



HEADWATERS
SCIENCE INSTITUTE

INVESTIGATING OCEAN ACIDIFICATION

INVESTIGATING HOW INCREASED CO_2 IMPACTS OCEAN
CHEMISTRY AND MARINE ORGANISMS

Student Investigation

In this lesson, students will investigate how increased carbon dioxide (CO_2) can affect calcium carbonate, a material used by corals and shelled organisms to build their shells and skeletons. Students will model different ocean conditions by creating an environment with increased CO_2 and comparing it to a control environment. They will use chalk as a model for calcium carbonate and track changes in pH, mass, and appearance over several days.

As they collect and analyze their data, students will observe how changes in ocean chemistry can affect calcium carbonate over time. They will interpret their results to better understand how ocean acidification may impact corals, shelled organisms, and the ecosystems that depend on them. Through this investigation, students will build skills in experimental design, data collection, observation, and analyzing patterns in scientific data.



NGSS STANDARDS

MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

MS-LS2-1: Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

HS-ESS2-6: Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.

HS-LS2-6 : Evaluate the claims, evidence, and reasoning that changing conditions may result in a new ecosystem.

This activity incorporates Science and Engineering Practices (SEPs) through planning and carrying out an investigation, making observations, collecting and analyzing data, identifying patterns, and using evidence to explain how changes in ocean chemistry can affect calcium carbonate and the organisms that depend on it.

AP Topics

- APES Unit 9: Global Change — Topic 9.7: Ocean Acidification

Educator Instructions: Leading the Investigation

Introduction

At Headwaters Science Institute, students don't just learn about science, they become scientists. Through student-driven research, students make observations, ask questions, collect evidence, and use data to better understand the world around them. This investigation is designed to help students experience the scientific process firsthand while exploring how changes in ocean chemistry can affect marine life and ecosystems.

Students will begin by considering the driving question and using it to guide their investigation. After learning about ocean acidification, carbon dioxide, and the role of calcium carbonate in corals and shelled organisms, students will model changing ocean conditions and compare an increased-CO₂ environment with a control. By measuring pH, observing changes, and tracking the mass of calcium carbonate over time, students will analyze their data and develop an evidence-based explanation for how changing ocean chemistry can affect marine organisms and the ecosystems and communities that depend on them.

Introducing the Lab: Use this activity as a teacher demonstration or have students complete it in their lab groups before beginning the investigation. As a demonstration, the activity can take up to 10 minutes to show visible results, giving you time to discuss the readings and observations with students while the pH change occurs. Use this activity to introduce the idea that carbon dioxide (CO₂) can change the chemistry of seawater. Students will observe a visible change in pH as CO₂ is produced and introduced into a water-based indicator. This provides a simple model and visual representation of a process students will investigate more deeply in the following activity.

Before beginning: Put on safety goggles and remind students that vinegar and the indicator solution should not come into contact with skin or eyes.

1. Pour 100 mL of bromothymol blue indicator solution into each of two clear beakers. Ask students to observe the color and measure the starting pH.
2. Add 2 grams of baking soda to a small paper cup.
3. Tape the paper cup inside one beaker so that it sits approximately 1 cm (½ inch) below the top of the beaker. Make sure the bottom of the paper cup does not touch the indicator solution. This will be the increased CO₂ environment. The second beaker will serve as the control.
4. Ask students to predict what will happen to the pH and color of the indicator when CO₂ is introduced.
5. Carefully add 6 mL of white vinegar to the baking soda. The reaction produces CO₂ gas. Be careful not to allow the vinegar to enter the indicator solution.
6. Immediately cover the increased-CO₂ beaker with a zip-top bag and secure it with a rubber band.
7. Have students observe the indicator as the CO₂ accumulates. Discuss how the color change provides evidence that the water's chemistry is changing.

Discussion Prompt:

What does the change in color tell us about the water? How might a similar change in ocean chemistry affect organisms that depend on calcium carbonate?

Teacher Tip: For this investigation, using ocean water or prepared saltwater helps mimic real ocean conditions and allows students to observe how environmental changes can affect seawater chemistry. You can purchase pre-made saltwater from a local pet store, or use Instant Ocean and mix it with distilled water according to the package instructions.



Ocean Acidification: Causes, Impacts, and Connections to Human Communities

Ocean acidification occurs when the ocean absorbs excess carbon dioxide from the atmosphere, causing seawater chemistry to change and become more acidic. These changes can make it more difficult for organisms such as shellfish, corals, and some plankton to build and maintain shells and skeletons. By investigating how ocean acidification affects marine organisms, students can better understand the connections between human activities, changes in ocean ecosystems, and the long-term impacts these changes may have on people, including fisheries, food resources, and coastal communities.



RAINFORESTS OF THE SEA

Corals and shelled organisms play a critical role in ocean ecosystems by providing habitat, supporting food webs, and sustaining healthy marine communities. Coral reefs are among the most biodiverse ecosystems on Earth, supporting an estimated 25% of marine biodiversity while covering less than 1% of the ocean floor. These organisms build their shells and skeletons using calcium carbonate. As the ocean absorbs excess carbon dioxide (CO_2), seawater becomes more acidic and carbonate ions become less available, making it harder to build and maintain these structures. Shells can become thinner, weaker, and more brittle, threatening the organisms and ecosystems that depend on them.



CHANGING OCEAN CHEMISTRY

Carbon dioxide (CO_2) enters the atmosphere through both natural processes and human activities, such as burning fossil fuels. The ocean naturally absorbs CO_2 from the atmosphere, where it reacts with seawater to form carbonic acid. When more CO_2 enters the ocean, more carbonic acid is produced, increasing the water's acidity and changing its chemistry. This reduces the availability of carbonate ions, which are essential for corals and shelled organisms to build and maintain their calcium carbonate structures. As ocean acidification increases, these organisms may face greater challenges growing strong shells and skeletons, potentially affecting marine ecosystems and the communities that depend on them.



A CHANGING OCEAN, A CHANGING WORLD

Ocean acidification can affect marine organisms and the ecosystems they depend on, with impacts that may extend beyond the ocean. Corals and shelled organisms may have greater difficulty building and maintaining calcium carbonate structures, which can affect populations, food webs, and habitats. Healthy coral reefs also support photosynthetic organisms that contribute oxygen to ocean environments, so changes to reef health can influence oxygen production and marine ecosystems. These changes can affect species that depend on reefs for food and shelter, as well as fisheries and other resources people rely on. Because ocean and land ecosystems are connected, changes in ocean life can have broader effects on coastal communities, economies, and the availability of marine resources.



Student Investigation

We've learned that ocean acidification occurs when carbon dioxide (CO_2) dissolves in seawater and changes its chemistry. Many marine organisms, including corals, clams, oysters, and other shelled animals, depend on calcium carbonate to build and maintain their shells and skeletons.

In this investigation, you will model different ocean conditions and observe how increased CO_2 may affect calcium carbonate over time. You will compare a normal ocean environment with an environment exposed to additional CO_2 . By measuring changes in pH and the mass of chalk, you will collect evidence to investigate how changing ocean chemistry can affect the materials marine organisms depend on to build their shells and skeletons.

How does increased CO_2 affect calcium carbonate in seawater?

Hypothesis:

Materials

- Safety Googles
- 2 × 500 mL beakers
- Ocean water or prepared saltwater (100mL per beaker)
- 2 paper dixie cups
- Baking soda
- White vinegar
- 2 pieces of white chalk (Calcium Carbonate)
- Digital scale or balance
- pH meter or pH strips
- 2 resealable plastic sandwich bags
- 2 rubber bands
- Masking Tape
- Graduated cylinder



Student Investigation

Procedure

Safety First: Wear safety goggles throughout the investigation, especially when handling vinegar and baking soda. Use caution when adding vinegar and avoid getting it in your eyes or on your skin.

In this investigation, you will create two different environments to model how increased carbon dioxide (CO₂) can affect ocean chemistry and calcium carbonate. One beaker will represent normal ocean conditions, while the other will have increased CO₂. You will observe changes in pH and measure the chalk before and after the investigation to see how the two environments affect calcium carbonate differently.

Follow the steps carefully and record your observations and measurements throughout the investigation.

Part 1: Set Up the Investigation

1. Pour 100 mL of ocean water into each of two 500 mL beakers.
2. Measure the starting pH of the water in each beaker. Record your results.
3. Add 3 grams of baking soda to a paper dixie cup.
4. Tape the paper dixie cup inside one of the beakers so that the top of the paper cup is about ½ inch (1 cm) below the top of the beaker. Make sure the bottom of the paper cup does not touch the ocean water. Keep the paper cup dry.
 - This beaker will be the Increased CO₂ Environment.
 - The second beaker will be the Normal Conditions (Control).
5. Break a piece of chalk in half. Weigh each piece and record the starting mass.
 - Increased CO₂ Environment: _____ g
 - Normal Conditions: _____ g
6. Place one piece of chalk into each beaker.
7. Carefully measure 9 mL of white vinegar using the graduated cylinder and add it to the paper cup containing the baking soda. Be careful not to spill any vinegar into the ocean water.
8. Immediately cover the Increased CO₂ Environment with a resealable plastic bag and secure it with a rubber band. This will help contain the CO₂ produced by the reaction.
9. Record your Day 1 observations.
10. Cover the Normal Conditions (Control) beaker with a plastic bag and secure it with a rubber band.

Part 2: Add CO₂ Each Day

Repeat the following steps each day to introduce additional CO₂ into the Increased CO₂ Environment:

1. Carefully remove the paper cup from the beaker.
2. Remove the used paper cup and replace it with a new, dry paper cup.
3. Add 3 grams of baking soda to the new paper cup.
4. Carefully position and secure the paper cup inside the beaker, making sure it does not touch the ocean water.
5. Measure 9 mL of white vinegar and add it to the baking soda.
6. Immediately cover the beaker with the resealable plastic bag and secure it with a rubber band.
7. Record your observations. Note the appearance of the chalk (calcium carbonate) each day.

Day 2 (24 hours): _____

Day 3 (48 hours): _____

Day 4 (72 hours): _____

Day 5 (96 hours): _____

Part 3: Final Measurements

1. At the end of Day 5, carefully remove the chalk pieces from both beakers.
2. Gently dry each piece of chalk with a paper towel. You may leave the chalk to dry overnight.
3. Measure the final mass of each piece.
 - Increased CO₂ Environment: _____ g
 - Normal Conditions: _____ g



Student Investigation

Calculate the percent change in mass of each piece of chalk from the beginning to the end of the investigation. Use the formula: $\text{Percent Change} = \frac{\text{Final Mass} - \text{Initial Mass}}{\text{Initial Mass}} \times 100$

Calculate the percent change for both the Increased CO₂ Environment and the Normal Conditions (Control).

- Increased CO₂ Environment: _____ %
- Normal Conditions: _____ %

Which environment showed the greater percent change in mass? What does this tell you about the effect of increased CO₂ on calcium carbonate?

Discussion Questions

1. How did the pH change in the Increased CO₂ Environment compared to the Normal Conditions (Control)? What does this tell you about the relationship between CO₂ and ocean chemistry?
2. How did the mass of the chalk change from the beginning to the end of the investigation? Which environment showed the greatest change? Use evidence from your data to support your answer.
3. What does the chalk represent in this investigation? Based on your results, how might increased CO₂ affect corals and other marine organisms that use calcium carbonate to build their shells or skeletons?
4. How could changes to coral reefs and shelled organisms affect other organisms that depend on them for food, shelter, or habitat?
5. Anthropogenic CO₂ emissions come from human activities such as burning fossil fuels. How might increasing CO₂ emissions affect the chemistry of the ocean over time? Use evidence from this investigation to support your explanation.
6. How could continued changes in ocean chemistry affect humans and communities that depend on the ocean for food, jobs, tourism, or coastal protection?
7. Compare the CO₂ levels in your two experimental environments. How might changes in the amount of CO₂ entering the ocean from outside sources affect ocean chemistry over time? Use evidence from your investigation and what you know about human activities that release CO₂ to support your explanation.