TEACHER INFORMATION

# Acid Rain

1. Editable Microsoft Word versions of the student pages and pre-configured TI-Nspire files can be found on the CD that accompanies this book. See *Appendix A* for more information.

2. The 1.0 M HCl solution can be prepared by adding 8.6 mL of concentrated acid per 100 mL of solution. **HAZARD ALERT:** Highly toxic by ingestion or inhalation; severely corrosive to skin and eyes. Hazard Code: A—Extremely hazardous.

   Draw the HCl solution into the Beral pipets through the short, narrow stem. Since a trial requires approximately 1 mL of 1.0 M HCl, or a total of 3 mL for 3 gases, fill the bulb 3/4 full (3–4 mL).

3. Solid $NaHCO_3$, $NaHSO_3$, and $NaNO_2$ can be placed in 100 mL beakers to a depth of 1–2 cm.

   **HAZARD ALERTS:**

   Sodium bisulfite: Severe irritant to skin and tissue as an aqueous solution; moderately toxic. Hazard Code: C—Somewhat hazardous.

   Sodium nitrite: Strong oxidizer; fire and explosion risk if heated; highly toxic by ingestion and inhalation. Hazard Code: B—Hazardous.

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

4. Thin-stem Beral pipets may be purchased from Flinn Scientific. The part numbers are:

   | | |
   |---|---|
   | AP1718 | Pkg. of 20 |
   | AP1444 | Pkg. of 500 |

   At a price of about $0.05 each, the pipets may be considered disposable. You can empty the pipets and discard or recycle them after using. You may also choose to empty, clean, and reuse the pipets.

5. One advantage of the microscale version of this experiment is that it avoids the odors of the two noxious gases, $NO_2$ and $SO_2$. Very little of either gas escapes into the room. You can operate the laboratory ventilation system during the experiment as a further precaution.

6. To make a narrower stem for the gas-collecting pipets and HCl pipets, it is necessary to stretch out the stem of the Beral pipet. To do this, place the pipet bulb in the palm of one hand with your thumb against the stem where it joins the bulb. Firmly grip the middle of the stem with your other hand and pull hard on the stem until it yields to the pressure and stretches out to a uniform narrow diameter. You can easily stretch it to the length needed for the gas-collecting pipets. Cut off the stems to a length of 15 cm for the gas pipets, and to a length of 4 cm for the HCl pipets. For the gas-generating pipet, cut the stem of a new Beral pipet to a length of 2 cm. Since it has a wider stem, the HCl and gas-collecting pipets will easily fit into it.

7. The directions in the experiment call for the use of a 100 mL beaker as a support for the Beral pipets. The pipets are placed in the beaker in an upright position, with the bulbs down.

Test tube racks for 13 × 100 mm test tubes or 24 well microscale well plates also work well as supports for the Beral pipets.

8. The procedure directs students to obtain the 1.0 M HCl from the teacher, and then return it. For safety reasons, we felt it might be better for teachers to directly account for pipets containing HCl. The directions also have students return the used gas-generating and gas-collecting pipets at the end of the period. Whether you choose to dispose, recycle, or reuse the pipets, we recommend that your students not empty or clean the pipets. This way, accidents that might result from carelessly squeezing pipets containing HCl can be avoided. Empty the gas-generating pipets under a fume hood.

9. If you choose to reuse the gas-collecting pipets, you need to ensure that they are perfectly dry. The $SO_2$ and $NO_2$ gases are highly soluble, even in small droplets of water. Draw air in and out of the pipets 10 to 15 times to dry the bulbs.

10. To save time, you may choose to perform Step 3 of the procedure ahead of time. Students have very little difficulty adding the $NaHCO_3$ and $NaHSO_3$ powders to the Beral pipets, but have more trouble adding the larger granules of $NaNO_2$.

11. The equations for the production of each of the gases, as performed in this experiment, are:

    Carbon dioxide: $NaHCO_3(s) + HCl(aq) \longrightarrow NaCl(aq) + H_2O(1) + CO_2(g)$

    Sulfur dioxide: $NaHSO_3(s) + HCl(aq) \longrightarrow NaCl(aq) + H_2O(1) + SO_2(g)$

    Nitrogen dioxide: $3\ NaNO_2(s) + 3\ HCl(aq) \longrightarrow 3\ NaCl(aq) + HNO_3(aq) + 2\ NO(g) + H_2O$

    $2\ NO(g) + O_2(g) \longrightarrow 2\ NO_2(g)$

12. Even though the procedure calls for tap water, distilled water can also be used. We use tap water because it normally contains enough dissolved $CO_2$, $HCO_3^-$, and $CO_3^{2-}$ to give it a small amount of buffering capacity. This stabilizes the pH reading when the pH Sensor is first placed in the water and avoids fluctuations or gradual changes in pH that students encounter with distilled water. In the sample graphs on the next page, the buffering effect causes a smaller drop in pH in the first 5–10 seconds after the gas is added, followed by a more rapid drop.

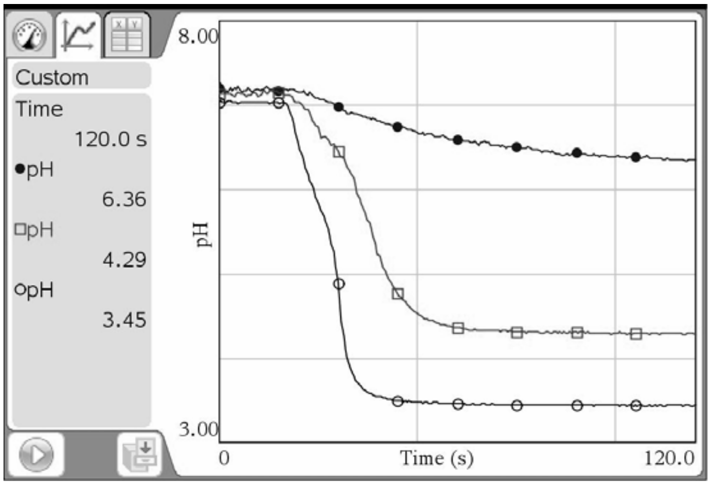
13. This is a good time to discuss the topic of anhydrides with your students. All three of these gases are oxides of non-metals and represent good examples of *acidic anhydrides*.

14. A 20 × 150 mm test tube works well in this experiment. Test tubes size 18 × 150 mm will not easily allow the narrow stem of the pipet to fit alongside the pH Sensor.

15. It is not necessary to calibrate your pH sensor, the stored pH calibration works well for this experiment.

## SAMPLE RESULTS

| Gas | Initial pH | Final pH | Change in pH (ΔpH) |
|---|---|---|---|
| $CO_2$ | 7.21 | 6.36 | –0.85 |
| $NO_2$ | 7.13 | 4.29 | –2.84 |
| $SO_2$ | 7.04 | 3.45 | –3.59 |




*pH* vs. *time graph for $CO_2$ (●), $NO_2$(□), and $SO_2$ (○) dissolving in water*

## ANSWERS TO QUESTIONS

1. Carbon dioxide, $CO_2$, caused the smallest drop in pH (ΔpH = –0.85).
2. Sulfur dioxide, $SO_2$, caused the largest drop in pH (ΔpH = –3.59). Nitrogen dioxide, $NO_2$, causes a drop in pH about the same as $SO_2$ (ΔpH = –2.84).
3. When low-sulfur coal is burned, it produces less sulfur dioxide. With lower concentrations of sulfur dioxide in the atmosphere, less sulfurous acid will be produced by the reaction:

$$SO_2(g) + H_2O(1) \longrightarrow H_2SO_3(aq)$$

4. Nitrous acid, $HNO_2$, and nitric acid, $HNO_3$, are produced by the reaction:

$$2\ NO_2(g) + H_2O(g) \longrightarrow HNO_2(aq) + HNO_3(aq)$$

5. Carbon dioxide gas, a natural component of the atmosphere, dissolves in rainwater and forms carbonic acid, $H_2CO_3$.
6. The acidity level is lower in actual rainfall because the concentration of $SO_2$, $NO_2$, and $CO_2$ gases in the atmosphere is much lower than in this experiment.