29:011 Notes for 7/24/13

Example: A 0.5 kg piece of copper at 200 C is added to 2 kg of water at 20C. What is the final temperature of the combination? Assume that the process takes place in an insulated container so that the only exchange of heat is between the water and the copper.

<u>**PRINCIPLE</u>**: heat gained by water = heat lost by copper</u>

$$\begin{aligned} Q_w &= Q_{Cu} \\ m_w c_w \Delta T_w &= m_{Cu} c_{Cu} \Delta T_{Cu} \\ (2kg)(4186J / kgC)(T_f - 20) &= (0.5kg)(387J / kgC)(200 - T_f) \\ 8372(T_f - 20) &= 109.5(200 - T_f) \\ 43.3(T_f - 20) &= (200 - T_f) \\ 43.4T_f - 865.3 &= 200 - T_f \\ 43.4T_f + T_f &= 200 + 865.3 \\ (43.3 + 1)T_f &= 1065.3 \\ 44.3T_f &= 1065.3 \\ \Rightarrow T_f &= 24 C \end{aligned}$$

Another important consideration is that no phase change takes place in the process. In other words, the water does not heat up above 100 C so that boiling occurs and water vapor is formed. In this case the final temperature is below the boiling point, so there is no phase change.

Change of Phase

Matter exists in three forms: <u>solid</u>, <u>liquid</u>, <u>and gas</u>; these are referred to as *phases*.

For example, H_2O exists as ice for T < 0 C, as water for 0 < T < 100 C, and as steam (water vapor) for T > 100 C. The phase of a particular substance depends on *both* temperature and pressure.

First consider starting with a block of ice taken from a freezer at -50 C, and gradually add more and more heat to it. The processes are all conducted at atmospheric pressure.



Note that when a phase change occurs there is no change in temperature. The heat that enters a system during a phase change is used to separate the molecules, not to raise the temperature. The energy needed to produce a phase change is called a latent heat.

For the melting/freezing transition, the heat energy per kilogram is called the *Latent heat of fusion*, L_{f} .

For the vaporization/condensation transition, the heat energy is called the *Latent heat of vaporization*, L_{ν} .

The heat that must me added or removed to change the phase of a mass of m kg of a substance is Q = m L.

Example: How much heat must be added to melt 4 kg of ice at -40 C?

This is a two-step process: first the ice must be heated up to the melting point 0 C, then, the ice at 0 C must be melted.

$$Q = Q_{heat} + Q_{melt}$$

$$Q = mc_{ice}\Delta T_{ice} + mL_f$$

$$Q = (4 kg)(2000 J / kgC)(40 C) + 4 kg (33.5 \times 10^4 J / kg)$$

$$Q = 3.2 \times 10^5 J = 1.34 \times 10^6 J$$

$$\Rightarrow Q = 1.66 \times 10^6 J$$

The phase of a particular substance depends on pressure as well as temperature. For example, the temperature at which water boils decreases with altitude.



When water is boiling, the water molecules must gain enough energy to escape from the liquid. The ability of the water molecules to escape depends on the pressure of air above the water surface. The lower the pressure, the easier it is for the molecules to escape.

Experiments

- Boil water with ice
- Freeze water in a vacuum