Sublimation is the transition of a substance directly from the solid to the gas state without passing through the liquid state. Sublimation is an endothermic process that occurs at temperatures and pressures below a substance's triple point in its phase diagram, which corresponds to the lowest pressure at which the substance can exist as a liquid. The reverse process of sublimation is deposition or desublimation, in which a substance passes directly from a gas to a solid phase. Sublimation has also been used as a generic term to describe a solid-to-gas transition (sublimation) followed by a gas-to-solid transition (deposition). While vaporization from liquid to gas occurs as evaporation from the surface if it occurs below the boiling point of the liquid, and as boiling with formation of bubbles in the interior of the liquid if it occurs at the boiling point, there is no such distinction for the solid-to-gas transition which always occurs as sublimation from the surface.

At normal pressures, most chemical compounds and elements possess three different states at different temperatures. In these cases, the transition from the solid to the gaseous state requires an intermediate liquid state. The pressure referred to is the *partial pressure* of the substance, not the *total* (e.g. atmospheric) pressure of the entire system. So, all solids that possess an appreciable vapour pressure at a certain temperature usually can sublime in air (e.g. water ice just below 0 °C). For some substances, such as carbon and arsenic, sublimation is much easier than evaporation from the melt, because the pressure of their triple point is very high, and it is difficult to obtain them as liquids.
The term *sublimation* refers to a physical change of state and is not used to describe the transformation of a solid to a gas in a chemical reaction. For example, the dissociation on heating of solid ammonium chloride into hydrogen chloride and ammonia is *not* sublimation but a chemical reaction. Similarly the combustion of candles, containing paraffin wax, to carbon dioxide and water vapor is *not* sublimation but a chemical reaction with oxygen.
Sublimation is caused by the absorption of heat which provides enough energy for some molecules to overcome the attractive forces of their neighbors and escape into the vapor phase. Since the process requires additional energy, it is an endothermic change. The enthalpy of sublimation (also called heat of sublimation) can be calculated by adding the enthalpy of fusion and the enthalpy of vaporization.

Carbon dioxide

Dry ice subliming in air

Solid carbon dioxide (dry ice) sublimes everywhere along the line below the triple point (e.g., at the temperature of −78.5 °C (194.65 K, −109.30 °F) at atmospheric pressure, whereas its melting into liquid CO_2 can occur only along the line at pressures and temperatures above the triple point (i.e., 5.2 atm, −56.4 °C).

Water

Snow and ice sublime, although more slowly, at temperatures below the freezing/melting point temperature line at 0 °C for partial pressures below the triple point pressure of 612 Pa (0.0006 atm). In freeze-drying, the material to be dehydrated is frozen and its water is allowed to sublime under reduced pressure or vacuum. The loss of snow from a snowfield during a cold spell is often caused by sunshine acting directly on the upper layers of the snow. Ablation is a process that includes sublimation and erosive wear of glacier ice.

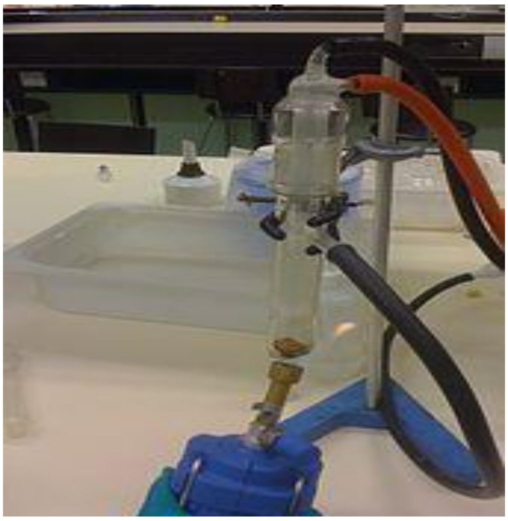
Naphthalene

Naphthalene, an organic compound commonly found in pesticides such as mothballs, sublimes easily because it is made of non-polar molecules that are held together only by van der Waals intermolecular forces. Naphthalene is a solid that sublimes at standard atmospheric temperature with the sublimation point at around 80 °C or 176 °F. At low temperature, its vapour pressure is high enough, 1 mmHg at 53 °C, to make the solid form of naphthalene evaporate into gas. On cool surfaces, the naphthalene vapours will solidify to form needle-like crystals.

Experimental set up for the sublimation reaction of naphthalene Solid naphthalene sublimes and form the crystal-like structure at the bottom of the watch glass

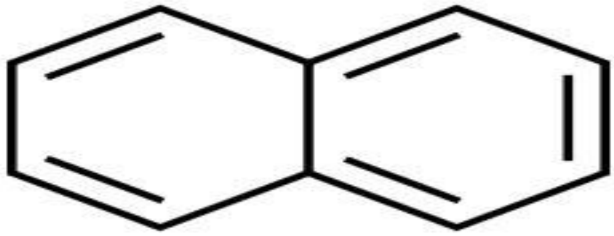
Solid compound of naphthalene sublimed to form a crystal-like structure on the cool surface.

Other substances

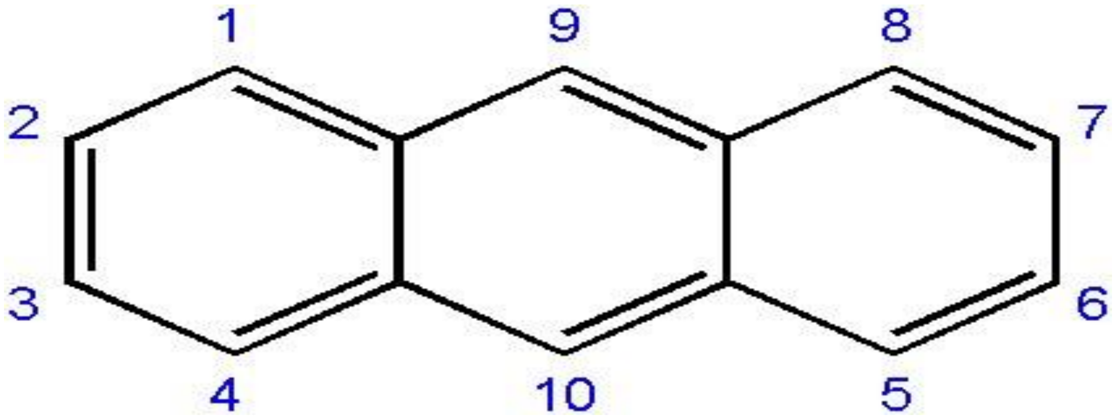


Camphor subliming in a cold finger. The crude product in the bottom is dark brown; the white purified product on the bottom of the cold finger above is hard to see against the light background.

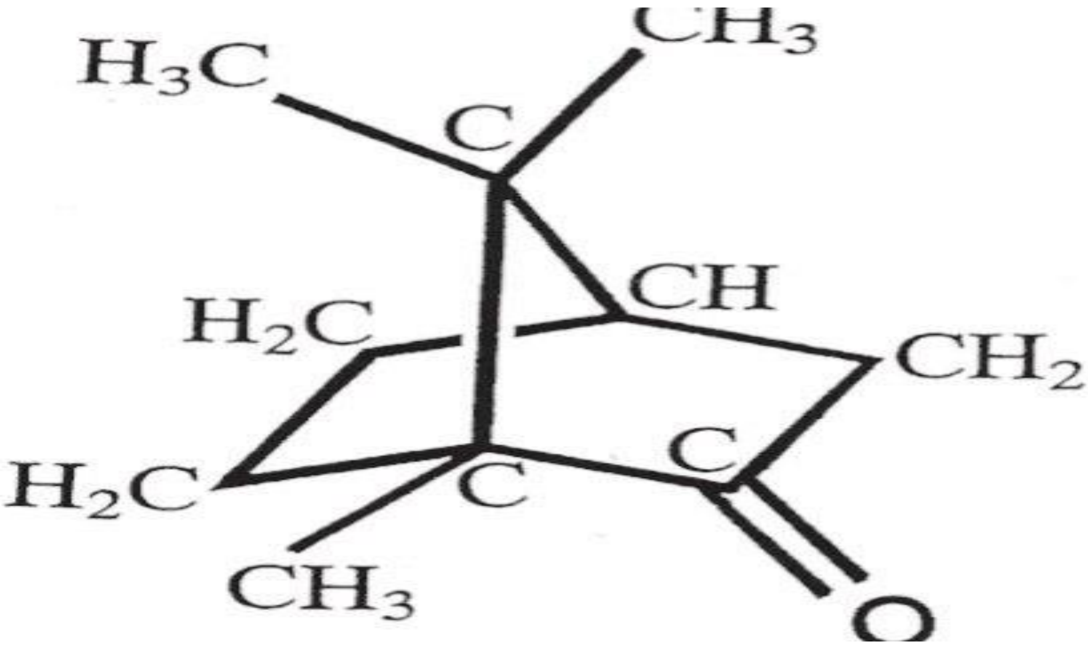
Iodine produces fumes on gentle heating, although this is above the triple point and therefore not true sublimation. It is possible to obtain liquid iodine at atmospheric pressure by controlling the temperature at just above the melting point of iodine. In forensic science, iodine vapor can reveal latent fingerprints on paperArsenic can also sublime at high temperatures. Cadmium and zinc are not suitable materials for use in vacuum because they sublime much more than other common materials



naphthalene structure.



Anthracene structure



Camphor structure