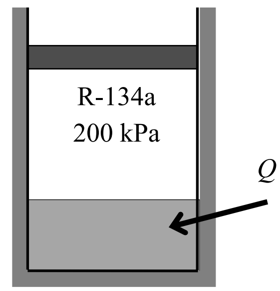
5-109 A cylinder is initially filled with saturated liquid-vapor mixture of R-134a at a specified pressure. Heat is transferred to the cylinder until the refrigerant vaporizes completely at constant pressure. The initial volume, the work done, and the total heat transfer are to be determined, and the process is to be shown on a P-v diagram.

Assumptions **1** The cylinder is stationary and thus the kinetic and potential energy changes are negligible. **2** The thermal energy stored in the cylinder itself is negligible. **3** The compression or expansion process is quasi-equilibrium.

Analysis (a) Using property data from R-134a tables (Tables A-11 through A-13), the initial volume of the refrigerant is determined to be

$$\left.\begin{array}{l} P_1 = 200 \text{ kPa} \\ x_1 = 0.25 \end{array}\right\} \begin{array}{ll} v_f = 0.0007533, & v_g = 0.099867 \text{ m}^3/\text{kg} \\ u_f = 38.28, & u_{fg} = 186.21 \text{ kJ/kg} \end{array}$$

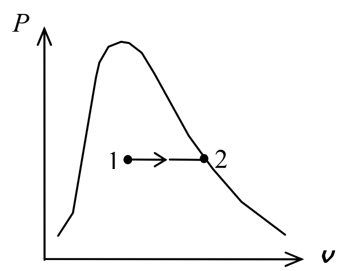


$$\begin{aligned} v_1 &= v_f + x_1 v_{fg} \\ &= 0.0007533 + 0.25 \times (0.099867 - 0.0007533) = 0.02553 \text{ m}^3/\text{kg} \end{aligned}$$

$$u_1 = u_f + x_1 u_{fg} = 38.28 + 0.25 \times 186.21 = 84.83 \text{ kJ/kg}$$

$$V_1 = m v_1 = (0.2 \text{ kg})(0.02553 \text{ m}^3/\text{kg}) = \mathbf{0.005106\ m^3}$$

(b) The work done during this constant pressure process is



$$\left.\begin{array}{l} P_2 = 200 \text{ kPa} \\ \text{sat. vapor} \end{array}\right\} \begin{array}{l} v_2 = v_{g@200 \text{ kPa}} = 0.09987 \text{ m}^3/\text{kg} \\ u_2 = u_{g@200 \text{ kPa}} = 224.48 \text{ kJ/kg} \end{array}$$

$$\begin{aligned} W_{b,\text{out}} &= \int_1^2 P\,dV = P(V_2 - V_1) = mP(v_2 - v_1) \\ &= (0.2 \text{ kg})(200 \text{ kPa})(0.09987 - 0.02553)\text{m}^3/\text{kg}\left(\frac{1 \text{ kJ}}{1 \text{ kPa} \cdot \text{m}^3}\right) \\ &= \mathbf{2.97\ kJ} \end{aligned}$$

(c) We take the contents of the cylinder as the system. This is a closed system since no mass enters or leaves. The energy balance for this stationary closed system can be expressed as

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

$$Q_{\text{in}} - W_{\text{b,out}} = \Delta U$$

$$Q_{\text{in}} = m(u_2 - u_1) + W_{\text{b,out}}$$

Substituting,

$$Q_{\text{in}} = (0.2 \text{ kg})(224.48 - 84.83)\text{kJ/kg} + 2.97 = \mathbf{30.9\ kJ}$$