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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?
1.3×10^{-6}	7.7×10^{-9} M	5.89	8.11	acidic

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

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

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

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

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

acid hydrolysis of $H_2AsO_3^-$ $H_2AsO_3^- + H_2O \rightleftharpoons HAsO_3^{2-} + H_3O^+$

base hydrolysis of $H_2AsO_3^-$ $H_2AsO_3^- + H_2O \rightleftharpoons H_3AsO_3 + OH^-$

c. Using data from the attached Table of Conjugate Acid-Base Pairs, what is the value of K_b for the oxalate ion, $C_2O_4^{2-}$?

$K_b = 1.56 \times 10^{-10}$

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: $HOCl(aq)$, $Fe(NO_3)_3(aq)$, $NH_4NO_3(aq)$?

Answer: $Fe(NO_3)_3$

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

HClO or $HClO_2$ $HClO_2$

H_2Se or H_2Te H_2Te

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

$$Cr^{3+} + 3\,C_2O_4^{2-} \rightarrow [Cr(C_2O_4)_3]^{3-}$$

acid base

g. The base B has $K_b = 1.0 \times 10^{-6}$. 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 = 8.00

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:

$Cu(NO_3)_2$ < 7.0 $Ba(CN)_2$ > 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 0.120 M solution of acetamide.

$$K_b = \frac{[OH^-]^2}{0.120 - [OH^-]} = 0.234$$

$$[OH^-]^2 + 0.234[OH^-] - 0.0280_8 = 0$$

$$[OH^-] = 0.0873_7\,M = 0.0874\,M$$

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

$$\%\ \text{hydrolysis} = \frac{0.0873_7}{0.120} \times 100\% = 72.8\%$$

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4. (44 points) $K_a = 1.34 \times 10^{-5}$ for propionic acid, $C_2H_5CO_2H$. Consider the titration of 25.0 mL of 0.160 M $C_2H_5CO_2H$ solution (the analyte), with 0.100 M NaOH(*aq*) solution (the titrant):

$$C_2H_5CO_2H(aq) + OH^-(aq) \rightarrow C_2H_5CO_2^-(aq) + H_2O(l)$$

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

$$V_b = \frac{M_a V_a}{M_b} = \frac{(0.160\,M)(25.0\,mL)}{0.100\,M} = 40.0\,mL$$

b. (2 points) What is the total volume in the solution at the equivalence point? 65.0 mL

c. (2 points) How many millimoles of $C_2H_5CO_2H$ are present in the analyte sample before any titrant has been added?

millimoles $C_2H_5CO_2H$ = 4.00

d. (6 points) What is the initial pH of the $C_2H_5CO_2H$ solution, before adding any titrant?

$$[H_3O^+] = \sqrt{(0.160)(1.34 \times 10^{-5})} = \sqrt{2.14_4 \times 10^{-6}}$$

$$= 1.46 \times 10^{-3}\,M$$

$$pH = 2.834$$

e. (6 points) What is the pH of the resulting solution after adding 20.0 mL of 0.100 M NaOH(*aq*) solution? [Hint: How far along in the titration is this?]

Half-titration point $\Rightarrow pH = pK_a$

$$pH = -\log(1.34 \times 10^{-5}) = 4.873$$

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f. (10 points) What is the pH of the resulting solution after adding 30.0 mL of 0.100 M NaOH(*aq*) solution?

$C_2H_5CO_2H + OH^- \rightarrow C_2H_5CO_2^- + H_2O$

Add	4.00	3.00	
Get	1.00		3.00

$K_a = \frac{[H_3O^+](3.00)}{1.00} = 1.34 \times 10^{-5}$

$[H_3O^+] = \frac{(1.00)(1.34 \times 10^{-5})}{3.00} = 4.47 \times 10^{-6}\ M$

$pH = 5.350$

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

$K_b = \frac{1.00 \times 10^{-14}}{1.34 \times 10^{-5}} = 7.46 \times 10^{-10}$

$C_{A^-} = \frac{4.00\ mmol}{65.0\ mL} = 6.15 \times 10^{-2}$

$[OH^-] = \sqrt{(7.46 \times 10^{-10})(6.15 \times 10^{-2})} = \sqrt{4.59 \times 10^{-11}}$

$= 6.78 \times 10^{-6}\ M$

$pOH = 5.169$

$pH = 8.831$

BONUS (5 points) What is the pH of the solution after the addition of 50.0 mL of 0.100 M NaOH solution?

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

$V = 75.0\ mL$

$[OH^-] = \frac{1.00\ mmol}{75.0\ mL} = 1.33 \times 10^{-2}\ M \Rightarrow pOH = 1.875$

$pH = 12.125$