

## Carbon dioxide – background information

This information has been provided in German by Professor Walter Jansen from the Chemol project and adapted by Marlene Rau and Andrew Brown.

### Chemistry

Carbon dioxide (CO<sub>2</sub>; relative molecular mass 44.01) is a colourless, non-flammable gas with no smell. It has a density of 1.977 g/l (at 0 °C) and a melting point of -57 °C at 5.185 bar. Liquid carbon dioxide is often used in fire extinguishers. Under high pressure, it is also used to extract natural materials. Coffee, for example, is currently decaffeinated almost solely using this highly pressurised form of the gas.

The solubility of carbon dioxide increases with increased pressure: 100 parts of water dissolve 171 volume parts of CO<sub>2</sub> at 0 °C, 119 at 10 °C, 88 at 20 °C, 75.7 at 25 °C and 27 at 60 °C. For example, about 1 l of CO<sub>2</sub> gas dissolves in 1 l of water (at room temperature) at 1 bar (normal air pressure); 2 l of CO<sub>2</sub> at 2 bar; 3 l at 3 bar, and 4 l at 4 bar. The aqueous solution is mildly acidic because 0.1% of the dissolved carbon dioxide molecules react with water to form carbonic acid. Its acidity will turn blue extract of beetroot slightly red, and it is also indicated by its sour taste.

### Physiological importance

As the energetically most stable form of carbon, carbon dioxide is a key compound in nature's carbon cycle. Following its absorption from the atmosphere, carbon dioxide reacts with water using energy from the Sun during photosynthesis in plants. This turns the carbon dioxide into energy-rich carbohydrates and is accompanied by a release of oxygen. The carbohydrates are taken up by animals as energy-supplying substrates for metabolism. There, they are either turned into biomass, or decomposed into carbon dioxide and water via respiration, after which the resulting carbon dioxide is emitted into the surrounding air. From the ratio of oxygen taken up to carbon dioxide released, you can calculate the basal metabolic rate of an animal. Dead animals or plants also release carbon dioxide when they are aerobically degraded, which ends up in the atmosphere or in aqueous solution.

Gaseous carbon dioxide is not poisonous (maximum allowable concentration at the workplace is 9000 mg/m<sup>3</sup>); in the body, relatively large amounts of carbon dioxide are always in circulation (in venous blood, 50–60 vol%), of which over 700 g (over 350 l) is breathed out daily. However, in larger amounts it can have a suffocating effect because it displaces oxygen. The human body can endure up to 2.5 vol% carbon dioxide in the air without major damage, even when breathing it in for hours. Amounts of 8–10 vol%, however, lead to headaches, dizziness, raised blood pressure and agitation; over 10 vol% to fainting, cramps and low blood pressure; and over 15 vol% to paralysis. Breathing in very high concentrations – such as those found at the bottom of some fermenting cellars or caves (carbon dioxide is heavier than air) – quickly leads to death if oxygen cannot be supplied quickly.

## Detection

Carbon dioxide can be detected using lime water ( $\text{Ca}(\text{OH})_2$ ): the gas turns it cloudy due to formation of a calcium carbonate ( $\text{CaCO}_3$ ) precipitate. Quantitative measurements can be made by reacting carbon dioxide-containing gas with a known quantity of potassium hydroxide (KOH) or by using gas analysis instruments.

## Occurrence

Free atmospheric air contains about 0.0388 vol% carbon dioxide – about  $75 \times 10^{10}$  tonnes, and in the oceans there is approximately 50 times as much ( $38 \times 10^{12}$  tonnes – partly dissolved and partly in the form of carbonate or hydrocarbonate). Within the air spaces of soils consisting of organic matter (humus), the carbon dioxide concentration due to the activity of cellulose-fermenting bacteria can be up to 7 vol% (air in normal soil contains 0.4–1.4 vol %). The air exhaled by humans contains about 4 vol% carbon dioxide.

In some areas, carbon dioxide gas is released from the ground. For example, the air in the *Grotta del Cane* (Dog's Cave) near Naples, Italy, contains about 70 vol% carbon dioxide, 24 vol% nitrogen and 6 vol% oxygen. In Mexico, in 1947, an underground carbon dioxide source was disturbed, which at times released  $247\,000 \text{ m}^3$  carbon dioxide per day. There is also a lot of carbon dioxide in volcanic gases, as well as in some springs of acidulous mineral water. In its chemically bound form, carbon dioxide occurs in vast amounts in carbonates (such as calcium carbonate and magnesium carbonate).

Every year about  $90 \times 10^9$  tonnes of carbon dioxide are released from the oceans into the air and vice versa. Photosynthesis by plants each year extracts about  $120 \times 10^9$  tonnes of carbon dioxide, but almost the same amount is released by the respiration of humans, animals and micro-organisms and decay. Only about  $10^8$  tonnes of carbon dioxide each year form sapropel (sedimentary deposits rich in organic matter) or similar, from which coal or oil can be formed over thousands of millions of years. About the same amount is released from volcanoes and other geological sources.