Natural Buffers in Lakes

Student Activity

What is this activity about?

Professor Isiah Warner, Boyd and Philip W. West Professor of Analytical and Environmental Chemistry at Louisiana State University, had an interest in chemistry since he was a young boy. His first experiments involved household chemicals. His parents always encouraged his curiosity for the world around him; they bought him his first chemistry set when he was ten years old. With further support from his teachers, Professor Warner eventually earned a Ph.D. in chemistry. He tells his students that they are not limited by background; they are only limited by how hard they work.

A common environmental issue is acid rain and its negative impact on lakes and their inhabitants. Rain is naturally acidic (pH ~ 5.6) because of the dissolved atmospheric carbon dioxide. Pollutants produced from the burning of fossil fuels can lower the pH of rainwater to values as low as 3 or 4. When this rainwater falls on lakes, their pH can be lowered and its plant and animal life suffers. Some lakes protect themselves from acid rain with their natural buffering ability. In this activity, you will study models of different lake systems to compare their buffering ability (ability to neutralize acid).

What Materials do I need?

Chemical splash goggles
Chemical-resistant Apron
6 Small bowls
Glass stirring rod
10 mL Graduated cylinder
100 mL Graduated cylinder
Plastic Pipettes
6 Test Tubes
Test tube rack
Distilled water
Vinegar
Sand
Limestone
Gravel
Marble
Universal Indicator solution

What safety precautions and disposal actions must I take?

1) Indicators and household substances are chemicals. Wear chemical splash goggles and a chemical-resistant apron when working with these materials.
2) Label all containers of substances being tested.
3) Solids may be disposed of in the trash.
4) All liquids may be flushed down the drain.

What procedure must I follow?

Day 1: *Preparation and Initial Testing of Lake Models*

1) Wear chemical splash goggles and a chemical-resistant apron while working in the lab.

2) Label each bowl as follows:

a) "water and vinegar" b) "water" c) "sand bed"
d) "limestone bed" e) "gravel bed" f) "marble bed"

3) Place the labeled bowls in an area where they will not be disturbed.
4) To the bowls labeled with the solid bed, cover the bottom of the bowl with a thin layer of the solid.
5) Add 100 mL of distilled water to each bowl.
6) Add 5.0 mL of distilled water to the bowl labeled "water" and stir with a clean stirring rod.
7) Add 5.0 mL of vinegar to each of the other bowls. Stir the contents of each bowl with a clean glass stirring rod.
8) Use step 2 to label six test tubes and place them in the test tube rack.
9) Place 10.0 mL of liquid from each bowl into the matching test tube. Add several drops of Universal Indicator to each test tube, stir, and record the color and pH in the data table provided.
10) To each of the test tubes b-f, add vinegar a drop at a time and stir. Continue adding the vinegar, a drop at a time, until the color of the liquid in the test tube matches the color of the liquid in the test tube labeled "water and vinegar." Record the number of drops of vinegar used in the data table.
11) Flush the contents of each test tube down the drain, rinse with distilled water, and place the inverted test tubes in the test tube rack to dry. You will use the test tubes for further testing.
12) Cover the bowls with plastic wrap and save for further testing. Clean your work station as directed by your teacher.

Day 2: *Retesting the Model Lakes-48 hours after initial set-up*

1) Wear chemical splash goggles and a chemical-resistant apron during testing and clean-up.
2) Place 10.0 mL of liquid from each bowl into the matching test tube. Add several drops of Universal Indicator to each test tube, stir, and record the color and pH in the data table.
3) To each of the test tubes b-f, add vinegar a drop at a time and stir. Continue adding the vinegar, a drop at a time, until the color of the liquid in the test tube matches the color of the liquid in the test tube labeled "water and vinegar." Record the number of drops of vinegar used in the data table.
4) Follow your teacher's directions for disposal of materials and clean-up.

How is this activity related to my knowledge of science/chemistry? (Questions)

1) Why does normal rain have a pH of about 6?
2) What controls are there in this activity?
3) Define the term "buffering capacity."
4) Complete the table.

Material	Chemical Name	Chemical Formula
Sand		
Limestone		
Gravel	mixture	----

Marble		

5) Do your results from Day 1 identify any buffer systems?
6) Do your results from Day 2 identify any buffer systems?
7) a) Which “Model Lake(s)” has/have the best buffering capacity? Explain.
   b) What chemical is present in the lake bed?
8) Write the neutralization reaction that is occurring for this buffer system (vinegar and calcium carbonate).
9) Which “Model Lake(s) has/have no buffering capacity? Explain.
10) You are hired as an environmental engineer by your community to neutralize the effects of acid rain on a local lake. What suggestions do you have?

How can I extend my learning with this activity? (Extensions)

1) Identify sources of acid rain in your area.
2) Collect samples of water from local streams and lakes and test their buffering capacities.
3) Test the pH of samples of rain water/snow collected at different times.

Natural Buffers in Lakes

Teacher's Guide

Concepts:

- pH and indicators
- Acid-base neutralization
- Buffers
- Acid rain

Background:

In this activity, students understand that rain is slightly acidic, acid rain occurs when pollutants dissolve in water, and some lakes have a natural buffering capacity. Students will identify natural buffers in lakes.

Chemistry:

$$CO_2(g) + H_2O(l) \rightleftarrows H_2CO_3(aq)$$

$$H_2CO_3(aq) \rightleftarrows H^+(aq) + HCO_3^-(aq)$$

Figure 1. The Chemistry of Natural Rainwater

Carbonic acid forms as the atmospheric carbon dioxide reacts with the rain. Clean natural rainwater has a pH ~ 5.6.

$$SO_3(g) + H_2O(l) \rightleftarrows H_2SO_4(aq)$$

$$H_2SO_4(aq) \rightleftarrows H^+(aq) + HSO_4^-(aq)$$

Figure 2. The Chemistry of Acid Rain

Acid rain forms when gases such as sulfur dioxide form from the burning of fossil fuels. Sulfur dioxide is oxidized by atmospheric hydroxide radicals to produce sulfur trioxide. The sulfur trioxide reacts with rainwater to produce sulfuric acid. Similarly, nitrogen dioxide reacts with the hydroxyl radical to form nitric acid. The pH of acid rain can be as low as 3.

$$H_2SO_4(aq) + CaCO_3(s) \rightleftarrows CaSO_4(aq) + CO_2(g) + H_2O(l)$$

Figure 3. The Buffering Capacity of Limestone

Lakes that have a limestone bed have a natural buffering ability to neutralize acid rain. Limestone is a sedimentary rock that is porous and somewhat 'soft.' Marble is a metamorphic rock that has been hardened over time under heat and pressure. Although limestone and marble both contain calcium carbonate, the porous nature of limestone allows it to react as a buffer more quickly.

Materials:

Chemical splash goggles
Chemical-resistant apron
6 Small bowls
Glass stirring rod
10 mL Graduated cylinder
100 mL Graduated cylinder
Plastic Pipettes
6 Test Tubes
Test tube rack
Distilled water
Vinegar
Sand
Limestone
Gravel
Marble
Universal Indicator solution

Procedure:

Small glass jars can be used in place of the small bowls

Sources of limestone:

1) Low dust chalk. Not all chalk contains calcium carbonate. Test the chalk by placing a few drops of vinegar on a piece of chalk. If bubbling occurs, the chalk is calcium carbonate.
2) Crushed lime can be purchased from a garden supply store.

Marble chips can also be purchased from garden supply stores.

Red cabbage juice can replace Universal Indicator solution. Red cabbage juice is also used in the *Test Strip Activity*.

This activity can be used as a guided inquiry by having students design their own procedure.

How is this activity related to my knowledge of science/chemistry? (Questions/Targeted Answers)

1) Why does normal rain have a pH of about 6?
   The CO_2 from the atmosphere dissolves in the rainwater to produce carbonic acid.
2) What controls are there in this activity?
   Each bowl has 100 mL water; each bowl has 10 mL vinegar or 10 mL water; 10 mL samples are tested.
3) Define the term "buffering capacity."
   It is the ability to neutralize an acid.
4) Complete the table.

Material	Chemical Name	Chemical Formula
Sand	silicon dioxide	SiO_2
Limestone	calcium carbonate	$CaCO_3$
Gravel	mixture	----
Marble	calcium carbonate	$CaCO_3$

5) Do your results from Day 1 identify any buffer systems?
   No
6) Do your results from Day 2 identify any buffer systems?

Yes, Limestone and Marble

7) a) Which "Model Lake(s)" has/have the best buffering capacity? Explain.
   The limestone model resisted the change in pH the most. It required the most drops of vinegar to lower the pH.
   b) What chemical is present in the lake bed?
   Calcium carbonate

8) Write the neutralization reaction that is occurring for this buffer system (vinegar and calcium carbonate).

$$2CH_3COOH + CaCO_3 \rightleftarrows H_2CO_3 + Ca(CH_3COO)_2 \rightleftarrows H_2O + CO_2 + Ca(CH_3COO)_2$$

9) Which "Model Lake(s) has/have no buffering capacity? Explain.
   Sand and Gravel

10) You are hired as an environmental engineer by your community to neutralize the effects of acid rain on a local lake. What suggestions do you have?
   Place a layer of limestone or marble at the lakebed.

Safety and Disposal:

Wear chemical splash goggles and a chemical-resistant apron when handling all materials.
All used materials can be safely washed down the drain or disposed of in the trash.

Extensions:

1) Identify sources of acid rain in your area.
2) Collect samples of water from local streams and lakes and test their buffering capacities.
3) Test the pH of samples of rain water/snow collected at different times.

References:

Halstead, Judith A. *J Chem Educ.* **1997**, 74, 1456A-1456B

JCE Staff, *J Chem Educ.* **2003**, 80, 40A-40-B

http://www.kyantec.com/Tips/phbuffering.htm

http://apbrwww5.apsu.edu/robertsonr/nova/AcidRainLab.pdf

Data Table

Day 1

	Color of Universal Indicator	pH	Number of drops vinegar used to reach color in Bowl 1
1. Vinegar and Water			0
2. Water			
3. Sand			
4. Limestone			
5. Gravel			
6. Marble			

Day 2 (48 hours later)

	Color of Universal Indicator	pH	Number of drops vinegar used to reach color in Bowl 1
1. Vinegar and Water			0
2. Water			
3. Sand			
4. Limestone			
5. Gravel			
6. Marble			