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

UMB Student Number _____

Chem 116 - Section 1
Hour Examination III
May 11, 2007

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.

4 a - e

4 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?
3.0×10^{-11}	3.3×10^{-4} M	10.52	3.48	basic

2. (32 points; 4 points each part) Fill in the blanks.

a. For the following reaction, label the conjugate acid-base pairs (i.e., $acid_1/base_1$; $acid_2/base_2$).

$$H_2P_2O_7^{2-} + H_2SeO_3 \rightleftharpoons H_3P_2O_7^- + HSeO_3^-$$

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

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

acid hydrolysis of $H_2PO_3^-$ $H_2PO_3^- + H_2O \rightleftharpoons HPO_3^{2-} + H_3O^+$

base hydrolysis of $H_2PO_3^-$ $H_2PO_3^- + H_2O \rightleftharpoons H_3PO_3 + OH^-$

c. Using data from the attached Table of Conjugate Acid-Base Pairs, what is the value of K_b for the tartrate ion, $C_4H_4O_6^{2-}$?

$K_b = 2.20 \times 10^{-10}$

d. 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: $HOI(aq)$, $Al(NO_3)_3(aq)$, $NH_4Cl(aq)$?

Answer: $Al(NO_3)_3$

e. For each of the following pairs, which one is the stronger acid?

$HClO_2$ or $HClO_3$ $HClO_3$

H_2S or H_2Se H_2Se

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

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

acid base

g. 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

h. 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:

$Ca(CN)_2$ > 7.0 $Cr(NO_3)_3$ < 7.0

3. (12 points) The following two problems pertain to a solution of the base acetamide, whose hydrolysis reaction and K_b are

$$CH_3CO_2NH_2 + H_2O \rightleftharpoons CH_3CO_2NH_3^+ + OH^- \qquad K_b = 2.34 \times 10^{-1}$$

a. (8 points) Calculate the concentration of hydroxide ion, $[OH^-]$, in a 0.140 M solution of acetamide.

$$K_b = \frac{[OH^-]^2}{0.140 - [OH^-]} = 0.234$$

$$[OH^-]^2 + 0.234[OH^-] - 0.0327_6 = 0$$

$$[OH^-] = 0.0985_2 M = 0.0985 M$$

b. (4 points) Based on your answer to part a, what is the percent hydrolysis of acetamide in this solution?

$$\%\ \text{hydrolysis} = \frac{0.0985_2}{0.140} \times 100\% = 70.4\%$$

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4. (44 points) $K_a = 1.54 \times 10^{-5}$ for butyric acid, $C_3H_7CO_2H$. Consider the titration of 25.0 mL of 0.200 M $C_3H_7CO_2H$ solution (the analyte), with 0.100 M NaOH(*aq*) solution (the titrant):

$$C_3H_7CO_2H(aq) + OH^-(aq) \rightarrow C_3H_7CO_2^-(aq) + H_2O(l)$$

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

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

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 $C_3H_7CO_2H$ are present in the analyte sample before any titrant has been added?

millimoles $C_3H_7CO_2H$ = 5.00

d. (6 points) What is the initial pH of the $C_3H_7CO_2H$ solution, before adding any titrant?

$$[H_3O^+] = \sqrt{(0.200)(1.54 \times 10^{-5})} = \sqrt{3.08 \times 10^{-6}}$$

$$= 1.75 \times 10^{-3}\,M$$

$$pH = 2.756$$

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 $\Rightarrow pH = pK_a$

$$pH = -\log(1.54 \times 10^{-5}) = 4.812$$

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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?

$$C_3H_7CO_2H + OH^- \longrightarrow C_3H_7CO_2^- + H_2O$$

Add 5.00 4.00

Get 1.00 4.00

$$K_a = \frac{[H_3O^+](4.00)}{1.00} = 1.54 \times 10^{-5}$$

$$[H_3O^+] = \frac{(1.00)(1.54 \times 10^{-5})}{4.00} = 3.85 \times 10^{-6}\ M$$

$$pH = 5.415$$

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

$$K_b = \frac{1.00 \times 10^{-14}}{1.54 \times 10^{-5}} = 6.49 \times 10^{-10}$$

$$C_{A^-} = \frac{5.00\ mmol}{75.0\ mL} = 6.67 \times 10^{-2}\ M$$

$$[OH^-] = \sqrt{(6.49 \times 10^{-10})(6.67 \times 10^{-2})} = \sqrt{4.33 \times 10^{-11}}$$

$$= 6.58 \times 10^{-6}\ M$$

$$pOH = 5.182$$

$$pH = 8.818$$

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

$$mmol\ xs\ OH^- = (10.0\ mL)(0.100\ M) = 1.00\ mmol$$

$$V = 85.0\ mL$$

$$[OH^-] = \frac{1.00\ mmol}{85.0\ mL} = 1.18 \times 10^{-2}\ M \Rightarrow pOH = 1.929$$

$$pH = 12.071$$