Lab: Cellular Respiration and pH

FOR THE TEACHER

Summary
In this lab, students learn how a pH indicator can be used to detect the presence of CO₂ when they exhale.

Grade Level
High and Middle School

Objectives
By the end of this lab, students should be able to
- Describe how the pH indicator, bromothymol blue, can detect the presence of CO₂.
- Explain why there is more CO₂ released after exercise in the breath.

Chemistry Topics
This lab supports students’ understanding of
- Acids & Bases
- Indicators
- pH

Time
Teacher Preparation: 10 minutes
Lesson: 30-40 minutes

Materials
(Per group)
- 1 straw
- 2 beakers of bromothymol blue (BTB) solution (directions below)
- Timing device

Safety
- Always wear safety goggles when handling chemicals in the lab.
- Students should wash their hands thoroughly before leaving the lab.
- Students should use caution when blowing into the BTB solution so it doesn’t splash out of the beaker.
- Remind students to NOT INHALE THE SOLUTION!!! Specifically instruct them to take their mouth off of the straw in order to inhale.
- When students complete the lab, they should pour the BTB solution down the sink and wash the beaker with soap and water. Straws should be thrown away.

Teacher Notes
- Make the solution of BTB by adding 5 drops of BTB to 50 ml of water. You will need to make two of these solutions for each group doing the test.
- I suggest dividing the students into groups of two. One will be the “participant” and the other will be the timer and recorder. Each participant will need to have their own straw and two beakers of BTB solution.
- If available, complete this lab in a gym or large open area to provide lots of room to move.
- The simplified chemical reaction for cellular respiration is
C₆H₁₂O₆ + 6O₂ → 6CO₂ + 6H₂O

- Cells use this chemical reaction to make the energy they need in order to function. If we make the cells do more work, they will perform cellular respiration even faster which produces more CO₂ in a shorter period of time.
- It should be noted that photosynthesis is this same reaction in reverse.
- When CO₂ concentration increases in water, it causes an increase in H⁺ ions because of the formation of an intermediary compound called carbonic acid, shown in the following chemical equation:
  \[ \text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{H}^+ + \text{HCO}_3^- \]
- Bromothymol Blue is a pH indicator that is blue in solution above a pH of 7 and is yellow below 7.
- As you increase the CO₂ concentration in solution you cause the pH to lower because of the addition of the H⁺ ions.
- In my experience, I have found that sometimes the solution does not go all the way yellow for the first trial. After about 3 minutes or so of blowing, have the students stop blowing and record the time and color for the first trial. The second trial will change within the first minute. The color is not a bright yellow. It is more of a yellowish green.

**FOR THE STUDENT**

**Lab**

**Cellular Respiration and pH**

**Background**

In order for cells to function, they must have energy. They acquire this energy by breaking down a sugar known as glucose through the following chemical equation:

\[ \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O} \]

This chemical reaction is known as cellular respiration. Notice that one of the products of this reaction is carbon dioxide. Carbon dioxide, when added to water, creates a weak acid called carbonic acid through the following chemical reaction:

\[ \text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{H}^+ + \text{HCO}_3^- \]

Note: We make soft drinks by adding carbon dioxide into solution. So, what are we consuming when we drink a Coke?

Because of the weak acid produced by carbon dioxide, we can detect its presence by using an acid-base indicator called bromothymol blue. Bromothymol blue (or BTB for short) is blue in a solution with a pH of 7 or above. The solution will turn to a green color when the pH falls below 7 and then to a yellow color.

**Problem**

Can we use the pH properties of BTB to detect CO₂ in our exhaled breath?

How will exercise affect the amount of product produced?

**Materials** (per group)

- 2 beakers of BTB solution
- 1 straw
- Stopwatch or other timing device

**Safety**

- Always wear safety goggles when handling chemicals in the lab.
- Wash your hands thoroughly before leaving the lab.
- Use caution when blowing into the BTB solution so it doesn’t splash out of the beaker.
- **DO NOT INHALE THE SOLUTION!!!** Take your mouth off of the straw in order to inhale.
- When you complete the lab, pour the BTB solution down the sink and wash the beaker with soap and water. Straws should be thrown away.

**Procedure**

1. Put on your goggles.
2. Acquire your materials.
3. Record the initial color of both solutions of BTB.
4. While at rest have one group member, “the participant” use the straw to blow into one of the beakers of BTB solution.
5. The other partner will use a stopwatch to time how long it takes for the solution to change from blue to yellow.
6. Record the time and final color of this first solution in the data table below.
7. “The participant” will then run in place or in circles for a total of 3 minutes.
8. At the end of the 3 minutes “the participant” should immediately begin blowing into the second solution of BTB.
9. The partner will use a stopwatch to time how long it takes for the solution to change colors.
10. Record the time and final color of this second solution in the data table below.

**Data**

<table>
<thead>
<tr>
<th>Solution 1</th>
<th>Initial Color</th>
<th>Time to Change</th>
<th>Ending Color</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Solution 2</td>
<td>Initial Color</td>
<td>Time to Change</td>
<td>Ending Color</td>
</tr>
<tr>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

**Analysis**

1. What caused the color change in the BTB?

2. Was there a difference in the time it took for the color change after exercise? Why?

3. What comparison can you make about the concentration of CO₂ in solution before blowing into the solution and after blowing into the solution and why?

4. What can you tell about the final pH of the solution?

5. What is the limitation of BTB in telling us pH?