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Name Key
(Please print family name last; e.g., Robert Boyle)

UMB Student Number _____

Chem 104 - Section 1
Hour Examination III
May 5, 2006

This test consists of seven (7) pages, including this cover page, a table of conjugate acid-base pairs with K_a values, and a periodic table. Be sure your copy is complete before beginning your work. If this test packet is defective, ask for another one. **Feel free to detach the acid-base table and/or periodic table to use for reference or scratch paper.**

Give all numerical answers to the proper number of significant figures.

$$K_w = 1.00 \times 10^{-14}$$

DO NOT WRITE BELOW THIS LINE

1.

2.

3 a - e

3 f & g
+ bonus

TOTAL

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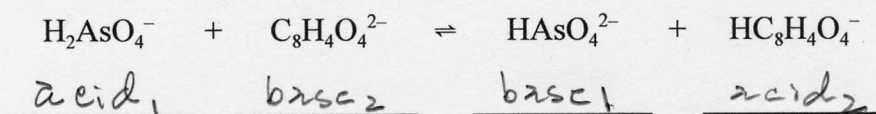
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1. (12 points; 3 points each part) Complete the following table by calculating the missing entries and indicating whether the solution is acidic or basic.

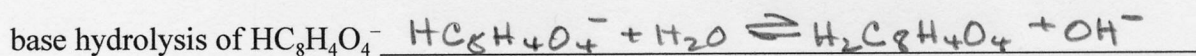
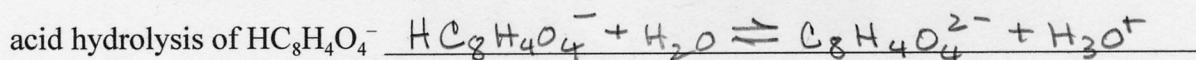
$[H_3O^+]$	$[OH^-]$	pH	pOH	acidic/basic?
1.8×10^{-10}	$5.6 \times 10^{-5} \text{ M}$	9.75	4.25	basic

2. (44 points; 4 points each part) Fill in the blanks.

- a. For the following reaction, label the conjugate acid-base pairs (i.e., acid₁/base₁; acid₂/base₂).



- b. Write a balanced chemical equation for each of the following equilibria:



- c. For the acid hydrolysis of *o*-phthalic acid, $H_2C_8H_4O_4$, $K_a = 1.3 \times 10^{-3}$. What is the value of K_b for the base hydrolysis of the hydrogen phthalate ion, $HC_8H_4O_4^-$?

$$K_b = \underline{7.7 \times 10^{-12}} \text{ for } HC_8H_4O_4^-$$

- d. For the acid hydrolysis of the hydrogen phthalate ion, $HC_8H_4O_4^-$, $K_a = 3.1 \times 10^{-6}$. Judging from this and the K_b value you just calculated in question c, would a 0.10 M solution of $NaHC_8H_4O_4(aq)$ be acidic or basic?

acidic (acidic/basic)

- e. Consider a 0.10 M solution of the diprotic acid $H_2C_8H_4O_4(aq)$, for which $K_1 = 1.3 \times 10^{-3}$ and $K_2 = 3.1 \times 10^{-6}$. What is the concentration of $C_8H_4O_4^{2-}$ ion in this solution?

$$[C_8H_4O_4^{2-}] = \underline{3.1 \times 10^{-6}} \text{ M}$$

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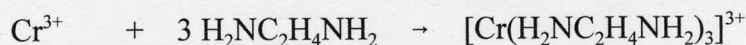
- f. Refer to the Table of Conjugate Acid-Base Pairs. Which one of the following solutions when added in excess to a solution containing 1.0 mmol $\text{Na}_3\text{PO}_4(aq)$ would produce 1.0 mmol H_2PO_4^- ion in solution: $\text{HOBr}(aq)$, $\text{Cr}(\text{NO}_3)_3(aq)$, $\text{NH}_4\text{Cl}(aq)$?

Answer: $\text{Cr}(\text{NO}_3)_3$

- g. Assuming equal concentrations, which one of the following pairs would produce the more acidic solution?

 $\text{HIO}_2(aq)$ or $\text{HIO}_3(aq)$ HIO_3 $\text{C}_6\text{H}_5\text{CO}_2\text{H}(aq)$ or $\text{BrC}_6\text{H}_4\text{CO}_2\text{H}(aq)$ $\text{BrC}_6\text{H}_4\text{CO}_2\text{H}$

- h. Identify the Lewis acid and Lewis base in the following reaction

acid base

- i. Consider a 0.10 M solution of the weak acid HA, for which $\text{p}K_a = 1.23$. Would the expression $[\text{H}_3\text{O}^+] = \sqrt{C_{\text{HA}}K_a}$ give a reasonably accurate estimate of the hydronium ion concentration (less than 5% error)? $K_a = 5.89 \times 10^{-2}$

Answer: NO (yes/no)

- j. The base B has $K_b = 1.0 \times 10^{-9}$. What is the pH of a buffer solution prepared by mixing 1.0 mol B with 1.0 mol of the salt HB^+Cl^- in enough water to make a liter of solution?

pH = 5.00

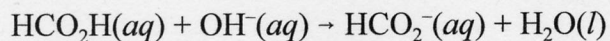
- k. Indicate whether 0.10 M aqueous solutions of each of the following solutions would have a $\text{pH} > 7.0$, $\text{pH} < 7.0$, or $\text{pH} \approx 7.0$:

 $\text{Sr}(\text{NO}_2)_2$ > 7.0 $\text{Cr}(\text{NO}_3)_3$ < 7.0

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3. (44 points) $K_a = 1.8 \times 10^{-4}$ for formic acid, HCO_2H . Consider the titration of 25.0 mL of 0.200 M HCO_2H solution (the analyte), with 0.100 M NaOH(aq) solution (the titrant):



- a. (4 points) How many milliliters of 0.100 M NaOH(aq) solution must be added to reach the equivalence point?

$$V_b = \frac{V_a M_a}{M_b} = \frac{(25.0 \text{ mL})(0.200 \text{ M})}{0.100 \text{ M}} = 50.0 \text{ mL}$$

- b. (2 points) What is the total volume in the solution at the equivalence point? 75.0 mL

- c. (2 points) How many millimoles of HCO_2H are present in the analyte sample before any titrant has been added?

$$\text{millimoles } \text{HCO}_2\text{H} = \underline{5.00}$$

- d. (6 points) What is the initial pH of the HCO_2H solution, before adding any titrant?

$$[\text{H}_3\text{O}^+] = \sqrt{(0.200)(1.8 \times 10^{-4})} = \sqrt{3.6 \times 10^{-5}} = 6.0 \times 10^{-3}$$

$$\text{pH} = 2.2218 = 2.22$$

- e. (6 points) What is the pH of the resulting solution after adding 25.0 mL of 0.100 M NaOH(aq) solution? [Hint: How far along in the titration is this?]

Half-titration point \Rightarrow equimolar buffer solution

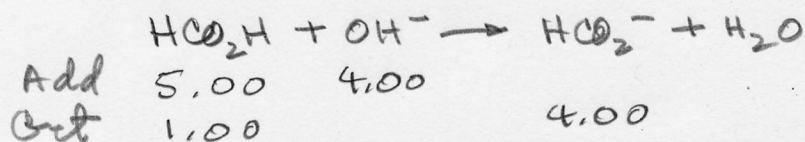
$$\text{pH} = \text{p}K_a = -\log(1.8 \times 10^{-4}) = 3.7447 = 3.74$$

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- f. (10 points) What is the pH of the resulting solution after adding 40.0 mL of 0.100 M NaOH(aq) solution?

$$\text{mmol OH}^- \text{ added} = (40.0 \text{ mL})(0.100 \text{ M}) = 4.00 \text{ mmol}$$



$$K_2 = \frac{[\text{H}_3\text{O}^+][\text{HCO}_2^-]}{[\text{HCO}_2\text{H}]} = 1.8 \times 10^{-4} = \frac{[\text{H}_3\text{O}^+](4.00)}{1.00}$$

$$[\text{H}_3\text{O}^+] = \frac{(1.00)(1.8 \times 10^{-4})}{4.00} = 4.5 \times 10^{-5} \Rightarrow \text{pH} = 4.35$$

- g. (14 points) What is the pH at the equivalence point?

All HCO_2H converted to 5.00 mmol HCO_2^- in 75.0 mL.

$$C_{\text{HCO}_2^-} = \frac{5.00 \text{ mmol}}{75.0 \text{ mL}} = 6.6667 \times 10^{-2} \text{ M}$$

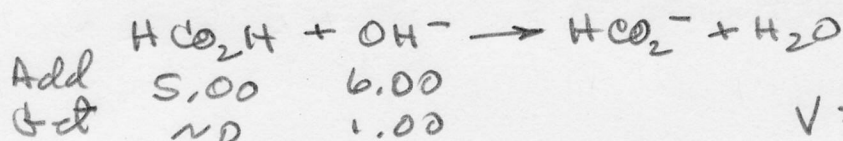
$$K_b^{\text{HCO}_2^-} = \frac{K_w}{K_a^{\text{HCO}_2\text{H}}} = \frac{1.0 \times 10^{-14}}{1.8 \times 10^{-4}} = 5.556 \times 10^{-11} = 5.6 \times 10^{-11}$$

$$[\text{OH}^-] = \sqrt{(6.6667 \times 10^{-2})(5.556 \times 10^{-11})} = \sqrt{3.704 \times 10^{-12}} = 1.925 \times 10^{-6}$$

$$\text{pOH} = 5.72 \Rightarrow \text{pH} = 8.28$$

- BONUS (5 points) What is the pH of the solution after the addition of 60.0 mL of 0.100 M NaOH solution?

$$\text{mmol OH}^- \text{ added} = (60.0 \text{ mL})(0.100 \text{ M}) = 6.00 \text{ mmol}$$



$$V = 85.0 \text{ mL}$$

$$[\text{OH}^-] = \frac{1.00 \text{ mmol}}{85.0 \text{ mL}} = 1.176 \times 10^{-2} \Rightarrow \text{pOH} = 1.929 \Rightarrow \text{pH} = 12.071$$