Experiment
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Acid Rain

Acid rain is a topic of much concern in today's world. As carbon dioxide gas, CO_2, dissolves in water droplets of unpolluted air, the following reaction occurs:

$$CO_2 + H_2O \longleftrightarrow H_2CO_3$$

H_2CO_3 is a weak acid that causes the rain from unpolluted air to be slightly acidic. This source of "acid rain" is not usually considered to be a pollutant, since it is natural and usually does not alter the pH of rain water very much. Oxides of sulfur dissolve in water droplets to cause more serious problems. Sulfur dioxide dissolves to produce sulfurous acid, H_2SO_3, by the equation:

$$SO_2 + H_2O \longleftrightarrow H_2SO_3$$

This source of sulfur dioxide can occur naturally, as from volcanic gases. More often, however, sulfur dioxide is considered a pollutant, since it is a by-product of fossil-fuel combustion.

The acidity of a solution can be expressed using the pH scale, which ranges from 0 to 14. Solutions with a pH above 7 are basic, solutions with pH below 7 are acidic, and a neutral solution has a pH of 7. In Part I of this experiment, you will study how the pH of water changes when CO_2 is dissolved in water. In Part II, you will study the effect sulfuric acid has on the pH of different water types.

OBJECTIVES

In this experiment, you will

- Use a pH Sensor to measure changes in pH.
- Study the effect of dissolved CO_2 on the pH of distilled water.
- Study the effect of dissolving H_2SO_4 in various waters on pH.
- Learn why some bodies of water are more vulnerable to acid rain than others.

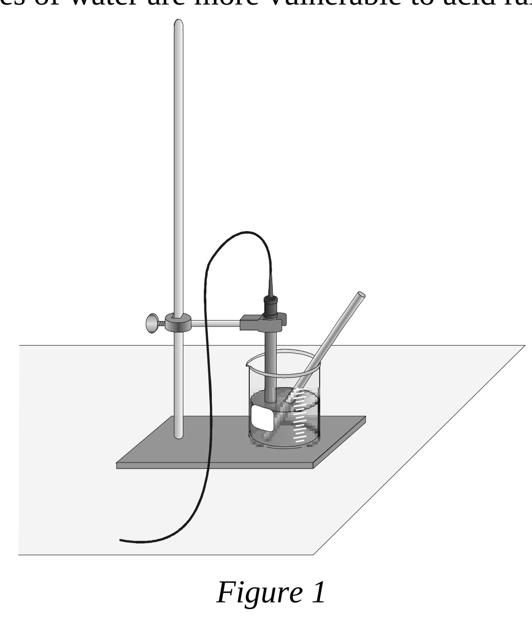

Figure 1

MATERIALS

TI-83 Plus or TI-84 Plus graphing calculator
EasyData application
data-collection interface
Vernier pH Sensor
Logger *Pro* or graph paper
250 mL and 100 mL beaker
buffer solution
dilute H_2SO_4
ring stand and utility clamp
straw
wash bottle with distilled water
water from a lake
water from the ocean (optional)

PROCEDURE

Part I CO_2 and Water

As carbon dioxide gas, CO_2, dissolves into water droplets suspended in the atmosphere, it changes the rainwater's pH. Here you will test to see if CO_2 will affect the pH of distilled water. The source of CO_2 will be your breath.

1. Obtain and wear goggles.

2. Before each use of the pH Sensor, you need to rinse the tip of the sensor thoroughly with distilled water. To do this, hold the pH Sensor above a rinse beaker and use the rinse bottle to thoroughly rinse the sensor tip.

   Important: Do not let the pH Sensor dry out. Keep it in a 250 mL beaker with about 100 mL of tap water when not in use. The tip of the sensor is made of glass—it is fragile. Handle with care!

3. Turn on the calculator. Connect the pH Sensor, data-collection interface, and calculator.

4. Set up EasyData for data collection.
   a. Start the EasyData application, if it is not already running.
   b. Select **File** from the Main screen, and then select **New** to reset the application.

5. Wash a 250 mL beaker with tap water and dry it with a paper towel. Note: All glassware must be clean in this experiment! Put 100 mL of distilled water into this clean beaker. Using a ring-stand and utility clamp, secure the pH Sensor in the beaker as shown in Figure 1. The tip of the sensor should be down in the distilled water. Swirl the water around the sensor tip briefly. Place a clean straw into the distilled water.

6. Record the pH value displayed on the screen as the initial pH (time 0) in Table 1.

7. Begin data collection by selecting **Start** from the Main screen. Take a deep breath, then gently blow your breath into the distilled water for as long as possible.

8. When data collection is finished, a graph of pH *vs.* time will be displayed on the calculator screen. As you move the cursor right or left, the time (X) and pH (Y) values of each data point are displayed above the graph. In Table 1, record the pH value at 10, 20, 30, 40, 50, 60, 70, 80, and 90 seconds.

Part II Simulating Acid Rain Using H_2SO_4

9. Empty the distilled water from the beaker and rinse the pH Sensor thoroughly with distilled water from a rinse bottle. Place the pH Sensor in the storage beaker with tap water.

10. Wash and dry the 250 mL beaker. Fill the beaker with a 50 mL portion of distilled water. Set up the beaker and pH Sensor as shown in Figure 1.

11. Change the data collection mode by selecting **Setup** from the Main screen, and then **Events with Entry**.

12. Select **Start**, then **OK** to overwrite the previous data and begin taking pH measurements. Monitor the pH readings displayed on the calculator screen. When the readings are stable, select **Keep**.

13. The calculatr will prompt you for the number of drops of acid you added to the beaker. Enter **0** and select **OK**.

14. Add 1 drop of acid to the beaker. Stir the solution thoroughly after addition. **CAUTION:** *Handle the sulfuric acid with care. It can cause painful burns if it comes in contact with the skin. Avoid spilling it on your skin or clothing.*

15. When the readings are stable, select **Keep** on the calculator. Enter the total number of drops of acid added to the water in the beaker and select **OK**.

16. Repeat Steps 14–15, adding 1 drop each time until a total of 10 drops has been added.

17. Select **Stop** to stop data collection. A graph will be displayed with pH along the y-axis and the number of drops added along the x-axis. Move the flashing cursor from point to point and record the pH values in Table 2. When finished, select **Main** to return to the Main screen.

H_2SO_4 and Water from the Ocean

18. Repeat Steps 12–17 using "Ocean Water" in place of distilled water. **Note**: After selecting **Start** to begin data collection, select **OK** to overwrite the previous data and begin data collection.

H_2SO_4 and Lake Water

19. Repeat Steps 12–17 using "Lake Water" in place of distilled water.

H_2SO_4 and Buffer Solution

20. Repeat Steps 12–17 using "Buffer Solution" in place of distilled water.

21. Using Logger *Pro*, or by hand, make a plot of pH vs. drops of acid added. Place all four graphs (distilled, ocean, lake, and buffered water) on the same plot.

DATA

Part I

Table 1: Adding CO_2 from your breath to water											
Time (s)	0	10	20	30	40	50	60	70	80	90	ΔpH
pH											

Part II

Table 2				
Drops	pH of this water type			
	distilled	ocean	lake	buffer
0				
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
ΔpH				

QUESTIONS

1. Calculate the change in pH (ΔpH) for the water in Part I. What conclusion can you make about your breath?
2. Why does the pH change rapidly at first, and remain stable after a time?
3. Calculate the change in pH (ΔpH) for each of the Part II trials.
4. Compare the ΔpH values. Which test gave the largest pH change? Which test gave the smallest pH change?

5. Water from the ocean is said to be “naturally buffered.” From the result of this experiment, what does this mean?

6. How does water from the ocean become buffered?

7. Many aquatic life forms can only survive in water with a narrow range of pH values. In which body of water, lakes or oceans, would living things be more threatened by acid rain? Explain.

8. There are numerous coal-burning electric power plants along the Ohio River in Southern Indiana where the river and lake waters are naturally buffered. However, air pollution produced there is more harmful to water life in Upstate New York where the river and lake waters are NOT buffered like those in Southern Indiana. A similar situation exists in Europe where air pollutants from highly industrialized Germany are more harmful to Scandinavian water life than to water life in Germany. Use the results of this experiment to explain these situations.

9. Summarize your conclusions of this laboratory experiment. Use your data to answer the purposes of this experiment.

EXTENSIONS

1. Test hard and soft water in the same way you tested lake and ocean water. How do they compare?

2. Do library research to get more information on the effects of acid rain on streams and lakes.

3. Do library research and prepare a report on “naturally buffered” streams and lakes.

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TEACHER INFORMATION

Acid Rain

1. There are several different combinations of equipment that will work for measuring pH. The most common method, which works for both the TI-83 Plus and TI-84 Plus families of calculators, is to use a pH Sensor connected to a LabPro or CBL 2.

   The other method, which uses the USB port on TI-84 Plus calculators, is to connect a pH Sensor to an EasyLink. For more information on EasyLink refer to *Appendix G*.

2. The water in Part I should be boiled, cooled, and stored in a bottle filled to capacity. This will prevent the CO_2 from the atmosphere from affecting its pH. Alternatively, you can adjust the pH with 0.050 M NaOH to about 7. The latter option is much easier to accomplish.

3. To prepare the dilute (0.02 M) H_2SO_4 solution, dilute 1.1 mL of concentrated sulfuric acid into distilled water to make a total volume of 1 L.

4. If ocean water is not available, synthetic ocean water can easily be prepared:
   - Dissolve the following ingredients, one at a time in the order given, in 800 mL of distilled water: 23.2 g NaCl, 1.11 g $CaCl_2$, 6.46 g $MgCl_2$.
   - Add 0.84 g of $NaHCO_3$ slowly with rapid stirring.
   - Add 5.40 g Na_2SO_4.
   - Bring the volume up to 1 L with distilled water.
   - Bring the pH of the solution to 7.8, using 0.01 M NaOH.
   - Fill the bottle completely and stopper it tightly. This will prevent the pH from lowering due to the absorption of CO_2.

5. If lake water is not available, hard or soft water might be used, depending upon the local water characteristics:

   A recipe for hard water follows:
   - To 800 mL of distilled water, add 0.12 g $CaCO_3$; 0.10 g $CaSO_4$; 0.038 g $MgCl_2$.
   - With rapid stirring, slowly add 0.10 g $NaHCO_3$.
   - Bring the volume up to 1 L with distilled water.

   A recipe for *softened* hard water follows:
   - To 800 mL of distilled water, add 0.191 g NaCl; 0.107 g Na_2SO_4.
   - With rapid stirring, slowly add 0.109 g $NaHCO_3$.
   - Bring the volume up to 1 L with distilled water.

6. To prepare a buffer solution, add up to four times the recommended amount of water to a commercially available pH 7 buffer tablet. Since the amount of acid added is very small, the buffer tablet need not be made to full strength.

   Vernier Software sells a pH buffer package for preparing buffer solutions with pH values of 4, 7, and 10 (order code PHB). To prepare a standard solution, simply add the capsule contents to 100 mL of distilled water. This solution can be diluted to 500 mL for this experiment.

You can also prepare a pH 7 buffer using the following recipe: Add 582 mL of 0.1 M NaOH to 1000 mL of 0.1 M potassium dihydrogen phosphate.

7. The pH calibration that is stored in the EasyData program works well for this experiment. For more accurate pH readings, you (or your students) can do a 2-point calibration for each pH system using pH 4 and pH 10 buffers.

SAMPLE RESULTS

The following data will be different from students' results.

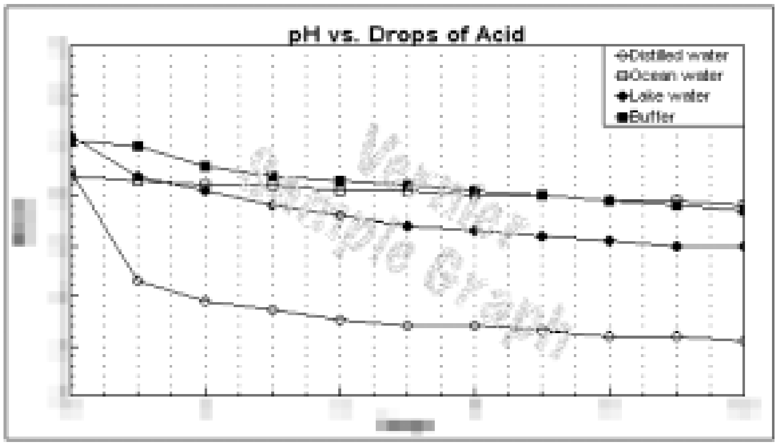
Part I

Table 1: Adding CO_2 from the breath to water.								
Time (s)	0	10	20	30	40	50	60	ΔpH
pH	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx

Part II

The following data were taken from the Puget Sound area.

Table 2				
Drops	pH of this water type			
	distilled	ocean	lake	buffer
0	xxxx	xxxx	xxxx	xxxx
1	xxxx	xxxx	xxxx	xxxx
2	xxxx	xxxx	xxxx	xxxx
3	xxxx	xxxx	xxxx	xxxx
4	xxxx	xxxx	xxxx	xxxx
5	xxxx	xxxx	xxxx	xxxx
6	xxxx	xxxx	xxxx	xxxx
7	xxxx	xxxx	xxxx	xxxx
8	xxxx	xxxx	xxxx	xxxx
9	xxxx	xxxx	xxxx	xxxx
10	xxxx	xxxx	xxxx	xxxx
ΔpH	xxxx	xxxx	xxxx	xxxx



ANSWERS TO QUESTIONS

Answers have been removed from the online versions of Vernier curriculum material in order to prevent inappropriate student use. Graphs and data tables have also been obscured. Full answers and sample data are available in the print versions of these labs.

ACKNOWLEDGMENT

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