7.4 Sublimation of dry ice in a sealed plastic bag

Subjects: Thermodynamics, work, energy, solid properties

Description: Dry ice is placed in a plastic bag and sealed. The dry ice sublimes producing CO₂ gas, which expands within the plastic bag, doing work on the surroundings.

Materials:
Resealable plastic bag, gallon size
A few pellets of dry ice◊
Bucket for dry ice*
Tongs
Phone book for placing on top of bag

*Shared item. Located on the shelves in the alcove.
◊Requires advanced preparation. Must get CO₂ from the stockroom prior to class.

Procedure:
1. Place the dry ice in the bag.
2. Remove excess air and seal the bag.
3. Observe the dry ice sublimating and the CO₂ gas expanding within the bag.
4. Place a book or other object on the bag to emphasize the work being done by the gas on the surroundings.

Discussion:
Sublimation is the process of the conversion of a solid directly to a gas. Sublimation is an endothermic process, absorbing energy like evaporation or melting. This energy is called the enthalpy of sublimation:

\[ \Delta_{\text{sublimation}} H = \text{energy required as heat} \]

An example of the sublimation of frozen water to gas is when frost evaporates in the morning.

This demo also illustrates the first law of thermodynamics. For a system, heat and work are transferred between the system and the surroundings. This is expressed by the following equation:

\[ \Delta U = q + w \]

\( \Delta U \) is the change in energy
q is the energy transferred as heat
w is the energy transferred as work

In the case of this demonstration gaseous CO₂ is the system. The bag, book, surface beneath the bag, and air outside the bag are the surroundings. The gaseous CO₂
expands within the plastic bag, lifting the bag and the book against the force of gravity and exerting a force against the surface and surrounding air. The system (gaseous CO$_2$) is expending energy in the form of work. Sublimation of CO$_2$ requires energy and this is transferred as heat to the system (CO$_2$) from the surroundings showing that sublimation is an endothermic process. The balance of energy transfer between the system and the surroundings can be expressed by the following equation:

$$\Delta U = q + w$$

Delta U is the change in energy, q is energy transferred as heat to or from the system and w is energy transferred as work to or from the system.

The work performed in this demonstration is an example of pressure-volume work. It is the work associated with a change in volume that occurs against a resisting external pressure.

$$w = -P\Delta V.$$ 

**Safety:** Dry ice is-78°C. Use insulating gloves when handling to prevent burns.

**Disposal:** None

**Reference:**