Example In a steady-state flow process, 1 mol s^{-1} of air at 600 K and 1 atm is continuously mixed with 2 mol s^{-1} of air at 450 K and 1 atm. The product stream is at 400 K and 1 atm. A schematic representation of the process is shown in Fig. Determine the rate of heat transfer and the rate of entropy generation for the process. Assume that air is an ideal gas with $C_P = (7/2)R$, that the surroundings are at 300 K, and that kinetic- and potential-energy changes are negligible.

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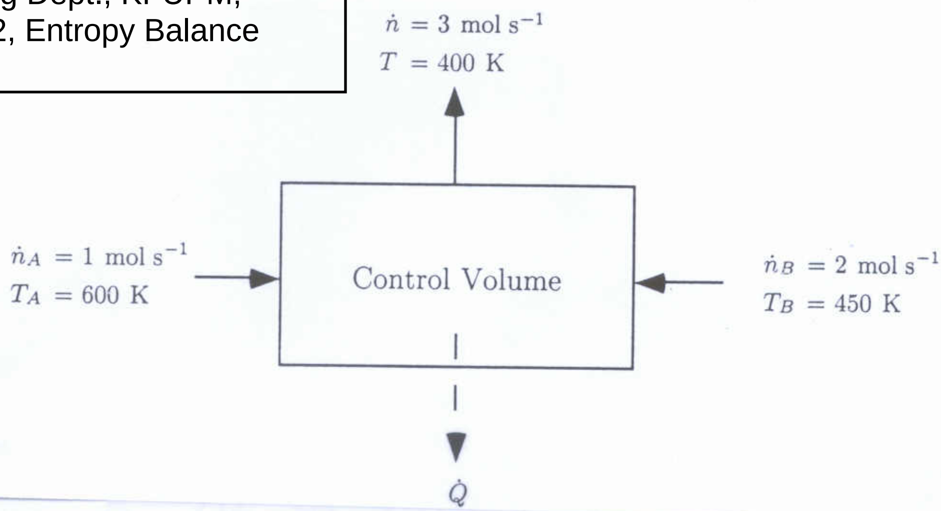
CHE303, Handout_2, Entropy Balance



solution: S.S. Energy Balance:

$$\Delta\left[\dot{n}\left(H + \tfrac{1}{2}u^2 + gz\right)\right] = \dot{Q} + \dot{W}_s$$

($\tfrac{1}{2}u^2 \to 0$, $gz \to 0$, $\dot{W}_s \to 0$)

$$\Rightarrow \dot{Q} = \dot{n}H - \dot{n}_A H_A - \dot{n}_B H_B$$

$$\dot{n} = \dot{n}_A + \dot{n}_B \quad \text{(mass balance)}$$

rearrange,

$$\dot{Q} = \dot{n}_A(H - H_A) + \dot{n}_B(H - H_B)$$

$$= \dot{n}_A C_p(T - T_A) + \dot{n}_B C_p(T - T_B)$$

$$= -8729.7 \ \frac{J}{s}$$

Entropy Balance (s.s.):

$$\Delta(\dot{n} S) = \sum \frac{\dot{Q}_j}{T_{\sigma,j}} + \dot{S}_{G,tot}$$

$$\Rightarrow \dot{S}_{G,tot} = \Delta(\dot{n} S) - \sum_j \frac{\dot{Q}_j}{T_{\sigma,j}}$$

$$= \dot{n} S - \dot{n}_A S_A - \dot{n}_B S_B - \frac{\dot{Q}}{T_{\sigma}}$$

$$= \dot{n}_A (S - S_A) + \dot{n}_B (S - S_B) - \frac{\dot{Q}}{T_{\sigma}}$$

$$= \dot{n}_A C_p \ln\left(\frac{T}{T_A}\right) + \dot{n}_B C_p \ln\left(\frac{T}{T_B}\right) - \frac{\dot{Q}}{T_{\sigma}}$$

$$= (1)\left(\frac{7}{2}\right)(8.314) \ln\left(\frac{400}{600}\right) + (2)\left(\frac{7}{2}\right)(8.314) \ln\left(\frac{400}{450}\right)$$

$$- \left(\frac{-8729.7}{300}\right) = 10.45 \ \frac{J}{K\,s}$$