Bubbles, Carbonation, and Climate Change

150th Anniversary Gala

of the

Wisconsin Academy of Sciences, Arts & Letters

Friday, March 6, 2020

Wisconsin State Historical Society

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In the Lab of Shakhashiri
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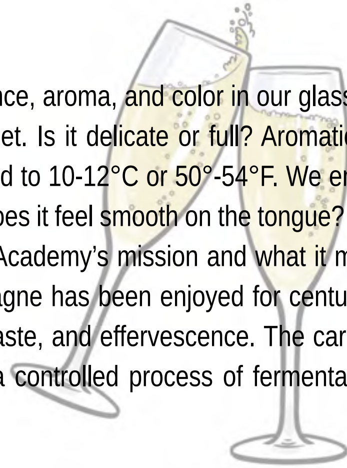
Long Live the Wisconsin Idea!

Cheers to the Academy!



We raise a bubbly toast and marvel at the effervescence, aroma, and color in our glasses. We watch the tiny bubbles rise. We smell the bouquet. Is it delicate or full? Aromatic or fruity? We sip, gently. We note the temperature, chilled to 10-12°C or 50°-54°F. We enjoy the tingling of the bubbles. Is the taste dry or fruity? Does it feel smooth on the tongue? We swallow. We watch and sip again. We celebrate the Academy's mission and what it must continue to do for Wisconsin and its people. Champagne has been enjoyed for centuries because of its alcoholic content (~14% by volume), taste, and effervescence. The carbon dioxide bubbles in champagne are formed through a controlled process of fermentation and aging.

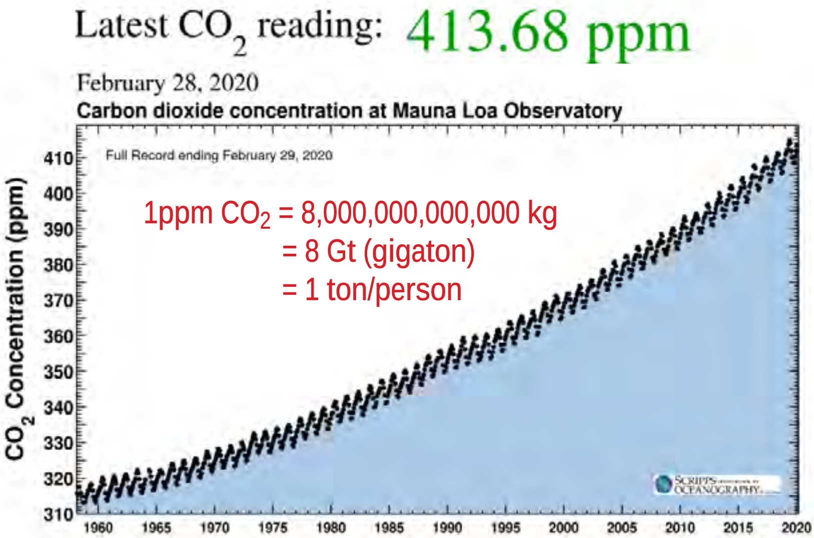
Bubbles are fascinating. They can exist in liquids and in solids. We experience bubbles everywhere, whether playing with soap bubbles, blowing a bubble with gum, boiling pasta, enjoying a souffle, or watching frothing on the surface of a lake or river. A bubble is a gas trapped inside a thin sheet of liquid (or solid) and is not very stable. We see air bubbles in tap water. The faucet usually has an aerator, but even without it we can see bubbles in the glass as the liquid warms up to room temperature. As soon as the water leaves the faucet, air bubbles come out because of the decrease in pressure. Bubbles are not very soluble in liquids. If they were, we wouldn't be able to see them. Both temperature and pressure affect the solubility of gases in liquids.

Carbonated beverages include a variety of ingredients. They are all sealed and contain carbon dioxide gas under a great deal of pressure. CO_2 is not very soluble in water, but some of it reacts with water to form a mild acidic solution. The pleasant tinglng sensation we feel in our mouth when we take a sip of a carbonated beverage is because the tiny gas bubbles come out of solution. It is also because of a chemical interaction facilitated by carbonic anhydrase, an enzyme in saliva.

Carbon dioxide, CO_2, is one of the gases in our atmosphere. Both natural processes and human activities contribute to its presence at a present concentration of about 0.040% (or 414 parts per million (ppm) on February 28, 2020) uniformly distributed over the Earth. Commercially, CO_2 is used as a refrigerant (dry ice is solid CO_2), in beverage carbonation, and in fire extinguishers.

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 two centuries, now rising at a rate of about 2-3 ppm per year, as shown in the Keeling Curve.

The Keeling Curve



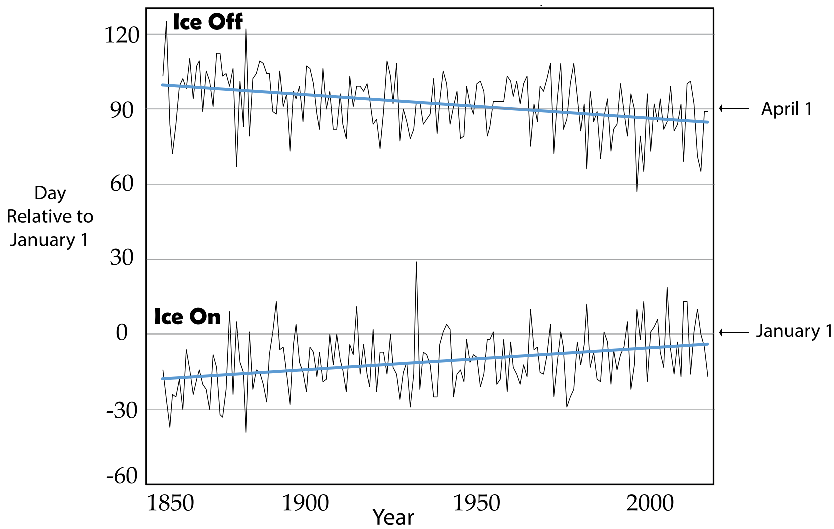
This is the Keeling Curve, named for the scientist, Charles Keeling, who began systematic monitoring of the atmospheric CO_2 concentration at a site on the top of the Mauna Loa volcano in Hawaii in 1957. These are the usual measurements quoted in news reports and articles on atmospheric CO_2 levels. Other stations around the world are now also monitoring atmospheric CO_2, but Keeling's are the longest continuous measurements.

Carbon dioxide is the Earth's thermostat. The greenhouse effect is a vitally important phenomenon that keeps the Earth warm enough to evolve and sustain life, as we know it. Carbon dioxide is one of the most important greenhouse gases that cause warming of the planet. Without the atmospheric carbon dioxide, the Earth's average temperature would be about 255 K ($^-$18 °C), an ice ball; there would be no liquid water. How can a gas that makes up less than one tenth of a percent of the atmosphere have such a profound effect?

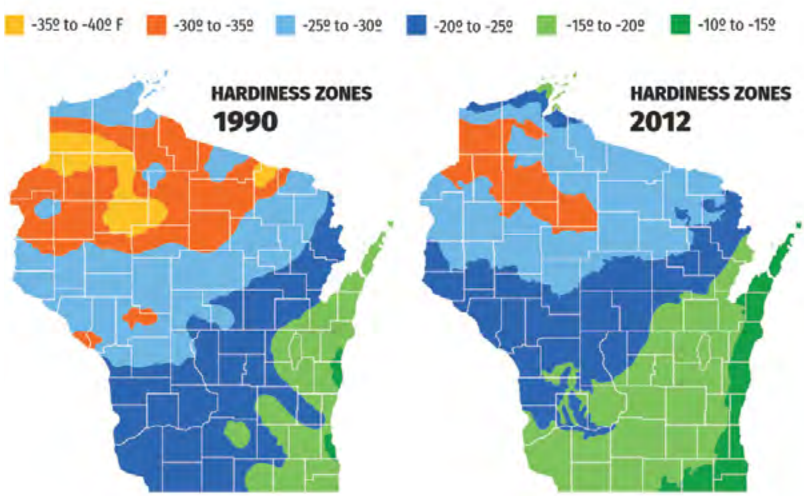
Carbon dioxide gas and all greenhouse gases absorb energy in the infrared region of the electromagnetic spectrum. Molecules that are good infrared absorbers also can emit infrared light in all directions. Infrared light leaving the Earth's surface is all going essentially up and out toward space. If some of it is absorbed and re-emitted in all directions by atmospheric greenhouse gases, less of what leaves the surface will make it out into space. That means the planet would not be in energy balance, because there would be more energy coming in from visible sunlight than infrared energy leaving. To compensate, the surface could get warmer, so more infrared light would leave the surface and enough of this would reach space to balance the incoming sunlight. "Trapping" some energy from Earth's infrared emission is the essence of the atmospheric greenhouse effect that has warmed Earth to average temperatures that support its abundance of life.

Local telltales of global warming:

Ice-on and Ice-off Dates for Lake Mendota
1855-2019



The Hardiness Zone Color Key
Shows the lowest observed winter temperatures in that area.



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