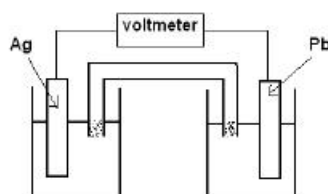


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**Applications of Thermodynamics**  
**9.7 Galvanic (Voltaic) and Electrolytic Cells**  
**9.8 Cell Potential and Free Energy**  
**Worksheet**

1) Write balanced net ionic equations for the following reactions:

- a. Solid zinc is placed in a solution of lead (II) nitrate.
- b. Solid nickel is placed in a solution of copper (II) sulfate.
- c. A silver nitrate solution is poured over solid tin.
- d. Solid iron is immersed in a solution of tin (II) nitrate.



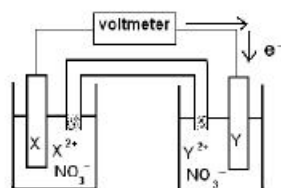
2) The following questions refer to the above diagram of a voltaic cell.

- a. Write the balanced net ionic equation for the thermodynamically favored redox reaction that occurs in the galvanic cell above.
- b. Calculate the standard cell potential,  $E^\circ$ , in volts for the thermodynamically favored reaction that occurs in this cell.
- c. What concentrations of  $\text{Ag}^+$  and  $\text{Pb}^{2+}$  are necessary for the cell to produce the standard cell potential calculated in part b.
- d. Which electrode is the anode and which is the cathode in the above cell.
- e. Would it be better to use  $\text{NaCl}$  or  $\text{NaNO}_3$  in the salt bridge? Explain.
- f. In which direction are the electrons flowing?

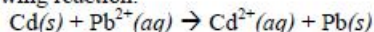
3) A galvanic cell is constructed with  $\text{Cr}/\text{Cr}^{3+}$  at one half cell and  $\text{Cu}/\text{Cu}^{2+}$  at the other. Both half cells are under standard conditions.

- a. Write the half reaction that takes place at the anode.
- b. At which electrode does the reduction occur?
- c. Write the balanced net ionic equation for the thermodynamically favored redox reaction that occurs in the galvanic cell.
- d. Calculate the standard cell potential,  $E^\circ$ , in volts for the thermodynamically favored reaction that occurs in this cell.
- e. Would it be better to use  $\text{Na}_2\text{SO}_4$  or  $\text{BaSO}_4$  in the salt bridge? Explain.

4)

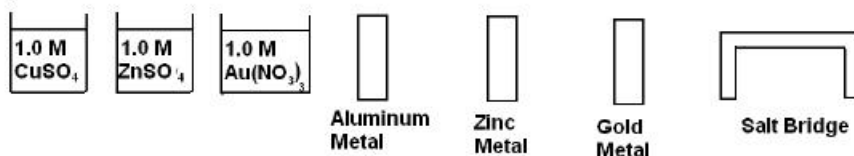


The galvanic cell above contains two standard half-cells, which function according to the following reaction.



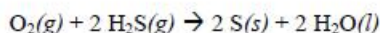
- What are Y and  $\text{Y}^{2+}$  in the diagram above?
- What is the initial concentration of  $\text{X}(\text{NO}_3)_2(aq)$  in the solution?
- Which electrode is the cathode and which is the anode?
- Write the balanced equation for the half cell reaction that occurs at the cathode.
- Calculate the standard cell potential,  $E^\circ$ , in volts for the thermodynamically favored reaction that occurs in this cell.

5)



Use the equipment above, as well as wires and a voltmeter, to construct a galvanic cell with the largest possible value for  $E^\circ_{\text{cell}}$ .

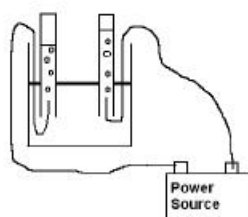
- Write the balanced net ionic equation for the reaction that produces the largest possible value for  $E^\circ_{\text{cell}}$ .
  - Calculate the standard cell potential,  $E^\circ$ , in volts for the thermodynamically favored reaction that occurs in this cell.
  - Which metal is used at the anode, and which is used at the cathode?
  - What would be the voltage of this cell if it was constructed without a salt bridge? Explain.
- 6) The following thermodynamically favored reaction takes place in an acidified galvanic cell.



- What is the half reaction that takes place at the anode?
- What is the half reaction the takes place at the cathode?
- Calculate the standard cell potential,  $E^\circ_{\text{cell}}$ .
- What must the partial pressures of the reactants be in order to produce the voltage in part c?

- 7) Use the list of standard reduction potential values to indicate which species in each set is most easily reduced.
- |   |   |
|---|---|
| a. $\text{Sn}^{2+}(\text{aq})$ or $\text{Pb}^{2+}(\text{aq})$ | d. $\text{Ag}^+(\text{aq})$ or $\text{Ag}(\text{s})$    |
| b. $\text{Cu}^+(\text{aq})$ or $\text{Cu}(\text{s})$          | e. $\text{Fe}^{2+}(\text{aq})$ or $\text{Cu}(\text{s})$ |
| c. $\text{Ag}^+(\text{aq})$ or $\text{Cu}(\text{s})$          | f. $\text{Na}^+(\text{aq})$ or $\text{Na}(\text{s})$    |
- 8) Use the list of standard reduction potential values to indicate which species in each set is most easily oxidized.
- $\text{Li}^+(\text{aq})$  or  $\text{Li}(\text{s})$
  - $\text{Au}(\text{s})$  or  $\text{Fe}(\text{s})$
  - $\text{Au}^{3+}(\text{aq})$  or  $\text{Ba}(\text{s})$
  - $\text{Ag}(\text{s})$  or  $\text{Cr}(\text{s})$
  - $\text{Mn}(\text{s})$  or  $\text{H}_2\text{O}(\text{l})$
  - $\text{Cu}(\text{s})$  or  $\text{Sn}(\text{s})$
- 9) A direct current is applied to an aqueous nickel (II) bromide solution.
- Write the balanced equation for the half reaction that takes place at the anode.
  - Write the balanced equation for the half reaction that takes place at the cathode.
  - Write the balanced equation for the overall reaction that takes place in the cell.
  - Do the electrons flow from the anode to the cathode or from the cathode to the anode?
  - Predict the sign for  $\Delta G^\circ$ . Justify your choice.
  - Calculate  $\Delta G^\circ$ .

10)



Water is being electrolysed in the apparatus above in the presence of a non-reactive electrolyte under standard conditions.

- Write the balanced equation for the oxidation half reaction.
- Write the balanced equation for the reduction half reaction.
- Write the balanced net ionic equation for the overall reaction that takes place in the cell.
- Label the anode and the cathode on the diagram above, and write the half reaction that takes place at each electrode.
- In which direction do the electrons flow?

- 11) A direct current is applied to a solution of manganese (II) iodide.
- Write the balanced equation for the oxidation half reaction.
  - Write the balanced equation for the reduction half reaction.
  - Write the balanced equation for the overall reaction that takes place in the cell.
  - Which reaction takes place at the cathode?
  - Predict the sign for  $\Delta G^\circ$ . Justify your choice.
  - Calculate  $\Delta G^\circ$ .
- 12) A direct current is applied to a solution of nickel (II) fluoride.
- Write the balanced equation for the reaction that takes place at the anode.
  - Write the balanced equation for the reaction that takes place at the cathode.
  - Write the balanced equation for the overall reaction that takes place in the cell.
  - Predict the sign for  $\Delta G^\circ$ . Justify your choice.
  - Calculate  $\Delta G^\circ$ .
- 13) A direct current is applied to a solution of  $\text{CaBr}_2$ , and a gas is evolved from one of the electrodes.
- Is the gas evolved at the anode or the cathode?
  - What is the gas?