PRELIMINARY ACTIVITY FOR

The Effect of Acid Deposition on Aquatic Systems

Open Inquiry Version

Acid deposition is a topic of much concern in today's world. It can kill fish and other water life by lowering the pH of lakes and rivers. The pH scale is a measure of acidity. A pH value of 7 is neutral, values lower than 7 are increasingly acidic, and values higher than 7 are increasingly basic. Acid deposition is more harmful in some areas than others because some water resists changes in pH better than others. This ability to resist pH change is called buffering capacity. In Part I of the Preliminary Activity, you will use a pH Sensor to monitor pH as dilute sulfuric acid is added drop wise to a water sample.

General water hardness is related to the dissolved minerals in the water. In Part II of the Preliminary Activity, you will use a Conductivity Probe to determine the conductivity of water from the same source.

The following table describes water hardness as determined by conductivity measurements.

Conductivity (µS/cm)	Hardness
0–140	Very Soft
140–300	Soft
300–500	Slightly Hard
500–640	Moderately Hard
640–840	Hard
Above 840	Very Hard

After completing the Preliminary Activity, you will first use reference sources to find out more about acid deposition before you choose and investigate a researchable question dealing with acid deposition. Some topics to consider in your reference search are:

- acid precipitation
- pH scale
- acid deposition
- water hardness
- effects of acid deposition

PROCEDURE

Part I Effect of Acid Deposition on the pH of a Water Sample

1. Obtain and wear goggles.

2. Connect the pH Sensor and the data-collection interface.

3. Set up the data-collection software for the Events with Entry mode.
4. Rinse the pH Sensor with distilled water.
5. Use a utility clamp to fasten the pH Sensor to a ring stand as is shown in Figure 1.
6. Get a 50 mL portion of water provided by your instructor. Lower the pH Sensor into the water. Stir thoroughly.
7. Keep a data point for "0" drops of sulfuric acid before any acid is added.
8. Add 1 drop of 0.10 M H_2SO_4 to the water. **CAUTION:** *Handle this sulfuric acid with care. It can cause painful burns if it comes into contact with skin, eyes, or clothing.*
9. Stir thoroughly. When the pH is stable, keep a data point for "1" drop of acid.
10. Repeat Steps 8 and 9, adding 1 drop at a time, until you have added a total of 6 drops of sulfuric acid.

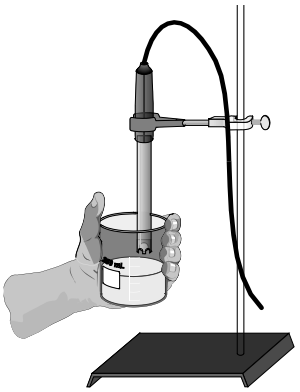

Figure 1

Part II Conductivity of a Water Sample

11. Connect the Conductivity Sensor and the data-collection interface.
12. Place the tip of the Conductivity Sensor into a new sample of the water provided by your instructor. Be sure to submerge the sensor far enough to cover the hole at the tip of the sensor. Record the displayed conductivity reading (in µS/cm).

QUESTIONS

1. How hard was the water sample that was tested?

2. How low did the pH drop?

3. Would the pH values of water samples from various sources be equally affected by the addition of dilute sulfuric acid? Why?

4. List at least one researchable question concerning the effects of acid deposition on aquatic systems.

Note: The plan that you submit for instructor approval should list laboratory safety concerns, including chemical safety concerns, and specify how you will address these safety concerns during your investigation.

Experiment
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The Effect of Acid Deposition on Aquatic Systems

OVERVIEW

In the Preliminary Activity, students learn techniques for using a pH Sensor to monitor pH change as dilute sulfuric acid is added drop wise to a water sample and for using a Conductivity Probe to determine the hardness of the water. A student handout for the Open Inquiry version of the Preliminary Activity can be found at the end of this experiment. A Guided Inquiry version is found on the CD accompanying this book.

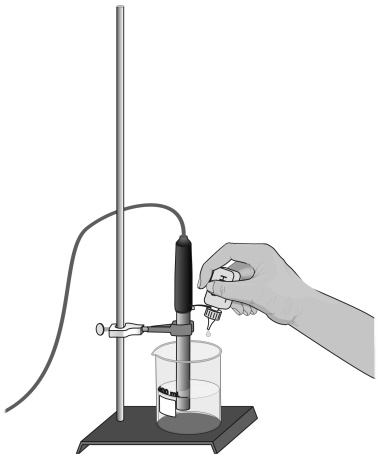

Figure 1

During the subsequent Inquiry Process, your students will first learn about acid deposition using the course textbook, other available books, and the Internet. They will then generate and investigate researchable questions concerning the effect of acid deposition on aqueous ecosystems as affected by water hardness. (In the Guided Inquiry approach, students will plan and conduct investigations of the researchable question(s) assigned by you.)

LEARNING OUTCOMES

In this inquiry experiment, students will

- Identify variables, design and perform the experiment, collect data, analyze data, draw a conclusion, and formulate a knowledge claim based on evidence from the experiment.
- Identify the probable effects of acid deposition on water samples from various sources.
- Determine the relationship between the hardness of water and its buffering capacity.

CORRELATIONS

IB Topic and Sub-Topic

Option E – Environmental Chemistry
Sub-Topic E.2 – Acid deposition

THE INQUIRY PROCESS

Suggested Time to Complete the Experiment

See the section in the introduction, Doing Inquiry Experiments, for more information on carrying out each phase of an inquiry experiment.

	Inquiry Phase	Open Inquiry	Guided Inquiry
I	Preliminary Activity	30 minutes	30 minutes
II	Generating Researchable Questions (Omitted in Guided Inquiry Approach)	15 minutes	0 minutes
III	Planning	15 minutes	15 minutes
IV	Carrying Out the Plan	40 minutes	35 minutes
V	Organizing the Data	15 minutes	15 minutes
VI	Communicating the Results	15 minutes	10 minutes
VII	Conclusion	10 minutes	10 minutes

MATERIALS

Make the following materials available for student use. Items in bold are needed for the preliminary activity.

data-collection interface
data-collection program
Vernier pH Sensor
Vernier Conductivity Probe
100 mL beaker
wash bottle and distilled water
0.10 M H_2SO_4 in a dropper bottle
ring stand and utility clamp
soft water
Vernier Stir Station (optional)
hard water
buffer solution
water from various local sources
others as requested by students

I Preliminary Activity

This inquiry experiment begins with a two-part activity to introduce useful data-collection techniques. Students first learn how to collect pH data using the Events with Entry data-collection mode. They subsequently gain experience collecting conductivity data.

Sample Results

Table 1: Preliminary Activity Data

Drops	pH	Drops	pH
0	6.99	4	3.87
1	6.91	5	3.64
2	6.62	6	3.49
3	4.51		

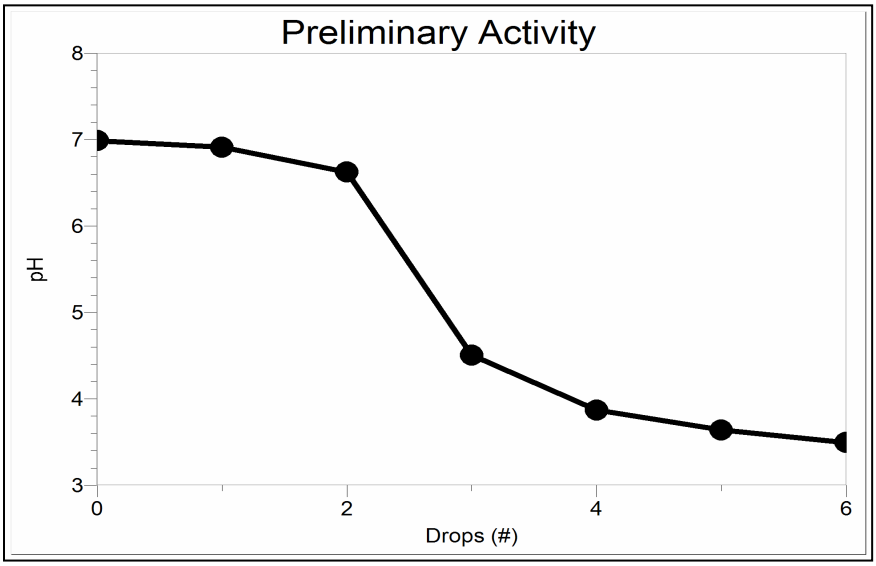

Figure 2 *Effect of acid on the pH of soft water*

Because soft water has relatively low buffering capacity, the addition of a small amount of acid can cause a large pH drop.

Answers to the Questions

1. How hard was the water sample that was tested?

   Answers will vary. However, we suggest that you provide your students with soft water for use in the Preliminary Activity.

2. How low did the pH drop?

   Answers will vary. The addition of six drops of 0.1 M H_2SO_4 will generally cause the pH of 50 mL of soft or very soft water to drop below 3.5.

3. Would the pH values of water samples from various sources be equally affected by the addition of dilute sulfuric acid? Why?

   No. The pH values of harder waters would be expected to drop less upon the addition of dilute sulfuric acid because they have more buffering capacity due to the presence of higher concentrations of dissolved minerals.

4. List at least one researchable question concerning the effects of acid deposition on aquatic systems. (Not applicable for the Guided Inquiry approach.)

   Answers will vary. See the Researchable Questions list below for some possible answers.

II Generating Researchable Questions

Note: Researchable questions are assigned by the instructor in the Guided Inquiry approach. See page xiii in the Doing Inquiry Experiments section for a list of suggestions for generating researchable questions. Some possible researchable questions for this experiment are listed below:

Recommended for Open Inquiry or Guided Inquiry (sample results provided)

- What is the relationship between water hardness and the effect of acid deposition on the pH of the water?

Recommended for Open Inquiry or Guided Inquiry (no sample results provided)

- How hard is local stream (lake) water and how vulnerable is it acid deposition?
- Does the susceptibility of local surface water to the influence of acid deposition vary depending on the time of the year?
- How do the hardnesses (and acid vulnerabilities) of surface water samples from various local sources compare?
- How do the hardnesses (and acid vulnerabilities) of water samples taken at various points on a local stream, from its source to its mouth, compare?
- How do the hardnesses (and acid vulnerabilities) of water samples from various sources around the country compare?
- How do the hardnesses (and acid vulnerabilities) of tap water samples collected at various points in the community compare?
- How do the hardnesses (and acid vulnerabilities) of various bottled waters compare?
- How do commercial water softeners affect the hardness (and acid vulnerability) of water?

There are many more possible researchable questions. Students should choose a researchable question that addresses the learning outcomes of your specific standards. Be sure to emphasize experimental control and variables. (Instructors using the Guided Inquiry approach select the researchable questions to be investigated by their students. We encourage you to assign multiple researchable questions because this strategy enhances student interaction and learning during phases IV–VII.)

III Planning

During this phase students should formulate a hypothesis, determine the experimental design and setup, and write a method they will use to collect data. Circulate among the student groups asking questions and making helpful suggestions.

IV Carrying Out the Plan

During this phase, students use their plan to carry out the experiment and collect data. Circulate among the student groups asking questions and making helpful suggestions.

V Organizing the Data

See page xv in the Doing Inquiry Experiments section for suggestions concerning how students can organize their data for their inquiry presentations.

VI Communicating the Results

See page xv in the Doing Inquiry Experiments section for a list of inquiry-presentation strategies.

VII Conclusion

See page xvi in the Doing Inquiry Experiments section for a list of suggestions concerning assessment and ways to utilize the results in subsequent instruction.

SAMPLE RESULTS

Student results will vary depending on experimental design.

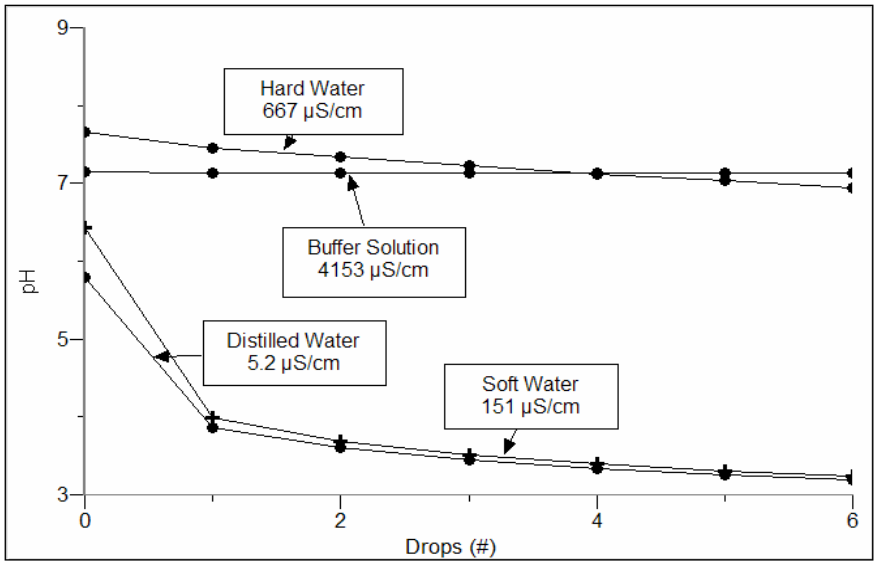

Figure 3 *Effect of adding acid on pH*

Table 2: Water Hardness and pH Changes				
Hardness	Conductivity (µS/cm)	Initial pH	Final pH	ΔpH
Distilled Water	5.2	5.79	3.20	2.59
Very Soft	42.7	6.28	3.25	3.03
Soft	187	6.99	3.49	3.50
Slightly Hard	391	8.05	7.00	1.05
Moderately Hard	547	7.42	6.90	0.52
Hard	667	7.66	6.94	0.72
Very Hard	930	8.28	7.54	0.74
Buffer Solution	4153	7.15	7.13	0.02

This investigation addresses the question, “What is the relationship between water hardness and the effect of acid deposition on the pH of the water?”

Because soft waters has relatively low buffering capacities, the addition of small amounts of acid can cause pH values to drop to low levels—all in the pH 3–4 range in this data above. Hard waters, in contrast, have greater buffering capacities and their pH values are less affected by the addition of acid. In the data above, the final pH values of the various hard-water samples were all 6.9 or higher.

TIPS

Experiment Information

1. Dilute sulfuric acid solution (0.10 M H_2SO_4) can be purchased from Flinn Scientific (Order code S0419 for 500 mL of 0.10 M H_2SO_4). To prepare the sulfuric acid solution yourself, dilute 5.6 mL of concentrated sulfuric acid into distilled water to make a total volume of 1.0 L. It should be made available in small dropper bottles. **HAZARD ALERT:** Severely corrosive to eyes, skin and other tissue; considerable heat of dilution with water; mixing with water may cause spraying and spattering. Solutions might best be made by immersing the mixing vessel in an ice bath. **Always add the acid to water, never the reverse**; extremely hazardous in contact with finely divided materials, carbides, chlorates, nitrates and other combustible materials. Hazard Code: A—Extremely hazardous.

   The hazard information reference is: Flinn Scientific, Inc., *Chemical & Biological Catalog Reference Manual*, (800) 452-1261, www.flinnsci.com. See *Appendix E* of this book for more information.

2. A pH 7 buffer solution can be used as the buffer solution and as a "pH soaking solution" in this experiment. It can be purchased from chemical supply companies. Vernier Software & Technology sells a package of capsules for preparing buffer solutions of pH 4, 7, and 10 (Order Code PHB). We recommend that you remove the pH Sensor from its storage bottle before class. If the pH Sensor is soaking in a beaker pH soaking solution, students will have an easier time taking pH measurements.

3. We suggest that you provide your students with relatively soft water for the preliminary activity, water that gives a large pH drop as the dilute sulfuric acid is added.

4. The use of Vernier Stir Stations (Order Code STIR) or magnetic stirrers speeds up data collection and enhances results in this experiment.

5. Because softer waters generally have lower initial pH values than harder waters and because of difficulties in measuring the initial pH of softer waters for the reasons mentioned in the Sensor Information found in *Appendix F*, it is more meaningful to compare final pH values rather than ΔpH values in this experiment.

6. The results of this experiment would imply that all hard waters (slightly hard to very hard) are well enough buffered to resist significant pH drop upon the addition of dilute sulfuric acid. Soft and very soft waters, on the other hand, experience large pH drops.

7. See *Appendix F* for sensor and sensor check information.

8. The plans that your students submit for approval should list laboratory safety concerns, including chemical safety concerns, and specify how they will address these safety concerns during their investigations.