13.3: Melting, Freezing, Sublimation, and Deposition

Learning Objectives

- Explain the processes of melting, freezing, sublimation, and deposition.

In the winter, many people find the snow and ice beautiful; they enjoy getting out to ski or ice-skate. When the snow melts, however, the roads get very sloppy and messy. Some people look forward to spring, when the ice and snow are gone and the weather is warmer. All of these events and factors are dependent on the melting point of a solid and the freezing point of a liquid.

Melting and Freezing

Solids are similar to liquids in that both are condensed states, with particles that are far closer together than those of a gas. However, while liquids are fluid, solids are not. The particles of most solids are packed tightly together in an orderly arrangement. The motion of individual atoms, ions, or molecules in a solid is restricted to **vibrational motion** about a fixed point. Solids are almost completely **incompressible** and are the densest of the three states of matter.

As a solid is heated, its particles vibrate more rapidly as it absorbs kinetic energy. Eventually, the organization of the particles within the solid structure begins to break down and the solid starts to melt. The **melting point** is the temperature at which a solid changes into a liquid. At its melting point, the disruptive vibrations of the particles of the solid overcome the attractive forces operating within the solid.

As with boiling points, the melting point of a solid is dependent on the strength of those attractive forces. Sodium chloride, NaCl, is an ionic compound that consists of a multitude of strong ionic bonds. Sodium chloride melts at 801°C. Ice (solid H_2O) is a molecular compound in which molecules that are held together by an attractive force called a hydrogen bond. Though hydrogen bonds are the strongest of the intermolecular attractive forces, the strength of hydrogen bonds is much less than that of ionic bonds. The melting point of ice is 0°C.

Figure 13.3.1: Melting ice cubes illustrate the process of this phase transition. (Public Domain; Moussa).

The melting point of a solid is the same temperature as the **freezing point** of its liquid. They are simply approached from opposite directions. When a substance is at its melting point or freezing point, the solid and liquid states of that substance are present in equilibrium. For water, this equilibrium occurs at 0°C.

$$H_2O\ (s) \rightleftharpoons H_2O\ (l)$$

We tend to think of solids as those materials that are solid at room temperature. However, all materials have melting points of some sort. Substances that are gases at room temperature eventually become solids at extremely low temperatures, as do liquids. Table 13.3.1 shows the melting points of several common materials.

Table 13.3.1: Melting Points of Common Materials

Materials	Melting Point (°C)
Hydrogen	–259
Oxygen	–219
Diethyl Ether	–116
Ethanol	–114
Water	0
Silver	961
Gold	1063
Iron	1538

Sublimation and Deposition

There is also a phase change where a solid goes directly to a gas, a process called **sublimation**:

$$\text{solid} \rightarrow \text{gas}$$

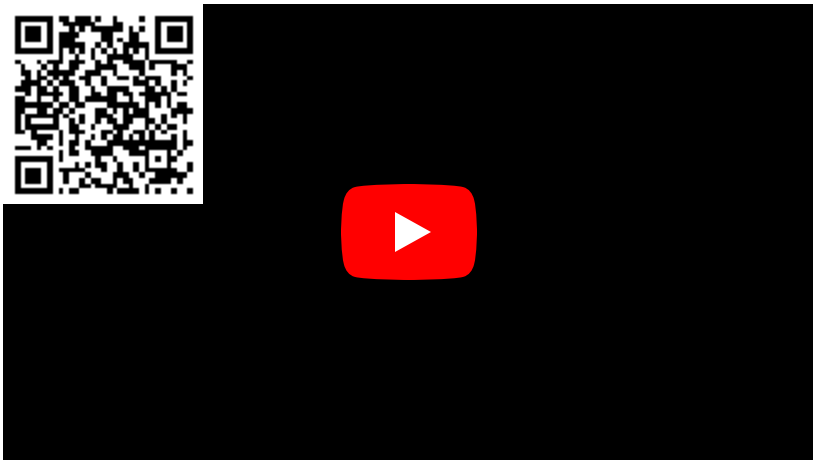
We encounter sublimation in several ways. You may already be familiar with dry ice, which is simply solid carbon dioxide (CO_2) (see Video 13.3.1). At −78.5°C (−109°F), solid carbon dioxide sublimes, changing directly from the solid phase to the gas phase:

$$CO_2\ (s) \xrightarrow{-78.5^\circ C} CO_2\ (g)$$

Solid carbon dioxide is called dry ice because it does not pass through the liquid phase. Instead, it goes directly to the gas phase. (Carbon dioxide *can* exist as liquid but only under high pressure.) Dry ice has many practical uses, including the long-term preservation of medical samples.

Even at temperatures below 0°C, solid H_2O will slowly sublime. For example, a thin layer of snow or frost on the ground may slowly disappear as the solid H_2O sublimes, even though the outside temperature may be below the freezing point of water. Similarly, ice cubes in a freezer usually get smaller over time. Although frozen, the solid water slowly sublimes, redepositing on the colder cooling elements of the freezer, which necessitates periodic defrosting (frost-free freezers minimize this redeposition). Lowering the temperature in a freezer will reduce the need to defrost as often.

Under similar circumstances, water will also sublime from frozen foods (e.g., meats or vegetables), giving them an unattractive, mottled appearance called freezer burn. It is not really a “burn,” and the food has not necessarily gone bad, although it looks unappetizing. Freezer burn can be minimized by lowering a freezer’s temperature and by wrapping foods tightly so water does not have any space to sublime into.



Video 13.3.1: Solid CO_2, also known as dry ice, goes directly from a solid phase to a gaseous phase in a process called sublimation.

The reverse process of sublimation is called **deposition**, a process in which a gas goes directly to a solid, bypassing the liquid phase. Deposition is involved in the formation of frost (see Video 13.3.2). Deposition may be observed in a freezer in a humid environment, such as a freezer kept in a garage during the summer or on cold metal surfaces and single pane windows in the middle of winter, particularly if they are exposed to relatively high humidity.

Video 13.3.2: Timelapse of frost forming on rose (Rosa) hips, in which water vapor goes directly from a gaseous phase to a solid phase in a process called deposition.

Exercise 13.3.1

A. How is the freezing point of a substance related to its melting point?
B. What is the name given to the phase change when a solid is converted directly to a gas?

Answer A

The freezing point and melting point occur at the same temperature for a substance, but are approached from opposite directions. Freezing occurs when a substance changes from a liquid to a solid, while melting occurs when a substance changes from a solid to a liquid.

Answer B

Sublimation.

Summary

- There is an energy change associated with any phase change.
- Sublimation is the change of state from a solid to a gas, without passing through the liquid state.
- Deposition is the change of state from a gas to a solid.
- Carbon dioxide is an example of a material that easily undergoes sublimation.
- The melting point is the temperature at which a solid changes into a liquid.
- Intermolecular attractive forces have a strong influence on melting point.