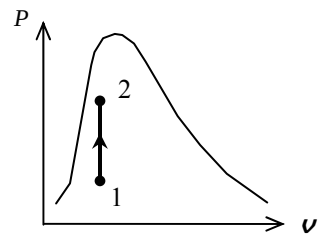
4-41 A rigid container that is filled with R-134a is heated. The temperature and total enthalpy are to be determined at the initial and final states.

R-134a
300 kPa
10 kg
14 L

Analysis This is a constant volume process. The specific volume is

$$v_1 = v_2 = \frac{V}{m} = \frac{0.014\ \text{m}^3}{10\ \text{kg}} = 0.0014\ \text{m}^3/\text{kg}$$

The initial state is determined to be a mixture, and thus the temperature is the saturation temperature at the given pressure. From Table A-12 by interpolation



$$T_1 = T_{\text{sat @ 300 kPa}} = \mathbf{0.61°C}$$

and

$$x_1 = \frac{v_1 - v_f}{v_{fg}} = \frac{(0.0014 - 0.0007736)\ \text{m}^3/\text{kg}}{(0.067978 - 0.0007736)\ \text{m}^3/\text{kg}} = 0.009321$$

$$h_1 = h_f + x_1 h_{fg} = 52.67 + (0.009321)(198.13) = 54.52\ \text{kJ/kg}$$

The total enthalpy is then

$$H_1 = mh_1 = (10\ \text{kg})(54.52\ \text{kJ/kg}) = \mathbf{545.2\ kJ}$$

The final state is also saturated mixture. Repeating the calculations at this state,

$$T_2 = T_{\text{sat @ 600 kPa}} = \mathbf{21.55°C}$$

$$x_2 = \frac{v_2 - v_f}{v_{fg}} = \frac{(0.0014 - 0.0008199)\ \text{m}^3/\text{kg}}{(0.034295 - 0.0008199)\ \text{m}^3/\text{kg}} = 0.01733$$

$$h_2 = h_f + x_2 h_{fg} = 81.51 + (0.01733)(180.90) = 84.64\ \text{kJ/kg}$$

$$H_2 = mh_2 = (10\ \text{kg})(84.64\ \text{kJ/kg}) = \mathbf{846.4\ kJ}$$

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4-54 CD EES A piston-cylinder device contains a saturated liquid-vapor mixture of water at 800 kPa pressure. The mixture is heated at constant pressure until the temperature rises to 350°C. The initial temperature, the total mass of water, the final volume are to be determined, and the P-v diagram is to be drawn.

Analysis (a) Initially two phases coexist in equilibrium, thus we have a saturated liquid-vapor mixture. Then the temperature in the tank must be the saturation temperature at the specified pressure,

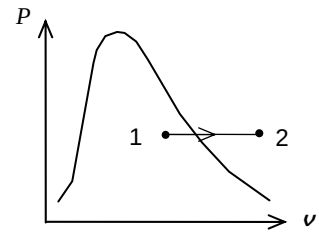
$$T = T_{\text{sat@800 kPa}} = \mathbf{170.41°C}$$

(b) The total mass in this case can easily be determined by adding the mass of each phase,

$$m_f = \frac{V_f}{v_f} = \frac{0.1 \text{ m}^3}{0.001115 \text{ m}^3/\text{kg}} = 89.704 \text{ kg}$$

$$m_g = \frac{V_g}{v_g} = \frac{0.9 \text{ m}^3}{0.24035 \text{ m}^3/\text{kg}} = 3.745 \text{ kg}$$

$$m_t = m_f + m_g = 89.704 + 3.745 = \mathbf{93.45 \text{ kg}}$$



(c) At the final state water is superheated vapor, and its specific volume is

$$\left.\begin{array}{l} P_2 = 800 \text{ kPa} \\ T_2 = 350^\circ \text{C} \end{array}\right\} v_2 = 0.35442 \text{ m}^3/\text{kg} \qquad \text{(Table A-6)}$$

Then,

$$V_2 = m_t v_2 = (93.45 \text{ kg})(0.35442 \text{ m}^3/\text{kg}) = \mathbf{33.12 \text{ m}^3}$$

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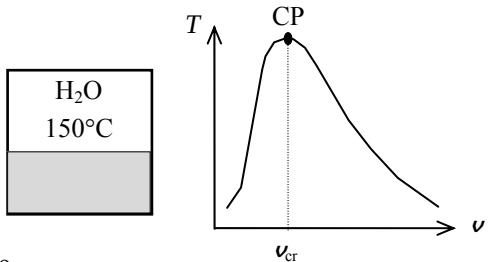
4-58 A rigid vessel that contains a saturated liquid-vapor mixture is heated until it reaches the critical state. The mass of the liquid water and the volume occupied by the liquid at the initial state are to be determined.

Analysis This is a constant volume process ($v = V/m$ = constant) to the critical state, and thus the initial specific volume will be equal to the final specific volume, which is equal to the critical specific volume of water,

$$v_1 = v_2 = v_{cr} = 0.003106 \text{ m}^3/\text{kg} \quad \text{(last row of Table A-4)}$$

The total mass is

$$m = \frac{V}{v} = \frac{0.3 \text{ m}^3}{0.003106 \text{ m}^3/\text{kg}} = 96.60 \text{ kg}$$



At 150°C, $v_f = 0.001091$ m^3/kg and $v_g = 0.39248$ m^3/kg (Table A-4). Then the quality of water at the initial state is

$$x_1 = \frac{v_1 - v_f}{v_{fg}} = \frac{0.003106 - 0.001091}{0.39248 - 0.001091} = 0.005149$$

Then the mass of the liquid phase and its volume at the initial state are determined from

$$m_f = (1 - x_1)m_t = (1 - 0.005149)(96.60) = \mathbf{96.10\ \ kg}$$

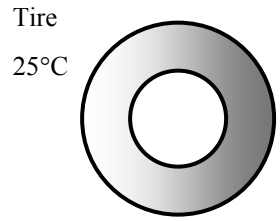
$$V_f = m_f v_f = (96.10 \text{ kg})(0.001091 \text{ m}^3/\text{kg}) = \mathbf{0.105\ m^3}$$

4-79 An automobile tire is inflated with air. The pressure rise of air in the tire when the tire is heated and the amount of air that must be bled off to reduce the temperature to the original value are to be determined.

Assumptions **1** At specified conditions, air behaves as an ideal gas. **2** The volume of the tire remains constant.

Properties The gas constant of air is $R = 0.287$ kPa.m^3/kg.K (Table A-1).

Analysis Initially, the absolute pressure in the tire is



$$P_1 = P_g + P_{\text{atm}} = 210 + 100 = 310\text{kPa}$$

Treating air as an ideal gas and assuming the volume of the tire to remain constant, the final pressure in the tire can be determined from

$$\frac{P_1 \cancel{V_1}}{T_1} = \frac{P_2 \cancel{V_2}}{T_2} \longrightarrow P_2 = \frac{T_2}{T_1} P_1 = \frac{323 \text{ K}}{298 \text{ K}}(310 \text{ kPa}) = 336 \text{ kPa}$$

Thus the pressure rise is

$$\Delta P = P_2 - P_1 = 336 - 310 = \mathbf{26\ kPa}$$

The amount of air that needs to be bled off to restore pressure to its original value is

$$m_1 = \frac{P_1 \cancel{V}}{RT_1} = \frac{(310 \text{ kPa})(0.025 \text{ m}^3)}{(0.287 \text{ kPa} \cdot \text{m}^3/\text{kg} \cdot \text{K})(298 \text{ K})} = 0.0906 \text{ kg}$$

$$m_2 = \frac{P_1 \cancel{V}}{RT_2} = \frac{(310 \text{ kPa})(0.025 \text{ m}^3)}{(0.287 \text{ kPa} \cdot \text{m}^3/\text{kg} \cdot \text{K})(323 \text{ K})} = 0.0836 \text{ kg}$$

$$\Delta m = m_1 - m_2 = 0.0906 - 0.0836 = \mathbf{0.0070\ kg}$$

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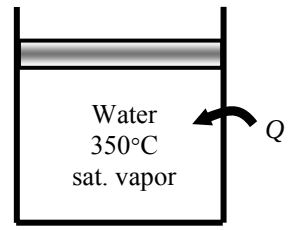
4-95 Water vapor is heated at constant pressure. The final temperature is to be determined using ideal gas equation, the compressibility charts, and the steam tables.

Properties The gas constant, the critical pressure, and the critical temperature of water are, from Table A-1,

$R = 0.4615$ kPa·m^3/kg·K, $T_{cr} = 647.1$ K, $P_{cr} = 22.06$ MPa

Analysis (*a*) From the ideal gas equation,

$$T_2 = T_1 \frac{v_2}{v_1} = (350 + 273\text{ K})(2) = \mathbf{1246\ K}$$



(*b*) The pressure of the steam is

$$P_1 = P_2 = P_{\text{sat@350°C}} = 16{,}529\text{ kPa}$$

From the compressibility chart at the initial state (Fig. A-15),

$$\left.\begin{aligned} T_{R1} &= \frac{T_1}{T_{cr}} = \frac{623\text{ K}}{647.1\text{ KR}} = 0.963 \\ P_{R1} &= \frac{P_1}{P_{cr}} = \frac{16.529\text{ MPa}}{22.06\text{ MPa}} = 0.749 \end{aligned}\right\} Z_1 = 0.593,\ v_{R1} = 0.75$$

At the final state,

$$\left.\begin{aligned} P_{R2} &= P_{R1} = 0.749 \\ v_{R2} &= 2v_{R1} = 2(0.75) = 1.50 \end{aligned}\right\} Z_2 = 0.88$$

Thus,

$$T_2 = \frac{P_2 v_2}{Z_2 R} = \frac{P_2}{Z_2}\frac{v_{R2} T_{cr}}{P_{cr}} = \frac{16{,}529\text{ kPa}}{0.88}\frac{(1.50)(647.1\text{ K})}{22{,}060\text{ kPa}} = \mathbf{826\ K}$$

(*c*) From the superheated steam table,

$$\left.\begin{aligned} T_1 &= 350°\text{C} \\ x_1 &= 1 \end{aligned}\right\} v_1 = 0.008806\text{ m}^3/\text{kg} \qquad \text{(Table A-4)}$$

$$\left.\begin{aligned} P_2 &= 16{,}529\text{ kPa} \\ v_2 &= 2v_1 = 0.01761\text{ m}^3/\text{kg} \end{aligned}\right\} T_2 = 477°\text{C} = \mathbf{750\ K} \qquad \text{(from Table A-6 or EES)}$$

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