CH102 Spring 2019
Discussion #7
Chapter 14
Assume room temperature for all reactions

Student name____________________________ TA name________________________ Section_______________________

Things you should know when you leave Discussion today:

- $K_w < K_b < 1$;
- $K_w < K_a < 1$;
- Significant figures for logarithms use Mahafy 2nd edition Appendix I, page I-4

1. 2 M of HCN has a $K_a = 5 \cdot 10^{-10}$. What is the pH at equilibrium and the percent reaction of the acid?

2. A 0.1M solution of HA has pH=3.0 at room temperature.
   a. Based on the information given do you have a reaction of acid with water or base with water? Why?

   b. Write the chemical equation for the acid-base reaction that occurs in this solution. What are the conjugate acid and base pairs in the solution?

   c. Write the expression for equilibrium constant K: (does your expression represent K_a or K_b?)

   d. Calculate equilibrium concentration of hydronium.

   e. What percent of the acid reacted in solution? Is this a strong or weak acid?

   f. Based on the information given will you expect the equilibrium constant to be: (choose one)

$K_a << 1$ or $K_a >> 1$

3. A 0.1M solution of NaA has pH = 9.0 at room temperature.
   a. Based on the information given do you have a reaction of acid with water or base with water? Why?

   b. When salts that also contain an acid or base, like NaA, dissolve in water they ionize before they react. Write the reaction for NaA dissolving in water.

   c. Write the chemical equation for the acid-base reaction that occurs in this solution. What are the conjugate acid and base pairs in the solution? *NEVER include spectator ions in equilibrium reactions.*

   d. Write the expression for equilibrium constant K: (does your expression represent K_a or K_b?)

   e. What percent of the base reacted in solution? Is this a strong or weak base?

   f. Based on the information given will you expect the equilibrium constant to be: (choose one)

   $K_b << 1$ or $K_b >> 1$

4. Using the equilibrium constants in questions 2 and 3 derive the expression for equilibrium constant for autoionization of water.
   a. Write the chemical equation for autoionization of water:

   b. Write the expression for equilibrium constant K_w:

   c. Use questions 2c and 3d to derive the expression for K_w using K_a and K_b:

5. A 0.1 M solution of an acid, HB, is found to have a pH of 3.52 (This suggests that it is an equilibrium pH).

   a. Based on the information given do you have a reaction of acid with water or base with water? Why?

   What is the chemical reaction?

Calculate equilibrium concentration of hydronium:

What is the equilibrium expression for K?

ICE table:

What was the percent reaction of the acid?

Calculate the value of K_a:

6. 0.5 M solution of NaD (D^- is a salt of the weak acid HD with the $K_a = 2.5 \times 10^{-10}$).
   a. Based on the information given do you have a reaction of acid with water or base with water? Why?

   Write the net chemical reaction:

   What is the equilibrium expression? (Is that a K_a , K_b or neither?)

   Calculate the value of K for the reaction of D^- and water? *(Hint: use the connection between K_a,K_b and K_w)*

   ICE table:

Fill in the data from the ICE table into your equilibrium expression K_b:

pOH (at equilibrium) =

pH (at equilibrium) =

7. Equal volumes of a 0.10 M solution of a weak acid, HC, with $K_a = 1 \cdot 10^{-6}$, and a 0.20 M solution of NaOH are combined. What is the pH of the resulting solution? *Hint: what will react first? What will react completely? What is the limiting reagent?*

8. When 0.1mol of NaA is dissolved in 1L of pure water at room temperature, the pH is measured to be 7.0. Is HA a strong or weak acid?

   a. Based on the information given will you expect the equilibrium constant to be: (choose one)

   $K_a << 1$ or $K_a >> 1$

9. Rank the acids HA, HB, HC, and HD from questions 5 through 8 in order of increasing acid strength.

10. You have a 1M solution of each of the salts below. Which of the salts will give the highest pH? Which of the salts will give the lowest pH?

    NH_4CH_3COO (ammonium acetate),
    NH_4CN (ammonium cyanide),
    $NH_4HC_2O_4$ (ammonium oxalate).

	K_a	K_b
CH_3COOH	$2 \cdot 10^{-5}$	
HCN	$6 \cdot 10^{-10}$	
$H_2C_2O_4$	$6 \cdot 10^{-2}$	
NH_3		$2 \cdot 10^{-5}$

11. 250. mL of an 0.8 M solution of NaAc (salt of the weak acid HAc with the K_a of $2.5x10^{-10}$) is added to 250. mL of water.

What is the chemical reaction?

What will be the concentration of Ac^- after dilution?

What is the equilibrium expression of K (Is it a K_a or K_b?) for the reaction of $NaAc^-$ and water:

Find the value of the K:

Based on the value of K_b is Ac^- a strong base or a weak base?

Based on the value of K_a is HAc a strong acid or a weak acid?

ICE table:

pOH (at equilibrium) =

pH (at equilibrium) =

Really Challenging problems to do at home:

12. One liter solution has 4.4 mol of HCl, 4.6mol of NaOH and 0.2 mol of HCN. What is the pH when the resulting solution reaches equilibrium? (K_a of HCN is 5×10^{-10}) *Hint: What will react completely? What is the limiting reagent?*

13. If equal volumes of 4.4 M HCl, 4.6 M NaOH and 0.2 M HCN are mixed (K_a of HCN is 5×10^{-10}), what is the pH when the resulting solution reaches equilibrium?

14. Determine the K_b of a base, at 25°C, if a 0.02 M aqueous solution of the base has a pH of 7.60 (This implies that it is an equilibrium pH). *Hint: compare pH of the solution with the pH of the water and decide if you can ignore the initial concentration of the $H3O^+$.*

In preparation for next week's discussion section:

1. You add HCl to a solution of equal moles of a weak acid and its conjugate base, and the number of moles of strong acid added is **smaller** than the number of moles of conjugate base initially present in the solution. Circle the correct answer(s) of the choices in the brackets.

    a. The number of moles of A^- [decreases / increases] from the initial amount.

    b. The number of moles of HA [decreases / increases] from the initial amount.

    c. The number of moles of [HCl / HA / A^-] = 0 after neutralization reaction took place but before an equilibrium is established because [HCl / HA / A^-] is the limiting reagent and will be used up completely.

    d. When the strong acid has completely reacted with the solution, you have a [weak acid / weak base / strong acid / both weak acid and weak base] present.

2. You add an HCl to a solution of equal moles of a weak acid and its conjugate base and the number of moles of strong acid added is **equal to** the number of moles of conjugate base initially present in the solution. Circle the correct answer(s) of the choices in the brackets:

    a. The number of moles of A^- [decreases / increases] from the initial amount.

    b. The number of moles of HA [decreases / increases] from the initial amount.

    c. The number of moles of [HCl / HA / A^-] = 0 after neutralization reaction took place but before an equilibrium is established because [HCl / HA / A^-] is the limiting reagent and will be used up completely.

    d. When the strong acid has completely reacted with the solution, you still have a [Weak acid / weak base / strong acid / both weak acid and weak base] present.

3. You add an HCl to a solution of equal moles of a weak acid and its conjugate base, and finally the number of moles of strong acid added is **greater than** the number of moles of conjugate base present in the solution initially. Circle the correct answer(s) of the choices in the brackets:

    a. The number of moles of A^- [decreases / increases] from the initial amount.

    b. The number of moles of HA [decreases / increases] from the initial amount.

    c. The number of moles of [HCl / HA / A^-] = 0 after neutralization reaction took place but before an equilibrium is established because [HCl / HA / A^-] is the limiting reagent and will be used up completely.

    d. When the HCl has completely reacted with the solution, you still have a

        [Weak acid / weak base / strong acid / strong base] present.

4. You add NaOH to a solution of equal moles of a weak acid and its conjugate base, and the number of moles of strong base added is **smaller** than the number of moles of conjugate base initially present in the solution. Circle the correct answer(s) of the choices in the brackets.

    a. The number of moles of A^- [decreases / increases] from the initial amount.

    b. The number of moles of HA [decreases / increases] from the initial amount.

    c. The number of moles of [OH^- / HA / A^-] = 0 after neutralization reaction took place but before an equilibrium is established because [OH^- / HA / A^-] is the limiting reagent and will be used up completely.

    d. When NaOH has completely reacted with the solution, you still have a [Weak acid / weak base / strong acid / strong base / both weak acid and weak base] present.

5. You add a NaOH to a solution of equal moles of a weak acid and its conjugate base and the number of moles of strong base added is **equal to** the number of moles of conjugate base initially present in the solution. Circle the correct answer(s) of the choices in the brackets:

    a. The number of moles of A^- [decreases / increases] from the initial amount.

    b. The number of moles of HA [decreases / increases] from the initial amount.

    c. The number of moles of [OH^- / HA / A^-] = 0 after neutralization reaction took place but before an equilibrium is established because [OH^- / HA / A^-] is the limiting reagent and will be used up completely.

    d. When NaOH has completely reacted with the solution, you still have a [weak acid / weak base / strong acid / strong base / both weak acid and weak base] present.

6. You add a NaOH to a solution of equal moles of a weak acid and its conjugate base, and finally the number of moles of strong base added is **greater than** the number of moles of conjugate base present in the solution initially. Circle the correct answer(s) of the choices in the brackets:

    a. The number of moles of A^- [decreases / increases] from the initial amount.

    b. The number of moles of HA [decreases / increases] from the initial amount.

    c. The number of moles of [OH^- / HA / A^-] = 0 after neutralization reaction took place but before an equilibrium is established because [OH^- / HA / A^-] is the limiting reagent and will be used up completely.

    d. When the NaOH has completely reacted with the solution, you still have a [weak acid / weak base / strong acid / strong base] present.

Answers:

1. pH = 4.5; 0.00158%
2.
   a. acid; pH < 7
   b. $HA_{(aq)} + H_2O_{(l)} \rightleftharpoons A^-_{(aq)} + H_3O^+_{(aq)}$;
      acid base conj. base conj. acid
   c. $K_a = \frac{[H_3O^+][A^-]}{[HA]}$
   d. 0.001 M
   e. 1%; weak
   f. $K_a << 1$
3.
   a. base; pH > 7
   b. $NaA_{(s)} \rightleftharpoons A^-_{(aq)} + Na^+_{(aq)}$
   c. $A^-_{(aq)} + H_2O_{(l)} \rightleftharpoons HA_{(aq)} + OH^-_{(aq)}$;
      base acid conj. acid conj. base
   d. $K_b = \frac{[OH^-][HA]}{[A^-]}$
   e. 0.01%; v weak
   f. $K_b << 1$
4.
   a. $2H_2O_{(l)} \rightleftharpoons H_3O^+_{(aq)} + OH^-_{(aq)}$
   b. $K_w = [OH^-][H_3O^+]$
   c. $K_w = K_bK_a$ will equal $K_w = [OH^-][H_3O^+]$
5. $HB_{(aq)} + H_2O_{(l)} \rightleftharpoons B^-_{(aq)} + H_3O^+_{(aq)}$; $K = \frac{[H_3O^+][B^-]}{[HB]}$; 0.32%; 9.12×10^{-7}
6. $D^-_{(aq)} + H_2O_{(l)} \rightleftharpoons HD_{(aq)} + OH^-_{(aq)}$; $K = \frac{[OH^-][HD]}{[D^-]}$; 4.0×10^{-5}; pOH = 2.3; pH = 11.7
7. 12.7
10. highest—NH_4CN; lowest—$NH_4HC_2O_4$
11. $Ac^-_{(aq)} + H_2O_{(l)} \rightleftharpoons HAc_{(aq)} + OH^-_{(aq)}$; $[Ac^-] = 0.4$ M; $K_b = \frac{[OH^-][HD]}{[D^-]}$; $K_b = 4 \times 10^{-5}$; weak base; v weak acid; pOH = 2.25; pH = 11.75
12. 11.3
13. 11.1
14. $K_b = 6 \times 10^{-12}$

In preparation for next week's discussion section:

1.
   a. Decreases
   b. Increases
   c. HCl, HCl
   d. Both weak acid and weak base
2.
   a. Decreases
   b. Increases
   c. HCl/A, HCl/A
   d. Weak acid
3.
   a. Decreases
   b. Increases
   c. A, A
   d. Weak acid, strong acid
4.
   a. Increases
   b. Decreases
   c. OH, OH
   d. Strong base/ Both weak acid and weak base
5.
   a. Increases
   b. Decreases
   c. OH, OH
   d. Weak base
6.
   a. Increases
   b. Decreases
   c. HA, HA
   d. Weak base/ Strong base