CHM 1046 - JOENS WORKSHEET #9 Due date: M,W,F Monday, October 31
T,R Tuesday, November 1

* While I prefer you turn in a hard copy of the worksheet, I will accept scanned copies sent to my email address, joensj@fiu.edu

Section: (circle one) M,W,F Tu,Tr

For problems involving calculations you must show your work for credit. Unless otherwise stated, you may assume T = 25.0 °C.

1) Which of the following reactions goes essentially to completion?

a) The reaction of a strong acid with a strong base
b) The reaction of a strong acid with a weak base
E c) The reaction of a weak acid with a strong base
d) Both b and c
e) Both a and b and c

In an acid+base reaction, if at least one of the reactants is strong the reaction will go essentially to completion.

2) A particular buffer contains 0.0240 M of carbonic acid (H_2CO_3), a weak acid, and 0.0150 M of hydrogen carbonate ion (HCO_3^-) the conjugate base of carbonic acid. Note that K_{a1}= 4.2 x 10^{-7} for carbonic acid.

a) What is the pH of the buffer solution? (HINT: This is an easy problem if you use the Henderson equation).

$pH = pK_a + \log_{10}\{[base]/acid]\}$ $pK_a = -\log_{10}(4.2 \times 10^{-7}) = 6.377$
$[acid] = [H_2CO_3] = 0.0240$ M
$[base] = [HCO_3^-] = 0.0150$ M

So $pH = 6.377 + \log_{10}\{(0.0150)/(0.0240)\} = 6.377 + (-0.204) = 6.17$

Note that when you make a buffer involving a polyprotic acid you only need to look at the equilibrium constant corresponding to the particular weak acid/conjugate base involved.

b) Give the reaction that occurs if a small amount of HCl, a strong monoprotic acid, is added to the system.

$HCl(aq) + HCO_3^-(aq) \rightarrow H_2CO_3(aq) + Cl^-(aq)$

c) Give the reaction that occurs if a small amount of NaOH, a strong soluble base, is added to the system.

$NaOH(aq) + H_2CO_3(aq) \rightarrow Na^+(aq) + HCO_3^-(aq) + H_2O(\ell)$

d) Based on your answers in b and c, explain why this system functions as a buffer system.

If we add a strong acid or base to an unbuffered solution the pH will change a lot, because the acids and bases are strong. But in a buffer system, the strong acid or base are converted into weak acid or base, as shown in the above reactions. Since weak acids or bases only dissociate to a small extent, they have a much smaller effect on pH (they do change the pH, but as we saw in the in class example, only by a small amount).

3) Potassium hydrogen phthalate ($C_8H_5KO_4$, MW = 204.22 g/mol) is a soluble ionic compound, and is often used to find the concentration of strong base solutions by titration. When added to water, it dissolves by the process:

$$C_8H_5KO_4(s) \rightarrow K^+(aq) + C_8H_5O_4^-(aq) \qquad (3.1)$$

The anion, $C_8H_5O_4^-$, is a weak acid, and reacts with KOH, a strong soluble base

$$C_8H_5O_4^-(aq) + KOH(aq) \rightarrow K^+(aq) + C_8H_4O_4^{2-}(aq) + H_2O(\ell) \qquad (3.2)$$

A 0.3145 g sample of potassium hydrogen phthalate is dissolved in water, and titrated with a sample of a stock solution of potassium hydroxide. After the addition of 37.18 mL of the KOH solution, the equivalence point of the titration is reached. Based on this information, find [KOH], the concentration of potassium hydroxide in the stock solution.

$$[NaOH] = \frac{\text{moles NaOH}}{\text{L soln}} \qquad \text{Liters NaOH solution} = 37.18\ \text{mL} = 0.03718\ \text{L}$$

To find the moles of NaOH we need to use the balanced reactions given above.

$$\text{moles } C_8H_5KO_4 = 0.3145\ \text{g } C_8H_5KO_4 \ \frac{1\ \text{mol}}{204.22\ \text{g}} = 1.5400 \times 10^{-3}\ \text{mol } C_8H_5KO_4$$

Based on reaction 3.1

$$\text{moles } C_8H_5O_4^- = 1.5400 \times 10^{-3}\ \text{mol } C_8H_5KO_4 \ \frac{1\ \text{mol } C_8H_5O_4^-}{1\ \text{mol } C_8H_5KO_4} = 1.5400 \times 10^{-3}\ \text{mol } C_8H_5O_4^-$$

Based on reaction 3.2

$$\text{moles NaOH} = 1.5400 \times 10^{-3}\ \text{mol } C_8H_5O_4^- \ \frac{1\ \text{mol KOH}}{1\ \text{mol } C_8H_5O_4^-} = 1.5400 \times 10^{-3}\ \text{mol KOH}$$

And so $[KOH] = \dfrac{1.5400 \times 10^{-3}\ \text{mol}}{003718\ \text{L}} = 0.04142\ \text{M}$

I have spelled out all the conversions to make it clear what is happening, but you could combine them into a single step. Since we know all the information in the problem to four significant figures we know the concentration of the KOH stock solution to that number of significant figures. In real life, you can actually achieve this level of precision if you are careful in doing a titration.