AP Chemistry Unit 10 Acids and Bases 1 Problem Sets.

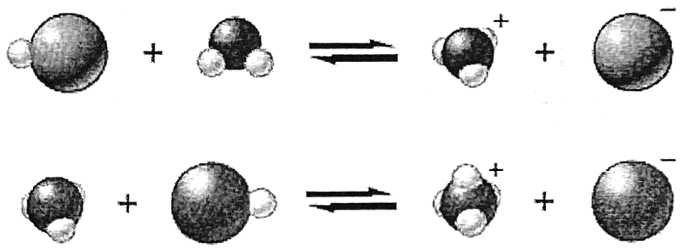
Problem Set 1

1

2. Differentiate between the terms *strength* and *concentration* as they apply to acids and bases. When is HCl strong? Weak? Concentrated? Dilute?

2

26. The following are representations of acid–base reactions:



a. Label each of the species in both equations as an acid or a base and explain your answers.

3

16.17 (a) Give the conjugate base of the following Brønsted–Lowry acids: (i) HIO_3, (ii) NH_4^+. (b) Give the conjugate acid of the following Brønsted–Lowry bases: (i) O^{2-}, (ii) $H_2PO_4^-$.

4

37. For each of the following aqueous reactions, identify the acid, the base, the conjugate base, and the conjugate acid.

a. $H_2O + H_2CO_3 \rightleftharpoons H_3O^+ + HCO_3^-$

b. $C_5H_5NH^+ + H_2O \rightleftharpoons C_5H_5N + H_3O^+$

c. $HCO_3^- + C_5H_5NH^+ \rightleftharpoons H_2CO_3 + C_5H_5N$

5

35. Write balanced equations that describe the following reactions.

a. the dissociation of perchloric acid in water

b. the dissociation of propanoic acid ($CH_3CH_2CO_2H$) in water

c. the dissociation of ammonium ion in water

6

5. Consider the reaction of acetic acid in water:

$HC_2H_3O_2\ (aq) + H_2O\ (l) \longleftrightarrow C_2H_3O_2^-\ (aq) + H_3O^+\ (aq)$ Keq = 1.8×10^{-5}

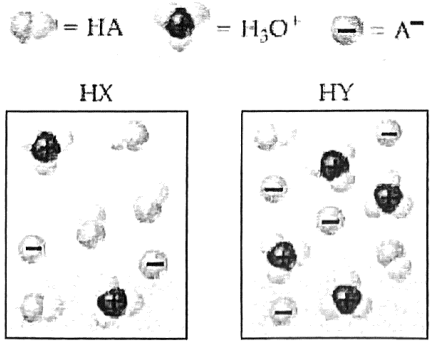
a) Which two bases are competing for the proton?
b) Which is the stronger base?
c) In light of your answer to (b), why do we classify the acetate ion as a weak base? Use an appropriate reaction to justify your answer.

7

16.2 The following diagrams represent aqueous solutions of two monoprotic acids, HA (A = X or Y). The water molecules have been omitted for clarity. (a) Which is the stronger acid, HX or HY? (b) Which is the stronger base, X^- or Y^-? (c) If you mix equal concentrations of HX and NaY, will the equilibrium

$$HX(aq) + Y^-(aq) \rightleftharpoons HY(aq) + X^-(aq)$$

lie mostly to the right ($K_c > 1$) or to the left ($K_c < 1$)? [Section 16.2]



8

7. Anions containing hydrogen (for example HCO_3^- and $H_2PO_4^-$) usually show amphoteric behavior. Write equations illustrating the amphoterism of these two anions.

9

10

47. Values of K_w as a function of temperature are as follows:

Temperature (°C)	K_w
0	1.14×10^{-15}
25	1.00×10^{-14}
35	2.09×10^{-14}
40.	2.92×10^{-14}
50.	5.47×10^{-14}

a. Is the autoionization of water exothermic or endothermic?

b. Calculate $[H^+]$ and $[OH^-]$ in a neutral solution at 50.°C.

45. Calculate the $[OH^-]$ of each of the following solutions at 25°C. Identify each solution as neutral, acidic, or basic.

a. $[H^+] = 1.0 \times 10^{-7}\,M$ **c.** $[H^+] = 12\,M$

b. $[H^+] = 8.3 \times 10^{-16}\,M$ **d.** $[H^+] = 5.4 \times 10^{-5}\,M$

46. Calculate the $[H^+]$ of each of the following solutions at 25°C. Identify each solution as neutral, acidic, or basic.

a. $[OH^-] = 1.5\,M$ **c.** $[OH^-] = 1.0 \times 10^{-7}\,M$

b. $[OH^-] = 3.6 \times 10^{-15}\,M$ **d.** $[OH^-] = 7.3 \times 10^{-4}\,M$

11

12. Answer the following questions about pH

a. What is meant by pH?

b. True or false: A strong acid solution always has a lower pH than a weak acid solution. Explain.

c. Can the pH of a solution ever be negative? Explain.

12

51. Fill in the missing information in the following table.

	pH	pOH	[H+]	[OH−]	Acidic, Basic, or Neutral?
Solution a	6.88	____	_____	_____	_____
Solution b	____	____	_____	$8.4 \times 10^{-14}\,M$	_____
Solution c	____	3.11	_____	_____	_____
Solution d	____	____	$1.0 \times 10^{-7}\,M$	_____	_____

13

Perform the following calculations regarding pH:

a. The $[H^+]$ given a concentration of $[OH^-]$ of 1.44×10^{-9} M.

b. The pH of a solution with $[H^+] = 1.0 \times 10^{-2}$ M.

c. The pH of a solution with $[OH^-] = 1.93 \times 10^{-6}$M.

d. The pH of a solution with a pOH of 9.47.

14

54. The pOH of a sample of baking soda dissolved in water is 5.74 at 25°C. Calculate the pH, $[H^+]$, and $[OH^-]$ for this sample. Is the solution acidic or basic?

Problem Set 2

1

2

1. Calculate the pH of a 0.389 M solution of $HClO_3$.	2. What are the major species present in a 0.250 M solution of each of the following acids? Calculate the pH in each. a. $HClO_4$ b. HNO_3
3	**4**
3. Calculate the pH of each of the following solutions of a strong acid in water: a. 1×10^{-11} M HCl b. 5.0 M HCl	4. Find the pH of a 0.25 M solution of lactic acid, $HC_3H_5O_3$ ($K_a = 8.3 \times 10^{-4}$).
5	**6**
5. Using the table of weak acids and weak bases, order the following from the weakest to the strongest acid: H_2O, HNO_3, HOCl, NH_4^+	6. The pH of a 0.0100 M solution of cyanic acid (HOCN) is 2.77 at 25°C. Calculate its K_a.
7	**8**
7. What are the major species present in 0.10M of each of the following solutions? Calculate the pH of each of these solutions (use the table for K_a values) a. HNO_2 b. $HC_2H_3O_2$	8. A solution with a total volume of 250.0 mL is prepared by diluting 20.0 mL of glacial acetic acid with water. Calculate the $[H^+]$ and the pH of this solution. Assume that glacial acetic acid is pure liquid acetic acid with a density of 1.05 g/mL.
9	**10**
9. Monochloroacetic acid, $HC_2H_2ClO_2$, is a skin irritant that is used in "chemical peels" intended to remove the top layer of dead skin from the face and ultimately improve the complexion. The value for the K_a of monochloroacetic acid is 1.35×10^{-3}. Calculate the pH of a 0.10 M solution.	10. A solution of formic acid (HCOOH, $K_a = 1.8 \times 10^{-4}$) has a pH of 2.70. Calculate the initial concentration of formic acid in this solution.
11	**12**
11. Calculate the percent dissociation in a 5.0 M solution of formic acid, $HCHO_2$ ($K_a = 1.8 \times 10^{-4}$).	12. A 0.15 M solution of a weak acid is 3.0% dissociated. Calculate K_a.
13	**14**
13. Calculate the pH of a mixture of 100.0 mL of 0.10 M HNO_3 and 200.0 mL of 0.30 M HCl.	14. A solution is prepared by adding 50.0 mL of 0.050 M HCl to 150.0 mL of 0.10 M HNO_3. Find its pH.
15	**16**
15. Calculate the pH and concentration of all species given a mixture of 0.10 M $HC_3H_5O_2$ ($K_a = 1.3 \times 10^{-5}$) and 0.10 M HCN ($K_a = 6.2 \times 10^{-10}$).	16. Calculate the pH of a solution that contains 1.0 M HF and 1.0 M HOC_6H_5. Also calculate the concentration of $OC_6H_5^-$ at equilibrium.
17	**18**
17. Write out the stepwise K_a reactions for citric acid ($H_3C_6H_5O_7$), a triprotic acid.	18. Calculate the pH and concentration of all species for 0.35 M H_3BO_3 (given the following: $K_{a1} = 5.4 \times 10^{-10}$, $K_{a2} = 1.8 \times 10^{-13}$, $K_{a3} = 1.6 \times 10^{-14}$)

Problem Set 3

1	2
1. Calculate the pH of a 0.40 M solution of sodium hydroxide.	2. Calculate the pH of a 0.40 M solution of barium hydroxide.
3	**4**

3. Calculate the pH of the following solutions: a. 0.10 M NaOH b. 2.0 M NaOH c. 1.0×10^{-10} M NaOH	4. Calculate the concentration of an aqueous $Sr(OH)_2$ solution that has a pH = 10.50.
5	**6**
5. Write the reaction and the corresponding K_b equilibrium expression for each of the following substances acting as bases in water: a. NH_3 b. C_5H_5N	6. Use the table of weak acids and weak bases to help answer the following questions: a. Which is the stronger base, NO_3^- or NH_3? b. Which is the stronger base, H_2O or NH_3? c. Which is the stronger base, OH^- or NH_3? d. Which is the stronger base, CH_3NH_2 or NH_3?
7	**8**
7. Calculate the pH of a 0.40 M solution of $(C_2H_5)_2NH$ ($K_b = 1.3 \times 10^{-3}$).	8. Calculate $[OH^-]$, $[H^+]$, and the pH of 0.20 M solutions of each of the following amines: a. Triethylamine $[(C_2H_5)_3N, K_b = 4.0 \times 10^{-4}]$ b. Hydroxylamine $[HONH_2, K_b = 1.1 \times 10^{-8}]$
9	**10**
9. Codeine ($C_{18}H_{21}NO_3$) is a derivative of morphine. It was once commonly used in cough syrups but is now available only by prescription because of its addictive properties. If the pH of a 1.7×10^{-3} M solution of codeine is 9.59, calculate K_b.	10. A weak base, B, has a K_b of 4.46×10^{-10}. A solution with an unknown initial concentration is tested, and found to have a pH of 8.39. Determine the initial concentration of B.
11	**12**

Problem Set 4

1	2

1. Are solutions of the following salts acidic, basic, or neutral? For those that are not neutral, write balanced chemical equations for the reactions causing the salt to be acidic or basic. If needed (both ions could contribute to pH), the relative K_a or K_b values are in tables for weak acids and bases.
   a. $NaNO_3$
   b. $NaNO_2$
   c. $C_5H_5NHClO_4$
   d. NH_4NO_2
   e. KOCl
   f. NH_4OCl

2. For each:
(A) predict the pH
(B) write the equation for hydrolysis *if it hydrolyzes*
(C) calculate pH.

   a. 0.50 M solution of $NaNO_3$.
   b. 0.50 M solution of NH_4ClO_4 (K_b $NH_3 = 1.8 \times 10^{-5}$).
   c. 0.50 M solution of KCN (K_a $HCN = 1.6 \times 10^{-10}$).
   d. 0.50 M solution of $LiHSO_3$ (For H_2SO_3, $Ka_1 = 1.4 \times 10^{-2}$, $Ka_2 = 6.3 \times 10^{-8}$)
   e. 0.50 M solution of $AlBr_3$ (K_a for $Al(H_2O)_6^{3+}$ is 1.4×10^{-5}).

3

3. Papervine hydrochloride (abbreviated $papH^+Cl^-$; molar mass 378.85 g/mol) is a drug that belongs to a group of medicines called vasodilators, which cause blood vessels to expand, thereby increasing blood flow. The drug is the conjugate acid of the weak base papaverine (abbreviated pap; $K_b = 8.33 \times 10^{-9}$ at 35.0°C). Calculate the pH of a 30.0-mg/mL aqueous dose of $papH^+Cl^-$ prepared at 35.0°C, where K_w at 35.0°C is 2.1×10^{-14}.

4

4. Consider a solution of an unknown salt having the general formulas BHCl, where B is one of the weak bases on your table. A 0.10 M solution of the unknown salt has a pH of 5.82. What is the weak base that was used?

5

Lactic acid is a weak acid found in milk. Its calcium salt is a source of calcium for growing animals. A saturated solution of this salt, which can be represented as $Ca(Lact)_2$ has $[Ca^{2+}] = 0.26$ M and a pH of 8.40. Assuming the salt is completely dissociated, calculate K_a of lactic acid.

6

Sodium hypochlorite, sold as chlorine bleach, is potentially dangerous because of the basicity of ClO^-, the active ingredient. What is the $[OH^-]$ in an aqueous solution that is 6.5% NaClO by mass? What is the pH of the solution? Assume the solution has a density of 1.0 g/mL

7

An unknown salt is either NaF, NaCl, or NaOCl. When 0.050 mol of the salt is dissolved in water to form a 0.500 L solution, the pH of the solution is 8.08. What is the identity of the salt?

8

9

10

11

12

AP Chemistry Unit 10 Acids and Bases II Problem Sets.

Problem Set 1 Buffers

1	2
17.19 Explain why a mixture of CH_3COOH and CH_3COONa can act as a buffer while a mixture of HCl and NaCl cannot.	19. A certain buffer is made by dissolving $NaHCO_3$ and Na_2CO_3 in some water. Write equations to show how this buffer neutralizes added H^+ and OH^-.
3	**4**
21. Calculate the pH of each of the following solutions. a. 0.100 *M* propanoic acid ($HC_3H_5O_2$. $K_a = 1.3 \times 10^{-5}$) b. 0.100 *M* sodium propanoate ($NaC_3H_5O_2$) c. pure H_2O d. a mixture containing 0.100 *M* $HC_3H_5O_2$ and 0.100 *M* $NaC_3H_5O_2$	35. Calculate the pH of each of the following buffered solutions. a. 0.10 *M* acetic acid/0.25 *M* sodium acetate b. 0.25 *M* acetic acid/0.10 *M* sodium acetate c. 0.080 *M* acetic acid/0.20 *M* sodium acetate d. 0.20 *M* acetic acid/0.080 *M* sodium acetate
5	**6**
31. Calculate the pH of a solution that is 1.00 *M* HNO_2 and 1.00 *M* $NaNO_2$. 33. Calculate the pH after 0.10 mole of NaOH is added to 1.00 L of the solution in Exercise 31, and calculate the pH after 0.20 mole of HCl is added to 1.00 L of the solution in Exercise 31.	39. Calculate the pH after 0.010 mole of gaseous HCl is added to 250.0 mL of each of the following buffered solutions. a. 0.050 *M* NH_3/0.15 *M* NH_4Cl b. 0.50 *M* NH_3/1.50 *M* NH_4Cl Do the two original buffered solutions differ in their pH or their capacity? What advantage is there in having a buffer with a greater capacity?
7	**8**
37. Calculate the pH of a buffered solution prepared by dissolving 21.5 g benzoic acid ($HC_7H_5O_2$) and 37.7 g sodium benzoate in 200.0 mL of solution.	48. Consider the bases in Table 14.3. Which base would be the best choice for preparing a pH = 5.00 buffer? Explain how to make 1.0 L of this buffer.
9	**10**
47. Consider the acids in Table 14.2. Which acid would be the best choice for preparing a pH = 7.00 buffer? Explain how to make 1.0 L of this buffer.	41. Calculate the mass of sodium acetate that must be added to 500.0 mL of 0.200 *M* acetic acid to form a pH = 5.00 buffer solution.
11	**12**
44. Calculate the ratio $[NH_3]/[NH_4^+]$ in ammonia/ammonium chloride buffered solutions with the following pH values: a. pH = 9.00 c. pH = 10.00 b. pH = 8.80 d. pH = 9.60	50. Calculate the pH of a solution that is 0.20 *M* HOCl and 0.90 *M* KOCl. In order for this buffer to have pH = pK_a, would you add HCl or NaOH? What quantity (moles) of which reagent would you add to 1.0 L of the original buffer so that the resulting solution has pH = pK_a?
13	**14**
53. What quantity (moles) of NaOH must be added to 1.0 L of 2.0 *M* $HC_2H_3O_2$ to produce a solution buffered at each pH? a. pH = pK_a b. pH = 4.00 c. pH = 5.00	45. Carbonate buffers are important in regulating the pH of blood at 7.40. If the carbonic acid concentration in a sample of blood is 0.0012 *M*, determine the bicarbonate ion concentration required to buffer the pH of blood at pH = 7.40. $H_2CO_3(aq) \rightleftharpoons HCO_3^-(aq) + H^+(aq)$ $K_a = 4.3 \times 10^{-7}$

Problem Set 2 Buffers 2

1	2

54. Calculate the number of moles of $HCl(g)$ that must be added to 1.0 L of 1.0 M $NaC_2H_3O_2$ to produce a solution buffered at each pH.

a. pH = pK_a b. pH = 4.20 c. pH = 5.00

40. An aqueous solution contains dissolved $C_6H_5NH_3Cl$ and $C_6H_5NH_2$. The concentration of $C_6H_5NH_2$ is 0.50 M and pH is 4.20.

a. Calculate the concentration of $C_6H_5NH_3^+$ in this buffer solution.

b. Calculate the pH after 4.0 g $NaOH(s)$ is added to 1.0 L of this solution. (Neglect any volume change.)

3

87. Phosphate buffers are important in regulating the pH of intracellular fluids at pH values generally between 7.1 and 7.2.

a. What is the concentration ratio of $H_2PO_4^-$ to HPO_4^{2-} in intracellular fluid at pH = 7.15?

$$H_2PO_4^-(aq) \rightleftharpoons HPO_4^{2-}(aq) + H^+(aq) \qquad K_a = 6.2 \times 10^{-8}$$

b. Why is a buffer composed of H_3PO_4 and $H_2PO_4^-$ ineffective in buffering the pH of intracellular fluid?

$$H_3PO_4(aq) \rightleftharpoons H_2PO_4^-(aq) + H^+(aq) \qquad K_a = 7.5 \times 10^{-3}$$

4

85. You have the following reagents on hand:

Solids (pK_a of Acid Form Is Given)	Solutions
Benzoic acid (4.19)	5.0 M HCl
Sodium acetate (4.74)	1.0 M acetic acid (4.74)
Potassium fluoride (3.14)	2.6 M NaOH
Ammonium chloride (9.26)	1.0 M HOCl (7.46)

What combinations of reagents would you use to prepare buffers at the following pH values?

a. 3.0 b. 4.0 c. 5.0 d. 7.0 e. 9.0

5

17.21 (a) Calculate the pH of a buffer that is 0.12 M in lactic acid and 0.11 M in sodium lactate. (b) Calculate the pH of a buffer formed by mixing 85 mL of 0.13 M lactic acid with 95 mL of 0.15 M sodium lactate.

6

17.23 A buffer is prepared by adding 20.0 g of acetic acid (CH_3COOH) and 20.0 g of sodium acetate (CH_3COONa) to enough water to form 2.00 L of solution. (a) Determine the pH of the buffer. (b) Write the complete ionic equation for the reaction that occurs when a few drops of hydrochloric acid are added to the buffer. (c) Write the complete ionic equation for the reaction that occurs when a few drops of sodium hydroxide solution are added to the buffer.

7

17.26 How many grams of sodium lactate [$CH_3CH(OH)COONa$ or $NaC_3H_5O_3$] should be added to 1.00 L of 0.150 M lactic acid [$CH_3CH(OH)COOH$ or $HC_3H_5O_3$] to form a buffer solution with pH 4.00? Assume that no volume change occurs when the sodium lactate is added.

8

17.31 You have to prepare a pH 3.50 buffer, and you have the following 0.10 M solutions available: HCOOH, CH_3COOH, H_3PO_4, HCOONa, CH_3COONa, and NaH_2PO_4. Which solutions would you use? How many milliliters of each solution would you use to make approximately a liter of the buffer?

9

17.80 Two buffers are prepared by adding an equal number of moles of formic acid (HCOOH) and sodium formate (HCOONa) to enough water to make 1.00 L of solution. Buffer A is prepared using 1.00 mol each of formic acid and sodium formate. Buffer B is prepared by using 0.010 mol of each. (a) Calculate the pH of each buffer, and explain why they are equal. (b) Which buffer will have the greater buffer capacity? Explain. (c) Calculate the change in pH for each buffer upon the addition of 1.0 mL of 1.00 M HCl. (d) Calculate the change in pH for each buffer upon the addition of 10 mL of 1.00 M HCl. (e) Discuss your answers for parts (c) and (d) in light of your response to part (b).

10

[17.88] Suppose you want to do a physiological experiment that calls for a pH 6.5 buffer. You find that the organism with which you are working is not sensitive to the weak acid H_2X ($K_{a1} = 2 \times 10^{-2}$; $K_{a2} = 5.0 \times 10^{-7}$) or its sodium salts. You have available a 1.0 M solution of this acid and a 1.0 M solution of NaOH. How much of the NaOH solution should be added to 1.0 L of the acid to give a buffer at pH 6.50? (Ignore any volume change.)

Problem Set 3 Titrations

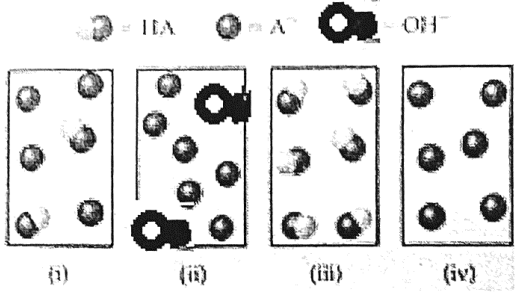
1

The following drawings represent solutions at various stages of the titration of a weak acid, HA, with NaOH.

2

Match the following descriptions of titration curves with the diagram

(The Na^+ ions have been omitted for clarity). To which of the following regions of the titration curve does each drawing correspond:

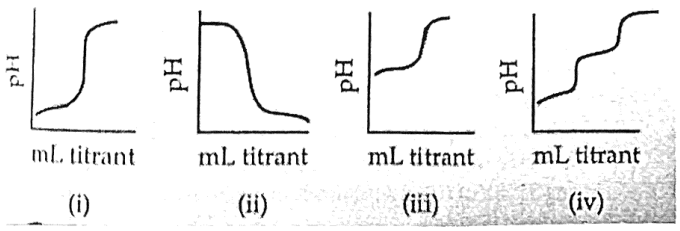


a)before addition of NaOH

b)after addition of NaOH but before equivalence point

c)at equivalence point

d)after equivalence point



a)strong acid added to strong base

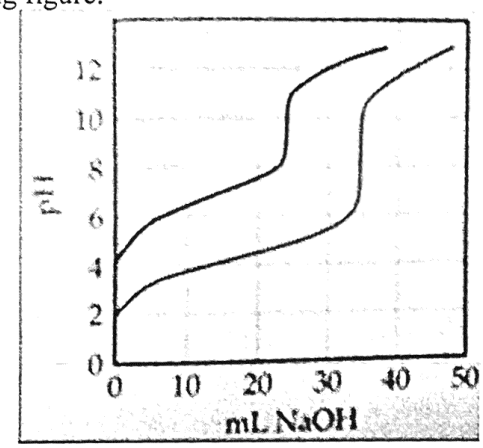
b)strong base added to weak acid

c)strong base added to strong acid

d)strong base added to polyprotic acid

3

Equal volumes of two acids are titrated with 0.10 M NaOH resulting in the two titration curves shown in the following figure.



a)Which curve corresponds to the more concentrated acid solution? Explain.

b)Which corresponds to the acid with the larger K_a? Explain.

4

How does titration of a 0.10 M strong, monoprotic acid with a 0.10 M strong base differ from titration of a 0.10 M weak, monoprotic acid with a 0.10 M strong base with respect to the following:

a)quantity of base required to reach the equivalence point

b)pH at the beginning of the titration

c)pH at the equivalence point

d)pH after addition of a slight excess of base

e)choice of indicator for determining the equivalence point

5

Predict whether the equivalence point of each of the following titrations is below, above, or at pH 7:

a)formic acid titrated with NaOH

b)calcium hydroxide titrated with perchloric acid

6

Sketch the titration curve for the titration of a generic weak base B with a strong acid. The titration reaction is:

$B + H^+ \longleftrightarrow BH^+$

On this curve, indicate the points that correspond to the following:

a)the stoichiometric (equivalence point)

c)pyridine titrated with nitric acid

b)the region with maximum buffering
c)pH = pK_a
d)pH depends only on [B]
e)pH depends only on $[BH^+]$
f)pH depends only on amount of excess strong acid

7

Assume that 30.0 mL of a 0.10 M solution of a weak base B that accepts one proton is titrated with a 0.10 M solution of the monoprotic strong acid HX.

a)How many moles of HX have been added at the equivalence point?

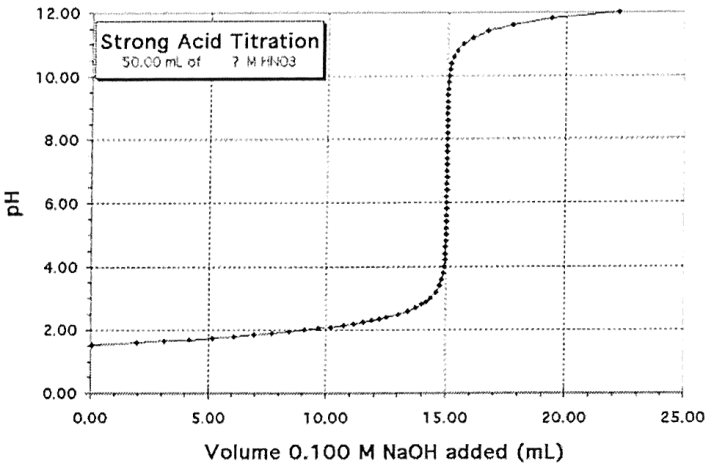
b)What is the predominant form of B at the equivalence point?

c)How can the pH be determined at the equivalence point?

d)Which indicator, phenolphthalein ($K_a = 10^{-8}$) or methyl red ($K_a = 10^{-5}$), is likely to be the better indicator for this titration?

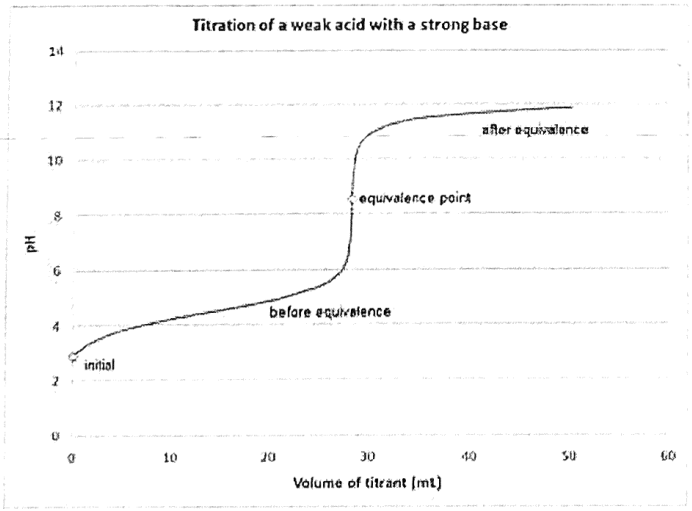
8

50.00 mL of an unknown concentration of HNO_3 were titrated according to the curve below. Determine its concentration through the results.



9

A 0.250 M solution of weak acid, HA, is titrated with 0.150 M KOH, generating the following titration curve. Determine the K_a of the weak acid.



10

Calculate the initial pH, the pH at the halfway point, the pH at the equivalence point, and the pH after the addition of 250.0 mL of titrant.

100.0 mL of 0.10 M $HC_7H_5O_2$ ($K_a = 6.4 \times 10^{-5}$) titrated by 0.10 M NaOH

Initial pH
pH at halfway point
pH at equivalence point
pH after 250.0 mL of titrant

11

Calculate the initial pH, the pH at the halfway point, the pH at the equivalence point, and the pH after the addition of 250.0 mL of titrant.

100.0 mL of 0.10 M $C_2H_5NH_2$ ($K_b = 5.6 \times 10^{-4}$) titrated by 0.20 M HNO_3

Initial pH

12

Calculate the initial pH, the pH at the halfway point, the pH at the equivalence point, and the pH after the addition of 250.0 mL of titrant.

100.0 mL of 0.50 M NaOH titrated by 0.25 M HCl

Initial pH
pH at halfway point
pH at equivalence point

pH at halfway point pH at equivalence point pH after 250.0 mL of titrant Sketch the titration curve based on your points.	pH after 250.0 mL of titrant Sketch the titration curve based on your points.