

## Chapter 6, Lesson 10: Carbon Dioxide Can Make a Solution Acidic

### **Key Concepts**

- Carbon dioxide (CO<sub>2</sub>) gas can react with water to make a solution acidic.
- Excess carbon dioxide in the atmosphere is making the oceans more acidic.

### **Summary**

The teacher blows into a bromothymol blue indicator solution until it changes color from blue-green to yellow. Students interpret this color change and explain that the solution becomes acidic. Students explore whether carbon dioxide from other sources, namely carbonated water and a chemical reaction between baking soda and vinegar, can also make a solution acidic. Students then observe a teacher demonstration showing that a burning candle also produces carbon dioxide gas that also makes a solution acidic. Students apply their observations to the environmental problem of ocean acidification by watching a video and doing research on this issue.

### **Objective**

Students will be able to explain that carbon dioxide from any source reacts chemically with water to form carbonic acid. They will also be able to use the color change of bromothymol blue indicator to identify the changing pH of a solution during a chemical reaction.

### **Evaluation**

Download the student activity sheet and distribute one per student when specified in the activity. The activity sheet will serve as the “Evaluate” component of each 5-E lesson plan.

### **Safety**

Be sure you and the students wear properly fitting goggles during the activity and wash hands afterwards. Use vinegar in a well-ventilated room. Read and follow all safety warnings on the label. Dispose of all liquid waste down the drain or according to local regulations.

### **Materials for the Demonstrations**

#### **Initial Demonstration**

- Bromothymol blue indicator solution
- Water
- 2 clear plastic cups
- Straw

### ***Final Demonstration***

- 2 glass flasks
- Tealight candle
- Match or lighter
- Bromothymol blue indicator solution
- Water
- 2 clear plastic cups

### ***Materials for Each Group***

- Water
- Bromothymol blue indicator solution in cup
- Carbonated water (club soda or seltzer water) in wide, clear, plastic cup
- Baking soda in wide, clear, plastic cup
- Vinegar
- 2 small clear plastic cups
- 4 wide clear plastic cups
- 4 taller, clear, plastic cups
- Graduated cylinder

### ***About the Materials***

Explain to students that they will be using a new indicator for this lesson. The indicator is called Bromothymol blue. It is bluish-green in plain water and turns more yellowish-green to yellow in an acid.

## **ENGAGE**

1. **Do a demonstration to show that adding CO<sub>2</sub> gas to water can make the water become acidic.**

### **Materials for the Demonstration**

- Bromothymol blue indicator solution
- Water
- 2 clear plastic cups
- Straw

### **Teacher Preparation**

#### ***Make indicator solution***

You will need about 100 mL of indicator solution for your demonstrations. Use 100 mL of water with about 4-5 mL of bromothymol blue. In the activities, each group will need about 80 mL of indicator solution. Make the students' indicator solution in a similar ratio to yours and pour at least 80 mL of this dilute indicator solution into a clean plastic cup for each student group.

**Note:** Your local tap water is likely fine for the demonstrations and activities in this lesson. Technically, bromothymol blue is green in water with a neutral pH. The indicator solution you make may be green, blue-green, or blue depending on the pH of your tap water. Any of these colors will work in the demonstrations and experiments. For the purpose of this lesson, we will show the bromothymol blue solution as blue-green in tap water. If your bromothymol blue solution not green, blue-green, or blue, you can use distilled water which is available in grocery stores and pharmacies.

### Prepare for the Demonstration

Pour about 25mL of indicator solution into each of two clear plastic cups for you to use in the demonstration.

### Procedure

1. Show students both samples of indicator solution.  
Place a straw in one of the samples so that the straw goes all the way to the bottom of the cup.
2. Hold the cup so that students can clearly see the liquid.  
Blow into the straw until the indicator solution changes from blue-green to yellow.



Ask students:

- **Does blowing into the indicator solution change its pH?**  
Yes, the color changes, so there must be a change in pH, too.
- **Does the solution become a little more acidic or a little more basic?**  
The color change shows that the solution is a little more acidic.

Tell students that a chemical reaction occurs between the molecules of carbon dioxide ( $\text{CO}_2$ ) and the molecules of water ( $\text{H}_2\text{O}$ ) to create a very small amount of an acid called *carbonic acid* ( $\text{H}_2\text{CO}_3$ ).

### Give each student an activity sheet.

Students will record their observations and answer questions about the activity on the activity sheet. The *Explain It with Atoms & Molecules* and *Take It Further* sections of the activity sheet will either be completed as a class, in groups, or individually, depending on your instructions. To find the answers to the activity sheet, go to the downloads area within the online version of this lesson.

## EXPLORE

2. Have students use carbonated water as a source of  $\text{CO}_2$  to see if the gas will change the pH of an indicator solution.

### Question to Investigate

Will carbon dioxide from carbonated water change the pH of an indicator solution?

### Materials for Each Group

- Bromothymol blue indicator solution in a plastic cup
- Water
- Carbonated water (club soda or seltzer water) in a wide clear plastic cup
- 1 wide, clear, plastic cup
- 2 taller, clear, plastic cups
- Graduated cylinder

### Teacher Preparation

Pour 25 mL of carbonated water into a wide, clear, plastic cup for each group.

### Procedure

1. Measure 30 mL of indicator solution and divide it evenly into two small, clear, plastic cups.
2. Add 25 mL of water to a wide plastic cup and 25 mL of carbonated water to another wide cup.
3. Stand the small cups with indicator solution in the liquid in the wider cups as shown.
4. Turn the two tall cups upside down and place them over the two wider cups.
5. While holding the top and bottom cups to keep them together, gently swirl both sets of cups. Watch the color of the indicator in both cups to see if there is any change.
6. Compare the color of the indicator in both cups.



### Expected Results

The indicator inside the cups with water remained blue-green, while the indicator with the carbonated water turned yellow.

### 3. Discuss student observations and what will happen in the following activity.

Ask students:

- **Did either indicator change color?**

Only the indicator with the carbonated water changed color.

- **What does the color change tell you about the pH of the indicator solution? Is it acidic or basic?**

The indicator solution is now acidic.

- **The carbonated water should not have splashed into the indicator. Why did the indicator solution change color in one set of cups?**

The carbon dioxide from the carbonated water dissolved in the indicator solution. The molecules of carbon dioxide reacted with the water, forming carbonic acid, and changed the color of the indicator.

Tell students that they have seen carbon dioxide gas from your breath and carbon dioxide gas from carbonated water turn an indicator solution acidic.

Ask students:

- **Do you think carbon dioxide gas produced during a chemical reaction will also turn an indicator solution acidic?**

Carbon dioxide from any source should cause the indicator solution to become acidic. The amount of carbon dioxide gas produced and dissolved in the indicator solution may cause the color of the indicator to vary, but on the acidic side.

- **What chemical reaction do you know of that can produce carbon dioxide gas?**

Students should remember that vinegar and baking soda react, producing carbon dioxide gas. Tell students that they will combine baking soda and vinegar in the next activity.

### 4. Use a chemical reaction to produce CO<sub>2</sub> to see if it changes the pH of an indicator solution.

#### Question to Investigate

Will carbon dioxide gas produced in the baking soda and vinegar reaction change the pH of an indicator solution?

#### Materials for Each Group

- Bromothymol blue indicator solution in cup
- Water
- Baking soda in small plastic cup

- Vinegar in cup
- 2 small clear plastic cups
- 1 wide clear plastic cups
- 2 taller clear plastic cups
- Graduated cylinder

### Teacher Preparation

- Pour about 50 mL of vinegar in a wide plastic cup for each group.
- Place about  $\frac{1}{2}$  teaspoon of baking soda into a small clear plastic cup for each group.

### Procedure

1. Measure and pour 25ml of vinegar into two wide plastic cups.
2. Pour 15ml of bromothymol blue indicator into two clean small plastic cups.
3. Pour all the baking soda into one of the cups of vinegar. Do not pour anything into the other.
4. Stand the small cups with indicator solution in both the wider cups as shown.
5. Turn the two tall cups upside down and place them over the two wider cups.
6. While holding the top and bottom cups to keep them together, gently swirl both sets of cups. Watch the color of the indicator in both cups to see if there is any change.
7. Compare the color of the indicator in each cup to find out whether the solution is acidic, neutral, or basic.



### Expected Results

The indicator inside the cup with only vinegar remained blue-green while the indicator inside the cup with the vinegar and baking soda reaction turned yellow.

## 5. Discuss student observations.

Ask students:

- **Did either indicator change color?**

Only the indicator with the chemical reaction changed color.

- **Why did one set of cups only have vinegar in the bottom?**

It is possible that vinegar by itself causes the indicator to change color. Since this indicator did not change color, it must be the carbon dioxide gas produced by the chemical reaction, and not just the vinegar that caused the color change. The indicator solution in the set of cups with only vinegar in the bottom serves as a control.

- **What does the color of the indicator solution tell you about the pH of each solution? Is it acidic, neutral, or basic?**

The color change shows that the indicator solution is acidic.

## **6. Demonstrate that carbon dioxide from a candle flame will also make water acidic.**

### ***Materials for the Demonstration***

- Tea light candle
- Matches or lighter
- 2 small clear plastic cups
- 2 glass flasks large enough to be placed over the candle
- Water
- Bromothymol blue indicator

### ***Safety***

Be sure you and the students wear properly fitting goggles. Be careful when lighting the candle. Be sure that the match and candle are completely extinguished when you are finished with the demonstration.

### ***Teacher Preparation***

If you do not have any dilute indicator solution, make some by adding about 3 mL of Bromothymol blue indicator to 50 mL of water.

Divide the dilute indicator solution equally into two small cups.

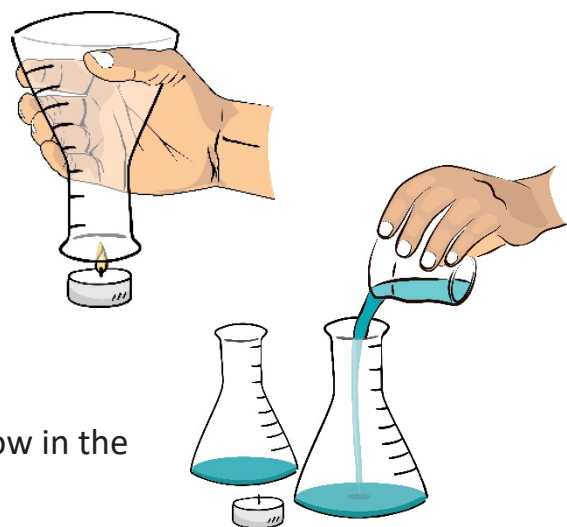
### ***Note***

After holding the flask over the candle for about 10 seconds, dilute bromothymol blue indicator solution will be added to the flask that was over the candle *and* to another flask as a *control*. Both flasks are swirled. The indicator will react with carbon dioxide in the flask that was over the candle but will not react in the other flask. This indicates that the candle produced carbon dioxide gas that made the solution acidic.



## Procedure

1. Carefully light a tea light candle.
2. Have 2 flasks available. Hold one flask above the candle as shown.
3. Hold it there for about 10 seconds and then turn the flask over.
4. Gently pour about 25 mL of bromothymol blue indicator solution into both flasks and swirl both.



## Expected Results

The indicator will change color from blue-green to yellow in the flask that was over the candle.

### 7. Have a class discussion about what gas was probably produced by the flame.

Ask students:

- **What gas was probably produced by the flame and how do you know?**

Carbon dioxide was probably produced by the flame because it reacted the same way to the indicator solution as the other samples of carbon dioxide.

## EXPLAIN

### 8. Explain that carbon dioxide from any source can make water acidic.

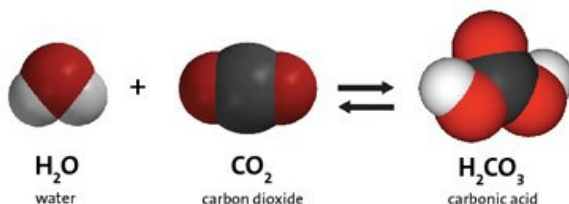
Ask students:

- **What did carbon dioxide from breath, carbonated water, and the baking soda and vinegar reaction all do to water?**

The  $\text{CO}_2$  from each source reacted with the water and made it acidic.

Project the illustration  *$\text{CO}_2$  Reacting with Water*.

[www.acs.org/middleschoolchemistry/simulations/chapter6/lesson10.html](http://www.acs.org/middleschoolchemistry/simulations/chapter6/lesson10.html)



Tell students that carbon dioxide reacts with water to produce carbonic acid. Students may count the number of atoms on each side of the equation to show that it is balanced. Point out that the double arrow in this equation means that carbonic acid breaks down readily to form carbon dioxide and water again.



Explain to students that too much CO<sub>2</sub> in the atmosphere causes Earth and its atmosphere to become warmer. But excess CO<sub>2</sub> can do something else which they have seen in the chemical equation and in their experiments. Carbon dioxide can make water more acidic which is causing a big problem in the oceans. The excess acid in ocean water, called ocean acidification, makes it difficult for some organisms to form shells and is especially damaging to coral.

## EXTEND

### 9. Explain how ocean acidification is bad for shell-making organisms and show a video about ocean acidification.

Explain that the ocean is actually basic. The pH of the ocean is about 8.2. The term “ocean acidification” means that the ocean is tending to become more acidic or less basic. It has moved from about 8.2 to 8.1. This may not seem like a big change, but it is a very big change to organisms in the ocean which are very sensitive to changes in pH. When ocean water becomes more acidic it causes two main problems for shell-making organisms like clams, oysters, and coral:

1. It becomes harder for these organisms to make their shells.
2. Over many years, if the water becomes too acidic, delicate shells can react with the more acidic water causing the shell to break down.

Clams, oysters, coral and other shell-making organisms make their shells out of two ions: the calcium ion (Ca<sup>+2</sup>) and the carbonate ion (CO<sub>3</sub><sup>-2</sup>). When these two ions join, they make calcium carbonate (CaCO<sub>3</sub>) which is the main substance for the structure of the shell. Ocean acidification affects the carbonate ion. Here’s how:

#### Project the illustration Carbonic acid and Carbonate ion.

[www.acs.org/middleschoolchemistry/simulations/chapter6/lesson10.html](http://www.acs.org/middleschoolchemistry/simulations/chapter6/lesson10.html)

Remind students that water and carbon dioxide react to form carbonic acid.



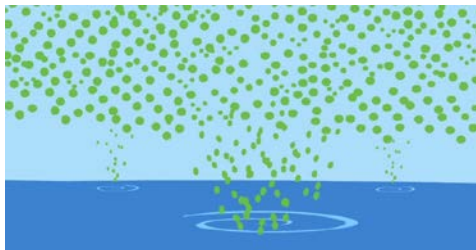
A hydrogen atom from the carbonic acid gets into the water as a hydrogen ion (H<sup>+</sup>). This hydrogen ion bonds to the carbonate ion in ocean water and creates bicarbonate ion (HCO<sub>3</sub><sup>-</sup>) which the shell-making organisms can’t use. This means there are fewer carbonate ions for the creatures to attach a calcium ion to, making it harder for them to make the calcium carbonate they need to make their shells.

Extra hydrogen ions in the water also makes the water more acidic. If the water eventually gets too acidic it might react with the calcium carbonate in the shells causing them to break down.

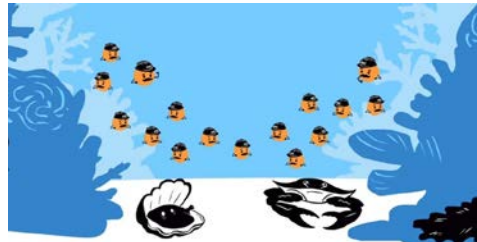
Show the video *Ocean Acidification*.

[www.acs.org/middleschoolchemistry/simulations/chapter6/lesson10.html](http://www.acs.org/middleschoolchemistry/simulations/chapter6/lesson10.html)

**Note:** The narration and action of the video go by pretty quickly so you might want to stop the video in a few places to help students understand what is being presented.



The green dots represent excess carbon dioxide in the atmosphere due to the burning of fossil fuels. The ocean absorbs a large amount of this carbon dioxide.



The little orange characters represent carbonate ions which the shell-making organisms need. They use carbonate ions and calcium ions to make calcium carbonate to build their shells.



Carbon dioxide reacts with water and produces carbonic acid (green irregular blob) which produces hydrogen ions. These ions bond to the carbonate ions and create a substance (bicarbonate ion not shown) that the organisms can't use.



With shells difficult to make, clams and other shell-making organisms will be smaller and not reproduce as much so the creatures that eat them may not get enough food. This could affect the whole food chain.



The extra hydrogen ions don't just bond to the carbonate ion, they also make the water more acidic.



The oceans could become so acidic in the future that the calcium carbonate shells could react with the water and break down.

**10. Have students do research on ways to reduce the amount of carbon dioxide released into the atmosphere.**

The vast majority of the excess carbon dioxide in Earth's atmosphere is from burning fossil fuels such as petroleum, natural gas, and coal. Most of this fuel is used for cars, trucks and other forms of transportation, for running power plants that produce electricity, and for heating homes and businesses.

Have students research alternative sources of energy that could help in burning less fossil fuel. Students could present their research in a short paper with illustrations, power point, tri-fold board, or in any way you feel will work. Students should describe how the renewable energy source works and the advantages and challenges of the technology.

Some possible topics could be:

**Renewable energy sources**

Wind

Solar

Geothermal

Biofuels

Hydroelectric

**New transportation technology**

Electric cars

Hydrogen fuel cells