[redacted]

Aufgabe 1

a) $0 = \dot m_{KW}(h_{ein} - h_{aus}) + \dot Q_{aus}$

$\dot Q_{aus} = \dot m_{KW}(h_{aus} - h_{ein})$

$= \dot m_{KW}\left[c(T_{aus} - T_{ein}) + v^{if}(p_{aus} - p_{ein})\right]$

b) $$\bar T = \frac{\int_e^a T\,ds}{s_a - s_e} = \frac{q_{rev}}{s_a - s_e} = \frac{h_{aus} - h_{ein}}{s_{aus} - s_{ein}} = \frac{c(T_{aus} - T_{ein}) + \underbrace{\cancel{v^{if}(p_{aus} - p_{ein})}}_{=0}}{c\,\ln\left(\frac{T_{aus}}{T_{ein}}\right)}$$

$$= \frac{T_{aus} - T_{ein}}{\ln\left(\frac{T_{aus}}{T_{ein}}\right)} = \frac{298.15K - 288.15K}{\ln\left(\frac{298.15K}{288.15K}\right)}$$

$$= \underline{\underline{293.12K}}$$

~~c) Entropiebilanz:~~ $\cancel{0 = \frac{\dot Q_{aus}}{\bar T_{KF}} + \dot S_{erz}}$

c) Entropiebilanz: $0 = + \frac{\dot Q_{aus}}{\bar T_{KF}} + \dot S_{erz} - \frac{\dot Q_{aus}}{T_{Reaktor,1}}$

$\cancel{\dot S_{erz} = \frac{\dot Q_{aus}}{T_{Reaktor,1}} - \frac{\dot Q_{aus}}{\bar T_{KF}} \quad 65'000W}$

$$\dot S_{erz} = -\frac{\dot Q_{aus}}{\bar T_{KF}} + \frac{\dot Q_R}{T_{Reaktor,1}} = -\frac{65'000W}{295K} + \frac{100'000W}{373.15K}$$

$$= \underline{\underline{47.64\,\frac{W}{K}}}$$

d) $\frac{dE}{dt} = \sum_i \dot{m}_i [h_i + \overset{0}{\cancel{pe_i}} + \overset{0}{\cancel{ke_i}}] - \dot{Q} - \overset{0}{\cancel{\dot{W}}}$

$\Delta U = \Delta m_{12} h_{ein} + \dot{Q}$

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

$(m_1 + \Delta m_{12}) u_2 - m_1 u_1 = \Delta m_{12} h_{ein} + \dot{Q}$

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

$-\dot{Q} + m_1 (u_2 - u_1) = \Delta m_{12} h_{ein} - \Delta m_{12} u_2$

$-\dot{Q} + m_1 (u_2 - u_1) = \Delta m_{12} (h_{ein} - u_2)$

$\Rightarrow \Delta m_{12} = \frac{m_1 (u_2 - u_1) - \dot{Q}}{h_{ein} - u_2}$

siedende Flüssigkeit => $x = 0.5$

$h_{ein} \underset{\text{TAB A-2}}{=} 83.96 + 0.5(2538.1 - 83.96) = \underline{1311.03 \frac{kJ}{kg}}$

$u_1 \underset{\text{TAB-A-2}}{=} 418.94 + 0.005(2506.5 - 418.94) = \underline{429.3778 \frac{kJ}{kg}}$

$u_2 \underset{\text{TAB-A-2}}{=} 292.95 + 0.5(2469.6 - 292.95) = \underline{1381.275 \frac{kJ}{kg}}$

$\Delta m_{12} = \frac{5755 kg (1381.275 \frac{kJ}{kg} - 429.3778 \frac{kJ}{kg}) + 35'000 kJ}{1311.03 \frac{kJ}{kg} - 1381.275 \frac{kJ}{kg}}$

[redacted]

~~e) ΔS =~~

e) Entropiebilanz: $\frac{dS}{dt} = \dot{m}_{ein} \cdot s_{ein} - \frac{\dot{Q}_{aus,12}}{\overline{T_j}} + \dot{S}_{erz}(t)$

$$\Delta S = m_2 s_2 - m_1 s_1$$

$$m_2 = m_1 + \Delta m_{12} = 5755\,kg + 3600\,kg = 9355\,kg$$

$$s_2 = 0.9549 + 0.5(7.7553 - 0.9549) = 4.3551\,\frac{kJ}{kg\,K}$$

TAB-A2

$$s_1 = 1.3069 + 0.005(7.3549 - 1.3069) = 1.33714\,\frac{kJ}{kg\,K}$$

$$\Delta S_{12} = 9355\,kg \cdot 4.3551\,\frac{kJ}{kg\,K} - 5755\,kg \cdot 1.33714\,\frac{kJ}{kg\,K}$$

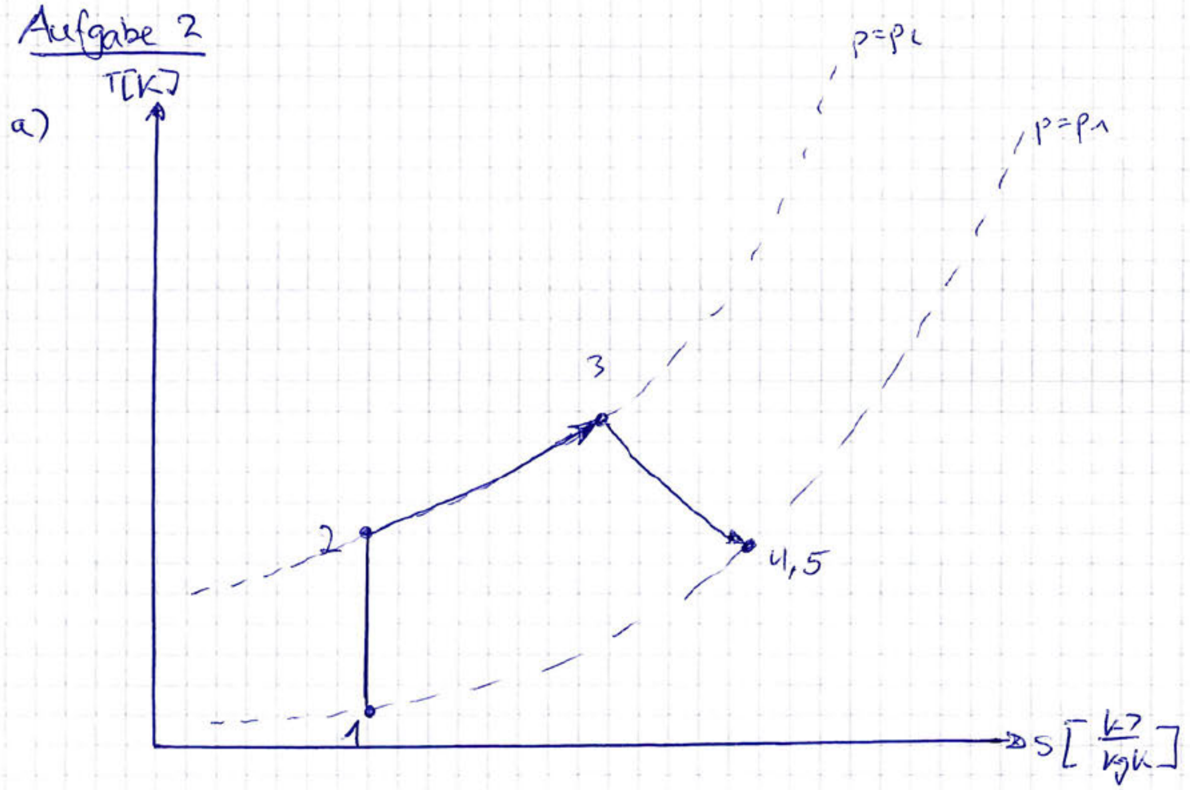
$$= 33046.7\,\frac{kJ}{K} = \underline{\underline{33.05\,\frac{MJ}{K}}}$$

[redacted]

~~Thermodynamik II~~

Aufgabe 2

a)



	T[K]	p[bar]	w [m/s]
1			
2			
3			
4			
5	431.9K	0.5	220 m/s
6			

b) 5 -> 6 isentrop => $\frac{T_6}{T_5} = \left(\frac{p_6}{p_5}\right)^{\frac{\kappa-1}{\kappa}} \Rightarrow T_6 = T_5 \cdot \left(\frac{p_6}{p_5}\right)^{\frac{\kappa-1}{\kappa}}$

$$\underline{\underline{T_6}} = 431.9K \cdot \left(\frac{0.191 bar}{0.5 bar}\right)^{\frac{0.4}{1.4}} = \underline{\underline{328.07K}}$$

Exergiebilanz: $0 = \dot{m}\left(h_5 - h_6 - T_0(s_5 - s_6) + \Delta ke\right) + \cancelto{0}{\sum_j \left(1 - \frac{T_0}{T_j}\right)\dot{Q}_j} - \dot{W}_t - \cancelto{0}{\dot{E}_{x,verl.}}$

$\dot{E}_{verl.} = T_0 \dot{S}_{erz} = 0$ (da reversibel)

$0 = \dot{m}(h_5 - h_6 - T_0(s_5 - s_6) + \Delta ke) - \dot{W}_t$

$\cancel{\dot{W}_t = \frac{1}{1-\kappa} p_2 v_2}$

$\dot{W}_t = \frac{R(T_6 - T_5)}{1-\kappa}$ (ideales Gas und isentrop)

$\dot{W}_t = \dot{m} \cdot w_t$

$\Rightarrow 0 = \cancel{\dot{m}}\left(h_5 - h_6 - T_0(s_5 - s_6) + \frac{1}{2}(w_6^2 - w_5^2)\right) - \frac{R(T_6 - T_5)}{1-\kappa} \cdot \cancel{\dot{m}}$

$\frac{R(T_6 - T_5)}{1-\kappa} = h_5 - h_6 - T_0(s_5 - s_6) + \frac{1}{2}w_6^2 - \frac{1}{2}w_5^2$

$\frac{1}{2}w_6^2 = \frac{R(T_6 - T_5)}{1-\kappa} + \frac{1}{2}w_5^2 + T_0(s_5 - s_6) + h_6 - h_5$

$(s_5 - s_6) = c_p \ln\left(\frac{T_5}{T_6}\right) - R \ln\left(\frac{p_5}{p_6}\right)$

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

$\Rightarrow \frac{1}{2}w_6^2 = \frac{R(T_6 - T_5)}{1-\kappa} + \frac{1}{2}w_5^2 + T_0\left[c_p \ln\left(\frac{T_5}{T_6}\right) - R \ln\left(\frac{p_5}{p_6}\right)\right]$

$+ c_p(T_6 - T_5)$

$$\Rightarrow w_6 = \sqrt{\frac{2R(T_6 - T_5)}{1-\kappa} + w_5^2 + 2T_0\left[c_p \ln\left(\frac{T_5}{T_6}\right) - R \ln\left(\frac{p_5}{p_6}\right)\right] + c_p(T_6 - T_5)}$$

[redacted]

c) $\Delta e_{x,str} = e_{x,str\,6} - e_{x,str\,0}$

$$= h_6 - h_0 - T_0(s_6 - s_0) + \frac{1}{2}\left(\omega_6^2 - \omega_{Luft}^2\right)$$

$$\underline{\underline{= c_p(T_6 - T_0) - T_0\left[c_p\ln\left(\frac{T_6}{T_0}\right) - R\ln\left(\frac{p_6}{p_0}\right)\right] + \frac{1}{2}\left(\omega_6^2 - \omega_{Luft}^2\right)}}$$

[redacted]

Aufgabe 3

a) $P_{G1} = P_{amb} + \frac{m_K \cdot g}{A} + \frac{m_{EW} \cdot g}{A} + P_{EW}$

$P_{EW}(T_{EW} = 0°C) = 1.4 bar$

$A = \pi \cdot \left(\frac{d}{2}\right)^2 = \pi \cdot \left(\frac{0.1m}{2}\right)^2 = 0.00785 m^3$

$\underline{\underline{P_{G1}}} = 1 bar + \frac{32kg \cdot 9.18 \, m/s^2}{0.00785 m^3} + \frac{0.1kg \cdot 9.81 m/s^2}{0.00785 m^3} + 1.4 bar$

$= \underline{\underline{2.8 bar}}$

$\underline{IG}$: $P_{G1} V_{G1} = m_{G1} R T_{G1}$ $\qquad R = \frac{\bar{R}}{M_g} = \frac{8.314 \frac{J}{mol K}}{0.05 \frac{kg}{mol}} = 166.28 \frac{J}{kg K}$

$m_{G1} = \frac{P_{G1} V_{G1}}{R T_{G1}}$

$= \frac{2.8 \cdot 10^5 Pa \cdot 3.14 \cdot 10^{-3} m^3}{166.28 \frac{J}{kgK} \cdot 773.15 K} = 0.006839 kg$

$= \underline{\underline{6.84 g}}$

b) Es fliesst erst keine Wärme mehr, wenn das ganze Eis geschmolzen ist. Dabei bleibt der Druck gleich

-> Temperatur $T_{G,2}$ ist gleich wie die Temperatur des EW's

=> $\underline{\underline{T_{G,2} = 0°C}}$

Der Druck des ~~gase~~ Gases bleibt gleich => $\underline{\underline{P_{G2} = 2.8 bar}}$

c) 1. HS um das Gas: $\frac{dE}{dt} = \cancel{\sum_i \dot{m}_i [h_i + pe_i + ke_i]} + \dot{Q} - \cancel{\dot{W}}$

$$\Delta U = Q_{12}$$

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

$$Q_{12} = m_g c_v (T_2 - T_1) \quad \text{(perfekter Gas)}$$

$$Q_{12} = 3.6 \cdot 10^{-3} kg \cdot 0.633 \frac{kJ}{kgK} (273.153K - 773.15K)$$

$$= -1.139 kJ = \underline{-1139.4 J}$$

$\Rightarrow$ $\underline{\underline{\text{Es wurde } 1139.4 J \text{ übertragen.}}}$

d) 1. HS um Eis: $\frac{dE}{dt} = \cancel{\sum_i \dot{m}_i [h_i + ke_i + pe_i]} + \dot{Q} - \cancel{\dot{W}}$

$$\Delta U = Q_{12}$$

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

$$u_2 - u_1 = \frac{Q_{12}}{m_{EW}} \Rightarrow u_2 = u_1 + \frac{Q_{12}}{m_{EW}}$$

$$u_1 = u_{fest} + x_{Eis,1}(u_{flüssig} - u_{fest})$$

$$= (-333.485 + 0.6(-0.045 + 333.485)) \frac{kJ}{kg}$$

$$= -133.421 \frac{kJ}{kg}$$

$$u_2 = -133.421 \frac{kJ}{kg} + \frac{1.5 kJ}{0.1 kg} = -118.421 \frac{kJ}{kg}$$

$$T_{G,2} = T_{EW,2} = 0.003°C$$

$$\underline{\underline{x_{Eis,2}}} = \frac{u_2 - u_{fest}}{u_{flüssig} - u_{fest}} = \frac{-118.421 + 333.442}{-0.033 + 333.442} = \underline{\underline{0.64}}$$

[redacted]

Aufgabe 4

b)

	T[°K]	P[bar]	
1	31.33		adiabate Prozess = isotherm + isenthalp $h_4 = h_1$
2	~~[illegible]~~ -22°C		$x_2 = 1$; $1 \to 2 : \dot{Q}_K$ } isobar
3	31.33	8bar	} $\dot{W}_K = 28W$ isentrop $\Rightarrow S_2 = S_3$
4	31.33	8bar	$x_4 = 0$

$$h_1 = h_4 = h_f(8bar) \overset{A-11}{=} 93.42 \ \frac{kJ}{kg}$$

$$s_2 = s_g(8bar) \overset{A-11}{=} 0.9066 \ \frac{kJ}{kgK}$$

$$2 \to 3: \text{ isentrop}: \ S_2 = S_3 = 0.9066 \ \frac{kJ}{kgK}$$

~~x_3~~ $\Rightarrow T_3 = T_{sat}$

<u>1. HS um Verdichter:</u> $\cancel{\frac{dE}{dt}}^{0} = \dot{m}_{R134a}(h_2 - h_3) + \cancel{\dot{Q}}^{0} - \dot{W}_K$

$$\dot{W}_K = \dot{m}_{R134a}(h_2 - h_3)$$

$$\underline{\underline{\dot{m}_{R134a} = \frac{\dot{W}_K}{h_2 - h_3}}}$$

c) <u>Zustand 1:</u> ~~[illegible] 31.33~~ $h_4 = h_1 = h_f(8bar) \overset{A-11}{=} 93.42 \ \frac{kJ}{kg}$

$$x_1 = \frac{h_1 - h_f}{h_g - h_f}$$

d) $\varepsilon_K = \frac{\dot{Q}_{zu}}{\dot{W}_t} = \frac{\dot{Q}_K}{\dot{W}_K + \dot{W}_D} = \frac{\dot{m}_{134a}(h_2 - h_1)}{\dot{m}_{134a}(h_4 - h_1) + \dot{W}_D}$

$W_D = \dot{m}_{134a}(h_4 - h_1)$

$\dot{Q}_K = \dot{m}_{134a}(h_2 - h_1)$

e) Die Temparatur würde immer weiter abnehmen bis man in den kritischen Bereich kommt.

a)