Carbon dioxide

Carbon dioxide is nonflammable, colorless, and odorless in the gaseous and liquid states. Carbon dioxide is a minor but important constituent of the atmosphere, averaging about 0.036% or 360 ppm by volume. It is also a normal end-product of human and animal metabolism.

Dry carbon dioxide is a relatively inert gas. In the event moisture is present in high concentrations, carbonic acid may be formed and materials resistant to this acid should be used. High flow rates or rapid depressurization of a system can cause temperatures approaching the sublimation point (–109.3°F [–78.5°C]) to be attained within the system. Carbon dioxide will convert directly from a liquid to a solid if the liquid is depressurized below 76 psia (61 psig). The use of materials which become brittle at low temperatures should be avoided in applications where temperatures less than –20°F (–29°C) are expected. Vessels and piping used in carbon dioxide service should be designed to the American Society of Mechanical Engineers (ASME) or Department of Transportation (DOT) codes for the pressures and temperatures involved.

Physical properties are listed in Table 1. Carbon dioxide in the gaseous state is colorless and odorless and not easily detectable. Gaseous carbon dioxide is 1.5 times denser than air and therefore is found in greater concentrations at low levels. Ventilation systems should be designed to exhaust from the lowest levels and allow make-up air to enter at a higher level.

Manufacture

Carbon dioxide is produced as a crude by-product of a number of manufacturing processes. Carbon dioxide is a by-product of steam reforming of methane, propane or naphtha. The fermentation of sugar to alcohol and the production of lime and sodium phosphate also generate carbon dioxide. Additionally, carbon dioxide exists in natural wells. Once the product has been isolated, impurities are filtered out, moisture is removed in driers, and the purified carbon dioxide is compressed for liquefaction.

Uses

Liquid carbon dioxide is used widely in the food industry for freezing meats, poultry, vegetables, and fruits. Solid carbon dioxide (dry ice) is used to cool meats prior to grinding and also to refrigerate meat and poultry during transit. Soft drinks, wines, and beers are produced using gaseous carbon dioxide for carbonation. Carbon dioxide is used in water treatment to neutralize alkaline water. Liquid carbon dioxide is also used to increase recovery from oil and gas wells. Other industrial uses include the production of chemicals, plastics, rubber, metals, and electronic components.

Health Effects

The physiological effects of carbon dioxide are unique because it is an end-product of metabolism, a vital component of the acid-base mechanism that controls blood pH, and an active messenger substance in the linking of respiration, circulation, and vascular response.

The blood and cellular fluids are actually a solutions of sodium bicarbonate and other substances. Severe exposure to carbon dioxide forms carbonic acid in the blood that exceeds buffering capacity of the sodium bicarbonate. The decrease in pH has a rapid toxic effect because the neural control systems are excessively driven. These effects are independent of the amount of oxygen in the atmosphere.

Low concentration of carbon dioxide can be tolerated for a considerable period of time without noticeable effect, or may merely cause an unnatural feeling of shortness of breath. Sustained exposure of 5% carbon dioxide produces stressful rapid breathing. When the carbon dioxide level exceeds 7%, the rapid breathing becomes labored and restlessness, faintness, severe headache, and dulling of consciousness occur. At 15%, unconsciousness accompanied by rigidity and tremors occurs in less than 1 minute and in the 20% to 30% range it produces unconsciousness and convulsions in less than 30 seconds. The effects occur quickly since the carbon dioxide diffuses in the tissue fluids at a rate approximately 20 times more rapidly than oxygen. High concentrations of carbon dioxide can asphyxiate quickly without warning and not possibility of self-rescue regardless of the oxygen concentration.

Table 1: Carbon Dioxide Physical and Chemical Properties

Molecular Formula	CO_2
Molecular Weight	44.01
Boiling Point @ 1 atm (sublimes)	–109.3°F (–78.5°C)
Freezing Point @ 76 psia	–69.9°F (–56.6°C)
Critical Temperature	87.9°F (31.0°C)
Critical Pressure	1,070 psia (72.9 atm)
Density, Liquid @ –35°F (–37°C), 11 atm	68.74 lb/cu. ft.
Density, Gas @ 68°F (20°C), 1 atm	0.115 lb/cu. ft.
Density, Solid @ –110°F (–79°C), 1 atm	97.4 lb/cu. ft.
Specific Gravity, Gas (air=1) @ 68°F (20°C), 1 atm	1.53
Specific Gravity, Liquid @ –35°F (–37°C), 11 atm	1.10
Specific Volume @ 68°F (20°C), 1 atm	8.7 cu. ft./lb
Latent Heat of Sublimation	10,900 Btu/lb mole
Solubility in Water @ 68°F (20°C), 1 atm	87.8% by volume

Occupation Exposure Limit

U.S. OSHA specifies that employee exposure to carbon dioxide in any 8-hour shift of a 40-hour work week shall not exceed the 8-hour time-weighted average (TWA-PEL) of 5,000 ppm (0.5%; 9,000 mg/m^3). According the American Conference of Governmental Industrial Hygienists (ACGIH), the short-term exposure limit (STEL/Ceiling) for 15 minutes of less is 30,000 ppm (3%; 54,000 mg/m^3). Since oxygen exposure limits and definitions vary by region/country, consult relevant legislation for the appropriate limits.

Containers

Bulk carbon dioxide is typically stored as a liquid in storage tanks with capacities of 6, 14, 26, and 50 tons. Tanks are insulated by polyurethane foam with a vapor barrier, which provides weather protection. The tanks are fabricated from carbon steel according to ASME Standards. Carbon dioxide is maintained below 305 psig by a refrigeration unit and above 245 psig with a pressure buildup coil so that carbon dioxide can be stored for an indefinite period without venting. Smaller liquid quantities are stored and shipped in cryogenic liquid cylinders with a capacity of 384 pounds (3352 standard cubic feet). Cryogenic liquid cylinders are vacuum-jacketed and can hold product for long periods without venting. Cryogenic liquid cylinders can either supply liquid or gas and liquid.

Carbon dioxide is shipped and stored as a liquefied compressed gas in hollow steel and aluminum cylinders. The cylinders have a concave base which allows the cylinders to stand upright and are tapered to a small opening on the top. The tapered or open end is threaded to receive a cylinder valve or other suitable outlet connection. Safety relief devices are part of the cylinder valve or the outlet connections. A threaded neck ring is secured to the tapered end of the cylinder to allow a protective cylinder cap to be installed. Cylinders are manufactured according to Department of Transportation (DOT) specifications. Cylinders in carbon dioxide service are hydrostatically tested upon manufacture, and every five years thereafter at 5/3 times the service pressure.

Gas cylinder valves

Carbon dioxide cylinder valve connection standards have been adopted by CGA. Carbon dioxide cylinders use a CGA 320 outlet connection. For additional information on cylinder valves, consult Air Products' "Safetygram-23: Cylinder Valves."

Safety devices

Bulk liquid storage tanks are protected against excessive pressures, which may result from heat leak, by reseatable relief devices. Cryogenic liquid cylinders are equipped with reseatable relief devices and are additionally protected with burst discs. Gas cylinders are protected from rupture due to fire by a frangible disc sometimes backed by a fusible metal with a melting temperature of about 212°F (100°C).

Shipment of carbon dioxide

In the United States, the transportation of carbon dioxide in interstate commerce by rail, highway, air and water is governed by federal authority under regulations promulgated by DOT.

- For bulk shipments by road DOT 10¾" x 10¾" nonflammable gas placards are required on the trailer.
- For gas cylinders a DOT 4" x 4" nonflammable gas label or tag is required
- Cryogenic liquid carbon dioxide cylinders are shipped under DOT Exemption Number 7638. A copy of this exemption must be carried aboard each vessel, aircraft or motor vehicle used to transport the cylinders. Each cryogenic cylinder must be plainly marked on both sides near the middle, in letters at least two inches high on a contrasting background, "DOT-E 7638." The DOT 4" x 4" green nonflammable gas label or tag is also required for common carrier shipments.

Safety considerations

Carbon dioxide is stored and transported as a liquefied compressed gas. The following hazards are associated with liquefied compressed carbon dioxide.

1. High pressure involved in storage and service equipment.
2. Carbon dioxide is 1.5 times heavier than air and will not readily disperse in the atmosphere. Asphyxiation may be a hazard in confined areas.
3. Carbon dioxide in high concentrations is toxic to humans as described in the health effects section.
4. Vaporizing carbon dioxide can produce very cold temperatures. Liquid carbon dioxide that contacts the skin can cause freeze burn or frostbite. Carbon dioxide, solid below 61 psig, is very cold and sublimes so quickly that prolonged contact with the skin causes freeze burn or frostbite.

Buildings

1. Provide adequate ventilation.
2. The atmosphere in areas in which carbon dioxide gas may be vented and collect should be tested with a portable or continuous monitoring carbon dioxide gas analyzer to ensure ventilation is adequate.

Handling and storage

Personnel should be trained in the proper storage, handling and use of carbon dioxide cylinders. For additional information, see CGA P-1, "Safe Handling of Compressed Gases in Containers," CGA G-6, "Carbon Dioxide," and CGA G-6.3, "Carbon Dioxide Cylinder Filling and Handling Procedures." Cylinders should always be stored in assigned locations.

Personnel equipment

Personnel must be thoroughly familiar with properties and safety considerations before being allowed to handle carbon dioxide and its associated equipment. Safety glasses, safety shoes, and leather work gloves are recommended when handling cylinders.

Where exposure to liquefied compressed gas may occur, employees should also wear a full face-shield and clean, loose-fitting, thermal-insulated gloves to protect the eyes, face and hands.

Emergency response

If carbon dioxide is present, its level must be monitored by a carbon dioxide specific detector, rather than relying on oxygen monitoring. Carbon dioxide presents a unique hazard, since a dangerous concentration of carbon dioxide may exist even when there is apparently adequate oxygen to support life.

Rescue personnel must wear a self-contained breathing apparatus (SCBA) or supplied air respirator in oxygen-deficient atmospheres or where the carbon dioxide concentration exceeds 3%.

First aid

People suffering from carbon dioxide exposure should be moved to fresh air. If the victim is not breathing, artificial respiration should be administered immediately. If the victim is breathing, give supplemental oxygen.

For skin contact with liquid or solids carbon dioxide, place the affected area in a warm water bath that has a temperature not in excess of 105°F (40°C). Do not rub the area. Never use dry heat. For any cold contact burn, seek medical attention immediately.

Fighting fires

Carbon dioxide is nonflammable and is an extinguishing agent for Class B & C fires.

Emergency Response System

T 800-523-9374 (Continental U.S. and Puerto Rico)
T +1-610-481-7711 (other locations)
For regional ER telephone numbers, please refer to the local SDS 24 hours a day, 7 days a week for assistance involving Air Products and Chemicals, Inc. products

Technical Information Center

T 800-752-1597 (U.S.)
T +1-610-481-8565 (other locations)
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