Respiration versus Photosynthesis

Introduction

Put critical thinking to the test with this apparent "reversal" of photosynthesis.

Concepts

- Photosynthesis
- Respiration
- pH

Materials

Bromthymol blue (BTB) indicator solution, 0.04% aqueous
Water, aged tap or spring
Aquatic snails, 4
Elodea (Anacharis) sprigs, 4
Glass wide-mouth bottles with tight-fitting lids, 8
Medicine dropper

Safety Precautions

Students should wear chemical splash goggles, and follow all other normal laboratory guidelines. Please review current Safety Data Sheets for additional safety, handling, and disposal information.

Procedure

1. Obtain eight bottles and number the bottles 1–8. Fill each about 4/5 full with spring water.
2. Add enough of the bromthymol blue indicator solution to each bottle to obtain a green color (about 2–3 mL). BTB should be green in color. Add either a few drops of acid or base to adjust the pH of the BTB.
3. Add the following items to the indicated bottles and cap the bottles tightly:

Bottles	Contents
1, 5	Sprig of *Elodea*
2, 6	Snail
3, 7	Sprig of *Elodea* and Snail
4, 8	Nothing—this is the control.

4. Place bottles 1–4 near a light source and place bottles 5–8 in the dark (inside a drawer, for example).
5. Within a few hours the following should result: Bottles 3, 4, and 8 should remain green, though Bottle 3 may turn a slightly different shade of green. Bottle 1 should be blue, and Bottles 2, 5, 6, and 7 should be yellow.
6. Describe the contents of each bottle, and the conditions (light or dark) under which each set of two bottles was kept.
7. Ask students to make observations and then explain the observations.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures, and review all federal, state and local regulations that may apply, before proceeding. The snails and Elodea will not be harmed by the BTB solution and can be returned to their place of origin. Snails or Elodea purchased from an outside source should not be released into the local environment. All solutions may be rinsed down the drain with excess water according to Flinn Suggested Disposal Method #26b.

Tip

- Demonstrate how the bromthymol blue solution is a pH indicator by adding drops of dilute acid or base to a dilute solution of bromthymol blue. BTB is yellow at pH <6, green from 6.0–7.6, and blue at pH>7.6.

Publication No. 141
032317

Discussion

Carbon dioxide dissolves in (and reacts with) water, forming carbonic acid, H_2CO_3. Carbonic acid then immediately dissociates into a hydrogen ion and a bicarbonate ion. The reaction occurring in solution is:

$$CO_2(g) + H_2O(l) \quad H_2CO_3 \quad H^+(aq) + HCO_3^-(aq)$$

The free hydrogen ions (H^+) lower the pH of the solution, making it more acidic. The degree to which the pH changes is proportional to the amount of CO_2 that dissolves in the water. In other words, as more CO_2 dissolves in water, the pH of the solution will continue to decrease. If CO_2 is removed from the solution, the pH will increase. A pH indicator such as BTB can therefore indicate the relative amount of CO_2 dissolved in water based on the color of the solution.

In this activity, photosynthesis occurring in the *Elodea* exposed to light removes CO_2 from the solution, thereby raising the pH. The general chemical equation representing photosynthesis is:

$$6CO_2 + 12H_2O \xrightarrow[\text{chlorophyll}]{\text{light energy}} \underset{\text{glucose}}{C_6H_{12}O_6} + 6H_2O + 6O_2$$

This higher pH is indicated by the blue color of the indicator in Bottle 1, which contained *Elodea* exposed to light, i.e., photosynthesizing. The snail, on the other hand, respires, producing CO_2, thereby lowering the pH. The general chemical equation representing respiration is:

$$C_6H_{12}O_6 + 6H_2O + 6O_2 \xrightarrow{\text{enzymes}} 6CO_2 + 12H_2O + \text{energy}$$

This lower pH is indicated by the yellow color of the indicator in Bottles 2 and 6, since the snail respires with or without light. In Bottle 7, the *Elodea* cannot photosynthesize in the absence of light. Bottle 3 will have a relatively neutral pH, since the snail is respiring and the plant is photosynthesizing. Bottle 5 will be the stumper for the students. It is yellow, indicating an acidic solution, but there is no snail; only *Elodea*. So where did the CO_2 come from? The CO_2 was produced as a result of cellular respiration by the *Elodea*. Both photosynthesis and cellular respiration occur in green plants when light is available. In Bottle 1, photosynthesis is the dominant process over respiration, resulting in a net decrease in CO_2 concentration. However, in the absence of light, the plant cannot photosynthesize; it can only respire. Therefore, there is a net increase in CO_2 concentration, and the pH drops as the CO_2 dissolves, producing carbonic acid..

Connecting to the National Standards

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

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

Content Standards: Grades 5–8
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, properties and changes of properties in matter
Content Standard C: Life Science, regulation and behavior

Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, chemical reactions
Content Standard C: Life Science, energy, and organization in living systems

Acknowledgment

Special thanks to David Eichinger, Assistant Professor of Science Education, Purdue University, West Lafayette, IN, for bringing this activity to our attention.

Materials for *Respiration versus Photosynthesis are* available from Flinn Scientific, Inc.

Catalog No.	Description
B0173	Bromthymol blue indicator solution, 100 mL
LM1106	Snails — pond, pkg/12
LM1132	*Elodea (Anacharis),* pkg/12
AP8445	Bottle, ointment jar style, 4 oz.

Consult the Flinn Scientific website for current prices.