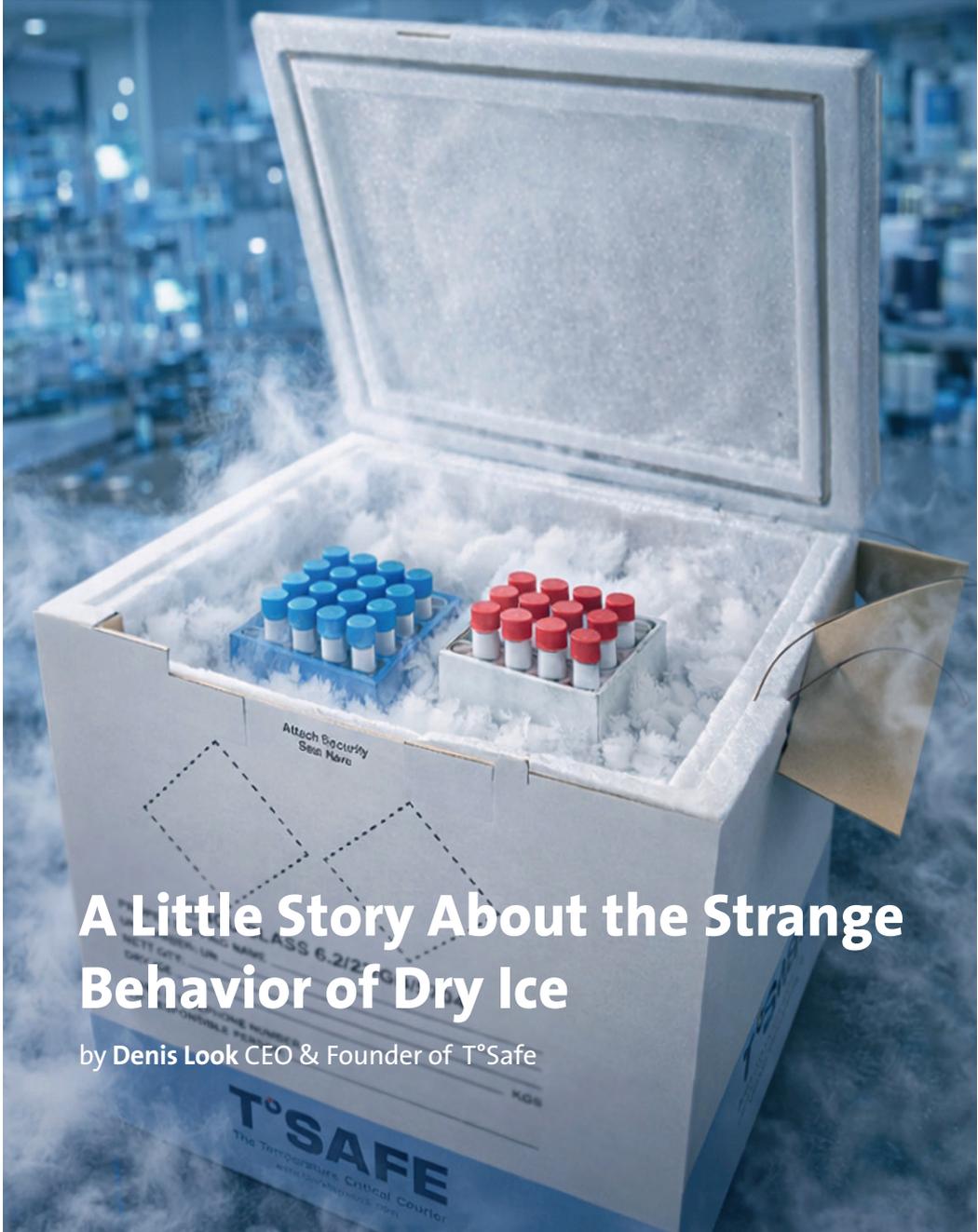


# T°SAFE

The Temperature Critical Courier



## A Little Story About the Strange Behavior of Dry Ice

by Denis Look CEO & Founder of T°Safe

**T°SAFE**  
The Temperature Critical Courier  
www.tosafe.com

# A Little Story About the Strange Behavior of Dry Ice

Denis Look CEO & Founder of T°Safe

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**Anyone who has worked with dry ice knows its ghostly chill: it hisses, smokes, and seems to stubbornly stay at  $-78.5^{\circ}\text{C}$ . Yet sometimes a thermometer shows lower values – perhaps  $-83^{\circ}\text{C}$  or even  $-90^{\circ}\text{C}$ .**

How can that be, if dry ice “only” sublimates at  $-78.5^{\circ}\text{C}$ ? And why do large, old chunks stay cold much longer than fresh pellets?

The answers take us deep into the fascinating world of **thermodynamics** – into the delicate interplay between pressure, energy, and states of matter.

## **Dry Ice – a Different Kind of Ice**

Dry ice is simply the solid form of carbon dioxide ( $\text{CO}_2$ ). Unlike water ice, it does not melt into a liquid when heated. Instead, it goes directly from a solid to a gas. This process is called sublimation.

As long as the surrounding pressure remains constant, sublimation always happens at a very specific temperature.

At normal atmospheric pressure (1 bar), that temperature is  $-78.5^{\circ}\text{C}$ . When dry ice warms up, it turns into gas at exactly that temperature – without ever melting in between.

The key point: the heat energy supplied does not make the ice warmer. It is entirely used to free  $\text{CO}_2$  molecules from their solid lattice structure.

That’s why the temperature stays constant during sublimation – just as water ice remains at  $0^{\circ}\text{C}$  while melting.

## **The Misconception About “ $-78$ Degrees”**

Many people believe dry ice is so cold because it sublimates. In reality, it is the other way around: it sublimates because it’s that cold.

The temperature is not the result of the sublimation itself – it is determined by the pressure under which it happens.

That distinction may sound subtle, but it is essential: the surrounding pressure defines the temperature at which solid and gaseous  $\text{CO}_2$  coexist in balance.

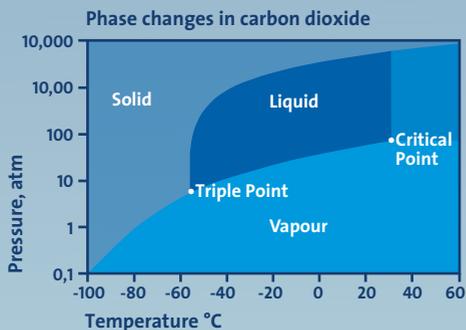
This balance is what gives dry ice its “selfstabilizing” temperature.

## **How Pressure and Temperature Are Connected**

The behavior of carbon dioxide can be shown in a phase diagram – a map of how matter changes with temperature and pressure. It reveals:

- At 5.1 bar and  $-56.6^{\circ}\text{C}$ , we find the triple point, where solid, liquid, and gaseous  $\text{CO}_2$  can all exist at once.
- At 1 bar, the sublimation point drops to  $-78.5^{\circ}\text{C}$ .
- At 0.5 bar, it’s already around  $-83^{\circ}\text{C}$ .
- And at even lower pressures, the temperature continues to fall.

In short: **the lower the pressure, the lower the temperature at which dry ice remains stable.**



### What Happens When the Pressure Changes

If the pressure decreases – for example, inside an airplane’s cargo hold, where it is typically only 0.5 to 0.7 bar – the CO<sub>2</sub> sublimates more readily.

That rapid sublimation absorbs heat from the surroundings, cooling the remaining dry ice further until a new equilibrium is reached – this time at a lower temperature.

That is why dry ice can sometimes be colder than -78.5 °C: it has simply adjusted to the lower ambient pressure. It is not a measurement error – it is physics at work.

### A Little Thought Experiment

Imagine taking a piece of dry ice at -100 °C out of a deep freezer and placing it on the table:

- At 1 bar (normal pressure), it slowly warms up until it reaches -78.5 °C and stays there until it’s gone.
- At 0.5 bar (as in an airplane), it would only warm to about -83 °C – and then remain steady.

This shows that it is not time or location that determines the temperature, but the pressure under which the phase transition occurs.

### Influencing Factors: Heat, Surface Area, Mass, Motion, and Moisture

#### Or: Why Clumped Dry Ice Stays Cold Longer

In practice, a large, solid block of dry ice “lives” much longer than a handful of pellets. The reason lies in the surface area.

Sublimation always happens at the surface. The larger the surface area relative to the mass, the faster the CO<sub>2</sub> gas escapes – and the faster the dry ice disappears.

A compressed, clumped, or “aged” block has less active surface area, so it sublimates more slowly and retains its cold longer. The temperature itself (depending on pressure) remains the same, but the cooling capacity lasts longer because there’s less surface for heat to enter.

Several factors affect how well dry ice holds its cold:

- **Heat input:** Accelerates sublimation.
- **Surface area:** Smaller grains > faster sublimation.
- **Mass:** Larger blocks warm more slowly.
- **Movement:** Strong vibration or transport shaking causes forced sublimation, pulling extra heat from the surroundings – temporarily making the dry ice even colder.
- **Moisture and aging:** Air humidity forms frost, which binds pellets together. This “old,” clumped ice has less exposed surface, sublimates more slowly, and, due to its dense mass, maintains deep temperatures longer – especially after pressure changes or agitation that cause additional cooling.

That is why dry ice is so well-suited for transporting vaccines, APIs, and biological or pharmaceutical samples – it is reliable and predictable.

### When Movement Changes Everything

Motion itself can alter the temperature. When dry ice is shaken or vibrated – for example, during transport – friction and air mixing cause extra CO<sub>2</sub> to sublimate at once.

This sudden gas formation absorbs additional heat, making the remaining ice briefly colder until equilibrium is restored.

In other words, movement can temporarily make dry ice colder than its theoretical sublimation point at that pressure – before it warms back to equilibrium.

### Dry Ice Above the Clouds

This phenomenon is particularly relevant in air transport. In airplane cargo holds, the pressure is reduced to about 0.5 - 0.7 bar.

That means dry ice doesn't sublime at  $-78.5^{\circ}\text{C}$  but at around  $-82^{\circ}\text{C}$ .

A compact block reaches this temperature slowly, but once there, it stays remarkably stable – ideal for long-distance cooling.

### How to Use Dry Ice Safely

To use dry ice effectively and safely, keep a few simple rules in mind:

1. **Ensure ventilation:**  $\text{CO}_2$  gas is heavier than air and can displace oxygen – risk of suffocation!
2. **Never seal tightly:** Sublimation creates gas pressure – closed containers can explode.
3. **Protect your skin:** Direct contact causes severe frostbite. Always use gloves.
4. **Plan your cold chain:** Temperature depends on pressure. Shipments traveling by air will experience slightly lower dry-ice temperatures, which should be accounted for in storage planning.

### The Physical Takeaway

Dry ice is a perfect example of a **thermodynamic equilibrium**. Its seemingly strange temperature changes are simply the points where heat absorption and sublimation balance each other.

When pressure drops, that balance point shifts downward – and the ice becomes colder.

When it moves or sublimates rapidly, it draws even more heat from its surroundings – cooling further until equilibrium returns.

At the same time, a smaller surface area – as in compact or moisture-clumped ice – slows that balancing process.

That is why old, solid dry ice stays cold longer than fine, fresh granules.

„Dry Ice is a perfect example of a thermodynamic equilibrium. Its seemingly strange temperature changes are simply the points where heat absorption and sublimation balance each other.“



### What Is Cold, Really?

Dry ice reminds us that cold is not a thing in itself – it is the absence of heat. Its temperature isn't random but governed by energy, pressure, and molecular motion.

Anyone who understands why dry ice can become colder than  $-78.5^{\circ}\text{C}$  – and why compact pieces retain their chill longer – is, in a sense, peering into the basic mechanisms of nature: Everything strives for balance – even a block of frozen  $\text{CO}_2$ .

### In short:

- The temperature of dry ice is determined by pressure, not by sublimation itself.
- Lower pressure > sublimation below  $-78.5^{\circ}\text{C}$ .
- Motion or rapid gas formation can make it temporarily colder.
- Compact or clumped pieces hold that deeper cold longer because they sublime more slowly.

# T°SAFE

The Temperature Critical Courier

Only Dedicated to Pharma

Premium Transport Services  
(Air Freight & dedicated drives)

GDP compliant  
ISO 9001:2015 certified

T°: dry ice / -20°C / 2-8°C  
/15-25°C & more

Global Operations  
incl. Customs

Pharma: API, IMP,  
Dangerous Goods  
& more

Personal and Assigned Project  
Manager for each shipment

Temperature  
Controlled Vehicles

Online Datalogger  
with GPS & T°

VIP/PCM  
Thermo Boxes

Book & Track  
with IDEX



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## API Transport & GPS-Live Datalogger

Your Partner in Global API Supply Chain Management

T°Safe's Cutting-edge LIVE technology provides unparalleled performance

### iDEX Support:

Tracking & Booking with LIVE GPS/ Temperature monitoring

### Seamless Communication:

NO call center but single points of contact support via dedicated project managers

### Supply Chain Expertise:

Advice on thermal packaging and container setup in all temperature ranges  
2-8°C // 15-25°C // -20°C // -80°C // -150°C

### Best Routes and Timelines:

Specifying optimal flight schedules

### Risk-Assessment & Supply Chain Validation:

Analysis of critical interfaces air/road & backup-solutions

### Customs and Documentation Consulting:

Assistance with documentation, declarations & customs clearance

### Regulatory Support:

Support with regulatory & import/export licenses

### Global Insurance:

In cooperation with a leading German Insurance

All shipments are actively monitored with GPS positioning, Temperature, Humidity, Shock, Light (box integrity) & Battery status.

Live GPS Tracking



Live Temperature Monitoring



Live Humidity Monitoring



Live Shock Sensing



Live Light Sensing



Live Battery Control

