CH 223 Practice Problem Set #3

*This is a **practice problem set** and not the actual graded problem set that you will turn in for credit.*
Answers to each problem can be found at the end of this assignment.

Covering: **Chapter Fourteen** *and* **Chapter Guide Three**
Important Tables and/or Constants: "**Titration Guide**" *(Handout),* "**Buffers and Henderson-Hasselbalch Guide**" *(Handout)* and the **Table of Acids and Bases for CH 223** *(in problem set #3),* **K_w = 1.00 x 10^{-14}** at 25 °C

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1. What are the products of each of the following acid–base reactions? Indicate the acid and its conjugate base, and the base and its conjugate acid.
   a. $HNO_3 + H_2O \rightarrow$
   b. $HSO_4^{-1} + H_2O \rightarrow$
   c. $H_3O^+ + F^{-1} \rightarrow$
2. Write balanced equations showing how the hydrogen oxalate ion, $HC_2O_4^{-1}$, can be both a Brønsted acid and a Brønsted base.
3. In each of the following acid–base reactions, identify the Brønsted acid and base on the left and their conjugate partners on the right.
   a. $C_5H_5N(aq) + CH_3CO_2H(aq) \rightleftharpoons C_5H_5NH^+(aq) + CH_3CO_2^-(aq)$
   b. $N_2H_{4(}aq) + HSO_4^-(aq) \rightleftharpoons N_2H_5^+(aq) + SO_4^{2-}(aq)$
   c. $[Al(H_2O)_6]^{3+}(aq) + OH^-(aq) \rightleftharpoons [Al(H_2O)_5OH]^{2+}(aq) + H_2O(l)$
4. An aqueous solution has a pH of 3.75. What is the hydronium ion concentration of the solution? What is the hydroxide ion concentration of the solution? Is it acidic or basic?
5. What is the pH of a 0.0015 M solution of $Ba(OH)_2$?
6. Several acids are listed here with their respective equilibrium constants:

$$C_6H_5OH(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + C_6H_5O^{-1}(aq)$$
$$K_a = 1.3 \times 10^{-10}$$
$$HCO_2H(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + HCO_2^{-1}(aq)$$
$$K_a = 1.8 \times 10^{-4}$$
$$HC_2O_4^{-1}(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + C_2O_4^{2-}(aq)$$
$$K_a = 6.4 \times 10^{-5}$$

   a. Which is the strongest acid? Which is the weakest acid?
   b. Which acid has the weakest conjugate base?
   c. Which acid has the strongest conjugate base?
7. Epinephrine hydrochloride has a pK_a value of 9.53. What is the value of K_a?
8. A weak base has $K_b = 4.7 \times 10^{-11}$. What is the value of K_a for the conjugate acid?
9. Which is the stronger of the following two acids?
   a. acetic acid, CH_3CO_2H, $K_a = 1.8 \times 10^{-5}$
   b. chloroacetic acid, $ClCH_2CO_2H$, pK_a = 2.87
10. Equal molar quantities of sodium hydroxide and sodium hydrogen phosphate (Na_2HPO_4) are mixed.
    a. Write the balanced, net ionic equation for the acid–base reaction that can, in principle, occur.
    b. Does the equilibrium lie to the right or left?
11. A 0.015 M solution of hydrogen cyanate, HOCN, has a pH of 2.67.
    a. What is the hydronium ion concentration in the solution?
    b. What is the ionization constant, K_a, for the acid?

12. A 0.015 M solution of a base has a pH of 10.09.
    a. What are the hydronium and hydroxide ion concentrations of this solution?
    b. What is the value of K_b for this base?
13. Phenol (C_6H_5OH), commonly called carbolic acid, is a weak organic acid.

$$C_6H_5OH(aq) + H_2O(l) \rightleftharpoons C_6H_5O^{-1}(aq) + H_3O^{+}(aq) \quad K_a = 1.3 \times 10^{-10}$$

    If you dissolve 0.195 g of the acid in enough water to make 125 mL of solution, what is the equilibrium hydronium ion concentration? What is the pH of the solution?
14. Calculate the pH of a 0.12 M aqueous solution of the base aniline, $C_6H_5NH_2$ (The K_b for aniline equals 4.0×10^{-10}).

$$C_6H_5NH_2(aq) + H_2O(l) \rightleftharpoons C_6H_5NH_3^{+1}(aq) + OH^{-1}(aq)$$

15. Calculate the hydronium ion concentration and pH in a 0.20 M solution of ammonium chloride, NH_4Cl.
16. Given the following solutions:
    a. 0.1 M NH_3
    b. 0.1 M Na_2CO_3
    c. 0.1 M NaCl
    d. 0.1 M CH_3CO_2H
    e. 0.1 M NH_4Cl
    f. 0.1 M $NaCH_3CO_2$
    g. 0.1 M $NH_4CH_3CO_2$

    i. Which of the solutions are acidic?
    ii. Which of the solutions are basic?
    iii. Which of the solutions is most acidic?
17. The equilibrium constant for the reaction of formic acid and sodium hydroxide is 1.8×10^{10}. Confirm this value.
18. Calculate the hydronium ion concentration and pH of the solution that results when 22.0 mL of 0.15 M acetic acid, CH_3CO_2H, is mixed with 22.0 mL of 0.15 M NaOH.
19. For each of the following cases, decide whether the pH is less than 7, equal to 7, or greater than 7.
    a. equal volumes of 0.10 M acetic acid, CH_3CO_2H, and 0.10 M KOH are mixed
    b. 25 mL of 0.015 M NH_3 is mixed with 25 mL of 0.015 M HCl
    c. 150 mL of 0.20 M HNO_3 is mixed with 75 mL of 0.40 M NaOH
20. Does the pH of the solution increase, decrease, or stay the same when you
    a. Add solid ammonium chloride to a dilute aqueous solution of NH_3?
    b. Add solid sodium acetate to a dilute aqueous solution of acetic acid?
    c. Add solid NaCl to a dilute aqueous solution of NaOH?
21. What is the pH of a solution that consists of 0.20 M ammonia, NH_3, and 0.20 M ammonium chloride, NH_4Cl?
22. What is the pH of the solution that results from adding 30.0 mL of 0.015 M KOH to 50.0 mL of 0.015 M benzoic acid?
23. What mass of sodium acetate, $NaCH_3CO_2$, must be added to 1.00 L of 0.10 M acetic acid to give a solution with a pH of 4.50?
24. What is the pH of the buffer solution that contains 2.2 g of NH_4Cl in 250 mL of 0.12 M NH_3? Is the final pH lower or higher than the pH of the original ammonia solution?
25. A buffer is composed of formic acid and its conjugate base, the formate ion.
    a. What is the pH of a solution that has a formic acid concentration of 0.050 M and a sodium formate concentration of 0.035 M?
    b. What must the ratio of acid to conjugate base be to increase the pH by 0.5 unit?

26. Calculate the pH of a solution that has an acetic acid concentration of 0.050 M and a sodium acetate concentration of 0.075 M.
27. Which of the following combinations would be the best to buffer the pH of a solution at approximately 9?
    a. HCl and NaCl
    b. NH_3 and NH_4Cl
    c. CH_3CO_2H and $NaCH_3CO_2$
28. Describe how to prepare a buffer solution from NaH_2PO_4 and Na_2HPO_4 to have a pH of 7.5.
29. A buffer solution was prepared by adding 4.95 g of sodium acetate, $NaCH_3CO_2$, to 2.50 x 10^2 mL of 0.150 M acetic acid, CH_3CO_2H.
    a. What is the pH of the buffer?
    b. What is the pH of 1.00 x 10^2 mL of the buffer solution if you add 82 mg of NaOH to the solution?
30. A buffer solution is prepared by adding 0.125 mol of ammonium chloride to 5.00 x 102 mL of 0.500 M solution of ammonia.
    a. What is the pH of the buffer?
    b. If 0.0100 mol of HCl gas is bubbled into 5.00 x 10^2 mL of the buffer, what is the new pH of the solution?
31. Phenol, C_6H_5OH, is a weak organic acid. Suppose 0.515 g of the compound is dissolved in exactly 125 mL of water. The resulting solution is titrated with 0.123 M NaOH.

$$C_6H_5OH(aq) + OH^-(aq) \rightleftharpoons C_6H_5O^{-1}(aq) + H_2O(l)$$

    a. What is the pH of the original solution of phenol?
    b. What are the concentrations of all of the following ions at the equivalence point: Na^+, H_3O^+, OH^-, and $C_6H_5O^{-1}$?
    c. What is the pH of the solution at the equivalence point?
32. You require 36.78 mL of 0.0105 M HCl to reach the equivalence point in the titration of 25.0 mL of aqueous ammonia.
    a. What was the concentration of NH_3 in the original ammonia solution?
    b. What are the concentrations of H_3O^+, OH^{-1}, and NH_4^+ at the equivalence point?
    c. What is the pH of the solution at the equivalence point?
33. For the titration of 50.0 mL of 0.150 M ethylamine, $C_2H_5NH_2$, with 0.100 M HCl, find the pH at each of the following points and then use that information to sketch the titration curve and decide on an appropriate indicator.
    a. at the beginning, before HCl is added
    b. at the halfway point in the titration
    c. when 75% of the required acid has been added
    d. at the equivalence point
    e. when 10.0 mL more HCl has been added than is required
    f. Sketch the titration curve.
    g. Suggest an appropriate indicator for this titration.

34. You titrate 25.0 mL of 0.10 M NH3 with 0.10 M HCl.
    a. What is the pH of the NH3 solution before the titration begins?
    b. What is the pH at the equivalence point?
    c. What is the pH at the halfway point of the titration?
    d. What indicator in Figure 18.10 could be used to detect the equivalence point?
    e. Calculate the pH of the solution after adding 5.00, 15.0, 20.0, 22.0, and 30.0 mL of the acid. Combine this information with that in parts (a)–(c) and plot the titration curve.
35. Aniline hydrochloride, $(C_6H_5NH_3)Cl$, is a weak acid with a conjugate base aniline ($C_6H_5NH_2$). The acid can be titrated with a strong base such as NaOH. Assume 50.0 mL of 0.100 M aniline hydrochloride is titrated with 0.185 M NaOH (K_a for aniline hydrochloride is 2.4×10^{-5}.) The equation: $C_6H_5NH_3^+(aq) + OH^-(aq) \rightleftharpoons C_6H_5NH_2(aq) + H_2O(\ell)$
    a. What is the pH of the $(C_6H_5NH_3)Cl$ solution before the titration begins?
    b. What is the pH at the equivalence point?
    c. What is the pH at the half-equivalence point?
    d. Calculate the pH of the solution after adding 10.0, 20.0 and 30.0 mL of base.
36. Assume you dissolve 0.235 g of the weak acid benzoic acid, $C_6H_5CO_2H$, in enough water to make 1.00×10^2 mL of solution and then titrate the solution with 0.108 M NaOH. *Use a table to look up relevant K values.*

$$C_6H_5CO_2H(aq) + OH^{-1}(aq) \rightleftharpoons C_6H_5CO_2^{-1}(aq) + H_2O(\ell)$$

    a. What is the pH of the original benzoic acid solution?
    b. What are the concentrations of the following ions at the equivalence point: Na^+, H_3O^+, OH^-, and $C_6H_5CO_2^-$? What is the pH at the equivalence point?
37. A solution of the weak base aniline, $C_6H_5NH_2$, $K_b = 4.0 \times 10^{-10}$, in 25.0 mL of water requires 25.67 mL of 0.175 M HCl to reach the equivalence point.

$$C_6H_5NH_2(aq) + H_3O^+(aq) \rightleftharpoons C_6H_5NH_3^+(aq) + H_2O(\ell)$$

    a. What was the concentration of the aniline in the original solution?
    b. What are the concentrations of H_3O^+, OH^- and $C_6H_5NH_3^+$ at the equivalence point? What is the pH of the solution at the equivalence point?
38. For each of the following reactions, predict whether the equilibrium lies predominantly to the left or to the right. Explain your prediction briefly. *Use a table of acids and bases to answer this question.*
    a. $H_2S(aq) + CO_3^{2-}(aq) \rightleftharpoons HS^{-1}(aq) + HCO_3^{-1}(aq)$
    b. $HCN(aq) + SO_4^{2-}(aq) \rightleftharpoons CN^{-1}(aq) + HSO_4^{-1}(aq)$
    c. $SO_4^{2-}(aq) + CH_3CO_2H(aq) \rightleftharpoons HSO_4^{-1}(aq) + CH_3CO_2^{-1}(aq)$
39. A saturated solution of milk of magnesia, $Mg(OH)_2$, has a pH of 10.52. What is the hydronium ion concentration of the solution? What is the hydroxide ion concentration? Is the solution acidic or basic?
40. The ionization constant of a very weak acid, HA, is 4.0×10^{-9}. Calculate the equilibrium concentrations of H_3O^+, A^{-1} and HA in a 0.040 M solution of the acid.
41. Calculate the hydronium ion concentration and pH for a 0.015 M solution of sodium formate, $NaHCO_2$. *Use a table of acids and bases to answer this question.*

42. Calculate the hydronium ion concentration and the pH when 50.0 mL of 0.40 M NH_3 is mixed with 50.0 mL of 0.40 M HCl. *Use a table to look up relevant K values. Hint: Determine the region this problem would use from the WB + SA Titration Calculations lab.*
43. What is the pH of the solution that results from adding 25.0 mL of 0.12 M HCl to 25.0 mL of 0.43 M NH_3? *Use a table to look up relevant K values.*
44. For each of the following, decide whether the pH is less than, equal to, or greater than 7.
    a. 150 mL of 0.20 M HNO_3 is mixed with 75 mL of 0.40 M LiOH
    b. equal volumes of 0.10 M acetic acid, CH_3CO_2H, and 0.10 M KOH are mixed
    c. 25 mL of 0.015 M NH_3 is mixed with 12 mL of 0.015 M HCl
    d. 25 mL of 0.45 M H_2SO_4 is mixed with 25 mL of 0.90 M NaOH
45. What is the pH of 100. mL of 0.15 M acetic acid to which 1.56 g of sodium acetate, $NaCH_3CO_2$, has been added? *Use a table to look up relevant K values.*
46. Lactic acid, $CH_3CHOHCO_2H$, is found in sour milk, in sauerkraut, and in muscles after activity. K_a for lactic acid = 1.4×10^{-4}.
    a. If 2.75 g of $NaCH_3CHOHCO_2$, sodium lactate, is added to 5.00×10^2 mL of 0.100 M lactic acid, what is the pH of the resulting buffer solution?
    b. Will the pH be lower or higher than the pH of the pure lactic acid solution?
47. Calculate the pH of a solution that has an ammonium chloride concentration of 0.050 M and an ammonia concentration of 0.045 M. *Use a table to look up relevant K values.*
48. You dissolve 0.425 g of NaOH in 2.00 L of a buffer solution that has $[H_2PO_4^-] = [HPO_4^{2-}] =$ 0.132 M. What is the pH of the solution before adding the NaOH? After adding the NaOH? *Use a table to look up relevant K values.*

Answers to the Practice Problem Set:

1. *Answers:*
   a. HNO_3 + $H_2O \rightarrow$ H_3O^+ + NO_3^-
   acid A base B conjugate acid of B conjugate base of A
   b. HSO_4^- + $H_2O \rightarrow$ H_3O^+ + SO_4^{2-}
   acid A base B conjugate acid of B conjugate base of A
   c. $H_3O^+ + F^- \rightarrow$ HF + H_2O
   acid A base B conjugate acid of B conjugate base of A
2. *Answers:*
   Brønsted acid: $HC_2O_4^-(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + C_2O_4^{2-}(aq)$
   Brønsted base: $HC_2O_4^-(aq) + H_2O(\ell) \rightleftharpoons H_2C_2O_4(aq) + OH^-(aq)$
3. *Answers:*

	Brønsted acid	Brønsted base	conjugate base	conjugate acid
a.	CH_3CO_2H	C_5H_5N	$CH_3CO_2^-$	$C_5H_5NH^+$
b.	HSO_4^-	N_2H_4	SO_4^{2-}	$N_2H_5^+$
c.	$[Al(H_2O)_6]^{3+}$	OH^-	$[Al(H_2O)_5(OH)]^{2+}$	H_2O

4. $[H_3O^+] = 1.8 \times 10^{-4}$ M; $[OH^-] = 5.6 \times 10^{-11}$ M; acidic
5. pH = 11.48
6. a. HCO_2H; weakest acid = C_6H_5OH b. HCO_2H c. C_6H_5OH
7. 3.0×10^{-10}
8. 2.1×10^{-4}
9. chloroacetic acid
10. a. $OH^-(aq) + HPO_4^{2-}(aq) \rightleftharpoons H_2O(\ell) + PO_4^{3-}(aq)$ b. right
11. a. 0.0021 M b. 3.6×10^{-4}
12. $[H_3O^+] = 8.1 \times 10^{-11}$ M; $[OH^-] = 1.2 \times 10^{-4}$ M b. 9.7×10^{-7}
13. $[H_3O^+] = 1.5 \times 10^{-6}$ M; pH = 5.83
14. pH = 8.84
15. $[H_3O^+] = 1.1 \times 10^{-5}$ M; pH = 4.98
16. a. CH_3CO_2H and NH_4Cl b. NH_3, Na_2CO_3, and $NaCH_3CO_2$ c. CH_3CO_2H
17. *Answers:*
    $HCO_2H(aq) + H_2O(\ell) \rightleftharpoons HCO_2^-(aq) + H_3O^+(aq)$ $K_a = 1.8 \times 10^{-4}$
    $OH^-(aq) + H_3O^+(aq) \rightleftharpoons 2\ H_2O(\ell)$ $K = 1/K_w$
    $HCO_2H(aq) + OH^-(aq) \rightleftharpoons H_2O(\ell) + HCO_2^-(aq)$ $K = (1.8 \times 10^{-4})/K_w = 1.8 \times 10^{10}$
18. $[H_3O^+] = 1.5 \times 10^{-9}$ M; pH = 8.81
19. a. > 7 b. < 7 c. = 7
20. a. decreases b. increases c. no change
21. 9.25
22. 4.38
23. 4.7 g
24. pH = 9.11; lower pH than original solution

25. a. 3.59 b. 0.45
26. 4.92
27. answer (b)
28. 2 mol of base for every 1 mol of acid to some amount of water
29. a. 4.95 b. 5.05
30. a. 9.55 b. 9.50
31. a. pH = 5.62 b. $[Na^+] = 0.0323$ M, $[H_3O^+] = 6.5 \times 10^{-12}$ M, $[OH^-] = 0.0015$ M, $[C_6H_5O^-] = 0.0307$ M c. pH = 11.19
32. a. $[NH_3] = 0.0154$ M b. $[H_3O^+] = 1.9 \times 10^{-6}$ M, $[OH^-] = 5.3 \times 10^{-9}$ M, $[NH_4^+] = 0.00625$ M c. pH = 5.73
33. a. pH = 11.89 b. pH = 10.63 c. pH = 10.15 d. pH = 5.93 e. pH = 2.13 f. WB + SA curve (see titration lab) g. Alizarin or bromcresol purple (two possible examples)
34. a. pH = 11.13 b. pH = 5.28 c. pH = 9.25 d. methyl red (one possible answer) e. at 5.00 mL, pH = 9.85; at 15.00 mL, pH = 9.08; at 20.00 mL, pH = 8.65; at 22.00 mL, pH = 8.39; at 30.00 mL, pH = 2.04; graph = WB + SA curve (see titration lab)
35. a. pH = 2.81 b. pH = 8.72 c. pH = 4.62 d. at 10.00 mL, pH = 4.39; at 20.00 mL, pH = 5.07; at 30.00 mL, pH = 11.84
36. a. 2.96 b. $[Na^+] = [C_6H_5CO_2^-] = 0.0163$ M, $[H_3O^+] = 6.2 \times 10^{-9}$ M, $[OH^-] = 1.6 \times 10^{-6}$ M, pH = 8.21
37. a. 0.180 M b. $[H_3O^+] = 0.0015$ M, $[OH^-] = 6.7 \times 10^{-12}$ M, pH = 2.83, $[C_6H_5NH_3^+] = 0.0887$ M
38. a. right b. left c. left
39. $[H_3O^+] = 3.0 \times 10^{-11}$ M, $[OH^-] = 3.3 \times 10^{-4}$ M, basic
40. $[A^-] = [H_3O^+] = 1.3 \times 10^{-5}$ M, [HA] = 0.040 M
41. $[H_3O^+] = 1.1 \times 10^{-8}$ M, pH = 7.96
42. $[H_3O^+] = 1.1 \times 10^{-5}$ M, pH = 4.98
43. pH = 9.7
44. a. = 7 b. > 7 c. > 7 d. > 7
45. pH = 4.84 (4.85 if full quadratic)
46. a. pH = 3.54 b. buffer has higher pH than acid by itself
47. pH = 9.20
48. pH before = 7.21, after NaOH pH = 7.24