

## A Demonstration of Acid Rain and Lake Acidification: Wet Deposition of Sulfur Dioxide

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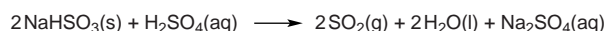
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Acid rain is a familiar environmental problem that is sometimes discussed in general chemistry lectures. Several demonstrations pertaining to acid precipitation have been published in this *Journal* (1–3) but none of these illustrate the dissolution of acidic oxides in airborne water droplets, or “wet deposition”, in the manner in which it occurs in the atmosphere. Nitrogen oxides come from cars and other combustion sources, whereas atmospheric sulfur oxides are a result of coal-fired power plants and the roasting of metal sulfide ores in smelters (4). Cloud droplets then scavenge these oxides. Acidification of lakes in areas geographically removed from the source can result when this acidified precipitation is deposited in lakes with no natural buffering capacity. A lake underlain by limestone will be resistant to acidification due to the buffering capacity of  $\text{CaCO}_3$  while a lake underlain by granite will not, since granite contains silicates rather than carbonates (5). In the United States, lake acidification has received the most attention in the Northeast where the bedrock is primarily granite (6).

In this demonstration, sulfur dioxide is prepared in solution by the following reaction



Two lakes, one based on limestone, the other based on granite, are simulated in large graduated cylinders, one of which contains  $\text{CaCO}_3$  for buffering. Rain from a simple spray bottle scavenges the  $\text{SO}_2$  and carries it into the lakes, demonstrating the acidification of the granite-based lake.

Precipitation in the absence of anthropogenic influences is not neutral due to equilibrium with atmospheric  $\text{CO}_2$ . This leads to a pH of close to 5.6 for unpolluted rain (4). The indicator chosen, bromocresol green, shifts from acidic to basic form near this point (7). The acidic form of the indicator predominates, leading to a yellow color, if the lake is more acidic than unpolluted rain and the blue or basic form predominates if it is not.

### Preparation

The  $\text{SO}_2$  gas is prepared ahead of time in a 1000-mL graduated cylinder in a hood. Place 5 g of  $\text{NaHSO}_3$  in the graduated cylinder and add 10 mL of 6 M  $\text{H}_2\text{SO}_4$ . Allow this solution to stand, covered with a watch glass, until the fizzing stops. Alternatively,  $\text{SO}_2$  gas may be prepared from 50 mL of 0.5 M  $\text{NaHSO}_3$  and 4 mL of 3 M  $\text{H}_2\text{SO}_4$ . This preparation results in less  $\text{SO}_2$  gas and may be used if the

$\text{SO}_2$  is not generated ahead of time in a hood.

The two lakes are simulated in separate 2000-mL graduated cylinders. For the granite-based lake, place 200 mL  $\text{H}_2\text{O}$  and 1 mL of  $1 \times 10^{-3}$  M bromocresol green in the cylinder and swirl to mix. The preparation of the limestone-based lake requires a bit more care. Place 200 mL  $\text{H}_2\text{O}$  and 1 mL of  $1 \times 10^{-3}$  M bromocresol green in another cylinder and swirl to mix. Add about 0.2 g of  $\text{CaCO}_3$  to this cylinder but do not swirl or stir. This allows the solid to settle to the bottom of the container. If particles of solid remain suspended on the surface of the liquid, stir very gently but do not swirl. (A sufficiently long stirring rod may be improvised from a plastic stirring rod with a flat end and a pair of crucible tongs.)

### Presentation

The colors to be observed may be demonstrated to the class by placing 150 mL of water and 5 drops of bromocresol green indicator in each of two 250-mL beakers. Add 2 mL of 3 M  $\text{H}_2\text{SO}_4$  to one beaker and stir both to illustrate the characteristic yellow and blue colors of the acid and base forms of the indicator.

To demonstrate the acidification, start by pouring the  $\text{SO}_2$  gas from the generation cylinder into the cylinder simulating the granite-based lake. Be careful not to slosh any of the solution from the  $\text{SO}_2$  generation cylinder into the lake cylinder as this will immediately acidify the lake solution. Because the gas cannot be seen, the amount may be quantified by timing the pour, with a five-to-ten-second pour giving good results. Once the gas has been added to the lake cylinder, spray into the cylinder using a spray bottle. This will carry the  $\text{SO}_2$  gas directly into the lake solution, which will begin to turn yellow. Delivery of 10 mL of  $\text{H}_2\text{O}$  should take about 20 squirts, depending on the spray bottle used. Once the water has been delivered and the solution has begun to show yellow, swirl gently to mix completely. Repeat the same process for the graduated cylinder simulating the limestone-based lake. The lake solution will show a yellow color when the  $\text{SO}_2$  gas is carried in which may persist as the solution is swirled. Continue swirling until enough of the  $\text{CaCO}_3$  solid has dissolved to turn the solution completely blue again.

Dry deposition may also be demonstrated using the same apparatus by simply leaving out the spray bottle step. Let the graduated cylinders stand covered for about 10 minutes and then swirl the simulated lakes to show the characteristic colors.

## Safety and Cleanup

The preparation of the SO<sub>2</sub> gas should be done in a hood. Keep the SO<sub>2</sub> generation cylinder covered except when pouring. Keep the lake cylinders covered after using the sprayer. Allow cylinders to stand covered at least 15 minutes after the presentation to allow dissolution of all the SO<sub>2</sub> before cleanup. All solutions may be neutralized and run down the drain with water.

## Acknowledgments

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## Literature Cited

1. Epp, D. N.; Curtright, R. *J. Chem. Educ.* **1991**, *68*, 1034–1035.
2. Driscoll, J. A. *J. Chem. Educ.* **1997**, *74*, 1424–1425.
3. Solomon, S.; Oliver-Hoyo, M.; Hur, C. *J. Chem. Educ.* **1998**, *75*, 1581–1582.
4. Bunce, N. J. *Environmental Chemistry*; Wuerz Publishing Ltd: Winnipeg, Canada, 1990; pp 139–141.
5. Brownlow, A. H. *Geochemistry*, 2nd ed.; Prentice Hall: Upper Saddle River, New Jersey, 1996; pp 351, 453.
6. Bunce, N. J. *Environmental Chemistry*; Wuerz Publishing Ltd: Winnipeg, Canada, 1990; pp 155.
7. *CRC Handbook of Chemistry and Physics*; 74th ed.; Lide, D. R., Ed.; CRC Press: Boca Raton, FL, 1993; pp 8–17.