[redacted]

①

a)

$$0 = \dot{m}\,(h_{ein} - h_{aus}) + \dot{Q}_R - \dot{Q}_{AB}$$

$$\dot{Q}_{AB} = \dot{Q}_R + \dot{m}_{ein}\,(h_{ein} - h_{aus}) = 100\,kW + 0.3\,\frac{kg}{s}\,(292.98 - 419.04)\,\frac{kJ}{kg} = \underline{\underline{62.18\,kW}}$$

$h_{ein} = h_1(70°C) = 292.98\,\frac{kJ}{kg}$ ← A2

$h_{aus} = h_1(100°C) = 419.04\,\frac{kJ}{kg}$ ← A2

b)

$$\bar{T}_{FK} = \frac{\int_{Se}^{Sa} T\,dS}{S_a - S_e} =$$

c)

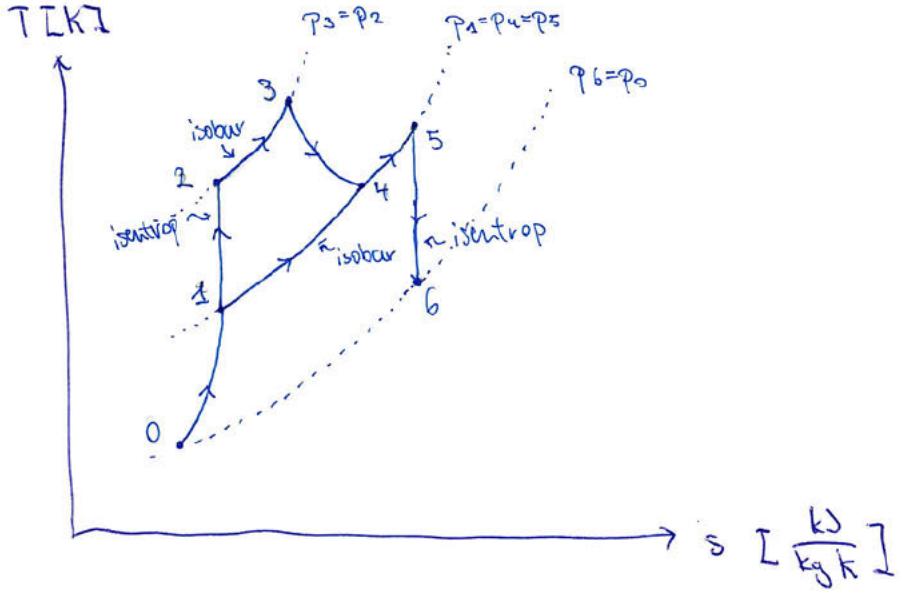
[redacted]

(2)

0→1 adiabat, Verdichtung
1→2 isentrop
2→3 isobar
3→4 adiabat, irrevers. ✶
4→5 mischung, isobar
5→6 isentrop

$p_5 = p_4 = p_1 = 0.5\,bar$

a)



b) w_6, T_6 ?

5→6 reversibel + adiabat → isentrop $S_5 = S_6$

$$T_6 = T_5 \left(\frac{p_6}{p_5}\right)^{0.4/1.4} = 431.3K \cdot \left(\frac{0.191}{0.5}\right)^{0.4/1.4} = \underline{328.07\,K}$$

st. FP.

$$0 = \dot{m}_{ges}\left(h_0 - h_6 + \frac{w_0^2 - w_6^2}{2}\right) + \cancel{\dot{Q}}^{0,\,adiabat} + \cancel{W_T}^{0} + q_B \dot{m}_K$$

$m_{ges} = m_M + m_K = m_K(1 + 5.253)$

$\dot{m}_K = \frac{1}{6.253}\,\dot{m}_{ges}$

$$w_6^2 = q_B + 2\,\dot{m}_{ges}(h_0 - h_6) + w_0^2 = 2\,c_{p,Luft}(T_0 - T_6) + w_0^2 + q_B \frac{1}{6.253}$$

$$w_6 = \sqrt{2 \cdot 1.006 \frac{kJ}{kgK}(-243.15K + 328.07K) + (200\,m/s)^2} = 459.2\,m/s$$

[redacted]

(2)

c)

$$e_{x,tr,0} = \left(h_0 - h_0 - T(s_0 - s_0) + \frac{w_0^2}{2}\right) = \frac{w_0^2}{2} = 20 \frac{kJ}{kg}$$

$$e_{x,tr,6} = h_6 - h_0 - T_0 (s_6 - s_0) + \frac{w_6^2}{2} = c_p (T_6 - T_0) - T_0 \left(c_p \ln\left(\frac{T_6}{T_0}\right) - R \ln\left(\frac{p_6}{p_0}\right)\right) + \frac{w_6^2}{2}$$

$$= 1.006 \frac{kJ}{kgK} \left(340\,K - 243.15\,K - 243.15\,K \cdot \ln\left(\frac{340\,K}{243.15\,K}\right)\right) + \frac{(510\,m/s)^2}{2}$$

$$= 145.47 \frac{kJ}{kg}$$

$$\Delta e_{x,tr} = 125.47 \frac{kJ}{kg}$$

(3)

a)

m_g , $p_{g,1}$

Kräfte ggw $\quad p_{g,1} \cdot \frac{D^2}{4}\pi = g(m_{EW} + m_K) + p_{amb} \frac{D^2}{4}\pi$

$$p_{g,1} = \frac{4}{D^2\pi} g(m_{EW} + m_K) + p_{amb}$$

$$= \frac{4}{(0.1m)^2\pi} 9.81 m/s^2 (0.1kg + 32kg) + 10^5 Pa$$

$$= \underline{1.40 bar}$$

$m_g R T_2 = p_{g2} V_{g2}$ $\quad \rightarrow R = \frac{\bar{R}}{M_g} = \frac{8.314 \frac{J}{mol\,K}}{50 \cdot 10^{-3} \frac{kg}{mol}} = 166.28 \frac{J}{kg\,K}$

$$m_g = \frac{p_{g2} V_{g2}}{R T_1} = \frac{1.4 \cdot 10^5 Pa \cdot 3.14 \cdot 10^{-3} m^3}{166.28 \frac{J}{kg\,K} \cdot 273.15 K} = \underline{3.419 g}$$

b)

$\underline{p_{g,2} = p_{g,1}}$ Das System muss weiterhin im Gleichgewicht mit dem Umgebungs-druck und der Gewichtskraft sein!

↳ $p_{g,2} = 1.40 bar$

$\underline{T_{g,2} = 0°C}$ Das Gas ist im thermodynamischen GGW mit dem Eiswasser, da $x_{Eis,2} > 0$ ist muss das Gemisch weiterhin bei $T_{Eis,2} = 0°$ sein und somit ist auch die Gastemperatur bei 0°C!

c)

$$\Delta E_{12} = \Delta U_{12} = m_g c_v (T_{2,g} - T_{1,g}) = Q_{12} - W_V$$

$$W_V = p_{g_2}(V_{2,g} - V_{1,g}) = 1.4 \cdot 10^5 Pa \, (1.109 - 3.14) \cdot 10^{-3} m^3 = -284.34 J$$

? reversible Arbeit an einem reibungsfreien zyklischen

$$V_{2,g} = \frac{m_g R T_2}{p_{2,g}} = \frac{3419 \cdot 10^{-3} kg \cdot 166.28 \frac{J}{kgK} \cdot 273.15 K}{1.4 \cdot 10^5 Pa} = \underline{1.109 L}$$

$$Q_{12} = m_g c_v (T_{g,2} - T_{g,1}) + W_V$$

$$= 3.419 \cdot 10^{-3} kg \cdot 0.633 \cdot 10^3 \frac{J}{kgK} (-500 K) - 284.34 J$$

$$= \underline{-1366.5 J}$$

d)

$$T_{EW,2} = T_{g,2} = 0°C$$

$$\Delta E_{kon\,12} = \Delta U_{12} = Q_{12}$$

$$m_{EW}(u_2 - u_1) = \text{~~} = Q_{12}$$

$$Q_{12} = m_{EW} \left(u_{Fest}(1.4bar) \cdot x_{2,Eis} + (1 - x_{2,Eis}) u_{Flüssig}(1.4bar) - u_{Fest}(1.4bar) x_{1,Eis} - (1 - x_1) u_{Flüssig} \right)$$

$$\frac{Q_{12}}{m_{EW}} = \left(x_{2,Eis} (u_{Fest} - u_{Flüssig}) + u_{Flüssig} \right) - \left(u_{Flüssig} + x_{1,Eis} (u_{Fest} - u_{Flüssig}) \right)$$

$$x_{2,Eis} = \frac{1}{u_{Fest} - u_{Flüssig}} \left(\frac{Q_{12}}{m_{EW}} \right) + x_{1,Eis}$$

$u_{Fest} = -333.458 \frac{kJ}{kg}$ TAB 1

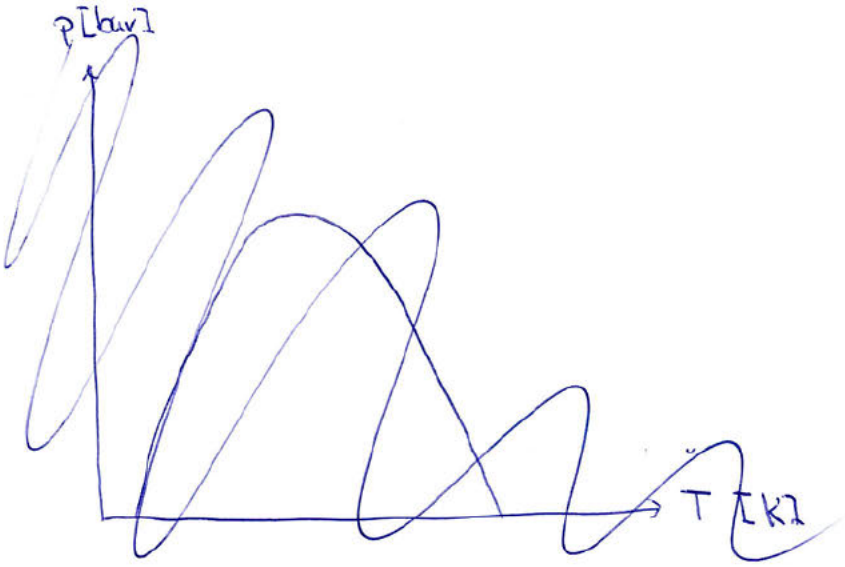
$u_{Flüssig} = -0.045 \frac{kJ}{kg}$

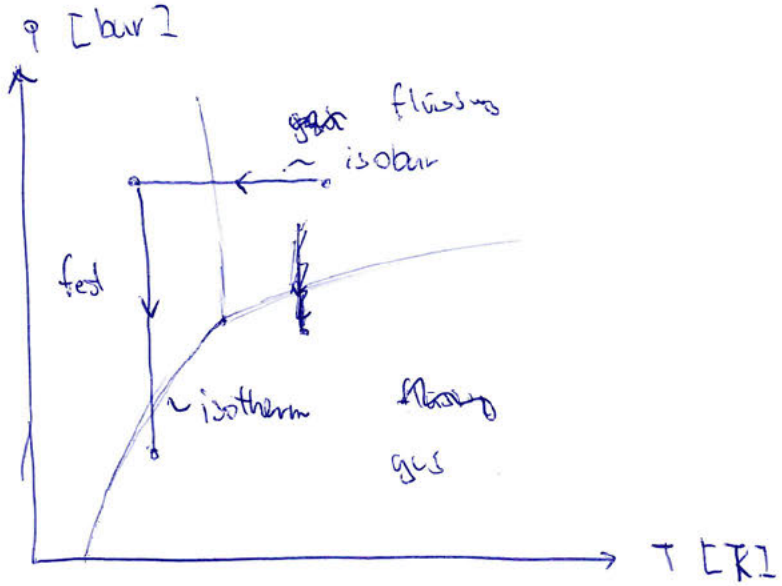
$$x_{2,Eis} = \frac{1}{(-333.458 + 0.045) \frac{kJ}{kg}} \cdot \left(\frac{-1366.5 J}{0.1 kg} \right) + 0.6$$

$$x_{2,Eis} = \underline{0.559}$$

(4)

a)





④

b)

$p_1 = p_2 \qquad p_3 = p_4 = 8\,bar \qquad \rightarrow p_2 = p_1 = p($

$h_4 = h_3 = h_f(8\,bar) = 93.42 \frac{kJ}{kg}$ (A11)

$s_3 = s_2$

$\dot{Q} = \dot{m}_R (h_2 - h_3) - \dot{W}_K$

$\dot{m}_R = \frac{\dot{W}_K}{h_2 - h_3} = \frac{-28\,kW}{(237.74 - 253.31)\frac{kJ}{kg}} = \underline{1.80 \frac{kg}{s}}$

$h_2 = h_g(257.15\,K) = h_g(-16°C) = \underline{237.74 \frac{kJ}{kg}}$ A10

$T_1 = T_2 = T_i - 6K = T_{Sättigung} + (10-6)K = (273.15K - 20K) + 4K = 257.15 = -16°C$

~~$h_3(8bar, s_2) = 93.43 \frac{kJ}{kg} + 264.15$~~

$s_2 = s_g(-16°C) = 0.9298 \frac{kJ}{kgK} = s_3$ A10

$h_3(8bar, s_2) = 264.15 \frac{kJ}{kg} \frac{273.66 - 264.15}{0.9374 - 0.9066} (0.9298 - 0.9066)$

$= \underline{253.31 \frac{kJ}{kg}}$

c)

$h_1 = 93.42 \frac{kJ}{kg} = h_f(-16°C) + x_1 (h_g - h_f)$ TAB 10 (16°C)

$\rightarrow x_1 = \frac{h_1 - h_f}{h_g - h_f} = \underline{0.3076}$

d)

$\varepsilon_K = \frac{|\dot{Q}_{zu}|}{|\dot{W}_T|} = \frac{|\dot{Q}_K|}{|\dot{W}_T|} = \frac{259.8}{28.} = \underline{9.28}$

$\dot{Q}_K = \dot{m}_R (h_2 - h_1) = 1.80 \frac{kg}{s} (237.74 - 93.42) \frac{kJ}{kg} = \underline{259.8\,kW}$

e) die Temperatur würde sich schwerlich auf $T_2 = -16°C$ einpendeln!