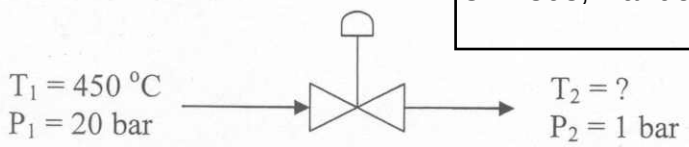
Example 2

Steam at 20 bar and 450 °C is throttled adiabatically to 1 bar. Estimate the final temperature and calculate the entropy generation for this process.

Chemica Engineering Dept., KFUPM,
CHE303, Handout_4, Throttling Valves



For an adiabatic throttling valve $\Delta H = 0$

$\Rightarrow H_2 = H_1$

$H_1 = 3357.8 \ \frac{kJ}{kg}$ ($T = 450\ ^\circ C$ and 2000 kPa)

at state 2 $P_2 = 100$ kPa and $H_2 = 3357.8$

at 100 kPa:

$T = 400\ ^\circ C$ $H = 3278.2 \ \left(\frac{kJ}{kg}\right)$

$T = 450\ ^\circ C$ $H = 3382.4$ (II)

H_2

$$\frac{T_2 - 400}{450 - 400} = \frac{3357.8 - 3278.2}{3382.4 - 3278.2}$$

$\Rightarrow T_2 = 438.2\ ^\circ C$

entropy balance:

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

$j \to 0$

adiabatic

$$\Rightarrow \frac{\dot{S}_{G\,tot}}{\dot{m}} = \Delta S = S_2 - S_1$$

↑ entropy generation per unit mass.

at $T_1 = 450^\circ C$ and $P_1 = 2000\ kPa$

$$S_1 = 7.2859 \quad kJ/(kg \cdot K)$$

at $T_2 = 438.2^\circ C$ and $P_2 = 100\ kPa$.

at $P = 100\ kPa$

$T = 400^\circ C$ $\quad S = 8.5442 \quad \left(\frac{kJ}{kg\,K}\right)$

$T = 450^\circ C$ $\quad S = 8.6934 \quad (11)$

$$\frac{S_2 - 8.5422}{8.6934 - 8.5442} = \frac{438.2 - 400}{450 - 400}$$

(T_2)

$$\Rightarrow S_2 = 8.6562 \frac{kJ}{kg\,K} \Rightarrow \frac{\dot{S}_{G\,tot}}{\dot{m}} = 1.3703 \frac{kJ}{kg \cdot K}$$