

a

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.**

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

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DO NOT WRITE BELOW THIS LINE

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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.

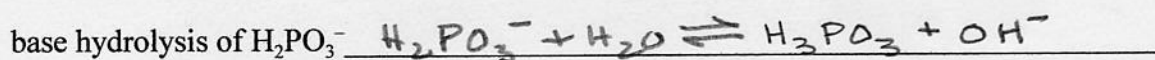
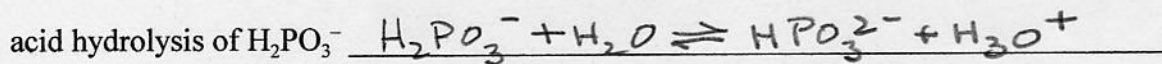
$[\text{H}_3\text{O}^+]$	$[\text{OH}^-]$	pH	pOH	acidic/basic?
$3.0 \times 10^{-11}$	$3.3 \times 10^{-4} \text{ M}$	10.52	3.48	basic

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<sub>1</sub>/base<sub>1</sub>; acid<sub>2</sub>/base<sub>2</sub>).



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



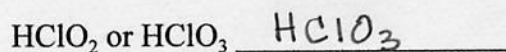
- c. Using data from the attached Table of Conjugate Acid-Base Pairs, what is the value of  $K_b$  for the tartrate ion,  $\text{C}_4\text{H}_4\text{O}_6^{2-}$ ?

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

- 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  $\text{Na}_3\text{PO}_4(\text{aq})$  would produce 1.0 mmol  $\text{H}_2\text{PO}_4^-$  ion in solution:  $\text{HOI}(\text{aq})$ ,  $\text{Al}(\text{NO}_3)_3(\text{aq})$ ,  $\text{NH}_4\text{Cl}(\text{aq})$ ?

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

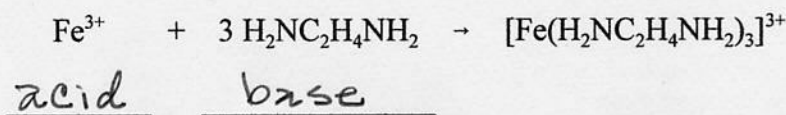
- e. For each of the following pairs, which one is the stronger acid?



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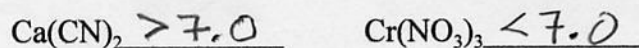
- f. Identify the Lewis acid and Lewis base in the following reaction



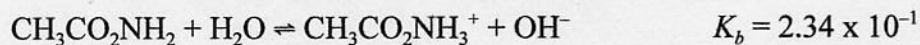
- g. The base B has
- $K_b = 1.0 \times 10^{-9}$
- . What is the pH of a buffer solution prepared by mixing 1.0 mol B with 1.0 mol of the salt HBCl in enough water to make a liter of solution?

$$\text{pH} = \underline{5.00}$$

- 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:



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



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

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

$$[\text{OH}^-]^2 + 0.234[\text{OH}^-] - 0.03276 = 0$$

$$[\text{OH}^-] = 0.09852 \text{ M} = 0.0985 \text{ M}$$

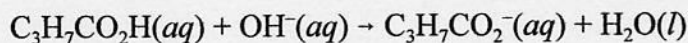
- b. (4 points) Based on your answer to part a, what is the percent hydrolysis of acetamide in this solution?

$$\% \text{ hydrolysis} = \frac{0.09852}{0.140} \times 100\% = 70.4\%$$

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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):



- 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?

$$\text{millimoles } C_3H_7CO_2H = \underline{5.00}$$

- 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?]

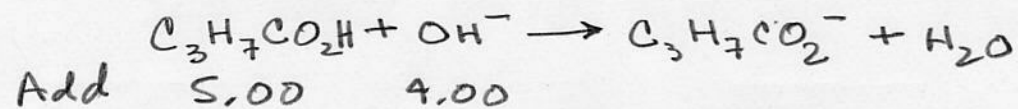
$$\text{Half-titration point} \Rightarrow pH = pK_a$$

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

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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?



Get 1.00 4.00

$$K_a = \frac{[\text{H}_3\text{O}^+](4.00)}{1.00} = 1.54 \times 10^{-5}$$

$$[\text{H}_3\text{O}^+] = \frac{(1.00)(1.54 \times 10^{-5})}{4.00} = 3.85 \times 10^{-6} \text{ M}$$

$$\text{pH} = 5.415$$

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

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

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

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

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

$$\text{pOH} = 5.182$$

$$\text{pH} = 8.818$$

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

$$\text{mmol of OH}^- = (10.0 \text{ mL})(0.100 \text{ M}) = 1.00 \text{ mmol}$$

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

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

$$\text{pH} = 12.071$$