CHM 106
Exam II

For problems 1-4, circle the letter of the answer that best satisfies the question.

1. Which of the following statements is true?

I. A weak base has a strong conjugate acid
II. The strength of an acid is inversely proportional to the affinity of the conjugate base for hydrogen ions
III. As base strength increases, the conjugate acid is more willing to donate hydrogen ions.
IV. The dissociation equilibrium for a strong acid lies to the right.

(A) **II** and **III**
(B) **I**, **II**, and **IV**
(C) **II** only
(D) **II** and **IV**
(E) all of the above

2. Lead (II) phosphate has a $K_{sp} = 8.0 \times 10^{-43}$. If the pH of a solution of lead (II) phosphate is increased, then:

(A) The K_{sp} for $Pb_3(PO_4)_2$ will increase because phosphate is a basic anion
(B) Nothing will happen to the solution because the salt is neither acidic nor basic
(C) The molar solubility for $Pb_3(PO_4)_2$ will decrease because phosphate is the conjugate base of a weak acid
(D) The solubility equilibrium will shift right because the concentration of $Pb^{2+}(aq)$ decreases
(E) The molar solubility of $Pb_3(PO_4)_2$ will increase because phosphate is a basic anion.

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

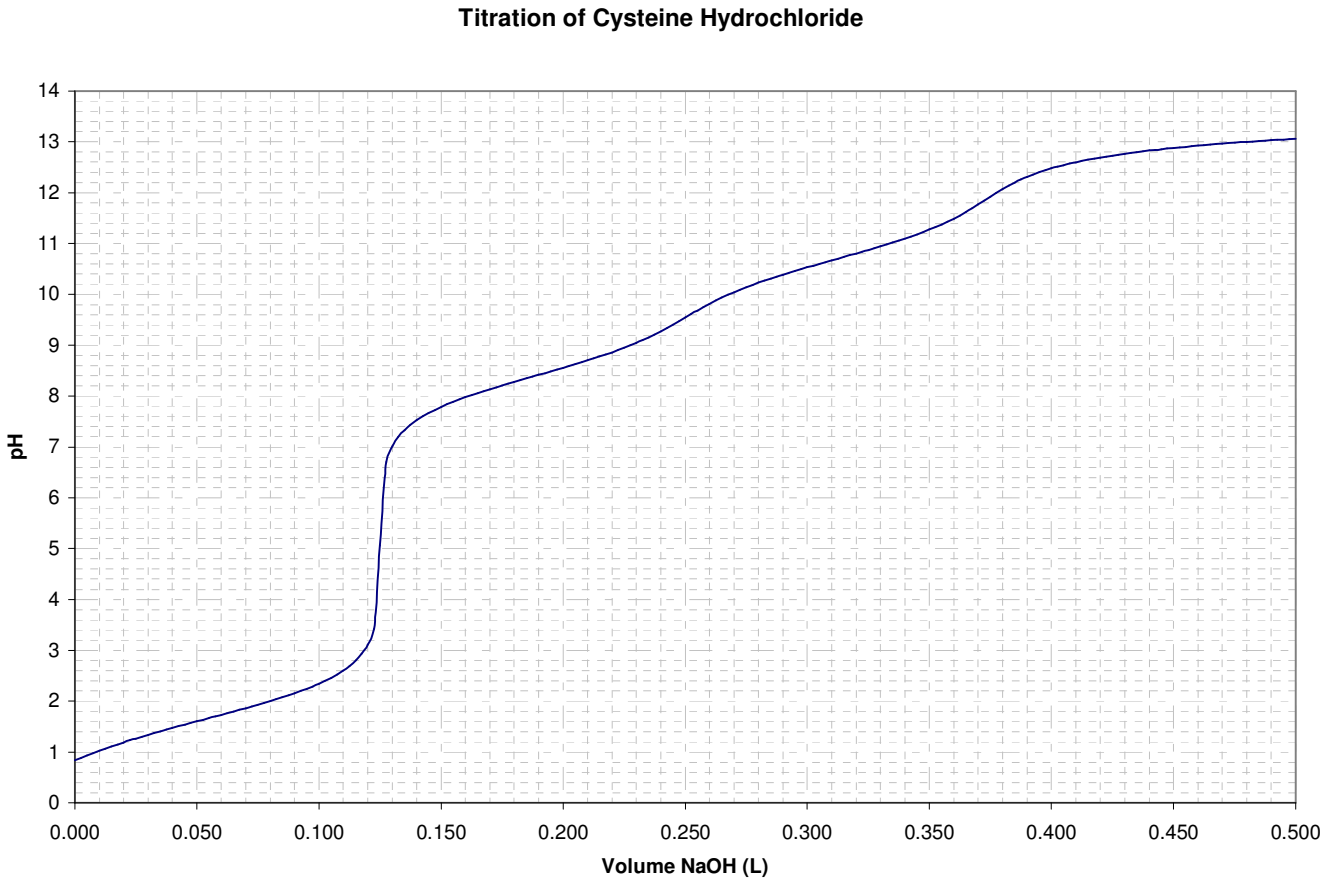
(A) HNO_3 ($pK_a = -1.37$) and KNO_3
(B) NaH_2PO_3 ($pK_a = 6.68$) and Na_2HPO_3
(C) HOCN ($pK_a = 3.46$) and KCl
(D) K_2HPO_4 ($pK_a = 11.90$) and K_3PO_4
(E) HF ($pK_a = 3.20$) and NaF

4. Which of the following statements is true?

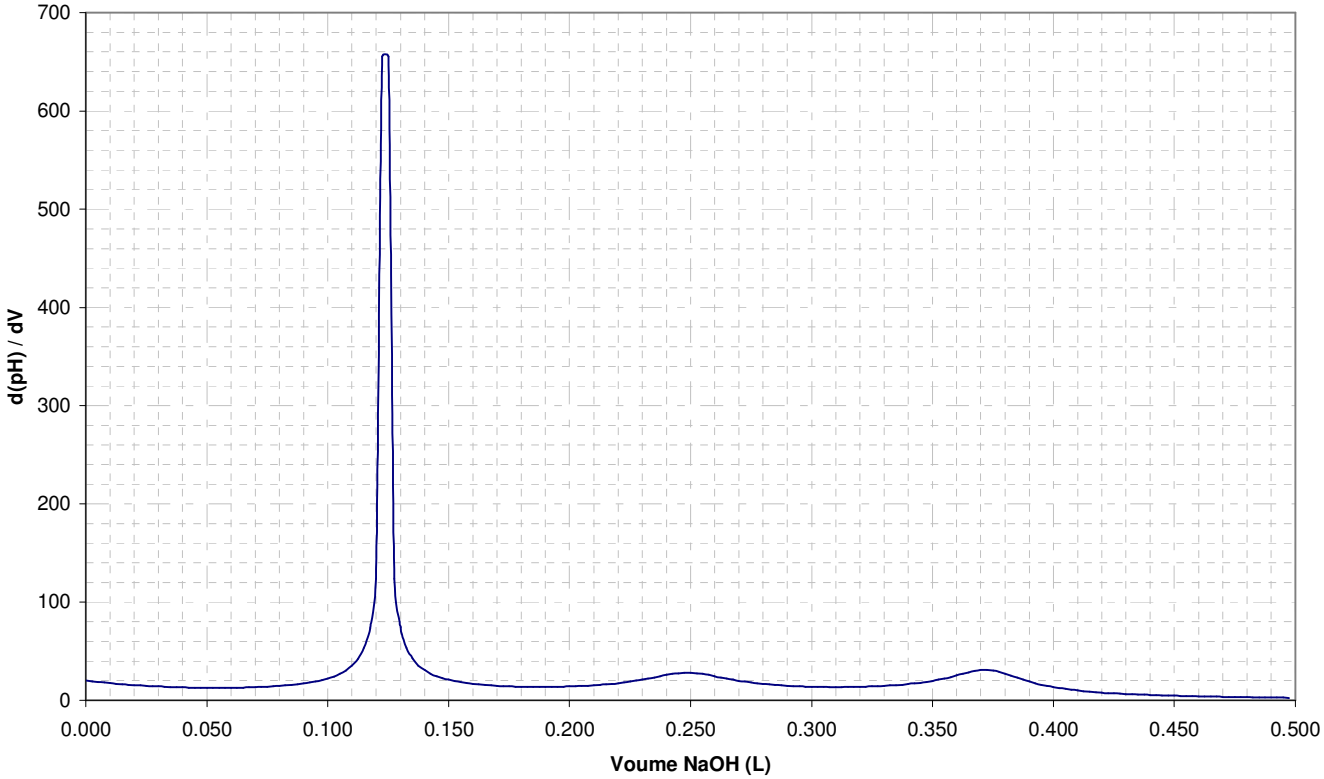
I. The pH of a solution of NH_4Cl is greater than 7 because NH_3 is a weak acid.
II. The concentration of hydroxide ions in acidic solution must be less than 10^{-7} M.
III. The salt of the conjugate acid of a weak base will produce a solution with pH less than 7.
IV The salt KNO_3 will produce a neutral solution because KOH is a strong base and HNO_3 is a strong acid.

(A) **II** and **IV**
(B) **I**, **II** and **III**
(C) **I**, **III**, and **IV**
(D) **II**, **III**, and **IV**
(E) all of the above

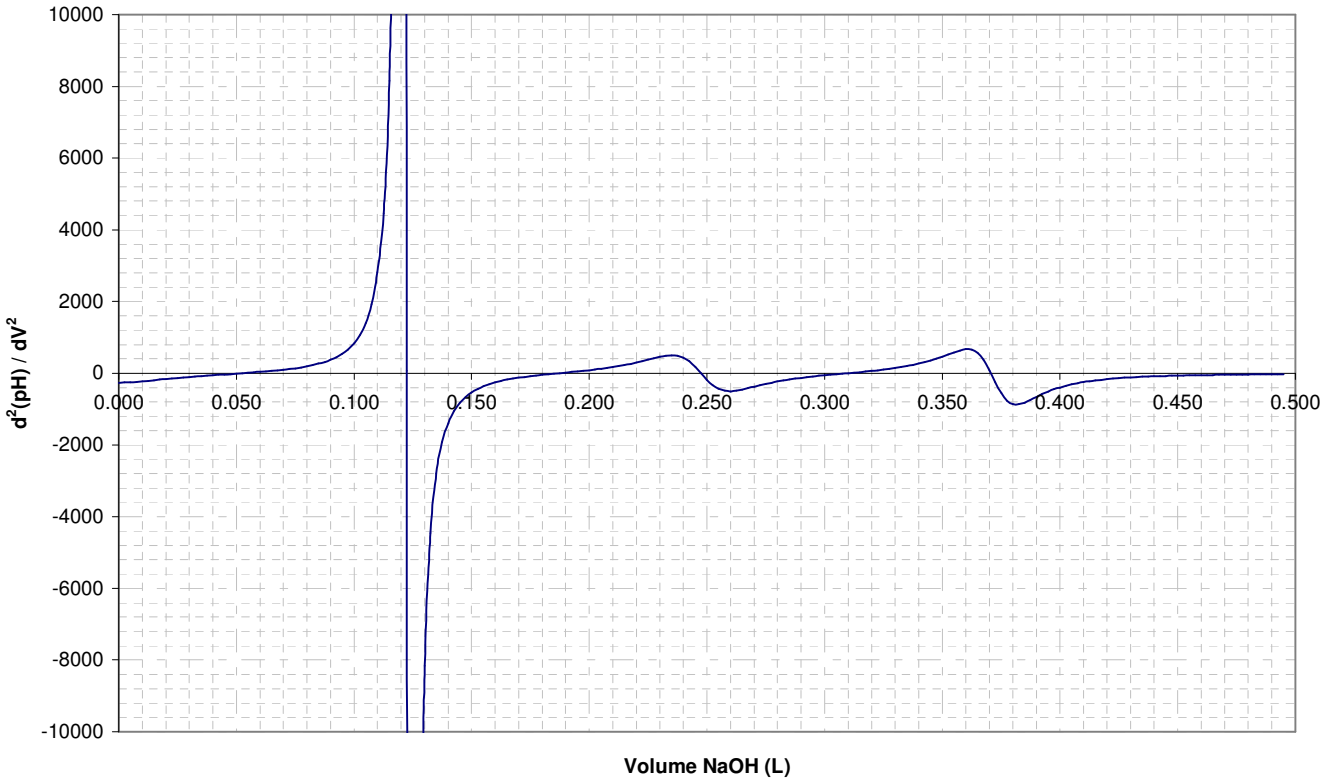
5. Cysteine hydrochloride is the acidic salt of cysteine, one of the twenty common amino acids that occur in proteins. A 50.00 mL sample of a solution of cysteine hydrochloride of unknown concentration was titrated with standard 0.500 M NaOH and the pH of the solution was recorded at regular intervals. Plots of pH versus volume NaOH along with the first and second derivative of the pH were constructed and are presented below:



Titration of Cysteine Hydrochloride
(first derivative of pH with respect to volume)



Titration of Cysteine Hydrochloride
(second derivative of pH with respect to volume)



a) What is the concentration of the cysteine hydrochloride solution? Estimate volumes from the plots to three decimal places.

b) What are the values for pKa_1, pKa_2, and pKa_3?

6. A solution of the weak diprotic acid malonic acid ($H_2C_3H_2O_4$) of volume 25.00 mL reacts completely with 37.43 mL of 0.1074 M potassium hydroxide.

a) Write a balanced chemical equation for this reaction. 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 malonic acid solution?

c) When this reaction is complete, will the solution be acidic, basic, or neutral? Explain.

7. Calcium hydroxide is slightly soluble in water with $K_{sp} = 5.5 \times 10^{-6}$.

a) Write an equilibrium expression for the dissolution of calcium hydroxide.

b) What is the molar solubility of calcium hydroxide?

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

d) Suppose 0.100 mol of $Ca(NO_3)_2(s)$ is added to 0.500 L of saturated calcium hydroxide. What is the molar solubility of calcium hydroxide in the new solution?

e) What is the pH of this new solution?

8. Ascorbic acid ($H_2C_6H_6O_6$) is a diprotic acid with $K_{a1} = 6.76 \times 10^{-5}$ and $K_{a2} = 2.69 \times 10^{-12}$.

a) Write equations showing the stepwise dissociation of ascorbic acid.

b) Write equilibrium expressions for these dissociations.

c) What is the pH of a solution of 0.050 M ascorbic acid?

d) What is the concentration of the ascorbate anion $[C_6H_6O_6^{2-}]$?

9. A 20.00 mL sample of a solution of 0.100 M benzoic acid is titrated with standard 0.100 M KOH. For benzoic acid, $K_a = 6.25 \times 10^{-5}$.

a) What is the pH of the solution before any potassium hydroxide is added?

b) What is the pH after 10.00 mL of KOH is added?

c) What is the pH at the equivalence point?

d) What is the pH after 40.00 mL of KOH is added?

e) Sketch a plot of pH versus volume of KOH added for this titration. Label the points calculated above.

f) If the indicators 2,4-dinitrophenol ($pK_a = 3.90$), bromothymol blue ($pK_a = 7.1$), and thymolphthalein ($pK_a = 10.0$) were available, which would you use for this titration? Explain.

10. Aziridine (C_2H_5N) has a $K_b = 1.10x10^{-6}$. Suppose you have a solution of 0.100 M aziridinium bromide (C_2H_5NHBr).

a) Write a balanced equation showing the dissociation of aziridinium bromide.

b) Write an equilibrium expression for this reaction.

c) Calculate the concentrations of $[H^+]$, $[OH^-]$, and $[Br^-]$.

d) What is the pH of this solution?

e) What is the percent dissociation of the aziridinium bromide?

11. Sulfuric acid has $pK_{a2} = 1.99$. Suppose you have a solution that has $[HSO_4^-] = 1.50$ M and $[SO_4^{2-}] = 5.00$ M.

a) What is the pH of this solution?

b) Suppose 0.25 g KOH(*s*) is added to 1.00 L of this solution. What is the new pH of the solution?

c) What chemical behavior does this solution exhibit?

Equations and Constants

$PV = nRT$

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

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

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

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

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

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

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

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

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

$ax^2 + bx + c = 0$

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

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

$pH + pOH = 14.00$

$K_a \cdot K_b = K_w$

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