Chemistry 12 Acid Base Worksheet No. 1 Name_____

1. Write the equations for the hydrolysis of the following acids in water and identify the congugate pairs.

   a. $HSO_3^-$

   b. $CH_3COOH$

   c. $NH_4^+$

   d. HCN

2. Write the equations for the hydrolysis of the following bases in water and identify the conjugate pairs.

   a. $O^{2-}$

   b. $OH^-$

   c. $NH_3$

   d. $CO_3^{2-}$

3. Calculate the pH of the following solutions:

   a. 0.0020 M HCl

   b. 0.10 M $HNO_3$

   c. 0.10 M NaOH

4. If a solution of acidified water has a pH of 3.00 what is its $[H_3O^+]$?

5. Arrange the following species according to their strength as bases:

   $H_2O$, $F^-$, $Cl^-$, $NO_2^-$, $CN^-$

6. At 60°C the value of $K_w$ is $1.0 \times 10^{-13}$. Calculate $[H_3O^+]$ and $[OH^-]$ at 60°C.

Chemistry 12 Acid Base Worksheet 2 Name_____

1. Fill in the missing values:

| Solution | $[H_3O^+]$ | $[OH^-]$ | pH | pOH |
|---|---|---|---|---|
| Water | $1.0 \times 10^{-7}$ | | | |
| 0.10 M HCl | | | 1.00 | |
| 0.010 M NaOH | | | 12.00 | |
| 1.0 M $HNO_3$ | | $1.0 \times 10^{-14}$ | | |
| 1.0 M $H_2SO_4$ | | | | 14.30 |
| blood | $3.98 \times 10^{-8}$ | | | |
| 16 M $HNO_3$ | | $6.25 \times 10^{-16}$ | | |
| 6.0 M NaOH | $1.67 \times 10^{-15}$ | | | |
| 0.10 M $Na_2O$ | | | | |
| 0.010 M $Ca(OH)_2$ | | | | |
| 2.0 M NaOH | | | | |

2. Calculate the concentration of $OH^-$ in a water solution in which the $H_3O^+$ concentration is $1.0 \times 10^{-11}$ M. Then calculate the pH, and tell whether the solution is acidic, basic, or neutral.

3. Calculate the concentration of $H_3O^+$ in a water solution in which the $OH^-$ concentration is $1.0 \times 10^{-8}$ M. Then calculate the pH, and tell whether the solution is acidic, basic, or neutral.

4. Calculate the concentration of $H_3O^+$ and $OH^-$ in a water solution in which the pH = 5.00. Tell whether the solution is acidic, basic, or neutral.

5. Calculate the pH of a solution in which pOH = 13.00. Then calculate the concentration of $OH^-$ and of $H_3O^+$ in the solution. Tell whether the solution is acidic, basic, or neutral.

6. Calculate the concentration of $OH^-$ in a water solution in which the $H_3O^+$ is $1.0 \times 10^{-12}$ M. Then calculate the pH and tell whether the solution is acidic, basic, or neutral, and support your answer.

7. Calculate the concentration of $H_3O^+$ in a water solution in which the $OH^-$ concentration is $1.0 \times 10^{-6}$ M. Then calculate the pH, and tell whether the solution is acidic, basic, or neutral and support your answer.

Chemistry 12 Acid Base Worksheet No. 3 Name_____

1. A solution of 0.25 M HCN is prepared at 25°C.
   a. Write the equation for the hydrolysis of HCN in water.
   b. Write the formula for the conjugate base of HCN.
   c. Write the equilibrium expression for the HCN in water.
   d. Calculate the $[H_3O^+]$ of the 0.25 M solution.
   e. Calculate the pH of the solution.
   f. Calculate the $[OH^-]$ of the solution.
   g. Calculate the equilibrium concentration of HCN in water.
   h. Calculate the % dissociation of the acid.

2. Calculate the $K_a$ and the % dissociation for a weak acid if a 0.20 M solution has a pH of 3.45.

3. HX is a weak acid with a $K_a$ of $1.0 \times 10^{-8}$. Calculate the pH of a 1.0 M solution of HX.

4. Write the acid-base equation for the reaction between $HPO_4^{2-}$ and $HCO_3^-$.

5. Write the equation for the reaction of $HNO_2$ with water, and indicate the conjugate acid-base pairs. Write the equilibrium expression and calculate the concentration of $[H_3O^+]$ in a 0.40 M solution of this acid.

6. Write an equation for the reaction of a weak monoprotic acid, HA, with water, and indicate the conjugate acid-base pairs. Then write an equilibrium expression and calculate $K_a$ for the acid, given that $[H_3O^+]$ in a 0.35 M solution of the acid is $4.5 \times 10^{-4}$ M. Where would this acid fit in your Strengths of Acids Table?

7. Write the equation for the reaction of HCN with water, and indicate the conjugate acid-base pairs. Then write the equilibrium expression and calculate the concentration of $CN^-$ in a solution made by dissolving 1.6 moles HCN in enough water to make 2.0 L of solution.

8. How many grams of $CH_3COOH$ are dissolved in 2.00 L of a solution with a pH=2.456?

9. A 1.0 mL sample of 0.1 M HCl is diluted with water to a volume of 100 mL. By how many pH units does the pH change because of the dilution?

10. A 0.18 M solution of an acid HX has a pH of 1.40. What is the $K_a$ for the acid?

11. A 1.0 M solution of a weak acid HX has a pH of 4.26. Calculate the $K_a$ for HX.

12. Calculate the % dissociation of 0.20 M HCN.

13. A 0.10 M solution of weak monoprotic acid is 0.025% dissociated. What is its $K_a$?

14. Determine the pH of a 0.50 M HF solution. Show all work and state any assumptions made.

15. A 0.10 M solution of a weak monoprotic acid has a pH of 1.60. Calculate the $K_a$. Show all work and state any assumptions made.

16. Calculate the $pK_a$ of an acid with a $K_a = 1.5 \times 10^{-9}$.

17. Consider the following experimental results:

| | $HIn_1/In_1^-$ | $HIn_2/In_2^-$ | $HIn_3/In_3^-$ |
|---|---|---|---|
| 1.0 M $HNO_3$ | yellow | blue | pink |
| 1.0 M KOH | pink | yellow | colourless |
| $HA_1/A_1^-$ | yellow | yellow | colourless |
| $HA_2/A_2^-$ | yellow | blue | pink |

a) what colour is each species: $HIn_1$ $In_1^-$
$HIn_2$ $In_2^-$
$HIn_3$ $In_3^-$

b) which is the stronger acid in each pair: $HIn_1$:$HA_1$
$HIn_1$:$HA_2$
$HIn_1$:$HIn_2$
$HA_1$:$HA_2$

18. Phophoric acid is a triprotic acid. Use the dissociation constants for the three separate dissociations to find the constant for the complete dissociation.

19. A sample of human blood was tested and found to have a pH of 7.43. Calculate the $[H^+]$ and $[OH^-]$.

20. Calculate the pH of a 2.0 M HCl solution.

21. Calculate the pH of a 0.15 M NaOH solution.

22. Calculate the pH of a 0.025 M $Ba(OH)_2$ solution.

Chemistry 12 Acid Base Worksheet No. 3b

1. A solution of 0.30 M $NH_3$ is prepared at 25°C.
   a. Calculate the $[OH^-]$ of the 0.30 M solution.
   b. Calculate the pH of the solution.
   c. Calculate the $[H_3O^+]$ of the solution.
   d. Calculate the equilibrium concentration of $NH_3$ in water.
   e. Calculate the % dissociation of the base.

2. Calculate the value of the $K_b$ for the acetate ion, $CH_3COO^-$.

3. Calculate the pH of a 1.0 M solution of $NH_3$. Show all work and state any assumptions made.

4. The cyanide ion, $CN^-$, is a Brönsted-Lowry base. Give the dissociation equation of the cyanide ion in water. What is the $K_b$ expression for this reaction. What is the value of $K_b$ at 25°C?

5. The $K_b$ of strychnine at 25°C is $1.8 \times 10^{-6}$. Calculate the $[OH^-]$ of a 0.15 M solution of strychnine and calculate the pH of the solution.

6. Give the dissociation equation of $NH_3$ in water. Calculate the pH of 0.10 M $NH_3$ solution at 25°C. What is the percentage dissociation of this solution?

7. Calculate the $pK_b$ of a base with a $K_b = 2.0 \times 10^{-7}$.

8. Calculate the $K_b$ for the acetate ion, $CH_3COO^-$ at 25°C. Find the pH of a 0.25 M solution of $NaCH_3COO$ (assuming that the $Na^+$ ion has no effect on pH).

9. Calculate the pOH of a 0.50 M solution of NaF, assuming that the $Na^+$ ion has no effect on the pOH.

10. Calculate the $K_a$ for the conjugate acid of a weak base if a 0.10 M solution of the base has a pH of 11.62 at 25°C.

11. Calculate the $K_b$ for a weak base is a 0.250 M solution has a pOH of 2.567.

12. Calculate the $K_b$ for a weak base if a 0.20 M solution has a pH of 10.45.

Chemistry 12 Self Test #1

1. Identify the acid-base reactions
   (a) $H_2SO_3 + HCO_3^- \text{------->} HSO_3^- + H_2CO_3$
   (b) $BaCl_2 + Na_2SO_4 \text{------->} 2NaCl + BaSO_4$
   (c) $2HCl + Zn \text{------->} ZnCl_2 + H_2$
   (d) $KHSO_3 + Na_3PO_4 \text{------->} K^+ + 3Na^+ + SO_3^{2-} + HPO_4^{2-}$
   (e) $Cu + 2Ag^+ \text{------->} 2Ag + Cu^{2+}$
   (f) $HNO_2 + NH_3 \text{------->} NO_2^- + NH_4^+$
   (g) $2KI + Pb(NO_3)_2 \text{------->} 2KNO_3 + PbI_2$
   (h) $H_2CO_3 + K_2S \text{------->} KHCO_3 + KHS$
   (i) $2C + 3H_2 \text{------->} C_2H_6$
   (j) $H_2O + NH_2^- \text{------->} NH_3 + OH^-$
   (k) $Cl_2 + 2NaI \text{------->} 2NaCl + I_2$
   (l) $NaClO_4 + HI \text{------->} NaI + HClO_4$

2. Write the conjugate acid of:
   (a) $NO_2^-$
   (b) $HCO_3^-$
   (c) $HPO_4^{2-}$
   (d) $CH_3NH_2$

3. Write the conjugate base of:
   (a) HF
   (b) $HCO_3^-$
   (c) $NH_3$
   (d) $N_2H_5^+$
   (e) $HPO_4^{2-}$
   (f) $(CH_3)_2NH_2^+$

4. Identify the two acids and the two bases.
   (a) $2HBr + S^{2-} \text{<------>} H_2S + Br_2$
   (b) $CO_3^{2-} + HNO_2 \text{<------>} NO_2^- + HCO_3^-$
   (c) $NH_3 + H_2O \text{<------>} NH_4^+ + OH^-$

5. Write the Bronsted-Lowry acid base equilibria which occur when the following pairs of substances are mixed in solution. Identify the conjugate pairs formed.
   (a) $HNO_2$ and $NH_3$
   (b) $CO_3^{2-}$ and HF
   (c) $HCO_3^-$ and $S^{2-}$
   (d) $H^-$ and $H_2O$
   (e) $H_2S$ and $HO_2^-$
   (f) $O^{2-}$ and $H_2O$
   (g) $H_2O$ and $H_2SO_3$

6. Classify each of the following as strong acid, weak acid, strong base, weak base, salt.
   (a) NaCl
   (b) KOH
   (c) $H_2O$
   (d) $CH_3COOH$
   (e) $H_2SO_4$
   (f) $NH_3$
   (g) KI
   (h) $CaCl_2$

7. List the following acids in decreasing order of strength.
   $CH_3COOH$, $HNO_2$, $HClO_4$ and $HCO_3^-$

8. List the conjugate bases of the following acids in decreasing order of strength.
   $CH_3COOH$, $HNO_2$, $HClO_4$ and $HCO_3^-$

9. Complete the following acid-base equilibria after identifying the stronger acid.
   (a) $H_2O_2$ and $HSO_3^-$
   (b) $H_2PO_4^-$ and $HCO_3^-$

10. Complete the following acid-base equilibria after identifying the stronger base.
   (a) $HCO_3^-$ and $HS^-$
   (b) $OH^-$ and $NH_3$
   (c) $HPO_4^{2-}$ and $HS^-$
   (d) $HS^-$ and $HSO_3^-$

11. Classify the following statments as true or false.
   (a) A strong electrolyte is more completely ionized than a weak electrolyte.
   (b) In solutions of equal concentration, a weak electrolyte will have a lower electrical conductivity than a strong electrolyte.
   (c) The stronger an acid, the stronger its conjugate base.

12. Explain why HF is a stonger acid than $H_2O$ but a weaker acid than HCl.

13. For the following, state whether reactants or products are favored.
   (a) $HPO_4^{2-} + HCO_3^- \leftrightarrow H_2PO_4^- + CO_3^{2-}$
   (b) $HCl + CH_3COO^- \leftrightarrow CH_3COOH + Cl^-$
   (c) $NH_4^+ + F^- \leftrightarrow HF + NH_3$
   (d) $CH_3COOH + CO_3^{2-} \leftrightarrow CH_3COO^- + HCO_3^-$
   (e) $HCN + F^- \leftrightarrow HF + CN^-$
   (f) $HCO_3^- + OH^- \leftrightarrow CO_3^{2-} + H_2O$
   (g) $HF + SO_4^{2-} \leftrightarrow F^- + HSO_4^-$
   (h) $H_2CO_3 + F^- \leftrightarrow HCO_3^- + HF$
   (i) $HSO_4^- + HCO_3^- \leftrightarrow SO_4^{2-} + H_2CO_3$

14. Write an equation to show the ionization of water.

15. Write the mathematical definition for pH

16. Calculate the $[H_3O^+]$ and the $[OH^-]$ in a solution in which:
(a) pH = 9.00
(b) pH = 4.75
(c) pH = -1.10
(d) pH = 0.00
(e) pH = 12.35
(f) pH = 14.80
(g) pOH = 9.00
(h) pOH = 4.75
(i) pOH = -1.10
(j) pOH = 0.00
(k) pOH = 12.35
(l) pOH = 14.80

17. Calculate the $[H_3O^+]$, the $[OH^-]$, the pH and the pOH for
(a) 0.0010 M HCl
(b) 4.0 M NaOH
(c) $2.5 \times 10^{-3}$ M $NaNH_2$
(d) $6.0 \times 10^{-3}$ M $Ca(OH)_2$
(e) Saturated solution of $Mg(OH)_2$ ; $K_{sp} = 5.6 \times 10^{-12}$

Chemistry 12 Acid-Base #1 Review

1. At 30°C, $K_w = 3.0 \times 10^{-14}$. Therefore, a solution at 30 °C in which the $[OH^-] = 1.732 \times 10^{-7}$ M is best described as
   A. acidic
   B. basic
   C. neutral
   D. amphoteric
   E. amphiprotic

2. What is the pH of a neutral solution at 10°C when $k_w = 3.0 \times 10^{-15}$?
   A. 3.0
   B. 7.0
   C. 7.3
   D. 12
   E. 14.5

3. The equation: pH + pOH = 14.00 is true
   A. for all solvents
   B. at all temperatures
   C. at 20°C
   D. at 25 °C
   E. for all solvents and at all temperatures

4. A 0.03 M borax solution has a pH of about 9.2. Which statement about this solution is true?
   A. $[H^+] = 6.3 \times 10^{-10}$ M
   B. $[H^+] = 1.6 \times 10^{-5}$ M
   C. $[H^+] = 2.0 \times 10^{-2}$ M
   D. $[H^+] = 9.2$ M
   E. the solution is basic

5. The concentration of hydroxide ion in an aqueous solution is $3.3 \times 10^{-6}$ M. What is the pH of the solution?
   A. $3.03 \times 10^{-9}$
   B. 3.3
   C. 5.48
   D. 8.52
   E. -5.48

6. The pH of a soft drink is 5.67. What is the concentration of the $OH^-$ ?
   A. $4.7 \times 10^{-9}$ M
   B. $2.1 \times 10^{-6}$ M
   C. $6.7 \times 10^{-5}$ M
   D. 5.67 M
   E. 8.33 M

7. A solution was made by dissolving 0.0788 g $Ca(OH)_2$, a strong base, in 100 mL water. The pH of this solution was

A. 1.67
B. 1.97
C. 9.33
D. 12.03
E. 12.33

8. The pH of a solution of hydrochloric acid was found to be 2.55. What was the concentration of the acid?

A. $3.6 \times 10^{-12}$ M
B. $2.8 \times 10^{-3}$ M
C. $5.5 \times 10^{-2}$ M
D. 2.6 M
E. 11 M

9. Nitrous acid is a weak acid that ionizes in water according to the following equilibrium:

$$HNO_2 + H_2O <----> H_3O^+ + NO_2^-$$

The expression for the acid ionization constant, $K_a$ , is

A. $K_a = \dfrac{[H_3O^+]\,[NO_2^-]}{[H_2O]\,[HNO_2]}$

B. $K_a = \dfrac{[H^+]\,[NO_2^-]}{[HNO_2]}$

C. $K_a = [H^+]\,[NO_2^-]$

D. $K_a = \dfrac{[HNO_2]}{[H^+]\,[NO_2^-]}$

E. $K_a = \dfrac{[H_2O]\,[HNO_2]}{[H_3O^+]\,[NO_2^-]}$

10. The pH of a 0.10 M lactic acid solution at 25°C is 2.43. What is the value of $K_a$ for this acid?

A. $1.3 \times 10^{-4}$
B. $1.4 \times 10^{-4}$
C. $3.7 \times 10^{-3}$
D. $7.4 \times 10^{-3}$
E. 0.24

11. The $K_a$ of glycollic acid at 25°C is $1.5 \times 10^{-4}$ . Calculate the pH of a 0.14 M solution of this acid.

A. 1.06
B. 1.49
C. 2.34
D. 2.96
E. 4.68

12. The $K_b$ of strychnine at 25°C is $1.8 \times 10^{-6}$ . What is the pH of a 0.15 M solution of this base?

A. 3.28
B. 5.74
C. 8.26
D. 10.72
E. 11.54

13. At 25°C, the pH of a 0.12 M solution of morphine, a base, is 10.64. What is the value of the $K_b$ for morphine?

A. $4.6 \times 10^{-21}$
B. $2.3 \times 10^{-8}$
C. $1.9 \times 10^{-7}$
D. $1.6 \times 10^{-6}$
E. $1.5 \times 10^{-4}$

14. The cyanide ion, $CN^-$, is a Bronsted base. In a dilute solution of this ion together with the sodium ion, which of the following relationships is true where $K_b$ refers to the base ionization constant for the cyanide ion?

A. $[OH^-] = \dfrac{[CN^-]}{[HCN]} \times K_b$

B. $[HCN] = \dfrac{[OH^-]}{[CN^-]} \times K_b$

C. $K_b = \dfrac{[H_2O]\,[CN^-]}{[HCN]\,[OH^-]}$

D. $[CN^-] = \dfrac{[HCN]}{[OH^-]} \times K_b$

E. $K_b = \dfrac{[HCN]\,[OH^-]}{[H_2O]\,[CN^-]}$

15. Calculate the % ionization of the acid in 0.075 M acetic acid solution at 25°C.

A. 0.018 %
B. 0.075 %
C. 0.12 %
D. 1.6 %
E. 100 %

16. An acid that is a weaker acid than acetic acid might have a $pK_a$ of
    A. $1.78 \times 10^{-6}$
    B. $8.5 \times 10^{-4}$
    C. 4.65
    D. 4.85
    E. -4.74

17. Considering the data in the following table, which species is the strongest base?

| compound | $pK_a$ |
|---|---|
| acetic acid | 4.74 |
| barbituric acid | 4.01 |
| tyrosine | 8.40 |
| phenol | 9.89 |

    A. phenol
    B. acetate ion
    C. anion of barbituric acid
    D. conjugate base of phenol
    E. conjugate base of tyrosine

18. An acid with a $K_a$ of $1.5 \times 10^{-9}$ has a $pK_a$ equal to
    A. 1.59
    B. 5.18
    C. 8.82
    D. 9.15
    E. 9.18

19. If an acid has a $pK_a$ equal to 6.63, its $K_a$ value is
    A. $4.3 \times 10^{-8}$
    B. $2.3 \times 10^{-7}$
    C. $5.8 \times 10^{-7}$
    D. $6.3 \times 10^{-6}$
    E. 7.37

20. The $K_a$ of a monoprotic acid is $3.6 \times 10^{-6}$ at 25°C. What is the $pK_b$ of its conjugate base?
    A. $2.79 \times 10^{-9}$
    B. 5.24
    C. 5.44
    D. 7.66
    E. 8.56

**Acid #4**

1. What is the concentration of a NaOH solution when 30 mL of 0.50 M HCl are needed to neutralize 50 mL of the base?

2. What is the concentration of acetic acid in vinegar when 32.5 mL of 0.56 M NaOH are required to neutralize 15 mL of vinegar?

3. What is the concentration of $NH_3$ in household ammonia when 48.25 mL of 0.525 M HCl are needed to neutralize 22.0 mL of the ammonia solution?

4. What is the concentration of an $H_2SO_4$ solution when 23 mL of 0.15 M KOH are needed to neutralize 15 mL of the acid?

5. A 5.0 g tablet of $Mg(OH)_2$ neutralizes 450 mL of HCl acid. What is the molarity of the HCl acid?

6. What mass of $Ca(OH)_2$ can be neutralized by 23 mL of 0.25 M $HNO_3$?

**Acid #5**

1. Complete the table by filling in the blank spaces.

| Acid | Base | Salt 0.10 M | Ion hydrolyzing | Relative acidity | pH |
|---|---|---|---|---|---|
| HCl | NaOH | | | | |
| | | KBr | | | |
| | | $Ca(NO_3)_2$ | | | |
| | $NH_3$ | $NH_4Cl$ | | | |
| $H_2SO_4$ | | $KHSO_4$ | | | omit |
| $H_2CO_3$ | | $Na_2CO_3$ | | | |
| $H_2CO_3$ | | $NaHCO_3$ | | | omit |
| HF | KOH | | | | |
| HCl | $Al(OH)_3$ | | | | omit |
| | | $FeCl_3$ | | | omit |
| | | HCOOK | | | |
| | $Ca(OH)_2$ | $Ca(CN)_2$ | | | |

2. Predict the relative acidity of each salt

| | |
|---|---|
| $AlCl_3$ | $NH_4Br$ |
| $Fe(NO_3)_3$ | $Ca(NO_3)_2$ |
| $Na_3PO_4$ | $Na_2CO_3$ |
| $NH_4CH_3COO$ | $K_2SO_4$ |
| $K_2HPO_4$ | $(NH_4)_2C_2O_4$ |
| $NaHCO_3$ | $(NH_4)_2CO_3$ |
| $NaHSO_3$ | $KH_2PO_4$ |
| $AlI_3$ | $KHSO_4$ |

CHEMISTRY 12 Name: _____

## Salt Hydrolysis / Chemical Indicators: Practice Problems

1. Which of the following substances is a salt that produces a basic aqueous solution?
   a. KBr
   b. $NH_3$
   c. $NH_4Cl$
   d. $Na_3PO_4$

2. An indicator, HInd, is found to establish the following equilibrium:

$$HInd_{(aq)} \leftrightarrow H^+_{(aq)} + Ind^-_{(aq)}$$

When the indicator was added to the solutions of various pH values, the following data were collected:

| **pH** | **2** | **4** | **6** | **8** | **10** | **12** |
|---|---|---|---|---|---|---|
| **Color** | yellow | yellow | yellow | yellow | green | blue |

At pH 10,
   a. $[H^+] = K_a$
   b. $[H^+] = pH$
   c. $[H^+] = [Ind^-]$
   d. $[H^+] = [HInd]$

3. Which of the following will have the greatest $[H_3O^+]$?
   a. 0.10 M NaF
   b. 0.10 M $NaIO_3$
   c. 0.10 M $Na_2SO_3$
   d. 0.10 M $NaCH_3COO$

4. A solution of unknown pH is tested with various indicators resulting in the following data:

| Indicator | Color |
|---|---|
| methyl violet | blue |
| bromcresol green | blue |
| methyl red | yellow |
| bromthymol blue | yellow |
| phenolphthalein | colorless |

From the above data, the pH of the solution is approximately

a. 1.6
b. 5.4
c. 6.0
d. 8.2

5. Consider the following data:

| Indicator | Color of Acid Form | Color of Base Form | Ka Value |
|---|---|---|---|
| 'A' | red | yellow | $1.0 \times 10^{-3}$ |
| 'B' | yellow | blue | $1.0 \times 10^{-9}$ |

At a pH of 7.0 the predominant color of

a. Indicator 'A' and indicator 'B' will both be yellow.
b. Indicator 'A' will be red and indicator 'B' will be yellow.
c. Indicator 'A' will be yellow and indicator 'B' will be blue.
d. Indicator 'A' will be orange and indicator 'B' will be green.

6. The approximate $K_a$ value for the indicator thymolphthalein is

a. $1 \times 10^{-10}$
b. $1 \times 10^{-4}$
c. 4
d. 10

7. The value of $K_b$ for $HSO_3^-$ is

a. $6.7 \times 10^{-13}$
b. $1.0 \times 10^{-7}$
c. $1.5 \times 10^{-2}$
d. $1.2 \times 10^{-2}$

8. Two indicators were added to separate samples of a solution giving the following results:

| Indicator | Color |
|---|---|
| Chlorophenol red | Red |
| Thymol blue | Yellow |

The pH of the solution is approximately:

a. 3
b. 5
c. 7
d. 10

9. Find the pOH and the pH of the following solutions:
   a. 0.50 M KCN
   b. 1.0 M $Na_2CO_3$
   c. 0.050 M $NaC_6H_5COO$ (sodium benzoate)
   d. 0.20 M $AlCl_3$

10. When a 0.10 M solution of $NH_3$ is titrated against a 0.10 M solution of HCl, the endpoint is reached at pH 5.10. Which indicator would be best to use in the titration of $NH_3$ with HCl?

11. Calculate the [OH⁻] midway through the color change (or transition point) for the indicator indigo carmine.

12. When the amphiprotic anion, $HPO_4^{2-}$, is added to water, does it act as an acid or as a base? Support your answer with calculations.

13. A 0.60 M base solution, $NaX_{(aq)}$ is found to have a [OH⁻] of 0.12 M. Determine the $K_b$ for the base.

14. Discuss, in terms of hydrolysis, the use of sodium acetate to produce the vinegar flavour on some potato chips.

**Acid #6**

1. Lemon juice has a pH of 2.10. This low pH can be attributed to the ionization of citric acid ($H_3Cit$) in the juice according to the equation:

   $$H_3Cit <----> H^+ + H_2Cit^- \qquad K_a = 8.4x10^{-4}$$

   Calculate the concentration of citric acid in lemon juice.

2. Determine the pH of a 1.0 M NaF solution.

3. What is the pH of a saturated solution of $Mg(OH)_2$, Ksp = $1.8x10^{-11}$ ?

4. A solution containing 2.0 g HF per liter has a pH of 2.21.
   (a) Calculate the $K_a$ for HF at this temperature.
   (b) Calculate the percentage dissociation of the solute.

5. Phenolphthalein changes color from colorless to magenta in the pH range 8.2 - 10.0. Calculate the change in $[OH^-]$ over this range.

6. In the following system, determine whether reactants or products are favored:

   $$H_3O^+ + F^- <----> HF+H_2O$$

   $$HF + NH_3 <----> NH_4^+ + F^-$$

7. Vinegar has an average pH of 3.2. Determine the mass in grams of acetic acid present in one liter of vinegar. $K_a = 1.8x10^{-5}$.

8. Explain why sodium sulphide solutions are strongly basic **and** have the odor of hydrogen sulphide gas. Include appropriate, balanced equations.

**Acid #7**

1. Given the value of the ionization constant for the acid HB as $1.0 \times 10^{-8}$, show that $[H^+] = \sqrt{K_a[HB]}$

2. Given:

$$H_2SO_3 <----> H^+ + HSO_3^- \quad K_{a1}$$
$$HSO_3^- <----> H^+ + SO_3^{2-} \quad K_{a2}$$

$$H_2SO_3 <----> 2H^+ + SO_3^{2-} \quad K_a$$

Show that $K_a = K_{a1} \times K_{a2}$ and calculate $K_a$

3. The ionization constant for butanoic acid has the value $1.54 \times 10^{-5}$.
   (a) Write an equation to show the ionization of butanoic acid.
   (b) What is the pH of a 0.010 M solution of butanoic acid?
   (c) How many milliliters of 0.35 M NaOH would be required to completely react with 100 mL of 0.010 M butanoic acid?
   (d) Name **and** write the formula of the two products formed when butanoic acid reacts with the NaOH solution.

4. 50 mL of 0.50 M $H_2SO_4$ is added to 100 mL of 0.25 M $H_2SO_4$. Calculate the final concentration of the acid.

5. Fumaric acid is only partially soluble in water. Explain why solid fumaric acid dissolves as it is titrated with NaOH solution.

6. Ethanol can be oxidized to ethanoic acid. Calculate the mass of ethanol per liter that has undergone oxidation in a wine with a pH of 2.80. Assume the ethanoic acid is the only source of $H^+$ and that the $K_a = 1.8 \times 10^{-5}$ for the ethanoic acid.

**Acid #8**

1. Although only slightly soluble in water, zinc hydroxide is considered to be a strong base. A saturated solution of $Zn(OH)_2$ has a pH of 9.627. Calculate the $K_{sp}$ for zinc hydroxide.

2. Write a balanced equation to show the process occurring when CaO dissolves in water **and** explain why this substance is a basic oxide.

3. (a) Write a balanced equation to show how $Al_2(SO_4)_3$ dissolves in water to give hydrated ions.
   (b) Write a balanced equation to show the subsequent hydrolysis reaction which causes the water solution of aluminum sulphate to display acidic properties.

4. Explain using equations how $H_2NCH_2COOH$ could act as both an acid and a base.

5. Algae growing in shallow water use $CO_2$ for photosynthesis. Daytime pH values as high as 10.0 have been observed in these waters. At night the pH of the water decreases. Explain why the pH drops at night.

6. Write equations for the reactions of the following oxides with water. Explain whether the solution formed is acidic or basic.

   (a) $K_2O$

   (b) $SO_3$

Acid #9

1. The pH of distilled water at 25 °C is 7.00 while at 5.0 °C it is 7.14. Explain the reason for this result.

2. Explain why two different indicators will change color at different $[H_3O^+]$.

3. 2.68 g of the diprotic acid oxalic acid ($H_2C_2O_4*2H_2O$) is dissolved in water and made up to 0.250 L. If 25.0 mL of this is titrated against NaOH, 19.32 mL of base is required for neutralization. What is the concentration of the NaOH?

4. Which one of the following will be the stronger base:
   $NO_2^-$ or $C_6H_5COO^-$ ?

5. A solution of aluminum nitrate is found to be acidic when tested with litmus. Using equations, explain this result.

6. Calculate the $K_a$ of a 0.100 M solution of a weak acid which is known to be 20.0% dissociated.

7. Calculate the % dissociation of a 0.0500 M solution of $H_2S$.

8. Will a solution in which the $[HPO_4^{2-}] = 0.0100$ M be acidic or basic?

9. 100.0 g of a diprotic strong acid of molecular mass 120 g/mol is dissolved to make 600.0 mL solution. Calculate the pH of the resulting solution.

10. The mythical indicator Squamish Green (HSg) has a green acid form and a red base form. Its ionization is:
    $HSg + H_2O \; <----> \; Sg^- + H_3O^+$
    (a) Which molecule or ion of this indicator would be present in larger concentration in a solution of 0.10 M HCl?
    (b) What color would you observe in this situation?

11. How many grams of oxalic acid ($H_2C_2O_4*2H_2O$) are needed to completely react with 50.0 mL of a 0.20 M NaOH solution?

12. Calculate the $K_b$ for the hydrolysis of the benzoate ion.

13. Calculate the pH of a 0.10 M solution of sodium benzoate.

14. A 0.0100 M solution of a weak acid, HA, is found to have a $[H_3O^+]$ of $3.0 \times 10^{-3}$ M. What is the value of $K_a$?

**Acid #10**

1. When $OH^-$ is added to a solution of $Al(NO_3)_3$, a precipitate forms, which redissolves when excess $OH^-$ is added. Explain why this occurs.

2. An indicator has a $K_a$ of $5.2 \times 10^{-4}$. Three drops of it are added to 100 mL of an unknown solution and the color that results is found to be just at the transition point of the indicator. What is the pH of the solution?

3. Calculate the $K_a$ for the reaction:
$$H_3PO_4 <----> 3H^+ + PO_4^{3-}$$

4. A saturated solution of $Ca(OH)_2$ is found to have a pH of 12.32. Calculate the $K_{sp}$ for calcium hydroxide.

5. 42.55 mL of 0.50 M NaOH was required to titrate a 2.6 g sample of an unknown monoprotic acid. Calculate the molecular mass of the acid.

6. State whether reactants or products are favored in the following equilibria:

$HSO_3^- + H_2PO_4^- <----> SO_3^{2-} + H_3PO_4$

$HCO_3^- + HO_2^- <----> H_2O_2 + CO_3^{2-}$

$HSO_3^- + HPO_4^{2-} <----> ? + ?$

$CH_3COO^- + H_2PO_4^- <----> ? + ?$

7. The following acid-base equilibria strongly favor the products:

$H_2A + B^- <----> HB + HA^-$

$HA^- + HC <----> H_2A + C^-$

$HB + A^{2-} <----> HA^- + B^-$

$HA^- + D^- <----> HD + A^{2-}$

(a) List the five acids in decreasing order of strength.
(b) Which conjugate base is the strongest base?
(c) Write an equation for the probable reaction that would occur when the salt NaD is added to water.

Acid Base III Worksheet No. 1

60.0 mL of 0.10 M HCl are titrated with 0.20 M NaOH solution. Calculate the pH and plot the titration curve for the process when the following volumes of NaOH are added.

| Mol $H^+$ | vol. NaOH added | Moles $OH^-$ | mol excess | [conc] | pH |
|---|---|---|---|---|---|
| | 0.0 mL | | | | |
| | 5.0 mL | | | | |
| | 10.0 mL | | | | |
| | 15.0 mL | | | | |
| | 20.0 mL | | | | |
| | 25.0 mL | | | | |
| | 28.0 mL | | | | |
| | 29.0 mL | | | | |
| | 29.5 mL | | | | |
| | 30.0 mL | | | | |
| | 30.5 mL | | | | |
| | 31.0 mL | | | | |
| | 35.0 mL | | | | |
| | 60.0 mL | | | | |

What is the pH at the equivalence point?

What is the volume of NaOH added at the midpoint

What is the pH at the midpoint?

What is the $K_a$ of the indicator you should use for this titration?

Which indicator should you choose?

Acid Base III Worksheet 2

1. The indicator HIn (Galasso green) is yellow in a solution of 1.0 M HCl and is blue in a solution of 1.0 M NaOH. When the $[H_3O^+]$ is $1.0 \times 10^{-5}$ M, the indicator is green.
   (a) what molecule or ion is responsible for the yellow colour?
   (b) what molecule or ion is responsible for the blue colour?
   (c) explain why the indicator turns the three observed colours in different $[H_3O^+]$

2. The following data were recorded during an acid-base titration to determine the concentration of a 10.0 ml sample of an acid known to be monoprotic.

| | |
|---|---|
| volume of 0.100 M KOH | 18.4 ml |
| pH at stoichiometric endpoint | 9.600 |
| mass of acid in 10.0 ml sample | 0.220 g |

   (a) calculate the concentration of the acid in the original 10.0 ml sample.
   (b) calculate the weight in grams of one mole of acid (molecular mass).
   (c) explain whether the acid is strong or weak

3. Calculate the pH that results when 50.0 mL of 0.0200 M $Ba(OH)_2$ is mixed with 30.0 mL of 0.0100 M $HNO_3$.

4. What pH will result when 30.0 ml of HCL solution of pH 2.63 is added to 70.0 ml of NaOH solution of pH 10.82.

5. What is the pH of a solution of $NH_4NO_3$ made by dissolving 2.0 g $NH_4NO_3$ in sufficient water to make 25.0 ml of solution.

6. What is the pH of 2.0 M ammonia solution?

7. Two unlabelled bottles in a laboratory are aqueous solutions of acids. Both solutions give a pH value of 3.0 upon testing. One sample is a $1.0 \times 10^{-3}$ M strong acid, the other is a 1.0 M weak acid. Describe as many experimental procedures as you can that would allow you to tell which is which.

8. A 10.0 mL sample of a weak acid, HA, is titrated with 0.10 M NaOH to give the following results.

| | |
|---|---|
| volume of 0.10 M NaOH | 20.0 mL |
| pH after adding 10.0 ml of NaOH | 5.67 |

   (a) what is the concentration of the weak acid sample?
   (b) what is the $K_a$ of the weak acid?

Acid Base III Worksheet 3

1. State what happens to the pH of a buffer solution when water is added to it.

2. Determine the pH of a buffer prepared when equal moles of acetic acid are mixed with sodium acetate.

3. Calculate the dissociation constant $K_a$ of a 0.100 M solution of a weak acid, HA, which is known to be 20% dissociated.

4. From the table of acid-base indicators, select two indicators which when combined will produce a solution that is red at pH 3.0, yellow at pH 6.0, and green at pH 12.0.

5. Calculate the pH of a solution prepared by adding 100.0 mL of 0.20 M HCl to 300.0 mL of 0.050 M $Ba(OH)_2$.

6. Explain why "normal" rain water is slightly acidic.

7. Give an example of a titration which would have an equivalence point less than pH 7.

8. Give an example of a titration which would have an equivalence point greater than pH 7.

9. What could you add to a solution of ammonium nitrate that would result in the formation of a buffer solution.

10. What is the percentage composition of NaOH in a household cleaner if a 10.0 g sample of the cleaner it titrated to a phenolpthalein endpoint with 25.0 mL of 1.0 M HCl.

# Acid/Base Review Sheet

For Acid/Base Test # 3: _____ (date)

What you're responsible for:

A. What chemical species hydrolyze in water?
* the conjugate base of a weak acid ($K_a < 1$) OR
* the conjugate acid of a weak base ($K_b < 1$).

1) Write the equilibrium equation for the hydrolysis of NaF in water.
What is the pH of a 0.25 M solution of NaF?
(Answer = 8.43)

B. What does % purity tell us about the concentration of a solution of acid?
* the number of grams of pure acid that are dissolved in 100 g of solution.

2) A solution of 5.5% acetic acid is titrated with 0.100 M NaOH.
What volume of NaOH will be required to neutralize a 10.0 mL sample of the vinegar?
The density of the vinegar solution is 1.05 g/mL
(Answer = 96 mL)

C. What are the components of a buffer?
* a weak acid and its conjugate base OR a weak base and its conjugate acid.

3) What ratio of $[CH_3COOH]/[CH_3COO^-]$ is required to prepare a buffer with pH = 4.50?
(Answer = 1.8)

D. Know how to write a titration equation. Use this equation to determine how many moles of acid or base have reacted.
[Understand that titrations that involve a strong acid or a strong base are complete reactions that go straight to the right.]
$NaOH + CH_3COOH \longrightarrow NaCH_3COOH + H_2O$

4) A 10.0 mL sample of sulphurous acid is titrated with 25.0 mL of 0.100 M NaOH.
Write the equation for this reaction and <u>determine</u> the concentration of the acid.
(Answer = 0.125 M)

E. Understand the titration of a strong acid with a strong base. Know that the pH of any point on this titration curve can be calculated by ONE formula:

$$[H^+] \text{ or } [OH^-] = \frac{\text{original moles of acid - total moles of base added}}{\text{volume of acid + total volume of base added}}$$

5) a. What is the pH when 49.0 mL of 0.100 M NaOH is added to 50.0 mL of 0.100 M HCl? (Answer = 2.996)
b. What is the pH when 51.0 mL of 0.100 M NaOH is added to 50.0 mL of 0.100 M HCl? (Answer = 10.996)

F. Understand the titration of a weak acid (HA) with a strong base.
Know that the pH of different points on this titration curve must be calculated using different methods.

There are 4 different "pH zones" on a weak acid/strong base titration curve:

i. the pH before titration begins.
Only the acid HA exists.
* pH is determined by the dissociation constant for the weak acid.
$K_a = X^2/[HA]$ where $X = [H^+]$

ii. the pH in the "buffer zone".
You will not be required to calculate points in this part of the titration curve.

iii. the pH at the equivalence point.
All the HA is gone or used up. All of HA has been changed into conjugate base $A^-$.
* pH is determined by the hydrolysis of the conjugate base $A^-$.
$A^- + H_2O \text{ <----> } HA + H_3O^+$

iv. the pH when base is added beyond equivalence point.
* pOH is determined from excess moles of base

(Hint: find the moles of unreacted base and divide by the total volume at this point in the titration.)

6) 30.0 mL of 0.150 M HCOOH is titrated with 0.150 M NaOH.
a. Calculate the pH of the solution when 0.00 mL of NaOH is added.
(Answer = 2.284)
b. Calculate the pH of the solution at the equivalence point. (Answer = 8.310)
c. Calculate the pH after 40.0 mL of base are added.
(Answer = 12.331)