Rain, Lakes, and Streams

Investigating Acidity and Buffering Capacity in the Environment

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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.

$$CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq) \qquad H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$

About the Activity

In this activity, students will discover why normal rain is not neutral when they observe the effect of their breath (typically 4% CO_2) on the pH of poorly buffered water. The addition of small amounts of acid (lemon juice or vinegar) noticeably alters the pH of a poorly buffered solution—the pH of a well-buffered solution does not change as easily.

Alkalinity or, more appropriately, *acid neutralizing capacity* (ANC) represents the ability of a solution to neutralize acid; that is, the buffering capacity when acid is added. Common minerals that contribute to ANC in natural waters include calcite (limestone or $CaCO_3$) and dolomite ($CaMg(CO_3)_2$). ANC is attributed to a mixture of several dissolved minerals, but it is represented as if it is entirely due to calcium carbonate and is given the units ppm $CaCO_3$ (mg $CaCO_3$/L). Both pH and alkalinity can be measured using inexpensive test strips available at swimming pool and spa supply stores. These strips are generally sold in packages of 50. They measure pH over a range of 6.4 to 8.4 and alkalinity from 0 to 240 ppm. In some cases student readings may go off the scale—above 240. Discuss this possibility, and the colors they may see, with your students prior to beginning the activity. Strips also test for free chlorine and bromine. These tests can be ignored.

Water for activities 1–5 should be pretested. Water with ANC below 25 ppm and pH > 6.8 is strongly recommended. Tap water in most parts of the country has a higher ANC. Distilled or deionized water purchased at a local grocery store is a reliable source of low-ANC water. Rain water or water from some mountain streams or springs may also be used. In the northeast U. S. the ANC of natural waters may vary from less than 10 to several hundred ppm calcium carbonate. An assessment of the potential impact from acid deposition on local water may be made using the acid sensitivity guideline at right (*1*).

Sensitivity Assessment	ANC (mg $CaCO_3$/L)
Extremely sensitive	<2
Moderately sensitive	2–10
Low sensitivity	10–25
Not sensitive	>25

Few people know the ANC of their local waters but many know the degree of water hardness. Hardness is formally a measure of the capacity of a water sample to precipitate soap and is related to the concentration of calcium and magnesium cations present. Generally, hardness correlates approximately to ANC. An aqueous solution of pure calcium carbonate would have numerical values for ANC and hardness that are equal, both given as ppm $CaCO_3$.

Integrating the Activity into Your Curriculum

The observation that clean, natural rain is not neutral can be used as an example of equilibrium or to introduce weak acids. The primary concept introduced by this activity is that of buffering capacity. A more quantitative determination of ANC can be made by titrating a solution with acid, generally to a pH of 4.5 (*2*).

More Information

See the December 1997 issue of the *Journal*, pages 1408–1462, and the following articles:

1. Loucks, O. L.; Miller, R. W.; Armentano, T. V. *Northeastern Environ. Sci.* **1984,** *3*, 8–23.
2. American Public Health Association; American Waterworks Association; Water Environmental Federation. *Standard Methods for the Examination of Water and Wastewater*, 19th ed.; Franson, M. A. H. Ed.; American Public Health Association: Washington, DC, 1995.
3. Baedecker, P. A.; Reddy, M. M. The erosion of carbonate stone by acid rain: Laboratory and field investigations. *J. Chem. Educ.* **1993,** *70*, 104.
4. Epp, D. N.; Curtright, R. Acid rain investigations. *J. Chem. Educ.* **1991,** *68*, 1034.
5. Charola, A. E. Acid rain effects on stone monuments. *J. Chem. Educ.* **1987,** *64*, 436.
6. Ophardt, C. E. Acid rain analysis by standard addition titration. *J. Chem. Educ.* **1985,** *62*, 257.
7. Barrow, L. H. Pre-chemistry acid rain activities for kids. *J. Chem. Educ.* **1985,** *62*, 339.
8. Jacob, A. T. *Acid Rain*; ICE Publ. 91-009; Institute for Chemical Education: University of Wisconsin, Madison, WI, 1991.

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Is rainwater pure water? If not, what's in it? What is acid rain? And why does it have a greater effect on some lakes than others? This activity will help you to understand these issues better.

In very pure water, the concentration of H^+ ions (or H_3O^+ ions) is 10^{-7} mol/L. Since pH = –log[H^+], the pH of very pure water is 7.0. Solutions with a pH less than 7.0 are acidic; solutions with a pH greater than 7.0 are basic.

Alkalinity or, more appropriately, *acid neutralizing capacity* (ANC) is the ability of a solution to neutralize acid. A solution's resistance to change in pH is more generally called the *buffering capacity*. In natural water it results from exposure to minerals, such as limestone, that contain carbonate ion. Pure water has no ANC. Bottled water, such as distilled or spring water (but not mineral or carbonated water), usually has low ANC.

Try This

Swimming pool or spa suppliers sell test strips that can determine the pH and alkalinity of water samples. Obtain some test strips. Read the package directions carefully and follow them when making measurements. Use only water that has a low ANC. Record your results for each experiment.

__ 1. Put 1/2 cup (~125 mL) water into each of four 12–16 oz cups. Determine the pH and ANC of the water in cup #1.

__ 2. Blow vigorously through a straw into cup #2 for two or three minutes; then determine the pH and ANC of the solution. (Breathe in through your nose, not your mouth!)

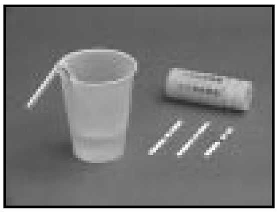
__ 3. Add 1/8 teaspoon of baking soda to cups #3 and #4; swirl until it dissolves; measure pH and ANC of cup #3.

__ 4. Blow vigorously through a straw into cup #4 for two or three minutes; determine pH and ANC of the solution.

__ 5. Add a few drops of lemon juice or vinegar to cups #1 and #3 and stir or swirl. Determine the pH in each cup.

Questions

How did the pH of the low-ANC water change when you blew into it with a straw? Why did this change occur? How did adding baking soda change the result? How much did the pH change when you added acid to cup #1? To cup #3? Why? Discuss the concepts of acid-sensitive, moderately acid-sensitive, and not acid-sensitive lakes with other students and your teacher.



More Things To Try

__ 1. Collect water samples from as many as possible of these sources: rain, melted snow, drinking water (municipal tap water, wells, etc.), lakes or streams. Measure the pH and ANC of each. Compare results to those for the low-ANC water. Can you lower pH by blowing into these samples? By adding a drop of vinegar or lemon juice?

__ 2. Which water samples are acid sensitive? Is there anything about your local geology to explain this?

Discussion

Rain falls through the earth's atmosphere, which contains naturally occurring carbon dioxide that dissolves to make carbonic acid. This lowers the pH of normal rain to about 5.6. In some areas or under some weather conditions, naturally occurring organic acids—acetic acid and formic acid—may cause the pH of normal rain to be as low as 5.2. Your breath contains about 4% CO_2 and therefore should lower the pH of low-ANC water.

The term *acid rain* describes rain that has a pH lower than normal for rain in a particular area. For example, rain in much of the eastern U. S. typically has a pH between 4.0 and 4.2, due to the presence of nitric acid (HNO_3) and acid sulfates (H_2SO_4 and HSO_4^-). These are produced by reactions of nitrogen oxides from car and truck emissions and sulfur dioxide from power plants and industrial sources.

Many lakes and streams in the northeastern United States no longer support native fish because their ANC was too small to neutralize acid rain. There is also considerable evidence that, along with ground-level ozone, acid deposition has heavily impacted northeastern evergreen forests. You can help prevent these problems from becoming worse even if you don't live in the northeast. Discuss with your class things you can do to help.

Information from the World Wide Web

http://www.epa.gov/acidrain/ardhome.html

http://nwcwww.er.usgs.gov/

http://www.globe.gov/