# CHAPTER 8
# CONSEQUENCES OF EQUILIBRIUM
# CHAPTER OUTLINE

**HW:** Questions are below. Solutions are in separate file on the course web site.

**Sect.** **Material**

1. Acids and Bases
2. Autoionization of Water
3. Strong Acids and Bases
4. Dissociation of Weak Acids
5. Weak Base Equilibria
6. Salts in Water: Hydrolysis
7. Buffers
8. Polyprotic Acids
9. Acid/Base Titrations
10. Amino Acids
11. Proteins
12. Solubility Equilibria

## Chapter 8 Homework

**8.1** Calculate the Molar concentrations of $H^+$ ions and the pH of the following solutions:

(a) 25.0 $cm^3$ of 0.144 M HCl(aq) was added to 25.0 $cm^3$ of 0.125 M NaOH(aq)

(b) 25.0 $cm^3$ of 0.15 M HCl(aq) was added to 35.0 $cm^3$ of 0.15 M KOH(aq)

(c) 21.2 $cm^3$ of 0.22 M $HNO_3$(aq) was added to 10.0 $cm^3$ of 0.30 M NaOH(aq)

**8.2** (a) What is the pH of a solution when 8.4 g of potassium lactate, KAc (M = 98.1), is used to prepare 250 $cm^3$ of solution. Ka(HLac) = $1.8x10^{-5}$.

(b) What is the pH of a solution when 3.75 g of ammonium bromide, $NH_4Br$ (M = 97.9), is used to make 100 $cm^3$ of solution? Kb($NH_3$) = $1.8x10^{-5}$.

**8.3** The acid dissociation constant of lactic acid is $K_a = 8.4x10^{-4}$. Calculate the pH of the following solutions.

(a) 200 mL of 0.10 M lactic acid.

(b) 200 mL of 2.0 M sodium lactate

(c) 200 mL of 0.10 M lactic acid following the addition of 100 mL of 0.05 M NaOH.

**8.4** The base equilibrium constant of aniline [$C_6H_5NH_2$ = Anil] is $K_b = 4.3x10^{-10}$. Calculate the pH of the following solutions.

(a) 400 mL of 0.05 M aniline

(b) 400 mL of 0.10 M anilinium chloride [$AnilCl^-$].

(c) 400 mL of 0.05 M aniline following the addition of 100 mL of 0.15 M of HCl

**8.5** For each of the solutions below, indicate whether the solution would be a buffer.

a) A solution prepared by adding 1 L of 0.50 M NaOH to 2 L of 0.5 M HAc (acetic acid)

b) A solution prepared by adding 1 L of 1.0 M HCl to 2 L of 0.80 M NaAc (sodium acetate)

c) A solution prepared by adding 1 L of 0.50 M $H_2CO_3$ to 1 L of 0.50 M $K_2CO_3$

d) A solution prepared by adding 1 L of 0.50 M HCl to 2 L of 0.50 M $K_2CO_3$

e) A solution prepared by adding 3 L of 0.50 M HCl to 2 L of 0.50 M $K_2CO_3$

f) A solution prepared by adding 5 L of 0.50 N HCl to 2 L of 0.50 M $K_2CO_3$

**8.6** The following **independent** questions are on pH calculations in solutions of Arsenic Acid ($H_3AsO_4$) and its various anions. $H_3AsO_4$ is a triprotic acid with Acid Dissociation Constants: $K_a{'} = 6.0x10^{-3}$ , $K_a{''} = 1.0x10^{-7}$ , $K_a{'''} = 3.2x10^{-12}$

a) Calculate the pH of a solution prepared by mixing 3.0 L of 0.40 M $H_3AsO_4$ with 1.0 L of 0.80 M KOH.

b) Calculate the pH of a solution prepared by mixing 3.0 L of 0.40 M $H_3AsO_4$ with 2.0 L of 0.80 M KOH.

c) Calculate the pH of a solution prepared by mixing 3.0 L of 0.40 M $Na_3AsO_4$ with 1.0 L of 0.80 M $HNO_3$.

d) Calculate the pH of a solution prepared by mixing 3.0 L of 0.40 M $Na_3AsO_4$ with 2.0 L of 0.80 M $HNO_3$.

e) What is the pH of a solution in which the following ratio is $[HAsO_4^{2-}] / [H_2AsO_4^-] = 1.50$

f) What is the pH of a solution in which the following ratio is $[HAsO_4^{-2}]/[AsO_4^{-3}] = 2.50$

g) What value of the ratio, $[H_2AsO_4^-]/[H_3AsO_4]$, is required to prepare a buffer with pH = 2.60?

h) What value of the ratio, $[HAsO_4^{2-}]/[AsO_4^{3-}]$, is required to prepare a buffer with pH = 10.90?

**8.7** The acid dissociation constant of formic acid [HCOOH] is $K_a = 1.8x10^{-4}$. A solution is prepared with an initial concentration [HCOOH] = 0.5 M. Sufficient KOH is added to the solution to raise the pH to 4.25 What are the concentrations, [HCOOH] and $[HCOO^-]$ of the solution at this pH?

**8.8** One initially has a solution containing 500 mL of 0.40 M benzoic acid [$K_a = 6.5x10^{-5}$].

(a) How many mL of 1.0 M NaOH are required to reach half-way to the equivalence point (stoichiometric point)? What is the pH of the solution at this point?

(b) How many mL of 1.0 M NaOH are required to reach the equivalence point (stoichiometric point)? What is the pH of the solution at this point?

**8.9** Alanine is an amino acid with R = $-CH_3$. Its pKa's are pKa'( $\alpha$-COOH)=2.35 and pKa''($\alpha$-$NH_3^+$)=9.69.

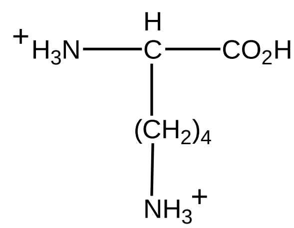
a) At what pH is the ratio $[Ala^+]/[Ala] = 0.25$?

b) What is the ratio $[Ala^-]/[Ala]$ at pH=10.5?

c) If one starts with a solution containing 0.8 M neutral [Ala], and the pH is lowered to 2.0, what are the concentrations of [Ala] and $[Ala^+]$ ?

**8.10** Lysine is an amino acid with R = $-(CH_2)_4NH_2$. Its pKa's are pKa'( $\alpha$-COOH)=2.18, pKa''($\alpha$-$NH_3^+$)=8.95 and pKa'''($\varepsilon$-$NH_3^+$)=10.53.

The structure of the fully protonated form is:




a) What is the pH and average charge after the addition of 0.5 equiv. of NaOH to the protonated form.

b) What is the pH and average charge after the addition of 1.0 equiv. of NaOH to the protonated form?

c) What is the isoelectric point, pI?

d) How many equiv. of NaOH must be added to the protonated form to reach pH=10.53?

e) What is the average charge after the addition of 2.5 equiv. of NaOH to the protonated form?

**8.11** The solubility product (aka solubility constant) of $MgF_2$ is $K_s=6.4x10^{-9}$.

(a) Calculate the solubility of $MgF_2$ in pure water.

(b) Calculate the solubility of $MgF_2$ in 0.1 M $MgCl_2$(aq).

(c) Calculate the solubility of $MgF_2$ in 0.2 M KF(aq).