7.16: Heat Transfer in Reversible Processes

If a system is in thermal contact with its surroundings, a reversible change can involve the exchange of heat between the system and the surroundings. In Chapter 6, we make a number of important observations about the nature of any heat transfer that occurs during a reversible process. Let us review these ideas.

A system can undergo a change in which it accepts (or liberates) heat while its temperature remains constant. If we boil a liquid at constant pressure, a thermometer immersed in the liquid continues to show the same temperature even though we add more and more heat energy. The added heat is used within the system to convert the liquid to its vapor. If the liquid is stirred well, any localized temperature excursions away from the equilibrium temperature are small; it is a good approximation to say that the temperature of the system is homogenous throughout the system and that it has a constant value.

Nevertheless, for a finite boiling rate we recognize that the idea of an isothermal process is indeed an approximation. For heat transfer to occur from the surroundings to the system, the surroundings must be at a higher temperature than the system. The portion of the system in immediate contact with the wall of the vessel must be at a higher temperature than the portion in the interior of the vessel.

When we think about a constant-temperature system undergoing a reversible change while in thermal contact with its surroundings, we imagine that heat can be transferred in either direction with equal facility. If the system is taking up heat as the process proceeds, we imagine that we can reverse the direction of the change simply by changing the direction of heat transfer. Heat will flow from the system to the surroundings, and the process will run backwards. We can reverse the direction of heat flow by changing the temperature of the surroundings. Initially the surroundings must be hotter than the system. To reverse the direction of heat flow, we must make the temperature of the surroundings less than that of the system. Since a reversible process is one whose direction can be reversed by an arbitrarily small change in some state function, the original temperatures must be arbitrarily close to one another.

For a system that exchanges heat with its surroundings, ***a process can be reversible only if the temperatures of the system and the surroundings are arbitrarily close to one another.*** In a reversible process, net heat transfer occurs between two entities—the system and its surroundings—that are arbitrarily close to thermal equilibrium. Such a process is an idealization. As we have noted several times, a reversible process is a creature of theory that is merely approximated in real systems. A reversible process does not have to be a constant-temperature process. If the temperatures of system and surroundings change simultaneously, they can remain arbitrarily close to one another throughout the process. Nor must a system undergoing reversible change be in thermal contact with its surroundings. A system can undergo a reversible change adiabatically.

Finally, we have noted that the term “isothermal process” is often intended to mean a constant-temperature thermally-reversible process. However, the same words are frequently intended to indicate only that the final temperature of the system is the same as the initial temperature. This is the case whenever the “isothermal process” is a spontaneous process. The intended meaning is usually clear from the context.