



Ocean Acidification

3: MODEL CO₂ DISSOLVES IN SEAWATER

Grade Level: 9-12

Time: 60-75 minutes

SUMMARY:

In this interactive lesson, students will learn the specific chemical reaction that occurs when atmospheric carbon dioxide dissolves in seawater. Students will create a physical model to describe the reaction and to demonstrate how increasing levels of carbon dioxide in the world's oceans contribute to a decrease in average pH.

OBJECTIVES:

Students will:

- Use 3D materials to visually represent the change in ocean chemistry that occurs when carbon dioxide reacts with seawater.
- Describe and discuss this reaction using their model.

STEM APPLICATIONS:

- **Science (chemistry)** - Chemical reaction of carbon dioxide and seawater is illustrated.
- **Technology** - Students will perform brief research on ocean acidification on computers.
- **Engineering** - Students will use materials to create a structure.

NGSS ALIGNMENT:

- **Practice 2.** Developing and Using Models
 - **9-12** - Develop, revise and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.
- **Practice 3.** Planning and Carrying Out Investigations
 - **9-12** - Select appropriate tools to collect, record, analyze and evaluate data.
 - **9-12** - Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.
- **Practice 6.** Constructing Explanations and Designing Solutions
 - **9-12** - Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables.
 - **9-12** - Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.
- **Practice 8.** Obtaining, Evaluating, and Communicating Information
 - **9-12** - Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

VOCABULARY:

Ocean acidification – A phenomenon that is occurring in the world's oceans due to increasing concentrations of anthropogenic carbon dioxide in the atmosphere. Acidification occurs when carbon dioxide dissolves in seawater and dissociates into carbonic acid and other carbon species, which in turn lowers the pH. The impacts to marine life are not fully understood, however a rapid change in the average oceanic pH could make it hard for marine organisms – especially shellfish – to survive.

Air-Sea Gas Exchange – A physio-chemical process where differences in concentrations of certain gases in seawater and the atmosphere cause molecules to continually cross the boundary between the ocean's surface and the air.

Ocean Chemistry – The chemical composition of seawater and the many compounds, elements, gases, minerals and organic and particulate matter it contains.

Carbon Dioxide – CO₂ – A gas produced by burning carbon. It is naturally present in the atmosphere, but humans have altered the carbon cycle and substantially increased the atmospheric concentration of carbon dioxide, mostly by burning fossil fuels like coal, natural gas, and oil.

Carbonic Acid – H₂CO₃ – A weak acid that forms when carbon dioxide (CO₂) reacts with water (H₂O). It is this acid, in addition to a greater concentration of free-floating hydrogen ions, that is causing the pH of the oceans to decrease.

Carbonate – CO₃²⁻ – Carbonate is an ion with a negative charge that is the only bioavailable species of carbon in ocean water. Calcifying organisms combine carbonate with calcium to form shells.

Bicarbonate – HCO₃⁻ – Like Carbonic Acid and Carbonate, Bicarbonate is a product of the chemical reaction between carbon dioxide and seawater.

Speciation – The chemical form or compound in which an element occurs. Carbonic Acid, Carbonate, and Bicarbonate are all "species" of carbon.

Dissolution – When a compound such as carbon dioxide sepa-



rates into individual elements by dissolving into a solvent such as ocean water, and recombines into another compound.

pH – A measure of the concentration of hydrogen ions present in a substance on a scale from 0-14, where low numbers represent very strong acids, high numbers are very strong bases, and “7” (about the pH of drinking water) is neutral.

MATERIALS:

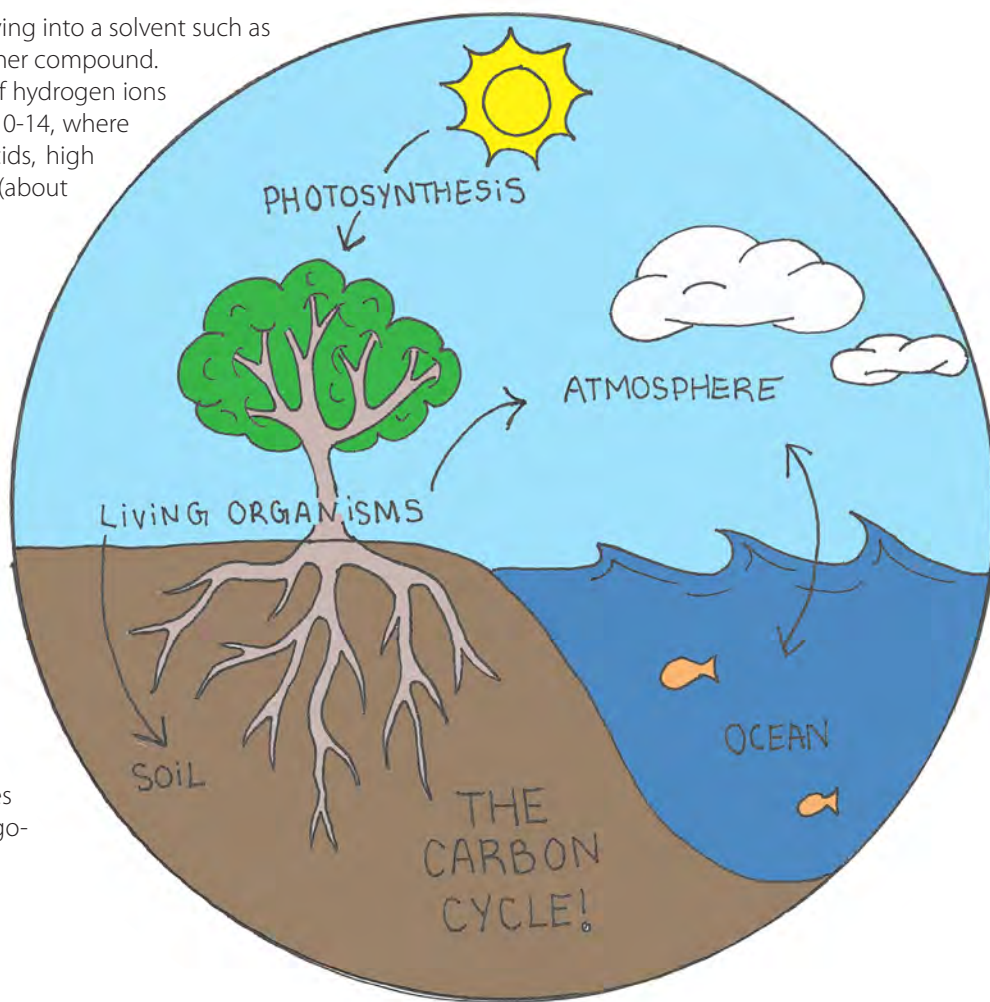
The materials you provide for this activity are at your discretion, and might include: straws, pipe cleaners or wooden dowels, sticky tack or glue to hold models together, construction paper or wooden blocks to represent the different chemical compounds, and various other materials for decoration or labeling purposes. The models themselves may be constructed in any shape or size (and the creativity of the students should reign there!) or, alternatively, the activity may be done as a 2D diagram on a poster-board or a piece of paper. You will need distinct materials/supplies to represent each of the following categories:

- Carbon dioxide molecules
- Carbonate ions
- Bicarbonate ions
- Hydrogen ions
- Carbonic Acid
- The ocean
- The atmosphere

BACKGROUND:

The concentration of carbon dioxide in the atmosphere is increasing rapidly, generated from human activities that require burning fossil fuels. While some of these carbon dioxide emissions remain in the atmosphere, about 1/3 are absorbed by the oceans. This is equivalent to about 22 million tons per day!

The dissolution of carbon dioxide in seawater produces carbonic acid – a naturally occurring substance that has remained in balance with other products like carbonate, bicarbonate and hydrogen ions. In the last century and a half, however, humans have added an immense amount of carbon dioxide to the atmosphere, disrupting the carbon cycle and causing a 0.1 unit drop in the average pH of the world’s oceans. If this trend of ocean acidification continues, marine species may face extraordinary challenges and conditions to which they are unable to adapt. Since this phenomenon was identified in 2005, ocean chemists have pinpointed the specific chemical processes that occur when carbon dioxide dissolves in seawater. In this activity, students will recreate this process with a physical model that shows just how our oceans are acidifying.



ACTIVITY:

1. Engage/Elicit

To begin this activity, it is helpful to have the students perform research to start to understand the process by which carbon dioxide enters the oceans. Divide the students into groups of 3-4 and ask them to take notes on articles they find on “carbon dioxide in ocean water.” You can suggest they do a Google search for these terms, or direct them to the following web pages, which illustrate this process clearly:

- <http://www.pmel.noaa.gov/CO2/story/Ocean+Carbon+Uptake>
- <http://earthobservatory.nasa.gov/Features/OceanCarbon/>
- <http://ocean.nationalgeographic.com/ocean/critical-issues-ocean-acidification/>

After 15-20 minutes of research and note taking, ask the students to share any interesting facts they have found about climate change and/or ocean chemistry. Incorporate their input and information to recreate the chart (Figure 1) at the end of this lesson as a drawing on a whiteboard, or print the chart out to display the process of carbon dioxide dissolving in seawater.

2. Explore

After posting the diagram of carbon dioxide dissolving in seawater clearly so the students can use it for reference, direct the groups of students to the materials you have provided for modeling. Ask each group to use the diagram to build a model that represents ocean acidification, or in other words, the dissolution and speciation of carbon in seawater. Be sure to ask students to label all parts of the model clearly.

3. Explain

Lead a discussion on the process that the students have now modeled. Students should understand that as carbonic acid accumulates, it contributes to the lowering of the overall pH value of ocean water – the fact that carbonic acid is an acid makes this rather intuitive. The resulting excess pool of hydrogen ions also contributes to the lowering pH, as the pH of any substance is a measure of the total number of H^+ ions in a given solution. Mention that the pH scale ranges from 0 to 14, with neutral being a pH value of 7. Acids, which have pH values below neutral, have increasingly higher concentrations of H^+ ions as the pH value decreases – 10 times more, in fact, at each interval. That is, a substance with a pH of 1 has 10 times more H^+ ions as a substance with a pH of 2, 100 times more H^+ ions as a substance with a pH of 3, 1,000 times more H^+ ions than a substance with a pH of 4, and so on! Therefore, a separation of just one number on the pH scale represents a huge difference in the overall acidity of the sub-

stance.

Explain that the average pH of seawater over the past 300 million years has been about 8.2, which is slightly basic. Since the industrial revolution, the pH of seawater has dropped about 0.1 units, which is a 25% increase in acidity in just 150 years! In the next century, pH is projected to decrease up to another 0.5 units – which could have grave consequences on marine life that may not be able to adapt to these rapidly acidifying conditions.

4. Evaluate/ Wrap-up

After the students have finished constructing their models, ask each group to present to the class on what they have made. Check their understanding by asking questions about each of the different chemical compounds – how they are formed, and in what order. Ask them to describe how this chemical reaction contributes to lower pH values and acidification.

5. Dive Deeper

The National Oceanic and Atmospheric Administration (NOAA) Ocean Acidification Program offers an up-to-date and comprehensive scientific analysis of this global marine issue, and with great resources to learn more and share knowledge. Access online at <http://oceanacidification.noaa.gov/>.

To learn more about ocean acidification and other important issues facing the world's oceans, please visit www.namepa.net/ education.

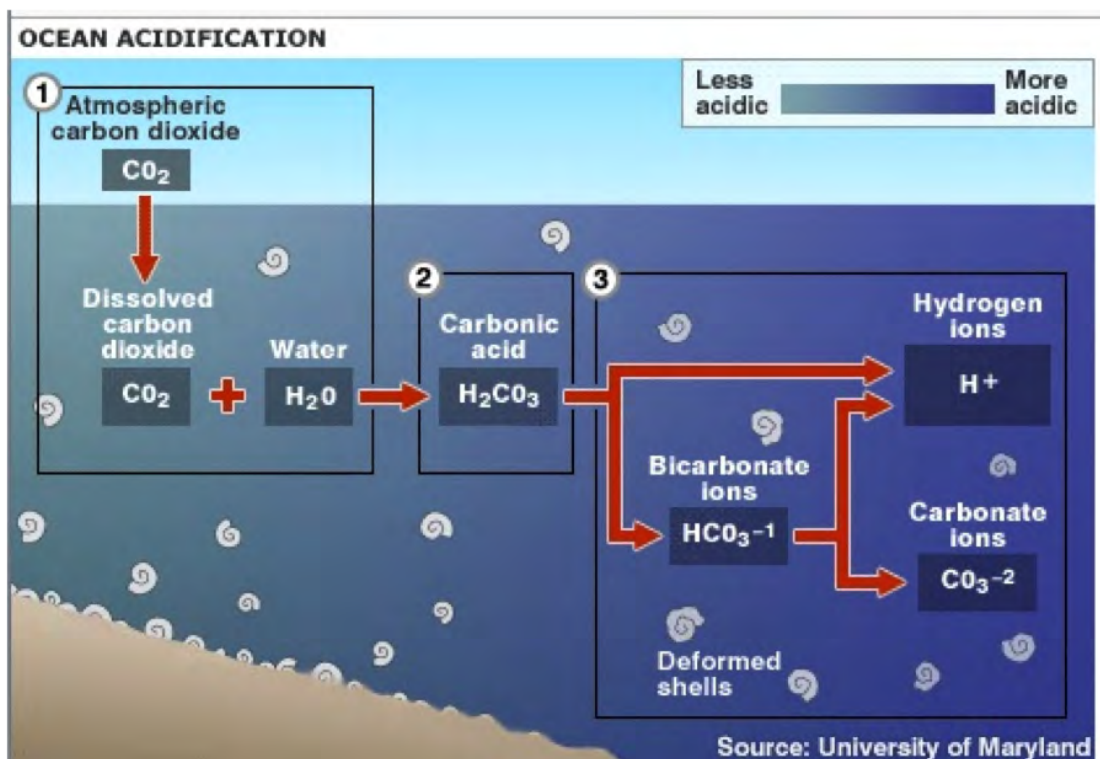


Figure 1. Ocean acidification