Lab -2- General chemistry( first stage ) Sublimation  MS.c Ala Jalal Ahmad

**Sublimation** is the transition of a substance directly from the [solid](https://en.wikipedia.org/wiki/Solid) to the [gas](https://en.wikipedia.org/wiki/Gas) phase, without passing through the intermediate [liquid](https://en.wikipedia.org/wiki/Liquid%22%20%5Co%20%22Liquid)phase.[[1]](file:///D%3A%5CSublimation%20%28phase%20transition%29%20-%20Wikipedia.htm#cite_note-1) Sublimation is an [endothermic process](https://en.wikipedia.org/wiki/Endothermic_process) that occurs at temperatures and pressures below a substance's [triple point](https://en.wikipedia.org/wiki/Triple_point) in its [phase diagram](https://en.wikipedia.org/wiki/Phase_diagram), which corresponds to the lowest pressure at which the substance can exist as a liquid. The reverse process of sublimation is[deposition](https://en.wikipedia.org/wiki/Deposition_%28phase_transition%29) or desublimation, in which a substance passes directly from a gas to a solid phase.[[2]](file:///D%3A%5CSublimation%20%28phase%20transition%29%20-%20Wikipedia.htm#cite_note-DepositionDef-2) 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](https://en.wikipedia.org/wiki/Deposition_%28phase_transition%29)).[[3]](file:///D%3A%5CSublimation%20%28phase%20transition%29%20-%20Wikipedia.htm#cite_note-3) While a transition from liquid to gas is described as [evaporation](https://en.wikipedia.org/wiki/Evaporation) if it occurs below the boiling point of the liquid, and as [boiling](https://en.wikipedia.org/wiki/Boiling) if it occurs at the boiling point, there is no such distinction within the solid-to-gas transition, which is always described as sublimation.

At [normal pressures](https://en.wikipedia.org/wiki/Standard_conditions_for_temperature_and_pressure), most [chemical compounds](https://en.wikipedia.org/wiki/Chemical_compound) and [elements](https://en.wikipedia.org/wiki/Chemical_element) possess three different states at different [temperatures](https://en.wikipedia.org/wiki/Temperature). In these cases, the transition from the solid to the [gaseous state](https://en.wikipedia.org/wiki/Gaseous_state) requires an intermediate liquid state. The pressure referred to is the [*partial pressure*](https://en.wikipedia.org/wiki/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](https://en.wikipedia.org/wiki/Vapour_pressure%22%20%5Co%20%22Vapour%20pressure) at a certain temperature usually can sublime in air (e.g. water ice just below 0 °C). For some substances, such as [carbon](https://en.wikipedia.org/wiki/Carbon) and [arsenic](https://en.wikipedia.org/wiki/Arsenic), sublimation is much easier than [evaporation](https://en.wikipedia.org/wiki/Evaporation) from the melt, because the pressure of their [triple point](https://en.wikipedia.org/wiki/Triple_point) is very high, and it is difficult to obtain them as liquids.

The term *sublimation* refers to a [physical change](https://en.wikipedia.org/wiki/Physical_change) of [state](https://en.wikipedia.org/wiki/State_of_matter) 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](https://en.wikipedia.org/wiki/Ammonium_chloride) into hydrogen chloride and ammonia is *not* sublimation but a chemical reaction. Similarly the combustion of candles, containing [paraffin wax](https://en.wikipedia.org/wiki/Paraffin_wax), to [carbon dioxide](https://en.wikipedia.org/wiki/Carbon_dioxide) and [water vapor](https://en.wikipedia.org/wiki/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](https://en.wikipedia.org/wiki/Intermolecular_force) of their neighbors and escape into the vapor phase. Since the process requires additional energy, it is an [endothermic](https://en.wikipedia.org/wiki/Endothermic) change. The [enthalpy of sublimation](https://en.wikipedia.org/wiki/Enthalpy_of_sublimation) (also called heat of sublimation) can be calculated by adding the[enthalpy of fusion](https://en.wikipedia.org/wiki/Enthalpy_of_fusion) and the [enthalpy of vaporization](https://en.wikipedia.org/wiki/Enthalpy_of_vaporization).



Dark green [crystals](https://en.wikipedia.org/wiki/Crystals) of [nickelocene](https://en.wikipedia.org/wiki/Nickelocene%22%20%5Co%20%22Nickelocene), sublimed and freshly deposited on a[cold finger](https://en.wikipedia.org/wiki/Cold_finger)

Example



Comparison of phase diagrams of carbon dioxide (red) and water (blue) showing the carbon dioxide sublimation point (middle-left) at 1 atmosphere. As dry ice is heated, it crosses this point along the bold horizontal line from the solid phase directly into the gaseous phase. Water, on the other hand, passes through a liquid phase at 1 atmosphere.

**Carbon dioxide**



[Dry ice](https://en.wikipedia.org/wiki/Dry_ice) subliming in air

Solid [carbon dioxide](https://en.wikipedia.org/wiki/Carbon_dioxide) ([dry ice](https://en.wikipedia.org/wiki/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](https://en.wikipedia.org/wiki/Atmospheric_pressure), whereas its melting into liquid CO2can occur only along the line at pressures and temperatures above the triple point (i.e., 5.2 atm, −56.4 °C).

**Water**

[Snow](https://en.wikipedia.org/wiki/Snow) and [ice](https://en.wikipedia.org/wiki/Ice) sublime, although more slowly, at temperatures below the freezing/[melting point](https://en.wikipedia.org/wiki/Melting_point) temperature line at 0 °C for most pressures; see line below triple point.[[4]](file:///D%3A%5CSublimation%20%28phase%20transition%29%20-%20Wikipedia.htm#cite_note-4) In [freeze-drying](https://en.wikipedia.org/wiki/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](https://en.wikipedia.org/wiki/Snowfield) during a cold spell is often caused by sunshine acting directly on the upper layers of the snow.[Ablation](https://en.wikipedia.org/wiki/Ablation) is a process that includes sublimation and erosive wear of [glacier ice](https://en.wikipedia.org/wiki/Glacier_ice).

**Naphthalene**

[Naphthalene](https://en.wikipedia.org/wiki/Naphthalene), an organic compound commonly found in pesticide such as [mothball](https://en.wikipedia.org/wiki/Mothball), sublimes easily because it is made of non-polar molecules that are held together only by [van der Waals](https://en.wikipedia.org/wiki/Van_der_Waals_force) intermolecular forces. Naphthalene is a solid that sublimes at[standard atmospheric temperature](https://en.wikipedia.org/wiki/Standard_conditions_for_temperature_and_pressure)[[5]](file:///D%3A%5CSublimation%20%28phase%20transition%29%20-%20Wikipedia.htm#cite_note-5) with the sublimation point at around 80 °C or 176 °F.[[6]](file:///D%3A%5CSublimation%20%28phase%20transition%29%20-%20Wikipedia.htm#cite_note-6) At low temperature, its vapour pressure is high enough, 1 mmHg at 53 °C,[[7]](file:///D%3A%5C%5CSublimation%20%28phase%20transition%29%20-%20Wikipedia.htm%22%20%5Cl%20%22cite_note-7) 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](https://en.wikipedia.org/wiki/Naphthalene%22%20%5Co%20%22Naphthalene)Solid naphthalene sublimes and form the crystal-like structure at the bottom of the [watch glass](https://en.wikipedia.org/wiki/Watch_glass)



Solid compound of [naphthalene](https://en.wikipedia.org/wiki/Naphthalene%22%20%5Co%20%22Naphthalene)sublimed to form a crystal-like structure on the cool surface.

**Other substances**



[Camphor](https://en.wikipedia.org/wiki/Camphor) subliming in a[cold finger](https://en.wikipedia.org/wiki/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](https://en.wikipedia.org/wiki/Iodine) produces fumes on gentle heating. 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](https://en.wikipedia.org/wiki/Forensic_science), iodine vapor can reveal latent [fingerprints](https://en.wikipedia.org/wiki/Fingerprint) on paper.[[8]](file:///D%3A%5CSublimation%20%28phase%20transition%29%20-%20Wikipedia.htm#cite_note-8) [Arsenic](https://en.wikipedia.org/wiki/Arsenic) can also sublime at high temperatures.

Purification by sublimation



Crystals of [ferrocene](https://en.wikipedia.org/wiki/Ferrocene%22%20%5Co%20%22Ferrocene) after purification by vacuum sublimation

Sublimation is a technique used by [chemists](https://en.wikipedia.org/wiki/Chemist) to purify [compounds](https://en.wikipedia.org/wiki/Chemical_compound). A solid is typically placed in a [sublimation apparatus](https://en.wikipedia.org/wiki/Sublimation_apparatus) and heated under[vacuum](https://en.wikipedia.org/wiki/Vacuum). Under this reduced [pressure](https://en.wikipedia.org/wiki/Pressure), the solid [volatilizes](https://en.wikipedia.org/wiki/Volatility_%28chemistry%29) and condenses as a purified compound on a cooled surface ([cold finger](https://en.wikipedia.org/wiki/Cold_finger)), leaving a non-volatile residue of [impurities](https://en.wikipedia.org/wiki/Impurities) behind. Once heating ceases and the vacuum is removed, the purified compound may be collected from the cooling surface.[[9]](file:///D%3A%5CSublimation%20%28phase%20transition%29%20-%20Wikipedia.htm#cite_note-9)[[10]](file:///D%3A%5CSublimation%20%28phase%20transition%29%20-%20Wikipedia.htm#cite_note-HarwoodMoodyEOCPAP-10) For even higher purification efficiencies a [temperature gradient](https://en.wikipedia.org/wiki/Temperature_gradient) is applied, which also allows for the separation of different fractions. Typical setups use an evacuated glass tube that is gradually heated in a controlled manner. The material flow is from the hot end, where the initial material is placed, to the cold end that is connected to a pump stand. By controlling temperatures along the length of the tube the operator can control the zones of recondensation, with very volatile compounds being pumped out of the system completely (or caught by a separate [cold trap](https://en.wikipedia.org/wiki/Cold_trap)), moderately volatile compounds recondensating along the tube according to their different volatilities, and non-volatile compounds remaining in the hot end. Vacuum sublimation of this type is also the method of choice for purification of organic compounds for the use in the [organic electronics industry](https://en.wikipedia.org/wiki/Organic_electronics), where very high purities (often > 99.99%) are needed to satisfy the standards for consumer electronics and other applications.

Historical usage

In ancient [alchemy](https://en.wikipedia.org/wiki/Alchemy), a protoscience that contributed to the development of modern chemistry and medicine, alchemists developed a structure of basic laboratory techniques, theory, terminology, and experimental methods. *Sublimation* was used to refer to the process in which a substance is heated to a vapor, then immediately collects as sediment on the upper portion and neck of the heating medium (typically a [retort](https://en.wikipedia.org/wiki/Retort) or [alembic](https://en.wikipedia.org/wiki/Alembic)), but can also be used to describe other similar non-laboratory transitions. It is mentioned by alchemical authors such as [Basil Valentine](https://en.wikipedia.org/wiki/Basil_Valentine) and [George Ripley](https://en.wikipedia.org/wiki/George_Ripley_%28alchemist%29), and in the [Rosarium philosophorum](https://en.wikipedia.org/wiki/Rosarium_philosophorum%22%20%5Co%20%22Rosarium%20philosophorum), as a process necessary for the completion of the[magnum opus](https://en.wikipedia.org/wiki/Magnum_opus_%28alchemy%29). Here, the word *sublimation* is used to describe an exchange of "bodies" and "spirits" similar to laboratory phase transition between solids and gases. Valentine, in his *Triumphal Chariot of Antimony* (published 1678) makes a comparison to [spagyrics](https://en.wikipedia.org/wiki/Spagyrics) in which a vegetable sublimation can be used to separate the spirits in wine and beer.[[11]](file:///D%3A%5CSublimation%20%28phase%20transition%29%20-%20Wikipedia.htm#cite_note-11) Ripley uses language more indicative of the mystical implications of sublimation, indicating that the process has a double aspect in the spiritualization of the body and the corporalizing of the spirit.[[12]](file:///D%3A%5CSublimation%20%28phase%20transition%29%20-%20Wikipedia.htm#cite_note-12) He writes

Sublimation predictions

The enthalpy of sublimation has commonly been predicted using the [equipartition theorem](https://en.wikipedia.org/wiki/Equipartition_theorem%22%20%5Co%20%22Equipartition%20theorem). If the [lattice energy](https://en.wikipedia.org/wiki/Lattice_energy) is assumed to be approximately half the packing energy, then the following thermodynamic corrections can be applied to predict the enthalpy of sublimation. Assuming a 1 [molar](https://en.wikipedia.org/wiki/Molar_concentration) [ideal gas](https://en.wikipedia.org/wiki/Ideal_gas) gives a correction for the thermodynamic environment (pressure and volume) in which pV = RT, hence a correction of 1RT. Additional corrections for the [vibrations](https://en.wikipedia.org/wiki/Molecular_vibration), [rotations](https://en.wikipedia.org/wiki/Rigid_rotor) and translation then need to be applied. From the [equipartition theorem](https://en.wikipedia.org/wiki/Equipartition_theorem%22%20%5Co%20%22Equipartition%20theorem) gaseous rotation and translation contribute 1.5RT each to the final state, therefore a +3RT correction. Crystalline vibrations and rotations contribute 3RT each to the initial state, hence −6RT. Summing the RT corrections ; −6RT + 3RT + RT = −2RT.[[14]](file:///D%3A%5CSublimation%20%28phase%20transition%29%20-%20Wikipedia.htm#cite_note-Gavezzotti-14) This leads to the following approximate sublimation enthalpy. A similar approximation can be found for the [entropy](https://en.wikipedia.org/wiki/Entropy) term if rigid bodies are assumed.ΔHsublimation=−Ulattice energy−2RT{\displaystyle \Delta H\_{\text{sublimation}}=-U\_{\text{lattice energy}}-2RT}

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