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 CO_2 gas, which expands within the plastic bag, doing work on the surroundings.

Materials:
Resealable plastic bag, gallon size
A few pellets of dry ice$^{\lozenge}$
Bucket for dry ice*
Tongs
Phone book for placing on top of bag

*Shared item. Located on the shelves in the alcove.
$^{\lozenge}$Requires advanced preparation. Must get CO_2 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 CO_2 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:

$\Delta_{sublimation}H$ = 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:

$\Delta U = q + w$	ΔU 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 CO_2 is the system. The bag, book, surface beneath the bag, and air outside the bag are the surroundings. The gaseous CO_2

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:

1. J. Kotz, P. Treichel, J. Townsend. *Chemistry & Chemical Reactivity*. 7th Ed; Teachers Edition; Brooks/Cole; 2009; p. 223-224