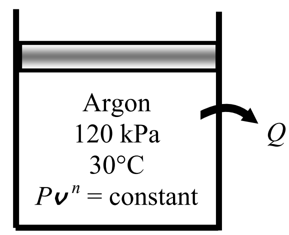
5-74 Argon is compressed in a polytropic process. The work done and the heat transfer are to be determined.

Assumptions **1** Argon is an ideal gas since it is at a high temperature and low pressure relative to its critical point values of 151 K and 4.86 MPa. **2** The kinetic and potential energy changes are negligible, $\Delta \mathrm{ke} \cong \Delta \mathrm{pe} \cong 0$.

Properties The properties of argon are $R = 0.2081$ kJ/kg·K and $c_v = 0.3122$ kJ/kg·K (Table A-2*a*).

Analysis We take argon as the system. This is a *closed system* since no mass crosses the boundaries of the system. The energy balance for this system can be expressed as



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

$$Q_{\text{in}} - W_{b,\text{out}} = \Delta U = mc_v(T_2 - T_1)$$

Using the boundary work relation for the polytropic process of an ideal gas gives

$$w_{b,\text{out}} = \frac{RT_1}{1-n}\left[\left(\frac{P_2}{P_1}\right)^{(n-1)/n} - 1\right] = \frac{(0.2081\,\text{kJ/kg}\cdot\text{K})(303\,\text{K})}{1\text{-}1.2}\left[\left(\frac{1200}{120}\right)^{0.2/1.2} - 1\right] = -147.5\,\text{kJ/kg}$$

Thus,

$$w_{b,\text{in}} = \mathbf{147.5\ kJ/kg}$$

The temperature at the final state is

$$T_2 = T_1\left(\frac{P_2}{P_1}\right)^{(n\text{-}1)/n} = (303\,\text{K})\left(\frac{1200\,\text{kPa}}{120\,\text{kPa}}\right)^{0.2/1.2} = 444.7\,\text{K}$$

From the energy balance equation,

$$q_{\text{in}} = w_{b,\text{out}} + c_v(T_2 - T_1) = -147.5\,\text{kJ/kg} + (0.3122\,\text{kJ/kg}\cdot\text{K})(444.7 - 303)\text{K} = -103.3\,\text{kJ/kg}$$

Thus,

$$q_{\text{out}} = \mathbf{103.3\ kJ/kg}$$