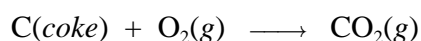


Chemical of the Week

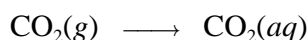
CARBON DIOXIDE

Carbon dioxide, CO_2 , is one of the gases in our atmosphere, being uniformly distributed over the earth's surface at a concentration of about 0.033% or 330 ppm. Commercially, CO_2 finds uses as a refrigerant (dry ice is solid CO_2), in beverage carbonation, and in fire extinguishers. Because the concentration of carbon dioxide in the atmosphere is low, it is not practical to obtain the gas by extracting it from air. Most commercial carbon dioxide is recovered as a by-product of other processes, such as the production of ethanol by fermentation and the manufacture of ammonia. Some CO_2 is obtained from the combustion of coke or other carbon-containing fuels.

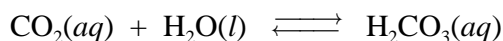


Carbon dioxide is released into our atmosphere when carbon-containing fossil fuels such as oil, natural gas, and coal are burned in air. As a result of the tremendous world-wide consumption of such fossil fuels, the amount of CO_2 in the atmosphere has increased over the past century, now rising at a rate of about 1 ppm per year. Major changes in global climate could result from a continued increase in CO_2 concentration.

In addition to being a component of the atmosphere, carbon dioxide also dissolves in the water of the oceans. At room temperature, the solubility of carbon dioxide is about 90 cm^3 of CO_2 per 100 mL of water. In aqueous solution, carbon dioxide exists in many forms. First, it simply dissolves.



Then, an equilibrium is established between the dissolved CO_2 and H_2CO_3 , carbonic acid.

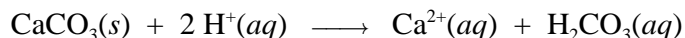


Only about 1% of the dissolved CO_2 exists as H_2CO_3 . Carbonic acid is a weak acid which dissociates in two steps.

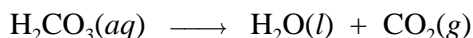


As carbon dioxide dissolves in sea water, an equilibrium is established involving the carbonate ion, CO_3^{2-} . The carbonate anion interacts with cations in seawater. According to the solubility rules, "all carbonates are insoluble except those of ammonium and Group IA elements." Therefore, the carbonate ions cause the precipitation of certain ions. For example, Ca^{2+} and Mg^{2+} ions precipitate from large bodies of water as carbonates. For CaCO_3 , the value of K_{sp} is 5×10^{-9} , and for MgCO_3 , K_{sp} is 2×10^{-3} . Extensive deposits of limestone (CaCO_3) and dolomite (mixed CaCO_3 and MgCO_3) have been formed in this way. Calcium carbonate is also the main constituent of marble, chalk, pearls, coral reefs, and clam shells.

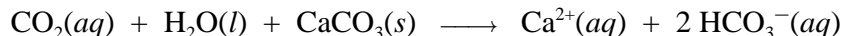
Although "insoluble" in water, calcium carbonate dissolves in acidic solutions. The carbonate ion behaves as a Brønsted base.



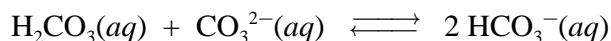
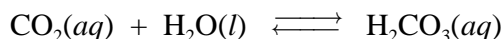
The aqueous carbonic acid dissociates, producing carbon dioxide gas.



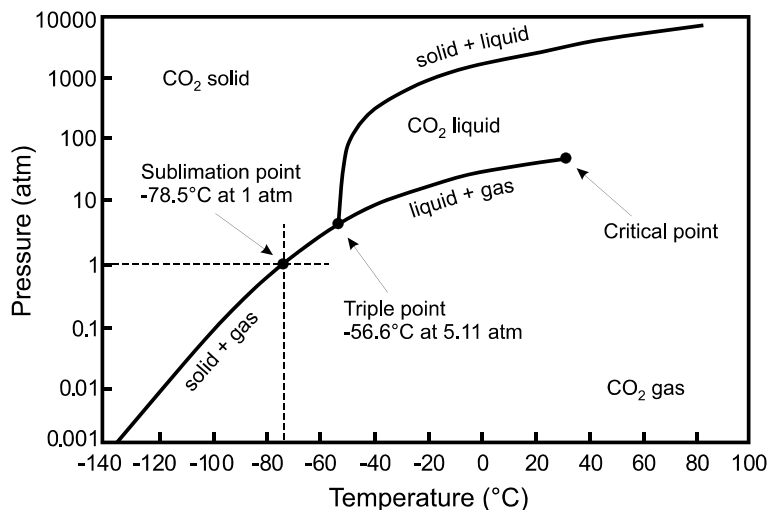
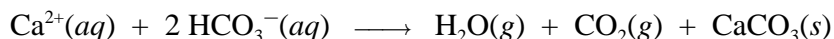
In nature, surface water often becomes acidic because atmospheric CO₂ dissolves in it. This acidic water can dissolve limestone.



This reaction occurs in three steps.



In the third step, carbonate ions accept hydrogen ions from carbonic acid. This reaction often occurs underground when rainwater saturated with CO₂ seeps through a layer of limestone. As the water dissolves calcium carbonate, it forms openings in the limestone. Caves from which the limestone has been dissolved are often prevalent in areas where there are large deposits of CaCO₃ (e.g., Mammoth Cave, Carlsbad Caverns, and Cave of the Mounds). If the water containing dissolved Ca(HCO₃)₂ reaches the ceiling of a cavern, the water will evaporate. As it evaporates, carbon dioxide escapes, and calcium carbonate deposits on the ceiling.



Pressure-Temperature phase diagram for CO₂.

A new use for liquid carbon dioxide currently under development is as a dry-cleaning solvent. Currently, most laundries use chlorinated hydrocarbons as dry-cleaning solvents. These chlorinated hydrocarbons are probable human carcinogens, so the search is on for replacements. Carbon dioxide does not exist in liquid form at atmospheric pressure at any temperature. The pressure-temperature phase diagram of CO₂ shows that liquid carbon dioxide at 20°C requires a pressure of 30 atmospheres. The lowest pressure at which liquid CO₂ exists is at the triple point, namely 5.11 atm at -56.6°C. The high pressures needed for liquid CO₂ require specialized washing machines. Like chlorinated hydrocarbons, liquid carbon dioxide is an effective solvent for grease and oils. Liquid CO₂ has some advantages over chlorinated hydrocarbons—items that cannot be dry cleaned with chlorinated hydrocarbons, such as leather, fur, and some synthetics, can be safely cleaned with liquid carbon dioxide. More information about alternative dry-cleaning solvents can be found in the Innovations section of *Environmental Health Perspectives*.

[http://ehpnet1.niehs.nih.gov/docs/1996/104\(5\)/innovations.html](http://ehpnet1.niehs.nih.gov/docs/1996/104(5)/innovations.html)