CHM 106
Exam II

1. Imidazole ($C_3H_4N_2$) is a weak base that can accept one proton. Suppose a 20.00 mL aliquot of imidzaole solution is titrated to the equivalence point with 32.91 mL of 0.1041 M HCl.

a) Write a balanced chemical equation for the reaction taking place. Under your equation, identify which species reacts as an acid, which species reacts as a base, which species is the conjugate acid, and which species is the conjugate base.

b) What is the concentration of the imidazole solution?

c) The pH of the original imidazole solution is 10.113. What is the value of K_b for imidazole?

2. Recipes for buffer solutions of known pH can be found in many reference handbooks. One such recipe starts with two stock solutions. Solution A is made by diluting 13.77 mL of concentrated (14.53 M) ammonia to 1.00 L. Solution B is made by diluting 10.699 g of solid ammonium chloride to 1.00 L. The buffer is then prepared by mixing 36.0 mL of solution A with 64.0 mL of solution B. For ammonia, $K_b = 1.762\times10^{-5}$.

a) What is the concentration of $NH_3(aq)$ in solution A?

b) What is the concentration of $NH_4^+(aq)$ in solution B?

c) What is the pH of the resulting buffer?

3. Magnesium hydroxide is slightly soluble in water with $K_{sp} = 1.8\times10^{-11}$.

a) Write balanced chemical equation and an equilibrium expression for the dissolution of magnesium hydroxide.

b) What is the molar solubility of magnesium hydroxide?

c) What is the pH of a saturated solution of magnesium hydroxide?

d) Suppose that 0.50 g of $Mg(NO_3)_2$ is added to this solution. What is the molar solubiulity of magnesium hydroxide in the new solution?

e) What is the pH of this new solution?

4. Salts of the weak base pyridine (C_5H_5N, $K_b = 1.48\times10^{-9}$) are frequently used in organic synthesis as mild acid catalysts due to their solubility in both aqueous and organic solvents. Suppose you have an aqueous solution of 0.100 M pyridinium bromide (C_5H_5NHBr).

a) Write a chemical equation that accounts for the acidity of pyridinium bromide.

b) In this solution, what are the concentrations of $[H^+]$, $[OH^-]$, and $[Br^-]$?

c) What is the pH of this solution?

d) What is the percent dissociation of the pyridinium ion?

5. A 25.0 mL sample of a 0.100 M formic acid solution is titrated with standard 0.100 M sodium hydroxide. For formic acid, $K_a = 1.77\times10^{-4}$.

a) What is the pH of the formic acid solution before any sodium hydroxide is added?

b) What is the pH after 12.5 mL of NaOH is added?

c) What is the pH after 25.0 mL of NaOH is added?

d) What is the pH after 50.0 mL of NaOH is added?

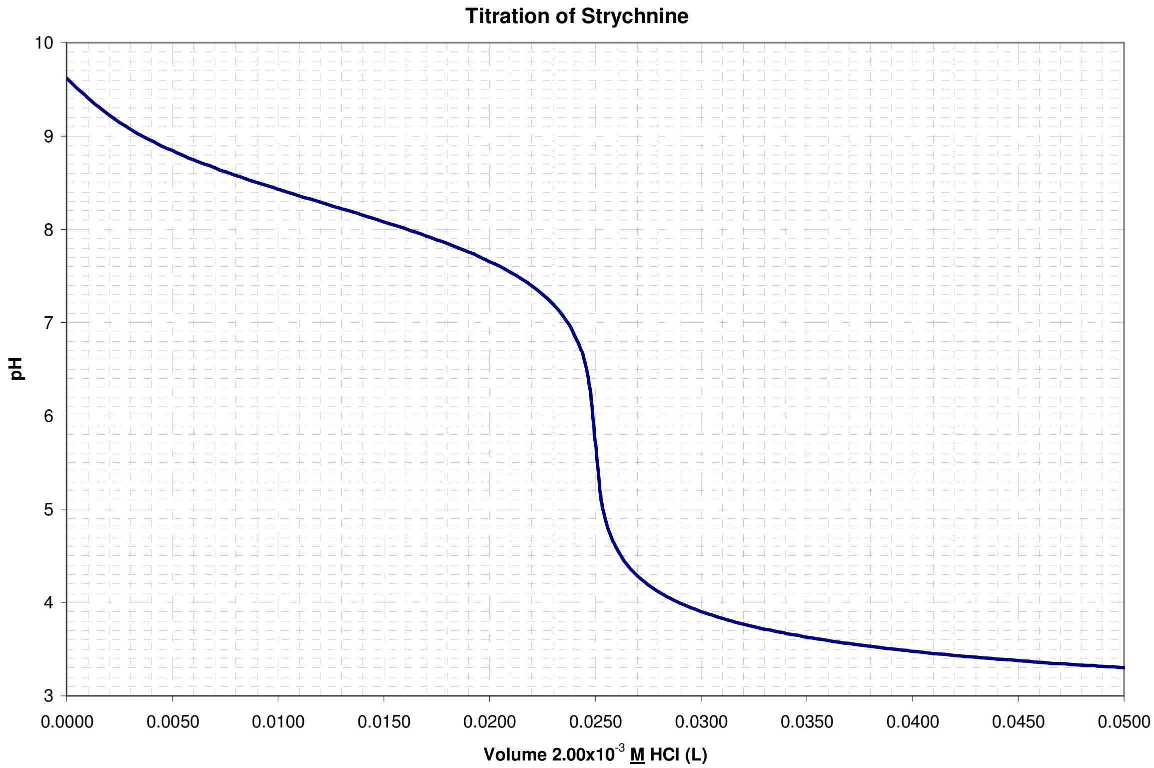
e) Sketch the titration curve for this titration. Label the following points: (1) pH depends only on formic acid, (2) pH depends only on the conjugate base formate, (3) pH depends only on excess base added, (4) the equivalence point, (5) pH = pK_a, (6) the buffer region.

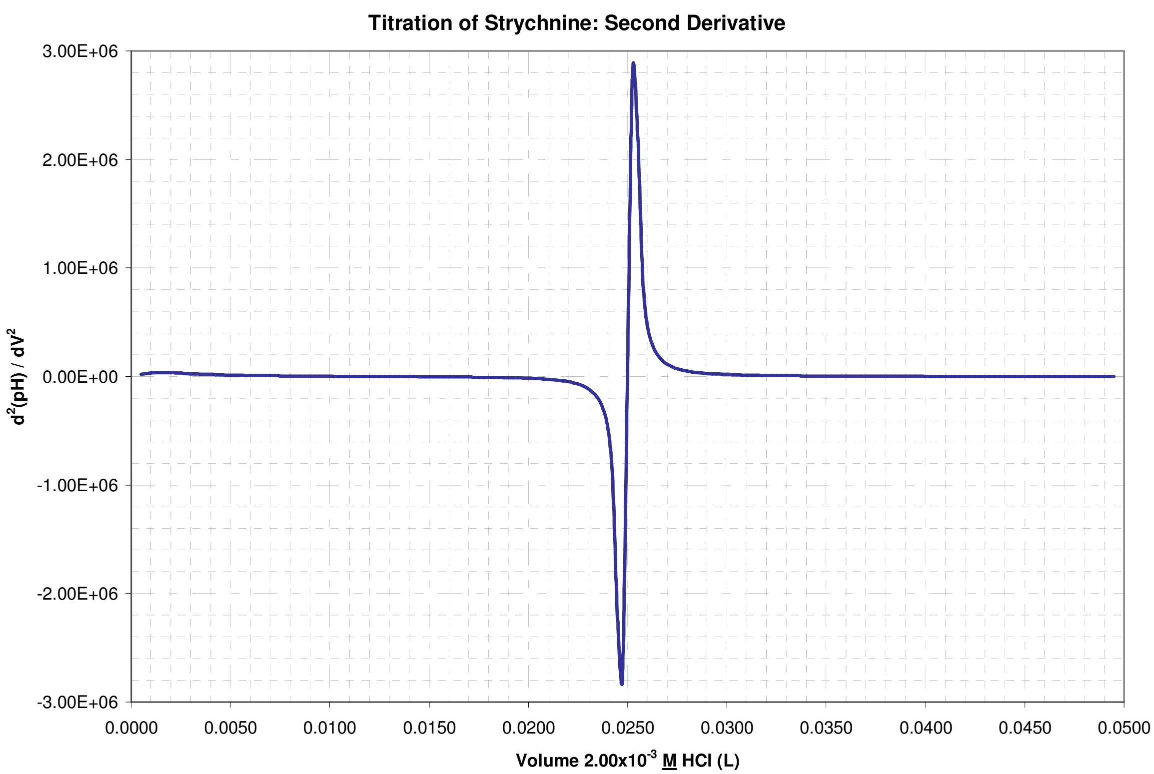
For the remaining questions, circle the letter of the answer that best satisfies the question.

6. A buffer of pH = 3.4 is desired. If the following reagents are available, which pair of reagents will make the buffer with the highest capacity?

(A) $HClO_3$ (pK_a = -2.70) and $NaClO_3$
(B) HOCN (pK_a = 3.46) and KCl
(C) K_2HPO_4 (pK_a = 11.90) and K_3PO_4
(D) NaH_2PO_4 (pK_a = 6.68) and Na_2HPO_4
(E) H_3PO_4 (pK_a = 2.15) and KH_2PO_4

Problems 7 through 9 concern the following plots:





7. Strychnine ($C_{21}H_{22}N_2O_2$) is a naturally occurring weak base that can accept one proton. A 50.00 mL aliquot of strychnine solution is titrated with standard 2.00×10^{-3} M HCl. Refer to the plots on the previous page. What is the concentration of the strychnine solution?

(A) 5.00×10^{-4} M
(B) 1.00×10^{-3} M
(C) 2.00×10^{-3} M
(D) 4.00×10^{-3} M
(E) The concentration cannot be determined by the information given.

8. Refer to the plots on the previous page. Given the information in problem 7, what is the value for the base dissociation constant K_b for strychnine?

(A) 5.72
(B) 8.26
(C) 1.82×10^{-6}
(D) 5.50×10^{-9}
(E) None of the above

9. Refer to the plots on the previous page. Which of the following indicators would be most appropriate to use for the titration of strychnine with HCl?

(A) Methyl orange ($pK_a = 3.3$)
(B) Chlorophenol red ($pK_a = 6.0$)
(C) Bromothymol blue ($pK_a = 7.1$)
(D) Cresol red ($pK_a = 8.2$)
(E) Phenolphthalein ($pK_a = 9.4$)

10. Solution A has a pH of 9.00 and solution B has a pH of 10.00. Which of the following statements are *true*?

I. Solution A has ten times as many OH^- ions as solution B.
II. Solution B has ten times as many OH^- ions as solution A.
III. Solution A has ten times as many H_3O^+ ions as solution B.
IV. Solution B has ten times as many H_3O^+ ions as solution A.
V. There are no H_3O^+ ions in either solution because they are both basic.

(A) **I** and **III**
(B) **I** and **IV**
(C) **II** and **III**
(D) **I**, **IV**, and **V**
(E) **II**, **III**, and **V**

For questions 11-13, refer to the following table of acid and base dissociation constants and circle the letter that best describes the acid/base properties of each of the following salts.

Substance	K_a	K_b
HF	6.31×10^{-4}	
$HC_2H_3O_2$	1.78×10^{-5}	
NH_3		1.78×10^{-5}

11. NH_4F

(A) produces an acidic solution when dissolved in water
(B) produces a basic solution when dissolved in water
(C) produces a neutral solution when dissolved in water

12. $NH_4C_2H_3O_2$

(A) produces an acidic solution when dissolved in water
(B) produces a basic solution when dissolved in water
(C) produces a neutral solution when dissolved in water

13. KF

(A) produces an acidic solution when dissolved in water
(B) produces a basic solution when dissolved in water
(C) produces a neutral solution when dissolved in water

14. Which of the following statements are *false*?

I. The strength of an acid is directly proportional to the affinity of its conjugate base for hydrogen ions.
II. A weak base has a strong conjugate acid.
III. A strong base has a weak conjugate acid.
IV. As acid strength increases, the conjugate base is less willing to accept hydrogen ions.
V. The dissociation equilibrium for a strong acid lies far to the left.

(A) **I** and **V**
(B) **III** and **IV**
(C) **I**, **II**, and **III**
(D) **II**, **III**, and **V**
(E) **I**, **II**, and **V**

15. Zirconium (IV) phosphate has a $K_{sp} = 1\times10^{-132}$. If the pH of a solution of zirconium phosphate is decreased. then:

(A) Nothing will happen because the salt is neither acidic nor basic.
(B) The K_{sp} for $Zr_3(PO_4)_4$ will increase because phosphate is a basic anion.
(C) The solubility equilibrium position will shift left.
(D) The molar solubility of $Zr_3(PO_4)_4$ will increase because phosphate is the conjugate base of a weak acid.
(E) Nothing will happen because this is a heterogeneous equilibrium and $Zr_3(PO_4)_4$ is a solid.

Equations and Constants

$$PV = nRT$$

$$\ln k = -\frac{E_a}{R}\frac{1}{T} + \ln A$$

$$\ln [A] = -kt + \ln [A]_0$$

$$\ln \frac{k_1}{k_2} = -\frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$$

$$\frac{1}{[A]} = kt + \frac{1}{[A]_0}$$

$$ax^2 + bx + c = 0$$

$$[A] = -kt + [A]_0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$K_p = K(RT)^{\Delta n}$$

$$K_w = 1.00\text{x}10^{-14} = [H^+][OH^-]$$

$$pH = -\log [H^+]$$

$$pH + pOH = 14.00$$

$$pOH = -\log [OH^-]$$

$$K_a \cdot K_b = K_w$$

$$pH = pK_a + \log \frac{[A^-]}{[HA]}$$

$R = 8.314 \text{ J / mol} \cdot \text{K} = 0.0821 \text{ L} \cdot \text{atm / mol} \cdot \text{K}$