乾冰

乾冰，是二氧化碳的固體形式。在正常氣壓下，乾冰的凝固點是攝氏的負 78.5 度，在保持物體維持冷凍或低溫狀態下非常有用。它無色，無味，不易燃，略帶酸性。乾冰的密度各不相同，但通常約為 1.4 至 1.6 g/cm^3。乾冰能夠急速的冷凍物體和降低溫度並且可以用隔離手套來做配置。現在乾冰已經被廣泛的使用在許多層面了，乾冰在增溫時是由固態直接昇華為氣態，直接轉化為氣體而省略轉為液態的程序，因此其相變並不會產生液體，也因此我們稱它做「乾冰」。要將二氧化碳變成液態，就必須加大壓強至 5.1 大氣壓才會出現液態二氧化碳。

- ✓ 製造人造雨：利用飛機將乾冰灑在雲上，雲中的小水滴就會被凍結成許多小冰晶，促使更多的水蒸氣凝結在上面，化為雨滴，降落到地面。
- ✓ 製造雲霧：由於乾冰的溫度很低，昇華後低溫的二氧化碳氣體碰到空氣後，可以使空氣中的水蒸氣凝結成小水滴，所以有白霧出現，所以舞台表演上，常使用乾冰來製造雲霧般的特殊效果。
- ✓ 冷凍劑：由於二氧化碳密度比空氣大，會停留在空氣下方，所以乾冰昇華後仍可包覆在冷凍的物品上，能夠維持較好的冷凍效果，尤其是在空運需要特別冷凍的物品，往往都使用它。

乾冰的安全操作

- ✓ 不可使兒童接觸
- ✓ 不可食用乾冰
- ✓ 為防止凍傷，接觸乾冰時應戴上手套。
- ✓ 乾冰常常被放在汽水裡製成乾冰汽水 放進去會冒煙

儲藏

將乾冰置於保溫箱中：保溫效果好的保溫箱可以減慢乾冰昇華的速度。

因為乾冰昇華所產生的壓力會引起爆炸，所以不可以將乾冰儲存在不透氣的保溫箱內。

For supplementary chemical data, see Carbon dioxide (data page).

Dry ice is the solid form of carbon dioxide (chemical formula: CO_2), comprising two oxygen atoms bonded to a single carbon atom. It is colourless, odourless, non-flammable, and slightly acidic.[1]

Carbon dioxide phase diagram

At temperatures above −56.4 °C (−69.5 °F) and pressures below 5.13 atm (the triple point), CO_2 changes from a solid to a gas with no intervening liquid form, through a process called sublimation. The opposite process is called deposition, where CO_2 changes from the gas to solid phase (dry ice). At atmospheric pressure, sublimation/deposition occurs at −78.5 °C (−109.3 °F).

The density of dry ice varies, but usually ranges between about 1.4 and 1.6 g/cm^3 (87–100 lb/ft^3).[2] The low temperature and direct sublimation to a gas makes dry ice an effective coolant, since it is colder than water ice and leaves no residue as it changes state.[3] Its enthalpy of sublimation is 571 kJ/kg (25.2 kJ/mol).

Dry ice is non-polar, with a dipole moment of zero, so attractive intermolecular van der Waals forces operate.[4] The composition results in low thermal and electrical conductivity.[5]

History

It is generally accepted that dry ice was first observed in 1834 by French chemist Charles Thilorier, who published the first account of the substance.[6][7] In his experiments, he noted that when opening the lid of a large cylinder containing liquid carbon dioxide, most of the liquid CO_2 quickly evaporated. This left only solid dry ice in the container.[6] In 1924, Thomas B. Slate applied for a U.S. patent to sell dry ice commercially. Subsequently, he became the first to make dry ice successful as an industry.[8] In 1925, this solid form of CO_2 was trademarked by the DryIce Corporation of America as "Dry ice", thus leading to its common name.[9] That same year the DryIce Co. sold the substance commercially for the first time; marketing it for refrigerating purposes.[8]

The alternative name "Cardice" is a registered trademark of Air Liquide UK Ltd.[10] It is sometimes written as "card ice".[11]

[edit] Manufacture

Small pellets of dry ice sublimating in air

Dry ice is easily manufactured.[12][13] There are common steps taken in producing dry ice. First, gases containing a high concentration of carbon dioxide are produced. Such gases can be a byproduct of some other process, such as producing ammonia from nitrogen and natural gas, or large-scale fermentation.[13] Second, carbon dioxide-rich gas is pressurized and refrigerated until it changes into its liquid form. Next, the pressure is reduced. When this occurs some liquid carbon dioxide vaporizes, and this causes a rapid lowering of temperature of the remaining liquid carbon dioxide. As a result, the extreme cold causes the liquid to solidify into a snow-like consistency. Finally, the snow-like solid carbon dioxide is compressed into either small pellets or larger blocks of dry ice.[14]

Dry ice is typically produced in two standard forms: blocks and cylindrical pellets. A standard block weighing approximately 30 kg is most common. These are commonly used in shipping, because they sublimate slowly due to a relatively small surface area. Pellets are around 1 cm (0.4 in) in diameter and can be bagged easily. This form is suited to small scale use, for example at grocery stores and laboratories.[*citation needed*]

Applications

Commercial

Sublimation

The most common use of dry ice is to preserve food,[1] using non-cyclic refrigeration.

It is frequently used to package items that need to remain cold or frozen, such as ice cream or biological samples,[15] without the use of mechanical cooling.[*citation needed*]

Moreover, dry ice can be used to flash freeze food,[16] laboratory biological samples,[17] carbonate beverages,[16] and make ice cream.[18]

Dry ice can be used to arrest and prevent insect activity in closed containers of grains and grain products, as it displaces oxygen, but does not alter the taste or quality of such foods. For the same reason, it can prevent or retard food oils and fats from becoming rancid.

When dry ice is placed in water sublimation is accelerated, and low-sinking, dense clouds of smoke-like fog are created. This is used in fog machines, at theaters, discothèques, haunted house attractions, and nightclubs for dramatic effects. Unlike most artificial fog machines, in which fog rises like smoke, fog from dry ice hovers above the ground.[14] Dry ice is useful in theater productions that require dense fog effects.[19]

It is occasionally used to freeze and remove warts.[20] However, liquid nitrogen performs better in this role, since it is colder so requires less time to act and less pressure.[21] However, dry ice has the advantage of having fewer problems with storage, since it can be generated from compressed carbon dioxide gas as needed.[21]

Plumbers use equipment that forces pressurised liquid CO_2 into a jacket around a pipe; the dry ice formed causes the water to freeze, forming an ice plug, allowing them to perform repairs without turning off the water mains. This technique can be used on pipes up to 4 in (100 mm) in diameter.[22]

Dry ice can be used as bait to trap mosquitoes, bedbugs, and other insects, due to their attraction to carbon dioxide.[23]

An alternative method to cooling computer parts is with the use of dry ice. This purpose is overshadowed by more conventional ways with fans, heat transfer fluids, liquid nitrogen, or phase change cooling.[24] Industrial

Dry ice blasting used for cleaning a rubber mold

Dry ice can be used for loosening asphalt floor tiles or car sound deadening making it easy to pry off,[25] as well as freezing water in valveless pipes to enable repair.[26]

One of the largest mechanical uses of dry ice is blast cleaning. Dry ice pellets are shot out of a nozzle with compressed air. This can remove residues from industrial equipment. Examples of materials being removed include ink, glue, oil, paint, mold and rubber. Dry ice blasting can replace sandblasting, steam blasting, water blasting or solvent blasting. The primary environmental residue of dry ice blasting is the sublimed CO_2, thus making it a useful technique where residues from other blasting techniques are undesirable.[27][dead link]

Dry ice is also useful for the de-gassing of flammable vapours from storage tanks — the sublimation of dry ice pellets inside an emptied and vented tank causes an outrush of CO_2 that carries with it the flammable vapours.[28]

The removal and fitting of cylinder liners in large marine engines requires the use of dry ice to chill and thus shrink the liner so that it freely slides within the block. When warmed in place the resulting interference fit prevents motion. Similar procedures may be used in fabricating mechanical assemblies with a high resultant strength, replacing the need for pins, keys, or welds.[29]

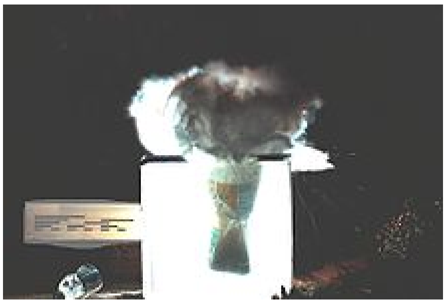
Scientific

In laboratories, a slurry of dry ice in an organic solvent is a useful freezing mixture for cold chemical reactions and for condensing solvents in rotary evaporators.[30]

The process of altering cloud precipitation can be done with the use of dry ice.[31] It was widely used in experiments in the United States in the 1950s and early 60s before being replaced by silver iodide.[31] Nevertheless, dry ice has the advantage of being relatively cheap and completely non-toxic.[31] Yet its main drawback is in having to be delivered directly into the supercooled region of any clouds being seeded.[31]

Dry ice bombs

Main article: Dry ice bomb



Dry ice bomb

Dry ice functions as an ingredient in dry ice bombs. A dry ice bomb is a bomb-like device constructed out of a dry ice and water-filled container, such as a plastic bottle. As the dry ice sublimates, pressure builds up, usually causing the bottle to explode. Because of its simplicity, the dry ice bomb has become a popular recreational activity. Despite its popular recreational use, dry ice bombs remain hazardous.

California law defines "destructive device" as a type of weapon, including "any sealed device containing dry ice (CO_2) or other chemically-reactive substances assembled for the purpose of causing an explosion by a chemical reaction."[32] However, dry ice bombs operate not via chemical reaction but via a phase change. The approximate volume of carbon dioxide gas produced by sublimating a known mass of dry ice can be calculated using the Ideal gas law.

The bomb was featured on *MythBusters*, episode 57 Mentos and Soda, which first aired on August 9, 2006.[33] It was also featured in an episode of Time Warp.

[edit] Safety

Dry ice pellet sublimating in water

Prolonged exposure to dry ice can cause severe skin damage through frostbites, and the fog produced may also hinder attempts to withdraw from contact in a safe manner. Because it sublimates into large quantities of carbon dioxide gas, which could displace oxygen-containing air and pose a danger of asphyxiation, dry ice should only be exposed to open air in a well-ventilated environment.[25] For this reason, dry ice is assigned the S-phrase S9 in the context of laboratory safety. Industrial dry ice may contain contaminants that make it unsafe for applications where it comes into direct contact with foodstuffs.[34]

Although dry ice is not classified as a dangerous substance by the European Union,[35] or as a hazardous material by the DOT for ground transportation, when shipped by air or water, it is regulated as a dangerous good and IATA packing instruction 904 (IATA PI 904) requires that it be labeled specially, including a diamond-shaped black-and white label, UN 1845. Also, arrangements must be in place to ensure adequate ventilation so that pressure build-up does not rupture the packaging.[36] The Federal Aviation Administration in the United States allows airline passengers to carry up to 2 kg of dry ice in carry-on baggage and 2.3 kg in checked baggage, when used to refrigerate perishables.[37]

[edit] Occurrence on Mars

Scientists following the Mariner 4 spacecraft in 1966 concluded that Mars' poles were made entirely of dry ice.[38] However, findings made in 2003 by researchers at the California Institute of Technology have shown that the Mars' poles are almost completely made of water, and dry ice only covers the top layer of the poles.[38][39] Scientists, such as Anthony Colaprete, have proposed the discovery of a phenomenon occurring on the polar regions of Mars known as dry ice storms. Colaprete compares Martian dry ice storms to Earth's thunderstorms, with crystalline CO_2 taking the place of water in the clouds.[40]