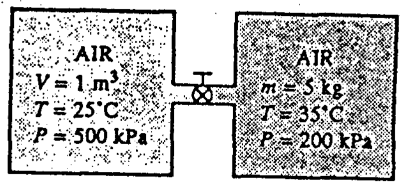
2-75 Let's call the first and the second tanks A and B. Treating air as an ideal gas, the volume of the second tank and the mass of air in the first tank are determined to be

$$V_B = \left(\frac{m_1 R T_1}{P_1}\right)_B = \frac{(5\ \text{kg})(0.287\ \text{kPa.m}^3/\text{kg.K})(308\ \text{K})}{200\ \text{kPa}} = 2.21\ \text{m}^3$$

$$m_A = \left(\frac{P_1 V}{R T_1}\right)_A = \frac{(500\ \text{kPa})(1.0\ \text{m}^3)}{(0.287\ \text{kPa.m}^3/\text{kg.K})(298\ \text{K})} = 5.846\ \text{kg}$$



Thus,

$$V = V_A + V_B = 1.0 + 2.21 = 3.21\ \text{m}^3$$
$$m = m_A + m_B = 5.846 + 5.0 = 10.846\ \text{kg}$$

Then the final equilibrium pressure becomes

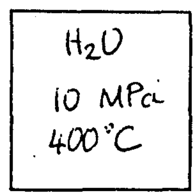
$$P_2 = \frac{mRT_2}{V} = \frac{(10.846\ \text{kg})(0.287\ \text{kPa.m}^3/\text{kg.K})(293\ \text{K})}{3.21\ \text{m}^3} = 284.1\ \text{kPa}$$

2-79 The gas constant, the critical pressure, and the critical temperature of water are, from Table A-1,

$$R = 0.4615\ \text{kPa.m}^3/\text{kg.K},\quad T_{cr} = 647.3\ \text{K},\quad P_{cr} = 22.09\ \text{MPa}$$

(a) From the ideal gas equation of state,

$$v = \frac{RT}{P} = \frac{(0.4615\ \text{kPa.m}^3/\text{kg.K})(673\ \text{K})}{(10{,}000\ \text{kPa})} = 0.03106\ \text{m}^3/\text{kg} \qquad (17.6\%\ \text{error})$$



(b) From the compressibility chart (Fig. A-30a),

$$\left.\begin{aligned} P_R &= \frac{P}{P_{cr}} = \frac{10\ \text{MPa}}{22.09\ \text{MPa}} = 0.453 \\ T_R &= \frac{T}{T_{cr}} = \frac{673\ \text{K}}{647.3\ \text{K}} = 1.04 \end{aligned}\right\} Z = 0.84$$

Thus,

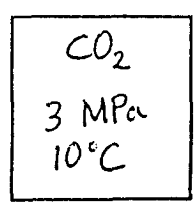
$$v = (Z)(v_{ideal}) = (0.84)(0.03106\ \text{m}^3/\text{kg}) = 0.02609\ \text{m}^3/\text{kg} \qquad (1.2\%\ \text{error})$$

(c) From the superheated steam table (Table A-6),

$$\left.\begin{aligned} P &= 10\ \text{MPa} \\ T &= 400^\circ\text{C} \end{aligned}\right\} \quad v = 0.02641\ \text{m}^3/\text{kg}$$

2-87 The critical pressure, and the critical temperature of CO_2 are, from Table A-1,

$$T_{cr} = 304.2\ \text{K} \quad \text{and} \quad P_{cr} = 7.39\ \text{MPa}$$



From the compressibility chart (Fig. A-30a),

$$\left.\begin{aligned} P_R &= \frac{P}{P_{cr}} = \frac{3\ \text{MPa}}{7.39\ \text{MPa}} = 0.406 \\ T_R &= \frac{T}{T_{cr}} = \frac{283\ \text{K}}{304.2\ \text{K}} = 0.93 \end{aligned}\right\} Z = 0.80$$

Then the error involved in treating CO_2 as an ideal gas is

$$\text{error} = \frac{v - v_{ideal}}{v} = 1 - \frac{1}{Z} = 1 - \frac{1}{0.80} = -0.25 \quad \text{or} \quad 25.0\%.$$

2-91 The specific volume of steam is

$$v = \frac{V}{m} = \frac{1 \text{ m}^3}{2.841 \text{ kg}} = 0.3520 \text{ m}^3/\text{kg}$$

H_2O
1 m^3
2.841 kg
0.6 MPa

(a) From the ideal gas equation of state,

$$T = \frac{Pv}{R} = \frac{(600 \text{ kPa})(0.352 \text{ m}^3/\text{kg})}{0.4615 \text{ kPa.m}^3/\text{kg.K}} = 457.6 \text{ K}$$

(b) The van der Waals constants for steam are determined from Eq. 2-24 to be

$$a = \frac{27R^2T_{cr}^2}{64P_{cr}} = \frac{(27)(0.4615 \text{ kPa.m}^3/\text{kg.K})^2(647.3 \text{ K})^2}{(64)(22{,}090 \text{ kPa})} = 1.704 \text{ m}^6\text{kPa/kg}^2$$

$$b = \frac{RT_{cr}}{8P_{cr}} = \frac{(0.4615 \text{ kPa.m}^3/\text{kg.K})(647.3 \text{ K})}{8\times 22{,}090 \text{ kPa}} = 0.00169 \text{ m}^3/\text{kg}$$

From Eq. 2-22,

$$T = \frac{1}{R}\left(P + \frac{a}{v^2}\right)(v - b) = \frac{1}{0.4615}\left(600 + \frac{1.704}{(0.3520)^2}\right)(0.352 - 0.00169) = 465.9 \text{ K}$$

(c) From the superheated steam table (Table A-6),

$$\left.\begin{aligned} P &= 0.6 \text{ MPa} \\ v &= 0.352 \text{ m}^3/\text{kg} \end{aligned}\right\} \quad T = 200^\circ\text{C} \qquad (473 \text{ K})$$

CB 2-104

$$(a)\quad C_p = a + bT + cT^2 + dT^3$$

$$\Delta H = H_2 - H_1 = \int_{T_1}^{T_2} C_p dT = \left[aT + b\frac{T^2}{2} + c\frac{T^3}{3} + d\,\frac{T^4}{4} \right]_{T_1}^{T_2}$$

$$= 12{,}454\, kJ/kmol = 447.8\, kJ/kg$$

$$(b)\, Average Temperature = (1000 + 600)/2 = 800K$$

$$At\;\; 800K, C_p = 1.121 kJ/kg \cdot K$$

$$\Delta H = H_2 - H_1 = \int_{T_1}^{T_2} C_p dT = C_p (T_2 - T_1) = 448.4\; kJ/kg$$

$$(c)\;\; At\;\; 300K,\; C_p = 1.039, \Delta H = 415.6 kJ/kg$$

CB2-106

Same procedure as in 2-104 but now we must evaluate

$$\Delta U = U_2 - U_1 = \int_{T_1}^{T_2} C_V dT = \left[aT + b\frac{T^2}{2} + c\frac{T^3}{3} + d\,\frac{T^4}{4} \right]$$

$$where$$

$$C_V = C_p - R$$

(a) 1212.6 kJ/kmol = 6406 kJ/kg
(b) 6288 kJ/kg
(c) 6110 kJ/kg