CHE 260 MIDTERM
2015

1) Air

100 kPa

300 K

200 m/s

100 mm^2

20 m/s

860 mm^2

$$h_2 - h_1 = \frac{V_1^2 - V_2^2}{2}$$

$$C_p (T_2 - T_1) = \frac{V_1^2 - V_2^2}{2}$$

$$\Rightarrow T_2 = T_1 + \frac{V_1^2 - V_2^2}{2C_p}$$

For air $C_p = 1.004$ kJ/kg K.

$$\Rightarrow T_2 = 300\,K + \frac{(200\,m/s)^2 - (20\,m/s)^2}{2 \times 1.004\,kJ/kg \times 1000\,J/kJ}$$

$$= 319.7\ K.$$

$$\dot{m} = \frac{\vec{V}_2 A_2}{v_2} = \frac{\vec{V}_1 A_1}{v_1}$$

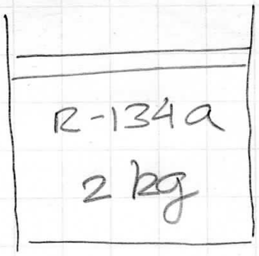
$$\Rightarrow \frac{v_1}{v_2} = \left(\frac{\vec{V}_1}{\vec{V}_2}\right)\cdot\left(\frac{A_1}{A_2}\right) = \left(\frac{T_1}{P_1}\right)\left(\frac{P_2}{T_2}\right)$$

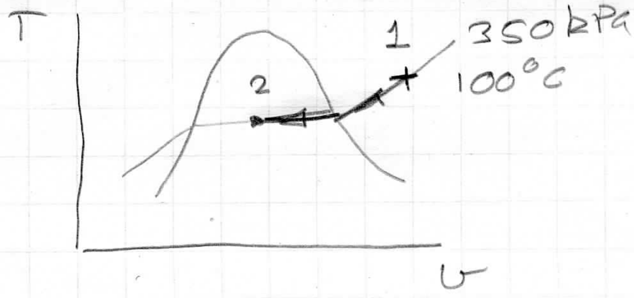
$$\Rightarrow P_2 = P_1 \left(\frac{T_2}{T_1}\right)\left(\frac{\vec{V}_1}{V_2}\right)\left(\frac{A_1}{A_2}\right)$$

$$= 100\,kPa \left(\frac{319.7\,K}{300\,K}\right)\left(\frac{200\,m/s}{20\,m/s}\right)\left(\frac{100\,mm^2}{860\,mm^2}\right)$$

$$= 123.9\ kPa.$$

2)





$P_1 = 320$ kPa

$T_1 = 100°C$

$x_2 = 0.75$

At const P $\quad W = -P(V_2 - V_1) = -mP(v_2 - v_1)$

Energy balance.

$$Q + W = \Delta U$$

$$Q = m(u_2 - u_1) - W$$

at 320 kPa, 100°C $\Big\}$ $v_1 = 0.09229$ m³/kg, $u_1 = 312.68$ kJ/kg

at 320 kPa

$v_f = 0.000777$ m³/kg

$v_g = 0.0632$ m³/kg

$u_f = 53.06$ kJ/kg

$u_g = 228.43$ kJ/kg.

$$v_2 = v_f + x_2(v_g - v_f)$$
$$= 0.000777 + 0.75(0.0632 - 0.000777)$$
$$= 0.047594 \text{ m}^3/\text{kg}$$

$$u_2 = u_f + x_2(u_g - u_f)$$
$$= 53.06 + 0.75(228.43 - 53.06)$$
$$= 184.59 \text{ kJ/kg}$$

$$W = -mP(v_2 - v_1) = -2 \times 320 \times (0.047594 - 0.09229)$$
$$= 28.6 \text{ kJ}$$

$$Q = 2\text{ kg}(184.59 - 312.68) - 28.6$$
$$= -284.78 \text{ kJ}$$

3

Energy Balance

$$Q + \underset{0}{\cancel{W}} = \Delta U = m C_v (T_2 - T_1)$$

For argon $C_v = 0.312$ kJ/kg K

$$q = \frac{Q}{m} = C_v (T_2 - T_1)$$

$$= 0.312 \frac{kJ}{kg\,K} (20°C - 70°C)$$

$$= -15.6 \text{ kJ/kg}$$

$$\Delta s = \underset{0}{\cancel{s_{in}}} - s_{out} + s_{gen}$$

$$\Rightarrow \quad s_{gen} = \Delta s + s_{out}$$

$$s_{out} = \frac{q}{T_{surr}} = \frac{15.6 \text{ kJ/kg}}{(273+20)\text{K}}$$

$$= 0.0532 \text{ kJ/kg K}$$

$$\Delta s = s_2 - s_1 = C_v \ln \frac{T_2}{T_1} + \cancel{R \ln \frac{v_2}{v_1}}$$

$$\Delta s = C_v \ln \frac{T_2}{T_1}$$

$= 0$, const volume

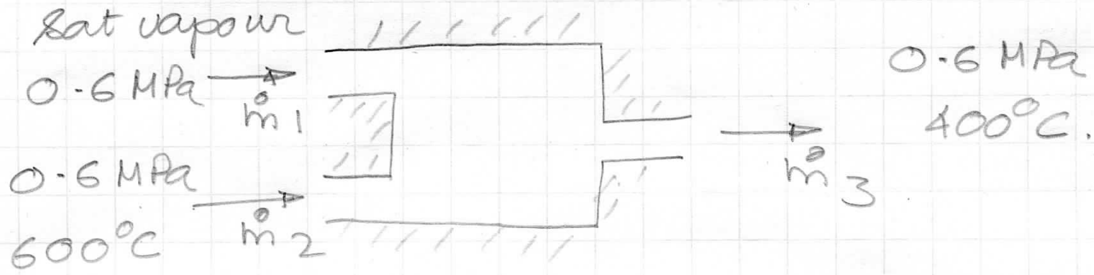
$$= 0.312 \frac{kJ}{kg\,K} \ln \left(\frac{20 + 273 \text{ K}}{70 + 273 \text{ K}} \right)$$

$$= -0.0492 \text{ kJ/kg K}$$

$$s_{gen} = -0.0492 \text{ kJ/kg K} + 0.0532 \frac{kJ}{kg\,K}$$

$$= 0.0040 \text{ kJ/kg K}$$

4)



At 0.6 MPa, sat vapour

$h_1 = 2756.8$ kJ/kg

$s_1 = 6.7600$ kJ/kg K.

At 0.6 MPa, 600°C

$h_2 = 3700.9$ kJ/kg

$s_2 = 8.2674$ kJ/kg K

At 0.6 MPa, 400°C

$h_3 = 3270.3$ kJ/kg

$s_3 = 7.709$ kJ/kg K

Mass Balance

$$\dot{m}_1 + \dot{m}_2 = \dot{m}_3$$

Energy Balance $\dot{m}_1 h_1 + \dot{m}_2 h_2 = \dot{m}_3 h_3$

$$\Rightarrow \dot{m}_1 h_1 + (\dot{m}_3 - \dot{m}_1) h_2 = \dot{m}_3 h_3$$

$$\Rightarrow \frac{\dot{m}_1}{\dot{m}_3} h_1 + \left(1 - \frac{\dot{m}_1}{\dot{m}_3}\right) h_2 = h_3$$

$$\Rightarrow \frac{\dot{m}_1}{\dot{m}_3} = \frac{h_3 - h_2}{h_1 - h_2} = \frac{3270.3 - 3700.9}{2756.8 - 3700.9} = 0.4561$$

Entropy Balance

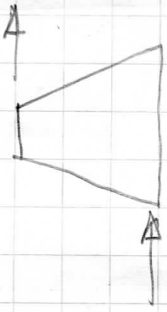
$$\dot{S}_{gen} + \dot{m}_1 s_1 + \dot{m}_2 s_2 = \dot{m}_3 s_3$$

$$\frac{\dot{S}_{gen}}{\dot{m}_3} = -\frac{\dot{m}_1}{\dot{m}_3} s_1 - \left(1 - \frac{\dot{m}_1}{\dot{m}_3}\right) s_2 + s_3$$

$$= -0.4561 \times 6.7600 - 0.5439 \times 8.2674 + 7.709.$$

$$= 0.1291 \text{ kJ/kg K.}$$

5)



For CO_2, $c_p = 0.842\ kJ/kgK$, $\gamma = 1.289$

$$W_a = h_2 - h_1 = c_p (T_2 - T_1)$$

$$= 0.842 \frac{kJ}{kg\,K} (520\ K - 300\ K)$$

$$= 185.24\ kJ/kg.$$

For isentropic compression

$$T_{2s} = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} = 300\ K \left(\frac{1000\ kPa}{100\ kPa}\right)^{\frac{0.289}{1.289}}$$

$$T_{2s} = 502.7\ K.$$

$$W_s = c_p (T_{2s} - T_1) = 0.842 \frac{kJ}{kg\,K} (502.7\ K - 300\ K)$$

$$= 170.69\ kJ/kg.$$

$$\eta_t = \frac{W_s}{W_a} = \frac{170.69}{185.24} = 0.9215$$

$$\eta_t = 92\%.$$

$$s_{gen} = s_2 - s_1 = c_p \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1}$$

For CO_2 $R = 0.1889\ kJ/kg\,K$

$$s_{gen} = 0.842 \ln\left(\frac{520\ K}{300\ K}\right) - 0.1889 \ln\left(\frac{1000}{10}\right)$$

$$= 0.0282\ kJ/kg\,K.$$