[redacted]

A1

a) Stat. Fliessprozess

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

$$0 = \dot{m}(h_e - h_a) + \dot{Q}_{aus} - \cancel{\dot{W}_T}^{\,0,\ \text{da isobar}}$$

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

$$h_a - h_e = c^{if}(T_a - T_e) + \cancel{v^{if}(p_2 - p_1)}^{\,0}$$

$$p_2 = p_1$$

$$\dot{Q}_{aus} = \dot{m}\, c_{if}(T_{kf,a} - T_{kf,e})$$

b)

$$\overline{T} = \frac{\int_{se}^{a} T\, ds}{s_a - s_e}$$

$$\frac{Q}{T} = s \rightarrow T = \frac{Q}{s}$$

$$= \frac{\dot{Q}_{aus} \ln\left(\frac{s_a}{s_e}\right)}{s_a - s_e}$$

$$s_a - s_e = \int_{T_1}^{T_2} c^{if} \frac{1}{T}\, dT = c^{if} \ln\left(\frac{T_2}{T_1}\right)$$

$$= \dot{Q}_{aus} \frac{\ln\left(\frac{s_a}{s_e}\right)}{c^{if} \ln\left(\frac{T_2}{T_1}\right)}$$

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

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

d) $T_1 = 100°C$

$T_2 = 70°C \qquad \Delta T = 30°C = 30K$

Halb offenes system: $\underbrace{m_2}_{(m_1+\Delta m_{12})} u_2 - m_1 u_1 = \Delta m \, h_{ein} + Q - \cancel{W_n}^{0}$

$\Delta m_{12} = \frac{1}{h_{ein}} \left(m_1(u_2 - u_1) + \Delta m_{12} u_2 - Q \right)$

$\Delta m_{12} \left(1 - \frac{u_e}{h_{ein}} \right) = \frac{1}{h_{ein}} \left(m_1(u_2 - u_1) - Q \right)$

$\Delta m_{12} = \frac{1}{h_{ein} - u_2} \left(m_1(u_2 - u_1) - Q \right)$

$m_1 = 5755 \, kg$

A2 [redacted]

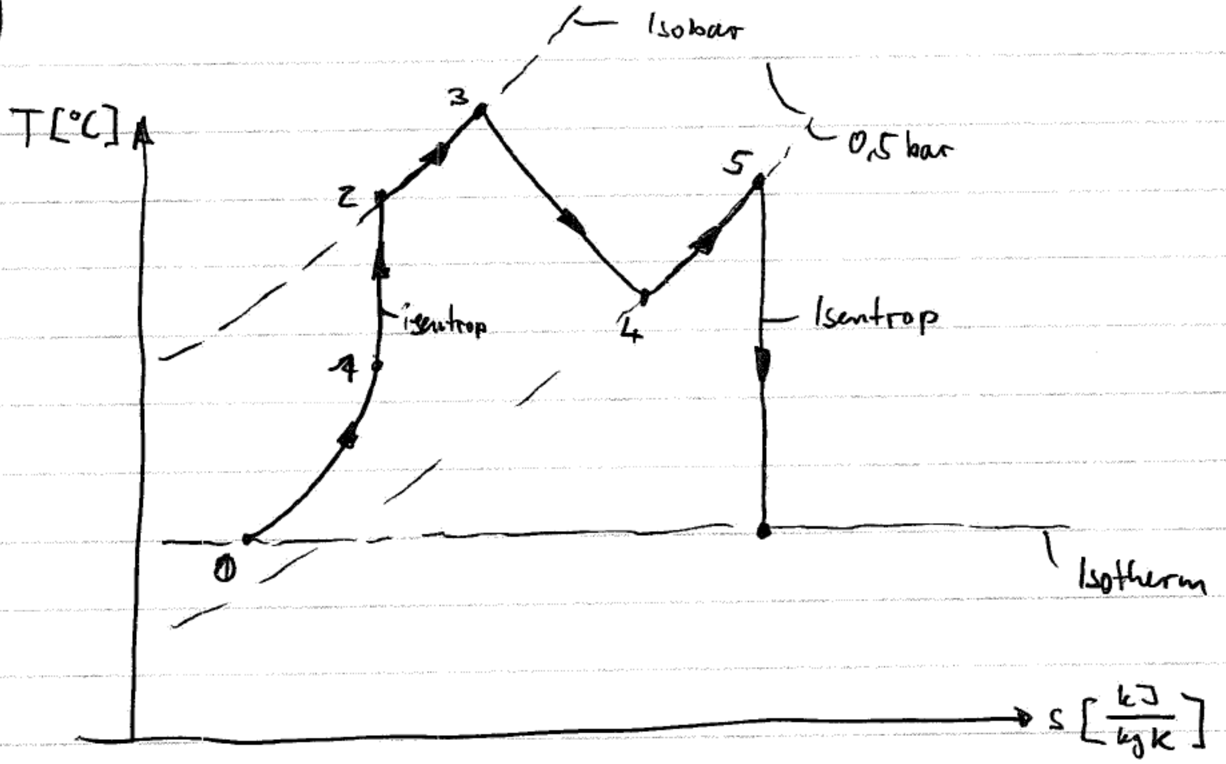
$c_p = 1{,}006 \frac{kJ}{kg\,K}$

$n = k = 1{,}4$

$PE = 0$

	p (bar)	T °C	s
0	0,191	-30°	
1	$p_1 > p_0$	$T_1 > T_0$	
2			$s_1 = s_2$
3	$p_3 = p_2$		
4			$s_3 < s_4$
5	$p_4 = p_5 = 0{,}5$	431,9K	
6			$s_5 = s_6$

a)



b) $w_5 = 220 \frac{m}{s}$ $p_5 = 0{,}5\,bar$ $T_5 = 431{,}9\,K$

Stat. Fliesspr.

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

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

$$\dot{W}_t^{Rev} = -\dot{m}\left(\int_1^2 v\,dp + \Delta ke\right) \qquad pv = RT$$

$$v = \frac{RT}{p}$$

$$= -\dot{m}(RT$$

c) $\dot{m}_{ges}\, ex_{str} = \dot{m}\left[h - h_0 - T_0(s - s_0) + k_e + \cancel{pe}^0\right]$ $w_6 = 510 \frac{m}{s}$

$$ex_{str6} = h_6 - h_0 - T_0(s_6 - s_0) + \frac{w_6^2}{2}$$

$$ex_{str,0} = \cancel{h_0 - h_0}^0 - \cancel{T_0(s_0 - s_0)}^0 + \frac{w_0^2}{2}$$

$$\Delta ex_{str} = h_6 - h_0 - T_0(s_6 - s_0) + \frac{w_6^2}{2} - \frac{w_0^2}{2}$$

$$h_6 - h_0 = c_p(T_6 - T_0)$$

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

$$\Delta ex_{str} = c_p(T_6 - T_0) - T_0\, c_p \ln\left(\frac{T_6}{T_0}\right) + \frac{w_6^2}{2} - \frac{w_0^2}{2}$$

$$= 1{,}006 \frac{kJ}{kg\,K}\left(340\,K - (-30 + 273{,}15)\,K\right) - (-30 + 273{,}15)\,K \cdot 1{,}006 \frac{kJ}{kg\,K} \ln\left(\frac{340}{-30 + 273{,}15}\right) + \frac{510^2}{2} - \frac{200^2}{2}$$

$$= 110'065{,}4218 \frac{kJ}{kg} \approx 110{,}1 \frac{MJ}{kg}$$

[redacted]

A2 forts

d) $e_{x,verl} = T_0 \, \dot{s}_{erz}$

$0 = \dot{m}(s_0 - s_6) + \cancel{\frac{\dot{Q}}{T}} + \dot{S}_{erz}$

adiabates Triebwerk

$\dot{s}_{erz} = s_6 - s_0 + \cancel{\frac{\dot{q}}{T}}$

$\dot{s}_{erz} = c_p \ln\left(\frac{T_6}{T_0}\right) - \cancelto{0}{R \ln\left(\frac{p_6}{p_0}\right)}$

$e_{x,verl} = T_0 \, c_p \ln\left(\frac{T_6}{T_0}\right)$ $\qquad T_0 = 243{,}15\,K$

$e_{x,verl} = 243{,}15\,K \cdot 1{,}006\,\frac{kJ}{kg\,K} \ln\left(\frac{340\,K}{243{,}15\,K}\right) = 82{,}009\,\frac{kJ}{kg}$

A3

[redacted]

Gas: $c_v = 0{,}633$

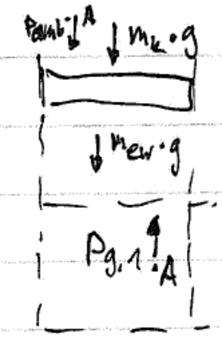
$M_g = 50 \frac{kg}{kmol}$

a) $p_{g,1}$: $pv = RT$ $R = \frac{\overline{R}}{M_g} = \frac{8{,}314 \frac{kJ}{kmol\,K}}{50 \frac{kg}{kmol}} = 0{,}16628 \frac{kJ}{kg\,K}$

$V_{g,1} = 3{,}14\,L$

$T_{g,1} = 500°C$ $m_{ew} = 0{,}1\,kg$

KGW



$\Rightarrow p_{g1} \cdot A = p_{amb} \cdot A + m_k \cdot g + m_{ew} \cdot g$

$p_{g1} = p_{amb} + \frac{m_k \cdot g}{A} + \frac{m_{ew} \cdot g}{A}$

$= 1 \cdot 10^5 \frac{N}{m^2} + \frac{32 \cdot 9{,}81\,N}{0{,}0079\,m^2} + \frac{0{,}1 \cdot 9{,}81\,N}{0{,}0079\,m^2} = 140'094{,}4406 \frac{N}{m^2}$

$\hat{=} 1{,}4\,bar$

$A = \frac{D^2}{4}\pi = \frac{(10 \cdot 10^{-2})^2\,m^2}{4}\pi = 0{,}00785398\,m^2$

$pV = mRT \rightarrow m_{g,1} = \frac{p_1 V_{g1}}{R\,T_1} = \frac{1{,}4 \cdot 10^5\,pa \cdot 3{,}14 \cdot 10^{-3}\,m^3}{0{,}16628 \cdot 10^3 \frac{J}{kgK} \cdot (500 + 273{,}15)\,K}$

$= 0{,}0034\,kg \hat{=} 3{,}422\,g$

b) $x_{eis,2} > 0$ $x_{eis,1} = \frac{m_{eis}}{m_{ew}} = 0{,}6$

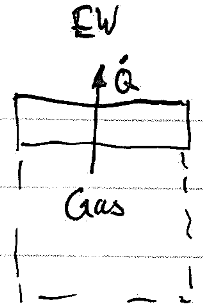
$\rightarrow m_{eis} = 0{,}6 \cdot m_{ew} = 0{,}06\,kg$

Gas und EW Thermodyn. GGW

Weil Dichte von Eis und Wasser gleich sind, verändert sich die Masse (und Volumen) von Eiswasser nicht. Durch das KGW sieht man, dass $p_{g,2} \overset{!}{=} p_{g,1}$

$p_{g,2} = 1{,}4\,bar$

b) forts.



$$m_{g1} = m_{g2} = 3,422\,g$$

Weil ~~das~~ EW ~~kann~~ wie Wasser im Nassdampf behandelt werden kann und $x_2 > 0$ ist, ist $T_{EW,2} = T_{EW,1} = 0°C$

Für thermodynamisches Gleichgewicht muss $T_{g,2} = T_{EW,2} = 0°C$ sein

c) Geschl. System an Kolben, Grenzen um Gas.

$$\Delta E = E_2 - E_1 = Q - W_V$$ kin. + pot. Energien vernachlässigen

$$m_g (u_2 - u_1) = Q - W_V$$

$$u_2 - u_1 = c_v (T_2 - T_1)$$

$$\rightarrow Q = m_g c_v (T_2 - T_1) + W_V$$

$$\rightarrow W_V = W_V^{rev} = m_g p_g (v_2 - v_1) = p_g (V_2 - V_1)$$

$$V_2 = \frac{m_g R T_2}{p_2} = \frac{0,034\,kg \cdot 0,166 \cdot 10^3 \frac{J}{kg\,K} \cdot 273,15\,K}{1,4 \cdot 10^5 \frac{N}{m^2}} = 0,00111\,m^3$$

$$\rightarrow W_V = 1,4 \cdot 10^5 \frac{N}{m^2} (0,0011\,m^3 - 3,14 \cdot 10^{-3}\,m^3) = -284,187\,J$$

$$\Rightarrow Q_{12} = 3,422 \cdot 10^{-3}\,kg \cdot 0,633 \cdot 10^3 \frac{J}{kg\,K} (273,15 - 500 + 273,15)\,K - 284,187\,J$$

$$= -1'367,24984\,J \approx -1,367\,kJ$$

A3 forts [redacted]

d) geschl. Kolben

$$E_2 - E_1 = Q - \cancel{W_v}^{\nearrow 0,\ \text{inkompressible Fl.}}$$

$$m_{ew}(u_2 - u_1) = Q$$

$$u_1 = u_f + x_1(u_g - u_f)$$

$$\rightarrow u_2 = \frac{Q}{m_{EW}} + u_1$$

Tab. 1: $u_f(T = 0°C) = -0{,}045 \ \frac{kJ}{kg}$

$u_g(T = 0°C) = -333{,}458 \ \frac{kJ}{kg}$

$$u_1 = -0{,}045 + 0{,}6(-333{,}458 - (-0{,}045))$$
$$= -200{,}0928 \frac{kJ}{kg}$$

$$\rightarrow u_2 = \frac{-1{,}367 \, kJ}{0{,}1 \, kg} - 200{,}0928 \frac{kJ}{kg} = -213{,}7628 \frac{kJ}{kg}$$

$$u_2 = u_f + x_2(u_g - u_f)$$

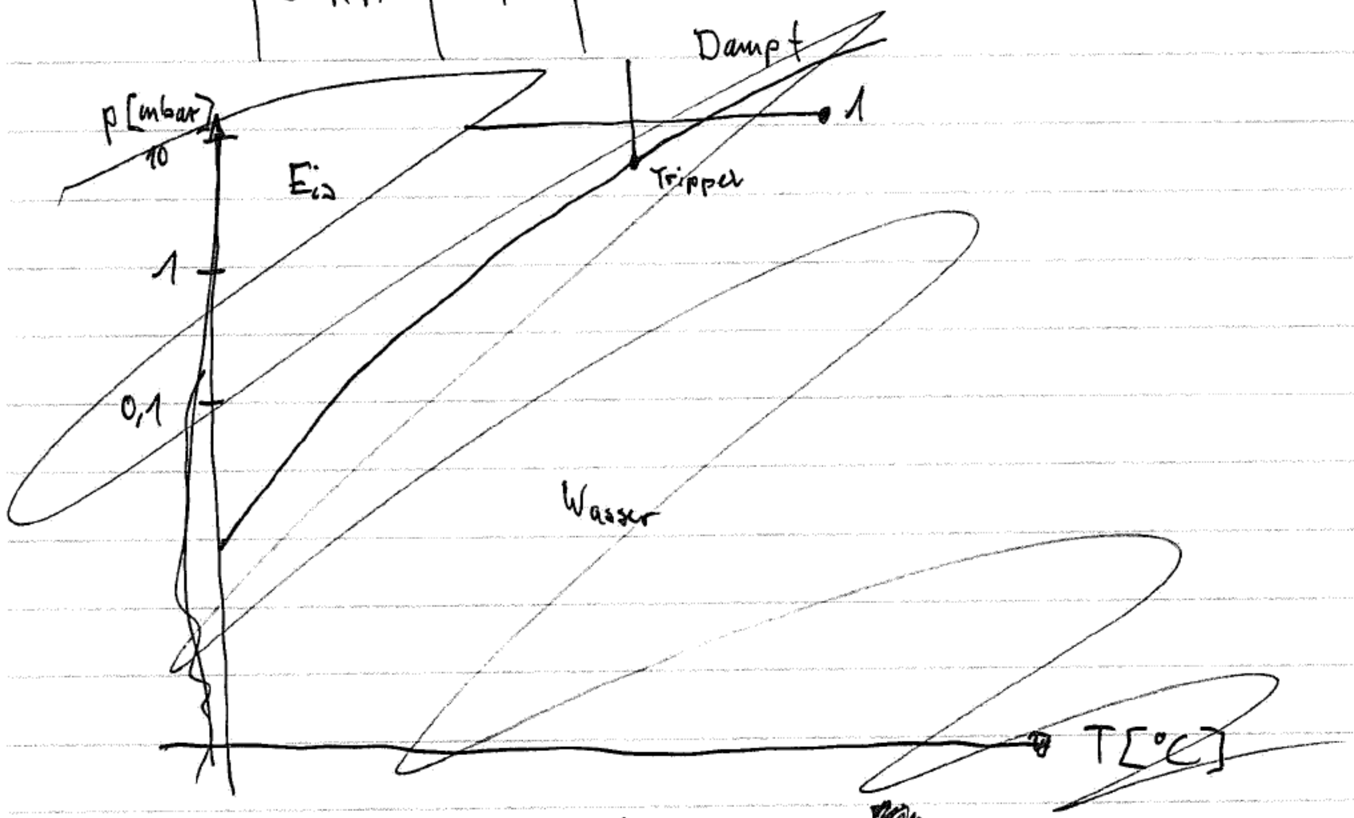
$$x_2 = \frac{u_2 - u_f}{u_g - u_f} = \frac{-213{,}7628 - (-0{,}045)}{-333{,}458 - (-0{,}045)} = 0{,}641$$

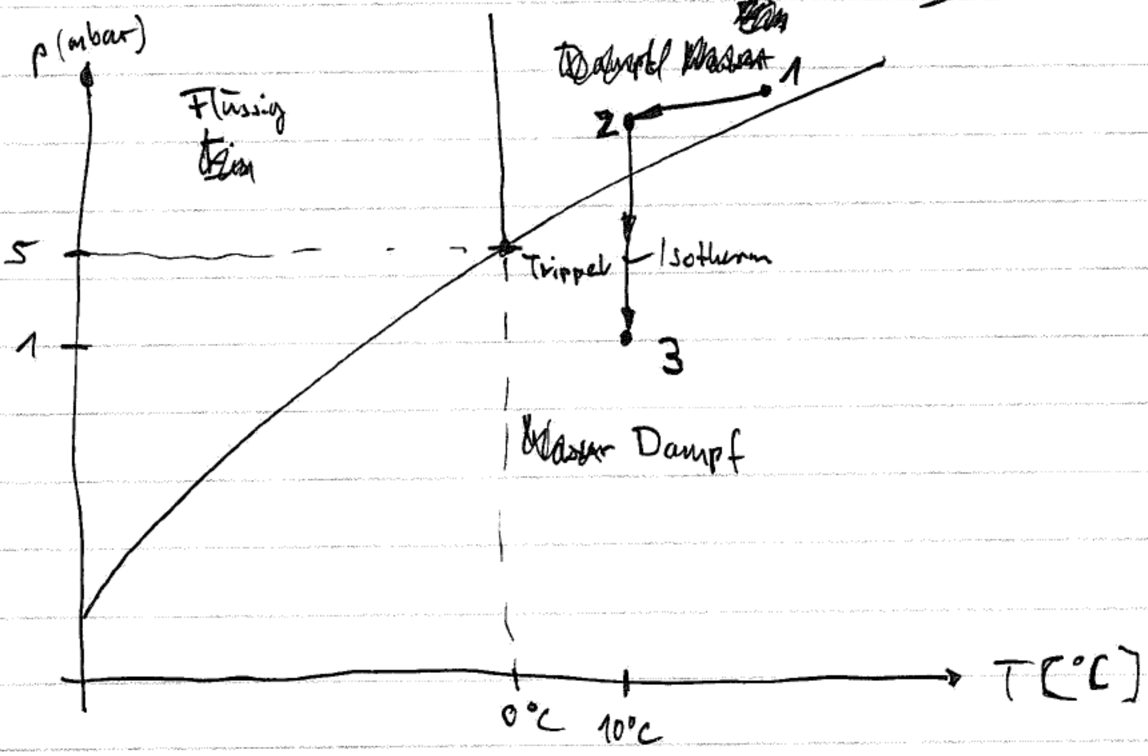
[redacted]

A4

a) Wasser der Lebensmittel

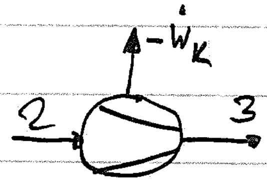
	p	T
1	$p_1 = p_2$	$> T_i$
2	$p_2 = p_1$	T_i
3	$p_3 < p(T_p)$	T_i





b) $\dot{m}_{R134a}$ $\qquad T_i = 10°C$

$T_1 = 4°C$



Stat. Fliess

$0 = \dot{m}(h_2 - h_3) + \underbrace{\cancel{\dot{Q}}}_{0,\ adiabat} - \dot{W}_K \rightarrow \dot{m} = \frac{\dot{W}_K}{h_2 - h_3}$

$p_2 = p_1$

$p_3 = p_4 = 8\,bar$

$h_3 = h_4 \rightarrow$ drossel

adiabat reversibel : $s_2 = s_3$

Tab A-11

$h_4 = h_f(8\,bar) = 93{,}42\ \frac{kJ}{kg} = h_1$

c) $h_1 = h_4 = 93{,}42\ \frac{kJ}{kg}$

$h_1 = h_f + x_1(h_g - h_f)$

$x_1 = \frac{h_1 - h_f}{h_{fg}}$

Tab A 10 $T = 4°C$

$h_f = 55{,}35$

$h_{fg} = 194{,}19$

$x_1 = \frac{93{,}42 - 55{,}35}{194{,}19} = 0{,}196$

d) $\epsilon_K = \frac{Q_{zu}}{W_T}$

e) Da der Druck abnimmt, wird auch die T_i abnehmen mit weiter laufendem Kreislauf, da der Prozess nicht mehr Isotherm ist.