Practice problems #4 from week 3:

Dear students,
Here are some of the problems I presented to you in lecture. I've put the solutions at the very end so you can try the problems first and look at the solutions. Be aware that midterm #1 is coming up soon (next week, ~~Friday~~ Wednesday, April 22, 2009) and so don't procrastinate.

(1) If the pH of an ammonium chloride (NH_4Cl) is 5.05, what is the concentration of this ammonium chloride solution? (note: pK_b of NH_3 = 4.72)

(2) If the pH of a potassium formate ($KCHO_2$) is 8.72, what is the concentration of this potassium formate solution? (note: pK_a of $HCHO_2$ = 4.75),

(3) What is the K_b for the conjugate base of gallic acid if a 0.100 M solution of gallic acid has a pH of 2.704.

(4) Write the K_a equilbrium (and the expression for K_a)for the weak acid complex ion, $Fe(H_2O)_6^{2+}$.

(5) How would you prove that the reaction of HCl with sodium acetate would be a virtually 100% . ($K_a = 1.8x10^{-5}$). Hint: start with the net ionic equation for this reaction.

(6) Indicate whether aqueous solutions containing the solutes below would be expected to be acidic, basic or neutral solutions? Explain which part of the solut is the acid or base in the solutions if any.

a) NH_4NO_3 b) K_2CO_3 c) $FeCl_3$ d) CH_3OH

(7) How would you prove that the reaction of NaOH to a weak acid, say, acetic acid (HAc, $K_a = 1.8x10^{-5}$) would result in virtually 100% completion. (Hint: start by writing the net ionic equation for the reaction).

8) Suppose that you titrate a 20.0-mL buffer solution containing 0.100M $NaHCO_3$ and 0.150M H_2CO_3 with 0.100 M NaOH. (pK_1 = 6.352, and pK_2 =10.329 for carbonic acid)

a) Write down the 2 titration equations corresponding to the first and second equivalence points. Write them in that sequence.

b) Write down the 2 equilibria that could apply to this solution during the titration. Write down also the values of the K's alongside each equilibrium:

Solution: H_2CO_3 === HCO_3^- + H^+ $K_1 = 10^{-6.352} = 4.45x10^{-7}$

HCO_3^- === CO_3^{2-} + H^+ $K_2 = 10^{-10.329} = 4.69x10^{-11}$

c) How many total mLs of NaOH will be needed to reach the first equivalence point (V_e)?

Solution: $OH^- + H_2CO_3 \rightarrow H_2O + HCO_3^-$

MV=MV since it's 1-to-1: V_e = (.100)(20.0mL)/(.100) = 20.0mL

d) How many mLs of NaOH (after the 1st e.p.) will be needed to reach the *second* equivalence point (V_{2e})?

e) Draw the expected qualitative pH curve for this

Solutions:

1) solution: the acid is NH_4^+ : $[H^+] = 10^{-pH} = 10^{-8.05} = 8.9_{13} \times 10^{-9}$; $pK_a = 14.00-4.72=$

NH_4^+ === NH_3 + H^+ $pK_a = 9.28$, $K_a=5.2_5x10^{-10}$

x $8.9_{13} \times 10^{-6}$ $8.9_{13} \times 10^{-6}$

$(8.9_1 \times 10^{-6})^2/x = K_a = 5.2_5x10^{-10}$ => $x = (8.9_1 \times 10^{-6})^2/ 5.2_5x10^{-10}= 0.15$ M

2) solution: the base is CHO_2^- : $[OH^-] = 10^{-14.00}/10^{-8.72} = 10^{-5.28}$

use K_b equilibrium:

$CHO_2^- + H_2O$ === $HCHO_2 + OH^-$ $K_b = 10^{-14.00} / 10^{-4.75} = 10^{-9.25}$

x $10^{-5.28}$ $10^{-5.28}$

and so: $K_b = (10^{-5.28})^2/x$ => $x = [OH^-] = (10^{-5.28})^2/10^{-9.25} = 4.9x10^{-2}$ M

3) solution:

First, get K_a of gallic acid: HGal ==== H^+ + Gal^-

$0.100-10^{-2.704}$ $10^{-2.704}$ $10^{-2.704}$

$K_a = (10^{-2.704})(10^{-2.704})/(0.100-10^{-2.704}) = 4.0x10^{-5}$

So $K_b = 10^{-14.00} / 4.0x10^{-5} = 2.51x10^{-10}$

4) solution:

$Fe(H_2O)_6^{2+}$ === $Fe(H_2O)_5(OH)^+ + H^+$; $K_a = [H^+][Fe(H_2O)_5(OH)^+]/[Fe(H_2O)_6^{2+}]$

5) solution:

net ionic equation: $H^+ + A^-$ ---> HA but this is the reverse of the K_a equilibrium so, $K_{eq} = 1/K_a = 1/1.8x10^{-5} = 5.55x10^4$>>1.

6) solution:

a) acid, NH_4^+ (conjugate acid of ammonia, NH_3);
b) base, CO_3^{2-} (conjugate base of HCO_3^-);
c) acid (Fe^{3+} is a metal cation which acts as a Lewis acid)
d) neutral (CH_3OH is a molecular compound which doesn't dissociate).

7) solution:

$OH^- + HAc \rightarrow H_2O + A^-$

This just happens to be the reverse of the K_b equilibrium which is:

$H_2O + A^-$ <====> $HA + OH^-$ $K_b = K_w/K_a = 1x10^{-14}/1.8x10^{-5} = 5.56x10^{-10}$

So: $OH^- + HAc$ <====> $H_2O + A^-$ $K = 1/K_a = 1/5.56x10^{-10} = 1.8x10^9$>>1

8) a) Solution: 1st ep: $OH^- + H_2CO_3 \rightarrow H_2O + HCO_3^-$

2nd ep: $OH^- + HCO_3^- \rightarrow H_2O + CO_3^{2-}$

b) Solution: H_2CO_3 === HCO_3^- + H^+ $K_1 = 10^{-6.352} = 4.45\text{x}10^{-7}$
HCO_3^- === CO_3^{2-} + H^+ $K_2 = 10^{-10.329} = 4.69\text{x}10^{-11}$

c) Solution: $OH^- + H_2CO_3 \rightarrow H_2O + HCO_3^-$

MV=MV since it's 1-to-1: V_e = (.100)(20.0mL)/(.100) = 20.0mL

d) Solution: 2nd ep: $OH^- + HCO_3^- \rightarrow H_2O + CO_3^{2-}$
5mmol

Here, we follow the moles:

#moles HCO_3^- present upon reaching 1st eq pt: $n_{H2CO3}° + n_{HCO3-}°$
$= M_{H2CO3}V_{buffer}° + M_{HCO3-}V_{buffer}°$ = (.100M)(20.0mL)+(.150M)(20.0mL)
= 2.00+3.00 mmol = 5 mmol
so you need 5 mmol of NaOH: V_{2e} = 5.00 mmol NaOH (1L/0.100mol)=50.0mL

e) check your text book on this one. Fig 17.9 would be the most similar.