Acid Rain and the Buffering Capacity of Water

Background

Rain and snow are naturally somewhat acidic because of carbon dioxide in the atmosphere. As rain falls through the air, carbonic acid is formed, resulting in a typical pH of clean natural rain of approximately 5.6. Atmospheric pollutants can lower the pH even more. The effect of acid rain on lakes and streams depends on their natural buffering capacity. Buffers are solutions that resist a change in pH. The buffering of lakes and streams is usually due to dissolved minerals. Some important reactions are given below.

$$CO_2\,(g) + H_2O \Leftrightarrow H_2CO_3\,(aq)$$

$$H_2CO_3\,(aq) \Leftrightarrow H^+\,(aq) + HCO_3^-$$

The extent of this reaction depends on the pressure of the CO_2; the greater the pressure the more carbonic acid is created. Carbonated beverages are made at pressures larger than normal atmospheric pressure. The carbonic acid produced can ionize slightly to give some H^+ in solution. Thus cola drinks are acidic.

$$H^+\,(aq) + HCO_3^-\,(aq) \Leftrightarrow H_2CO_3\,(aq)$$

This reaction is just the reverse of the previous one. The production of the weak electrolyte carbonic acid is favored when acid is added to a solution of bicarbonate ion and explains why the bicarbonate ion keeps the pH of a solution from changing when acid is added. The H^+ is neutralized by the bicarbonate ion and most is stored in the unionized carbonic acid.

$$OH^-\,(aq) + HCO_3^-\,(aq) \Leftrightarrow CO_3^{-2}\,(aq) + H_2O$$

This equation explains why the bicarbonate ion buffers a solution when base is added. The OH^- is neutralized by the bicarbonate ion. Although some of the carbonate ion will react with the water to produce hydroxide ion, most of the hydroxide will be found in the water molecules that are formed.

Procedure:

1. Put about 100 mL of distilled water into each of 4 small cups. Determine the pH of cup #1 using a pH meter. _____
2. Blow vigorously through a straw into cup #2 for two or three minutes; then determine the pH of the solution. _____
3. Why is the pH different? Write a couple of reactions which summarize this and also explain in words.

4. Add a spoonful of baking soda to cups #3 and #4; swirl until it dissolves and measure the pH. _____

Why is the pH different? Write a reaction that could explain what is happening with the baking soda.

5. Blow vigorously through a straw into cup #4 for two or three minutes; determine the pH of the solution. _____
   How did the baking soda affect the pH?

6. See if you can write a reaction of the bicarbonate ion from the baking soda with the H^+ that is coming from the carbonic acid made from the carbon dioxide in your breath. Can you explain why the pH acts as it does?

7. Add a few drops of vinegar to cups #1 and #3 and stir. Determine the pH in each cup.
   #1 _____ #3 _____

   Why are the pH's different?

8. Natural waters in this area have a good deal of carbonate and bicarbonate ion in them because of our limestone rock geology. Write reactions and explain why we have not been hurt as hard as other areas from acid rain.

What is Hard Water?

People use the term "hard water" to refer to water which has a lot of certain dissolved minerals in it. The minerals that cause water to be "hard" are *calcium*, *magnesium*, and *iron* and are present in the form of ions in the water. These elements prevent soap from being able to clean as well because they form insoluble precipitates with the soap molecules and reduce the amount of soap available for cleaning. This is why people don't like hard water. There is nothing in hard water that is unhealthy though - it just makes it tougher to clean things. (You may also see a deposit of the insoluble carbonate compounds of these ions on your pipes, in your hot water heater, or even on your cooking pots.) In this activity you will test some water samples to see which is the hardest. You will use a process called a titration to find out.

Materials

Water samples, Hardness I, II and III solutions made by the Hach company, small bottle or test tube, graduated cylinder.

Procedure

Fill the measuring tube supplied with the Hach test kit and empty into the small bottle. Follow the directions that come with the kit.

If the directions are not present then do the following. First add 3 drops of the Hardness 1 solution. Then add 2 drops of the Hardness 2 solution. This will turn the solution red. Then add drop by drop the Hardness 3 solution. Swirl after each drop.

Count the number of drops that it takes to change the color from red to dark blue. The more drops it takes the "harder" the water is. Each drop represents a water "hardness" of 17.1 ppm. (A ppm is a "part per million" and represents how many grams of calcium carbonate there would be per 1,000,000 grams of water). Put your data in a table similar to that below.

Water Sample	Drops of titrant	Water Hardness (ppm)

Results

Rank the samples from softest to hardest and explain the relative hardness of each with a sentence or two. This means you should be able to explain why some types of water should be expected to be harder than others.