

## OCEAN ACIDIFICATION

### INTRODUCTION

For over 600,000 years, the ocean has been mildly alkaline with a pH of approximately 8.2. However, since the industrial revolution in the early 1800s, the ocean's pH has dropped to 8.1, the equivalent of a 30 percent increase in acidity (Figure 1).

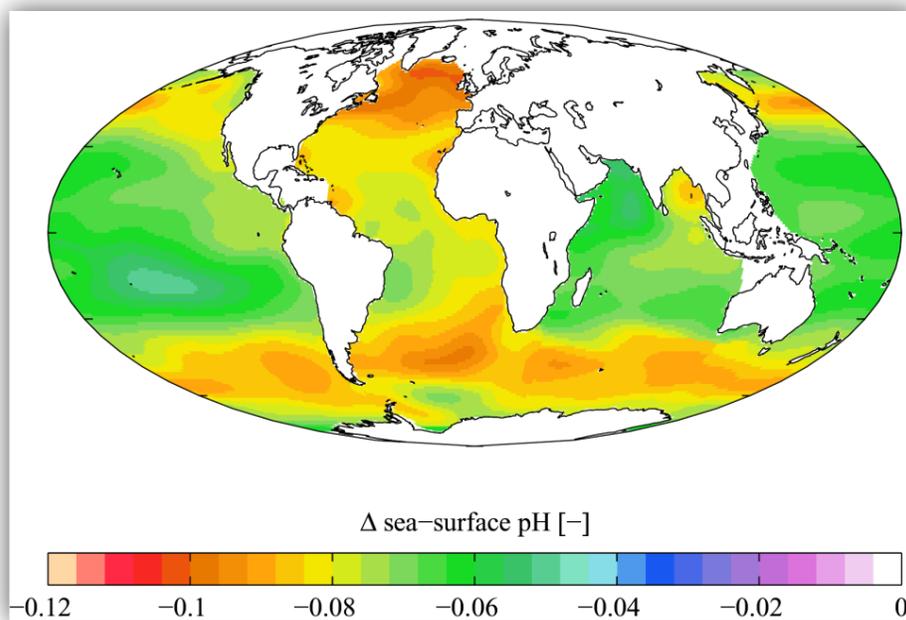


Figure 1: Historical changes in annual mean sea surface pH between 1700s and 1990s.  
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Atmospheric carbon dioxide ( $\text{CO}_2$ ) is in equilibrium with dissolved carbon dioxide in seawater. When the atmospheric  $\text{CO}_2$  level increases, more  $\text{CO}_2$  is absorbed by the oceans. Scientists estimate that something like a quarter to a third of all human-created  $\text{CO}_2$  emissions is absorbed by the ocean. When carbon dioxide dissolves in the water at the ocean's surface, it reacts with water to form carbonic acid ( $\text{H}_2\text{CO}_3$ ).

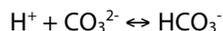


Carbonic acid is the same chemical that gives carbonated beverages their fizz. Carbonic acid dissociates, or separates, into a hydrogen ion ( $\text{H}^+$ ) and a bicarbonate ion ( $\text{HCO}_3^-$ ).

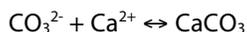


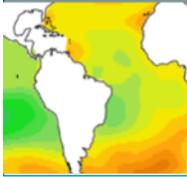
Acidity is measured in pH, which is a logarithmic scale of the hydrogen ion concentration. As hydrogen ion concentration increases, the acidity increases, and the pH decreases. Changing the pH of the environment has a large impact on chemical reactions and life processes.

The free hydrogen ion combines with a dissolved carbonate ion ( $\text{CO}_3^{2-}$ ) to form another bicarbonate ion ( $\text{HCO}_3^-$ ).



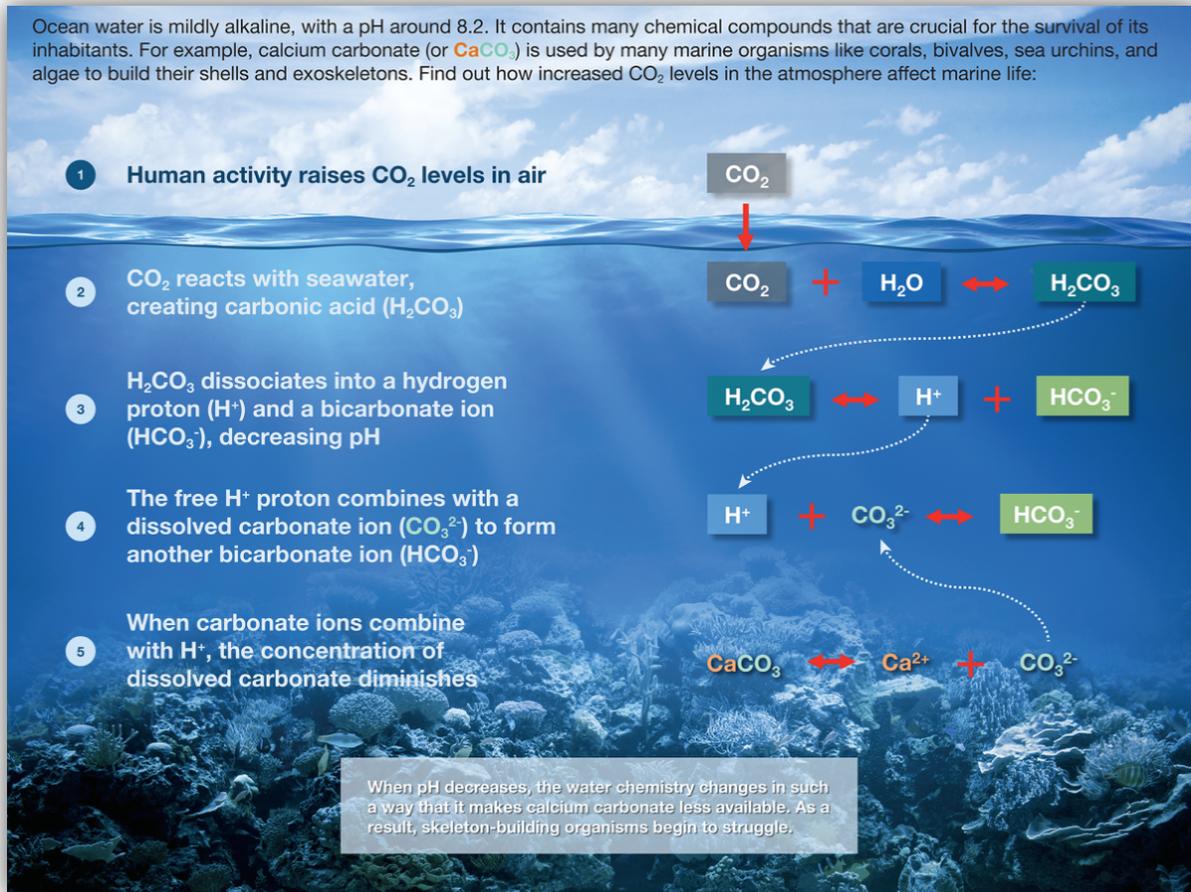
As carbonate ions combine with free hydrogen ions, the concentration of dissolved carbonate ions decreases. Many marine organisms, including corals, plankton, clams, oysters, sea urchins, barnacles, crabs, and lobsters, use carbonate ions with dissolved calcium ions ( $\text{Ca}^{2+}$ ) to form calcium carbonate ( $\text{CaCO}_3$ ), the main building block of their shells and exoskeletons.





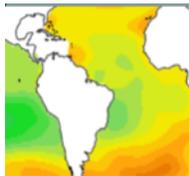
Decreasing carbonate ion concentration has been shown to reduce growth in many of these species. Experiments suggest that if the seawater were to become extremely acidic, the chemical reactions can even start to partially dissolve the shells and exoskeletons, but such an extreme condition is unlikely even if we burn all of our fossil fuels.

In this activity, you will simulate increasing atmospheric carbon dioxide levels and observe the effects on pH. You will also predict how long it will take to reach the increased level of atmospheric carbon dioxide based on current rate models.



## MATERIALS

- Beaker or cup to hold 100 ml of seawater
- Straw
- Blue or red sticky dots (or colored pencils)
- Timer
- Student Handout
- Data-collection graphs OR poster
- pH meters or pH paper
- Distilled or tap water for rinsing off pH meters



**PROCEDURE**

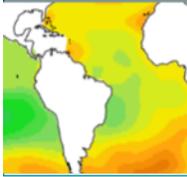
1. Each student team should obtain the following:
  - a. 1 beaker with 100 ml of seawater
  - b. Straw
2. Measure the initial pH of the seawater in your beaker. Alternatively, you can record the pH of the seawater in the tank from a sensor left in the tank.
3. Your teacher will assign you the amount of time you will blow into the beaker, either 10 or 20 seconds.
4. One member of the team will serve as the timer; the second member will use the straw to blow gently, but consistently, into the beaker for the designated amount of time. Blow gently to make sure no seawater splashes out of the beaker.
5. At the end of the time period, record the final pH of the seawater in the beaker.
6. Rinse your pH probe and clean up as directed by your instructor.
7. **Determine the CO<sub>2</sub> concentration:** Using dots of the appropriate color (blue for 10 seconds, red for 20 seconds), place one dot on Graph A: pH of Surface Seawater as a Function of Atmospheric CO<sub>2</sub> Concentration. Use a colored pencil if you are using individual graphs. Use the final pH of the seawater to determine the concentration of atmospheric CO<sub>2</sub> which would produce the pH of surface seawater.
8. **Determine date of CO<sub>2</sub> concentration:** Using the atmospheric CO<sub>2</sub> concentration determined in Graph A, place a second dot (of the same color) on Graph B: Projected Dates of Atmospheric CO<sub>2</sub> to show when that concentration of atmospheric CO<sub>2</sub> would be reached at the current rate of increase. Use a colored pencil if you are using individual graphs.

**OCEAN ACIDIFICATION DATA TABLE**

<b>Initial pH of 100-ml seawater sample</b>	
<b>Number of seconds blowing into beaker</b>	
<b>Final pH of 100-ml seawater sample</b>	
<b>Atmospheric CO<sub>2</sub> concentration at final pH</b>	
<b>Year in which experimental atmospheric CO<sub>2</sub> concentration will be reached</b>	

**ANALYSIS**

1. Why was it important to record the pH of the seawater sample before blowing into it?
2. What chemical molecule did you measure with the pH probe? Where did this molecule come from?
3. How does atmospheric carbon dioxide influence pH levels in the ocean?
4. What are two ways bicarbonate ions can be formed in the ocean?



5. How does lower pH decrease available carbonate ions in the ocean?
  
6. Some groups blew into their beakers for 10 seconds; others blew into their beakers for 20 seconds, twice as long. Describe the patterns or trends you observed as you compare the data from the different lengths of time.
  
7. The mineral aragonite is a particularly soluble form of calcium carbonate used in the formation of tropical coral reefs and cold-water pteropods. Pteropods, commonly called “sea butterflies,” are free-swimming mollusks about the size of a small pea and are the primary food source for krill, whales, salmon, and other important fish such as cod and pollock. Since carbon dioxide, like most gases, is more soluble in cold water than warm water, which organism (corals or pteropods) will be the first to be affected by ocean acidification? Justify your answer.
  
8. Coral reefs are composed of thousands of individual coral animals whose exoskeletons are joined together. Experiments have shown that, in controlled conditions, individual coral animals are able to survive and even reproduce without their calcium carbonate exoskeleton in acidified conditions. Further, they are able to resume building their exoskeletons when reintroduced to normal marine conditions.
  - a. Even though individual coral animals can survive and reproduce without their exoskeletons, what are the negative effects on both coral animals and those that depend on coral reef structures?
  
  - b. How do these experiments suggest how humans could help corals survive as ocean acidification increases?