Part I-Acid Rain in a Bottle

View the video found at http://employees.oneonta.edu/viningwj/Chem111/acidrain2.mov and answer the following questions.

Demonstration Notes:
- 50µL of a 1.0M potassium hydroxide solution was added to 250mL of water containing the pH indicator phenolphthalein (1µL = 1x10^-6 L)
- Phenolphthalein is pink at pH’s ≥ 8.2
- Sulfurous acid is a weak acid

1. What is the initial concentration of potassium hydroxide in the jar?

\[
[\text{KOH}] = \frac{5.0 \times 10^{-5} \text{mol}}{0.250 \text{L}} = 2.0 \times 10^{-4} \text{M}
\]

2. What is the initial pH of the potassium hydroxide solution?

\[
\text{pH} = 14 - \text{pOH} = -\log[\text{OH}^-]
\]

\[
\text{pOH} = -\log[2 \times 10^{-3}]
\]

\[
\text{pH} = 14 - 3.70 = 10.3
\]

3. Write balanced chemical equations to describe:
   a. Potassium hydroxide dissolving in water

\[
\text{KOH}(s) + \text{H}_2\text{O}(l) \rightarrow \text{K}^+(aq) + \text{OH}^-(aq)
\]

b. Sulfur combustion (sulfur combines with the oxygen in the air to form sulfur dioxide).

\[
\text{S}(s) + \text{O}_2(g) \rightarrow \text{SO}_2(g)
\]

c. The production of hydrogen sulfite (hint- think polyatomic ion), aka sulfurous acid when sulfur dioxide is mixed with the water in the jar.

\[
\text{SO}_2(s) + \text{H}_2\text{O}(l) \rightarrow \text{H}_2\text{SO}_3(aq)
\]

d. The reaction between the sulfurous acid and potassium hydroxide.

\[
\text{H}_2\text{SO}_3(aq) + 2\text{KOH}(aq) \rightarrow 2\text{H}_2\text{O}(l) + \text{K}_2\text{SO}_3(aq)
\]

e. The total ionic equation for the reaction between sulfurous acid and potassium hydroxide.

\[
\text{H}_2\text{SO}_3(aq) + 2\text{K}^+(aq) + 2\text{OH}^-(aq) \rightarrow 2\text{H}_2\text{O}(l) + 2\text{K}^+(aq) + \text{SO}_3^{2-}(aq)
\]

(f. The net ionic equation for the reaction between sulfurous acid and potassium hydroxide.

\[
\text{H}_2\text{SO}_3(aq) + 2\text{OH}^-(aq) \rightarrow 2\text{H}_2\text{O}(l) + \text{SO}_3^{2-}(aq)
\]
4. What is the minimum amount of sulfurous acid needed to neutralize all of the potassium hydroxide in the jar? How many grams of sulfur need to be burned to make this much sulfurous acid?

From #1: Total amount of KOH = \(5.0 \times 10^{-5}\) mol

From #3d: \(\frac{1\text{ mol } \text H_2\text{SO}_3}{2\text{ mol } \text KOH}\) \(\frac{\text H_2\text{SO}_3 \text{ molar mass}}{82.07\text{ g/mol}}\)

\[
\text{Total amount of KOH} \times \frac{1\text{ mol } \text H_2\text{SO}_3}{2\text{ mol } \text KOH} = \frac{2.5 \times 10^{-5} \text{ mol } \text H_2\text{SO}_3 \text{ needed}}{(2.5 \times 10^{-5} \text{ mol } \text H_2\text{SO}_3 \times 82.07\text{ g/mol})} = 0.002\text{ g } \text{H}_2\text{SO}_3
\]

\#g Sulfur: Look at equations 3b - 3c. You see that for each mole of \(\text{H}_2\text{SO}_3\) produced, 1 mole of S was burned.

\[
\#g \text{ S} = 2.5 \times 10^{-5} \text{ mol } \text{H}_2\text{SO}_3 \times \frac{1\text{ mol } \text{S}}{1\text{ mol } \text{H}_2\text{SO}_3} \times \frac{32.065\text{ g}}{1\text{ mol}} = 8.0 \times 10^{-4}\text{ g } \text{S}
\]

5. Which best represents the probable pH of the solution at the end of the demonstration?
   a. 2.5 \(\text{H}_2\text{SO}_3\) is a weak acid, so excess \(\text{H}_2\text{SO}_3\) is not likely to lower the pH this much.
   b. 6.5
   c. 8.5 \(\text{Phenolphthalein changes color at 8.2, so if the solution is colorless and not pink, the pH < 8.2.}\)
   d. 10.5

Part II-A Solution Concentration Problem Based on a True Story

Dr. Gallagher's 2-year-old had a high fever. She went to the medicine cabinet to get some acetaminophen (the active ingredient in Tylenol) to help bring down the fever, but the infant's acetaminophen bottle was almost empty. The label on the infant's acetaminophen bottle said that the dose for a 2-year-old should be 1.6mL of a 100mg/ml solution of infant formulation. Although there was not enough medicine in the bottle of infant acetaminophen, Dr. Gallagher noticed that she did have a full bottle of children's acetaminophen. Both bottles contain the same medicine, but because it is more difficult to get a smaller child to swallow medicine, infant medicines are more concentrated. The concentration of the children's formulation is 32mg/ml.

6. What is the proper dosage (in mg) for a 2-year-old?

\[
1.6\text{mL} \times \frac{100\text{mg}}{\text{mL}} = 160\text{mg}
\]

7. How much of the Children's Acetaminophen did Dr. Gallagher give her son?

WARNING: Be careful! Acetaminophen can cause liver toxicity and death - if given in too high a dose! (By the way, the actual story had a happy ending, and the 2-year-old is now in kindergarten 😊)

\[
160\text{mg} \times \frac{1\text{mL}}{32\text{mg}} = 5\text{mL}
\]