***CH1020 Exercises (Worksheet 10)***

1. What is the definition of an Arrhenius acid and base? What is the definition of a Brønstedt-Lowry acid and base? Give an example of a Brønstedt-Lowry base that is not an Arrhenius acid.

   Arrhenius: Acid generates $H_3O^+$ and base generates $OH^-$ when added to water.
   Brønsted-Lowry: Acids are proton donors and bases are proton acceptors in a reaction.

   $$H_2O(l) + HC_2H_3O_2(aq) \rightleftharpoons H_3O^+(aq) + C_2H_3O_2^-(aq)$$

   In this reaction a proton is transferred from acetic acid ($HC_2H_3O_2$), which is an Arrhenius acid, to $H_2O$, which is not considered an acid or base in the Arrhenius sense.

   For the gas phase reaction
   $$HCl(g) + NH_3(g) \rightarrow NH_4Cl(s)$$
   neither HCl or $NH_3$ are Arrhenius an acid or base (the reaction takes place in the absence of water, i.e., $H_3O^+$ and $OH^-$ cannot be formed), but they are a Brønsted-Lowry acid/base.

2. Write balanced complete ionic and net ionic equations for each acid/base reaction:

   a. $$2H^+(aq) + 2I(aq) + Ca^{2+}(aq) + 2OH^-(aq) \rightarrow 2H_2O(l) + Ca^{2+}(aq) + 2I^-(aq)$$
   $$2H^+(aq) + 2OH^-(aq) \rightarrow 2H_2O(l) \quad \Rightarrow \quad H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

   b. $$2H^+(aq) + SO_4^{2-}(aq) + 2Na^+(aq) + 2OH^-(aq) \rightarrow 2H_2O(l) + 2Na^+(aq) + SO_4^{2-}(aq)$$
   $$2H^+(aq) + 2OH^-(aq) \rightarrow 2H_2O(l) \Rightarrow H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

   c. $$Al(OH)_3(s) + 3H^+(aq) + 3NO_3^-(aq) \rightarrow 3H_2O(l) + Al^{3+}(aq) + 3NO_3^-(aq)$$
   $$Al(OH)_3(s) + 3H^+(aq) \rightarrow 3H_2O(l) + Al^{3+}(aq)$$

   d. $$K^+(aq) + OH^-(aq) + HCHO_2(aq) \rightarrow H_2O(l) + K^+(aq) + CHO_2^-(aq)$$
   $$OH^-(aq) + HCHO_2(aq) \rightarrow H_2O(l) + CHO_2^-(aq)$$

   Note: Don't ionize weak acids (hence $HCHO_2$ rather than ~~$H^+$(aq) + $CHO_2^-$ (aq)~~ )

e. $Na^+(aq) + HSO_4^-(aq) + Na^+(aq) + OH^-(aq) \rightarrow H_2O(l) + 2Na^+(aq) + SO_4^{2-}(aq)$
$HSO_4^-(aq) + OH^-(aq) \rightarrow H_2O(l) + SO_4^{2-}(aq)$

f. $2Na^+(aq) + HPO_4^{2-}(aq) + Na^+(aq) + OH^-(aq) \rightarrow H_2O(l) + PO_4^{3-}(aq) + 3Na^+(aq)$
$HPO_4^{2-}(aq) + OH^-(aq) \rightarrow H_2O(l) + PO_4^{3-}(aq)$

g. $2Na^+(aq) + HPO_4^{2-}(aq) + 2H^+(aq) + 2Cl^-(aq) \rightarrow H_3PO_4(aq) + 2Cl^-(aq) + 2Na^+(aq)$
$HPO_4^{2-}(aq) + 2H^+(aq) \rightarrow H_3PO_4(aq)$

h. $H_3AsO_4(aq) + 3NH_3(aq) \rightarrow 3NH_4^+(aq) + AsO_4^{3-}(aq)$
(complete and net ionic equations are the same)

3. Write balanced complete ionic and net ionic equations for each acid/base reaction:

   a. Reaction of aqueous phosphorous acid and aqueous sodium hydroxide

$H_3PO_3(aq) + 3Na^+ + 3OH^- \rightarrow 3H_2O(l) + 3Na^+(aq) + PO_3^{3-}(aq)$
$H_3PO_3(aq) + 3OH^- \rightarrow 3H_2O(l) + PO_3^{3-}(aq)$

   b. Reaction of aqueous hydrocyanic acid and aqueous barium hydroxide

$2HCN(aq) + Ba^{2+}(aq) + 2OH^- \rightarrow 2H_2O(l) + 2Ba^{2+}(aq) + 2CN^-(aq)$
$2HCN(aq) + 2OH^- \rightarrow 2H_2O(l) + 2CN^-(aq)$

   c. Reaction of aqueous nitrous acid and solid chromium(III)hydroxide

$3HNO_2(aq) + Cr(OH)_3(s) \rightarrow 3H_2O(l) + Cr^{3+}(aq) + 3NO_2^-$
(complete and net ionic equations are the same)

   d. Reaction of solid magnesium carbonate with aqueous perchloric acid

$MgCO_3(s) + 2H^+(aq) + 2ClO_4^-(aq) \rightarrow H_2O(l) + CO_2(g) + Mg^{2+}(aq) + 2ClO_4^-(aq)$
$MgCO_3(s) + 2H^+(aq) \rightarrow H_2O(l) + CO_2(g) + Mg^{2+}(aq)$

4. A 25.00 mL sample of an unknown perchloric acid solution requires titration with 22.62 mL of 0.2000M NaOH to reach the equivalence point. Provide the

balanced molecular equation and calculate the concentration of the unknown perchloric acid solution.

$$HClO_4(aq) + NaOH(aq) \rightarrow H_2O(l) + NaClO_4(aq)$$

0.1810 M $HClO_4$

5. A 30.00 mL sample of an unknown phosphoric acid solution is titrated with a 0.100 M sodium hydroxide solution. The equivalence point is reached when 26.38mL sodium hydroxide solution is added. Provide the balanced molecular equation and calculate the concentration of the unknown phosphoric acid solution.

   $$H_3PO_4(aq) + 3NaOH(aq) \rightarrow 3H_2O(l) + Na_3PO_4(aq)$$

   0.0293 M $H_3PO_4$

6. An acid solution is 0.100 M in HCl and 0.200 M in $H_2SO_4$. What volume of a 0.150 M KOH solution would completely neutralize all the acid in 500.0 mL of this solution?

   1.67 L KOH solution

7. A solid sample of $Zn(OH)_2$ is added to 0.350 L of 0.500 M aqueous HBr. The solution that remains is still acidic. It is then titrated with 0.500 M NaOH solution and it takes 88.5 mL of the NaOH solution to reach the equivalence point. What mass of $Zn(OH)_2$ was added to the HBr solution?

   0.0654 mol $Zn(OH)_2$ => 6.5 g $Zn(OH)_2$

8. By titration, 15.0 mL of 0.1008M sodium hydroxide is needed to neutralize a 0.2053 g sample of a weak acid. The weak acid is monoprotic.

   a. What is the molar mass of the sample? 135.8 g/mol

   b. An elemental analysis of the acid indicates that it is composed of 5.89% H, 70.6% C and 23.5% O by mass. What is its molecular formula? $C_8H_8O_2$

9. A sample of 7.75 g of $Mg(OH)_2$ is added to 25.0 mL of 0.200 M $HNO_3$.

   a. Write the chemical equation for the reaction that occurs

   $$Mg(OH)_2(s) + 2HNO_3(aq) \rightarrow 2H_2O(l) + Mg(NO_3)_2$$

   b. Which is the limiting reactant in the reaction?

   $HNO_3$

c. How many moles of $Mg(OH)_2$, $HNO_3$ and $Mg(NO_3)_2$ are present after the reaction is complete?

0.128 M $Mg(OH)_2$
0 M $HNO_3$
0.0025 M $MgNO_3$