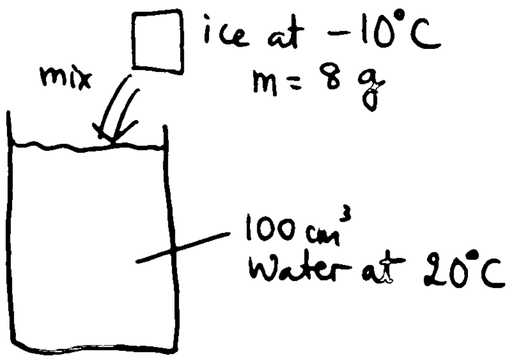
16 An 8.0 g ice cube at $-10°C$ is put into a Thermos flask containing 100 cm^3 of water at 20°C. By how much has the entropy of the cube–water system changed when equilibrium is reached? The specific heat of ice is 2220 J/kg · K.



$T_f = ?$

$$Q_{lost} + Q_{gained} = 0$$

$$m_w C_w (T_f - 20) + m_{ice} C_{ice} (0-(-10)) + m_{ice} L_f + m C_w (T_f - 0) = 0$$

$$0.1 * 4186 * (T_f - 20) + 0.008 * 2220 * 10 + 0.008 * 333 \times 10^3$$

$$+ 0.008 * 4186 * T_f = 0$$

$$452.1 T_f = 5590.4 \Rightarrow \boxed{T_f = 12.4 °C}$$

$$\Delta S_{ice} = m_{ice} C_{ice} \ln\left(\frac{T_{fusion}}{T_i}\right) + \frac{m_{ice} L_f}{T_{fusion}} + m_w C_w \ln\left(\frac{T_f}{T_{fusion}}\right)$$

$$= 0.008 * 2220 \ln\left(\frac{273}{263}\right) + \frac{0.008 \times 333 \times 10^3}{273} + 0.008 \times 4186 \ln\left(\frac{285.4}{273}\right)$$

$$= 0.66 + 9.76 + 1.49 = 11.91 \text{ J/K}.$$

$$\Delta S_{water} = m_w C_w \ln\left(\frac{T_f}{T_i}\right) = 0.1 * 4186 * \ln\left(\frac{285.4}{293}\right)$$

$$= -11.00 \text{ J/K}.$$

$$\boxed{\Delta S_{system} = 0.91 \text{ J/K}}$$

•21 A Carnot engine operates between 235°C and 115°C, absorbing 6.30×10^4 J per cycle at the higher temperature. (a) What is the efficiency of the engine? (b) How much work per cycle is this engine capable of performing? **SSM WWW**

Carnot engine (ideal engine)

$T_H = 235°C = 508\ K$

$T_L = 115\ °C = 388\ K$

$Q_H = 6.3 \times 10^4\ J\ /\ cycle.$

a) $\varepsilon_c = 1 - \dfrac{T_L}{T_H} = 1 - \dfrac{388}{508} = 0.236 = 23.6\ \%$

b) $\varepsilon_c = \dfrac{W}{Q_H} \Rightarrow W = \varepsilon_c Q_H = 1.49 \times 10^4\ J/cycle.$

••26 A 500 W Carnot engine operates between constant-temperature reservoirs at 100°C and 60.0°C. What is the rate at which energy is (a) taken in by the engine as heat and (b) exhausted by the engine as heat?

Carnot engine $T_H = 373K$ $T_L = 333K$.

a) $P = 500W = \frac{W}{t}$

$\varepsilon_c = 1 - \frac{T_L}{T_H} = 1 - \frac{333}{373} = 0.107 = 10.7\%$

$\varepsilon_c = \frac{W}{Q_H} \Rightarrow Q_H = \frac{W}{\varepsilon_c}$

$\frac{Q_H}{t} = \frac{W/t}{\varepsilon_c} = \frac{P}{\varepsilon_c} = \frac{500}{0.107} = \boxed{4672 \text{ J/s}}$

b) $W = Q_H - |Q_L| \Rightarrow \frac{|Q_L|}{t} = \frac{Q_H}{t} - \frac{W}{t}$

$= 4672 - 500$

$\boxed{\frac{|Q_L|}{t} = 4172 \text{ J/s}}$

••27 Figure 20-27 shows a reversible cycle through which 1.00 mol of a monatomic ideal gas is taken. Process *bc* is an adiabatic expansion, with p_b = 10.0 atm and V_b = 1.00 × 10^{-3} m³. For the cycle, find (a) the energy added to the gas as heat, (b) the energy leaving the gas as heat, (c) the net work done by the gas, and (d) the efficiency of the cycle. SSM ILW

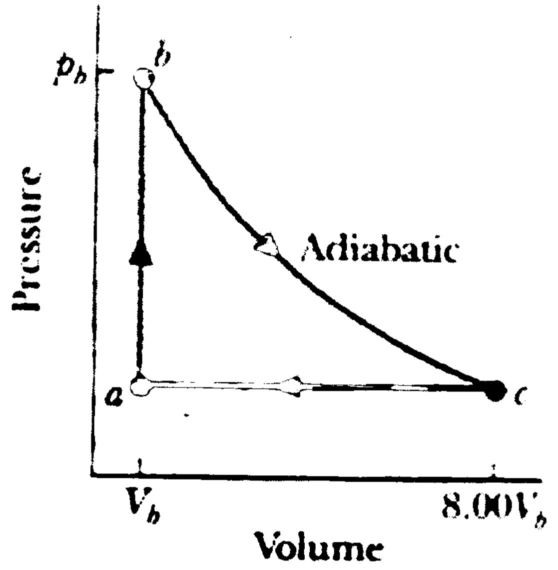


Fig. 20-27. Problem 27.

Reversible cycle, n = 1 mole, monatomic ideal gas $\gamma = 1.67$

$P_b = 10$ atm $\quad V_b = 1 \times 10^{-3}$ m³

a) Heat added $Q > 0$ or Q_H. It is $Q_{a\to b}$

$$Q_{ab} = n\, C_v\, \Delta T = \cancel{n} \times \frac{3}{2}\cancel{R} \times \frac{P_b V_b - P_a V_a}{\cancel{n}\cancel{R}}$$, but $P_a = P_c$

c → b adiabatic process ⇒ $P_c V_c^{\gamma} = P_b V_b^{\gamma} \Rightarrow P_c = P_b \left(\frac{V_b}{V_c}\right)^{\gamma} = 10\left(\frac{1}{8}\right)^{1.67}$

$$= 0.31 \text{ atm} = P_a$$

$$Q_{ab} = \frac{3}{2} \times \left(10 \times 1.01 \times 10^{5} \times 10^{-3} - 0.31 \times 1.01 \times 10^{5} \times 10^{-2}\right) = \boxed{1.47 \times 10^{3}\,\text{J}}$$

$\underline{\underline{> 0}}$

$Q_{ab} = Q_H$

b) $Q_{bc} = 0$ and $Q_{ca} < 0$ or Q_L

$$Q_{ca} = n\, C_p\, \Delta T = \cancel{n} \times \frac{5}{2} \cancel{R} \times \frac{P_a V_a - P_c V_c}{\cancel{n} \cancel{R}}$$

$$= \frac{5}{2}\left(0.31 \times 1.01 \times 10^{5} \times 10^{-3} - 0.31 \times 1.01 \times 10^{5} \times 8 \times 10^{-3}\right)$$

$$\boxed{Q_{ca} = -548\ \text{J}} < 0 \Leftarrow Q_L$$

c) $W = Q_H - |Q_L| = 1470 - 548 = \boxed{922\ \text{J}}$

d) $\varepsilon = \dfrac{W}{Q_H} = \dfrac{922}{1470} = 0.627 \simeq 63\%$

•36 The electric motor of a heat pump transfers energy as heat from the outdoors, which is at −5.0°C, to a room that is at 17°C. If the heat pump were a Carnot heat pump (a Carnot engine working in reverse), how much energy would be transferred as heat to the room for each joule of electric energy consumed?

Ideal heat pump (Carnot heat pump)

$W = 1\,J \qquad T_L = -5\,°C = 268\,K$

$T_H = 17\,°C = 290\,K$

Q_H?

Carnot $\Rightarrow \dfrac{Q_H}{|Q_L|} = \dfrac{T_H}{T_L} \Rightarrow \dfrac{Q_H}{Q_H - W} = \dfrac{T_H}{T_L}$

$Q_H = (Q_H - W)\dfrac{T_H}{T_L} \Rightarrow Q_H\left(1 - \dfrac{T_H}{T_L}\right) = -W\dfrac{T_H}{T_L}$

$Q_H = \dfrac{W}{1 - \dfrac{T_L}{T_H}} = \dfrac{1}{1 - \dfrac{268}{290}} = \boxed{13.2\,J}$

••42 The motor in a refrigerator has a power of 200 W. If the freezing compartment is at 270 K and the outside air is at 300 K, and assuming the efficiency of a Carnot refrigerator, what is the maximum amount of energy that can be extracted as heat from the freezing compartment in 10.0 min?

$P = 200\,W$ refrigerator

$T_L = 270\,K$

$T_H = 300\,K$

Coefficient of performance for Carnot refrig. $\Rightarrow K_c = \dfrac{T_L}{\Delta T} = 9 = \dfrac{|Q_L|/t}{W/t}$

$\dfrac{|Q_L|}{t} = 9 * P = 9 * 200 = 1800\ J/s$

in 10 min $\boxed{|Q_L| = 10.8 \times 10^5\ J}$