Aqueous Equilibria: Part 1 - Buffers & Titrations

PSI AP Chemistry **Name--------------------------**

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Multiple Choice questions

Common-Ion Effect

1) The pH of a solution that contains 0.818 M acetic acid (K_a = 1.77x10^{-5}) and 0.172 M sodium acetate is __________.

A) 4.077 B) 5.434 C) 8.571 D) 8.370 E) 9.922

2) Calculate the pH of a solution prepared by dissolving 0.37 mol of formic acid (HCO_2H) and 0.23 mol of sodium formate ($NaCO_2H$) in water sufficient to yield 1.00 L of solution. The K_a of formic acid is 1.77x10^4.

A) 2.1 B) 10.46 C) 3.55 D) 2.31 E) 3.95

3) Calculate the pH of a solution prepared by dissolving 0.25 mol of benzoic acid ($C_7H_5O_2H$) and 0.15 of sodium benzoate ($NaC_7H_5O_2$) in water sufficient to yield 1.00 L of solution. The K_a of benzoic acid is 6.50x10^{-5}.

A) 4.41B) 2.40 C) 3.97 D) 10.08 E) 4.19

4) Calculate the pH of a solution prepared by dissolving 0.15 mol of benzoic acid (HBz) and 0.30 mol of sodium benzoate in water sufficient to yield 1.00L of solution. The K_a of benzoic acid is 6.50x10^{-5}.

A) 2.52 B) 3.89 C) 4.49 D) 10.16 E) 4.20

5) Calculate the pH of a solution prepared by dissolving 0.750 mol of NH_3 and 0.250 mol of NH_4Cl in water sufficient to yield 1.00 L of solution. The K_b of ammonia is 1.77x10^{-5}.

A) 5.22 B) 4.27 C) 9.73 D) 8.78 E) 0.89

6) The pH of a solution prepared by dissolving 0.350 mol of solid methylamine hydrochloride (CH_3NH_3Cl) in 1.00L of 1.10M methylamine (CH_3NH_2) is __________. The K_b for methylamine is 4.4 x 10^{-4}. (Assume the final volume is 1.00 L.)

A) 1.86 B) 2.66 C) 10.15 D) 11.14 E) 10.64

Buffers

7) What does a buffer do?

a) Keeps the pH of a solution constant
b) Keeps the salt concentration of a solution constant
c) Keeps the cation concentration constant
d) Keeps the anion concentration constant

8) What substances are present in a buffer?

a) A weak base or acid and its salt
b) A hydrolyzing salt only
c) A weak base or acid only
d) A salt only

9) The addition of hydrofluoric acid and __________ to water produces a buffer solution.

A) HCl B) $NaNO_3$ C) NaF D) NaCl E) NaBr

10) Which of the following could be added to a solution of sodium acetate to prepare a buffer?

acetic acid hydrochloric acid ammonium acetate sodium chloride

A) acetic acid only
B) hydrochloric acid only
C) acetic acid or hydrochloric acid
D) ammonium acetate only
E) sodium chloride or ammonium acetate

11) Which of the following could not be added to a solution of sodium acetate to prepare a buffer?

A) ammonium acetate
B) acetic acid
C) hydrochloric acid
D) nitric acid
E) more than one of these answers is correct

12) Which of the following could be added to a solution of potassium fluoride to prepare a buffer?

A) sodium hydroxide
B) potassium acetate
C) hydrochloric acid
D) sodium fluoride
E) ammonia

13) Which one of the following pairs <u>cannot</u> be mixed together to form a buffer solution?

A) NH_3, NH_4Cl
B) $NaC_2H_3O_2$, HCl ($C_2H_3O_2^-$ = acetate)
C) RbOH, HBr
D) KOH, HF
E) H_3PO_4, KH_2PO_4

14) Which one of the following pairs <u>cannot</u> be mixed together to form a buffer solution?

A) C_5H_5N, C_5H_5NHCl
B) $HC_2H_3O_2$, NaOH
C) KOH, HI
D) NH_2CH_3, HCl
E) NaClO, HNO_3

15) A solution containing which one of the following pairs of substances will be a buffer solution?

A) NaI, HI
B) KBr, HBr
C) RbCl, HCl
D) CsF, HF
E) none of the above

16) Which of the following would not make a good buffer system?

A) Sulfate ion and sulfuric acid
B) Bicarbonate ion and carbonic acid
C) Ammonia and ammonium ion
D) Acetate and acetic acid

17) Of the following solutions, which has the greatest buffering capacity?

A) 0.821 M HF and 0.217 M NaF
B) 0.821 M HF and 0.909 M NaF
C) 0.100 M HF and 0.217 M NaF
D) 0.121 M HF and 0.667 M NaF
E) They are all buffer solutions and would all have the same capacity.

18) Of the following solutions, which has the greatest buffering capacity?

A) 0.521 M $HC_2H_3O_2$ and 0.217 M $NaC_2H_3O_2$
B) 0.821 M $HC_2H_3O_2$ and 0.713 M $NaC_2H_3O_2$
C) 0.365M $HC_2H_3O_2$and 0.497 M $NaC_2H_3O_2$
D) 0.121 M $HC_2H_3O_2$and 0.116 M $NaC_2H_3O_2$

19) Of the following solutions, which has the greatest buffering capacity?

A) 0.543 M NH_3 and 0.555 M NH_4Cl
B) 0.087 M NH_3 and 0.088 M NH_4Cl
C) 0.234 M NH_3 and 0.100 M NH_4Cl
D) 0.100 M NH_3 and 0.455 M NH_4Cl
E) They are all buffer solutions and would all have the same capacity.

20) The K_a of acetic acid is1.76×10^{-5}. The pH of a buffer prepared by combining 50.0 mL of 1.00 M potassium acetate and 50.0 mL of 1.00 M acetic acid is __________.

A) 1.705 B) 0.851 C) 3.406 D) 4.754 E) 2.383

21) The K_b of ammonia is 1.77×10^{-5}. The pH of a buffer prepared by combining 50.0 mL of 1.00 M ammonia and 50.0 mL of 1.00 M ammonium nitrate is __________.

A) 4.63 B) 9.25 C) 4.74 D) 9.37 E) 7.00

22) Which of the following reactions shows what happens when nitric acid is added to an ammonium ion-ammonia buffer?

A) $H^+ + NH_3 \rightarrow NH_4$
B) $H + NH_4 \rightarrow NH_5$
C) $Cl + NH_3 \rightarrow NH_3Cl$
D) $Cl + NH_4 \rightarrow N_4Cl$

23) Which of the following reactions shows what happens when potassium hydroxide is added to an ammonium ion-ammonia buffer?

A) $OH^- + NH_3 \rightarrow NH_3OH$
B) $OH^- + NH_4^+ \rightarrow NH_3 + H_2O$
C) $K^+ + NH_3 \rightarrow KNH_3$
D) $K^+ + NH_4^+ \rightarrow NH_4K$

24) The reaction that takes place when a strong acid is added to an acetic acid- acetate buffer (CH_3COOH/ CH_3COO-) is _____________.

A) $CH_3COOH + H^+ \rightarrow CH_4 + CO_2$
B) $CH_3COOH + H^+ \rightarrow CH_3COO^- + H_2$
C) $CH_3COO^- + H^+ \rightarrow CH_3COOH$
D) $CH_3COOH + H^+ \rightarrow CH_3COO^- + H_2O$

25) What change will be caused by addition of a small amount of HCl to a solution containing fluoride ions and hydrogen fluoride?

A) The concentration of hydronium ions will increase significantly.
B) The concentration of fluoride ions will increase as will the concentration of hydronium ions.
C) The concentration of hydrogen fluoride will decrease and the concentration of fluoride ions will increase.
D) The concentration of fluoride ion will decrease and the concentration of hydrogen fluoride will increase.
E) The fluoride ions will precipitate out of solution as its acid salt.

26) Consider a buffer solution containing 0.100 M fluoride ions and 0.126 M hydrogen fluoride. The pH of this solution is __________ The Ka of HF is 3.5×10^{-4}

A) 1.156 B) 2.256 C) 3.356 D) 8.856 E) 11.562

27) Consider a solution containing 0.100 M fluoride ions and 0.126 M hydrogen fluoride. The concentration of <u>fluoride ions</u> after the addition of 5.00 mL of 0.0100 M HCl to 25.0 mL of this solution is __________ M.

A) 0.0850 B) 0.00167 C) 0.0980 D) 0.0817 E) 0.00253

28) Consider a solution containing 0.100 M fluoride ions and 0.126 M hydrogen fluoride. The concentration of <u>hydrogen fluoride</u> after addition of 5.00 mL of 0.0100 M HCl to 25.0 mL of this solution is __________ M.

A) 0.107 B) 0.100 C) 0.126 D) 0.00976 E) 0.00193

29) Consider a solution containing 0.100 M fluoride ions and 0.126 M hydrogen fluoride. The pH after addition of 5.00 mL of 0.0100 M HCl to 25.0 mL of this solution is __________ M.

A) 2.93 B) 3.13 C) 3.33 D) 4.33 E) 9.33

30) The Henderson-Hasselbalch equation is __________.

A) $[H^+] = K_a + \frac{[\text{base}]}{[\text{acid}]}$ B) $pH = pK_a - \log\frac{[\text{base}]}{[\text{acid}]}$

C) $pH = pK_a + \log\frac{[\text{base}]}{[\text{acid}]}$ D) $pH = pK_a + \log\frac{[\text{acid}]}{[\text{base}]}$

E) $pH = \log\frac{[\text{acid}]}{[\text{base}]}$

31) In a solution, when the concentrations of a weak acid and its conjugate base are equal,

A) the system is not at equilibrium.
B) the buffering capacity is significantly decreased.
C) the -log of the $[H^+]$ and the -log of the K_a are equal.
D) all of the above are true.

Neutralization

32) Write a complete and balanced equation for the following acid-base reaction:

$H_2SO_4 + Al(OH)_3 \rightarrow$

33) Write a complete balanced equation for the following acid-base reaction:

$HCl + Mg(OH)_2 \rightarrow$

34) Write a complete and balanced equation for the following acid-base reaction:

$H_3PO_4 + Ca(OH)_2 \rightarrow$

35) Write a complete and balanced equation for the following acid-base reaction:

$HNO_3 + NH_4OH \rightarrow$

36) How many moles of sodium hydroxide are needed to neutralize 3.0 moles of phosphoric acid?

A) 1 mol B) 3 mol C) 6 mol D) 9 mol E) 12 mol

37) How many moles of magnesium hydroxide are needed to neutralize 2.0 moles of phosphoric acid?

A) 2 mol B) 3 mol C) 4 mol D) 5 mol E) 6 mol

Titration

38) What is the purpose of a titration?
- A) To determine the color of the indicator
- B) To determine the concentration of acid or base
- C) To determine the concentration of acid only
- D) To determine the volume of base

39) What is the primary measurement instrument that is used when performing titrations?
- A) graduate cylinder
- B) buret
- C) volumetric pipet
- D) syringe
- E) Erlenmeyer flasK

40) A 25.0 mL sample of 0.723 M $HClO_4$ is titrated with a 0.273 M KOH solution. What is the $[H^+]$ (molarity) before any base is added?

A) 0.439 B) 1.00×10^{-7} C) 0.723 D) 2.81×10^{-13} E) 0.273

41) A 25.0 mL sample of 0.723 M formic acid is titrated with a 0.273 M KOH solution. The K_a of formic acid is 1.77×10^{-4}. What is the pH of the acid before any base is added?

A) 0.14 B) 1.95 C) 3.89 D) 7.00 E) 8.19

42) A 25.0 mL sample of 0.22 M hydrazoic acid (HN_3 ; K_a = 2.6 x 10-5) is titrated with a 0.30 M KOH solution. What is the pH of the solution before any base is added?

A) 2.62 B) 5.42 C) 7.00 D) 8.97 E) 11.22

43) The pH of a solution prepared by mixing 50.0 mL of 0.125 M KOH and 50.0 mL of 0.125 M HCl is __________.

A) 6.29 B) 7.00 C) 8.11 D) 5.78 E) 0.00

44) What is the pH of a solution resulting from 65 mL of 0.15 M $HClO_3$ titrated with 45 mL of 0.18 M NaOH?

A) 0.65 B) 1.45 C) 1.82 D) 7.95 E) 8.21

45) A 25.0 mL sample of 0.22 M hydrazoic acid (HN_3 ; K_a = 2.6 x 10-5) is titrated with a 0.30 M KOH solution. What is the pH of the solution after 16.0 mL of base is added?

A) 2.62 B) 5.42 C) 7.00 D) 8.97 E) 11.22

46) A 25.0 mL sample of 0.800 M $HClO_4$ is titrated with a 0.300 M KOH solution. The H_3O^+ concentration after the addition of 10.0 mL of KOH is __________ M.

A) 0.486 B) 1.00×10^{-7} C) 0.723 D) 2.81×10^{-13} E) 0.273

47) A 30.0 mL sample of 0.50 M $HClO_4$ is titrated with a 0.25 M KOH solution. The H_3O^+ concentration after the addition of 5.0 mL of KOH is __________ M.

A) 0.00125 B) 0.0138 C) 0.0150 D) 0.393 E) 0.439

48) A 30.0 mL sample of 0.72 M $HClO_4$ is titrated with a 0.27 M KOH solution. What is the H_3O^+ concentration after the addition of 80.0 mL of KOH?

A) 1.00×10^{-7} B) 0.0216 C) 0.196 D) 0.27 E) 0.72

49) What volume (mL) of 0.5M HNO_3 is necessary to titrate 25 mL of 0.05M KOH solution to the endpoint?

A) 2.5 B) 5.0 C) 10 D) 25 E) 50

50) What volume (mL) of 0.5M HNO_3 is necessary to titrate 25 mL of 0.05M $Ca(OH)_2$ solution to the endpoint?

A) 2.5 B) 5.0 C) 10 D) 25 E) 50

51) How much 1.5 M NaOH is necessary to exactly neutralize 20.0 mL of 2.5 M H_3PO_4?

A) 20 B) 33 C) 40 D) 60 E) 100

52) A 25.0 mL sample of an HCl solution is titrated with a 0.15 M NaOH solution. The equivalence point is reached with 75.0 mL of base. The concentration of HCl is _________ M.

A) 11.7 B) 0.00214 C) 0.450 D) 0.267 E) 0.139

53) A 50.0 mL sample of an aqueous H_2SO_4 solution is titrated with a 0.100 M NaOH solution. The equivalence point is reached with 100 mL of NaOH solution. The concentration of H_2SO_4 is __________ M.

A) 0.050 B) 0.100 C) 0.150 D) 0.200 E) 0.400

54) How many mL of 0.15 M NaOH are required to reach the equivalence point if it is titrated into a 35.0-mL sample of 0.20 M acetic acid?

A) 8.5×10^{-4} B) 26 C) 40 D) 47 E) 58

55) A 25.0 mL sample of an acetic acid solution is titrated with a 0.18 M NaOH solution. The equivalence point is reached when 37.0 mL of the base is added. The concentration of acetic acid in the sample was __________ M.

A) 0.119 B) 1.83×10^{-4} C) 0.266 D) 0.365 E) 0.175

56) What is the pH of the resulting solution in the previous problem? Ka acetic acid = 1.8×10^{-5}

A) 2.57 B) 5.72 C) 8.80 D) 10.65 E) 12.91

57) A 30.0 mL sample of 0.44M hydrazoic acid, (HN_3 ; K_a = 2.6 x 10-5) is titrated with a 0.22M KOH solution. What is the pH of the solution after 60.0 mL of base is added?

A) 2.82 B) 4.32 C) 7.00 D) 8.87 E) 12.3

58) A 25.0 mL sample of 0.72 M $HClO_4$ is titrated with a 0.27 M KOH solution. The H_3O^+ concentration after the addition of 80.0 mL of KOH is __________ M.

A) 0.40 B) 1.00×10^{-7} C) 0.70 D) 3.00×10^{-13} E) 4.00×10^{-2}

59) A 25.0 mL sample of 0.50 M HCl is titrated with a 0.25 M NaOH solution. The pH after the addition of 80.0 mL of NaOH is ___________ M.

A) 1.146 B) 1.903 C) 2.215 D) 10.679 E) 12.854

60) A 25.0 mL sample of 0.22 M hydrazoic acid, (HN_3 ; K_a = 2.6 x 10-5) is titrated with a 0.18 M KOH solution. What is the pH of the solution after 35.0 mL of base is added?

A) 2.61 B) 6.95 C) 8.79 D) 11.62 E) 12.27

Indicator	Ka
bromthymol blue	1×10^{-7}
indigo carmine	1×10^{-12}
m-cresol purple	1×10^{-8}
methyl orange	1×10^{-4}

61) Which of the indicators listed above would be appropriate for the titration of HF with NaOH?

A) bromthymol blue B) indigo carmine C) m-cresol purple D) methyl orange

62) Which of the indicators listed above would be appropriate for the titration of HCl with NH_3?

A) bromthymol blue B) indigo carmine C) m-cresol purple D) methyl orange

IV Conceptual questions

1) A certain buffer solution contains equal concentration of X- and HX. The Ka of HX is 10^{-8} . The pH of the buffer is

A) 6

B) 8

C) 11

D) 14

E) 9

2) In the titration of weak acid against strong base, at the half equivalence point,

A) pH = 1/2pKa

B) pH = pKa

C) pH = 2pKa

D) neutral

E) none of the above

3) The pH indicators are

A) salts of strong acids and bases

B)salts of weak acids and weak bases

C) either weak acid or weak bases

D) either strong acids or strong bases

E) none of the above

4) The pH of a solution obtained by mixing 50 ml of 0.4 M HCl and 50 ml of 0.2M NaOH is
A) –log 2
B) –log 0.2
C) –log4
D) 1.0
E) 2.0

5) In a mixture of weak acid and its salt, the ratio of the concentration of acid to salt is increased ten fold. The pH of the solution
A) decreases by one
B) decreases by one tenth
C) increases by one
D) increases ten fold
E) decreases by 10

6) Which one of the following is true for any diprotic acid, H_2X?
A) $Ka_2 > Ka1$
B) $Ka1 > Ka2$
C) $Ka2 = 1/Ka1$
D) $Ka2 = Ka1$
E) $Ka1 = 1/Ka1$

7) Which of the following statements about pH and H^+ ion concentration is incorrect?
A) a solution of the mixture of one equivalent each of CH_3COOH and NaOH has a pH of 7
B) A cold and concentrated H_2SO_4 has lower H^+ ion concentration than a dilute solution of H_2SO_4
C) pH of the pure neutral water is not zero
D) addition of one drop of concentrated HCl in NH_4OH solution decreases pH of the solution
E) addition of one drop of con KOH to a solution of CH_3COOH will increase the pH of the solution.

8) Which of the following has lowest pH value?
A) M HCl
B) 1M NaOH
C) 1M H_2SO_4
D) 1M C_2H_5OH
E) 1M Ca $(OH)_2$

9) pH of water is 7. When a substance Y is dissolved in water, the pH becomes 13. The substance Y is a salt of
A) weak acid and weak base
B) strong acid and strong base
C) strong acid and weak base
D) weak acid and strong base
E) weak base

10) Which solutions are mixed to form a buffer solution?
A) strong acid and its salt
B) strong base and its salt
C) weak acid and its salt
D) weak acid with weak base
E) none of the above

11) The pH of an aqueous solution of CH_3COONa will be
A) 7
B) 3
C) 9
D) 14
E) 1

12) Which of the following is not a buffer?
A) H_2CO_3/HCO_3^-
B) CH_3COOH/CH_3COONa
C) NH_4OH/NH_4Cl
D) NH_4OH /CH_3COOH
E) NH_3/NH_4Br

13) The pH of blood is maintained by a buffering system which is
A) H_2CO_3/HCO_3^-
B) NaCl/HCl
C) NH_4OH/NH_4Cl
D) sodium citrate/citric acid
E) KCl/HCl

14) For a buffer solution with equal amounts of the salt and the acid with Ka = 10^{-8}, the pH is
A) 0

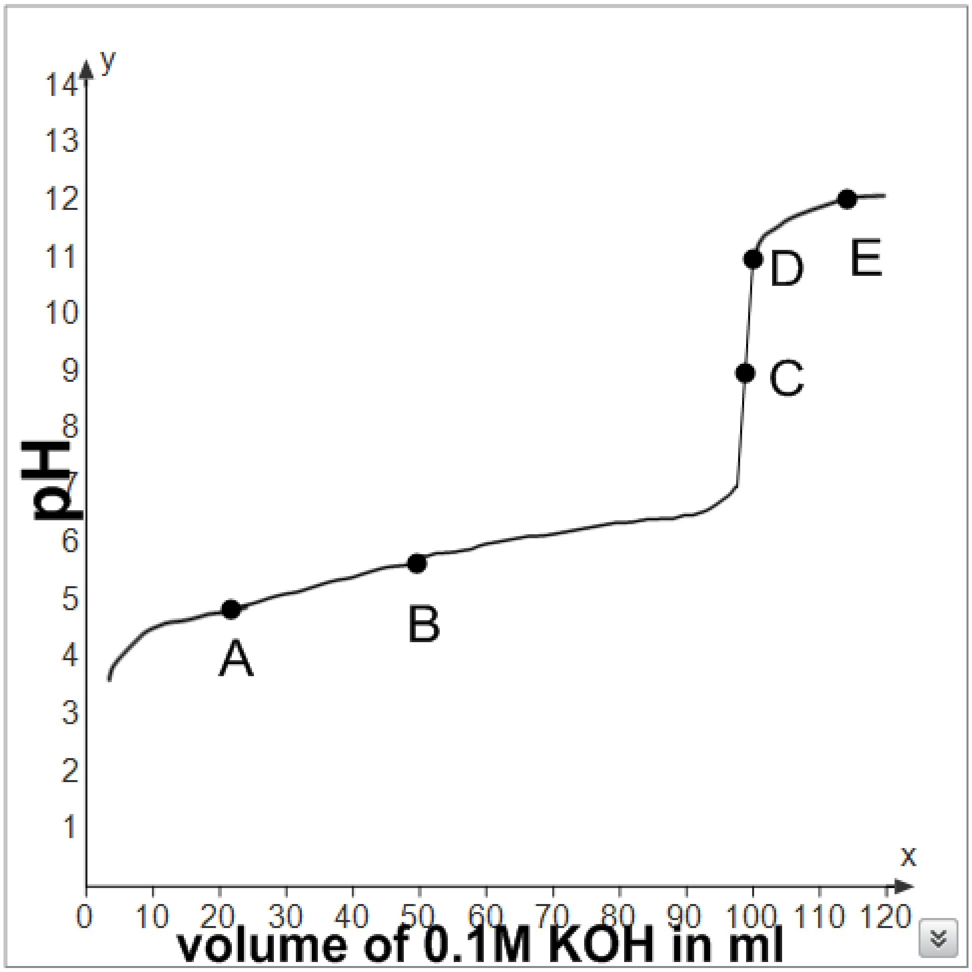
B) 13
C) 6
D) 8
E) 8-log6

15) The Pka of HCN is 9.30. The pH of a solution prepared by mixing 2.5 moles of KCN and 2.5 moles of HCN in water and making upto total volume to 500ml is
A) 9.30
B) 7.30
C) 10.30
D) 8.30
E) 4.70

16) The pH 0f a 0.1 M solution of the following salts increases in the order
A) NaCl < NH_4Cl < NaCN < HCl
B) HCl < NH_4Cl < NaCl < NaCN
C) NaCN < NH_4Cl < NaCl < HCl
D) HCl < NaCl < NaCN < NH_4Cl
E) NH_4Cl < NaCl < NaCN < HCl

17) which of the following solutions has a pH greater than 7.0?
A) 0.10M KBr
B) 0.10M NH_4Cl
C) 0.10M $HC_2H_3O_2$
D) 0.01M NaF
E) 0.01M HI

A solution of a weak monoprotic acid is titrated with a solution of a strong base, KOH. Consider the points labeled A through E on the titration curve that results, as shown below. The questions (24-26) below are based on the graph below.

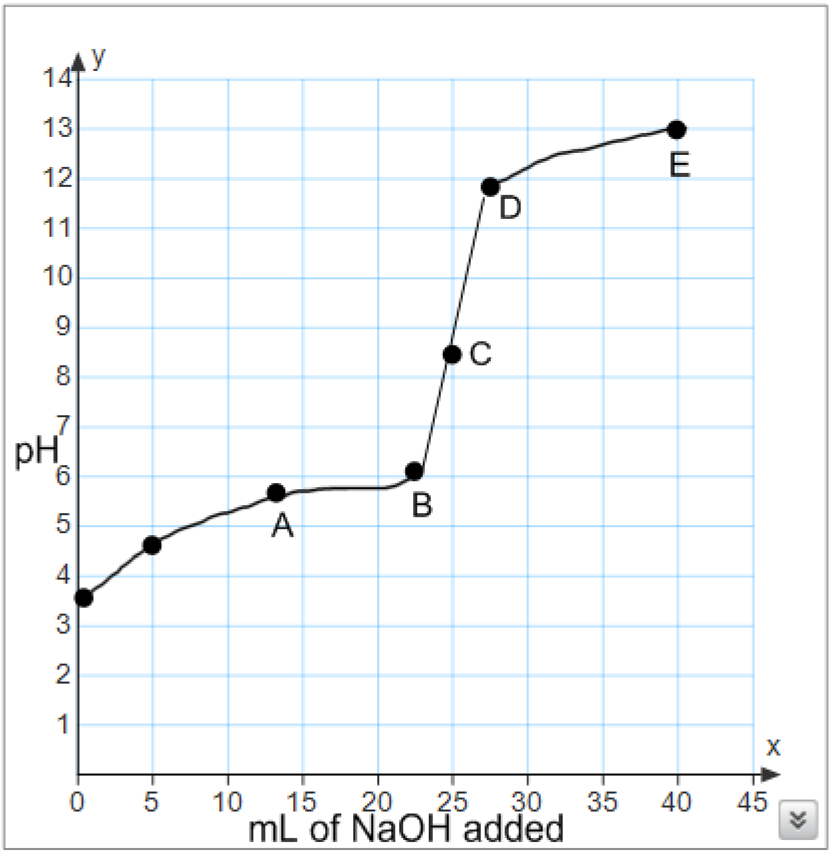


18) The point at which the moles of the added strong base are equal to the moles of the weak acid initially present

19) The point at which the pH is closest to that of the strong base being added

20) The point at which the concentrations of the weak acid and its conjugate base are approximately equal

The graph below shows the titration curve that results when 100 ml of 0.25M acetic acid is titrated with 0.10M NaOH. Answer questions 27-29 is based on the curve below.



21) Which of the following indicators is the best choice for this titration?

Indicator	pH range of colors
A) methyl orange	3.2-4.4
B) Methyl red	4.8-6.0
C) Bromothymol blue	6.1-7.6
D) Phenolphthalein	8.2-10.0
E) Alizarin	11.2-12.4

22) What part of the curve corresponds to the optimum buffer action of the acetic acid /acetate ion pair?

A) point D
B) point A
C) Point E
D) all along the section BD

E) all along the section DE

23) What is the volume of the base used at the end point?
A) 14mL
B) 22mL
C) 25mL
D) 27mL
E) 40mL

24) Mixtures that would be considered buffers include which of the following?
I 0.10M HCl + 0.10M NaCl
II 0.10M HF + 0.01M NaF
III 0.01M HBr + 0.01M NaBr

A) I only
B) II only
C) III only
D) I and II
E) II and III

25) Ascorbic acid, $H_2C_6H_5O_6$ is a diprotic acid with K1=7.9 x10^{-5} and K2= 1.6 x10^{-12}. In a 0.005M aqueous solution of ascorbic acid, which of the following is present in lowest concentrations?
A) $H_2O(l)$
B) H_3O+
C) $H_2C_6H_5O_6$
D) $HC_6H_5O_6^-$
E) $C_6H_5O_6^{2-}$

The following questions 26-29 are based on the given solutions below.
A) NaCl B) NaCN C) NH_4NO_3 D) $Ba(OH)_2$

26) A basic solution
27) A neutral solution
28) An acidic solution
29) A strong basic solution

Answers:

1) A	27) D	48) A
2) C	28) A	49) A
3) C	29) C	50) B
4) C	30) C	51) E
5) C	31) C	52) C
6) D	32. $3H_2SO_4 + 2Al(OH)_3 \rightarrow 2Al_2(SO_4)_3 + 6H_2O$	53) B
7) A	33. $2HCl + Mg(OH)_2 \rightarrow MgCl_2 + 2H_2O$	54) D
8) A	34. $2H_3PO_4 + 3Ca(OH)_2 \rightarrow Ca_3(PO_4)_2 + 6H_2O$	55) C
9) C	35. $HNO_3 + NH_4OH \rightarrow NH_4NO_3 + H_2O$	56) C
10) C	36) D	57) D
11) A	37) B	58) D
12) C	38) B	59) E
13) C	39) B	60) E
14) C	40) C	61) C
15) D	41) B	62) D
16) A	42) A	
17) B	43) B	
18) B	44) C	
19) A	45) B	
20) D	46) A	
21) B	47) D	
22) A		
23) B		
24) C		
25) D		
26) C		

Conceptual Questions Answers:

1B	8C	15A	22B	29D
2B	9D	16B	23C	
3C	10C	17D	24B	
4D	11C	18C	25E	
5A	12A	19E	26B	
6B	13D	20B	27A	
7A	14D	21D	28C	

Buffers and Titration Free response HW
PSI AP Chemistry Name------------------------------

Write the completed balanced equation for the following reactions:

1) $H_2SO_4 + Al(OH)_3 \rightarrow$

1) $HCl + Mg(OH)_2 \rightarrow$

2) $H_3PO_4 + Ca(OH)_2 \rightarrow$

3) $HNO_3 + NH_4OH \rightarrow$

4) Calculate the concentration of hydrochloric acid if 30 ml of this acid is neutralized by 40 ml of 0.010M sodium hydroxide.

5) Calculate the concentration of sulfuric acid if 60.0 ml of this acid is neutralized by 10.0 ml of 0.010M sodium hydroxide.

6) What volume of 0.3M H_2SO_4 is required to titrate 90 ml of 0.4M NaOH to the end point?

7) How many ml of water needs to be added to make 500ml of 3M HCl from a stock solution of 250mL of the acid which is 6M ?

8) Predict the following salt solutions will be acidic, basic or neutral. Also fill in the rest of the table regarding the parent acid and base from which they were formed.

Salt	Parent acid	Parent base	Type of solution (Basic or acidic)
KCl			
NH_4NO_3			
Na_3PO_4			
NH_4 F			
CuI_2			
$SrSO_4$			
$Li(CH_3COO)$			
$Ba_3(PO_4)_2$			

Ka of HF = 3.5×10^{-4}, Kb of NH_3 = 1.8×10^{-5}

Free response

1) The overall dissociation of oxalic acid, $H_2C_2O_4$, is represented below. The overall dissociation constant is also indicated.

$$H_2C_2O_4 \leftrightarrow 2\ H^+ + H_2C_2O_4^{2-} \qquad K = 3.78 \times 10^{-6}$$

(a) What volume of 0.400-molar NaOH is required to neutralize completely a 5.00 x 10^{-3} mole sample of pure oxalic acid?

(b) Give the equations representing the first and second dissociations of oxalic acid. Calculate the value of the first dissociation constant, K_1, for oxalic acid if the value of the second dissociation constant, K_2, is 6.40 x 10^{-5}.

(c) To a 0.015-molar solution of oxalic acid, a strong acid is added until the pH is 0.5. Calculate the [$C_2O_4^{2-}$] in the resulting solution. (Assume the change in volume is negligible.)

(d) Calculate the value of the equilibrium constant, K_b, for the reaction that occurs when solid $Na_2C_2O_4$ is dissolved in water.

2) A buffer solution contains 0.40 mole of formic acid, HCOOH, and 0.60 mole of sodium formate, HCOONa, in 1.00 liter of solution. The ionization constant, K_a, of formic acid is 1.8×10^{-4}.

(a) Calculate the pH of this solution.

(b) If 100 milliliters of this buffer solution is diluted to a volume of 1.00 liter with pure water, the pH does not change. Discuss why the pH remains constant on dilution.

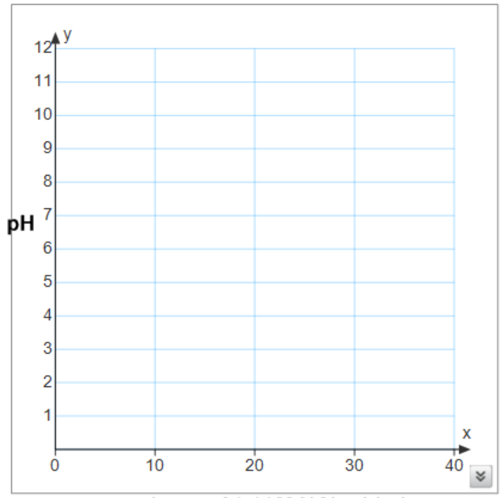
(c) A 5.00 milliliter sample of 1.00 molar HCl is added to 100 milliliters of the original buffer solution. Calculate the [H_3O^+] of the resulting solution.

(d) A 800 milliliter sample of 2.00-molar formic acid is mixed with 200 milliliters of 4.80-molar NaOH. Calculate the [H_3O^+] of the resulting solution.

3) A volume of 30.0 ml of 0.10M NH_3 is titrated with 0.20M HCl. The value of the base dissociation constant, K_b for NH_3 in water is 1.8×10^{-5}.

(a) Write the net ionic equation for the reaction of NH_3 with HCl

(b) Using the axes provided below, sketch the titration curve that results when a total of 40ml of 0.20M HCl is added drop wise to the 30ml volume of 0.10M NH_3



volume of 0.20M HCl added

(c) From the table below, select the most appropriate indicator for the titration. Justify your answer.

Methyl red	5.5
Bromothymol blue	7.1
Phenolphalein	8.7

(d) If equal volumes of 0.10 M NH_3 and 0.10M NH_4Cl are mixed, is the resulting solution acidic basic or neutral? Explain.

4) $HOCl \leftrightarrow OCl^- + H^+$

Hypochlorous acid , HOCl is a weak acid commonly used as a bleaching agent. The acid dissociation constant $K_a = 3.2 \times 10^{-8}$

a) Calculate the $[H^+]$ of a 0.14 M solution of HCl.

b) Write the correctly balanced net ionic equation for the reaction that occurs when NaOCl is dissolved in water and calculate the numerical value of the equilibrium constant for the reaction.

c) Calculate the pH of a solution made by combining 40ml of 0.14M HOCl and 10.0 ml of 0.56M NaOH

d) How many millimoles of solid NaOH must be added to 50ml of 0.20M HOCl to obtain a buffer that has a pH of 7.49? Assume that the addition of the solid NaOH results in a negligible change in volume.

e) House hold bleach is made by dissolving chlorine gas in water.

$$Cl_2\,(g) + H_2O \rightarrow Cl^- + HOCl\,(aq)$$

Calculate the pH of such a solution if the concentration of HOCl in the solution is 0.065M.

5) Answer the following questions that relate to the chemistry of halogen oxoacids.

(a) Use the information in the table below to answer part (a)(i).

Acid	*Ka* at 298 K
HOCl	2.9×10^{-8}
HOBr	2.4×10^{-9}

i. Which of the two acids is stronger, HOCl or HOBr ? Justify your answer in terms of K_a.
ii. Draw a complete Lewis electron-dot diagram for the acid that you identified in part (a)(i).
iii. Hypoiodous acid has the formula HOI. Predict whether HOI is a stronger acid or a weaker acid than the acid that you identified in part (a)(i). Justify your prediction in terms of chemical bonding.

(b) Write the equation for the reaction that occurs between hypochlorous acid and water.

(c) A 1.2 *M* NaOCl solution is prepared by dissolving solid NaOCl in distilled water at 298 K. The hydrolysis reaction $OCl^-(aq) + H_2O(l) \leftrightarrow HOCl(aq) + OH^-(aq)$ occurs.

i. Write the equilibrium-constant expression for the hydrolysis reaction that occurs between $OCl^-(aq)$ and $H_2O(l)$.
ii. Calculate the value of the equilibrium constant at 298 K for the hydrolysis reaction.
iii. Calculate the value of [OH-] in the 1.2 *M* NaOCl solution at 298 K.

(d) A buffer solution is prepared by dissolving some solid NaOCl in a solution of HOCl at 298 K. The pH of the buffer solution is determined to be 6.48.

i. Calculate the value of $[H_3O+]$ in the buffer solution.
ii. Indicate which of $HOCl(aq)$ or $OCl^-(aq)$ is present at the higher concentration in the buffer solution. Support your answer with a calculation.

6) A pure 14.85 g sample of the weak base ethylamine, $C_2H_5NH_2$, is dissolved in enough distilled water to make 500. mL of solution.

(a) Calculate the molar concentration of the $C_2H_5NH_2$ in the solution.

The aqueous ethylamine reacts with water according to the equation below.

$C_2H_5NH_2(aq) + H_2O(l) \leftrightarrow C_2H_5NH_3+(aq) + OH^-(aq)$

(b) Write the equilibrium-constant expression for the reaction between $C_2H_5NH_2$ (*aq*) and water.

(c) Of $C_2H_5NH_2$ (*aq*) and $C_2H_5NH_3^+(aq)$, which is present in the solution at the higher concentration at equilibrium? Justify your answer.

(d) A different solution is made by mixing 500. mL of 0.500 *M* $C_2H_5NH_2$ with 500. mL of 0.200 *M* HCl. Assume that volumes are additive. The pH of the resulting solution is found to be 10.93.

i. Calculate the concentration of $OH^-(aq)$ in the solution.
ii. Write the net-ionic equation that represents the reaction that occurs when the $C_2H_5NH_2$ solution is mixed with the HCl solution.
iii. Calculate the molar concentration of the $C_2H_5NH_3^+(aq)$ that is formed in the reaction.
iv. Calculate the value of K_b for $C_2H_5NH_2$.

7) $HC_3H_5O_3\ (aq) \leftrightarrow H^+\ (aq) + C_3H_5O_3^-\ (aq)$

Lactic acid, $HC_3H_50_3$, is a monoprotic acid that dissociates in aqueous solution, as represented by the equation above. Lactic acid is 1.66 percent dissociated in 0.50 *M* $HC_3H_50_3$ *(aq)* at 298 K. For parts (a) through (d) below, assume the temperature remains at 298 K.

(a) Write the expression for the acid-dissociation constant, K_a, for lactic acid and calculate its value.

(b) Calculate the pH of 0.50 *M* $HC_3H_50_3$.

(c) Calculate the pH of a solution formed by dissolving 0.045 mole of solid lactate, $NaC_3H_50_3$, in 250 mL of 0.50 *M* $HC_3H_50_3$. Assume that volume change is negligible.

(d) A 100mL sample of 0.10 *M* HCl is added to 100 mL of 0.50 *M* $HC_3H_50_3$. Calculate the molar concentration of lactate ion, $C_3H_50_3^-$, in the resulting solution.

Answers:

1) $3H_2SO_4 + 2\,Al(OH)_3 \rightarrow Al_2(SO_4)_3 + 6H_2O$

2) $2HCl + Mg(OH)_2 \rightarrow MgCl_2 + 2H_2O$

3) $2H_3PO_4 + 3Ca(OH)_2 \rightarrow Ca_3(PO_4)_2 + 6H_2O$

4) $HNO_3 + NH_4OH \rightarrow NH_4NO_3 + H_2O$

5) Calculate the concentration of hydrochloric acid if 30 ml of this acid is neutralized by 40 ml of 0.010M sodium hydroxide. = 0.013M

6) Calculate the concentration of sulfuric acid if 60.0 ml of this acid is neutralized by 10.0 ml of 0.010M sodium hydroxide. =0.00083M

7) What volume of 0.3M H_2SO_4 is required to titrate 90 ml of 0.4M NaOH?=60 ml

8) How many ml of water needs to be added to make 500ml of 3M HCl from a stock solution, which is 6M. = 250 ml acid + 250mL water

9) Predict the following salt solutions will be acidic, basic or neutral. Also fill in the rest of the table regarding the parent acid and base from which they were formed.

Salt	Parent acid	Parent base	Type of solution
KCl	Hydrochloric	KOH	N
NH_4NO_3	Nitric	Ammonia	A
Na_3PO_4	phosphoric	NaOH	N
NH_4F	hydrofluoric	ammonia	A (acid is stronger than base : Ka > Kb)
CuI_2	hydroiodic	$Cu(OH)_2$	A
$SrSO_4$	sulfuric	$Sr(OH)_2$	N
$Li(CH_3COO)$	acetic	LiOH	B
$Ba_3(PO_4)_2$	phosphoric	$Ba(OH)_2$	N

Free response

1)

(a) $M_1V_1 = (M_2V_2)2$

$(0.4)(V) = (5 \times 10^{-3})2$

$V = 0.025\ L = 25\ mL$

(b) Eq 1: $H_2C_2O_4 \leftrightarrow H^+ + HC_2O_4^-$ K_1

Eq 2: $HC_2O_4^- \leftrightarrow H^+ + C_2O_4^{2-}$ K_2

(c) pH = 0.5 $[H^+] = -\log 0.50 = 0.316$ M

$3.78\text{x}10^{-6} = \dfrac{[H^+]^2[C_2O_4^{2-}]}{[H_2C_2O_4]} = \dfrac{x(0.316)^2}{(0.015–x)} = 5.6\text{x}10^{-7}$ M

(d)

$K_b = \dfrac{1 \times 10^{-14}}{6.4 \times 10^{-5}} = 1.56 \times 10^{-10}$

2)

(a) Use the Henderson-Hasselbalch equation:

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

pH = $-\log(1.8 \times 10^{-4}) + \log(0.6/0.4) = 3.92$

(b) The pH remains unchanged because the ratio of the formate and formic acid concentration stays the same.

(c) Initial concentrations

1.00 M HCl x (5.00mL/105mL) = 0.0476

0.40 M HCOOH x (100mL/105mL) = 0.38 M

0.60 M $HCOO^-$ x (100mL/105mL) = 0.57 m

Concentrations after H^+ reacts with $HCOO^-$

0.38M + 0.05M = 0.43M HCOOH

0.57M - 0.05M = 0.52M $HCOO^-$

$[H_3O^+] = 1.8 \times 10^{-4} \times (0.43M/0.52M) = 1.5 \times 10^{-4}M$

(d) 0.800L $\times$ 2.00M HCOOH = 1.60 mol

0.200L $\times$ 4.80M NaOH = 0.96 mol OH^-

at equilibrium: (1.60 - 0.96) = 0.64 mol HCOOH and 0.96 mol $HCOO^-$

$[H_3O^+] = 1.8 \times 10^{-4} \times (0.64M/0.96M) = 1.2 \times 10^{-4}M$

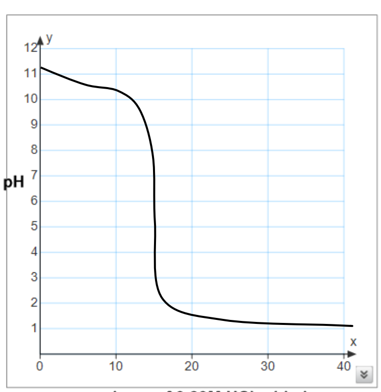
3)

(a) $NH_3(aq) + H^+(aq) \rightarrow NH_4^+(aq)$

OR

$NH_3(aq) + H_3O^+(aq) \rightarrow NH_4^+(aq) + H_2O(l)$

(b)



volume of 0.20M HCl added

(c) Methyl Red would be the best choice for the indicator because the pK_a for Methyl Red is closest to the pH at the equivalence point.

(d) The resulting solution is basic. K_b for NH_3($1.8x10^{-5}$) and the K_a for NH_4^+ ($5.6x10^{-10}$) indicate that is NH_3 a stronger base than NH^{4+}.

OR

$[OH^-] = K_b = 1.8 x10^{-5}$ because of equimolar and equal volume amounts of ammonia and ammonium ion, cancellation of [log A/B] component in the buffer pH calculation. Thus pOH ≈ 5 and pH ≈ 9 (i.e., recognition of buffer, so that log(.05/.05) = 0, pOH = pK_b ≈ 5, pH = 14 – pOH ≈ 9)

4)

(a) $[H^+] = [OCl^-] = (0.14 \times 3.2 \times 10^{-8})^{1/2} = 6.7 \times 10^{-5}$ M

(b) $OCl^- + H_2O \leftrightarrow HOCl + OH^-$

OR

$NaOCl + H_2O \rightarrow Na^+ + HOCl + OH^-$

$K_b = K_w / K_a = (1 \times 10^{-14} / 3.2 \times 10^{-8}) = 3.1 \times 10^{-7}$

(c) [HOCl] = [(0.0400) (0.14)] / 0.050 = 0.11 M

$[OH^-]$ = [(0.0100) (0.56)] / 0.050 = 0.11 M

Thus reaction is essentially complete and exactly equals a solution of NaOCl and $[OCl^-]$ = 0.11 M (or reaction is at equivalence point).

Then

$[OH^-] = [HOCl]$

$K_b = [OH^-]^2 / 0.11 = 3.1 \times 10^{-7}$

$[OH^-] = [(0.11) (3.1 \times 10^{-7})]^{1/2} = 1.8 \times 10^{-4}$

pOH = 3.73

pH = 14 - 3.73 = 10.27

(d) pH = 7.49 therefore $[H^+] = 3.2 \times 10^{-8}$

pH = pK_a , or $[H^+] = K_a$.

So $[OCl^-]$ / [HOCl] = 1 , or solution must be half neutralized.

initial mmol HOCl = 50.0 x 0.20 = 10.0 mmol

mmol NaOH required = 10.0 ÷ 2 = 5.0 mmol

(e) From equation, 1 mol H^+ produced for each 1 mole of HOCl produced, thus $[H^+]$ = [HOCl] = 0.065 therefore pH = 1.19

5)

(ai) HOCl is the stronger acid because its K_a value is greater than the K_a value of HOBr.

(ii) H : O : Cl :

(iii) HOI is a weaker acid than HOCl because the O—H bond in HOCl. The lower electronegativity of I compared with that of Cl results in an electron density that is higher (hence a bond that is stronger) between the H and O atoms in HOI compared with the electron density between the H and O atoms in HOCl.

OR

The conjugate base OCl^- is more stable than OI^- because Cl, being more electronegative, is better able to accommodate the negative charge.

(b) $HOCl + H_2O \leftrightarrow OCl^- + H_3O^+$

OR

$HOCL \leftrightarrow OCl^- + H^+$

(ci) $K_b = \dfrac{[HOCl][OH^-]}{[OCl^-]}$

(ii) $K_b = K_w/K_a = (1.0x10^{-14}/2.9x10^{-8}) = 3.4x10^{-7}$

(iii) $K = (x)(x)/(1.2-x) \approx x^2/1.2$

$x^2 = (1.2)(\ 3.4x10^{-7})$

$x = [OH^-] = 6.4 \times 10^{-4}$ M

(di) $[H^+] = 10^{-6.48} = 3.3 \times 10^{-7}$ M

(ii) $K_a = \dfrac{[H^+][OCl^-]}{[HOCl]} = 2.9 \times 10^{-8}$

$\dfrac{[OCl^-]}{[HOCl]} = \dfrac{2.9 \times 10^{-8}}{3.3 \times 10^{-7}} = 0.088 \Rightarrow [HOCl] > [OCl^-]$

6)

(a) $n_{C2H5NH2} = 14.84$ g $C_2H_5NH_2$ / 45.09 g/mol $C_2H_5NH_2$ = 0.3293 mol $C_2H_5NH_2$

M = 0.3293 mol $C_2H_5NH_2$ / 5.00 L = 0.659 M

(b) $K_b = \dfrac{[C_2H_5NH_3^+][OH^-]}{[C_2H_5NH_2]}$

(c) $C_2H_5NH_2$ is present in the solution at the higher concentration at equilibrium. Ethylamine is a weak base, and thus is has a small K_b value. Therefore, only partial dissociation of $C_2H_5NH_2$ occurs in water, and $[C_2H_5NH_3^+]$ is thus less than $[C_2H_5NH_2]$.

(di) $pH = -\log[H^+]$

$[H^+] = 10^{-10.93} = 1.17 \times 10^{-11}$

$[OH^-] = K_w / [H^+] = 8.5 \times 10^{-4}$ M

OR

$pOH = 14 - pH = 3.07$

$[OH^-] = 10^{-3.07} = 8.5 \times 10^{-4}$

(ii) $C_2H_5NH_2 + H_3O^+ \leftrightarrow C_2H_5NH_3^+ + H_2O$

(iii) moles of $C_2H_5NH_2$ = (0.5 x 0.5 mol / 1 L) = 0.250 mol

Moles of H_3O^+ = (.5 x .2 mol/ 1 L) = 0.100 mol

	$[C_2H_5NH_2]$	$[H_3O^+]$	$[C_2H_5NH_3^+]$
Initial	0.250	0.100	~0
Change	-0.100	-0.100	+0.100
Final Value	0.150	~0	0.100

(iv) $[C_2H_5NH_2] = 0.150$ M

$K_b = \dfrac{[C_2H_5NH_3^+][OH^-]}{[C_2H_5NH_2]} = \dfrac{(0.1)(8.5 \times 10^{-4})}{0.150} = 5.67 \times 10^{-4}$

7)

a) $K_a = \underline{[H^+][C_3H_5O_3^-]}$; 0.50 m X 0.0166 = 0.0083 M = x

$[HC_3H_5O_3]$

$HC_3H_5O_3$	$\leftrightarrow$	H^+	+	$C_3H_5O_3^-$
0.50		0		0
-x		+x		+x
0.50 –x		x		x

$$K_a = \frac{[H^+][C_3H_5O_3^-]}{[HC_3H_5O_3]} = \frac{[0.0083]\ [0.0083]}{[0.50 - 0.0083]} = 1.4 \times 10^{-4}$$

b) $[H^+] = 0.0083$ M ; pH = -log(0.0083 M) = 2.08

c) 0.045 mol $NaC_3H_5O_3$/ 0.250 L = 0.18 M $C_3H_5O_3^-$

$$K_a = \frac{[H^+][C_3H_5O_3^-]}{[HC_3H_5O_3]} = 1.4 \times 10^{-4} = \frac{[H^+][0.18]}{[0.50]} \ ; [H^+] = 3.9 \times 10^{-4} \ ; pH = 3.41$$

OR

$pH = pK_a + \log(0.18/0.50) = 3.41$

d) 0.50 M $HC_3H_5O_3$ (100mL/200mL) = 0.25 M $HC_3H_5O_3$

0.10 M HCl (100mL/200mL) = 0.50 M H^+

$HC_3H_5O_3$	$\leftrightarrow$	H^+	+	$C_3H_5O_3^-$
0.25		0.050		0
-x		+x		+x
0.25 –x		0.05 + x		x

$$K_a = \frac{[H^+][C_3H_5O_3^-]}{[HC_3H_5O_3]} = \frac{[0.05 + x][x]}{[0.25 - x]} \ ; \text{Assume } x \ll 0.050\text{ M}$$

$$K_a = 1.4 \times 10^{-4} = \frac{[0.050][x]}{[0.25]} \ ; x = 7.0 \times 10^{-4}\text{ M} = [C_3H_5O_3^-]$$