Ocean Acidification
Age Group: Grades 6-8

Education Standards:
• This activity follows the Next Generation Science Standards (NGSS) for middle school-level Earth Science. The standard this activity teaches is listed below.
• MS-ESS3-4: Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth’s systems.
  • Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise.

Big Idea:
• In March 2015, the global monthly average of the atmospheric concentration of CO$_2$ was around 400 parts per million (ppm), or 0.04%. This is a small amount, but it is increasing by more than 2 ppm every year due to the combustion of fossil fuels such as oil, gasoline, natural gas, and coal, as well as land-use changes such as deforestation.
• Increases in the concentration of atmospheric CO$_2$ have led to increases in the concentration of CO$_2$ and other carbon-containing molecules in seawater. The CO$_2$ added to seawater reacts with the water molecules to form carbonic acid in a process known as ocean acidification.

Activity Description:
• In this activity, you will get to create a carbon dioxide–rich atmosphere in a cup and watch how it changes the water beneath it. This model of ocean-atmosphere interaction shows how carbon dioxide gas diffuses into water, causing the water to become more acidic. Ocean acidification is a change that can have big consequences on the marine environment.

Materials Provided for Ocean Acidification:
• Acid-Base Indicator (phenol red)
• Phenol Red pH Color Scale
• Biodegradable Reaction Cup
• Baking soda

Materials Scavenger Hunt: Look in your home to find these supplies!
• Two tall, clear glasses (or plastic cups)
• Saran wrap/Tin foil
• Measuring Spoons
• Vinegar
• Tape
Directions for Ocean Acidification:

1. Start by pouring 1½ fluid ounces (40–50 mL) of acid-base indicator solution into each of the two clear glass or plastic cups.
2. Add ½ teaspoon of baking soda to the reaction cup.
3. Tape the reaction cup inside one of the clear cups containing the indicator solution so that the top of the reaction cup is about ½ inch below the top of the clear cup. Make sure the bottom of the reaction cup is not touching the surface of the liquid indicator solution in the clear cup—you don’t want the reaction cup to get wet. The second clear cup containing the indicator solution will be your control (to compare how the solution changes).
4. **Optional** Place both clear glass or plastic cups onto a sheet of white paper and arrange another piece of white paper behind the cups as a backdrop (this makes it easier to see the change).
5. Carefully add 1 teaspoon of white vinegar to the reaction cup containing the baking soda. Be very careful not to spill any vinegar into the indicator solution. Immediately place saran wrap or tin foil over the top of each clear cup.
6. Position yourself so you are at eye level with the surface of the indicator solution and look closely. What do you see? Where is the color change taking place?
7. After a few minutes have passed, you should notice a distinct color change at the surface of the liquid indicator solution. As you continue to observe the reaction taking place, the liquid in other parts of the cup will also begin to change color.
8. Compare the color change to your acid-base color scale and discuss your observations.

Take It Further!

1. Use your new-found understanding of acid-base indicators to monitor your water, by using pH test strips to check the quality of your drinking water, pool, or ocean nearby! Look online to purchase your very own water testing kit.

Funded by: ReMain Nantucket Fund

Created by: Maria Mitchell Association
Ocean Acidification Information Sheet

What’s Going On?

This activity illustrates how the diffusion of a gas into a liquid can cause ocean acidification. It also models part of the short-term carbon cycle—specifically the interaction between our atmosphere and the ocean’s surface.

Mixing vinegar and baking soda together in the paper cup creates carbon dioxide gas (CO$_2$). The CO$_2$ gas then diffuses into the liquid below. When CO$_2$ gas diffuses into water, the following chemical reaction takes place and forms carbonic acid (H$_2$CO$_3$):

$$\text{CO}_2 (aq) + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3$$

Carbonic acid dissociates into hydrogen (H$^+$) and HCO$_3^-$ ions. The increase in H$^+$ ions makes the solution more acidic.

Carbonic acid is a weak acid. Even so, the presence of this acid affects the pH of the solution. Thus, after a short time, the surface of the indicator solution changes color: from yellow to red. This color change indicates a pH change caused by the diffusion of CO$_2$ gas into the liquid.

Outside of your paper cup, on a much larger scale, CO$_2$ from the atmosphere diffuses into the Earth’s oceans. Oceans are the primary regulator of atmospheric CO$_2$.

Human activities such as burning fossil fuels and changes in land use have increased the amount of carbon dioxide (CO$_2$) in our atmosphere from 540 gigatons of carbon (Gt C) in pre-industrial times to 800 Gt C in 2015.

Current atmospheric CO$_2$ levels are greater than they have been in 800,000 years, and as a result, the short-term carbon cycle is no longer in balance. From 1860 to 2009, the oceans absorbed an additional 150 Gt C from the atmosphere.

The CO$_2$ taken up by the oceans lowers oceanic pH through a series of chemical reactions. The first of these is the reaction you just observed: the creation of carbonic acid via the diffusion of CO$_2$ gas into water.

In pre-Industrial times, the pH of the oceans was close to 8.2. In 2005, it was approximately 8.1. While the pH of the ocean is still basic, it is more acidic than it used to be. In fact, oceans are 30% more acidic now than they were in pre-Industrial times.

Additional Resources
- NOAA PMEL Carbon Program: What is Ocean Acidification?
- NOAA: Ocean Acidification
Ocean Acidification Information Sheet Continued...

**Vocabulary**

- **Ocean acidification** - the ongoing decrease in the pH value of the Earth’s oceans, caused by the uptake of carbon dioxide from the atmosphere.

- **Diffusion** - the net movement of anything from a region of higher concentration to a region of lower concentration.

- **pH** - a figure expressing the acidity or alkalinity of a solution on a logarithmic scale on which 7 is neutral, lower values are more acidic and higher values more alkaline (or basic).

- **Short-term carbon cycle** - the process by which carbon cycles through living creatures, the ocean, and the atmosphere. This cycle occurs over one to a few hundred years.

- **Long-term carbon cycle** - the long-term storage of carbon in the ocean or rocks. This cycle occurs over thousands to hundreds of thousands of years.

**Phenol Red pH Indicator Color Scale**

<table>
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<tr>
<th>6.0</th>
<th>6.4</th>
<th>6.7</th>
<th>7.1</th>
<th>7.5</th>
<th>7.8</th>
<th>8.2</th>
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More acidic

More alkaline/basic