

LESSON 2

Inquiry into Ocean Acidification

INTRODUCTION & BACKGROUND

What is ocean acidification?

Acidification is the process in which the pH of a liquid becomes more acidic than its original pH. Today, the world's oceans are becoming more and more acidic as a result of large amounts of carbon dioxide that human activity has added to the atmosphere. The situation has become so concerning that a 2005 report from The Royal Society of London explained “even the current level of ocean acidification is essentially irreversible during our lifetimes. It will take tens of thousands of years for ocean chemistry to return to a condition similar to that occurring at pre-industrial times.” Ocean acidification affects many marine organisms, such as corals and invertebrates, which play important roles in global chemical cycles and food webs.

Is seawater an acid?

Teachers and students typically discuss acids and bases in terms of the pH scale. A solution with a pH value from 0-7 is an acid. A solution with a pH value from 7-14 is a base. A solution with a pH value of 7 is neutral.

Although the ocean is becoming more acidic (through the process of acidification), its pH is still above 7. In order for seawater to fit the definition of being an acid, the pH needs to be below 7.

Normally, seawater in the Pacific and Atlantic around the Americas varies within the range of 7.9 – 8.2 (Royal Society, 2005). Within this pH range, living organisms thrive within the marine environment. Some species are able to adapt to pH values higher or lower than their “optimal” range. However, when the pH shifts too far beyond the range that can be tolerated – in either direction, acidic or basic – organisms die.

How does acidification affect calcareous (calcium carbonate-containing) species?

Acidification severely affects marine organisms that produce calcium carbonate (CaCO_3) structures and shells. These organisms include corals, zooplankton (such as coccolithophores, pteropods, and foraminifera), and invertebrates. Calcium carbonate dissolves in the presence of acids. **Calcareous** marine organisms continuously add calcium carbonate to their shells/exoskeletons. In a healthy system, the rate at which CaCO_3 dissolves and the rate at which calcareous organisms can replace CaCO_3 are balanced.

What are the sources of calcium carbonate in the ocean?

The calcium and carbonate ions found in the ocean originate from rocks and minerals on land. These ions are dissolved in rivers and transported to the ocean. Corals, marine invertebrates (such as crabs, mollusks and echinoderms) and zooplankton combine calcium and carbonate ions and secrete hard exoskeletons. Most of the calcium carbonate in ocean waters and sediments comes from the exoskeletons of zooplankton. Recently, researchers at the University of Exeter have begun studying the contribution of calcium carbonate from the excretions of bony fish. They have calculated that approximately 3-15% (and perhaps more) of the total carbonates produced in the ocean are contributed by bony fish (Wilson, 2009). “For a given total mass of fish, smaller fish produce more than bigger fish, and fish at higher temperatures produce more than fish at lower temperatures” (Brahic, 2009).

Depth (decibars)	0.00
Temperature (celsius)	9.632
Conductivity (mmhos)	4.770
Salinity (psu)	1.950
O2-% (O2 %)	83.6
O2-ppm (O2 ppm)	7.75
pH (pH)	7.855
Eh (mV)	55.4

Ocean Watch measures the pH of seawater. Above is an example of a lower-than-average pH measurement observed in the Gulf of Alaska.
© David Thoreson Images

**ACTIVITY MISSION****Time: 45 min.**

Ocean acidification involves seawater that is more acidic than the optimum range, yet it is still a base, with a pH greater than 7. Therefore, ocean acidification describes a *process*, not a state. Students will observe the effects of a weak acid on the dissolution of calcium carbonate. Students will make predictions about the effect of basic (alkaline) solutions on the calcium carbonate. Students will design an experiment to test their hypotheses with various solutions ($\text{pH} \geq 7$). This activity assumes students are familiar with basic concepts of acids and bases.

CONCEPTS

- The ocean is becoming more acidic, largely because of human activity.
- Acids dissolve calcium carbonate, which is found in corals and the shells of marine invertebrates.
- Acidification is a process, not a state.
- Changes in ocean pH can harm organisms when these changes exceed the functional range.

LEARNING OBJECTIVES

- Students will be able to demonstrate their knowledge of ocean acidification by defining terms.
- Students will be able to demonstrate their understanding of ocean acidification by making predictions.
- Students will be able to analyze ocean acidification and its impact on marine environments by designing an experiment and making inferences.

STANDARDS & PRICIPLES**U.S.:** 8.8, 8.9, 12.1, 12.3, 12.4-9**Canada:** 307-5, 208-5, 208-6, 208-7, 208-8, 209-1, 209-2, 209-3, 209-4, 209-6, 210-11**Ocean Literacy Principles:** 3e, 3f**PRE-DELIVERY PREP****Supplies Needing a Day or More to Prepare**

- Universal pH indicator, liquid or strips – Available from science education supply company or local aquarium supply store

Hard-to-Obtain Materials

- None

SAFETY GUIDELINES**Safety Procedures**

- Wipe up any spills immediately.
- Keep hands clean and away from eyes, nose and mouth.
- In case of eye contact, flush eyes with water for 15 min. Consult medical authorities.
- Clean-up: Contents of cups can be rinsed down the sink with large amounts of water. Plastic cups that are not cracked can be rinsed and re-used for other science activities (NOT FOR FOOD USE).

Hazardous Materials

- Universal indicator is flammable (alcohol base). Follow MSDS (Material Safety Data Sheet) for handling and storage.
- Eye irritants – ammonia and vinegar can be very irritating to eyes.

Safety Concerns for Students

- Monitor students for appropriate handling of chemicals and materials.

ACTIVITY MISSION

Durable Supplies

ITEM	DESCRIPTION	QUANTITY
Cups	Clear, plastic	3/group
Safety goggles		1/student, teacher

Consumable Supplies

ITEM	DESCRIPTION	QUANTITY
Antacid tablets	Containing CaCO_3 (white, if possible)	50/class
Water		As needed
Ammonia, baking soda, or calcium carbonate	Household	As needed
Vinegar	Household	As needed
pH strips or universal indicator		1-2 strips/liquid sampled
Pipets or droppers for universal indicator		As needed
Paper and Pencil/Pen	To record data	1/student

PROCESS & PROCEDURE

This is a teacher demonstration or student activity. Recommended Group Size: four students per group.

Teaching about CaCO_3 and Acidic Solutions

1. Always wear safety goggles.
2. Add approximately 2 TBS (50 mL) vinegar to a clear plastic cup. (Amounts will vary with the supplies used - the solution should fill about 1 in. (2.5 cm) of the cup).
3. Measure the pH of the solution by dipping the edge of the pH strip into the vinegar or by adding 5 drops of universal indicator (enough to get a definite reading).

- What does the change in color tell you about the pH of vinegar? (The orange-red color shows that the vinegar is acidic.)
4. Add an antacid tablet to the solution and observe changes. (The CaCO_3 reacts with the acid, producing carbon dioxide (CO_2) bubbles. The tablet breaks apart as it dissolves.)

Making Predictions and Designing Protocol

- How will CaCO_3 react in bases (solutions with basic pH values, $\text{pH} > 7$)?
- Using the basic lab procedure (with or without modification) and the solutions available, what variables would you test? Why? (For example, test 3 different solutions $\text{pH} < 7$; test 3 different solutions $\text{pH} \geq 7$; test 3 solutions of same pH and vary time.)

Teaching about CaCO_3 and Basic Solutions

1. Always wear safety goggles.
2. Add approximately 50 mL (2 TBS) basic solution to a clear plastic cup.
3. Measure the pH of the solution by dipping the edge of a pH strip into the solution or by adding 5 drops of universal indicator (enough to get a definite reading). (*The pH should match product label. Otherwise, add drops of diluted ammonia, etc. to adjust pH.*)
4. Record the pH of this solution.
5. Add an antacid tablet to the solution and record observations. (*The tablet bubbles and starts to break apart as it dissolves.*)
6. Repeat procedure with the other two solutions.
7. Clean and put away materials according to teacher instructions.

Recipes for Basic Solutions with Ammonia and Vinegar

pH = 10 – undiluted ammonia (or ammonia:water 1:1)

pH = 9 – ammonia:vinegar 8 parts:2 parts

pH = 8 – ammonia:vinegar 6 parts:4 parts (OMSI, 1997)

- This will give approximate pH values. Test with pH strip or universal indicator.
- If pH needs adjustment, add more vinegar to make the solution more acidic or more ammonia to make it more basic.
- These solutions should be prepared the day of use. Without buffers, the pH of these solutions will not remain constant for long periods of time.

Notes: Universal indicator works best with clear liquids.

Misconception Alert: If colored calcium carbonate tablets are used, students may observe that the solution turns green (or pink, or orange...) as the tablet dissolves and the coloring mixes with the liquid. This is a physical change. Bubbles indicate chemical reactions.

K-5 ADAPTATIONS

Dissolve an Eggshell in Vinegar:

Put an egg in a clear container of vinegar. Make daily observations over 3-5 days. As the CaCO_3 shell dissolves, foam will form at the surface made from CO_2 bubbles and egg proteins. CaCO_3 structures dissolve slowly. Corals and marine invertebrates continuously form new shells.

Test the pH of Familiar Liquids:

Use pH strips to test the pH of liquids such as coffee, soda pop, orange or lemon juice, water, carbonated water, saltwater, milk, milk of magnesia, ammonia, bleach, etc. If the students are not familiar with acids and bases, show them a pH scale with the pH of these liquids. Have students test the pH of all liquids. Next, select four solutions – a very acidic/basic pair (such as vinegar/ammonia), and a slightly acidic/basic pair (coffee/saltwater). Have the students test the pH of all the solutions. Add an antacid tablet to the vinegar/ammonia pair of solutions and record observations. Make predictions about the intensity of the reaction (amount of bubbling) that the other two solutions will produce. Add antacid tablets and record observations.

