[redacted]

1) a) $\dot{Q}_{aus}$: Energiebilanz (stationär)

$$0 = \dot{m}_{ein}\left(h_e(70°C) - h_{aus}(100°C)\right) + \dot{Q}_R + \dot{Q}_{aus} - \cancel{\dot{W}}^{\,0}$$

im Reaktor $x = 0.005$

$$h_{ein} = h(70°C, 0.005) \overset{\text{TAB A-2}}{=} 292.98 + 0.005\,(2626.8 - 292.98) = \underline{304.6491\ \tfrac{kJ}{kg}}$$

$$h_{aus} = h(100°C, 0.005) \overset{\text{TAB A-2}}{=} 419.04 + 0.005\,(2676.1 - 419.04) = \underline{430.3253\ \tfrac{kJ}{kg}}$$

$$\Rightarrow \dot{Q}_{aus} = \dot{m}_{ein}\left(h_{aus} - h_{ein}\right) - \dot{Q}_R = 0.3\,(430.3253 - 304.6491) - 100\cdot$$

$$\underline{\underline{= -62.297\ kJ}}$$ (Vorzeichenkonvention: Q_{ein} positiv, Q_{aus} negativ)

(wenn wie auf Skizze: $\dot{Q}_{aus} = 62.297\,kJ$)

b) $$\overline{T} = \frac{\int_e^a T\,ds}{s_a - s_e}$$

$$s_a^{if} - s_e^{if} = \int_{T_1}^{T_2} \frac{c^{if}(T)}{T}\,dT = c^{if}\ln\left(\frac{T_2}{T_1}\right)$$

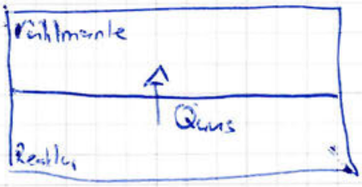
$$\int T\,ds = dH - V\,\underbrace{dp}_{0,\ \text{da druck konstant}}$$

$$\int T\,ds = dH = \int_{T_1}^{T_2} c^{if}\,dT + v^{if}\cancel{(p_2 - p_1)}^{\,0} = c^{if}(T_2 - T_1)$$

$$\cancel{\overline{T} = \frac{c^{if}(T_2 - T_1)}{c^{if}\ln\left(\frac{T_2}{T_1}\right)} = \frac{288.15 - 298.15}{\ln\left(\frac{288}{\ }\right)}}$$

$$\overline{T}_{KF} = \frac{c^{if}(T_2 - T_1)}{c^{if}\ln\left(\frac{T_2}{T_1}\right)} = \frac{298.15 - 288.15}{\ln\left(\frac{298.15}{288.15}\right)} = \underline{\underline{293.12\,K}}$$

c) $\dot{S}_{erz}$:



Entropiebilanz: $$0 = \dot{m}(s_e - s_a) + \frac{\dot{Q}_{aus}}{\overline{T}_{KF}} + \dot{S}_{erz}$$

$$\dot{S}_{erz} = \dot{m}(s_a - s_e) - \frac{\dot{Q}_{aus}}{\overline{T}_{KF}}$$

$$s_a = s(100°C, x = 0.005) \overset{\text{TAB A2}}{=} 1.3069 + 0.005\,(7.3549 - 1.3069) = \underline{1.33714\ \tfrac{kJ}{kgK}}$$

$$s_e = s(70°C, x = 0.005) = 0.9549 + 0.005\,(7.7553 - 0.9549) = \underline{0.9889\ \tfrac{kJ}{kgK}}$$

$$\dot{S}_{erz} = 0.3\,(1.33714 - 0.9889) + \frac{62.297}{293.12} = \underline{\underline{0.317\ \tfrac{kJ}{K}}}$$

[redacted]

d) Energiebilanz.

$$m_2u_2 - m_1u_1 = \underbrace{(m_2 - m_1)}_{\Delta m} h_{ein} + \dot{Q} - \cancel{W}^{0}$$

TAB A2

$$u_1 = u(100°C, x=0.005) = 418.94 + 0.005(2506.5 - 418.94) = \underline{429.3778 \frac{kJ}{kg}}$$

$$m_2 = (m_1 + \Delta m)$$

$$(m_1 + \Delta m)u_2 - m_1u_1 = \Delta m h_{ein} + \dot{Q}_{R,12}$$

$$\Delta m(h_{ein} - u_2) = m_1u_2 - m_1u_1 - \dot{Q}_{R12}$$

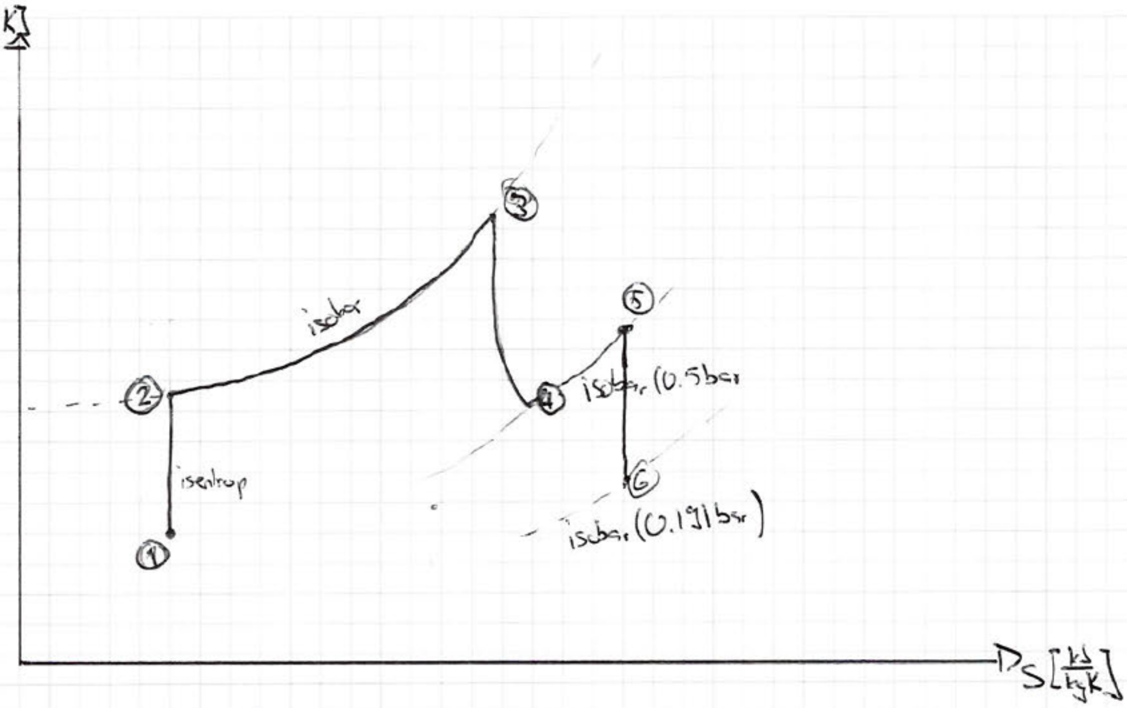
$$\Delta m = \frac{m_1(u_2 - u_1) - Q_{R12}}{h_{ein} - u_2}$$

e) $\Delta S_{12} = m_2s_2 - m_1s_1$ aus Aufgabe d)

$$m_2 = 5755kg + 3600kg = \underline{6355kg}$$

[redacted]

2a)



b) $s_5 = s_6$

$$h_5 = h(431.9K, 0.5bar) \overset{\text{TAB A22 interpolieren}}{=} \frac{441.61-431.43}{440-430}(431.9-430)+431.43 = \underline{433.3642 \frac{kJ}{kg}}$$

$$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} \quad n=k \text{ da isentrop}$$

$$T_6 = \left(\frac{p_6}{p_5}\right)^{\frac{0.4}{1.4}} \cdot T_5 = \left(\frac{0.191}{0.5}\right)^{\frac{0.4}{1.4}} \cdot 431.9K = \underline{328.075K}$$

Energiebilanz Schubdüse:

$$0 = \dot{m}\left(h_5 - h_6 + \frac{w_5^2 - w_6^2}{2}\right) + \cancel{\dot{Q}}^{0} - \cancel{\dot{W}}^{0}$$

$$h_6 = h(328.075K)$$

$\dot{m}_{ges}$: Entropiebilanz Brennkammer: $0 = \dot{m}_K(s_2 - s_3) + \frac{\dot{Q}_B}{T_B} + \cancel{\dot{S}_{erz}}^{0}$

$$w_6 = \sqrt{2(h_5-h_6)+w_5^2} = \sqrt{2\cdot(433.3642-328.40)\cdot 10^3 + 220^2} = \cancel{438.915 \frac{m}{s}} \; \underline{508.26 \frac{m}{s}}$$

$$h_6 = h(328.075K) \overset{\text{TAB A22}}{=} \frac{330.34-325.31}{330-325}(328.075-325)+325.31 = \underline{328.40 \frac{kJ}{kg}}$$

[redacted]

c) $\Delta e_{x,str} = \dot{m}\left(h_6 - h_0 - T_0(s_6 - s_0) + ke_6 - ke_0\right)$

$h_6?$

$$s_6 - s_0 = s^\circ(T_6) - s^\circ(T_0) - \cancel{R\ln\left(\frac{p_6}{p_0}\right)} \rightarrow 0$$

TABA22

$$s^\circ(T_6) = s^\circ(328.075K) = \frac{1.79783 - 1.78249}{330 - 325} * (328.075 - 325) + 1.78249 = \underline{1.7674 \frac{kJ}{kgK}}$$

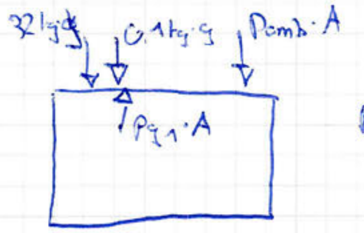
$$s^\circ(T_0) = s^\circ(243.15K) = \cancel{1.47824} = \frac{1.51917 - 1.47824}{250 - 240}(243.15 - 240) + 1.47824 = \underline{1.4911 \frac{kJ}{kgK}}$$

$$h_0 = h(243.15K) = \frac{250.05 - 240.02}{250 - 240}(243.15 - 240) + 240.02 = \underline{243.21 \frac{kJ}{kg}}$$

$$\Delta e_{x,str} = \dot{m}\left(328.40 - 243.21 - 243.15(1.7674 - 1.4911) + \frac{1}{2}(508.26^2 - 200^2)\right)$$

[redacted]

3a) p_{g1}, m_g:



$A = \cancel{0.005}$ $A = 0.05\,m^2 \cdot \pi$

$$p_{g1} = \frac{32 \cdot 9.81 + 0.1 \cdot 9.81 + 10.5 \cdot \cancel{0.005^2 \pi}\, 0.05^2 \cdot \pi}{0.05^2 \cdot \pi}$$

$$= \underline{\underline{1.4\,bar}}$$

m_g: $pV = mRT$

$$m_g = \frac{p_{g1} \cdot V_{g1}}{R T_{g1}} \qquad R = \frac{\bar{R}}{M_g} = \frac{8.314}{50} \frac{kJ}{mol\,kgK}$$

$$m_g = \frac{14 \cdot 10^5 \cdot 3.14 \cdot 10^{-3}}{\frac{8314}{50} \cdot 773.15} = 0.0034\,kg = \underline{\underline{3.4\,g}}$$

b) T_{g2} p_{g2} $\underline{\underline{T_{g2} = 0°C}}$: da sich das EW immernoch im 2-Phasengebiet befindet, bleibt die Temperatur gleich und da das ganze System im ggw. ist ist auch $T_{g2} = 0°C$.

$m_g = konst.$

$p_{g1} = \underline{\underline{p_{g2} = 1.4\,bar}}$: Da das EW immernoch die gleiche Masse hat und der aussendruck und das Gewicht des Kolben gleich bleiben, bleibt auch der Druck im gas gleich,

c) Q_{12}: Energiebilanz gas:

$$U_2 - U_1 = \dot{Q} - \dot{W}$$

$$U_2 - U_1 = m_g \cdot c_v (T_{2g} - T_{1g}) = 3.4\,g \cdot 0.633 \frac{kJ}{kgK} (0 - 500°C) = \cancel{-1076\,J}\ -1076\,J$$

$$W = \int_1^2 p\,dV \xrightarrow{p\ konst.} W = \cancel{m_g}\ m_g\, p_g (V_2 - V_1) = 3.4\,g \cdot 1.4\,bar\,(-0.002019) = \text{(unten)}$$

$$V_2 - V_1 = \frac{mR}{p} (T_2 - T_1) = \frac{3.4\,g \cdot R}{1.4\,bar} (\cancel{500}\ 0 - 500) = -0.002018\,m^3$$

$\rightarrow W = -0.961098\,J$

(nächste Seite)

[redacted]

c) $\dot{Q} = \Delta U_{12} + \dot{W} = -1076\,J - 0.9611\,J = \underline{\underline{-1076.96\,J}}$

d) $x_1 = 0.6 \quad, T = 0°$

$u_1 = -0.045 + 0.6\,(-333\,458 + 0.045) = \underline{-200{,}0928 \frac{kJ}{kg}}$

~~$u_2 = u_1 = \text{cst}$~~

~~sla~~:

Energiebilanz: $m_{EW}\,\Delta U_{12} = Q - \cancel{W}^{\,0}$ with $Q = 1076.96\,J$

$\Delta u_{12} = \frac{1076.96\,J}{0.1\,kg} = \cancel{10'769}\; \underline{10.769 \frac{kJ}{kg}}$

$u_2 = u_1 + \Delta u_{12} = \underline{-189\,324 \frac{kJ}{kg}}$

~~Kalorische bei~~ $T = 0°$: $\quad x = \frac{u_2 - u_f}{u_g - u_f} = \frac{-189.324 + 0.045}{-333\,458 + 0.045} = \underline{0.5677}$

$\underline{\underline{x_2 = 0.568}}$

[redacted]

4) ~~b)~~ c) $T_2 = -22°C$, ~~$\dot{m}(\frac{24kg}{h})$~~ $\dot{m} = \frac{24kg}{h} = \frac{24kg}{3600s} = 0.00\cancel{667}\,111 \frac{kg}{s}$

$T_1 = 0°C$

$T_{Verdampfer} = -6°C$

~~Energiebilanz drossel:~~

$h_1 = h_4$

$p_4 = 8 bar \Rightarrow h_4 = h_f(8 bar) = 93.42 \frac{kJ}{kg}$

TAB A10

$h_1 = 93.42 \frac{kJ}{kg}$

~~$T_1 = T_{Verdampfer} = -6°C$~~ ~~$T_1 = T_2 = -22°C$~~ $T_1 = T_2 = -22°C$

noch mit falschen T_1 gerechnet

~~h_f~~ interpolieren $h_f(-6°) = \frac{44.75 - 39.54}{-4-(-8)}(-6-(-8)) + 39.54 = \underline{42.145 \frac{kJ}{kg}}$

$h_g(-6°) = \frac{244.9 - 242.54}{-4-(-8)}(-6-(-8)) + 242.54 = \underline{243.72 \frac{kJ}{kg}}$

bei $(-6°)$:

$x = \frac{h_1 - h_f}{h_g - h_f} = \underline{\underline{0.254}}$

d) $\varepsilon_K = \frac{\dot{Q}_{zu}}{\dot{W}_t} = \frac{\dot{Q}_K}{\dot{W}_K}$

$\dot{Q}_K$: ~~E~~ 1.H.S Verdampfer:

$0 = \dot{m}(h_1 - h_2) + \dot{Q}$

$\dot{Q} = \dot{m}(h_2 - h_1) = \dot{m}(h_g(-6°) - 93.42)$

$= 0.00\cancel{667}\,111 \frac{kg}{s}(243.72 - 93.42) = \cancel{1.00}\ 01668\ kW$

$\underline{= 166.8 W}$

$\varepsilon_K = \frac{166.8}{28} = \underline{\underline{5.957}}$

[redacted]

4b) ~~$T_2 = T_1 - 6K$ $T_1 - 6K = -6°C$~~