CHE 260 MID-TERM 2019.

1) $m_{N_2} = \left(\frac{P_1 V_1}{RT_1}\right)_{N_2} = \frac{500\,kPa \times 1\,m^3}{0.2968\,\frac{kJ}{kgK} \times 353K} = 4.772\,kg$

$m_{He} = \left(\frac{P_1 V_1}{RT_1}\right)_{He} = \frac{500\,kPa \times 1\,m^3}{2.0769\,\frac{kJ}{kgK} \times 298K} = 0.8079\,kg$

Energy balance $\Delta U = 0$

$$\left[m\,c_v\,(T_2 - T_1)\right]_{N_2} + \left[m\,c_v\,(T_2 - T_1)\right]_{He} = 0$$

$$4.772\,kg \times 0.743\,\frac{kJ}{kgK}\,(T_2 - 80)^\circ C + 0.8079\,kg \times 3.1156\,\frac{kJ}{kgK}\,(T_2 - 25) = 0$$

$$3.546\,T_2 - 283.65 + 2.517\,T_2 - 62.93 = 0$$

Final temp $T_2 = 57.2\,^\circ C$.

In final state $P_{N_2} = P_{He} = P$

$PV_{N_2} = (mRT)_{N_2} = 4.772\,kg \times 0.2968\,\frac{kJ}{kgK} \times 330.2K$

$PV_{N_2} = 467.67\,kJ$

$PV_{He} = (mRT)_{He} = 0.8079\,kg \times 2.0769\,\frac{kJ}{kgK} \times 330.2K$

$PV_{He} = 554.05\,kJ$

$\Rightarrow \frac{V_{N_2}}{V_{He}} = 0.84409.;\ V_{N_2} + V_{He} = 2m^3$

$\Rightarrow V_{He} = 1.085\,m^3,\ V_{N_2} = 0.915\,m^3$

2) $$m = \frac{P_1 V_1}{R T_1} = \frac{100\,kPa \times 0.2\,m^3}{2.0769\,\frac{kJ}{kg\,K} \times 283\,K} = 0.03403\,kg$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \Rightarrow V_2 = \frac{T_2}{T_1} \cdot \frac{P_1}{P_2} \cdot V_1$$

$$\Rightarrow V_2 = \frac{563\,K}{283\,K} \times \frac{100\,kPa}{700\,kPa} \times 0.2\,m^3$$

$$V_2 = 0.05684\,m^3$$

$$P_1 V_1^{\,n} = P_2 V_2^{\,n} \Rightarrow \frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^n$$

$$\Rightarrow n \ln\left(\frac{V_1}{V_2}\right) = \ln\left(\frac{P_2}{P_1}\right)$$

$$\Rightarrow n \ln\left(\frac{0.2\,m^3}{0.05684\,m^3}\right) = \ln\left(\frac{700\,kPa}{100\,kPa}\right)$$

$$\Rightarrow n = 1.547.$$

$$W_{12} = \frac{P_2 V_2 - P_1 V_1}{n-1} = \frac{mR(T_2 - T_1)}{n-1.}$$

$$W_{12} = \frac{0.03403\,kg \times 2.0769\,\frac{kJ}{kg\,K}\,(563 - 283)\,K}{1.547 - 1}$$

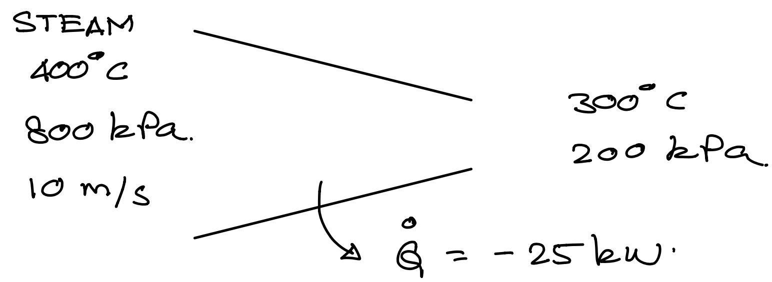
$$W_{12} = 36.18\,kJ$$

$$W_{12} + Q_{12} = m c_v (T_2 - T_1)$$

$$\Rightarrow Q_{12} = 0.03403\,kg \times 3.1156\,\frac{kJ}{kg\,K}\,(563-283)\,K - 36.18\,kJ$$

$$Q_{12} = -6.49\,kJ$$

3



$$\left.\begin{aligned} P_1 &= 800\ \text{kPa} \\ T_1 &= 400^\circ C \end{aligned}\right\} \quad \begin{aligned} v_1 &= 0.38429\ \text{m}^3/\text{kg} \\ h_1 &= 3267.7\ \text{kJ/kg} \end{aligned}$$

$$\left.\begin{aligned} P_2 &= 200\ \text{kPa} \\ T_2 &= 300^\circ C \end{aligned}\right\} \quad \begin{aligned} v_2 &= 1.31623\ \text{m}^3/\text{kg} \\ h_2 &= 3072.1\ \text{kJ/kg} \end{aligned}$$

$$\dot{m} = \frac{A_1 V_1}{v_1} = \frac{800 \times 10^{-4}\ \text{m}^2 \times 10\ \text{m/s}}{0.38429\ \text{m}^3/\text{kg}}$$

$$\dot{m} = 2.082\ \text{kg/s}$$

$$\dot{Q} + \cancel{\dot{W}}^{\,0} = \dot{m}\left[(h_2 - h_1) + \frac{V_2^2 - V_1^2}{2}\right]$$

$$-25\ \text{kW} = 2.082\ \frac{\text{kg}}{\text{s}}\left[(3072.1 - 3267.7)\ \frac{\text{kJ}}{\text{kg}} + \frac{V_2^2 - \left(10\ \frac{\text{m}}{\text{s}}\right)^2}{2 \times 1000\ \frac{\text{J}}{\text{kJ}}}\right]$$

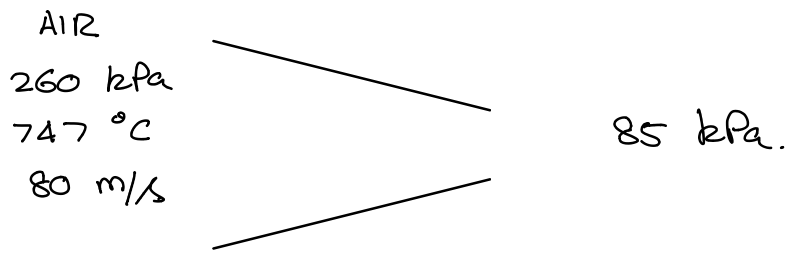
$$V_2 = 606.0\ \text{m/s}$$

$$A_2 = \frac{\dot{m}\, v_2}{V_2} = \frac{2.082\ \text{kg/s} \times 1.31623\ \text{m}^3/\text{kg}}{606.0\ \text{m/s}}$$

$$A_2 = 45.2 \times 10^{-4}\ \text{m}^2$$

$$A_2 = 45.2\ \text{cm}^2$$

(4)



For an isentropic process.

$$\frac{T_{2s}}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}}$$

$$\Rightarrow \quad T_{2s} = 1020\,K\left(\frac{85\,kPa}{260\,kPa}\right)^{\frac{0.4}{1.4}} = 741.1\ K.$$

$$\cancel{\dot{Q}}^{\,0} + \cancel{\dot{W}}^{\,0} = \dot{m}\left[(h_{2s} - h_1) + \frac{V_{2s}^2 - V_1^2}{2}\right]$$

$$\Rightarrow \quad \frac{V_{2s}^2 - V_1^2}{2} = -c_p\,(T_{2s} - T_1)$$

$$\Rightarrow \quad \frac{V_{2s}^2 - (80\ m/s)^2}{2 \times 1000\ J/kJ} = -1.005\ \frac{kJ}{kg\,K}\,(741.1 - 1020\,K)$$

$$V_{2s} = 753.0\ m/s$$

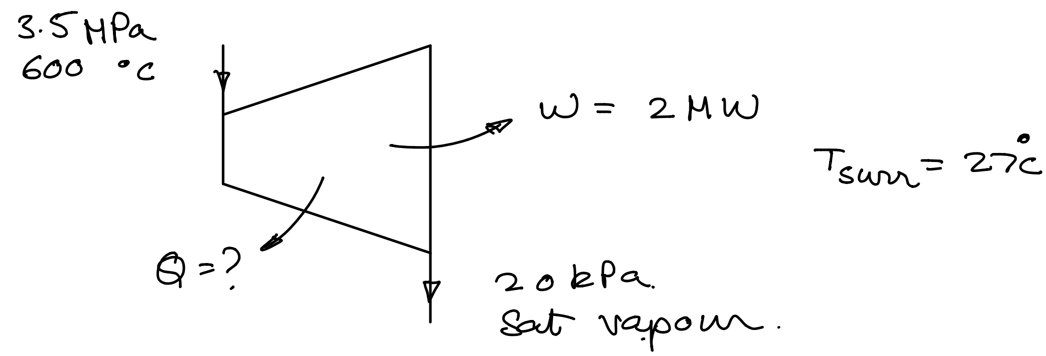
$$V_{2a} = \sqrt{\eta_{nozzle}}\ V_{2s} = \sqrt{0.92}\ (753\ m/s)$$

$$V_{2a} = 722.3\ m/s$$

$$T_{2a} - T_1 = -\frac{V_{2a}^2 - V_1^2}{2\,c_p}$$

$$T_{2a} = 1020\,K - \frac{(722.3\ m/s)^2 - (80\ m/s)^2}{2 \times 1000\ J/kJ \times 1.005\ \frac{kJ}{kg\,K}} = 763.6\ K$$

(5)



$$\left.\begin{array}{l} P_1 = 3.5\,\text{MPa} \\ T_1 = 600^\circ C \end{array}\right\} \begin{array}{l} h_1 = 3678.9 \ \text{kJ/kg} \\ s_1 = 7.4357 \ \text{kJ/kg K} \end{array}$$

At 20 kPa. $h_2 = h_g = 2608.9$ kJ/kg

$s_2 = s_g = 7.9073$ kJ/kg K

$$\dot{Q} = -\dot{W} + \dot{m}\,(h_2 - h_1)$$

$$\dot{Q} = +2000 \ \frac{\text{kJ}}{\text{s}} + \frac{125 \ \frac{\text{kg}}{\text{min}}}{60 \ \text{s/min}} (2608.9 - 3678.9)$$

$$\dot{Q} = -229.2 \ \text{kW}$$

$$\dot{S}_{in} - \dot{S}_{out} + \dot{S}_{gen} = 0$$

$$\dot{m} s_1 + \frac{\dot{Q}}{T_{surr}} - \dot{m} s_2 + \dot{S}_{gen} = 0$$

$$\Rightarrow \quad \dot{S}_{gen} = \dot{m}\,(s_2 - s_1) - \frac{\dot{Q}}{T_{surr}}$$

$$= \frac{125}{60}(7.9073 - 7.4357) + \frac{229.2}{300}$$

$$\dot{S}_{gen} = 1.75 \ \text{kW/K}.$$