[redacted]

1 Energie bilanz

a) 1. HS. FP:

$$0 = \dot{m}\left[h_e - h_a + \cancel{k_E} + \cancel{p_E}\right] + \Sigma\dot{Q} - \Sigma\cancel{\dot{W}}^{0}$$

$$= \dot{m}(h_e - h_a) + \dot{Q}_R - \dot{Q}_{aus}$$

$$\dot{Q}_{aus} = \dot{m}(h_e - h_a) + \dot{Q}_R$$

$$= 0.3\frac{kg}{s}\left(h_f(T=70°C) - h_f(T=100°C)\right) + 100kW$$

$$= 0.3(292.98 - 419.04) + 100kW$$

$$= 62.182kW$$

b) Thermo. Mittel temp.: $\tilde{T} = \frac{\int_e^a T\,ds}{s_a - s_e} = \frac{c_w \ln\left(\frac{T_a}{T_a}\right)}{c_w(T_a - T_e)} =$

c) Entrop bilanz:

Geschlossenes System, adiabat

$$\Delta S = \sum_j \frac{\dot{Q}_j}{T_j} + \dot{S}_{erz}$$

$$\Delta S \overset{0}{\uparrow} = \sum_j \frac{\dot{Q}_j}{T_j} + \dot{S}_{erz}$$

$$= \dot{Q}_{aus}\left(\cancel{\frac{1}{288.15}} - \cancel{\frac{1}{298.15}}\right) + \dot{S}_{erz}$$

$$\left(\frac{1}{T_R} - \frac{1}{\tilde{T}}\right)$$

$\dot{Q}_{aus}$ ~~neg. Vorzeichen~~

$$\dot{S}_{erz} = -\dot{Q}_{aus}\left(\frac{1}{T_R} - \frac{1}{\tilde{T}}\right) = -65kW \cdot \left(\frac{1}{373.15K} - \frac{1}{295K}\right) =$$

$$= 0.0465 = 46.15\frac{J}{kg}$$

$$c_w\,\frac{h_a - h_e + c_w(T_a - T_e) + v(p_2/\rho_e)}{s_a - s_e} = \frac{}{c_w \ln\left(\frac{T_a}{T_e}\right)}$$

$$= \frac{10}{\ln\left(\frac{298.15}{288.15}\right)} = 293.12K$$

[redacted]

d) Energie bilanz Halloffnes

$$\Delta E = m_2 u_2 - m_1 u_1 = \sum \Delta m_i \left[h_i + \cancel{kE + pE} \right] + \sum_j Q_j \cancel{+W} - \sum_n \cancel{p_n}$$

$$= \underbrace{(m_1 + \Delta m) u_2}_{m_1 u_2 + \Delta m u_2} - m_1 u_1 = \Delta m \, h_e + Q_{12}$$

$\rightarrow \Delta m =$

$$\Delta m = \frac{Q_{12} + m_1 u_1 - m_1 u_2}{u_2 - h_e}$$ mit

$Q_{12} = 35 \cdot 10^6 \, J = 35 \cdot 10^3 \, kJ$

$m_1 = 5755 \, kg$

$u_1 = u_F(100°C) + x \, u_{Fg}(100°C)$

$h_e = h_F(20°C)$

$u_2 = u_F(70°C)$

stimmt doch!

$u_1 = 418.94 + 0.005 (2506.5 - 418.94)$

$u_2 = 292.15$

$h_e = 83.96$

$= \cancel{0.17 \cdot 10^6 \, kg}$

$= 3924.3 \, kg$

e) $m_{12} = 3500 kg$

$\Delta S = m_2 s_2 - m_1 s_1$

$= 9355 \, kg \; s_F(70°C) - 5755 \, kg \; s_1$

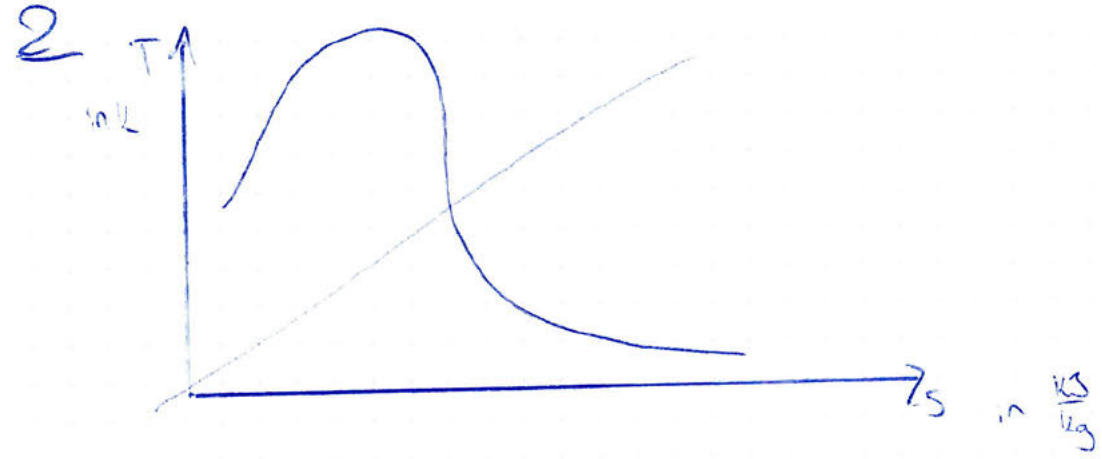
$= 1237.85 \, kJ$

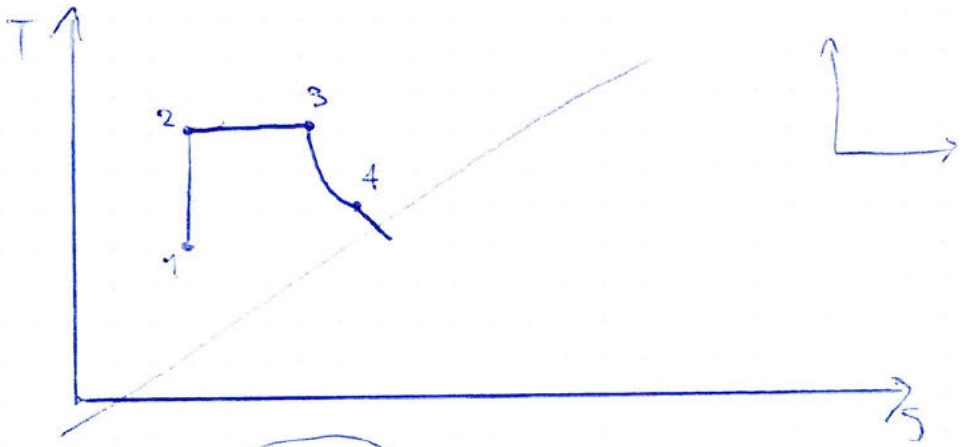
$s_1 = s_F(100°C) + x \, s_{Fg}(100°C)$

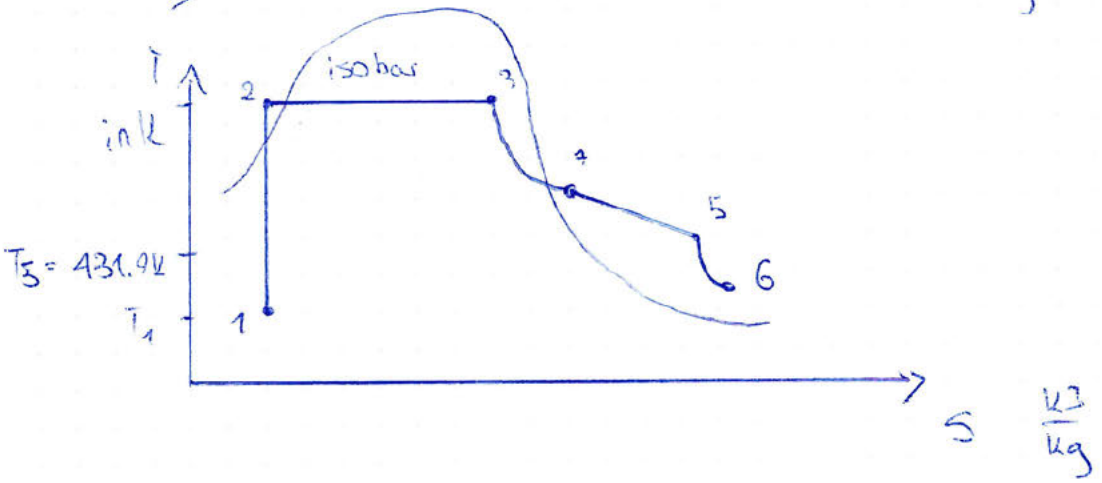
$= 1.3069 + 0.005 \cdot (7.3549 - 1.3069)$

$= 1.33714$

2


T
in K
s
in $\frac{kJ}{kg}$


T
2
3
4
1
s


T
in K
isobar
2
3
4
5
6
T_3 = 431.9K
T_1
1
s
$\frac{kJ}{kg}$

3

a) p_{g1} n_{g1} Gewicht = ~~32kg~~ g

$$p_{g1} = \frac{m_K \cdot g}{\pi \cdot \left(\frac{D}{2}\right)^2} + \frac{m_{ew} \cdot g}{\pi \cdot \left(\frac{D}{2}\right)^2} + p_0$$

$$= 319615 + 140094.4\ Pa$$

$$= 1.401\ bar$$

perfektes Gas

$$n_g = \frac{p_1 V_1}{\frac{R}{M} \cdot T} = \frac{1.401 \cdot 10^5 Pa \cdot 3.14 \cdot 10^{-3} m^3 \cdot 50 \frac{kg}{kmol}}{8.314 \frac{kJ}{kmol \cdot K} \cdot 773.15 K} = 3.429\ kg$$

b) p bleibt gleich: es herrschen dieselben Bedingungen wie Zustand 1

$$\frac{m \cdot g}{A} + \dots$$

Wir sehen das Volumen ist kleiner: aus Gas-Gesetz Folgt

$$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} \longrightarrow T_2 = T_1 \left(\frac{p_2}{p_1}\right)^{\frac{0.2627}{1.2627}}$$

das T_2 auch kleiner ist

$$n = \frac{c_p}{c_v} = \frac{\frac{R}{M} + c_v}{c_v} = 1.2627$$

$T_{g2} = 273.153 K$

c) Energie Bilanz

Geschlossenes System: $\Delta E = E_2 - E_1 = \sum Q - \sum W$

$m_{1Eis} = 0.6 \cdot 0.1 kg = 0.06 kg$ $= m_2 u_2 - m_1 u_1$

$m_{1w} = 0.4 \cdot 0.1 kg = 0.04 kg$

umdrehen

c)

$$\Delta E = E_2 - E_1 = \Sigma Q - \Sigma W^{\nearrow 0}$$

$$= m_{g1}(u_2 - u_1) = Q_{12}$$

$$= m_{g1}(c_v(T_2 - T_1)) = Q$$

$$= 3.424 \cdot 0.633 \cdot (500 - 0.003) = 1085.273 = |Q_{12}|$$

d) Energie Bilanz

Geschlossenes System: $\Delta E = \Sigma Q - \Sigma W^{\nearrow 0}$

$$= m_{EW}\left(\underbrace{x\, u_E^{0.002°} + (1-x)\, u_W^{0.003°}}_{} - 0.6\, u_E^{0°} + 0.4\, u_W^{0°}\right) = Q_{12}$$

$$= m_{EW}\left(x \cdot 333\right) x(u_E - u_W) + u_W$$

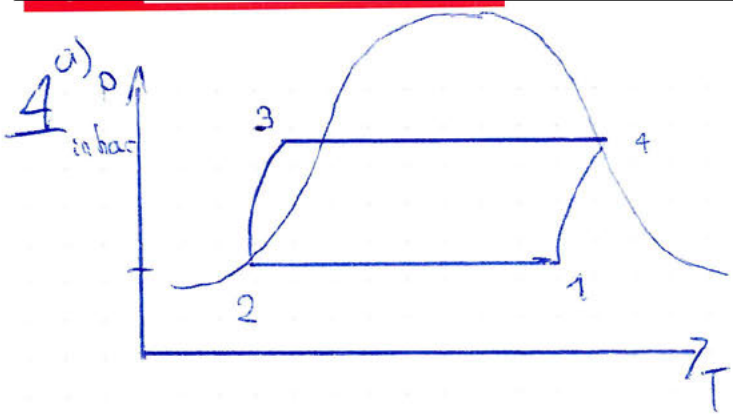
$$\rightarrow X = \frac{\frac{Q_{12}}{m_{EW}} + 0.6 u_E - 0.4 u_W - u_W}{u_E - u_W}$$

$$= \frac{\frac{1500}{3.6g} + 0.6(-333.458) - 0.4(-0.015) - (-0.033)}{-333.442 - 0.033}$$

$$= -0.65 \quad -0.64965$$

$$x = 0.65 \quad x = 0.650$$

4 a)



$T_1 = -22$

$T_1 = -26$

$T_1 = -26$

$T_1 = -20$ → $T_2 = -26$

b) $T_1 = -26\,°C$

→ $T_1 = T_2 = -32\,°C$

	T	p	V	x	Q	W
1	T_1=-6	p			Q_{12}	
2	T_1=-6	=p_1		1		$\lvert W_{23}\rvert$=28W
3		8				
4		8			0	

b) Energie bilanz

st. FP: $0 = \dot{m}[h_e - h_a + \tfrac{1}{2}(c_e^2 - c_a^2) + g(z_e - z_a)] + \sum \dot{Q} - \sum W$

→ $\dot{m} = \frac{|W_{23}|}{h_2 - h_3}$

$= \frac{-28W}{227.9 - 276.27}$

$= 0.579 \frac{kg}{s} \cdot 10^{-3}$

$= 2084 \frac{kg}{h}$

$= 2083.4 \frac{kg}{h}$

A-12

interpolieren

$h_2 = h_f(T = -32°C) = 9.52$

$= h_g(T = -32°C) = 227.90$

$h_1 = h_g(p = 8bar) = 264.15 \frac{kJ}{kg}$

$h_f(8bar)$

$s_1 = s_2 = s_g(8bar) = 0.9066$

adi. & rev. → $s_2 = s_3$

$s_2 = s_f(T = -32°C) = 0.0401$

$= s_g(T = -32°C) = 0.9456$

$h_3 = (s_3 = 0.9456, p_3 = 8bar)$

$h_3 = \frac{0.9456 - 0.9374}{0.9711 - 0.9374}\,(h(s = 0.9711, 8bar) - h(0.9374, 8bar) + h(0.9374, 8bar))$

$= 276.27$

A-11

c) $h_4 = h_f(8\,bar) = 93.42$ $\quad T_1 = -22°C$

$s_4 = 0.3459 = s_1$ $\quad s_f(-22°C) = 0.0897$

$s_f(8\,bar)$ $\quad s_g(-22°C) = 0.9351$

$T = -22°C$

$$x = \frac{s_1 - s_f}{s_g - s_f} = 0.303$$