Bromothymol Blue: The Demo We All Do!

Often science teachers perform demonstrations only to discover that students have already seen the experiment in a previous course. Teachers should take advantage of these opportunities to showcase the interconnectedness of different science disciplines. One example of a demonstration used across most science disciplines and grade levels involves bromothymol blue (BTB). A few drops of BTB is placed in a 500 mL flask three-quarters full of water; this initial solution is blue. The teacher places a straw in the flask and blows through the straw, following proper safety precautions.

The BTB eventually changes from blue to yellow. The speed of the color change depends on the amount of exhaled air into the flask. The BTB changes color because it functions as an acid/base indicator. BTB is blue at pH 7.6 and yellow at pH 6.0. The chemical reaction involves carbon dioxide from the teacher's lungs dissolving in the BTB solution and the water in the solution forming carbonic (weak) acid:

$$CO_2 + H_2O \leftrightarrow H_2CO_3$$

carbon dioxide + water ↔ carbonic acid

Prior to the demonstration the teacher may choose to discuss the idea of an indicator, divulge the indicator colors of BTB, and reveal what the BTB color change indicates. On the other hand, the teacher may want to keep these answers a mystery to use for a subsequent class discussion.

The chemistry teacher can use the BTB demonstration to introduce the concept of acid/base neutralization in a titration lab. The teacher may not even bother to blow in a straw to change the water into a weak acid, but instead, drop a little hydrochloric acid or vinegar into the BTB so students can quickly see the color change.

Physical science teachers can use the BTB demonstration to discuss the solubility of gases. For example, if the water is cool, more carbon dioxide is dissolved. This is a good time to discuss with students that the solubility of gases increases with decreasing temperatures, while the solubility of solids is the reverse.

In biology class, a BTB-filled flask may be used to demonstrate that carbon dioxide is expelled from lungs during respiration. A second flask can be used to show respiration from other organisms, such as yeast. In the second flask, teachers should add a teaspoon of yeast and a teaspoon of sugar to warm water and use tubing to pipe the air from the yeast flask into the BTB solution. Teachers should be sure to seal the yeast flask opening around the tubing with a cork or plastic wrap. In a few minutes, the BTB will begin to change color. Biology teachers might also have students investigate the bicarbonate buffer system that is present in both blood plasma and seawater (Figure 1).

If seawater is available, the demonstration can be repeated to show its buffering capacity, as the solution retains its neutral blue-green color

even after CO_2 is added.

In Earth or environmental science classes, BTB can be used to show that natural acid rain—with an approximate pH 5.6—forms when precipitation falls through the atmosphere dissolving carbon dioxide. This can then lead into a lesson on acid rain (nitric and sulfuric acid).

Finding demonstrations that work is important for all science teachers. For any of the different science subjects, connections to everyday life are always a good way to engage students. For example, students will be interested to know that soft drinks get their fizz by the carbon dioxide added to the solution. This means that a soft drink is a weak acid. The carbonic acid and added phosphoric acid gives the soft drink its slightly sour taste.

David Haase provides a fun lab using soft drinks and data collection (2005). Teachers could also demonstrate that the carbonation is really carbon dioxide by piping the air from the shaken soft drink into a flask of BTB. (Want to learn more? Complete a webquest at *www.ameribev.org*.) Follow-up investigations might include

- Where do manufacturers get the carbon dioxide to make soft drinks fizz?
- How does temperature affect the amount of carbon dioxide in soft drinks?
- What is a carbonator?
- Does carbon dioxide have a taste?
- How are soft drinks manufactured?

Repeating a demonstration is not a waste of time when its relevance is highlighted across disciplines and extensions are encouraged (Figure 2). Imagine all this science from one simple demo!

FIGURE 1

Bicarbonate buffer system present in both blood plasma and seawater.

$$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow HCO_{3^-} + H^+ \leftrightarrow CO_{3^-} + 2H^+$$

carbon dioxide + water ↔ carbonic acid ↔ bicarbonate + hydrogen ↔ carbonate + hydrogen
ion ion ion ion

FIGURE 2

Interdisciplinary nature of the BTB demonstration.

Discipline	Concept	Connections/extensions/questions
Chemistry or physical science	Acid/base indicator	•What other solutions can we test using BTB? Do you expect these solutions to be acidic or basic? •Neutralization of acid/base in a titration.
	Solubility of gases	• Would I have to blow in more or less air if the BTB was warmer/cooler?
Biology	Respiration	• Does the amount of CO_2 expelled from your lungs increase with exercise? Design an experiment to find out.
	Bicarbonate buffer	• Blood plasma and seawater buffers.
Earth and environmental science	Acid rain	• Natural acid rain from atmospheric CO_2 versus acid rain from pollution such as sulfur dioxide–(SO_2). • Discuss the destruction of statues and buildings due to acid rain and other examples of weathering. • Formation of caves due to natural acid rain.

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Reference

Haase, D.G. 2005. How much CO_2 is in a bottle of soda? The Science House. *www.science-house.org/CO2/activities/co2/soda.html.*