CORALS AND CHEMISTRY

DESCRIPTION

This lesson plan helps students understand how increased carbon dioxide (CO_2) emissions from the burning of fossil fuels is changing the acidity (pH) of the ocean and affecting coral reefs and other marine animals. Students conduct an experiment to see whether CO_2 is making the oceans more basic or acidic.

BACKGROUND

The world's oceans play a vital role in keeping the Earth's carbon cycle (See "Carbon Through the Seasons" lesson plan) in balance. As people add more greenhouses gases to the atmosphere by burning fossil fuels, the oceans respond by absorbing more CO_2. When CO_2 is absorbed by seawater, chemical reactions occur that reduce the pH of seawater, causing the water to become more acidic. These chemical reactions are called "ocean acidification."

Over the last few decades, the amount of CO_2 dissolved in the ocean has increased all over the world, and so has ocean acidity. Increasing acidity is a problem because it reduces the availability of chemicals needed to make calcium carbonate, which corals, shellfish, some types of plankton, and other creatures rely on to produce their hard skeletons and shells.

Coral reefs are created in shallow tropical waters by millions of tiny animals called corals. Each coral makes a skeleton for itself, and over time these skeletons build up to create coral reefs. Protecting coral reefs is very important because they provide food and habitat for many kinds of fish and marine animals, serve as natural breakwaters against storms and hurricanes, and provide fishing and recreational opportunities for millions of people.

MATERIALS

- Three large, clear jars or cups for the educator demonstration
- Two small, clear jars with lids (such as baby food jars) for each group of four students in the class
- One straw for each student in the class
- 1 red cabbage
- Enough red cabbage juice (see instructions for how to prepare under "Advance Preparations") to fill each small jar about 1 inch high and each large jar about 2 inches high)
- Common household acid (vinegar or lemon juice)

TIME: 45 to 60 minutes

LEARNING OBJECTIVES:

Students will:

- Learn that corals and other marine animals need a certain pH range to thrive
- Learn that increased amounts of CO_2 in the atmosphere from the burning of fossil fuels are changing the pH of the ocean
- Investigate whether increased amounts of CO_2 in the atmosphere are making our oceans more basic or more acidic
- Learn how a change in oceanic pH is impacting coral reefs

NATIONAL SCIENCE STANDARDS:

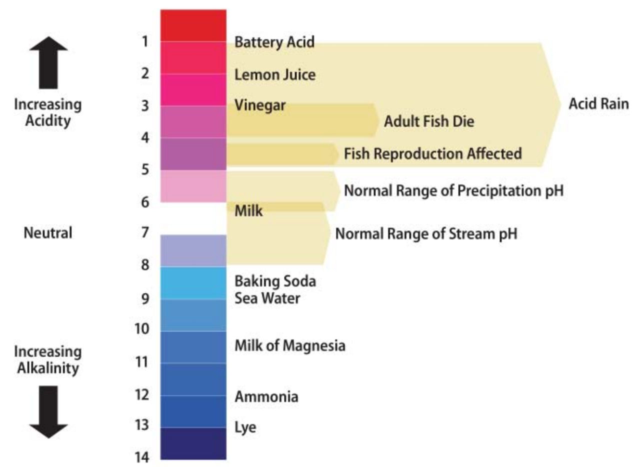
- Content Standard A: Science as inquiry
- Content Standard B: Physical science
- Content Standard C: Life science

ADAPTED FROM:

California Academy of Sciences: http://www.calacademy.org/teachers/resources/lessons/coral-and-chemistry.

- Common household base (baking soda or ammonia-based cleaning product)
- "Corals and Chemistry" worksheet (one copy per group of four students)
- Video of coral (optional): http://www.youtube.com/watch?v=MwjtChtIOA8 focuses on coral systems and their importance, while http://www.youtube.com/watch?v=9EaLRcVdTbM provides an overview of the ocean acidification process and the effects on corals and shellfish

pH Scale



A pH unit is a measure of acidity ranging from 0 to 14. The lower the number, the more acidic the substance.

Image source: U.S. EPA

The Science Behind Ocean Acidification

CO_2 chemically reacts with water to form carbonic acid (H_2CO_3), as shown by the chemical equation below:

$$CO_{2\,(aq)} + H_2O \leftrightarrow H_2CO_3$$

carbon dioxide + water ↔ carbonic acid

Almost immediately, carbonic acid breaks apart to form bicarbonate ions (HCO_3^-), carbonate ions (CO_3^{2}), and hydrogen ions (H^+), as shown by the chemical equation below:

$$H_2CO_3 \leftrightarrow HCO_3- + H^+ \leftrightarrow CO_3^{2-} + 2H^+$$

carbonic acid ↔ bicarbonate + hydrogen ↔ carbonate + hydrogen

The presence of hydrogen ions from dissolved carbonic acid is what makes the water more acidic.

VOCABULARY

Acid:
A substance that increases the hydrogen ion concentration in a solution, which decreases the solution's value.

Base:
A substance that reduces the hydrogen ion concentration in water, which increases the solution's pH value.

Carbon dioxide (CO_2):
A colorless, odorless greenhouse gas. It is produced naturally when dead animals or plants decay, and it is used by plants during photosynthesis. People are adding carbon dioxide into the atmosphere, mostly by burning fossil fuels such as coal, oil, and natural gas. This extra carbon dioxide is the main cause of today's climate change.

Carbonic acid:
An acid that forms when carbon dioxide dissolves in seawater. Extra carbonic acid is making the oceans more acidic, which can make it harder for corals and shellfish to build their skeletons and shells.

Corals:
Corals are tiny animals that make their own skeletons. Over time, these skeletons build up to create coral reefs, which provide habitat for fish and many other ocean creatures.

Habitat:
The place or environment where a plant or animal naturally lives and grows.

pH:
A measure of the acidity of a solution; described on a scale ranging from 0 (most acidic) to 14 (most basic). Pure water has a pH of about 7, which is considered neutral. The pH scale is based on powers of 10, which means a substance with a pH of 3 is 10 times more acidic than a substance with a pH of 4.

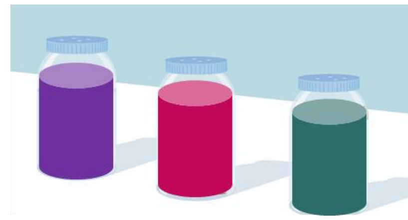
INSTRUCTIONS

Advance Preparations

1. Cut the red cabbage into pieces and boil with the lid on until the water is a dark color.
2. Strain the cabbage. Save the cabbage juice and discard the rest.
3. Pour a small amount of cabbage juice into each small jar. Fill each jar less than 1 inch high.
4. Pour a slightly larger amount of cabbage juice into the three larger jars. Fill each jar no more than 2 inches high.

Educator Demonstration

Red cabbage juice is a pH indicator

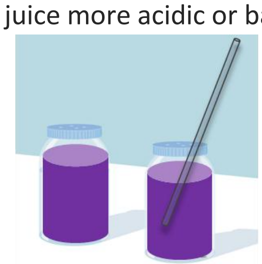


Part 1: Educator Demonstration

1. Give a brief explanation of how people are adding CO_2 to the atmosphere through activities that burn fossil fuels, like driving cars, using electricity, and manufacturing products.
2. Discuss how the ocean plays a vital role in regulating the amount of CO_2 in the atmosphere. As more CO_2 is added to the atmosphere from the burning of fossil fuels, the ocean absorbs more CO_2 to stay in balance.
3. Explain that the acidity of a substance can be measured by its pH. Tell the students that they will be performing an experiment to determine whether the ocean is becoming more acidic or more basic.
4. In front of the class, show the three large jars of cabbage juice. Tell students that the jars contain water in which red cabbage has been boiled. Red cabbage is a natural pH indicator, meaning that it changes color to indicate changes in pH.
5. Show students the household acid (vinegar or lemon juice) and ask "Is this acidic or basic?" Show students the household base (baking soda or ammonia-based cleaning product) and ask "Is this acidic or basic?"
   [Answer: Vinegar and lemon juice are acidic. Baking soda and ammonia cleaning product are basic.]
6. Pour some of the acid to one of the large jars with cabbage juice and some of the base to the second large jar. (The last jar of cabbage juice will serve as the control.) Make sure to add enough of the acid and base that you see a color change. Discuss what this test means.
   [Answer: Acids reduce the pH of the cabbage juice, making it more pink/red. Bases increase the pH of the cabbage juice, making it more blue/green.]

Student Experiment

Will the CO_2 from my breath make the cabbage juice more acidic or basic?



Part 2: Student Experiment

Divide the class into groups of four and pass to each group the two small jars (and lids) with the red cabbage juice inside, the straws, and one "Corals and Chemistry" worksheet.

CORALS AND CHEMISTRY

1. Tell students that they are going to perform an experiment to mimic CO_2 absorption by oceans by blowing air into one of these jars. As the students exhale CO_2 into the cabbage juice water, some of it will be absorbed, become dissolved, and change the pH of the water.

2. Based on the demonstration they just saw, ask each group of students to develop a hypothesis about what they think will happen when they blow into the two jars. Ask them to write their hypothesis in the space provided on the "Corals and Chemistry" worksheet.
[Answer: The increased CO_2 from my breath will reduce the pH of the cabbage juice and make it more acidic (pinkish).]

3. Have one student from each group place his or her straw in one of the jars and then cover it with a lid to prevent spraying the juice. This is the **experimental jar**. Tell each group of students to blow lightly into the jar by taking turns. Each student should use his or her own straw. The second jar is the **control jar**. Put a lid on it, and do not blow into it.

4. ***Optional:*** While the students are taking turns blowing into the jars, show them a short video about coral reefs, such as this YouTube video that shows how coral reefs provide the foundational ecosystem for millions of marine animals and plants: http://www.youtube.com/watch?v=MwjtChtIOA8.

5. After four to six minutes, the color of the cabbage juice in the experimental jar should change from a dark purple to a purple-pink as the water becomes more acidic. Tell students to write down their results on the "Corals and Chemistry" worksheet.

6. Discuss the following questions as a class:

   - How is increased CO_2 in the atmosphere affecting oceans and coral?
     [Answer: As long as we keep putting extra CO_2 in the atmosphere, the ocean will continue to become even more acidic. Increasing ocean acidity makes it harder for corals to build skeletons and for shellfish to build the shells they need for protection.]

   - Why is it important to protect corals?
     [Answer: Coral reefs are important because they provide food and habitat for many kinds of fish and marine animals. They also provide fishing and recreational opportunities for millions of people, and they protect the land from hurricane and storm waves.]

EXTENSION

Coral reefs in many parts of the world's oceans are struggling to survive. A number of factors, in addition to ocean acidity, are to blame, including increasing sea temperature and pollution. Have students take the "Expedition to the Great Barrier Reef" (see http://www.epa.gov/climatechange/students/expeditions/temp-acidity/index.html) either in class or as a homework assignment. This 8-minute video explores how changes in ocean temperature and acidity threaten coral reefs. The video pauses to ask students questions, providing an interactive learning experience.

CORALS AND CHEMISTRY WORKSHEET

NAME: ______________________ **DATE:** ______________

Hypothesis:

Will the increased carbon dioxide from my breath make the cabbage juice more acidic (pinkish) or more basic (greenish)?

Results:

What happened to the cabbage juice in the control jar?

What happened to the cabbage juice in the experimental jar?

Has the pH of the cabbage juice in the experimental jar changed?

CORALS AND CHEMISTRY WORKSHEET—ANSWER KEY

Hypothesis:

Will the increased carbon dioxide from my breath make the cabbage juice more acidic (pinkish) or more basic (greenish)?

[Correct hypothesis: Blowing my breath into the cabbage juice will lower its pH and make it more acidic.]

Results:

What happened to the cabbage juice in the control jar?

[Answer: The control jar did not change color.]

What happened to the cabbage juice in the experimental jar?

[Answer: The cabbage juice in the experimental jar became more pinkish.]

Has the pH of the cabbage juice in the experimental jar changed?

[Answer: Yes, the pH of the cabbage juice in the experimental jar has decreased (become more acidic).]