7-163 A hot water stream is mixed with a cold water stream. For a specified mixture temperature, the mass flow rate of cold water stream and the rate of entropy generation are to be determined.

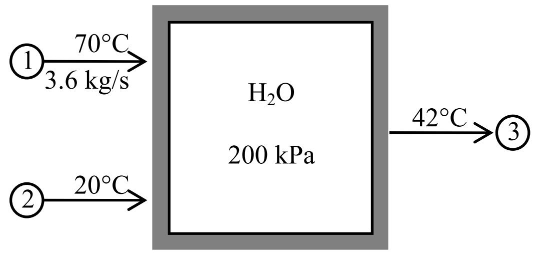
Assumptions **1** Steady operating conditions exist. **2** The mixing chamber is well-insulated so that heat loss to the surroundings is negligible. **3** Changes in the kinetic and potential energies of fluid streams are negligible.

Properties Noting that $T < T_{\text{sat @ 200 kPa}} = 120.21°\text{C}$, the water in all three streams exists as a compressed liquid, which can be approximated as a saturated liquid at the given temperature. Thus from Table A-4,

$$\left.\begin{array}{l} P_1 = 200 \text{ kPa} \\ T_1 = 70°\text{C} \end{array}\right\} \begin{array}{l} h_1 \cong h_{f@70°\text{C}} = 293.07 \text{ kJ/kg} \\ s_1 \cong s_{f@70°\text{C}} = 0.9551 \text{ kJ/kg}\cdot\text{K} \end{array}$$

$$\left.\begin{array}{l} P_2 = 200 \text{ kPa} \\ T_2 = 20°\text{C} \end{array}\right\} \begin{array}{l} h_2 \cong h_{f@20°\text{C}} = 83.91 \text{ kJ/kg} \\ s_2 \cong s_{f@20°\text{C}} = 0.2965 \text{ kJ/kg}\cdot\text{K} \end{array}$$

$$\left.\begin{array}{l} P_3 = 200 \text{ kPa} \\ T_3 = 42°\text{C} \end{array}\right\} \begin{array}{l} h_3 \cong h_{f@42°\text{C}} = 175.90 \text{ kJ/kg} \\ s_3 \cong s_{f@42°\text{C}} = 0.5990 \text{ kJ/kg}\cdot\text{K} \end{array}$$



Analysis (*a*) We take the mixing chamber as the system, which is a control volume. The mass and energy balances for this steady-flow system can be expressed in the rate form as

Mass balance: $\dot{m}_{\text{in}} - \dot{m}_{\text{out}} = \Delta \dot{E}_{\text{system}}^{\nearrow 0 \text{ (steady)}} = 0 \longrightarrow \dot{m}_1 + \dot{m}_2 = \dot{m}_3$

Energy balance:

$$\underbrace{\dot{E}_{\text{in}} - \dot{E}_{\text{out}}}_{\substack{\text{Rate of net energy transfer} \\ \text{by heat, work, and mass}}} = \underbrace{\Delta \dot{E}_{\text{system}}^{\nearrow 0 \text{ (steady)}}}_{\substack{\text{Rate of change in internal, kinetic,} \\ \text{potential, etc. energies}}} = 0$$

$$\dot{E}_{\text{in}} = \dot{E}_{\text{out}}$$

$$\dot{m}h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3 \quad (\text{since } \dot{Q} = \dot{W} = \Delta\text{ke} \cong \Delta\text{pe} \cong 0)$$

Combining the two relations gives

$$\dot{m}_1 h_1 + \dot{m}_2 h_2 = (\dot{m}_1 + \dot{m}_2) h_3$$

Solving for $\dot{m}_2$ and substituting, the mass flow rate of cold water stream is determined to be

$$\dot{m}_2 = \frac{h_1 - h_3}{h_3 - h_2}\dot{m}_1 = \frac{(293.07 - 175.90)\text{kJ/kg}}{(175.90 - 83.91)\text{kJ/kg}}(3.6 \text{ kg/s}) = \mathbf{4.586 \text{ kg/s}}$$

Also, $\dot{m}_3 = \dot{m}_1 + \dot{m}_2 = 3.6 + 4.586 = 8.186 \text{ kg/s}$

(*b*) Noting that the mixing chamber is adiabatic and thus there is no heat transfer to the surroundings, the entropy balance of the steady-flow system (the mixing chamber) can be expressed as

$$\underbrace{\dot{S}_{\text{in}} - \dot{S}_{\text{out}}}_{\substack{\text{Rate of net entropy transfer} \\ \text{by heat and mass}}} + \underbrace{\dot{S}_{\text{gen}}}_{\substack{\text{Rate of entropy} \\ \text{generation}}} = \underbrace{\Delta \dot{S}_{\text{system}}^{\nearrow 0}}_{\substack{\text{Rate of change} \\ \text{of entropy}}} = 0$$

$$\dot{m}_1 s_1 + \dot{m}_2 s_2 - \dot{m}_3 s_3 + \dot{S}_{\text{gen}} = 0$$

Substituting, the total rate of entropy generation during this process becomes

$$\begin{aligned} \dot{S}_{\text{gen}} &= \dot{m}_3 s_3 - \dot{m}_2 s_2 - \dot{m}_1 s_1 \\ &= (8.186 \text{ kg/s})(0.5990 \text{ kJ/kg}\cdot\text{K}) - (4.586 \text{ kg/s})(0.2965 \text{ kJ/kg}\cdot\text{K}) - (3.6 \text{ kg/s})(0.9551 \text{ kJ/kg}\cdot\text{K}) \\ &= \mathbf{0.1054 \text{ kW/K}} \end{aligned}$$