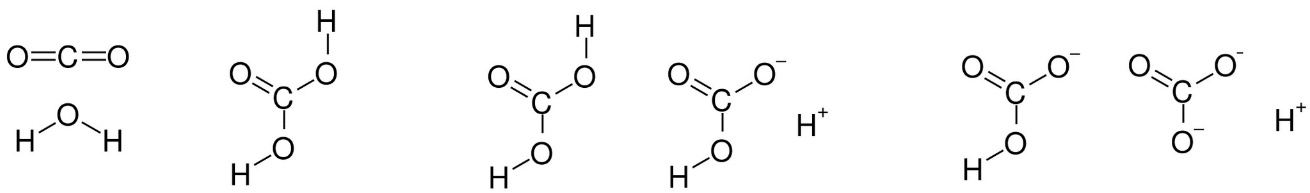
Carbon Dioxide, Water, Oxygen and Life

Carbon Dioxide and Water

When carbon dioxide CO_2 from the air enters water, it makes the water acidic. This seems strange because there are no hydrogen atoms in CO_2 to raise the free proton count of the water, and hence lower its pH. The following explanation relates to the pH change in the oceans as well as in carbonated beverages.

Although most CO_2 molecules remain intact when they are dissolved in water, enough combine with water that one H^+ ion is produced for every 5 CO_2 molecules that are present in water. The following three equations illustrate how this happens:

$\mathbf{CO_2 + H_2O \Leftrightarrow H_2CO_3}$ $\quad$ $\mathbf{H_2CO_3 \Leftrightarrow HCO_3^- + H^+}$ $\quad$ $\mathbf{HCO_3^- \Leftrightarrow CO_3^{--} + H^+}$



In ocean water we have a fourth reaction $\mathbf{Ca^{++} + CO_3^{--} \Leftrightarrow CaCO_3}$ that produces calcium carbonate, the shell material for marine animals. Historically, these reactions had achieved a balance that left the concentration of H^+ ions in the ocean at a level that allowed the $CaCO_3$ in marine animal shells to be stable. Unfortunately, a significant increase of CO_2 in the atmosphere causes the first equation to make more H_2CO_3 which in turn leads the second equation to produce more H^+ ions. This then causes the third reaction to shift toward the left, using up available CO_3^{--} ions. Then the fourth equation also shifts toward the left, using up $CaCO_3$ from the shells of marine animals. This is summarized by the reactions:

$$CO_2 + H_2O \Rightarrow H_2CO_3$$

$$H_2CO_3 \Rightarrow HCO_3^- + H^+$$

$$CO_3^{--} + H^+ \Rightarrow HCO_3^-$$

$$CaCO_3 \Rightarrow Ca^{++} + CO_3^{--}$$

with the net result that

$$\mathbf{CO_2 + H_2O + CaCO_3 \Rightarrow 2HCO_3^- + Ca^{++}}$$

An increase in CO_2 in the ocean leads to a dissolution of sea shells. This may seem a bit contradictory since one might think that more CO_2 would produce more $CaCO_3$. That would be the case if the oceans were pure water without any added ions or living creatures, but these 4 reactions compete with each other in a manner dependent on existing concentrations of reactants and products. For the present concentrations and pH of the ocean, adding CO_2 causes more H^+, a decrease in CO_3^{--}, and a decrease of $CaCO_3$. The whole ocean food chain would be affected by such changes.

The rise in atmospheric CO_2 concentration is considered the primary cause of global warming, yet the oceans have the capacity to absorb enough CO_2 to bring its concentration very close to the level it was hundreds of years ago. Unfortunately, the process of CO_2 absorption by the ocean proceeds very slowly, and many decades are required for it to respond to the current atmospheric changes and reduce the CO_2 concentration in the atmosphere. As the oceans absorb the carbon dioxide, however, they become acidic and shelled marine animals will ultimately be adversely affected.

In the case of carbonating soft drinks, water saturated with a normal atmospheric concentration of 0.034% CO_2 will have a pH of 5.65. When drinks are carbonated, CO_2 at a pressure of 2.5 times atmospheric pressure is used. At that high pressure, the pH of the drink is 3.72. The acidification from carbonation produces a sour and sparkling taste...and weakens the enamel of teeth.

Carbon Dioxide, Oxygen and Plants

Plants use light energy to break apart carbon dioxide and water in order to make sugar. Oxygen is a by-product of this process. At night, plants grow by burning some of the sugars and releasing some carbon dioxide. The remainder of the sugar is usually stored as starches, but also used for growth as cellulose. There was little oxygen in the earth's atmosphere until plant life appeared. Animals that eat plants then digest the starches into sugars or digest the plant sugars directly to obtain energy. They exhale exhale carbon dioxide as a by-product.

When plants and animals die, they decay with microbes turning their carbon back into carbon dioxide. So, ordinarily, plant growth only *temporarily* removes carbon dioxide from the atmosphere. Sometimes, however, this process is prevented by burial, and their organic (carbon) matter is eventually converted into oil or coal. Those are what we call fossil fuels. When we mine and burn fossil fuels, we convert the carbon to carbon dioxide and release it back into the atmosphere. Unfortunately, we do that at a rate that is thousands of times faster than when it was stored.

An increase in atmospheric CO_2 should make it easier for plants to grow and some people might argue that more food will become available. In reality, we eat plants for carbohydrates *and* nutrients. Greater plant growth with the same amount of soil nutrients means a smaller percentage nutrients per calorie of plant eaten. If you are interested, one long, technical article about this is at *https://www.frontiersin.org/articles/10.3389/fpls.2018.00924/full* .

Carbon Dioxide and Animal Respiration

Animals breath in oxygen, and transport it to muscles and the brain using hemoglobin in the blood. There, food molecules are oxidized to provide energy. When the blood meets a place with a high CO_2 concentration such as in active muscles, its hemoglobin releases the oxygen and picks up the CO_2 . Upon returning to the lungs, the low CO_2 concentration there causes the hemoglobin to release its CO_2 and pick up a fresh load of O_2 . The hemoglobin is actually responding to the pH level change in the blood caused by the local concentration of CO_2 .

If you hold your breath, it is the excess of CO_2 that causes you to want to breath again, not the lack of O_2 . Someone breathing air that lacks O_2 will not be concerned as long as the CO_2 content of the air does not rise significantly. That is why workers have died upon entering tanks of nitrogen gas. They did not know they were confronting a deadly situation; they just passed out for lack of oxygen. If you are writing the alphabet while exhaling CO_2 , but not receiving O_2 , your writing will become progressively messy and you may not even notice your mental deterioration.