8-68 Computer chips are cooled by placing them in saturated liquid R-134a. The entropy changes of the chips, R-134a, and the entire system are to be determined.

Assumptions **1** The system is stationary and thus the kinetic and potential energy changes are zero. **2** There are no work interactions involved. **3** There is no heat transfer between the system and the surroundings.

Analysis (a) The energy balance for this system can be expressed as

$$\underbrace{E_{\text{in}} - E_{\text{out}}}_{\substack{\text{Net energy transfer}\\ \text{by heat, work, and mass}}} = \underbrace{\Delta E_{\text{system}}}_{\substack{\text{Change in internal, kinetic,}\\ \text{potential, etc. energies}}}$$

$$0 = \Delta U = \left[m(u_2 - u_1)\right]_{\text{chips}} + \left[m(u_2 - u_1)\right]_{\text{R-134a}}$$

$$\left[m(u_1 - u_2)\right]_{\text{chips}} = \left[m(u_2 - u_1)\right]_{\text{R-134a}}$$

The heat released by the chips is

$$Q_{\text{chips}} = mc(T_1 - T_2) = (0.010\,\text{kg})(0.3\,\text{kJ/kg}\cdot\text{K})\left[20 - (-40)\right]\text{K} = 0.18\,\text{kJ}$$

The mass of the refrigerant vaporized during this heat exchange process is

$$m_{g,2} = \frac{Q_{\text{R-134a}}}{u_g - u_f} = \frac{Q_{\text{R-134a}}}{u_{fg\,@-40°\text{C}}} = \frac{0.18\,\text{kJ}}{207.40\,\text{kJ/kg}} = 0.0008679\,\text{kg}$$

Only a small fraction of R-134a is vaporized during the process. Therefore, the temperature of R-134a remains constant during the process. The change in the entropy of the R-134a is (at -40°F from Table A-11)

$$\begin{aligned}\Delta S_{\text{R-134a}} &= m_{g,2}s_{g,2} + m_{f,2}s_{f,2} - m_{f,1}s_{f,1}\\ &= (0.0008679)(0.96866) + (0.005 - 0.0008679)(0) - (0.005)(0)\\ &= \mathbf{0.000841\,kJ/K}\end{aligned}$$

(b) The entropy change of the chips is

$$\Delta S_{\text{chips}} = mc\ln\frac{T_2}{T_1} = (0.010\,\text{kg})(0.3\,\text{kJ/kg}\cdot\text{K})\ln\frac{(-40+273)\text{K}}{(20+273)\text{K}} = \mathbf{-0.000687\ kJ/K}$$

(c) The total entropy change is

$$\Delta S_{\text{total}} = S_{\text{gen}} = \Delta S_{\text{R-134a}} + \Delta S_{\text{chips}} = 0.000841 + (-0.000687) = \mathbf{0.000154\ kJ/K}$$

The positive result for the total entropy change (i.e., entropy generation) indicates that this process is possible.

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