Thawing Acid Rain

Introduction

Acid rain has received a great deal of attention in recent years and its effect on the environment is well documented. Acid rain can arrive in the form of rain, snow, or ice. Winter snow pack can be thought of as frozen acid rain waiting for the spring thaw. What happens when the snow pack melts? Does it matter whether it melts quickly or slowly?

Concepts

- pH measurement
- Acid rain
- Differential freezing

Background

Acids from atmospheric pollution can fall to the Earth in a variety of forms such as rain, snow, and sleet. In poorly buffered watersheds, acidic precipitation can cause severe damage to land and water ecosystems. Some streams and lakes that are not permanently acidic can become so during spring thaw and runoff. This, unfortunately, can coincide with the delicate spawning season for some species of fish or the mating time of other aquatic species. The sudden acidification of stream water can greatly reduce the fertilization rate in fish or the viability of the fry that do manage to develop. Every spring, the conditions in a given area are different. The ability to predict exact consequences of runoff are difficult. But it is likely that the timing between fish spawning and rapid snow melt can have major impact on the resulting fish population.

To understand why an early, quick thaw could release more acid in a short time than a slow thaw, one needs to consider what happens when solutions freeze and thaw. The freezing point of a solution is lower than that for a pure solvent. The pure solvent (e.g., water) freezes prior to the freezing of a solution containing solute. When a solution is cooled below the solvent's freezing point, the solvent will begin to solidify and the remaining solution becomes more concentrated with solute. Eventually, the solution reaches a low enough temperature and both components (solvent and solute) begin to freeze. When the frozen mass of materials is thawed, the reverse occurs. The solute-containing portion melts first (at the lowest temperature) producing a solution containing a high concentration of the solute. As thawing continues, the solvent will eventually melt but at a higher temperature. The solvent becomes a liquid again but only after the solute solution has already melted (and perhaps flowed away).

When a solution is melting or freezing, the composition of the liquid and the solid are never the same. In this experiment, when the acid solution (vinegar) freezes, the pure water will solidify first leaving behind a more concentrated acetic acid solution which takes longer to freeze. When the cubes melt, the opposite occurs and the more concentrated acetic acid melts first and leaves behind a less acidic frozen solid. If samples are collected during the melting process, the initial liquid samples will be more acidic than the later samples. The melting cubes in this experiment simulate a spring thaw of an acid snow pack.

Materials

Vinegar, white distilled, 200 mL
Clamp
Freezer
Funnel, large
Graduated cylinder, 25-mL
Hand-held blow dryer(s)
Ice cube tray
pH meter, ± 0.01 accuracy
Plastic wrap or zipper-lock bags
Ring stand
Test tubes, vials, or beakers, 6
Thermometer
Wax pencil or marker

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Safety Precautions

Vinegar is a weak acetic acid solution and is irritating to skin and eyes. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Please review current Safety Data Sheets for additional safety, handling, and disposal information. Wash hands thoroughly with soap and water before leaving the laboratory.

Pre-Lab Preparation

1. Pour white distilled vinegar into clean, dry ice cube trays.
2. Cover each tray with plastic wrap or put each tray inside a plastic bag and place in freezer. Label the contents of the tray to prevent vinegar cubes from being mistaken for regular ice cubes.
3. Leave the trays in the freezer overnight and keep cubes frozen until lab time.
4. Prepare enough cubes so that each lab group has six cubes.
5. Gently break the frozen cubes so the centers of the cubes are exposed.

Procedure

1. Using a wax pencil or marker, label six collection containers (test tubes, vials, or beakers) #1–#6.
2. Use a graduated cylinder to measure 20 mL of water and pour it into the collection container. On the outside of the container, make a mark at the meniscus and then pour the water out. Dry out the container. Make a similar mark on the other containers.
3. Make a data table with space to record the air temperature, time and pH of each sample to be collected.
4. Plug in a blow dryer and set the temperature and speed which your group has been assigned. Turn it on and hold a thermometer in the air stream for 30 seconds. Record the temperature in the data table.
5. Obtain about 12–15 large pieces of frozen vinegar cubes and place them in a large, dry funnel. Suspend the funnel using a ring stand and clamp or support. Put container #1 under the funnel and record the time.
6. Immediately turn on the blow dryer and collect liquid until it reaches the outside mark made in step 2. Make sure the blow dryer is the same distance away from the funnel during the whole experiment. As each container is replaced, record the time in the data table. Continue until all the containers have been used or the ice is totally melted.
7. Use a pH meter to measure the pH of each of the samples after they are collected. Record the pH values in the data table.
8. Make a graph of the group's results by plotting pH versus time.
9. Discuss the results and their implications for understanding the potential impact of a fast spring snow melt on nearby streams.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. Solutions can be washed down a sink with volumes of water following Flinn Suggested Disposal Method #26b.

Tips

- The teacher should set up this experiment identical to each student group but allow the ice cubes to melt at room temperature without using a blow dryer to speed up the melting process. Set a kitchen timer for 30 minutes as a reminder to replace each container throughout the day. Since the teacher's melt time will be slower than the student groups, the pH of the teacher's samples can be used as a comparison to the faster melt times.
- The observed pH changes will usually be between 0.6 to 1.4 pH units with a range from 2.5 to 4.5. Due to these small changes, pH paper is usually not sensitive enough for use in this experiment. A pH meter with a sensitivity of ± 0.01 units is required. Follow the operating instructions of the pH meter carefully to insure accurate results.
- Assign student groups different ice melting parameters. For example, cool, warm, hot temperature; low or high speed; 4

- Crushing the ice cubes slightly will give better results since ice cubes freeze on the outside first. The more concentrated acid is normally found on the inside of the cube. If the ice cube is broken into smaller fragments, a small object or piece of glass wool may need to be placed in the funnel to prevent ice chunks from falling into the collection container.
- If any group does not collect 20 mL of liquid, it's okay. 10–15 mL is usually sufficient for testing with a pH meter.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Systems, order, and organization
Evidence, models, and explanation
Constancy, change, and measurement

Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standard C: Life Science, population and ecosystems
Content Standard F: Science in Personal and Social Perspectives, Natural Hazards

Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard C: Life Science, interdependence of organisms
Content Standard F: Science in Personal and Social Perspectives; environmental quality, natural and human-induced hazards

Reference

Holstead, J. A.; *Journal of Chemical Education;* Vol. 75 No. 4, April, 1998.

Materials for *Thawing Acid Rain* are available from Flinn Scientific, Inc.

Catalog No.	Description
V0005	White Vinegar, 4 L
AP3202	Funnel, Utility, Polyethylene
AP8673	Checker™ pH Meter
AP4663	Vials, with Snap-on Cap
AP8230	Ring, Support with Rod Clamp

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.