4 Heat and the First Law of Thermodynamics

$$Q = C\Delta T = mc\Delta T \qquad Q = mL \qquad \Delta E_{int} = Q - W$$

$$C_V = \frac{d}{2}R \qquad C_p = \left(1 + \frac{d}{2}\right)R \qquad \gamma = \frac{C_p}{C_V} = 1 + \frac{2}{d}$$

$$c_{H20} = 4190 \sim 4000 \text{ J/(kg K)} \qquad L_f^{H2O} = 333 \text{ kJ/ kg} \qquad L_v^{H2O} = 2256 \text{ kJ / kg}$$

4.a RHK Exercises

23-17 A 100 g copper bowl contains 200 g of water, with both at 27 °C. A very hot 300 g copper cylinder is dropped into the water. This causes the water to boil, with 5 g being converted to steam, and the final temperature of the entire system is 100 °C. *(a)* How much heat was transferred to the water? *(b)* How much to the bowl? *(c)* What was the original temperature of the cylinder? (First use c_{Cu}, c_{H2O} and L_v algebraically. Then take the values $c_{Cu} \sim 500$, $c_{H2O} \sim 4000$ J/(kg K), and $L_v \sim 2000$ kJ/kg.)

23-20 What mass of steam at 100 °C must be mixed with 150 g of ice at 0 °C, in a thermally insulated container, to produce liquid water at 50 °C? (Round $L_f \sim 300$ J/g)

23-35 In an experiment, 2 mol of oxygen (O_2) are heated at constant pressure starting at 300 K. How much heat must be added to the gas to double its volume?

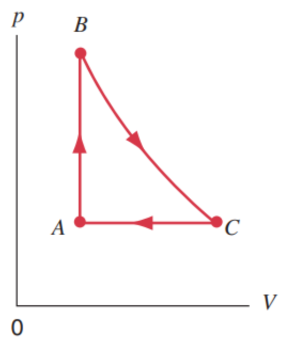

FIGURE 23-34. Exercise 40.

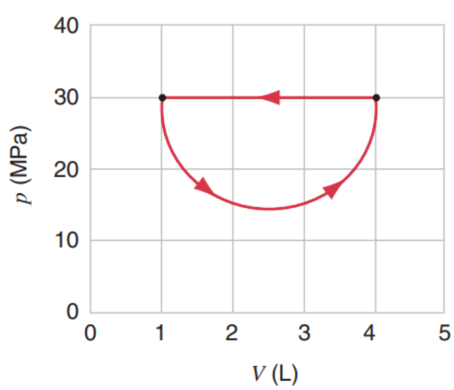

FIGURE 23-36. Exercise 46.

23-40 Gas within a chamber passes through the cycle shown in Fig. 23-34. Determine the net heat added to the gas during process CA if $Q_{AB} = 20$ J, $Q_{BC} = 0$, and $W_{BCA} = 15$ J.

23-42 A sample of n moles of an ideal gas undergoes an isothermal expansion. Find the heat flow into the gas in terms of the initial and final volumes and the temperature.

23-43 A quantity of ideal gas occupies an initial volume V_0 at a pressure p_0 and a temperature T_0 . It expands to volume V_1 (a) at constant pressure, (b) at constant temperature, and (c) adiabatically. Graph each case on a pV diagram. In which case is Q greatest? Least? In which case is W greatest? Least? In which case is ΔE_{int} greatest? Least?

23-46 Gas within a chamber undergoes the processes shown in the PV diagram of Fig. 23-36. Calculate the net heat added to the system during one complete cycle.

4.b RHK Problems

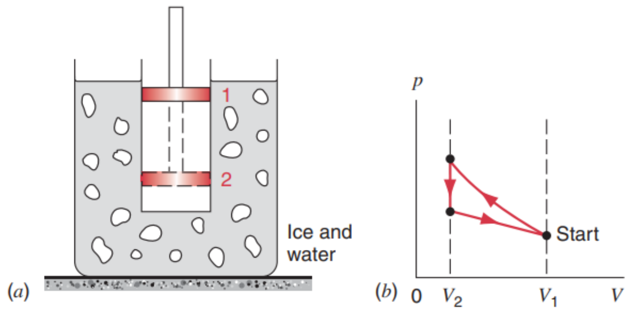

FIGURE 23-38. Problem 18.

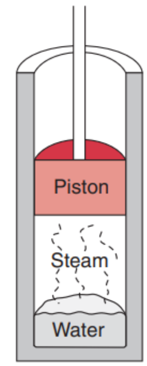

FIGURE 23-40. Problem 20.

23-8 A flow calorimeter is used to measure the specific heat of a liquid. Heat is added at a known rate to a stream of the liquid as it passes through the calorimeter at a known rate. Then a measurement of the resulting temperature difference between the inflow and the outflow points of the liquid stream enables us to compute the specific heat of the liquid. A liquid of density ρ flows through a calorimeter with speed v and a cross-section area A. Heat is added by means of a X Watt electric heating coil, and a temperature difference of ΔT is established in steady-state conditions between the inflow and the outflow points.

(a) Draw a diagram of this device.

(b) Find the specific heat of the liquid.

23-9 Water standing in the open at 27 °C evaporates because of the escape of some of the surface molecules. The heat of vaporization is approximately equal to ϵn, where ϵ is the average energy of the escaping molecules and n is the number of molecules per kilogram.

(a) Explain why this is true.

(b) Determine the value of ϵ.

(c) What is the ratio of ϵ to the average kinetic energy of H_2O molecules, assuming that the kinetic energy is related to temperature in the same way as it is for gases?

23-18 Figure 23-38a shows a cylinder containing gas and closed by a movable piston. The cylinder is submerged in an ice–water mixture. The piston is quickly pushed down from position 1 to position 2. The piston is held at position 2 until the gas is again at 0 ° C and then is slowly raised back to position 1. Figure 23-38b is a PV diagram for the process.

(a) If 100 g of ice are melted during the cycle, how much work has been done by the gas?

(b) Identify which of the processes is *isochoric*, which is *isothermal* and which is *adiabatic*.

(c) Find an expression for W as a function of the number of moles n of gas, the ice water temperature T, the volume ratio $r = V_2/V_1$, and the adiabatic constant γ.

23-40 A cylinder has a well-fitted, 2 kg metal piston whose cross-sectional area is 2 cm^2 (Fig. 23-40). The cylinder contains water and steam at constant temperature. The piston is observed to fall slowly at a rate of 0.30 cm/s because heat flows out of the cylinder through the cylinder walls. As this happens, some steam condenses in the chamber. The density of the steam inside the chamber is 6×10^4 g/cm^3 and the atmospheric pressure is 1.0 atm.

(a) Calculate the rate of condensation of steam.

(b) At what rate is heat leaving the chamber?

(c) What is the rate of change of internal energy of the steam and water inside the chamber?