ocean explorer
www.oceanexplorer.noaa.gov

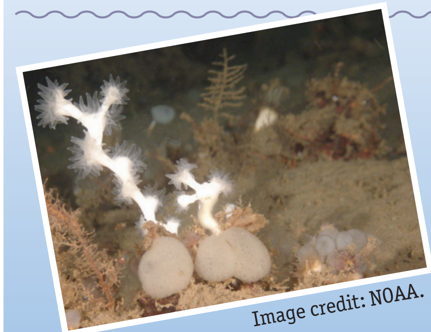
Image credit: NOAA.


Image credit: NOAA.

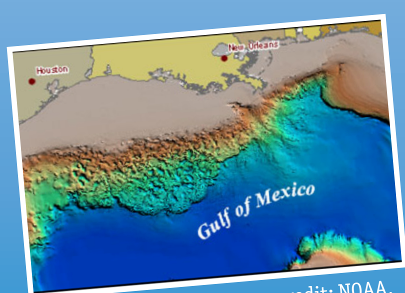

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Image captions on Page 2.

lesson plan

***Lophelia* II 2009:**
Deepwater Coral Expedition: Reefs Rigs, and Wrecks

Off Base

(updated from the 2008 Deepwater Coral Expedition: Reefs, Rigs, and Wrecks)

Focus
pH, buffers, and ocean acidification

Grade Level
9-12 (Biology/Chemistry/Earth Science)

Focus Question
What factors tend to resist changes in pH of the ocean, and why is the ocean becoming more acidic?

Learning Objectives
- Students will be able to define pH.
- Students will be able to define a buffer and explain in general terms the carbonate buffer system of seawater.
- Students will be able to explain Le Chatelier's Principle and will be able to predict how the carbonate buffer system of seawater will respond to a change in concentration of hydrogen ions.
- Students will be able to identify how an increase in atmospheric carbon dioxide might affect the pH of the ocean and will be able to discuss how this alteration in pH might affect biological organisms.

Materials
- Copies of *Ocean Acidification Inquiry Guide*; one copy for each student group
- (Optional) Copies of Ocean Acidification: A Summary for Policymakers from the Second Symposium on the Ocean in a High-CO2 World (http://ioc3.unesco.org/oanet/OAdocs/SPM-lorezv2.pdf)
- Protective goggles and gloves; one set for each student and one for the teacher
- 100 ml glass beaker; one for each student group
- 100 ml graduated cylinder; one cylinder may be shared by several student groups, but have separate cylinders for distilled water and seawater
- 500 ml glass beaker
- 2 - 1 liter beakers or Erlenmeyer flasks for mixing solutions
- Glass stirring rod; one for each student group
- Sodium hydroxide pellets, approximately 50 grams (see Learning Procedure Step 1)

- Solid citric acid (to neutralize sodium hydroxide spills); approximate 450 grams
- Distilled water; approximately 150 ml for each student group, plus 1.5 liters for making solutions (see Learning Procedure Step 1)
- Artificial seawater; approximately 150 ml for each student group, plus approximately 250 ml for demonstration
- pH test paper, wide range; one roll for each student group
- Dilute acetic acid solution in dropper bottles; one bottle containing approximately 50 ml for each student group (see Learning Procedure Step 1)
- 0.1 M sodium hydroxide solution in dropper bottles; one bottle containing approximately 50 ml for each student group (see Learning Procedure Step 1)

Audio-Visual Materials

- Marker board, overhead projector with transparencies, or digital equivalent

Teaching Time

Two 45-minute class periods, plus time for student inquiry

Seating Arrangement

Groups of two to four students

Maximum Number of Students

32

Key Words

Deep-sea coral
Lophelia
Buffer
pH
Calcium carbonate
Ocean acidification

Background Information

[*NOTE: Explanations and procedures in this lesson, except for the Inquiry Guide, are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators usually will need to adapt the language and instructional approach to styles that are best suited to specific student groups.*]

Deepwater coral ecosystems on hard substrates in the Gulf of Mexico are often found in locations where hydrocarbons are seeping through the seafloor. Hydrocarbon seeps may indicate the presence of undiscovered petroleum deposits, and make these locations potential sites for exploratory drilling and possible development of offshore oil

Images from Page 1 top to bottom:
Lophelia pertusa colony with polyps extended.
http://oceanexplorer.noaa.gov/explorations/08lophelia/logs/sept24/media/green_canyon_lophelia.html

The ROV from SeaView Systems, Inc., is prepared for launch.
http://oceanexplorer.noaa.gov/explorations/08lophelia/logs/sept20/media/rov_prep.html

Multibeam bathymetry allows terrain models to be created for large areas of the seafloor.
http://oceanexplorer.noaa.gov/explorations/08lophelia/logs/sept21/media/gomex_multibeam.html

Lophelia pertusa create habitat for a number of other species at a site in Green Canyon.
http://oceanexplorer.noaa.gov/explorations/08lophelia/logs/sept24/media/green_canyon_lophelia.html

wells. Responsibility for managing exploration and development of mineral resources on the Nation's outer continental shelf is a central mission of the U.S. Department of the Interior's Minerals Management Service (MMS). Besides managing the revenues from mineral resources, an integral part of this mission is to protect unique and sensitive environments where these resources are found.

For the past three years, NOAA's Office of Ocean Exploration and Research (OER) has collaborated with MMS on a series of expeditions to locate and explore deep-sea chemosynthetic communities in the Gulf of Mexico. These communities not only indicate the potential presence of hydrocarbons, but are also unique ecosystems whose importance is presently unknown. To protect these ecosystems from negative impacts associated with exploration and extraction of fossil fuels, MMS has developed rules that require the oil and gas industry to avoid any areas where geophysical survey data show that high-density chemosynthetic communities are likely to occur. Similar rules have been adopted to protect archeological sites and historic shipwrecks.

OER-sponsored expeditions in 2006, 2007, and 2008 were focused on discovering seafloor communities near seeping hydrocarbons on hard bottom in the deep Gulf of Mexico; detailed sampling and mapping at selected sites; studying relationships between coral communities on artificial and natural substrates; and gaining a better understanding of processes that control the occurrence and distribution of these communities. The *Lophelia* II 2009: Deepwater Coral Expedition: Reefs, Rigs, and Wrecks will take place aboard the NOAA Ship *Ronald H. Brown*, and is directed toward exploring deepwater natural and artificial hard bottom habitats in the northern Gulf of Mexico with emphasis on coral communities. The most basic goal of this study is to be able to predict deep-water coral distribution in the Gulf of Mexico. This information will enhance efforts to protect these fragile habitats as human activities extend offshore into deeper and deeper waters.

Unfortunately, deep-water reefs are threatened by other human activities as well. Throughout Earth's ocean, rising levels of atmospheric carbon dioxide are causing increased acidity, which can affect the ability of corals (and other organisms) to produce body structures made of calcium carbonate.

This lesson guides a student inquiry into some properties of the ocean's carbonate buffer system, and how changes in atmospheric carbon dioxide levels may affect ocean pH and biological organisms that depend upon calcification. This lesson was first created for the 2008 Deepwater Coral Expedition: Reefs, Rigs, and Wrecks, but has been updated in 2009 to include recently published information.

NOTE: Be careful! Concentrated sodium hydroxide is dangerous. Use goggles and protective rubber gloves when working with solid chemicals and solutions, and be sure the surfaces of gloves and bottles are dry to avoid accidental slippage when bottles are handled. Any chemical that contacts the skin should be immediately washed off with copious quantities of water. Then apply dilute vinegar solution to neutralize traces of the alkali. Spills of alkalis should be diluted as above before mopping up. For large spills, solid citric acid should be used as a neutralizer.

Learning Procedure

1. To prepare for this lesson:
   - Review introductory essays for the *Lophelia* II 2009: Deepwater Coral Expedition: Reefs, Rigs, and Wrecks at http://oceanexplorer.noaa.gov/explorations/09lophelia/welcome.html;
   - Review procedures and questions on the *Ocean Acidification Inquiry Guide*, and make copies for student groups;
   - Prepare solutions for student inquiries (See sidebar at left!):
     (a) 4 M sodium hydroxide solution: Dissolve 40 g NaOH in 100 ml water, then dilute to 250 ml.
     (b) 0.1 M sodium hydroxide solution: Dilute 25 ml of 4 M sodium hydroxide solution to a volume of 1 liter. Transfer the solution to dropper bottles, one bottle for each student group.
     (c) Dilute acetic acid solution: Transfer white vinegar to dropper bottles, one bottle for each student group.
     (d) Artificial Seawater: Follow directions on package to prepare required quantity (see Materials; typically, 1 liter will require about two tablespoons of the dry powder).

2. Briefly introduce the *Lophelia* II 2009: Deepwater Coral Expedition: Reefs, Rigs, and Wrecks and describe deepwater coral communities. You may want to show images from http://oceanexplorer.noaa.gov/gallery/livingocean/livingocean_coral.html. Point out the variety of organisms found in these communities, and briefly discuss their potential importance. Tell students that while deepwater coral reefs were discovered in the Gulf of Mexico nearly 50 years ago, very little is known about the ecology of these communities or the basic biology of the corals that produce them. Say that one of the primary objectives of the Deepwater Coral Expedition is to determine the effects of temperature, pH, dissolved oxygen, and electrical current on growth and survival of deepwater corals. Review the concept of acids, bases, pH, and Le Chatelier's Principle (If a system that is in equilibrium is changed, the system will react in such a way as to undo the effect of the change). Ask students what might cause significant pH changes in the ocean. If students do not identify increased atmospheric carbon dioxide as a potential cause, do not prompt them on this point right now.

3. Tell students that their assignment is to investigate some of the aspects of pH in seawater, and impacts of reduced pH. Provide each student group with a copy of the *Ocean Acidification Inquiry Guide* and the materials listed on the worksheet.

4. When students have completed the procedures described in the *Inquiry Guide*, lead a discussion of their results.

Background Research & Analysis Questions

1. About 25% of the CO_2 added to the atmosphere from human activities is absorbed by the ocean each year.
2. When CO_2 dissolves in seawater, carbonic acid is formed.
3. Ocean acidification may affect shell and skeleton formation, physiology, and/or reproduction in marine organisms.
4. Polar regions of Earth's ocean are expected to be first to become corrosive enough to dissolve some shells.
5. Ocean acidity has increased 30% since the Industrial Revolution.
6. An episode of ocean acidification 65 million years ago is linked to mass extinctions of marine organisms.
7. The present increase in ocean acidification is happening 100 times faster than any other acidification event in at least 20 million years.
8. Current CO_2 emissions are higher than the worst case scenario developed by the Intergovernmental Panel on Climate Change in the 1990's.
9. Ocean acidification is a result of CO_2 emissions, not climate change.
10. The only measures that will reduce ocean acidification are those that reduce atmospheric CO_2.
11. As a result of ocean acidification coral calcification rates will decline by one-third and erosion of corals will exceed new growth by the middle of this century. By 2100, 70% of cold-water corals will be exposed to corrosive waters.
12. Economic impacts expected from ocean acidification include impacts on marine food webs that include commercially fished species, which threaten the food security of millions of people. In addition, impacts on coral reefs will affect shoreline protection and tourism.
13. Ocean acidification has a "feedback" effect on climate change, because decreasing pH reduces the ocean's capacity to absorb CO_2, which will make it more difficult to stabilize atmospheric CO_2 concentrations.
14. Atmospheric CO_2 concentrations can be stabilized with technology that is presently available or will soon be available. The cost of stabilizing atmospheric CO_2 at a level that will avoid most of the negative impacts of ocean acidification is less than the cost of doing nothing.

Hands-on Inquiry

Students should have found that seawater is much more resistant to changes in pH than distilled water, and consequently is a good buffer. Write the following equation on a marker board or overhead transparency so that it is visible to all students:

CO_2	+	H_2O	<>	H_2CO_3	<>	H^+	+	HCO_3^-	<>	H^+	+	CO_3^{2-}
carbon dioxide		water		carbonic acid		hydrogen ion		bicarbonate ion		hydrogen ion		carbonate ion

Tell students that this equation describes the carbonate buffer system of seawater. The equation shows that carbon dioxide dissolves in seawater to form carbonic acid, a weak acid. Most of the carbonic acid normally dissociates to form hydrogen ions, bicarbonate ions, and carbonate ions. Be sure students understand that carbon dioxide, carbonic acid, bicarbonate ions, and carbonate ions are all present in normal seawater, although not in the same concentrations (bicarbonate and carbonate concentrations are much higher than carbon dioxide and carbonic acid). When these chemicals are in equilibrium, the pH of seawater is about 8.1 – 8.3 (slightly basic).

Considering Le Chatelier's Principle, students should realize that if hydrogen ions are added to normal seawater the system will react in a way that tends to remove hydrogen ions from solution, so the reactions will proceed to the left. Similarly, if a very basic solution is added to normal seawater, students should predict that the system will react in a way that tends to add more hydrogen ions, and so the reactions will proceed to the right. In both cases, the system shifts so the change in pH is less than it would be if the system were not present (that is, the system buffers the effect of the added ions.)

The Bridge Connection

http://www.vims.edu/bridge/ – Scroll over "Ocean Science Topics," then click "Chemistry," or "Atmosphere" for links to resources about ocean chemistry or climate change.

The "Me" Connection

Have students write a brief essay describing how buffer systems are of personal benefit, and how a change in ocean pH might have personal impacts.

Connections to Other Subjects

English/Language Arts, Social Sciences, Mathematics

Assessment

Students' responses to *Inquiry Guide* questions and class discussions provide opportunities for assessment.

Extensions

1. Have students visit http://oceanexplorer.noaa.gov/explorations/09lophelia/welcome.html to find out more about the *Lophelia* II 2009: Deepwater Coral Expedition: Reefs, Rigs, and Wrecks.
2. Have student groups prepare scientific posters about the ocean acidification issue. See http://oceanexplorer.noaa.gov/explorations/09bioluminescence/background/edu/media/ds_09_livinglight.pdf for information about scientific posters, and "Other Resources" for additional sources of information about ocean acidification.

Multimedia Discovery Missions

http://oceanexplorer.noaa.gov/edu/learning/welcome.html
Click on the links to Lessons 3, 5, and 6 for interactive multimedia presentations and Learning Activities on Deep-Sea Corals, Chemosynthesis and Hydrothermal Vent Life, and Deep-Sea Benthos.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

(*All of the following Lesson Plans are targeted toward grades 9-12*)

What's the Difference?
(PDF, 300 kb) (from the Lophelia II 2008 Expedition)
http://oceanexplorer.noaa.gov/explorations/08lophelia/background/edu/media/difference.pdf

Focus: Identification of biological communities from survey data (Life Science)

In this activity, students will be able to calculate a simple similarity coefficient based upon data from biological surveys of different areas, describe similarities between groups of organisms using a dendrogram, and infer conditions that may influence biological communities given information about the groupings of organisms that are found in these communities.

My Wet Robot
(300kb) (from the Bonaire 2008: Exploring Coral Reef Sustainability with New Technologies Expedition)
http://oceanexplorer.noaa.gov/explorations/08bonaire/background/edu/media/wetrobot.pdf

Focus: Underwater Robotic Vehicles (Physical Science)

In this activity, students will be able to discuss the advantages and disadvantages of using underwater robots in scientific explorations, identify key design requirements for a robotic vehicle that is capable of carrying out specific exploration tasks, describe practical approaches to meet identified design requirements, and (optionally) construct a robotic vehicle capable of carrying out an assigned task.

Cool Corals
(7 pages, 476k) (from the Expedition to the Deep Slope 2007)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/corals.pdf

Focus: Biology and ecology of *Lophelia* corals (Life Science)

In this activity, students will describe the basic morphology of *Lophelia* corals and explain the significance of these organisms, interpret preliminary observations on the behavior of *Lophelia* polyps, and infer possible explanations for these observations. Students will also discuss why biological communities associated with *Lophelia* corals are the focus of major worldwide conservation efforts.

This Old Tubeworm
(10 pages, 484k) (from the Expedition to the Deep Slope 2007)
http://oceanexplorer.noaa.gov/explorations/07mexico/background/edu/media/old_worm.pdf

Focus: Growth rate and age of species in cold-seep communities (Life Science)

Students will be able to explain the process of chemosynthesis, explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps, and construct a graphic interpretation of age-specific growth, given data on incremental growth rates of different-sized individuals of the same species. Students will also be able to estimate the age of an individual of a specific size, given information on age-specific growth in individuals of the same species.

Biochemistry Detectives
(8 pages, 480k) (from the 2002 Gulf of Mexico Expedition)
http://oceanexplorer.noaa.gov/explorations/02mexico/background/edu/media/gom_biochem.pdf

Focus: Biochemical clues to energy-obtaining strategies (Chemistry)

In this activity, students will be able to explain the process of chemosynthesis, explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps, and describe three energy-obtaining strategies used by organisms in cold-seep communities. Students will also be able to interpret analyses of enzyme activity and ^{13}C isotope values to draw inferences about energy-obtaining strategies used by organisms in cold-seep communities.

Hot Food
(4 pages, 372k) (from the 2003 Gulf of Mexico Deep Sea Habitats Expedition)
http://oceanexplorer.noaa.gov/explorations/03mex/background/edu/media/mexdh_hotfood.pdf

Focus: Energy content of hydrocarbon substrates in chemosynthesis (Chemistry)

In this activity, students will compare and contrast photosynthesis and chemosynthesis as processes that provide energy to biological communities, and given information on the molecular structure of two or more substances, will make inferences about the relative amount of energy that could be provided by the substances. Students will also be able to make inferences about the potential of light hydrocarbons as an energy source for deepwater coral reef communities.

What Was for Dinner?
(5 pages, 400k) (from the 2003 Life on the Edge Expedition)
http://oceanexplorer.noaa.gov/explorations/03edge/background/edu/media/dinner.pdf

Focus: Use of isotopes to help define trophic relationships (Life Science)

In this activity, students will describe at least three energy-obtaining strategies used by organisms in deep-reef communities and interpret analyses of ^{15}N, ^{13}C, and ^{34}S isotope values.

Chemosynthesis for the Classroom
(9 pages, 276k) (from the 2006 Expedition to the Deep Slope)
http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20Chemo.pdf

Focus: Chemosynthetic bacteria and succession in chemosynthetic communities (Chemistry/Biology)

In this activity, students will observe the development of chemosynthetic bacterial communities and will recognize that organisms modify their environment in ways that create opportunities for other organisms to thrive. Students will also be able to explain the process of chemosynthesis and the relevance of chemosynthesis to biological communities in the vicinity of cold seeps.

C.S.I. on the Deep Reef
(Chemotrophic Species Investigations, That Is)
(11 pages, 280k) (from the 2006 Expedition to the Deep Slope)
http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20CSI.pdf

Focus: Chemotrophic organisms (Life Science/Chemistry)

In this activity, students will describe at least three chemotrophic symbioses known from deep-sea habitats and will identify and explain at least three indicators of chemotrophic nutrition.

This Life Stinks
(9 pages, 280k) (from the 2006 Expedition to the Deep Slope)
http://oceanexplorer.noaa.gov/explorations/06mexico/background/edu/GOM%2006%20Stinks.pdf

Focus: Methane-based chemosynthetic processes (Physical Science)

In this activity, students will be able to define the process of chemosynthesis, and contrast this process with photosynthesis. Students will also explain the process of methane-based chemosynthesis and explain the relevance of chemosynthesis to biological communities in the vicinity of cold seeps.

Other Resources

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

http://oceanexplorer.noaa.gov – Web site for NOAA's Ocean Exploration Program

http://celebrating200years.noaa.gov/edufun/book/welcome.html#book – A free printable book for home and school use introduced in 2004 to celebrate the 200th anniversary of NOAA; nearly 200 pages of lessons focusing on the exploration, understanding, and protection of Earth as a whole system

Ocean Acidification: A Summary for Policymakers from the Second Symposium on the Ocean in a High-CO_2 World available at (http://ioc3.unesco.org/oanet/OAdocs/SPM-lorezv2.pdf

SCOR/IOC Symposium Planning Committee. 2004. The Ocean in a High-CO_2 World. *Oceanography* **17**(3):72-78; available online at http://www.tos.org/oceanography/issues/issue_archive/issue_pdfs/17_3/17.3_scor_ioc.pdf

Feely, R. A., C. L. Sabine, and V. J. Fabry. 2006. "Carbon Dioxide and Our Ocean Legacy". Ocean Science Brief available online at http://www.pmel.noaa.gov/pubs/PDF/feel2899/feel2899.pdf

http://www.ucar.edu/communications/Final_acidification.pdf – "Impacts of Ocean Acidification on Coral Reefs and Other Marine Calcifiers: A Guide for Future Research;" report from a workshop sponsored by the National Science Foundation, the National Oceanic and Atmospheric Administration, and the U.S. Geological Survey

Havenhand,J.N., F.-R. Buttler, M.C. Thorndyke, J.E. Williamson. 2008. Near-future levels of ocean acidification reduce fertilization success in a sea urchin. *Current Biology*, **18**:R651-R652

http://www.terrain.org/articles/21/burns.htm – Article on ocean acidification from Terrain.org

http://www.oceana.org/climate/impacts/acid-oceans/ – Oceana article on ocean acidification

http://www.gomr.mms.gov/index_common.html - Minerals Management Service Web site

http://www.gomr.mms.gov/homepg/lagniapp/chemcomp.pdf (PDF) - *Chemosynthetic Communities in the Gulf of Mexico* teaching guide to accompany a poster with the same title, introducing the topic of chemosynthetic communities and other ecological concepts to middle and high school students

http://www.coast-nopp.org/ - Resource Guide from the Consortium for Oceanographic Activities for Students and Teachers, containing modules, guides, and lesson plans covering topics related to oceanography and coastal processes

http://cosee-central-gom.org/ - Web site for The Center for Ocean Sciences Education Excellence: Central Gulf of Mexico (COSEE-CGOM)

National Science Education Standards

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science

- Properties and changes of properties in matter

Content Standard D: Earth and Space Science

- Structure of the Earth system

Content Standard F: Science in Personal and Social Perspectives

- Populations, resources, and environments
- Science and technology in society
- Natural and human-induced hazards

Content Standard G: History and Nature of Science

- Nature of science

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.
The Earth has one big ocean with many features.
Fundamental Concept g. The ocean is connected to major lakes, watersheds and waterways because all major watersheds on Earth drain to the ocean. Rivers and streams transport nutrients, salts, sediments and pollutants from watersheds to estuaries and to the ocean.
Fundamental Concept h. Although the ocean is large, it is finite and resources are limited.

Essential Principle 5.
The ocean supports a great diversity of life and ecosystems.
Fundamental Concept d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.
Fundamental Concept g. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, and methane cold seeps rely only on chemical energy and chemosynthetic organisms to support life.

Essential Principle 6.
The ocean and humans are inextricably interconnected.
Fundamental Concept b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.
Fundamental Concept e. Humans affect the ocean in a variety of ways. Laws, regulations and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (such as point source, non-point source, and noise pollution) and physical modifications (such as changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean.
Fundamental Concept g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Essential Principle 7.
The ocean is largely unexplored.
Fundamental Concept a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.
Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.
Fundamental Concept c. Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.
Fundamental Concept d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.
Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

Send Us Your Feedback

We value your feedback on this lesson.
Please send your comments to:
oceanexeducation@noaa.gov

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Off Base

Ocean Acidification Inquiry Guide

A buffer is a solution that tends to resist changes in pH. Your assignment is to investigate the some of the pH buffering capabilities of seawater.

Background Research & Analysis

Obtain a copy of *Ocean Acidification: A Summary for Policymakers from the Second Symposium on the Ocean in a High-CO_2 World* (http://ioc3.unesco.org/oanet/OAdocs/SPM-lorezv2.pdf), and find answers to the following questions:

1. About how much of the CO_2 added to the atmosphere from human activities is absorbed by the ocean each year?

2. When CO_2 dissolves in seawater, what compound is formed?

3. How may ocean acidification affect marine organisms?

4. Which regions of Earth's ocean will be first to become corrosive enough to dissolve some shells?

5. How much has ocean acidity increased since the Industrial Revolution?

6. In geologic history, has ocean acidification ever been linked to mass extinctions of marine organisms?

7. Ocean pH is known to fluctuate. How is the present increase in acidity different?

8. In the 1990's the Intergovernmental Panel on Climate Change developed a worst case scenario for projected CO_2 emissions. How do current CO_2 emissions compare with the worst case scenario?

Off Base

Ocean Acidification Inquiry Guide - continued

9. Is ocean acidification another result of climate change?

10. Will initiatives to combat climate change also reduce ocean acidification?

11. What impacts is ocean acidification expected to have on reef-building corals?

12. What are some economic impacts expected from ocean acidification?

13. Does ocean acidification have any "feedback" effect on climate change?

14. Practically speaking, is there anything that can be done to avoid the negative impacts associated with decreasing ocean pH?

Off Base

Ocean Acidification Inquiry Guide - continued

Hands-On Inquiry

Materials

- Distilled water, approximately 150 ml
- Artificial seawater, approximately 150 ml
- pH test paper
- Dilute acetic acid solution in dropper bottle
- 0.1 M sodium hydroxide solution in dropper bottle
- 100 ml glass beaker
- 100 ml graduated cylinder
- Glass stirring rod
- Data Chart for Buffer Properties of Seawater

Procedure

Wear eye protection and gloves throughout this inquiry!
Wash your hands thoroughly when you are finished!
Do not eat, drink, or chew anything while you are in the laboratory!

1. Measure 50 ml of distilled water into a 100 ml glass beaker. Test the pH by dipping a strip of pH test paper into the water and comparing the color of the paper to the chart on the test paper container. Record the pH on the Data Chart for Buffer Properties of Seawater.

2. Add one drop of dilute acetic acid to the beaker, stir with a glass stirring rod, test the pH, and record the result on the data chart.

3. Repeat Step 2 until 20 drops of dilute acetic acid have been added, testing and recording the pH after each drop.

4. Rinse the beaker, then repeat Steps 1 through 3 using seawater instead of distilled water. Be sure to use a separate graduated cylinder for measuring the seawater.

5. Rinse the beaker and repeat Steps 1 through 3 with distilled water and seawater (use a different graduated cylinder for each!), but use 0.1 M sodium hydroxide solution instead of the dilute acetic acid.

6. **Wash your hands thoroughly!**

Data Chart for Buffer Properties of Seawater Inquiry

Drops Added	Test with Added Acetic Acid: Distilled Water pH	Test with Added Acetic Acid: Seawater pH	Test with Added Sodium Hydroxide: Distilled Water pH	Test with Added Sodium Hydroxide: Seawater pH
0	________	________	________	________
1	________	________	________	________
2	________	________	________	________
3	________	________	________	________
4	________	________	________	________
5	________	________	________	________
6	________	________	________	________
7	________	________	________	________
8	________	________	________	________
9	________	________	________	________
10	________	________	________	________
11	________	________	________	________
12	________	________	________	________
13	________	________	________	________
14	________	________	________	________
15	________	________	________	________
16	________	________	________	________
17	________	________	________	________
18	________	________	________	________
19	________	________	________	________
20	________	________	________	________

Off Base

Ocean Acidification Inquiry Guide - continued

Analysis

1. What do your data suggest about the buffer system of seawater compared to distilled water?

2. Recall Le Chatelier's Principle. What do you think would happen if hydrogen ions were added to normal seawater?

3. What do you think would happen if a very basic solution (which tends to remove hydrogen ions from solution) were added to normal seawater?