CHM 1046 - JOENS WORKSHEET #8 Due date: Monday, November 13th

WORKSHEETS ARE DUE AT THE BEGINNING OF CLASS ON THE DATE GIVEN ON THE WORKSHEET. LATE WORKSHEETS WILL NOT BE ACCEPTED.

NAME ______________________________ Panther ID ____________________________

For problems involving calculations you must show your work for credit.

For each of the problems below you may assume T = 25. °C.

1) A buffer solution is prepared by adding 2.45 g of benzoic acid (C_6H_5COOH, MW = 122.1 g/mol, K_a = 6.5 x 10^{-5}) and 1.18 g of sodium benzoate (C_6H_5COONa, MW = 144.1 g/mol) to water, to form a solution with total volume V = 500.0 mL.

a) What is the pH of the above buffer solution?

mol benzoic acid = $2.45\text{ g}\ \frac{1\text{ mol}}{122.1\text{ g}} = 0.0201$ mol benzoic acid

mol sodium benzoate = moles benzoate ion = $1.18\text{ g}\ \frac{1\text{ mol}}{144.1\text{ g}} = 0.0082$ mol benzoate ion

From the Henderson equation

$$pH = pK_a + \log_{10}\text{ [base]/acid]} = -\log_{10}(6.5 \times 10^{-5}) + \log_{10}(0.0082/0.0201)$$

$$= 4.19 + (-0.39) = 3.80$$

Note that since the benzoic acid and benzoate ion are both in the same solution (and so have the same volume) we can use moles of acid and base rather than concentration.

b) 0.010 g of sodium hydroxide (NaOH, MW = 40.0 g/mol) is added to the above solution. What is the pH after the addition of the sodium hydroxide? You may assume that the volume remains constant.

moles NaOH = $0.010\text{ g}\ \frac{1\text{ mol}}{40.0\text{ g}} = 0.00025$ mol NaOH

NaOH reacts with benzoic acid as follows

$$C_6H_5COOH(aq) + NaOH(aq) \rightarrow Na^+(aq) + C_6H_5COO^-(aq) + H_2O(\ell)$$

The reaction involves a strong base and so goes essentially to completion. After the reaction, the moles of benzoic acid and benzoate ion are

moles benzoic acid = 0.0201 mol - 0.00025 mol = 0.01985 mol

mol benzoate ion = 0.0082 mol + 0.00025 mol = 0.00845 mol

We can again use the Henderson equation, and so

$$pH = pK_a + \log_{10}\text{ [base]/acid]} = -\log_{10}(6.5 \times 10^{-5}) + \log_{10}(0.00845/0.01985)$$

$$= 4.19 + (-0.37) = 3.82$$

Notice that the pH increased, as expected when a strong base is added to a buffer solution

2) Consider the following four weak acids:

CH_3COOH	$K_a = 1.8 \times 10^{-5}$	$HClO_2$	$K_a = 1.1 \times 10^{-2}$
$HBrO$	$K_a = 2.5 \times 10^{-9}$	C_6H_5OH	$K_a = 1.3 \times 10^{-10}$

Which of the following weak acid/conjugate base pairs would be best suited to make a pH = 9.50 buffer?

a) CH_3COOH and CH_3COONa (4.74)
b) HBrO and NaBrO (8.60)
D c) $HClO_2$ and $NaClO_2$ (1.96)
d) C_6H_5OH and C_6H_5ONa (9.89)
e) All of the above are equally suited to make a pH = 9.50 buffer

I have added the pK_a values next to each answer. The one that is closest to pH = 9.50 is C_6H_5OH, and so d corresponds to the best choice for buffer. We could make a buffer from b, since the pK_a value is within ± 1 of the desired pH, but D is closer and so a better choice.

3) Which of the following reactions will go essentially to completion?

a) NaOH(aq) + HBr(aq) strong base + strong acid
b) NH_3(aq) + HBr(aq) weak base + strong acid
D c) NH_3(aq) + HClO(aq) weak base + weak acid
d) Both a and b
e) Both a and b and c

In an acid + base reaction, the reaction goes essentially to completion if at least one of the reactants is strong. Since that is true for the first two reactions, the correct answer is d.

4) A 20.00 mL sample of a stock solution of aniline ($C_6H_5NH_2$, a weak base) is titrated with a 0.0186 M solution of hydrochloric acid (HCl, a strong acid). The reaction that occurs is

$$C_6H_5NH_2(aq) + HCl(aq) \rightarrow C_6H_5NH_3^+(aq) + Cl^-(aq)$$

After the addition of 16.93 mL of the HCl solution the equivalence point of the titration is reached?

a) What is the concentration of aniline in the stock solution?

$$\text{mol aniline} = 0.01693 \text{ L HCl} \; \frac{0.0186 \text{ mol HCl}}{\text{L soln}} \; \frac{1 \text{ mol aniline}}{1 \text{ mol HCl}} = 3.149 \times 10^{-4} \text{ mol aniline}$$

$$[\text{aniline}] = \frac{3.149 \times 10^{-4} \text{ mol aniline}}{0.0200 \text{ L}} = 0.0157 \text{ M}$$

b) What is the pH at the equivalence point for the titration (circle the correct answer)?

Larger than 7.0 Equal to 7.0 **Smaller than 7.0**

At the equivalence point in a titration of a weak base with a strong acid both the weak base ($C_6H_5NH_2$) and strong acid (HCl) will have disappeared, leaving only the conjugate acid of the weak base ($C_6H_5NH_3^+$). Since there is a weak acid present, and nothing else with significant acid or base properties, pH < 7.0