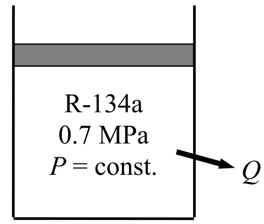
8-32 A cylinder is initially filled with R-134a at a specified state. The refrigerant is cooled and condensed at constant pressure. The exergy of the refrigerant at the initial and final states, and the exergy destroyed during this process are to be determined.

Assumptions The kinetic and potential energies are negligible.

Properties From the refrigerant tables (Tables A-11 through A-13),

$$\left.\begin{array}{l} P_1 = 0.7\text{ MPa} \\ T_1 = 60°\text{C} \end{array}\right\} \begin{array}{l} \boldsymbol{v}_1 = 0.034875\text{ m}^3/\text{kg} \\ u_1 = 274.01\text{ kJ/kg} \\ s_1 = 1.0256\text{ kJ/kg}\cdot\text{K} \end{array}$$



$$\left.\begin{array}{l} P_2 = 0.7\text{ MPa} \\ T_2 = 24°\text{C} \end{array}\right\} \begin{array}{l} \boldsymbol{v}_2 \cong \boldsymbol{v}_{f@24°C} = 0.0008261\text{ m}^3/\text{kg} \\ u_2 \cong u_{f@24°C} = 84.44\text{ kJ/kg} \\ s_2 \cong s_{f@24°C} = 0.31958\text{ kJ/kg}\cdot\text{K} \end{array}$$

$$\left.\begin{array}{l} P_0 = 0.1\text{ MPa} \\ T_0 = 24°\text{C} \end{array}\right\} \begin{array}{l} \boldsymbol{v}_0 = 0.23718\text{ m}^3/\text{kg} \\ u_0 = 251.84\text{ kJ/kg} \\ s_0 = 1.1033\text{ kJ/kg}\cdot\text{K} \end{array}$$

Analysis (*a*) From the closed system exergy relation,

$$X_1 = \Phi_1 = m\{(u_1 - u_0) - T_0(s_1 - s_0) + P_0(\boldsymbol{v}_1 - \boldsymbol{v}_0)\}$$

$$= (5\text{ kg})\{(274.01 - 251.84)\text{ kJ/kg} - (297\text{ K})(1.0256 - 1.1033)\text{ kJ/kg}\cdot\text{K}$$

$$+ (100\text{ kPa})(0.034875 - 0.23718)\text{m}^3/\text{kg}\left(\frac{1\text{ kJ}}{1\text{ kPa}\cdot\text{m}^3}\right)\}$$

$$= \mathbf{125.1\ kJ}$$

and

$$X_2 = \Phi_2 = m\{(u_2 - u_0) - T_0(s_2 - s_0) + P_0(\boldsymbol{v}_2 - \boldsymbol{v}_0)\}$$

$$= (5\text{ kg})\{(84.44 - 251.84)\text{ kJ/kg} - (297\text{ K})(0.31958 - 1.1033)\text{ kJ/kg}\cdot\text{K}$$

$$+ (100\text{ kPa})(0.0008261 - 0.23718)\text{m}^3/\text{kg}\left(\frac{1\text{ kJ}}{1\text{ kPa}\cdot\text{m}^3}\right)\}$$

$$= \mathbf{208.6\ kJ}$$

(*b*) The reversible work input, which represents the minimum work input $W_{\text{rev,in}}$ in this case can be determined from the exergy balance by setting the exergy destruction equal to zero,

$$\underbrace{X_{\text{in}} - X_{\text{out}}}_{\substack{\text{Net exergy transfer} \\ \text{by heat, work, and mass}}} - \underbrace{X_{\text{destroyed}}^{\nearrow 0\ \text{(reversible)}}}_{\substack{\text{Exergy} \\ \text{destruction}}} = \underbrace{\Delta X_{\text{system}}}_{\substack{\text{Change} \\ \text{in exergy}}}$$

$$W_{\text{rev,in}} = X_2 - X_1 = 208.6 - 125.1 = 83.5\text{ kJ}$$

Noting that the process involves only boundary work, the useful work input during this process is simply the boundary work in excess of the work done by the surrounding air,

$$W_{\text{u,in}} = W_{\text{in}} - W_{\text{surr,in}} = W_{\text{in}} - P_0(\boldsymbol{V}_1 - \boldsymbol{V}_2) = P(\boldsymbol{V}_1 - \boldsymbol{V}_2) - P_0 m(\boldsymbol{v}_1 - \boldsymbol{v}_2)$$

$$= m(P - P_0)(\boldsymbol{v}_1 - \boldsymbol{v}_2)$$

$$= (5\text{ kg})(700 - 100\text{ kPa})(0.034875 - 0.0008261\text{ m}^3/\text{kg})\left(\frac{1\text{ kJ}}{1\text{ kPa}\cdot\text{m}^3}\right) = 102.1\text{ kJ}$$

Knowing both the actual useful and reversible work inputs, the exergy destruction or irreversibility that is the difference between the two is determined from its definition to be

$$X_{\text{destroyed}} = I = W_{\text{u,in}} - W_{\text{rev,in}} = 102.1 - 83.5 = \mathbf{18.6\ kJ}$$

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