[redacted]

Aufgabe 1

	ein	aus	Kein	Kaus
$\dot m$	0,3	0,3		
T	$70°$	$100°$	288,15 K	298,15 K
x	1	1		

$m_{ges} = 5755\,kg$

$x_D = \frac{m_P}{m_{ges}} = 0{,}005$

$T_{Relt} = 100°C$

$Q_R = 100\,kW$

$Q_{aus} =$

a) Ges: Q_{aus}

Energiebilanz

$$h_{(x=1,70°)} = 292{,}98\,\frac{kJ}{kg}$$
$$h(x=1,100°) = 419{,}04\,\frac{kJ}{kg}$$
Tabelle A-2

$$\frac{dE}{dt} = \sum_i^n \dot m\, h_i + Q - W_t \rightarrow \cancel{0 = \dot m_{ein} h_{ein} - \dot m_{aus} h_{aus} + \dot m}$$

$$0 = \dot m(h_e - h_a) + Q_R - Q_{aus} + \cancel{Q} \rightarrow Q_{aus} = \dot m(h_e - h_a) + Q_R$$

$$Q_{aus} = 0{,}3\,(292{,}98 - 419{,}04) + 100\,kW = 62{,}18\,kW$$

b) Ges: $\overline{T}_{KF}$

$$\int T ds = q_{rev} = h_a - h_e$$

$$\overline{T}_{KF} = \frac{\int_e^a T\,ds}{s_a - s_e} = \frac{h_a - h_e}{s_a - s_e} = \frac{\cancel{c}^{if}(T_2 - T_1) + \cancel{v}(\cancel{p_2 - p_1})^{0}}{\cancel{c}^{if} \cdot \ln\left(\frac{T_2}{T_1}\right)} = \frac{T_2 - T_1}{\ln\left(\frac{T_2}{T_1}\right)} = \frac{298{,}15 - 288{,}15}{\ln\left(\frac{298{,}15}{288{,}15}\right)} =$$

$$\overline{T}_{KF} = \frac{10}{\ln\left(\frac{298{,}15}{288{,}15}\right)} = 293{,}12$$

c) Ges: S_{ez}

$$0 = \dot m\left[s_e - s_a\right] + \frac{\dot Q_j}{\overline{T}_j} + S_{ez} \rightarrow S_{ez} = \dot m\left[s_a - s_e\right] - \frac{\dot Q_{aus}}{\overline{T}_j}$$

$$\dot S_{ez} = 0{,}3\left[7{,}3549 - 7{,}7553\right] - \frac{62{,}18}{293{,}12} = -0{,}12012 - 0{,}212132 = 0{,}33\,\frac{kJ}{kg}$$

$$s(1/70°) = 7{,}7553$$
$$s(1/100°) = 7{,}3549$$
Tab-A2

~~Aufgabe 1~~

~~a) Ges: $\dot{Q}_{aus}$~~

d) $T_1 = 100°C$ $\quad$ $T_2 = 70°C$ $\quad$ Ges: Δm_{12}

$m_1 = 5'755\, kg$ $\quad$ $T_{12ein} = 20°C \quad (x=1)$

$Q_{12} = 35\, MJ$

$W \stackrel{!}{=} 0$ $\quad$ Energiebilanz mit Q

$$Q_1 - Q_{12_{ein}} = Q_{12} \quad \rightarrow \quad m_1 \cdot c_v \cdot T_1 - m_{12} \cdot cv \cdot T_2 = Q_{12}$$

$$\boxed{cv(T_1 - T_2) \rightarrow u_1 - u_2}$$

$u_1(100°/x=0{,}005) = 429{,}38 \frac{kJ}{kg}$
$u_2(x=1/20°) = 2402{,}9 \frac{kJ}{kg}$
Tab A2

$$m_1 \cdot u_1 - m_{12} \cdot u_2 = Q_{12}$$

$$m_{12} = \frac{m_1 \cdot u_1 - Q_{12}}{u_2} = \frac{5'755 \cdot 429{,}38 - 35'000}{2402{,}9} =$$

$u_1 = u_F + x(u_G - u_G) = 418{,}94 + 0{,}005(2506{,}4 - 418{,}94) = 429{,}377$

Tabelle A-2

$m_{12} = 1'014\, kg$

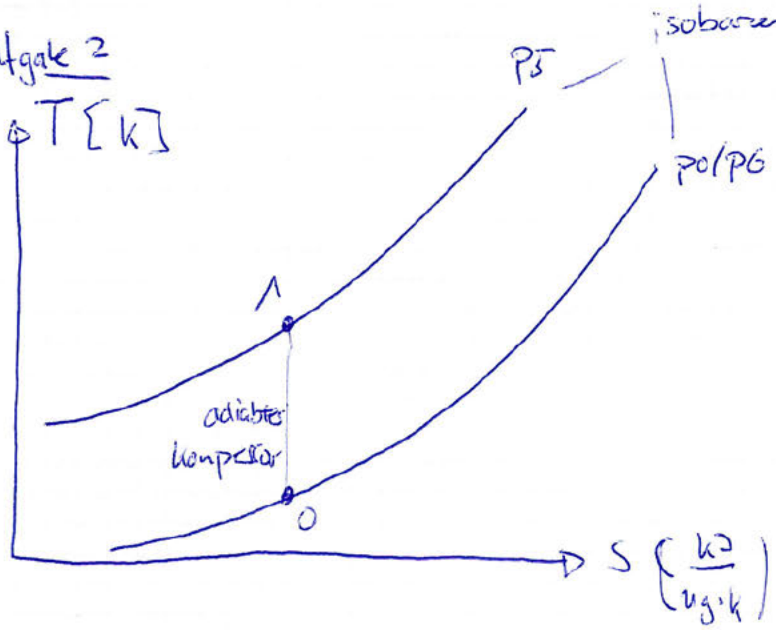
e) Ges: $\dot{S}_{erz}$

$$m_2 \cdot s_2 - m_1 \cdot s_1 = m_{12} \cdot s_{12} + \dot{S}_{erz}$$

[redacted]

Aufgabe 2

a



b) ges: w_6 + T_6

Düse: $Q = 0$ | $W = 0$ $\Rightarrow h_5 = h_6$!

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

$0 = \cancel{\dot m}\left[\cancel{h_5 - h_6} + \frac{w_5^2 - w_6^2}{2}\right] \rightarrow w_5 = w_6 = 220 \frac{m}{s}$

c) $\dot m_{ex,t} = \dot m\left[h_6 - h_0 - T_0(s_6 - s_0) + ke + \cancel{pe}\right]$

$\dot m_{ext} = \dot m_{ges}\left[c_p(T_6 - T_0) - T_0\left(c_p \cdot \ln\left(\frac{T_6}{T_0}\right) - R \cdot \ln\left(\frac{p_6}{p_0}\right) + \frac{(200 \frac{m}{s})^2 - (510 \frac{m}{s})^2}{2}\right)\right.$

$\dot m_{ext} = \dot m_{ges}\left[1{,}006(340 K - 243{,}15) - 243{,}15\left(1{,}006\left(\frac{340}{243{,}15}\right)\right) - \right.$

$R = c_p - c_v$ $\quad n = \kappa = \frac{c_p}{c_v} \rightarrow \boxed{c_v = \frac{c_p}{\kappa}}$

d) $e_{x,vel} = \frac{T_0 \cdot \dot S_{erz}}{\dot m_{ges}}$

Aufgabe 3

[redacted]

→ ideal Gas

	Zustand 1	Zustand 2
V_g	3,14 L	
T_g	500°C = 773,15	
m_{EW}	0,1 kg	
T_{EW}	0°C	
X_E	0,6	

$m_K = 32\,kg$ / $p_{amb} = 1\,bar$ / $D = 0{,}1\,m$ / $c_v = 0{,}633 \frac{kJ}{kg \cdot K}$ / $M_g = 50 \frac{kg}{kmol}$

a) Gas: $p_{g,1}$ / m_g

Wasser inkompressibel daher wie extra gewicht!

$\boxed{F = p \cdot A}$ $\quad A = \frac{d^2 \cdot \pi}{4}$

$p_0 \downarrow \quad \downarrow F_{G,K} \quad \downarrow F_{g,E}$

Membran

$\uparrow p_{g1}$

$$p_0 \cdot A + m_K \cdot g + m_{EW} \cdot g = p_{g1} \cdot A$$

$$\rightarrow p_{g1} = \frac{p_0 \cdot A + m_K \cdot g + m_{EW} \cdot g}{A} = \frac{\frac{1 \cdot 10^5 \cdot 0{,}1^2 \cdot \pi}{4} + 32 \cdot 9{,}81 + 0{,}1 \cdot 9{,}81}{\frac{0{,}1^2 \cdot \pi}{4}}$$

$$p_{g1} = \frac{785{,}398 + 313{,}92 + 0{,}981}{\frac{0{,}1^2 \cdot \pi}{4}} = 140'094\,Pa = 1{,}4\,bar$$

$$R = \frac{\bar{R}}{M} = \frac{8{,}314\,J \cdot \cancel{mol}}{50 \cdot 10^{-3} \cdot kg \cdot \cancel{mol} \cdot K}$$

$$R = 166{,}28 \frac{J}{kg \cdot K}$$

$$p_g \cdot V_g = m_g R T \rightarrow m_g = \frac{p_g \cdot V_g}{R \cdot T} = \frac{140'094 \cdot 3{,}14 \cdot 10^{-3}}{166{,}28 \cdot 773{,}15} = 3{,}422 \cdot 10^{-3}\,kg$$

↳ 3,422 g

$$\left[\frac{\cancel{N} \cdot \cancel{m^3} \cdot kg \cdot K}{\cancel{m^2} \cdot \cancel{J} \cdot K} \right]$$

[redacted]

b) Ges: T_{g2} + p_{g2}

Der Vorgang ist adiabat daher ist der Übergang polytrop pV^n = constant.
aus der idealen gasgleichung $pV = mRT$ folgt wenn pV = const, muss
das ganze auch isotherm sein!

Daher $T_{g2} = T_{g1} = 500°C$

$$\left(\begin{array}{l} pV^n = mRT \\ p_2 = \frac{mRT}{V^n} = \frac{3{,}422 \cdot 10^{-3} \cdot 166{,}28}{(3{,}14 \cdot 10^{-3})} \end{array} \right)$$

c) Ges: Q_{12}

$\cancel{U + KE + PE - Q - W}$

$$\frac{dE}{dt} = Q - W = 0 \rightarrow \text{da geschlossenes System}$$

$$Q = W = \int_1^2 p \cdot dV = p_0 (V_{g2} - V_{g1}) = 1'500\,J$$

d) Ges: x_{Eis2}

$m_{Eis1} = 0{,}6 \cdot m_E = 0{,}06\,kg$ $\qquad V_1 = V_2 \qquad p_1 = p_2 \qquad T_1 = 273{,}15\,K = 0°$

$m_{Wasser1} = 0{,}04\,kg$

$$\Delta U_{Fl} = Q = u(T_2) - u(T_1) = m c_v (T_2 - T_1) = 1'500\,J$$

$$p_E = p_0 + \frac{m_K \cdot g}{A} = 1 + 0{,}4 = 1{,}4\,bar$$

$$T_2 - T_1 = \cancel{\Delta u} \cdot \frac{Q}{c_v} \rightarrow T_2 = \cancel{\Delta u} \cdot \frac{Q}{c_v} + T_1 = \frac{\Lambda}{0{,}633 \frac{kJ}{kg \cdot K}} \cdot 1{,}5\,kJ\ ;$$

$$U = m(\Delta u) = m \cdot c_v (T_2 - T_1) = Q$$

$$T_2 - T_1 = \frac{Q}{m \cdot c_v} \rightarrow T_2 = \frac{Q}{m c_v} + T_1 = \frac{1{,}5\,kJ \cdot \cancel{kg} \cdot K}{0{,}1\,kg \cdot 0{,}633\,\cancel{kJ}} + 273{,}15 = 296{,}846\,K$$

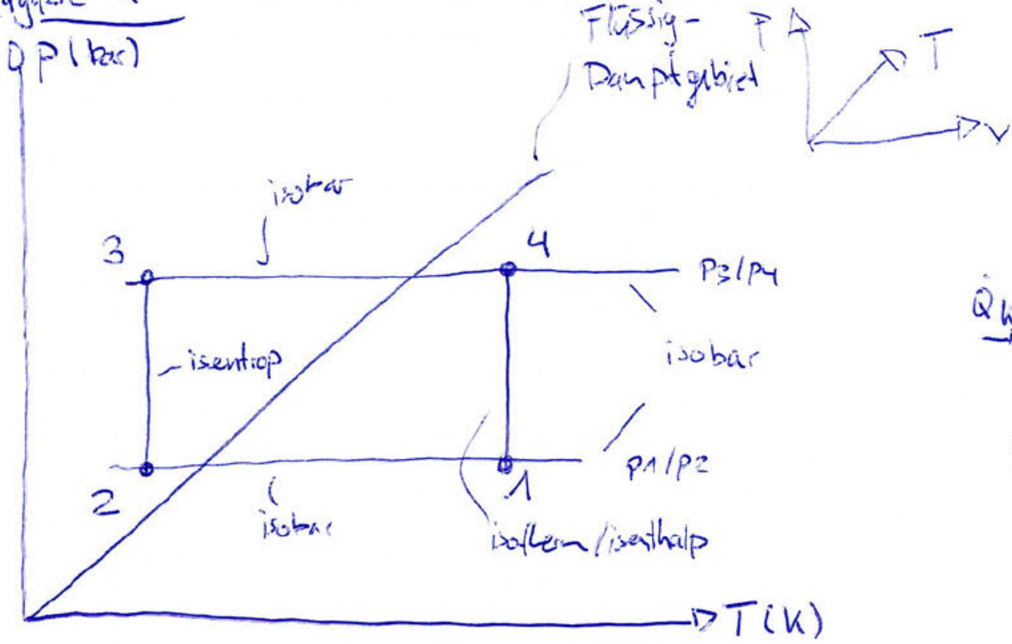
$$\Delta u = \frac{1'500\,\cancel{J}\,kJ}{0{,}1\,kg \cdot 1000\,\cancel{J}} = 15 \frac{kJ}{kg}$$

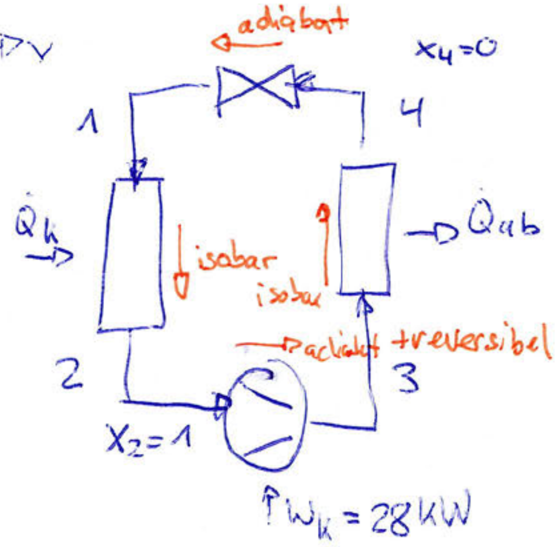
$u_{Fest}(1{,}4\,bar) = -333{,}458 \frac{kJ}{kg}$ $\qquad u_{Flüssig}(1{,}4\,bar) = -0{,}045 \frac{kJ}{kg}$

$$\Delta u = u_{Fl} + x(u_{Fest} - u_{Fl}) \Rightarrow x = \frac{\Delta u - u_{Fl}}{u_{Fest} - u_{Fl}} = \frac{15 - 0{,}045}{333{,}458 - 0{,}045} = 0{,}045$$

[redacted]

Aufgabe 4





b) ges: $\dot{m}_{R134a}$

Stationärer Fliessprozess, E-bilanz

$$0 = \dot{m}\left[h_1 - h_2\right] + \dot{Q}_K$$

$$\dot{Q}_K = \dot{m}\left[h_2 - h_1\right]$$

	1	2	3	4
p			$8 \cdot 10^5$	$8{,}10^5$
x		1		0
T		$T_i - 6 = -22$		$T_i - 6$
h	93,42	234,08		93,42

$$0 = \dot{m}\left[h_2 - h_3\right] - W_K$$

$$\dot{m} = \frac{W_K}{h_2 - h_3} = \frac{-28\,kW}{(234{,}08 - 571{,}39)\,\frac{kJ}{kg}} = 0{,}083\,\frac{kg}{s}$$

$\boxed{p_3 = p_4}$ $\boxed{h_1 = h_4}$ $\boxed{T_1 = T_4}$

→ adiabate Drossel

$$s_2 = s_3 = s_2(-22|x=1) = 0{,}9351\,\frac{kJ}{kg \cdot K}$$

Tab A-10

$$h_2(-22°|x=1) = 234{,}08\,\frac{kJ}{kg}$$

$$s_3(8\,bar) = 0{,}9351$$

$\boxed{A\text{-}12}$

→ zwischen $s(8|40)$ $s(8\,bar|50°C)$

interpolieren:

$$h_3 = h(40) + \frac{h(50) - h(40)}{s(50) - s(40)} \cdot s_3$$

$$h_3 = 273{,}66 + \frac{284{,}39 - 273{,}66}{0{,}9711 - 0{,}9374} \cdot 0{,}9351 = 571{,}39\,\frac{kJ}{kg}$$

c) Ges: x_1 [redacted]

$\boxed{h_1 = h_4}$ $\boxed{T_1 = T_4}$

$x_4 = 0$ $h_4 (x=0 / 8\,bar) = 93{,}42\ \frac{kJ}{kg}$ Tabelle A-11

$h_1 = h_4 = 93{,}42\ \frac{kJ}{kg}$ ~~→ T_4 = 31,33 °C~~ ~~Tabelle A-11~~

d) $\varepsilon_K = \frac{|\dot{Q}_{zu}|}{|W_t|} = \frac{|\dot{Q}_K|}{|\dot{W}_K|} = \frac{|12\ kW|}{|28\ kW|} = 0{,}429$

$0 = \dot{m}_{R134}(h_1 - h_2) + \dot{Q}_K \rightarrow \dot{Q}_K = \dot{m}_{R134}(h_2 - h_1) = 0{,}083\,(238{,}08 - 93{,}42) = 12\ kW$

e) Wasser geht sofort in Gasphase über.