[redacted]

1.a) Entropiebilanz um Mantel:

$$0 = \dot{m}[h_{ein} - h_{aus}] + \dot{Q}_{aus}$$

$$\Delta S = \frac{\dot{Q}_{aus}}{\overline{T}}$$

$$\dot{Q}_{aus} = \dot{m}[h_{aus} - h_{ein}]$$

$$= \dot{m}\left[\int_{T_{ein}}^{T_{aus}} c\, dT + v^{if}(p_2 - p_1)\right]$$

$$\dot{Q}_{aus} = \dot{m}\, c\,(T_{aus} - T_{ein})$$

b) $$\overline{T} = \frac{\int_{ein}^{aus} T\, ds}{s_{aus} - s_{ein}} = \frac{q_{rev}}{s_{aus} - s_{ein}} = \frac{c_p (T_{aus} - T_{ein})}{c_p \ln\left(\frac{T_{aus}}{T_{ein}}\right)} = \underline{\underline{293{,}12\,K}}$$

c) Entropiebilanz um Wand:

$$\dot{S}_{erz} = \frac{\dot{Q}_{aus}}{\overline{T}} = \frac{65\,kW}{293.12\,K} = \underline{\underline{0.222\,\frac{kW}{K}}}$$

d) $$Q_1 = m_{ges,1} \cdot c \cdot T$$

$$\Delta E = \Delta m_{12}(h_2 - h_1) + Q_{R,12}$$

$$\Delta u = \Delta m_{12}(h_2 - h_1) + Q_{R,12}$$

$$\Delta m_{12} = \frac{u_2 - u_1 - Q_{R,12}}{h_2 - h_1}$$

e) Entropiebilanz: $$\Delta S = \Delta m(s_2 - s_1) + \frac{Q_{R,12}}{\overline{T}_{12}} =$$

$$\overline{T}_{12} = \frac{T_2 - T_1}{\ln\left(\frac{T_2}{T_1}\right)}$$

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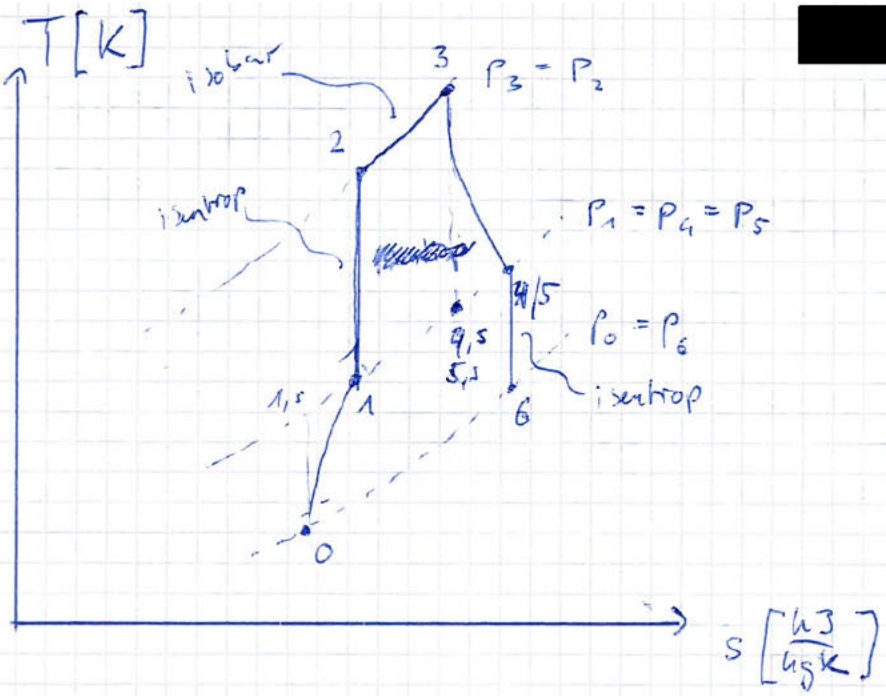
2.a)



b) Energiebilanz um Schubdüse

$w_5 = 220 \frac{m}{s}$ $\quad p_5 = 0.5\,bar$ $\quad T_5 = 431.9\,K$

$\dot{m}_5 = \dot{m}_c = \dot{m}_{ges}$ $\quad p_6 = 0.191\,bar$ $\quad T_6 = T_0 = -30°C = 243.15\,K$

$0 = \dot{m}\left[h_5 - h_6 + \frac{(w_5^2 - w_6^2)}{2}\right] - \dot{W}_{t,56}$

~~$w_6 = \sqrt{2(h_6 - h_5) - w_5^2}$~~

~~$h_6 - h_5 = c_p \Delta T = c_p(T_6 - T_5)$~~

~~$w_6^2 = 2(h_5 - h_6) - w_5^2 + w_{t,56}$~~

~~$w_6 = \sqrt{w_5^2 - 2(h_6 - h_5)}$~~ ~~$= 400.8 \frac{m}{s}$~~

~~$h_6 - h_5 = c_p(T_6 - T_5)$~~

$w_{t,56} = -\int_5^6 v\,dp + \Delta ke$

$= -RT_5 \ln\left(\frac{p_6}{p_5}\right) + \frac{(w_6^2 - w_5^2)}{2}$

$v_5 = \frac{RT_5}{p_5}$

$0 = h_5 - h_6 + w_5^2 -$

2.c) $e_{x,str} = h - h_0 - T_0(s - s_0) + ke + \cancel{pe}^{0}$, $R = c_p - \frac{c_p}{\kappa}$

$= 0.287 \frac{kJ}{kg\,K}$

$e_{x,str,6} = h_6 - h_0 - T_0(s_6 - s_0) + \frac{w_6^2}{2}$

$= c_p(T_6 - T_0) - T_0\left(c_p \ln\left(\frac{T_6}{T_0}\right) - R \ln\left(\frac{p_6}{p_0}\right)\right) + \frac{w_6^2}{2}$

$= 130'005 \frac{kJ}{kg} = \underline{130 \frac{MJ}{kg}}$

$e_{x,str,0} = ke = \frac{w_6^2}{2}$

$\Delta e_{x,str} = e_{x,str,6} - ke_0$

→

d) Exergiebilanz um str. FP (ganzes System):

$0 = E_{x,str,0} - E_{x,str,6} + E_{x,Q,0} - E_{x,Q,6} - E_{x,verl}$

$e_{x,verl} = -\Delta e_{x,str} + (-\delta e_{x,Q})$

$\Delta e_{x,Q} =$

Über Entropiebilanz:

$0 = \dot{m}_{ges} s_0 - \dot{m}_{ges} s_6 + \frac{\dot{Q}_{06}}{\overline{T}_{06}} + s_{erz}$

$s_{erz} = s_6 - s_0 - \frac{q_{06}}{\overline{T}_{06}}$

$q_{06} = q_B$; $\overline{T} = \frac{h_6 - h_0}{s_6 - s_0} = \frac{c_p \Delta T}{c_p \ln\left(\frac{T_6}{T_0}\right)} = 288.87\,K$; $s_6 - s_0 = c_p \ln\left(\frac{T_6}{T_0}\right)$

$s_{erz} = 3.79 \frac{kJ}{K}$

$e_{x,verl} = T_0 s_{erz} = \underline{-923.856 \frac{kJ}{kg}}$

3. a) $p_{g,1} = \frac{m_{EW} g}{A} + \frac{m_K g}{A} + p_{amb}$

$A = \pi \left(\frac{D}{2}\right)^2 = 0.0079\ m^2$

$p_{g,1} = \underline{1.39861\ bar}$

i. G. $m = \frac{pV}{RT}$; $R = \frac{\bar{R}}{M_g} = 0.16628\ \frac{kJ}{kg K}$

$m_g = 0.0034\ kg$

$= \underline{3.416036\ g}$

b) System im Gleichgewicht

c) $Q_{12} = m_g c_V \Delta T = 0.633 \frac{kJ}{kg K} \cdot 3.6 \cdot 10^{-3}\ kg \cdot (773.15K - 273.153K)$

$= \underline{1.139\ kJ}$

d) $T_{EW,2} = T_{g,2}$ (da, Gleichgewicht)

$\leftarrow$ (alle bei $p = 1\ bar$, $T = 0.003°C$)

$x_{Eis,1} + x_{Eis,2} = \frac{u_2 - u_{fest}}{u_{flüssig} - u_{fest}} = 0.644$

$Q_{12} = \Delta U$, da isochor

$q_{12} = u_2 - u_1$

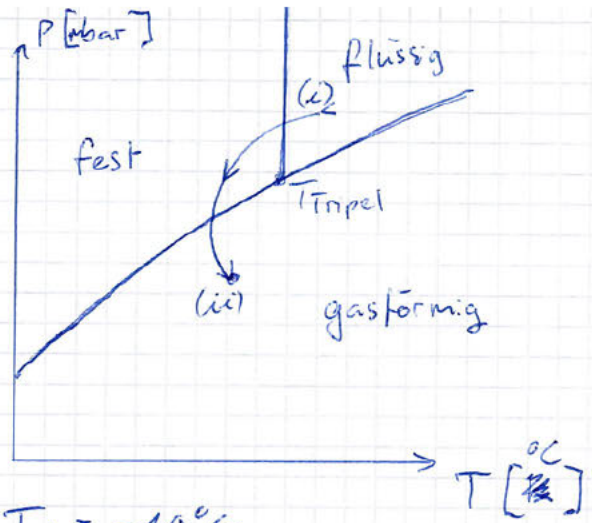
$u_2 = q_{12} + u_1 = \frac{Q_{12}}{m_{EW}} + u_1 = \frac{1500kJ}{0.1 kg} + \left(-133.41 \frac{kJ}{kg}\right) = -118.41 \frac{kJ}{kg}$

$u_1 = u_{fest} + x_1 \left(u_{flüssig} - u_{fest}\right)$ alle bei $p = 1.4\ bar$, $T = 0°C$

$= -133.41 \frac{kJ}{kg}$

$x_{Eis,2} = 0.555$

9 a)



b) $T_i = -10°C$

Energiebilanz um Verdichter:

$$0 = \dot{m}[h_2 - h_3] - \dot{W}_K$$

$$\dot{m} = \frac{\dot{W}_K}{h_2 - h_3}$$

$h_2 = h_g(T = T_i - 6K) = 237.14 \frac{kJ}{kg}$ (A-10)

$h_3 = ?$

$s_3 = s_2 = s_g(T = T_i - 6K) = 0.9298 \frac{kJ}{kgK}$ (A-10)

$$h_3 = h(s = s_3, p = 8bar) = h(T_{sat}, 8bar) + \frac{h(40°C, 8bar) - h(T_{sat}, 8bar)}{s(40°C, 8bar) - s(T_{sat}, 8bar)}\left(s_3 - s(T_{sat}, 8bar)\right)$$

$$= 271.31 \frac{kJ}{kg}$$

$$\dot{m} = \frac{28 \cdot 10^{-3} kW}{h_2 - h_3} = 0.000834 \frac{kg}{s}$$

c)