Chapter 17: Aqueous Equilibria

1) (10 pts) Sketch a titration curve for the titration of 20.0 mL of 0.10 M H\textsubscript{2}SO\textsubscript{4}(aq) with 0.10 M NaOH(aq). Indicate the following values on the curve: The approximate pH before any NaOH is added, the volume of NaOH delivered at the first equivalence point and the volume of NaOH delivered at the second equivalence point. (Note: These are the only numbers that you need to label on the graph. I am not asking you to label pH values or volumes for any other points along the curve!)

2) (6 pts) Indicate whether the equivalence point of each of the following titrations is below, above, or at a pH of 7.
   a) HNO\textsubscript{3} titrated with LiOH
   b) Benzoic Acid (C\textsubscript{6}H\textsubscript{5}COOH) titrated with LiOH

3) (6 pts) Relative to pure water, will the solubility of Ba\textsubscript{3}(PO\textsubscript{4})\textsubscript{2}(s) (A) increase, (B) decrease, or (C) stay the same when dissolved in
   a) 0.50 M HCl?
   b) 0.50 M NaCl?
   c) 0.50 M Ba(NO\textsubscript{3})?

4) (6 pts) Zinc hydroxide, Zn(OH)\textsubscript{2}, is amphoteric. Write balanced net ionic equations for reactions that show the amphoteric behavior of Zn(OH)\textsubscript{2}. Include phase symbols!

Chapter 20: Electrochemistry

1. (3 pts) Which of the following species CAN act as a reducing agent? (Circle all that apply)
   (a) Mg\textsuperscript{2+}(aq)       (b) Fe\textsuperscript{2+}(aq)       (c) H\textsubscript{2}(g)
2. (3 pts) Which ONE of the following is the STRONGEST Oxidizing agent?

(a) Li⁺   (b) Ag⁺   (c) Al   (d) F⁻

3. (14 pts) A voltaic cell is represented by the following shorthand notation:

\[ \text{Al(s)} | \text{Al}^{3+}(aq) \mid \mid \text{Cl}_2(g) | \text{Cl}^-(aq) | \text{Pt} \]

a) Write the balanced net ionic chemical equation for the overall reaction that occurs.

b) Calculate \( E^{\circ}_{\text{cell}} \).

c) What would happen to the cell voltage (increase, decrease, or remain the same) if:
   i) 6 M NH₃ is added to the anode half-cell, bringing the pH to 9-10? Explain your answer.
   ii) The partial pressure of the Cl₂(g) is increased in the Cl₂/Cl⁻ half-cell? Explain your answer.

4. (8 pts) The overall reaction that occurs when a lead-acid battery (used in cars) operates is:

\[ \text{PbO}_2(s) + \text{Pb}(s) + 2\text{HSO}_4^-(aq) + 2\text{H}^+(aq) \rightarrow 2\text{PbSO}_4(s) + 2\text{H}_2\text{O}(l) \]

a) Give one disadvantage of the lead-acid battery.

b) What is the electrolyte?

(c) Identify the substance that is reduced in this reaction.

d) The lead-acid battery is a secondary battery. What does this mean?

5. (3 pts) What type of cell, (1) voltaic or (2) electrolytic, is characterized by:

a) a positive \( E^{\circ}_{\text{cell}} \)?

b) a positive \( \Delta G \)?

c) the system does work on the surroundings?
6. (2 pts) Which electrode of a voltaic cell corresponds to the LOWER POTENTIAL ENERGY for the electrons?

7. (6 pts) Iron can be protected from corrosion by coating the iron with paint or with a layer of zinc. Both methods are effective as long as the coating remains intact. However, if a break occurs in the coating, one of these methods is superior to the other in protecting the iron. Which one is better and why is it better?

8. (10 pts) An aqueous solution containing 1 M AgNO₃ is prepared (pH=7). Two inert electrodes are inserted into the solution and a voltage is applied. Write the HALF-REACTIONS with their corresponding voltages that occur at each electrode when the minimum voltage needed to cause a reaction is applied.
   a) Reaction at the anode:
   b) Reaction at the cathode:
   c) What is the minimum voltage needed?

9. This problem involves the spontaneous operation of the cell shown. For the cell:
   a) (4 pts) Label the cathode and the anode.

   ![Diagram of a voltaic cell with a switch and two electrodes labeled Zn and Ni, with Zn⁺ and Ni²⁺ symbols nearby.]

   a) (2 pts) Give the spontaneous half-reaction that occurs at the cathode:
   b) (2 pts) Indicate on the diagram the direction of electron flow through the system.
   c) (2 pts) Give a substance that could be used in the salt bridge:
   d) (2 pts) Label on the diagram the direction cations within the salt bridge will move to maintain charge balance.
   e) (2 pts) Which electrode(s) will lose mass as the cell operates?
Problem Solving

1. (8 pts) For PbF$_2$(s):
   a) Calculate the solubility (g/100 mL solution) of PbF$_2$ in pure water at 25˚ C.

   b) Calculate the molar solubility of PbF$_2$ in a 0.15 M solution of Pb(NO$_3$)$_2$(aq) at 25˚ C.

2. (10 pts) Consider the titration of 30.0 mL of 0.200 M methylamine (CH$_3$NH$_2$, K$_b$=4.4x10$^{-4}$) with a 0.300 M HCl(aq) solution.
   a) Determine the pH of the solution at 25˚C when 12.0 mL of the acid has been added.

   b) Determine the pH of the solution at 25˚C when 25.0 mL of the acid has been added.
1) (7 pts) Electrolysis of molten MgCl$_2$ is the final step in the isolation of magnesium from seawater. How many amps are required to produce 35.6 g of Mg metal by electrolysis in 9.50 hours?

2) (10 pts) For the oxidation of I$^-$(aq) by Zn$^{2+}$(aq), the balanced net ionic chemical equation is

\[ \text{Zn}^{2+}(aq) + 2\text{I}^-(aq) \leftrightarrow \text{Zn(s)} + \text{I}_2(s) \]

a) Calculate the equilibrium constant and $\Delta G^\circ$ for this reaction at 298 K.

b) Is this reaction spontaneous under standard conditions? Provide reasoning for your conclusion.

3) (7 pts) Consider a voltaic cell with the overall reaction: Mg(s) + 2H$^+$(aq) $\rightarrow$ Mg$^{2+}$(aq) + H$_2$(g)

Calculate the pH of the cathode compartment solution if the cell emf at 298 K is measured to be 2.14 V when [Mg$^{2+}$] = 0.50 M and $P_{H_2}$ = 0.90 atm.
3. (10 pts) You are to solve one of the two problems below. Indicate clearly which problem is to be graded. ONLY ANSWER ONE! THERE IS NO EXTRA CREDIT! If you do work for both, but do not indicate which one you want graded, then only the first one will be graded.

   (i) A 6.00 M NaF(aq) solution is added dropwise to 500 mL of a solution containing 0.010 M Ba(NO\(_3\))\(_2\) and 0.010 M Ca(NO\(_3\))\(_2\) at 25°C.
   a) What is the first precipitate to form? Give reasoning to support your conclusion.
   b) Can the Ba\(^{2+}\) and Ca\(^{2+}\) be quantitatively separated by selective precipitation using NaF? Show work to support your conclusion.

   OR

   (ii) One step in the developing of photographic film involves dissolving of AgBr(s) by adding sodium thiosulfate, Na\(_2\)S\(_2\)O\(_3\). The reaction is:
   \[
   \text{AgBr(s)} + 2 \text{S}_2\text{O}_3^{2-}(\text{aq}) \rightleftharpoons \text{Ag(S}_2\text{O}_3)_2^{3-}(\text{aq}) + \text{Br}^- (\text{aq})
   \]
   a) Calculate the equilibrium constant for this reaction at 25°C. (Show all the steps/reasoning involved.)
   b) If you want to dissolve 1.0 g of AgBr in 1.0 L of solution at 25°C, what must be the minimum final concentration of S\(_2\)O\(_3\)\(^{2-}\)?
   c) What mass of Na\(_2\)S\(_2\)O\(_3\) must be added to the solution to achieve this final concentration of S\(_2\)O\(_3\)\(^{2-}\)?