

From Conceptual Chemistry

10.6 Carbon Dioxide Acidifies the Oceans

LEARNING OBJECTIVE

Describe the impact atmospheric carbon dioxide has on the ocean's pH and mineral composition.

EXPLAIN THIS

Why are colder ocean waters more vulnerable to the effect of carbon dioxide-mediated ocean acidification?

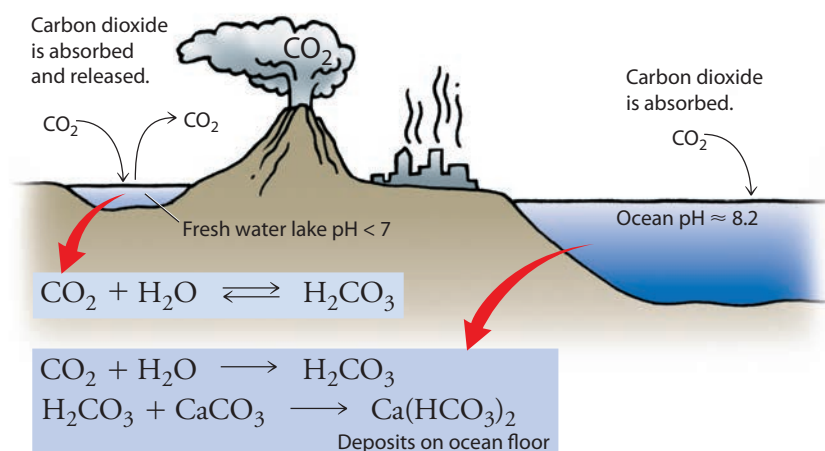
READING CHECK

What chemical forms when carbon dioxide dissolves in water?

The amount of carbon dioxide put into the atmosphere by human activities is growing. Surprisingly, however, the atmospheric concentration of CO_2 is not increasing proportionately. One explanation has to do with the oceans, as described in **Figure 10.21**. When atmospheric CO_2 dissolves in any body of water—a raindrop, a lake, or an ocean—it forms carbonic acid, H_2CO_3 . In fresh water, this carbonic acid transforms back to water and carbon dioxide, which is released back into the atmosphere. In the ocean, however, the carbonic acid is quickly neutralized by dissolved alkaline minerals. (The ocean is alkaline, $\text{pH} \approx 8.1$.) As discussed in the introduction to this chapter, the products of this neutralization eventually end up on the ocean floor as insoluble solids. Thus, carbonic acid neutralization in the ocean prevents CO_2 from being released back into the atmosphere. The ocean, therefore, is a carbon dioxide *sink*—most of the CO_2 that goes in doesn't come out. Pushing more CO_2 into our atmosphere means pushing more of it into our vast oceans. So far, the oceans have been absorbing about one-third of our CO_2 emissions.

► Figure 10.21

Carbon dioxide forms carbonic acid upon entering any body of water. In fresh water, this reaction is reversible, and the carbon dioxide is released back into the atmosphere. In the alkaline ocean, the carbonic acid is neutralized to such compounds as calcium bicarbonate, $\text{Ca}(\text{HCO}_3)_2$, which precipitate to the ocean floor. As a result, most of the atmospheric carbon dioxide that enters our oceans remains there.



The movement of our CO_2 into the oceans, however, comes at a cost. Notice from Figure 10.21 that the CO_2 -derived carbonic acid, H_2CO_3 , reacts with calcium carbonate, CaCO_3 . The addition of carbon dioxide into our oceans, therefore, has the effect of decreasing the amount of calcium carbonate in the ocean water, as well as other carbonates, such as magnesium carbonate, Mg_2CO_3 . Coral, shelled organisms, and many other marine species, however, use these carbonates to build and maintain their bodily structures. Importantly, they can only do this when the ocean water is saturated with these minerals, which is currently the case in most surface waters. But the addition of CO_2 leads to ocean water unsaturated with carbonates. In regions where this occurs, the carbonate-based creatures begin to dissolve, which means they perish. This, in turn, can have a significant impact throughout the marine ecosystem, which would affect us as well. Consider this example: pink salmon off the southern coast of Alaska live on a diet of sea snails, also known as pteropods, which are dependent on carbonate minerals. The destruction of this pteropod population by ocean acidification would also mean an end to the Alaskan pink salmon fishing industry.



CHEMICAL CONNECTIONS

How is petroleum connected to the pH of the oceans?

CONCEPT CHECK

How does adding CO_2 to the oceans cause a decrease in the concentration of carbonate ions, CO_3^{2-} ?

CHECK YOUR ANSWER The CO_2 reacts with water, H_2O , to form carbonic acid, H_2CO_3 , which effectively removes the carbonate ion, CO_3^{2-} , by reacting with it to form the bicarbonate ion, HCO_3^- .

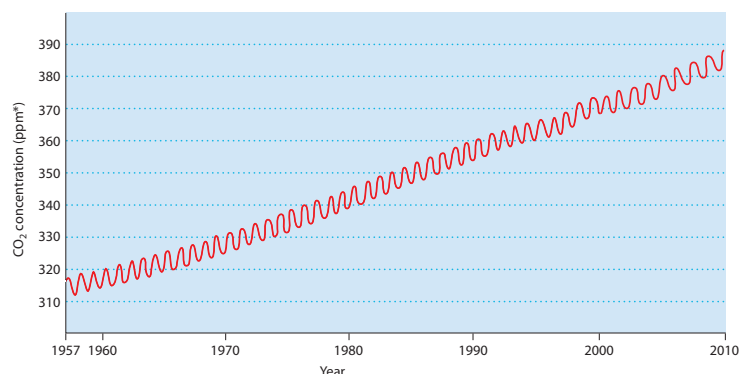
Is the effect of human-produced CO_2 on ocean pH measurable? Absolutely, and it is significant. Over the past 100 years, increases in atmospheric carbon dioxide—primarily due to the burning of fossil fuels—has lowered the average pH of the ocean by about 0.1 pH unit. On a geologic time scale, this is lightning fast. The last comparable decrease in ocean pH occurred about 56 million years ago. At that time, major increases in atmospheric carbon dioxide caused the pH of the ocean to decrease by about 0.45 unit. These changes, however, took place over 5000 years for an average decrease in ocean pH of about 0.01 unit per century. The result was a huge die-off of marine organisms, which can be seen as a distinct layer of brown sediment within core samplings of the ocean floor. We are on track for surpassing this event at a rate that is about ten times as fast.

The media give much attention to the role atmospheric carbon dioxide plays in global climate (Figure 10.22). We discuss many of the details of this important issue in Chapter 16. You should understand, however, that our production of copious amounts of carbon dioxide is a twofold problem. One is the potential for a not-so-predictable change in global climate. The other is a very predictable change in ocean chemistry. Both need to be considered carefully.



READING CHECK

When was the last decrease in ocean pH that would have been comparable to what is taking place today?



*ppm = parts per million, which tells us the number of carbon dioxide molecules for every million molecules of air.

◀ **Figure 10.22**

Researchers at the Mauna Loa Weather Observatory in Hawaii have recorded increasing concentrations of atmospheric carbon dioxide since they began collecting data in the 1950s. This famous graph is known as the Keeling curve, after the scientist Charles Keeling, who initiated this project and first noted the trends. The oscillations within the Keeling curve reflect seasonal changes in CO_2 levels.