[redacted]

1. 1. HS: $0 = \dot{m}(h_e - h_a) + \cancel{\Sigma\dot{Q} - \Sigma\dot{W}}$

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

$h_e = \cancel{h(T=100°C, x=1)}\ h_{fg}(T=100°C) = h_e$

$\cancel{h_a = h(T=70, x=1)}\ h_{fg}(T=70°) = h_a$

aus Tabelle A2

$h_a = 2333{,}8\ \frac{kJ}{kg}$

$h_e : 2257\ \frac{kJ}{kg}$

$\Rightarrow -\dot{Q}_{aus} = 0{,}3\,(2257 - 2333{,}8) + 100\,kW = 76{,}96\ kW$

b) (weiter mit $\dot{Q}_{aus} = 65\,kW$)

$\cancel{\Delta S = S_2 - S_1 = \frac{Q_i}{T_i}}$

$$\bar{T} = \frac{\int_e^a T\,ds}{S_a - S_e} = \frac{S_a \cdot T_a - S_e T_e}{S_a - S_e}$$

$\cancel{s_e = s_f(15°C) =}$

$\cancel{s_a = s_f(25°C) =}$

$s_e - s_a = \int_{T_a}^{T_e} \frac{c}{T}\,dT = c \cdot (\ln(T_e) - \ln(T_a)) =$

$=$

c) (weiter mit $T_{KF} = 295K$)

$$0 = \dot{m}(s_e - s_a) + \frac{\sum Q_j}{T} + \dot{S}_{erz}$$

$$-\dot{S}_{erz} = 0{,}3\,\frac{kg}{s} \cdot \left(s(100°C)_f - s_f(70°C)\right) - \frac{65\,kJ}{295K} + \frac{100\,kJ}{295K}$$

$-\dot{S}_{erz}$ Aus TAB A2

$s_f(100°C) = 1{,}3069$

$s_f(70°C) = 0{,}9549$

$$\Rightarrow -\dot{S}_{erz} = 0{,}258\,\frac{kJ}{s}$$

d) $\Delta E = \Delta U = m(u_1 - u_2)$

$u_1 = \left(x \cdot u_g(100°C) + (1-x) \cdot u_f(100°C)\right)$

$u_2 = u_f(70°)$

$$\Rightarrow u_1 = 0{,}005 \cdot 2506{,}5 + 0{,}995 \cdot 418{,}94 \left(\frac{kJ}{kg}\right) = 429{,}38\,\frac{kJ}{kg}$$

$u_2 = 292{,}95\,\frac{kJ}{kg}$

$$\Rightarrow \Delta E = 5755 \cdot (429{,}38 - 292{,}95) = 784982\,kJ = 785{,}0\,MJ$$

$\Delta E = \Delta m \cdot c_{Wasser} \cdot \Delta T$

$\Delta E = (m_{tot} - m_1) \cdot c_W \cdot \Delta T$

$$m_{tot} = \frac{\Delta E}{c_W \Delta T} + m_1 \quad , c_W = 4{,}22$$

$$m_{tot} = \frac{785000\,kJ}{4{,}22\,\frac{kJ}{kgK} \cdot 50} + 5755 = \cancel{11{,}935\,kg}\ 9475\,kg$$

$\Rightarrow$ ~~$\Delta m = 11935 - 5755 = 6200\,kg$~~

$\Delta m = 9475 - 5755 = 3720\,kg$

[redacted]

① e) $\Delta S = m_2 s_2 - m_1 s_1$

$s_1 = 0{,}005 \cdot s_g(100°) + 0{,}995 \cdot s_f(100°)$

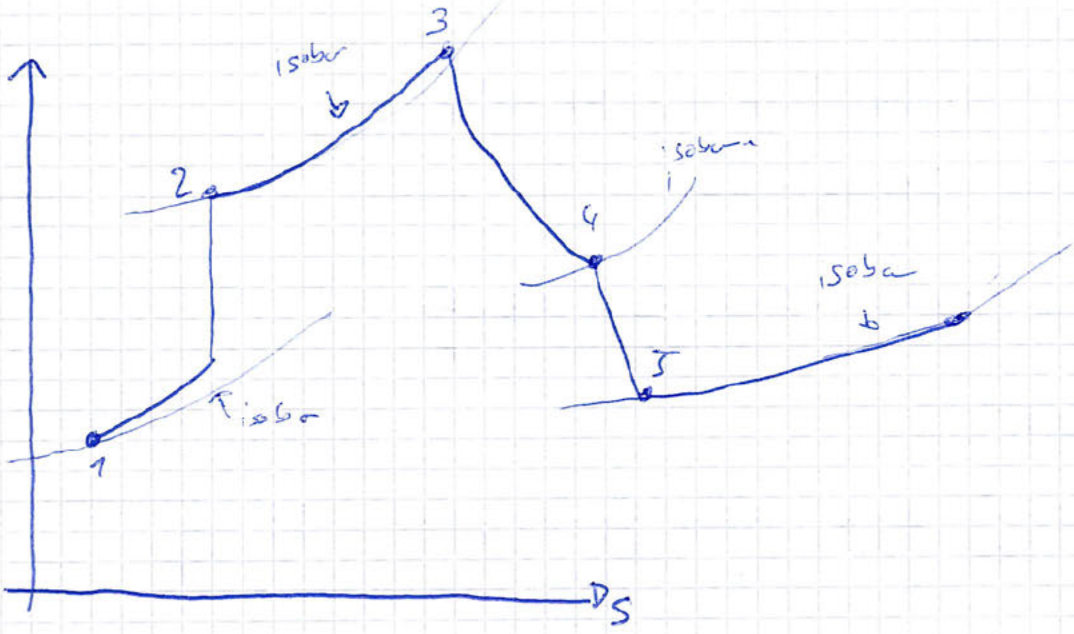
$s_2 = s_f(70°C) = 0{,}9549 \frac{kJ}{kgK}$

$s_1 = 1{,}337 \frac{kJ}{kgK}$

$\Rightarrow \Delta S = 9475 \cdot 1{,}337 - 5755 \cdot 0{,}9549 = 7172{,}6 \frac{kJ}{K}$

[redacted]

② a)



b)

$w_5 = 220 \frac{m}{s}$

$\cancel{T_5} \; p_5 = 0{,}5\,bar$

$p_6 = 0{,}191\ bar$

$\dot{m}_5 = \dot{m}_6$

$\cancel{\dot{m}_5} \Rightarrow \quad w_5 \cdot p_5 = w_6 \cdot p_6$

$$\Rightarrow \cancel{p_6} = \frac{w_5 \cdot p_5}{\cancel{p_6}} = 575{,}9 \frac{m}{s}$$

$$\frac{T_6}{T_5} = \left(\frac{p_6}{p_5}\right)^{\frac{n-1}{n}} \Rightarrow T_6 = T_5 \cdot \left(\frac{p_6}{p_5}\right)^{\frac{n-1}{n}} \quad , n = 1{,}4$$

$$\Rightarrow T_6 = 431{,}9\,K \cdot \left(\frac{0{,}191\,bar}{0{,}5\,bar}\right)^{\frac{0{,}4}{1{,}4}} = 328{,}1\,K.$$

c) (mit $w_6 = 510 \frac{m}{s}$, $T_6 = 340K$)

Exergie einer Strömung

$$\dot{m}_{ex,Str} = \dot{m}\left(h - h_0 - T_0(s - s_0) + ke + \cancel{pe}\right)$$

$$\Rightarrow e_{x,Str} = h - h_0 - T_0(s - s_0) + ke$$

$$ke = \frac{1}{2}\, 510 \frac{m}{s}^2 - \frac{1}{2} 200^2 = 110\,050 \frac{J}{kg} = 110 \frac{kJ}{kg}$$

$$h - h_0 = \int_{T_1}^{T_2} c_p^{ig}(T)\, dT$$

$$\Rightarrow h - h_0 = 1{,}006 \frac{kJ}{kgK} \cdot 340K - 1{,}006 \frac{kJ}{kgK} \cdot 243{,}15K = 97 \frac{kJ}{kg}$$

$$s - s_0 = c_p^{ig} \int_{T_1}^{T_2} \frac{dT}{T} - R \ln\left(\frac{p_2}{p_1}\right)$$

$$\Rightarrow s - s_0 = 1{,}006 \cdot \ln\left(\frac{340K}{243{,}15K}\right) - 8{,}314 \cdot \ln(1)^{=0}$$

$$\Rightarrow s - s_0 = 0{,}3372 \frac{kJ}{kg \cdot K}$$

$$\cancel{\Rightarrow e_{x,Str} = 97 \frac{kJ}{kg} + 243{,}15 \cdot}$$

$$e_{x\,Str} = 97 \frac{kJ}{kg} - 243{,}15K \cdot 0{,}3372 \frac{kJ}{kg \cdot K} + 110 \frac{kJ}{kg}$$

$$e_{x,Str} = 125{,}06 \frac{kJ}{kg}$$

d)

$$E_{x,verl} = \Delta m_i \cdot e_{x,Str} + \left(1 - \frac{T_0}{T_j}\right) \cdot Q_j - \Delta E_x$$

$$e_{x,verl} = e_{x\,Str} + 1 - \frac{T_0}{T_B} \cdot q - \Delta e_x$$

$$\Delta e_x = \Delta e_{x,u} + \Delta e_{x\,kE}$$

[redacted]

3

3

a) $\cancel{pV = nRT}$ $p = \frac{F}{A}$

$$p = \overset{p_{atm}}{\cancel{1bar}} + \frac{g(m_K + m_{EW})}{\pi r^2}$$, $r = 5\,cm$, $m_k = 32\,kg$, $m_{EW} = 0{,}1\,kg$, $g = 9{,}81\,\frac{m}{s^2}$

$$\Rightarrow p = 1 \times 10^5 \frac{N}{m^2} + \frac{9{,}81 \cdot (32{,}1\,kg)\frac{m^2}{s^2}}{\pi \cdot 0{,}05\,cm^2} = 140094{,}4\,Pa = 1{,}4\,bar$$

perfektes Gas $pV = nRT$

$$n = \frac{pV}{RT} = \frac{1{,}4\,bar \cdot 3{,}14\,L}{8{,}314\,\frac{Pa\,m^3}{mol\,K} \cdot 773{,}15\,K} = 6{,}839 \times 10^{-2}\,mol$$

$$m = 50\,\frac{g}{mol} \cdot 6{,}839 \cdot 10^{-2} = \cancel{3{,}42\,g}\ 3{,}42\,g$$

b) $c_{V_{Gas}} = 0{,}633\,\frac{kJ}{kg\,K}$, $T_2 = 0\,°C = 273{,}15\,K$ → Die Temperatur des Wassers verändert sich nicht, bis ~~alles~~ das ganze Eis geschmolzen ist. (Angabe: $x_{Eis} > 0$)

$$\Delta E = 0{,}633\,\frac{J}{g\,K} \cdot 500\,K \cdot 3{,}42\,g$$

$$\Delta E = 1082{,}4\,J$$

$\Rightarrow$ $\cancel{p_2 = \frac{nRT_2}{V}}$

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

$$n = \frac{c_p}{c_v} \Rightarrow c_p = c_v + \frac{R}{M} \qquad \Rightarrow n = \frac{0{,}79928}{0{,}633} = 1{,}263$$

$$\Rightarrow c_p = 0{,}799{,}28$$

$$\Rightarrow p_2^{\frac{n-1}{n}} = p_1^{\frac{n-1}{n}} \cdot \frac{T_2}{T_1} \Rightarrow p_2^{\frac{0{,}263}{1{,}263}} = 0{,}379\,bar \Rightarrow p_2 = 9{,}47 \times 10^{-3}\,bar$$

c) $Q_{12} = W_{1,2}$

$$Q_{12} = \int_1^2 p\,dV = \frac{R(T_2 - T_1)}{1-n} = \cancel{\frac{\bar{R}(T_2 - T_1)}{1-n}} = \cancel{\frac{0{,}16638(773{,}15 - 273{,}15)}{1-1{,}263}}$$

$$= \frac{8{,}314\,(773{,}15 - 273{,}15)}{1-1{,}263} \times 10^{-1}$$

Kürzungsgleich von R

$\Rightarrow \cancel{Q_{12} = -316{,}1\,kJ}$

$\Rightarrow Q_{12} = \cancel{-15806{,}1}\; -1580{,}6\,J$

d) $x = \frac{u - u_{Fl}}{u_{Fe} - u_{Fl}}$

$u_{Fl} = u_{F_1}(1{,}4bar) = 0{,}045$

$u_{Fe} = u_{Fe}(1{,}4bar) = -333{,}458$

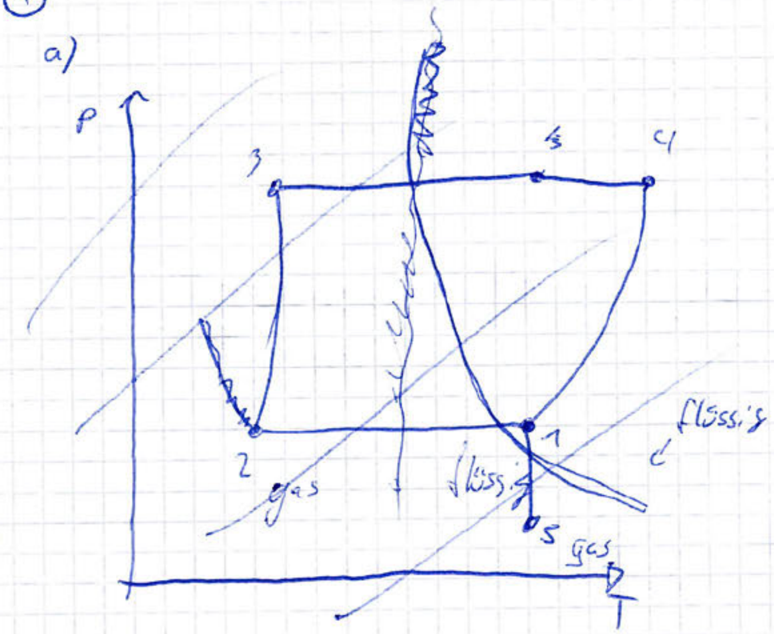
$\cancel{\mu = \frac{Q}{m}}$

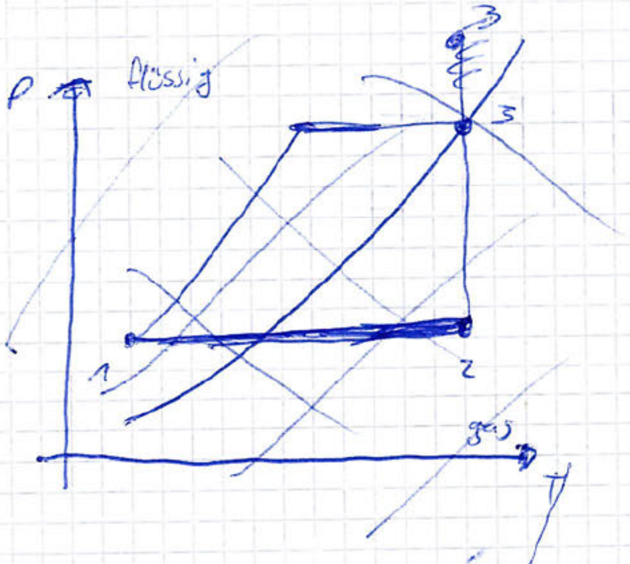
$\cancel{\mu = \frac{-1580{,}6\,J}{3{,}42\,J}} =$

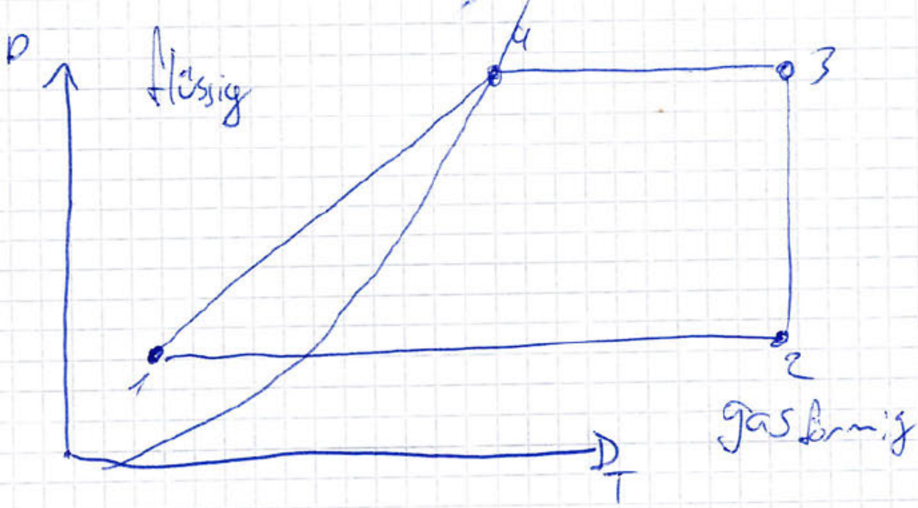
[redacted]

(4)

a)







b) 1. HS

$$0 = \dot{m}(h_e - h_a) + \sum \dot{Q} - \sum \dot{W}$$

$$\Rightarrow \dot{m} = \frac{\dot{W}}{h_e - h_a} = \frac{\dot{W}}{h_3 - h_2}$$

~~h_3~~ $T_1 = -10°C$

$T_2 = T_1$

$\Rightarrow h_{22} =$ interpoliert aus TAB A-10

~~$h_2 = h_g(-8°C)$~~

$$h_2 = \frac{h_g(-8°C) - h_g(-12°C)}{-8°C + 12°C} (-8°C + 10°C) + h_g(12°C) = \cancel{240{,}78 \frac{kJ}{kg}}\ \cancel{244{,}31 \frac{kJ}{kg}}\ 243{,}7$$

~~h_3~~

~~$T_3 = T_2 \cdot \left(\frac{p_3}{p_2}\right)^{\frac{n}{n-1}}$~~

Aus TAB A12

~~p(8bar)~~ $h(p_{3,r}) = h_3 = 264{,}15$

$$\Rightarrow \dot{m} = \frac{28 \frac{J}{s}}{\cancel{264{,}15-246{,}79}\ 264{,}15-243{,}7} = \cancel{1{,}41 \frac{kg}{h}}\ \cancel{1{,}41 \times 10^{-3} \frac{kg}{s}} = \cancel{5{,}1 \frac{kg}{h}}$$

$$= 1{,}369 \times 10^{-3} \frac{kg}{s} = 4{,}92 \frac{kg}{h}$$

c) (mit $\dot{m} = 4 \frac{kg}{h}$ & $T_2 = -22°C$)

~~$x_1 = h_2 - h$~~

$$x = \frac{h - h_f}{h_g - h_f}$$

d) $$\varepsilon_K = \frac{|\dot{Q}_{zu}|}{|W_t|} = \frac{Q_{zu} - Q_{ab}}{28\,W}$$

e) Der Druck würde immer weniger werden und das Wasser würde sublimieren, zuerst.
Irgendwann würde das Wasser den Trippelpunkt erreichen und nicht aus dem Essen entweichen.