AP Chemistry

Acid/Base FRQs

WORKSHEET #12

Name: _____

Period: ____

Seat #: ____

1999

$$NH_3(aq) + H_2O(l) \rightleftarrows NH_4^+(aq) + OH^-(aq)$$

1. In aqueous solution, ammonia reacts as represented above. In 0.0180 M $NH_3(aq)$ at 25°C, the hydroxide ion concentration, $[OH^-]$, is 5.60×10^{-4} M. In answering the following, assume that temperature is constant at 25°C and that volumes are additive.

   (a) Write the equilibrium-constant expression for the reaction represented above.

   (b) Determine the pH of 0.0180 M $NH_3(aq)$.

   (c) Determine the value of the base ionization constant, K_b, for $NH_3(aq)$.

   (d) Determine the percent ionization of NH_3 in 0.0180 M $NH_3(aq)$.

   (e) In an experiment, a 20.0 mL sample of 0.0180 M $NH_3(aq)$ was placed in a flask and titrated to the equivalence point and beyond using 0.0120 M $HCl(aq)$.

   (i) Determine the volume of 0.0120 M $HCl(aq)$ that was added to reach the equivalence point.

   (ii) Determine the pH of the solution in the flask after a total of 15.0 mL of 0.0120 M $HCl(aq)$ was added.

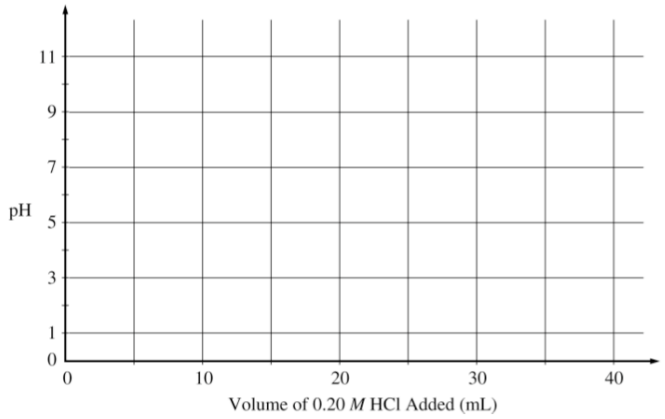
   (iii) Determine the pH of the solution in the flask after a total of 40.0 mL of 0.0120 M $HCl(aq)$ was added.

2000

8. A volume of 30.0 mL of 0.10 M $NH_3(aq)$ is titrated with 0.20 M $HCl(aq)$. The value of the base-dissociation constant, K_b, for NH_3 in water is 1.8×10^{-5} at 25°C.

   (a) Write the net-ionic equation for the reaction of $NH_3(aq)$ with $HCl(aq)$.

   (b) Using the axes provided below, sketch the titration curve that results when a total of 40.0 mL of 0.20 M $HCl(aq)$ is added dropwise to the 30.0 mL volume of 0.10 M $NH_3(aq)$.



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

Indicator	pK_a
Methyl Red	5.5
Bromothymol Blue	7.1
Phenolphthalein	8.7

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

2002

$$HOBr(aq) \rightleftarrows H^+(aq) + OBr^-(aq) \qquad K_a = 2.3 \times 10^{-9}$$

1. Hypobromous acid, HOBr, is a weak acid that dissociates in water, as represented by the equation above.

   (a) Calculate the value of $[H^+]$ in an HOBr solution that has a pH of 4.95.

   (b) Write the equilibrium constant expression for the ionization of HOBr in water, then calculate the concentration of $HOBr(aq)$ in an HOBr solution that has $[H^+]$ equal to 1.8×10^{-5} M.

   (c) A solution of $Ba(OH)_2$ is titrated into a solution of HOBr.

   (i) Calculate the volume of 0.115 M $Ba(OH)_2(aq)$ needed to reach the equivalence point when titrated into a 65.0 mL sample of 0.146 M $HOBr(aq)$.

   (ii) Indicate whether the pH at the equivalence point is less than 7, equal to 7, or greater than 7. Explain.

   (d) Calculate the number of moles of $NaOBr(s)$ that would have to be added to 125 mL of 0.160 M HOBr to produce a buffer solution with $[H^+] = 5.00 \times 10^{-9}$ M. Assume that volume change is negligible.

   (e) HOBr is a weaker acid than $HBrO_3$. Account for this fact in terms of molecular structure.

2003

$$C_6H_5NH_2(aq) + H_2O(l) \rightleftarrows C_6H_5NH_3^+(aq) + OH^-(aq)$$

1. Aniline, a weak base, reacts with water according to the reaction represented above.

   (a) Write the equilibrium constant expression, K_b, for the reaction represented above.

   (b) A sample of aniline is dissolved in water to produce 25.0 mL of a 0.10 M solution. The pH of the solution is 8.82. Calculate the equilibrium constant, K_b, for this reaction.

   (c) The solution prepared in part (b) is titrated with 0.10 M HCl. Calculate the pH of the solution when 5.0 mL of the acid has been added.

   (d) Calculate the pH at the equivalence point of the titration in part (c).

   (e) The pK_a values for several indicators are given below. Which of the indicators listed is most suitable for this titration? Justify your answer.

Indicator	pK_a
Erythrosine	3
Litmus	7
Thymolphthalein	10

2005

$$HC_3H_5O_2(aq) \rightleftarrows C_3H_5O_2^-(aq) + H^+(aq) \qquad K_a = 1.34 \times 10^{-5}$$

1. Propanoic acid, $HC_3H_5O_2$, ionizes in water according to the equation above.

   (a) Write the equilibrium-constant expression for the reaction.

   (b) Calculate the pH of a 0.265 M solution of propanoic acid.

   (c) A 0.496 g sample of sodium propanoate, $NaC_3H_5O_2$, is added to a 50.0 mL sample of a 0.265 M solution of propanoic acid. Assuming that no change in the volume of the solution occurs, calculate each of the following.

      (i) The concentration of the propanoate ion, $C_3H_5O_2^-(aq)$, in the solution

      (ii) The concentration of the $H^+(aq)$ ion in the solution

   The methanoate ion, $HCO_2^-(aq)$, reacts with water to form methanoic acid and hydroxide ion, as shown in the following equation.

$$HCO_2^-(aq) + H_2O(l) \rightleftarrows HCO_2H(aq) + OH^-(aq)$$

   (d) Given that $[OH^-]$ is 4.18×10^{-6} M in a 0.309 M solution of sodium methanoate, calculate each of the following.

      (i) The value of K_b for the methanoate ion, $HCO_2^-(aq)$

      (ii) The value of K_a for methanoic acid, HCO_2H

   (e) Which acid is stronger, propanoic acid or methanoic acid? Justify your answer.

2005B

$$K_a = \frac{[H_3O^+][OCl^-]}{[HOCl]} = 3.2 \times 10^{-8}$$

1. Hypochlorous acid, HOCl, is a weak acid in water. The K_a expression for HOCl is shown above.

   (a) Write a chemical equation showing how HOCl behaves as an acid in water.

   (b) Calculate the pH of a 0.175 M solution of HOCl.

   (c) Write the net ionic equation for the reaction between the weak acid $HOCl(aq)$ and the strong base $NaOH(aq)$.

   (d) In an experiment, 20.00 mL of 0.175 M $HOCl(aq)$ is placed in a flask and titrated with 6.55 mL of 0.435 M $NaOH(aq)$.

      (i) Calculate the number of moles of $NaOH(aq)$ added.

      (ii) Calculate $[H_3O^+]$ in the flask after the $NaOH(aq)$ has been added.

      (iii) Calculate $[OH^-]$ in the flask after the $NaOH(aq)$ has been added.

2006B

1. Benzoic acid, C_6H_5COOH, dissociates in water as shown in the equation above. A 25.0 mL sample of an aqueous solution of pure benzoic acid is titrated using standardized 0.150 *M* NaOH.

   (a) After addition of 15.0 mL of the 0.150 *M* NaOH, the pH of the resulting solution is 4.37. Calculate each of the following.

   (i) $[H^+]$ in the solution

   (ii) $[OH^-]$ in the solution

   (iii) The number of moles of NaOH added

   (iv) The number of moles of $C_6H_5COO^-(aq)$ in the solution

   (v) The number of moles of C_6H_5COOH in the solution

   (b) State whether the solution at the equivalence point of the titration is acidic, basic, or neutral. Explain your reasoning.

   In a different titration, a 0.7529 g sample of a mixture of solid C_6H_5COOH and solid NaCl is dissolved in water and titrated with 0.150 *M* NaOH. The equivalence point is reached when 24.78 mL of the base solution is added.

   (c) Calculate each of the following.

   (i) The mass, in grams, of benzoic acid in the solid sample

   (ii) The mass percentage of benzoic acid in the solid sample

2007

$$HF(aq) + H_2O(l) \rightleftarrows H_3O^+(aq) + F^-(aq) \qquad K_a = 7.2 \times 10^{-4}$$

1. Hydrofluoric acid, $HF(aq)$, dissociates in water as represented by the equation above.

   (a) Write the equilibrium-constant expression for the dissociation of $HF(aq)$ in water.

   (b) Calculate the molar concentration of H_3O^+ in a 0.40 *M* $HF(aq)$ solution.

   $HF(aq)$ reacts with $NaOH(aq)$ according to the reaction represented below.

   $$HF(aq) + OH^-(aq) \rightarrow H_2O(l) + F^-(aq)$$

   A volume of 15 mL of 0.40 *M* $NaOH(aq)$ is added to 25 mL of 0.40 *M* $HF(aq)$ solution. Assume that volumes are additive.

   (c) Calculate the number of moles of $HF(aq)$ remaining in the solution.

   (d) Calculate the molar concentration of $F^-(aq)$ in the solution.

   (e) Calculate the pH of the solution.

2002B #1

$$HC_3H_5O_3(aq) \rightleftarrows H^+(aq) + C_3H_5O_3^-(aq)$$

1. Lactic acid, $HC_3H_5O_3$, 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* $HC_3H_5O_3(aq)$ 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* $HC_3H_5O_3$.

   (c) Calculate the pH of a solution formed by dissolving 0.045 mole of solid sodium lactate, $NaC_3H_5O_3$, in 250. mL of 0.50 *M* $HC_3H_5O_3$. Assume that volume change is negligible.

   (d) A 100. mL sample of 0.10 *M* HCl is added to 100. mL of 0.50 *M* $HC_3H_5O_3$. Calculate the molar concentration of lactate ion, $C_3H_5O_3^-$, in the resulting solution.

2001

3. Answer the following questions about acetylsalicylic acid, the active ingredient in aspirin.

(a) The amount of acetylsalicylic acid in a single aspirin tablet is 325 mg, yet the tablet has a mass of 2.00 g. Calculate the mass percent of acetylsalicylic acid in the tablet.

(b) The elements contained in acetylsalicylic acid are hydrogen, carbon, and oxygen. The combustion of 3.000 g of the pure compound yields 1.200 g of water and 3.72 L of dry carbon dioxide, measured at 750. mm Hg and 25°C. Calculate the mass, in g, of each element in the 3.000 g sample.

(c) A student dissolved 1.625 g of pure acetylsalicylic acid in distilled water and titrated the resulting solution to the equivalence point using 88.43 mL of 0.102 *M* NaOH(*aq*). Assuming that acetylsalicylic acid has only one ionizable hydrogen, calculate the molar mass of the acid.

(d) A 2.00×10^{-3} mole sample of pure acetylsalicylic acid was dissolved in 15.00 mL of water and then titrated with 0.100 *M* NaOH(*aq*). The equivalence point was reached after 20.00 mL of the NaOH solution had been added. Using the data from the titration, shown in the table below, determine

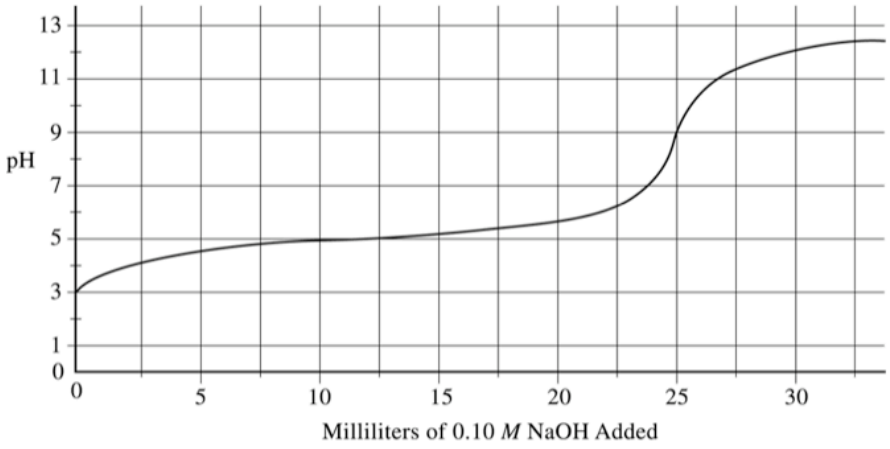
(i) the value of the acid dissociation constant, K_a, for acetylsalicylic acid and

(ii) the pH of the solution after a total volume of 25.00 mL of the NaOH solution had been added (assume that volumes are additive).

Volume of 0.100 *M* NaOH Added (mL)	pH
0.00	2.22
5.00	2.97
10.00	3.44
15.00	3.92
20.00	8.13
25.00	?

2002B #8

8. The graph below shows the result of the titration of a 25 mL sample of a 0.10 *M* solution of a weak acid, HA, with a strong base, 0.10 *M* NaOH.



(a) Describe two features of the graph above that identify HA as a weak acid.

(b) Describe one method by which the value of the acid-dissociation constant for HA can be determined using the graph above.

(c) On the graph above, sketch the titration curve that would result if 25 mL of 0.10 *M* HCl were used instead of 0.10 *M* HA.

(d) A 25 mL sample of 0.10 *M* HA is titrated with 0.20 *M* NaOH.

(i) What volume of base must be added to reach the equivalence point?

(ii) The pH at the equivalence point for this titration is slightly higher than the pH at the equivalence point in the titration using 0.10 *M* NaOH. Explain.

2003B

2. Answer the following questions that relate to chemical reactions.

(a) Iron(III) oxide can be reduced with carbon monoxide according to the following equation.

$$Fe_2O_3(s) + 3\ CO(g) \rightarrow 2\ Fe(s) + 3\ CO_2(g)$$

A 16.2 L sample of $CO(g)$ at 1.50 atm and 200.°C is combined with 15.39 g of $Fe_2O_3(s)$.

(i) How many moles of $CO(g)$ are available for the reaction?

(ii) What is the limiting reactant for the reaction? Justify your answer with calculations.

(iii) How many moles of $Fe(s)$ are formed in the reaction?

(b) In a reaction vessel, 0.600 mol of $Ba(NO_3)_2(s)$ and 0.300 mol of $H_3PO_4(aq)$ are combined with deionized water to a final volume of 2.00 L. The reaction represented below occurs.

$$3\ Ba(NO_3)_2(aq) + 2\ H_3PO_4(aq) \rightarrow Ba_3(PO_4)_2(s) + 6\ HNO_3(aq)$$

(i) Calculate the mass of $Ba_3(PO_4)_2(s)$ formed.

(ii) Calculate the pH of the resulting solution.

(iii) What is the concentration, in mol L^{-1}, of the nitrate ion, $NO_3^-(aq)$, after the reaction reaches completion?

2001

1. Answer the following questions relating to the solubility of the chlorides of silver and lead.

(a) At 10°C, 8.9×10^{-5} g of $AgCl(s)$ will dissolve in 100. mL of water.

(i) Write the equation for the dissociation of $AgCl(s)$ in water.

(ii) Calculate the solubility, in mol L^{-1}, of $AgCl(s)$ in water at 10°C.

(iii) Calculate the value of the solubility-product constant, K_{sp}, for $AgCl(s)$ at 10°C.

(b) At 25°C, the value of K_{sp} for $PbCl_2(s)$ is 1.6×10^{-5} and the value of K_{sp} for $AgCl(s)$ is 1.8×10^{-10}.

(i) If 60.0 mL of 0.0400 *M* $NaCl(aq)$ is added to 60.0 mL of 0.0300 *M* $Pb(NO_3)_2(aq)$, will a precipitate form? Assume that volumes are additive. Show calculations to support your answer.

(ii) Calculate the equilibrium value of $[Pb^{2+}(aq)]$ in 1.00 L of saturated $PbCl_2$ solution to which 0.250 mole of $NaCl(s)$ has been added. Assume that no volume change occurs.

(iii) If 0.100 *M* $NaCl(aq)$ is added slowly to a beaker containing both 0.120 *M* $AgNO_3(aq)$ and 0.150 *M* $Pb(NO_3)_2(aq)$ at 25°C, which will precipitate first, $AgCl(s)$ or $PbCl_2(s)$? Show calculations to support your answer.

2004

1. Answer the following questions relating to the solubilities of two silver compounds, Ag_2CrO_4 and Ag_3PO_4.

Silver chromate dissociates in water according to the equation shown below.

$$Ag_2CrO_4(s) \rightleftarrows 2\ Ag^+(aq) + CrO_4^{2-}(aq) \qquad K_{sp} = 2.6 \times 10^{-12} \text{ at } 25°C$$

(a) Write the equilibrium-constant expression for the dissolving of $Ag_2CrO_4(s)$.

(b) Calculate the concentration, in mol L^{-1}, of $Ag^+(aq)$ in a saturated solution of Ag_2CrO_4 at 25°C.

(c) Calculate the maximum mass, in grams, of Ag_2CrO_4 that can dissolve in 100. mL of water at 25°C.

(d) A 0.100 mol sample of solid $AgNO_3$ is added to a 1.00 L saturated solution of Ag_2CrO_4. Assuming no volume change, does $[CrO_4^{2-}]$ increase, decrease, or remain the same? Justify your answer.

In a saturated solution of Ag_3PO_4 at 25°C, the concentration of $Ag^+(aq)$ is 5.3×10^{-5} *M*. The equilibrium-constant expression for the dissolving of $Ag_3PO_4(s)$ in water is shown below.

$$K_{sp} = [Ag^+]^3[PO_4^{3-}]$$

(e) Write the balanced equation for the dissolving of Ag_3PO_4 in water.

(f) Calculate the value of K_{sp} for Ag_3PO_4 at 25°C.

(g) A 1.00 L sample of saturated Ag_3PO_4 solution is allowed to evaporate at 25°C to a final volume of 500. mL. What is $[Ag^+]$ in the solution? Justify your answer.

2006

1. Answer the following questions that relate to solubility of salts of lead and barium.

   (a) A saturated solution is prepared by adding excess $PbI_2(s)$ to distilled water to form 1.0 L of solution at 25°C. The concentration of $Pb^{2+}(aq)$ in the saturated solution is found to be $1.3 \times 10^{-3}\ M$. The chemical equation for the dissolution of $PbI_2(s)$ in water is shown below.

   $$PbI_2(s) \rightleftarrows Pb^{2+}(aq) + 2\ I^-(aq)$$

   (i) Write the equilibrium-constant expression for the equation.

   (ii) Calculate the molar concentration of $I^-(aq)$ in the solution.

   (iii) Calculate the value of the equilibrium constant, K_{sp}.

   (b) A saturated solution is prepared by adding $PbI_2(s)$ to distilled water to form 2.0 L of solution at 25°C. What are the molar concentrations of $Pb^{2+}(aq)$ and $I^-(aq)$ in the solution? Justify your answer.

   (c) Solid NaI is added to a saturated solution of PbI_2 at 25°C. Assuming that the volume of the solution does not change, does the molar concentration of $Pb^{2+}(aq)$ in the solution increase, decrease, or remain the same? Justify your answer.

   (d) The value of K_{sp} for the salt $BaCrO_4$ is 1.2×10^{-10}. When a 500. mL sample of $8.2 \times 10^{-6}\ M$ $Ba(NO_3)_2$ is added to 500. mL of $8.2 \times 10^{-6}\ M$ Na_2CrO_4, no precipitate is observed.

   (i) Assuming that volumes are additive, calculate the molar concentrations of $Ba^{2+}(aq)$ and $CrO_4^{2-}(aq)$ in the 1.00 L of solution.

   (ii) Use the molar concentrations of $Ba^{2+}(aq)$ ions and $CrO_4^{2-}(aq)$ ions as determined above to show why a precipitate does not form. You must include a calculation as part of your answer.