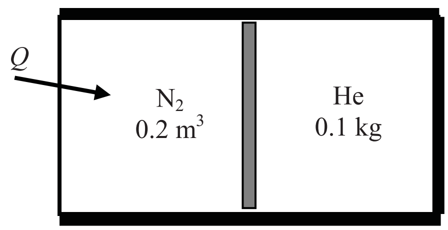
8-183 A horizontal cylinder is separated into two compartments by a piston, one side containing nitrogen and the other side containing helium. Heat is added to the nitrogen side. The final temperature of the helium, the final volume of the nitrogen, the heat transferred to the nitrogen, and the entropy generation during this process are to be determined.

Assumptions **1** Kinetic and potential energy changes are negligible. **2** Nitrogen and helium are ideal gases with constant specific heats at room temperature. **3** The piston is adiabatic and frictionless.

Properties The properties of nitrogen at room temperature are R = 0.2968 kPa.m^3/kg.K, c_p = 1.039 kJ/kg.K, c_v = 0.743 kJ/kg.K, k = 1.4. The properties for helium are R = 2.0769 kPa.m^3/kg.K, c_p = 5.1926 kJ/kg.K, c_v = 3.1156 kJ/kg.K, k = 1.667 (Table A-2).

Analysis (a) Helium undergoes an isentropic compression process, and thus the final helium temperature is determined from



$$T_{\text{He},2} = T_1\left(\frac{P_2}{P_1}\right)^{(k-1)/k} = (20+273)\text{K}\left(\frac{120\text{ kPa}}{95\text{ kPa}}\right)^{(1.667-1)/1.667} = \mathbf{321.7\ K}$$

(b) The initial and final volumes of the helium are

$$V_{\text{He},1} = \frac{mRT_1}{P_1} = \frac{(0.1\text{ kg})(2.0769\text{ kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(20+273\text{ K})}{95\text{ kPa}} = 0.6406\text{ m}^3$$

$$V_{\text{He},2} = \frac{mRT_2}{P_2} = \frac{(0.1\text{ kg})(2.0769\text{ kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(321.7\text{ K})}{120\text{ kPa}} = 0.5568\text{ m}^3$$

Then, the final volume of nitrogen becomes

$$V_{\text{N2},2} = V_{\text{N2},1} + V_{\text{He},1} - V_{\text{He},2} = 0.2 + 0.6406 - 0.5568 = \mathbf{0.2838\ m^3}$$

(c) The mass and final temperature of nitrogen are

$$m_{\text{N2}} = \frac{P_1V_1}{RT_1} = \frac{(95\text{ kPa})(0.2\text{ m}^3)}{(0.2968\text{ kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})(20+273\text{ K})} = 0.2185\text{ kg}$$

$$T_{\text{N2},2} = \frac{P_2V_2}{mR} = \frac{(120\text{ kPa})(0.2838\text{ m}^3)}{(0.2185\text{ kg})(0.2968\text{ kPa}\cdot\text{m}^3/\text{kg}\cdot\text{K})} = 525.1\text{ K}$$

The heat transferred to the nitrogen is determined from an energy balance

$$\begin{aligned}Q_{\text{in}} &= \Delta U_{\text{N2}} + \Delta U_{\text{He}} \\ &= [mc_v(T_2-T_1)]_{\text{N2}} + [mc_v(T_2-T_1)]_{\text{He}} \\ &= (0.2185\text{ kg})(0.743\text{ kJ/kg.K})(525.1-293) + (0.1\text{ kg})(3.1156\text{ kJ/kg.K})(321.7-293) \\ &= \mathbf{46.6\ kJ}\end{aligned}$$

(d) Noting that helium undergoes an isentropic process, the entropy generation is determined to be

$$\begin{aligned}S_{\text{gen}} &= \Delta S_{\text{N2}} + \Delta S_{\text{surr}} = m_{\text{N2}}\left(c_p\ln\frac{T_2}{T_1} - R\ln\frac{P_2}{P_1}\right) + \frac{-Q_{\text{in}}}{T_R} \\ &= (0.2185\text{ kg})\left[(1.039\text{ kJ/kg.K})\ln\frac{525.1\text{ K}}{293\text{ K}} - (0.2968\text{ kJ/kg.K})\ln\frac{120\text{ kPa}}{95\text{ kPa}}\right] + \frac{-46.6\text{ kJ}}{(500+273)\text{ K}} \\ &= \mathbf{0.057\ kJ/K}\end{aligned}$$