Part B — Metathetical Reaction: **$Cu^{2+}(aq) \rightarrow Cu(OH)_2(s)$**

1. Copy the equation: $NaOH(aq) + HNO_3(aq) \rightarrow NaNO_3(aq) + H_2O(\ell)$
   a. This is a typical acid-base neutralization using Arrhenius (IPS) model. Describe the Arrhenius model of an acid and a base.

   Arrhenius model of an acid hydrogen ion (H+) with anion (negative ion) and a base hydroxide ion (OH-) with a cation.

   b. Copy the net ionic equation: $OH^-(aq) + H^+(aq) \rightarrow H_2O(\ell)$
   Use the net ionic equation to explain the neutralization and formation of water.

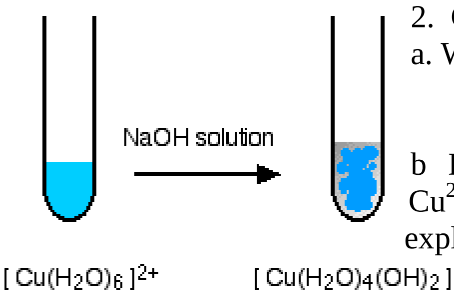
   Hydroxide ions in solution from the base react with hydrogen ions in solution from the acid to form water molecules. A covalent bond forms between the oxygen and hydrogen. The concentration of hydrogen ions decreases as they react with the hydroxide. The decrease in hydrogen ions is measured as an increase in pH.

   c. Copy the alternate net ionic equation $OH^-(aq) + H_3O^+(aq) \rightarrow 2\,H_2O(\ell)$
   Identify the Bronsted-Lowry acid and base and their conjugate pairs.

   $OH^-(aq) + H_3O^+(aq) \rightarrow H_2O(\ell) + H_2O(\ell)$
   BL base   BL acid   BL acid   BL base

   Describe the neutralization using the Bronsted-Lowry model of proton transfer.

   The hydroxide ion accepted the proton (H+) from the H_3O^+ (hydronium ion). The hydroxide ion is the Bronsted-Lowry base and becomes a water molecule – its conjugate acid pair. The conjugate pair is the product of the base after it loses the H+. When the reaction runs in reverse this conjugate acid will donate an H+ and return to the same base. The hydronium ion donated proton acting as a Bronstef-Lowry acid becoming a water molecule its conjugate base.



2. Copper (II) hydroxide forms the blue precipitate in the aqueous solution.
   a. Write the net ionic equation for the formation of this precipitate.

   $Cu^{2+}(aq) + OH^-(aq) \rightarrow Cu(OH)_2(s)$

   b Based upon the formation of the precipitate, is the ionic bond stronger between Cu^{2+} and OH^- or Cu^{2+} and NO_3^-? Justify your answer by using bond strength to explain their relative solubility.

   Copper(II) nitrate is soluble while copper (II) hydroxide is insoluble. When ionic compounds dissolve the ions dissociate – the ionic bond breaks. The ions become dispersed in the water surrounded by the water molecules with ion-dipole attractions. The extent to which an ionic compound dissolves – its solubility- depends upon both the strength of the ionic bond and the ion-dipole attraction. With stronger ionic bonds, the ions are less likely to dissociate when water molecules collide. In order to dissociate the water molecules must collide with enough kinetic energy to break the ionic bonds. This suggest that the copper (II)hydroxide must have stronger ionic bonds between Cu^{2+} and OH^- ions than between Cu^{2+} and NO_3^- ions in the copper (II)nitrate.

   c. Write the reversible reaction occurring in the saturated solution of copper (II) hydroxide and the equation for the equilibrium constant (Ksp). Describe the equilibrium that occurs in the saturated solution of copper (II) hydroxide. Include rates and conditions of the system in your description.

   $Cu(OH)_2(s) \leftrightarrows Cu^{2+}(aq) + OH^-(aq)$

   A saturated solution of an ionic compound has both ions in solution and ions in the solid. The mixture may appear cloudy (the solid suspended in the solution) or the solid may settle to the bottom. The concentration of ions in the solution has reached a maximum. If more solid is added the concentration remains constant. The ions in the solid and solution are in equilibrium.

The ions are simultaneously dissociating into solution (forward reaction) and crystallizing into the solid (reverse reaction). Both reactions are still occurring. In this dynamic equilibrium the rate of the forward reaction equals the rate of the reverse reaction. Due to these equal rates there is no net change. The concentration of ions in the solution will remain constant.

d. Use either the Handbook of Chemistry and Physics or your text to find the value of the Ksp for $Cu(OH)_2$. Use your understanding of equilibrium and the value of the Ksp to explain why some copper ions would remain in solution at equilibrium.

Copper(II) hydroxide is labeled insoluble which implies no copper (II) hydroxide dissolves. However the Ksp indicates that a small concentration will dissolve. If indeed it were as simple as dissolve or not the Ksp would be zero. However solubility varies. The Ksp for copper (II) hydroxide is 4.8×10^{-20}. The value is very small so it indicates that very little does dissolve.

e. Calculate the $[Cu^{2+}]$ if no excess hydroxide were added. Explain how adding excess hydroxide decreases the concentration of Cu^{2+} in solution. Use Le Chatelier and Ksp.

Set $x = [Cu(OH)_2]$ so $x = [Cu^{2+}]$ and $2x = [OH^-]$

$$Ksp = [Cu^{2+}][OH^-]^2 = 4.8\times10^{-20}$$

$$(x)\ (2x)^2$$

$$x\ 4x^2 = 4x^3 = 4.8\times10^{-20}$$

$$x = 2.3 \times 10^{-7} M$$

The concentration of copper ions is very low but nonetheless copper ions remain in solution. If extra hydroxide ions are added the equilibrium will shift to the equilibrium to the left. The increased concentration of hydroxide ions will lead to a decreased concentration of copper ions in solution. Notice the Ksp will still be Ksp $= [Cu^{2+}][OH^-]^2 = 4.8\times10^{-20}$. Notice in the equation with a higher concentration of hydroxide to keep the Ksp constant there will be a lower concentration of copper ions.