[redacted]

1

~~a) Energiebilanz für stationäres System:~~

~~$\frac{dE}{dt}^{\to 0} = \sum \dot{m}(h_i(t) + ke_i + pe) + \sum Q - \sum W$~~

~~$0 = \dot{m}(h_{ein} - h_{aus}) + \sum Q - \sum \cancel{W}$~~

~~$Q = \dot{m}(h_{aus} - h_{ein})$~~

A

a) Energiebilanz für stationäres System

$0 = \dot{m}(h_{ein} - h_{aus}) + \sum Q - \sum \cancel{W}^{\to 0}$

$\dot{Q}_{aus} = \dot{m}(h_{aus} - h_{ein})$ ~~a~~ $100kW$

A-2

b) (mit $Q_{aus} = 65\ kW$)

$$\bar{T} = \frac{\int_e^a T\,ds}{s_a - s_e}$$

$dH = T\,dS + \cancel{V\,dp}^{\to \text{isobar}}$

$ds = \frac{dH}{dT}$

$$= \frac{\int_e^a dH}{s_a - s_e} = \frac{\int_{T_e}^{T_a} c^{ip}\,dT}{\int_{T_e}^{T_a} \frac{c^{if}}{T}\,dT} = \frac{\cancel{c^{if}} \cdot (T_a - T_e)}{\cancel{c^{if}} \cdot \ln\left(\frac{T_a}{T_e}\right)}$$

$$= \cancel{288.15 - 298} \frac{(298.15 - 288.15)K}{\ln\left(\frac{298.15}{288.15}\right)} = 293.12K$$

[redacted]

c) stationärer Fließprozess:

$$0 = \dot{m}(s_e - s_a) + \sum \frac{\dot{Q}}{T} + S_{erz}$$

$$\Rightarrow S_{erz} = \dot{m}(s_a - s_e) - \frac{\dot{Q}_{KW}}{T}$$

$$=$$

d) Halboffenes System

$$m_2 \cdot u_2 - m_1 u_1 + \Delta \cancel{KE}^0 + \cancel{\Delta PE}^0 = \sum \Delta m_i \left(h_i + \cancel{\frac{w_i^2}{2}} + \cancel{g z_i}\right) + \sum Q - \cancel{\sum W}^0$$

$$\frac{m_2 u_2 - m_1 u_1 - Q}{h_{ein}} = \Delta m_{12}$$

e) $\Delta S = S_2 - S_1 = \cancel{m_2 m}\ m_2 s_2 - m_1 s_1 = \left(\sum \Delta m_{12} \cdot s_{ein} + \sum \frac{Q}{T} + S_{erz}\right)$

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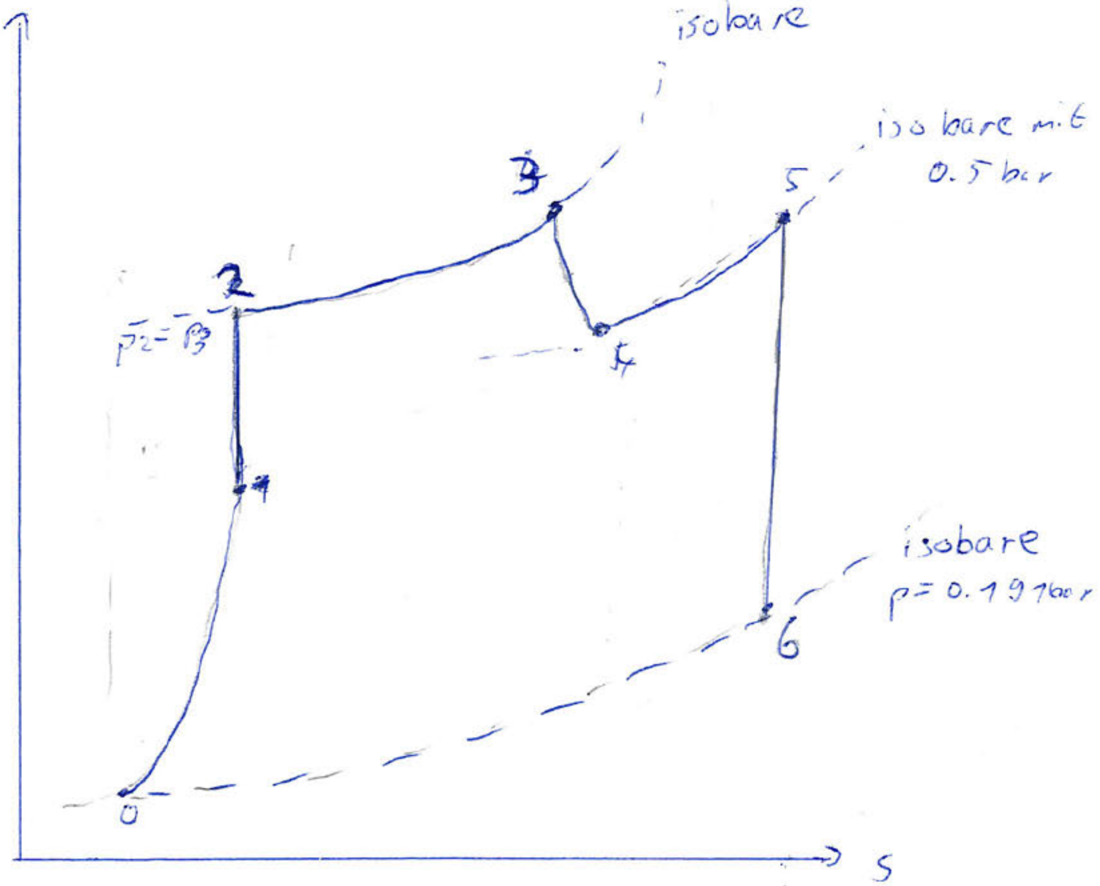
(2)

a)



b) Schubdüse = isentrop

$$\frac{T_6}{T_5} = \left(\frac{p_6}{p_5}\right)^{\frac{n-1}{n}} \Rightarrow T_6 = T_5\left(\frac{p_6}{p_5}\right)^{\frac{n-1}{n}}$$

$$T_6 = 431.9\,K\left(\frac{0.191\,bar}{0.5\,bar}\right)^{\frac{0.4}{1.4}} = 328.075\,K$$

stat FP:

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

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

$$= \sqrt{2 \cdot c_p(T_5 - T_6) \cdot 10^3 + (220\,m/s)^2}$$

$$= 507.24\,m/s$$

[redacted]

(2)

c) $\Delta e_{xstr} = e_{xstr6} - e_{xstr0}$

$$= \left(h_6 - h_0 - T_0(s_6 - s_0) + \frac{w_6^2}{2} - \frac{w_0^2}{2}\right)$$

$$= c_p^{ig}(T_6 - T_0) - T_0\left(c_p \cdot \ln\left(\frac{T_6}{T_0}\right) - \cancel{R \cdot \ln\left(\frac{p_6}{p_0}\right)}^{0}\right) + \frac{w_6^2}{2} - \frac{w_0^2}{2}$$

$T_6 = 328.075\,K \quad T_0 = 243.15\,K$

$c_p = 1.006 \quad w_6 = 507.24\,m/s \quad w_0 = 200\,m/s$

$\Delta e_{xstr} = 120.8\,\frac{kJ}{kg}$

d) ~~Exverl~~

$e_{xverl} = -\Delta e_{x00} + \left(1 - \frac{T_0}{T_B}\right) \cdot q_b \qquad T_B = 1289\,K$

$q_B = 1195$

$= 848.78\,\frac{kJ}{kg}$

[redacted]

(3)

a) ~~pAA~~

$$\frac{p_{a1}}{A} = \cancel{m_{Ew}}\, m_{Ew}\, g + m_K \cdot g + \frac{p_{amb}}{A}$$

$$p_{a1} = \frac{m_E + m_K}{A} \cdot g + p_{amb}$$

$$= \frac{0.1kg + 32kg}{\pi \cdot (0.1m)^2} \cdot 4 \cdot 9.81 m/s^2 + 1 \cdot 10^5 N/m$$

$$= 1.40\ bar$$

$$pV = mRT \Rightarrow m = \frac{pV}{\cancel{m}RT} \cdot M_w$$

$$= \frac{1.4 \cdot 10^2 kPa \cdot 3.74 \cdot 10^{-3} m^3}{8.314 \frac{kJ}{kmol \cdot K} \cdot 773.15K} \cdot 50 \frac{kg}{kmol}$$

$$= 3.664\ g$$

b) ~~Druck bleibt konstant $p_{2,g} = 1.40 bar$~~

~~$T_2 = \frac{pV}{mR} \cdot M_w =$~~

Druck bleibt konstant bei $p_{2,g} = 1.40 bar$ was sich durch die oben genutzte Formel für $p_{1,a}$ erklären lässt, denn es verändern sich keine der ~~derg~~ genutzten Größen.

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c) mit $T_{a,2} = 0.003°C$

$$\frac{dE}{dt} = \Delta U = \Sigma Q - \Sigma W$$

$$\cancel{W = p_1 (V_2 - V_1) = 140 kPa (3.14 - 7.89) \cdot 10^{-3} m^3}$$

$$\cancel{V_2 = \frac{mRT}{pM_w} = 1.189 L}$$

$$Q = \dot{m} \cdot c_v \cdot (T_2 - T_1) =$$

d) $Q_{12} = 1500 J$

$T_{w2} = T_{a2} = 0.003°C$ $\qquad \frac{dE}{dt} = Q - \cancel{W}^0 = \Delta U_w$

$$\cancel{\frac{dE}{dt} = \Sigma Q - W = \Delta U_w + \Delta U_G = 0}$$

$$m_w (u_2 - u_1) + \cancel{m_G \cdot c_v (T_2 - T_1)} = Q$$

$$u_2 = u_1 \cancel{+ \frac{m_G}{m_w} \cdot c_v (T_1 - T_2)} \frac{Q_{12}}{m_w}$$

$$u_1 = u_{Flüssig} + x_{Eis,1} (u_{fest} - u_{flüssig})$$
$$= -0.045 + 0.6 (-333.458 + 0.045) = -200.09 \frac{kJ}{kg}$$

$$u_2 = -200.09 \frac{kJ}{kg} + \frac{1.5 kJ}{0.1 kg} = -185.09$$

$$x_2 = \frac{u_2 - u_{flüssig,2}}{u_{fest,2} - u_{flüssig,2}} = 0.555$$

$u_{flüssig} = -0.033$

$u_{fest} = -333.442$

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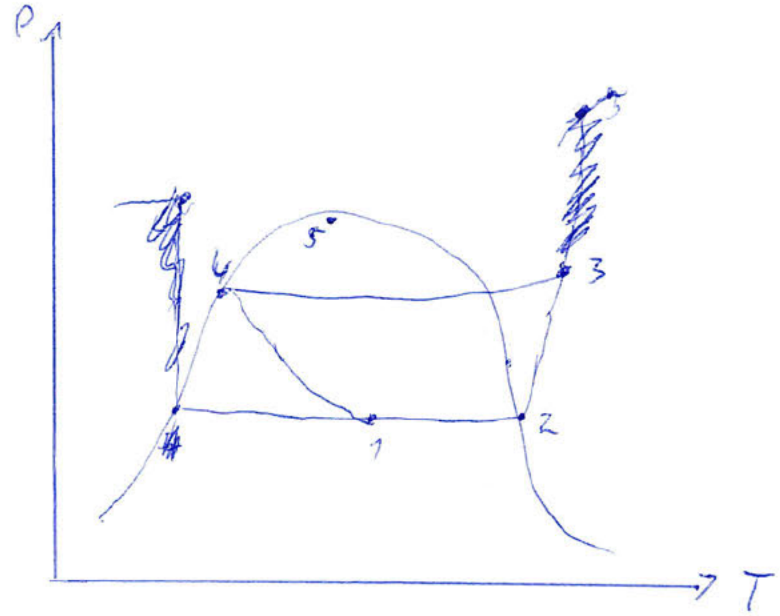
4 a)



b) $2 \to 3$ isentrop

$s_2 = s_3$

Zustand	p[bar]	T	x	s	h	
1					h_1	
2			1	$s_2 = s_3$		
3	8					
4	8		0		$h = h_4$	

$\Rightarrow x_3 =$

A-11: $h_f = h_f(8\,\text{bar}) = 93.42 \frac{kJ}{kg} = h_1$

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c) $T_2 = 22°C$ $\quad \dot{m} = 4 \frac{kg}{h}$

$x_1 = \frac{h_1 - h_f}{h_g - h_f}$ $\quad h_1 = 93.42 \frac{kJ}{kg}$

~~$h_g = 264.45 \frac{kJ}{kg}$~~

$T_2 = 22°C$

$p_2 = \frac{(6.4566 - 5.716)\,bar}{(24-20)°C}(22-20)°C + 5.716$

$= 6.0863\,bar \approx 6\,bar$

h_f ~~$(0.6.087)$~~ $= h_f(6\,bar) = 79.48 \frac{kJ}{kg}$

~~$h_g(259.79)$~~

$h_g(6\,bar) = 259.19 \frac{kJ}{kg}$

$x_1 = 0.0776$

d) $\varepsilon_K = \frac{|Q_{zu}|}{|W_t|} = \frac{\dot{Q}_K}{\dot{W}_K} = \frac{\frac{4\,kg}{3600\,s}(h_2 - h_1)}{0.028} = 6.587$

$Q_K = \dot{m}(h_2 - h_1)$

$h_2 = \frac{258.36 + 260.45}{2} \frac{kJ}{kg} = 259.41 \frac{kJ}{kg}$