Dissolving Issues: Ocean Acidification

Material adapted from:
New Jersey Marine Science Center Consortium, Education Program Lesson Plans
http://www.njmsc.org/education/Lesson_Plans/pH.pdf
Monterey Bay Research Institute EARTH Lesson Plans Ocean Acidification
http://www.mbari.org/earth/
USC COSEE-West Resources
http://www.usc.edu/org/cosee-west/resources.html#co2

Data obtained from

Introduction:

Global climate change is in the news daily. We hear about increased air temperatures, glaciers melting and more extreme weather events, but other effects may include changes to natural biogeochemical cycles, such as the carbon cycle. Although the natural absorption of CO_2 by the world's oceans may mitigate the climatic effects of anthropogenic emissions of CO_2, the resulting decrease in pH could have negative consequences for oceanic organisms. In this activity, students will review the carbon cycle, test how an increase in dissolved CO_2 can affect the pH of seawater and hypothesize on how this could affect calcium carbonate-based organisms.

Objectives:

Students will:

- Develop an understanding of the role of oceans in the carbon cycle
- Investigate how an increase in dissolved CO_2 can change the pH of a solution and how this relates to ocean chemistry
- Investigate the effects of increased acidity on calcium carbonate and what this means for oceanic organisms

Materials:

(Materials in **bold** are provided by SMILE)

Unopened 16oz bottle of coke or pepsi
Empty 16oz soda bottle with cap
Glue/duct tape
Length of thin plastic tubing (approx 2ft)
Beakers or cups (6 per team, plus one for demonstration)
pH Testing Paper
White vinegar
Lemon Juice
Soda (any, but not diet)
Pieces of white chalk
Markers
Stopwatches (optional)
Small scale for weighing chalk
Paper Towels

Materials provided are enough to support **20** students

Handouts/Overheads:

Carbon Cycle Transparency
Student Worksheet
Answer Sheet

Procedure

1. Before the class starts prepare a demonstration experiment. Set up a beaker of tap water and the unopened bottle of soda at the front of the class. Take the cap off the empty bottle and poke a small hole through it, big enough for the tubing. Push one end of the tubing into the hole in the cap and secure in place with a little glue or duct tape on both sides of the cap.

2. Inform the students they will be investigating the effect of carbon dioxide on the oceans. Show them the beaker of water and soda and ask them to tell you the gas that is released when soda fizzes (CO_2). Have a few of the students use pH paper to test the starting pH of the tap water and note the result.

3. Open the full bottle of soda, remove the new cap and replace it with the modified cap. Gently shake the bottle of soda to fizz it up a little, pinching off the tubing by the cap to prevent too much initial CO_2 escaping and spillage. Place the other end of the tubing into the beaker of water. Ask the students to hypothesize what they think might happen with this experiment. Slow bubbles of CO_2 from the soda should be flowing out of the tubing through the water. Leave the experiment to run, you will return to it later.

4. Divide the students into 4 groups and give each team a copy of student worksheet 1. Review the carbon cycle by using the carbon cycle transparency, pointing out the interaction between atmospheric CO_2 and the surface of the ocean (CO_2 dissolves in seawater). Have them read the first section and answer the questions in their teams.

5. Provide students with the beakers, chalk and vinegar. Have them follow the instructions for their experiment on their worksheets, making hypotheses about their investigation before they begin. Have each team write their hypotheses on the board.

6. Whilst the students wait for their chalk to sit, return to the demonstration. Have a few students take the pH of the tap water. Ask them what happened (CO_2 dissolved into water, lowering the pH and therefore increasing the water acidity) and why it happened. Have them return to their experiments, and re-evaluate their original hypotheses with this new information.

7. Once teams are finished with their experiments, hold a class discussion on the results.

Questions to ask the students:

- What happened in each of their experiments? How did the chalk react? Did it fizz? Did it just sit there?
- Were your hypotheses supported by your data? Why or why not?

- What do you think is happening? If your chalk fizzed, why do you think it did that?
- Were there any different/similar results between the variables?
- Why were only weak acids used for testing? (Similar to diluted carbonic acid)

Extensions:

1. Coral bleaching exemplifies organisms threatened by not only ocean acidification but also by increasing ocean temperatures. Use NOAA's coral conservation program to help better understand this process and have students develop a PowerPoint presentation or public education poster on the information.

Lesson plan:
http://www.coralreef.noaa.gov/outreach/resourcecd08/resources/lessonplans/do_not_bleach_lp.pdf
Resources
http://www.coralreef.noaa.gov/outreach/resourcecd08/welcome.html

2. Have students check out some real time data for CO_2 content in the oceans online, for example:

NOAA Earth System Research Laboratory: http://www.esrl.noaa.gov/gmd/ccgg/trends
CO_2 Information Analysis Center: http://cdiac.ornl.gov/oceans/global_pco2.html
Pacific Marine Environmental Laboratory: http://www.pmel.noaa.gov/co2/OA/

3. Have the students investigate biological pumping. Iron fertilization is one idea to reduce anthropogenic CO_2. Have the students evaluate the idea of carbon sequestration and hold a class debate on the advantages and disadvantages of implementing such ideas.

Vocabulary

Biogeochemical cycle
A circuit or pathway by which a chemical element or molecule moves through both biotic and abiotic components of an ecosystem. In effect, the element is recycled, although in some such cycles there may be places (sinks) where the element is accumulated or held for a long period of time.

Carbon Sequestration
Also known as carbon capture and storage (CCS), this is an approach to reduce the effects of global climate change by capturing CO_2 from large point sources (e.g. fossil fuel plants) and storing it instead of releasing it into the atmosphere. Although CO_2 has been injected into geological formations for various purposes, the long-term storage of CO_2 is a relatively untried concept and controversial. One such method is iron fertilization, adding iron to productive areas of the ocean to increase phytoplankton growth and hence CO_2 uptake from the atmosphere.

pH
The measure of the acidity or alkalinity of a solution. It is formally a measure of the activity of dissolved hydrogen ions (H+).

Dissolving Issues: Student Worksheet

When CO_2 dissolves in seawater, it reacts to form carbonic acid ($H_2CO_3^-$)

(1) $CO_2 + H_2O \rightarrow H_2CO_3^-$

Carbonic acid can disassociate to form bicarbonate (HCO_3)

(2) $H_2CO_3^- \rightarrow H^+ + HCO_3^-$

Bicarbonate can then disassociate to form carbonate ions (HCO_3^-)

(3) $HCO_3^- \rightarrow H^+ + CO_3^{2-}$

Some marine organisms use bicarbonate to form the compound calcium carbonate ($CaCO_3$),

(4) $2HCO_3^- + Ca^{2+} \rightarrow CaCO_3 + CO_2 + H_2O$

which they utilize in building skeletons as in coral reefs, or protective shells as in snails. For that reason alone, bicarbonate is an extremely important component of the dissolved materials in the ocean.

However, carbonate ions are also very important, for they are chiefly responsible for buffering the ocean against changes in pH. If an acid is added to seawater, the carbonate ion ties up the excess H^+, which results in the production of carbonic acid

(5) $CO_3^{2-} + H_2SO_4$ (sulfuric acid, for example) $\rightarrow H_2CO_3 + SO_4^{2-}$

If a base is added, carbonic acid will donate hydrogen ions, which neutralize the excess OH^-. Because of this, carbonate ions regulate the pH of seawater.

Questions:

1. Using equation (1), what do you think may happen if the quantity of CO_2 is increased?

2. All of these reactions are reversible, meaning a chemical change can shift them in the opposite direction. Thinking about your answer from question 1 what would an increase in CO_2 mean for the calcium carbonate in equation (4)?

3. What would this then mean for

(a) Equation (5)

(b) Marine organisms that build skeletal structures or have shells?

Experiment:

1. Collect together beakers, pH paper, chalk and an acidic liquid.
   - Label 2 of your beakers “control 1” and “experiment 1”
   - Pour 25ml of tap water into each and measure the pH. Record both pH values on data sheet #1
   - Weigh 2 pieces of chalk on a scale and record on the same data sheet
   - Place one chalk piece in control 1 and one in experiment 1
   - Measure the pH for both again
   - Measure out 25ml of lemon juice (variable) and add this to **experiment 1 only**
   - Measure the pH for both again and record any observations

2. Repeat step 1 above, this time marking the beakers as “control 2” and “experiment 2”, using vinegar as the new variable. Mark results on data sheet #2.

3. Repeat step 1 above, this time marking the beakers as “control 3” and “experiment 3”, using soda as the new variable. Mark results on data sheet #2.

4. Leave the chalk to sit in each beaker for 10-15 min

5. After the time is up, remove the chalk from experiment 1, blot it gently with paper towel and re-weigh. Repeat with control 1. Record results.

6. Repeat step 5 with experiment 2 and control 2.

7. Repeat step 5 with experiment 3 and control 3.