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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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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}	5.6×10^{-5} 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., acid$_1$/base$_1$; acid$_2$/base$_2$).

$$H_2AsO_4^- \quad + \quad C_8H_4O_4^{2-} \quad \rightleftharpoons \quad HAsO_4^{2-} \quad + \quad HC_8H_4O_4^-$$

acid$_1$ base$_2$ base$_1$ acid$_2$

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

acid hydrolysis of $HC_8H_4O_4^-$ $HC_8H_4O_4^- + H_2O \rightleftharpoons C_8H_4O_4^{2-} + H_3O^+$

base hydrolysis of $HC_8H_4O_4^-$ $HC_8H_4O_4^- + H_2O \rightleftharpoons H_2C_8H_4O_4 + OH^-$

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, $HC_8H_4O_4^-$?

$K_b =$ 7.7×10^{-12} 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?

$[C_8H_4O_4^{2-}] =$ 3.1×10^{-6} M α Name Key

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 $Na_3PO_4(aq)$ would produce 1.0 mmol $H_2PO_4^-$ ion in solution: $HOBr(aq)$, $Cr(NO_3)_3(aq)$, $NH_4Cl(aq)$?

Answer: $Cr(NO_3)_3$

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

$HIO_2(aq)$ or $HIO_3(aq)$ HIO_3

$C_6H_5CO_2H(aq)$ or $BrC_6H_4CO_2H(aq)$ $BrC_6H_4CO_2H$

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

$$Cr^{3+} + 3\ H_2NC_2H_4NH_2 \rightarrow [Cr(H_2NC_2H_4NH_2)_3]^{3+}$$

acid base

i. Consider a 0.10 M solution of the weak acid HA, for which $pK_a = 1.23$. Would the expression $[H_3O^+] = \sqrt{C_{HA}K_a}$ 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 HBCl 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 pH > 7.0, pH < 7.0, or pH ≈ 7.0:

$Sr(NO_2)_2$ >7.0 $Cr(NO_3)_3$ <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):

$$HCO_2H(aq) + OH^-(aq) \rightarrow HCO_2^-(aq) + H_2O(l)$$

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

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

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?

millimoles HCO_2H = 5.00

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

$$[H_3O^+] = \sqrt{(0.200)(1.8 \times 10^{-4})} = \sqrt{3.6 \times 10^{-5}} = 6.0 \times 10^{-3}$$

$$pH = 2.22_{18} = 2.22$$

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 ⇒ equimolar buffer solution

$$pH = pK_a = -\log(1.8 \times 10^{-4}) = 3.74_{47} = 3.74$$

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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?

mmol OH^- added = (40.0 mL)(0.100 M) = 4.00 mmol

$$HCO_2H + OH^- \rightarrow HCO_2^- + H_2O$$

	HCO_2H	OH^-	HCO_2^-
Add	5.00	4.00	
Get	1.00		4.00

$$K_a = \frac{[H_3O^+][HCO_2^-]}{[HCO_2H]} = 1.8\times10^{-4} = \frac{[H_3O^+](4.00)}{1.00}$$

$$[H_3O^+] = \frac{(1.00)(1.8\times10^{-4})}{4.00} = 4.5\times10^{-5} \Rightarrow pH = 4.35$$

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.

$$C_{HCO_2^-} = \frac{5.00\text{ mmol}}{75.0\text{ mL}} = 6.66_{67}\times10^{-2}\text{ M}$$

$$K_b^{HCO_2^-} = \frac{K_w}{K_a^{HCO_2H}} = \frac{1.0\times10^{-14}}{1.8\times10^{-4}} = 5.5_{56}\times10^{-11} = 5.6\times10^{-11}$$

$$[OH^-] = \sqrt{(6.66_{67}\times10^{-2})(5.5_{56}\times10^{-11})} = \sqrt{3.7_{04}\times10^{-12}} = 1.9_{25}\times10^{-6}$$

pOH = 5.72 ⇒ 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?

mmol OH^- added = (60.0 mL)(0.100 M) = 6.00 mmol

$$HCO_2H + OH^- \rightarrow HCO_2^- + H_2O$$

	HCO_2H	OH^-
Add	5.00	6.00
Get	no	1.00

V = 85.0 mL

$$[OH^-] = \frac{1.00\text{ mmol}}{85.0\text{ mL}} = 1.17_6\times10^{-2} \Rightarrow pOH = 1.929 \Rightarrow pH = 12.071$$