8-79 A rigid tank initially contains saturated R-134a vapor. The tank is connected to a supply line, and R-134a is allowed to enter the tank. The mass of the R-134a that entered the tank and the exergy destroyed during this process are to be determined.

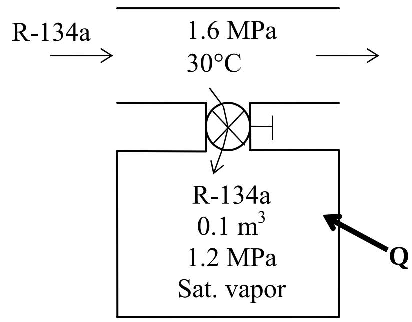
Assumptions **1** This is an unsteady process since the conditions within the device are changing during the process, but it can be analyzed as a uniform-flow process since the state of fluid at the inlet remains constant. **2** Kinetic and potential energies are negligible. **3** There are no work interactions involved. **4** The direction of heat transfer is to the tank (will be verified).

Properties The properties of refrigerant are (Tables A-11 through A-13)

$$\left.\begin{array}{l} P_1 = 1.2\text{ MPa} \\ \text{sat. vapor} \end{array}\right\} \begin{array}{l} \boldsymbol{v}_1 = \boldsymbol{v}_{g@1.2\text{ MPa}} = 0.01672\text{ m}^3/\text{kg} \\ u_1 = u_{g@1.2\text{ MPa}} = 253.81\text{ kJ/kg} \\ s_1 = s_{g@1.2\text{ MPa}} = 0.91303\text{ kJ/kg}\cdot\text{K} \end{array}$$

$$\left.\begin{array}{l} T_2 = 1.4\text{ MPa} \\ \text{sat. liquid} \end{array}\right\} \begin{array}{l} \boldsymbol{v}_2 = \boldsymbol{v}_{f@1.4\text{ MPa}} = 0.0009166\text{ m}^3/\text{kg} \\ u_2 = u_{f@1.4\text{ MPa}} = 125.94\text{ kJ/kg} \\ s_2 = s_{f@1.4\text{ MPa}} = 0.45315\text{ kJ/kg}\cdot\text{K} \end{array}$$

$$\left.\begin{array}{l} P_i = 1.6\text{ MPa} \\ T_i = 30°\text{C} \end{array}\right\} \begin{array}{l} h_i = 93.56\text{ kJ/kg} \\ s_i = 0.34554\text{ kJ/kg}\cdot\text{K} \end{array}$$



Analysis We take the tank as the system, which is a control volume. Noting that the microscopic energies of flowing and nonflowing fluids are represented by enthalpy *h* and internal energy *u*, respectively, the mass and energy balances for this uniform-flow system can be expressed as

Mass balance:

$$m_{\text{in}} - m_{\text{out}} = \Delta m_{\text{system}} \rightarrow m_i = m_2 - m_1$$

Energy balance:

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

$$Q_{\text{in}} + m_i h_i = m_2 u_2 - m_1 u_1 \quad (\text{since } W \cong \text{ke} \cong \text{pe} \cong 0)$$

(*a*) The initial and the final masses in the tank are

$$m_1 = \frac{\boldsymbol{V}_1}{\boldsymbol{v}_1} = \frac{0.1\text{ m}^3}{0.01672\text{ m}^3/\text{kg}} = 5.983\text{ kg}$$

$$m_2 = \frac{\boldsymbol{V}_2}{\boldsymbol{v}_2} = \frac{0.1\text{ m}^3}{0.0009166\text{ m}^3/\text{kg}} = 109.10\text{ kg}$$

Then from the mass balance

$$m_i = m_2 - m_1 = 109.10 - 5.983 = \mathbf{103.11\text{ kg}}$$

The heat transfer during this process is determined from the energy balance to be

$$\begin{aligned} Q_{\text{in}} &= -m_i h_i + m_2 u_2 - m_1 u_1 \\ &= -(103.11\text{ kg})(93.56\text{ kJ/kg}) + (109.10)(125.94\text{ kJ/kg}) - (5.983\text{ kg})(253.81\text{ kJ/kg}) \\ &= 2573\text{ kJ} \end{aligned}$$

(*b*) The exergy destroyed during a process can be determined from an exergy balance or directly from its definition $X_{\text{destroyed}} = T_0 S_{\text{gen}}$. The entropy generation S_{gen} in this case is determined from an entropy balance on an *extended system* that includes the tank and its immediate surroundings so that the boundary temperature of the extended system is the surroundings temperature T_{surr} at all times. It gives

$$\underbrace{S_{\text{in}} - S_{\text{out}}}_{\substack{\text{Net entropy transfer}\\ \text{by heat and mass}}} + \underbrace{S_{\text{gen}}}_{\substack{\text{Entropy}\\ \text{generation}}} = \underbrace{\Delta S_{\text{system}}}_{\substack{\text{Change}\\ \text{in entropy}}}$$

$$\frac{Q_{\text{in}}}{T_{\text{b,in}}} + m_i s_i + S_{\text{gen}} = \Delta S_{\text{tank}} = (m_2 s_2 - m_1 s_1)_{\text{tank}}$$ Substituting, the exergy destruction

$$S_{\text{gen}} = m_2 s_2 - m_1 s_1 - m_i s_i - \frac{Q_{\text{in}}}{T_0}$$

is determined to be

$$X_{\text{destroyed}} = T_0 S_{\text{gen}} = T_0 \left[m_2 s_2 - m_1 s_1 - m_i s_i - \frac{Q_{\text{in}}}{T_0} \right]$$

$$= (318\text{ K})[109.10 \times 0.45315 - 5.983 \times 0.91303 - 103.11 \times 0.34554 - (2573\text{ kJ})/(318\text{ K})]$$

$$= \mathbf{80.3\ kJ}$$