{Pb}^{2+}(aq) + 2 \text{Ag(s)}$$

A. 0.93
B. 0.67
C. 1.73
D. 1.47
E. 0.52

QUESTION 4

What are the standard cell potentials for the following reactions?

a. $\text{Cl}_2 + 2 \text{Br}^-(aq) \rightarrow \text{Br}_2 + 2 \text{Cl}^-(aq)$
b. $\text{Ni(s)} + 2 \text{Fe}^{3+}(aq) \rightarrow \text{Ni}^{2+}(aq) + 2 \text{Fe}^{2+}(aq)$
c. $\text{Fe(s)} + 2 \text{Fe}^{3+}(aq) \rightarrow 3 \text{Fe}^{2+}(aq)$
QUESTION 5
The standard cell potential for the following reaction is 1.71 V. What is the standard half-cell potential for the Rh$^{4+}$/Rh$^{3+}$ couple?

$$2 \text{Rh}^{4+}(aq) + \text{Ni}(s) \rightarrow 2 \text{Rh}^{3+}(aq) + \text{Ni}^{2+}(aq) \quad E^\circ = 1.71 \text{V}$$

QUESTION 6
Using the following reduction half cell potentials, answer the following questions.

- AuBr$_4^-$ (aq) + 3 e$^-$ → Au(s) + 4 Br$^-$ (aq) \quad E^\circ \text{ (red)} = -0.848 \text{V}
- \text{Ni}^{2+}(aq) + 2 e^- \rightarrow \text{Ni}(s) \quad E^\circ \text{ (red)} = -0.28 \text{V}
- I$_3^-$ (aq) + 2 e$^- \rightarrow 3 I^-$ (aq) \quad E^\circ \text{ (red)} = +0.53 \text{V}
- \text{Sn}^{2+}(aq) + 2 e^- \rightarrow \text{Sn}(s) \quad E^\circ \text{ (red)} = -0.136 \text{V}

a. Write the balanced reaction that will have the largest positive overall cell potential and determine the $E^\circ_{\text{cell}}$ for that reaction.
b. Write the balanced reaction that will have the smallest positive potential and determine the $E^\circ_{\text{cell}}$ for that reaction.

QUESTION 7
Using copper, iron, nickel, silver and/or zinc, construct a cell with the highest standard electromotive force. Which half reactions correspond to this voltaic cell?

A. Ag(s) → Ag$^+(aq)$ + e$^-; \text{Zn}^{2+}(aq) + 2 e^- \rightarrow \text{Zn}(s)$
B. Zn(s) → Zn$^{2+}(aq) + 2 e^-; \text{Ag}^+(aq) + e^- \rightarrow \text{Ag}(s)$
C. Ni(s) → Ni$^{2+}(aq) + 2 e^-; \text{Cu}^{2+}(aq) + 2 e^- \rightarrow \text{Cu}(s)$
D. Fe(s) → Fe$^{2+}(aq) + 2 e^-; \text{Ni}^{2+}(aq) + 2 e^- \rightarrow \text{Ni}(s)$
E. Zn(s) → Zn$^{2+}(aq) + 2 e^-; \text{Cu}^{2+}(aq) + 2 e^- \rightarrow \text{Cu}(s)$

QUESTION 8
Considering the cell below, which of the following statements is false?

A. Electrons will flow from the cobalt strip to the tin strip.
B. The tin electrode will grow bigger with time.
C. NO$_3^-$ ions will move out of the salt bridge into the left hand compartment.
D. The Co$^{2+}(aq)$ concentration in the right hand compartment will increase with time.
E. Electrons will flow through the wire.

QUESTION 9
Which one of the following is most easily reduced?

A. F$_2$
B. Cl$_2$
C. Br$_2$
D. I$_3^-$
E. F$^-$
**QUESTION 10**

A voltaic cell is shown in the figure below.

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![Diagram of voltaic cell](image)

1M AgNO₃  1 M Cr(NO₃)₃

a. What are the half-cell and overall cell reactions that are occurring?
b. Which cell is the anode? Which one is the cathode?
c. Which electrode will increase in mass as the reaction proceeds? Which one will decrease in mass?
d. What is the standard cell potential for this electrochemical cell?

**QUESTION 11**

Using standard cell potentials, decide which substance in the given pairs will be most easily reduced.

a. Ca²⁺(aq) and Al³⁺(aq)
b. NO₃⁻(aq) to NO(g) (in acid) and Sn²⁺(aq)
c. H⁺(aq) and I₂(s)

**QUESTION 12**

Which of the following is the best reducing agent?

A. Cl⁻(aq)
B. Fe(s)
C. Fe³⁺(aq)
D. Fe²⁺(aq)
E. Cl₂(g)

**QUESTION 13**

What is the oxidizing agent in this cell?  

2 Ag⁺(1.0 M) + Ni(s) → Ni²⁺(1.0 M) + 2 Ag(s)

A. Ag(s)
B. Ag⁺(aq)
C. Ni²⁺(aq)
D. Ni(s)
E. both Ag⁺(aq) and Ni²⁺(aq)
QUESTION 14

Arrange the following oxidizing agents in order of increasing oxidizing power:

I$_2$(s), IO$_3^-$ (aq), F$_2$ (g), PbO$_2$(s), Na$^+$ (aq), Zn$^{2+}$(aq)

A. I$_2$ < Zn$^{2+}$ < IO$_3^-$ < PbO$_2$ < Na$^+$ < F$_2$
B. F$_2$ < PbO$_2$ < IO$_3^-$ < I$_2$ < Zn$^{2+}$ < Na$^+$
C. I$_2$ < IO$_3^-$ < PbO$_2$ < F$_2$ < Zn$^{2+}$ < Na$^+$
D. Na$^+$ < Zn$^{2+}$ < I$_2$ < IO$_3^-$ < PbO$_2$ < F$_2$
E. I$_2$ < IO$_3^-$ < PbO$_2$ < F$_2$ < Na$^+$ < Zn$^{2+}$

QUESTION 15

a. Find the oxidation states of the central atom in the following oxyanions.

MnO$_4^-$ (aq)
BrO$_3^-$ (aq)
Cr$_2$O$_7^{2-}$ (aq)

b. The reduction half cell potentials for each of these anions in acid solution are given below:

MnO$_4^-$ (aq) + 8 H$^+$(aq) + 5 e$^-$ → Mn$^{2+}$(aq) + 4 H$_2$O(l) $E^*(\text{red}) = 1.51 \text{ V}$
BrO$_3^-$ (aq) + 12 H$^+$(aq) + 10 e$^-$ → Br$^-(l)$ + 6 H$_2$O(l) $E^*(\text{red}) = 1.52 \text{ V}$
Cr$_2$O$_7^{2-}$ (aq) + 14 H$^+$(aq) + 6 e$^-$ → 2 Cr$^{3+}$(aq) + 7 H$_2$O(l) $E^*(\text{red}) = 1.33 \text{ V}$

What is the connection between the oxidation states of the central atom and the reduction potential? Could you use information about oxidation state to predict anything about the reduction potential?

QUESTION 16

Use the table of standard cell potentials to find $\Delta G$ and $K_{eq}$ for the following reaction at standard conditions.

Ag$^+$ (aq) + Fe$^{2+}$(aq) → Ag(s) + Fe$^{3+}$(aq)

QUESTION 17

Use the table of standard cell potentials to find $\Delta G$ and $K_{eq}$ for the following reaction at standard conditions.

Pb$^{2+}$(aq) + H$_2$(g) → Pb(s) + 2 H$^+$(aq)

QUESTION 18

What is the equilibrium constant for the following reaction at 25°C? Note: the answer to this problem is very sensitive to the values you use in the calculation. Use the values in the Chem 112 data table.

Zn(s) + Sn$^{2+}$(aq) → Zn$^{2+}$(aq) + Sn(s)

A. $2 \times 10^5$
B. $1 \times 10^{-21}$
C. $3 \times 10^{10}$
D. $2 \times 10^{21}$
E. $3 \times 10^{30}$

QUESTION 19

Which of the following are true for a voltaic cell?

I. $\Delta G^* > 0$
II. Oxidation will occur at the anode.
III. At equilibrium, $E_{\text{cell}}^\text{o}$ will equal 0.

A. I only  
B. II only  
C. I and II only  
D. II and III only  
E. I and III only

**QUESTION 20**

The value of $E^o$ for the following reaction is 0.63 V. What is the value of $E_{\text{cell}}^o$ for this reaction when the concentration of $\text{Zn}^{2+}$ is 0.0002 M and the concentration of $\text{Pb}^{2+}$ is 1.0 M?

$$\text{Pb}^{2+}(aq) + \text{Zn}(s) \rightarrow \text{Zn}^{2+} + \text{Pb}(s)$$

A. 0.85 V  
B. 0.74 V  
C. 0.52 V  
D. 0.41 V  
E. 0.30 V

**QUESTION 21**

An electrochemical cell based on the following reaction is built.

$$\text{Pb}^{2+}(aq) + \text{Zn}(s) \rightarrow \text{Pb}(s) + \text{Zn}^{2+}(aq)$$

a. What happens to the cell potential when water is added to the anode compartment?  
b. What happens to the cell potential if the mass of the Zn electrode is increased?  
c. What will happen to the cell potential if KI(aq) is added to the cathode compartment producing $\text{PbI}_2(s)$?

**QUESTION 22**

An electrochemical cell is built using the following reaction.

$$2 \text{ Sn}^{2+}(aq) + \text{O}_2(g) + 4 \text{ H}^+(aq) \rightarrow 2 \text{ Sn}^{4+}(aq) + 2 \text{ H}_2\text{O}(l)$$

a. What is the cell potential for this reaction under standard conditions?  
b. What is $E_{\text{cell}}^o$ if the $[\text{Sn}^{2+}]$ is 0.35 M and the $[\text{Sn}^{4+}]$ is 0.66 M while the cathode compartment is kept at standard conditions?  
c. What is $E_{\text{cell}}^o$ if the $[\text{Sn}^{2+}]$ and the $[\text{Sn}^{4+}]$ are equal (but not 1.00 M) while the cathode compartment is kept at standard conditions?  
d. What is $E_{\text{cell}}^o$ if the partial pressure of $\text{O}_2(g)$ is 0.20 atm and the pH is 4, while the anode compartment is kept at standard conditions?

**QUESTION 23**

A voltaic cell is based on the following spontaneous redox reaction. What is the cell voltage when the conditions are non-standard, with $[\text{Ag}^+] = 0.01 \text{ M}$ and $[\text{Ni}^{2+}] = 2.0 \text{ M}$?

$$2 \text{ Ag}^+(aq) + \text{Ni}(s) \rightarrow 2 \text{ Ag}(s) + \text{Ni}^{2+}(aq)$$

A. 0.95V  
B. 0.83V  
C. 1.05V  
D. 1.21V  
E. 0.76 V

**QUESTION 24**

The equilibrium constant for the following reaction at 298K is $7.676 \times 10^3$. What is the emf of the electrochemical cell at 298K if $[\text{Fe}^{3+}] = [\text{Fe}^{2+}] = 4.51 \times 10^{-3} \text{ M}$, and $[\text{VO}^{2+}] = [\text{VO}_2^{+}] = 0.152 \text{ M}$, while the cell is maintained at a pH of 7? **Note:** the answer to this problem is very sensitive to the values you use in the calculation. Use the values in the Chem 112 data...
VO_2^{+}(aq) + Fe^{+2}(aq) + 2H^+(aq) → Fe^{+3}(aq) + VO^{2+}(aq) + H_2O(ℓ)

A. 0.230V  
B. 0.958V  
C. 0.414V  
D. 0.644V  
E. −0.599 V

**QUESTION 25**

What is the concentration of the Pb(NO_3)_2 in the voltaic cell pictured below when \( E_{\text{cell}} = 0.524 \text{ V} \) at room temperature? **Note: the answer to this problem is very sensitive to the values you use in the calculation. Use the values in the Chem 112 data table.**

A. 1.00 M  
B. \( 1.52 \times 10^{-4} \text{ M} \)  
C. 0.110 M  
D. 52.0 M  
E. \( 1.39 \times 10^{-2} \text{ M} \)

**QUESTION 26**

Consider an electrochemical cell based on the reaction below. Which one of the following actions would increase the measured cell potential?

\[ 2H^+(aq) + \text{Sn}(s) \rightarrow \text{Sn}^{2+}(aq) + H_2(g) \]

A. Decrease the pH in the cathode compartment.  
B. Increase the mass and surface area of the Sn electrode.  
C. Increase the [Sn^{2+}] in the anode compartment.  
D. Increase the pressure of hydrogen gas in the cathode compartment.  
E. All of the above will increase the measured cell potential.

**QUESTION 27**

Consider a voltaic cell based upon the following reaction, where \( E^o = +0.36 \text{ V} \).

\[ \text{Pb}(s) + 2 \text{H}^+(aq) + \text{SO}_4^{2-}(aq) \rightarrow \text{PbSO}_4(s) + \text{H}_2(g) \]

The following changes are made in an attempt to increase the voltage of the cell. Which change(s) would increase the cell voltage?

I. The area of the Pb electrode is increased.  
II. The [H^+(aq)] is increased.  
III. The pressure of \( \text{H}_2(g) \) is increased.
A. I, II and III
B. II only
C. III only
D. I only
E. None of the above changes will have an effect on the cell voltage.

QUESTION 28

Consider a cell in which the following reaction takes place. The measured voltage at 25 °C is 0.293 V. What are the values of $K_{eq}$ and of $E^\circ$ for the cell?

$$\text{Cd(s)} + \text{Pb}^{2+}(aq, 0.150 \text{ M}) \rightarrow \text{Pb(s)} + \text{Cd}^{2+}(aq, 0.0250 \text{ M})$$

<table>
<thead>
<tr>
<th>Answer</th>
<th>$K_{eq}$</th>
<th>$E^\circ$ (V)</th>
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</thead>
<tbody>
<tr>
<td>A.</td>
<td>$1.32 \times 10^9$</td>
<td>0.270</td>
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<tr>
<td>B.</td>
<td>$2.36 \times 10^8$</td>
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<td>C.</td>
<td>$7.92 \times 10^9$</td>
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<td>D.</td>
<td>$1.31 \times 10^9$</td>
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<td>E.</td>
<td>$5.56 \times 10^3$</td>
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