[redacted]

Aufgabe 1

(a) $\dot{Q}_{aus} = ?$

Kühlflüssigkeit

Energiebilanz:

stationär:

wird keine Arbeit geleistet!

$$\cancel{\frac{dE}{dt}}^{0} = \sum \dot{m} [h_i + ke + pe] + \sum \dot{Q} - \cancel{\sum \dot{W}}^{0}$$

$$0 = \dot{m}[h_{ein} - h_{aus}] + \dot{Q}_R - \dot{Q}_{aus}$$

$$\dot{Q}_{aus} = \dot{m}[h_{ein} - h_{aus}] + \dot{Q}_R =$$

TAB A-2:
reines Wasser   siedene Flüssigkeit $\Rightarrow h_f$

$h_f(70°C) = 292{,}98 \frac{kJ}{kg}$ $\dot{Q}_R = 100 kW$

$h_f(100°C) = 419{,}04 \frac{kJ}{kg}$

$$\dot{Q}_{aus} = 0{,}3 \frac{kg}{s} [h_f(70) - h_f(100)] + \dot{Q}_R$$

$$\underline{\underline{\dot{Q}_{aus} = 62{,}182 kW}} \quad \Rightarrow A$$

(b) $\bar{T}_{KF} = \frac{\int_e^a T\,ds}{s_a - s_e}$

$dH = T\,ds + \cancel{V\,dp}^{\,0}$ isobar!

$p_{aus} = p_{ein}$

$dH = h_a - h_e$

$$\bar{T}_{KF} = \frac{h_a - h_e}{s_a - s_e}$$

$$\bar{T}_{KF} = \frac{h_{aus} - h_{ein}}{s_{aus} - s_{ein}}$$

Ideale Flüssigkeit:

$s_{if} = s_f(T)$

~~$s_{aus} = s_f(298{,}15\,K, 25\,°C) =$~~

~~$s_{ein} = s$~~

$$h_{aus} - h_{ein} = \int_{T_{ein}}^{T_{aus}} c^{if}(T)\,dT + v^{if}\cancel{(p_{aus} - p_{ein})}^{\,0, 130 bar}$$

$$= c^{if}(T) \cdot (T_{aus} - T_{ein})$$

$$s_{aus} - s_{ein} = \int_{T_{ein}}^{T_{aus}} \frac{c^{if}(T)}{T}\,dT = c^{if}(T)\left[\ln\left(\frac{T_{aus}}{T_{ein}}\right)\right]$$

$$\Rightarrow \bar{T}_{KF} = \frac{\cancel{c^{if}} \cdot T_{aus} - T_{ein}}{\cancel{c^{if}}\,\ln\left(\frac{T_{aus}}{T_{ein}}\right)} = \underline{\underline{293{,}12\,K}}$$

$T_{aus} = 298{,}15\,K$

$T_{ein} = 288{,}15\,K$

Aufgabe 1 [redacted]

(c)

~~Instationär~~ $\frac{dS}{dt} = \sum \frac{\dot{Q}}{T} + \dot{S}_{erz}$

$\cancel{S_{aus} - S_{ein} = \frac{Q_{aus}}{T} + \dot{S}_{erz}}$

$\cancel{\dot{S}_{erz} = S_{aus} - S_{ein} + \frac{Q_{aus}}{T}}$ aus (b)

~~stationär:~~

$\cancel{\frac{dS}{dt} = \sum \frac{Q}{T} + \dot{S}_{erz}}$

$\cancel{S_{aus} - S_{ein} = \frac{Q_{aus}}{T} + \dot{S}_{erz}}$

stationär → $\cancel{\dot{S}_{erz} = S_{aus} - S_{ein} - \frac{Q_{aus}}{T}}$

Entropiebilanz

$0 = \dot{m}\,[s_{ein} - s_{aus}] + \sum \frac{\dot{Q}}{T} + \dot{S}_{erz}$

vom reinen Wasser

$\dot{S}_{erz} = \dot{m}\,[s_{aus} - s_{ein}] - \left(\frac{\dot{Q}_R}{T_R} + \frac{\dot{Q}_{aus}}{T_{KF}} \right)$

$\dot{m} = \underline{0{,}3}$

TAB A-2

$s(70) = s_f(70) = 0{,}9549 \ \frac{kJ}{kgK}$

$s(100) = s_f(100) = 1{,}3069 \ \frac{kJ}{kgK}$

negativ

$\dot{S}_{erz} = 0{,}1056 \frac{kJ}{KS} - \left(\frac{100}{(100+273{,}15)} + \frac{\dot{Q}_{aus}}{(T_{KF})} \right)$

$\underline{\underline{\dot{S}_{erz} = 49{,}75 \ \frac{W}{K}}}$

(d)

$T_R = 70°$

Δm_{12} $\quad$ $T_{ein,12} = 20°C$

$\underline{Q_{R,12} = 35\ MJ}$ $\quad$ $m_1 =$

<u>Energiebilanz:</u> $\quad$ <u>Halboffener System:</u> $\quad$ $\underline{ke + pe = 0}$

$$\Delta E = m_2 u_2 - m_1 u_1 = m_i \cdot h_i + \Sigma Q - \cancel{\Sigma W}^{0}$$

$$\boxed{m_2 u_2 - m_1 \cdot u_1 = \Delta m_{12} \cdot h_i(20°C) + Q_{aus}}$$

$m_1 = 5755\, kg$ $\quad$ $(m_2 - m_1) \cdot h_i(20°C) + Q_{aus}$

$u_1 =$ $\quad$ <u>TAB A-2:</u>

$h_i(20°C) = h_f(20°C) = 83{,}96\ \frac{kJ}{kgK}$

$u_2 =$ $\quad$ <u>TAB A-2</u> $\quad$ $u_f(100°C) = 418{,}94$

$u_1 = u_f + x(u_g - u_f) =$ $\quad$ $u_g(100°C) = 2506{,}5$

TAB A-2: $\quad$ $\boxed{429{,}3778\ \frac{kJ}{kg}}$

$$\boxed{u_2 = u_f(70°) = 292{,}95\ \frac{kJ}{kg}}$$

$$\Rightarrow m_2 \cdot u_2 - m_1 \cdot u_1 = m_2 h_i(20°) - m_1 \cdot h_1 + Q_{aus}$$

$$m_2(u_2 - h_i) = m_1 \cdot u_1 - m_1 \cdot h_1 + Q_{aus}$$

$$m_2 = \frac{m_1 \cdot u_1 - m_1 \cdot h_i + Q_{aus}}{(u_2 - h_i)} = \underline{9679{,}31\,kg}$$

$$\Delta m_{21} = m_2 - m_1 = \underline{3\,924{,}31\,kg}$$

[redacted]

1

(e)

ΔS_{12}

$m_2 \cdot s_2 - m_1 \cdot s_1 =$

$\Delta S_{12} = 1547{,}5 \frac{kJ}{K}$

TAB A-2:

$s_1 = s_f + x(s_g - s_f)$

$s_f(100\,°C) = 1{,}3069$

$s_g(100°C) = 7{,}3549$

$x = 0{,}005$

$s_1 = 1{,}33714$

$s_2 = s_f(70°C) = 0{,}9549$ TAB A-2

aus d

$$\boxed{\begin{aligned} m_2 &= 9679{,}31 \\ m_1 &= 5755 \end{aligned}}$$

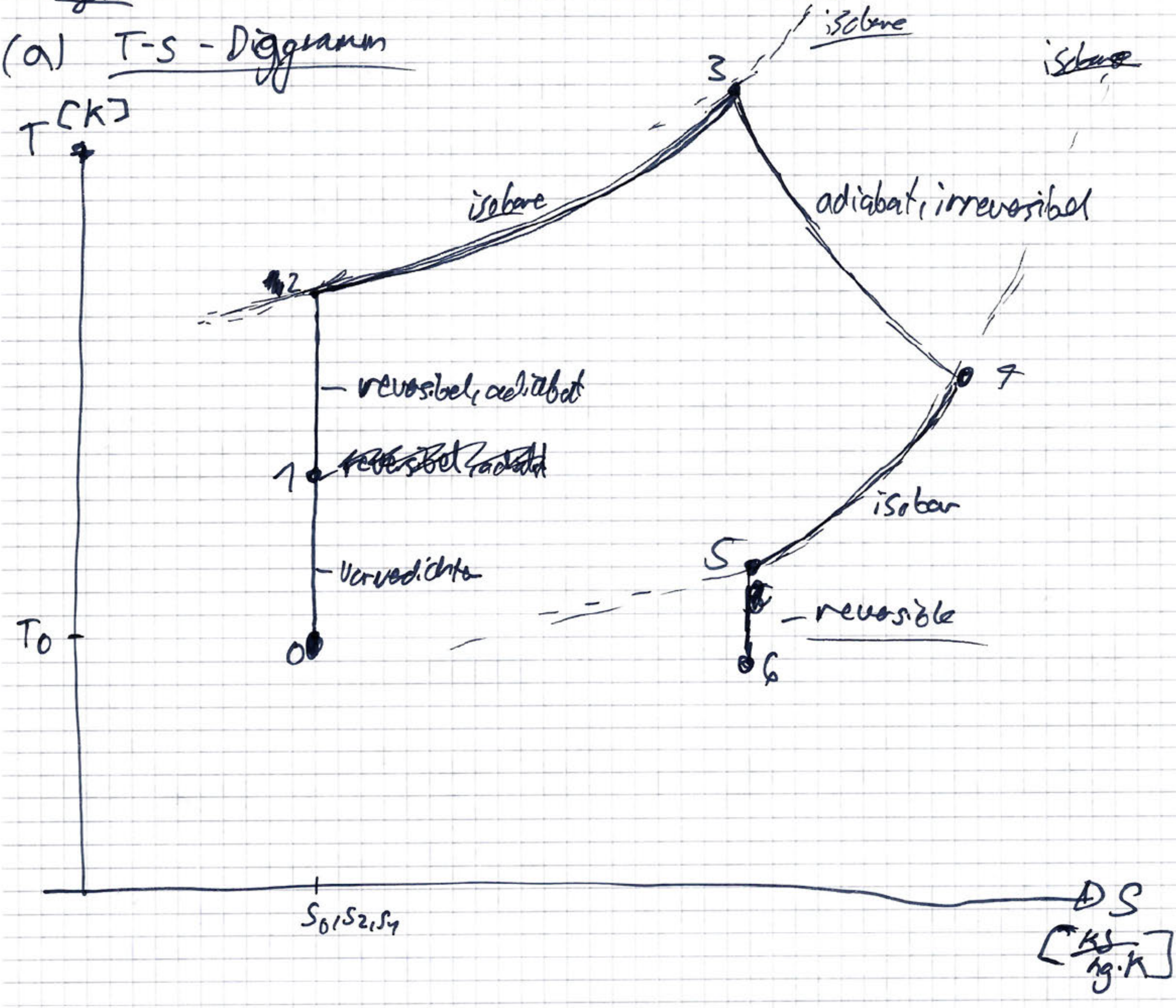
[redacted]

Aufgabe 2

~~Aufgabe~~

(a) T-s - Diagramm

$T_0 = 243{,}15\,K$



⑥

$w_6 = ?$ $T_6 = ?$

$T_6 = ?$

$\underline{n = k = 1{,}4}$

$p_6 = p_0 = 0{,}191\,\text{bar}$

$p_5 = 0{,}5\,\text{bar}$

$T_5 = 431{,}9\,K$

ideale Gas:

$$\left(\frac{T_6}{T_5}\right) = \left(\frac{p_6}{p_5}\right)^{\frac{n-1}{n}}$$

$$T_6 = T_5 \cdot \left(\frac{p_6}{p_5}\right)^{\frac{n-1}{n}} = \underline{\underline{328{,}07\,K = T_5}}$$

$\underline{w_6 = ?}$

$5 \to 6$ adiabat reversibel!

$\hookrightarrow Q = 0$

Energiebilanz:

~~$W = 0$~~

stationär:

$$0 = \dot{m}\left[h_5 - h_6 + \frac{w_5^2 - w_6^2}{2} + g(\cancel{z_5 - z_6})\right] + \Sigma\cancel{Q} - \Sigma W$$

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

$$W_t \cdot \dot{m} = -\int_1^2 v\,dp$$

$$n \cdot \int_1^2 p\,dv$$

$n \neq 1$

$$h_5 - h_6 + \frac{w_5^2 - w_6^2}{2} = \frac{n \cdot R(T_6 - T_5)}{1-n}$$

$$\dot{m}\left(\cdot\, n \cdot \frac{R(T_6 - T_5)}{1-n}\right) = W_t$$

Luft!

[redacted]

(2)

(b)

$$w_6 = \sqrt{\left(\frac{n \cdot R \cdot (T_6 - T_5)}{1-n} + h_6 - h_5 + w_5^2\right) \cdot 2}$$

$$h_6 - h_5 \rightarrow c_p (T_6 - T_5)$$

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

$$R = \frac{\overline{R}}{M_{Luft}} = \frac{\frac{J}{mol\,K}}{\frac{kg}{k \cdot mol}} = 0{,}2869 \frac{kJ}{kg\,K}$$

$c_p = 1{,}006 \frac{kJ}{kgK}$

$$w_6 = 310{,}61 \frac{m}{s}$$

(c) Exergie:

$$\Delta ex_{,str} = [h - h_0 - T_0 (s - s_0) + ke + pe]$$

$$\Delta ex_{,str} = [h_6 - h_0 - T_0 (s_6 - s_0) + ke + \cancel{pe}^{\,0}] = 122{,}2 \frac{kJ}{kg}$$

$h_6 (p_6 = 0{,}191,\ T_6 = 328{,}07) =$

$s_6 (p_6 = 0{,}191,\ T_6 = 328{,}07) =$

$$h_6 - h_0 = c_p^{ig}(T) \cdot (T_6 - T_0)$$

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

$\frac{p_6}{p_0} = 1$

$\ln(1) = 0$

wie bei aufgabe 1 hergeleitet

$$h_6 - h_0 = c_p^{ig} (T_6 - T_0) = 85{,}43 \frac{kJ}{kg}$$

$$s_6 - s_0 = 0{,}301 \frac{kJ}{kgK} \quad \Rightarrow \cdot T_0 = 73{,}27 \frac{kJ}{kg}$$

$$ke = \frac{w_6^2}{2} - \frac{w_{Luft}^2}{2} = 110 \frac{kJ}{kg}$$

d)

nigge

$e_{x,verl}$

Stationär Exergiebilanz:

$$0 = \underbrace{\dot{m}\left[h_e \cdots\cdots\right]}_{e_{x,str}} + \cancel{\not{d}}\, e_{x,Q} - w_{t,n} - \dot{e}_{x,verl}$$

ganze ist adiabat!

$$e_{x,ver} = \Delta e_{x,str\,0,6} + \cancel{e_{x,Q\,0,6}} - w_{t,n}$$

$$e_{x,ver} = \Delta e_{x,str\,0,6} - w_{t,n}$$

Turbine:

aufgabe b) $\Rightarrow w_t = \dfrac{-n \cdot R(T_6 - T_5)}{1-n}$

$= -104260{,}9 \frac{J}{kg}$

$$\Delta e_{x,verl} = 100 \frac{kJ}{kg} + 104260{,}9 \frac{kJ}{kg}$$

$$= \underline{\underline{204{,}26 \frac{kJ}{kg}}}$$

3

[redacted]

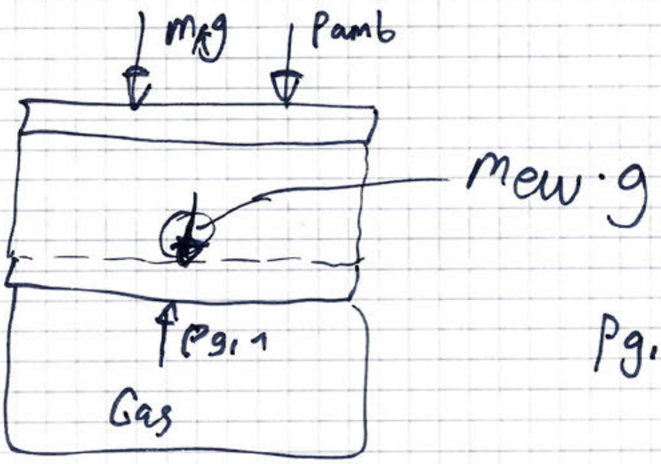
(a) $p_{g,1}$ Zustand 1

m_g im Zylinder

$c_v = 0{,}637 \frac{kJ}{kgK}$

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

~~pV = mRT~~ $p_{g,1}$:



$p = \frac{F}{A}$ $g = 9{,}81$

$$p_{g,1} = \frac{m_{ew} \cdot g}{A} + \frac{m_K g}{A} + p_{amb}$$

Zylinder:

$$A = \pi r^2 = \pi \left(\frac{D}{2}\right)^2 = \pi \cdot \left(\frac{0{,}1}{2}\right)^2 =$$

$$A = 0{,}007854\,m^2$$

$$p_{g,1} = 140094{,}44\,Pa$$

$$= 1{,}401\,bar$$

m_g:

$$pV = mRT$$

$$\frac{p_1 V_1}{R T_1} = m_g = 0{,}003421\,kg = 3{,}421\,g$$

$$R = \frac{\bar{R}}{M_G} = \frac{8{,}314 \frac{kJ}{molK}}{50 \frac{kg}{kmol}}$$

$$0{,}16628 \frac{kJ}{kgK} = R$$

LoB

$$V_1 = 3{,}14\,L = 3{,}14 \cdot 10^{-3}\,m^3$$

$$T_1 = 500°C \Rightarrow 773{,}15\,K$$

③ ⑥

$x_{Eis,2} > 0$

Da der Zustand 2 ein ~~g~~ ~~Gleichgewicht darstellt~~ ~~=w~~ Endzustand und immer noch Eis vorhanden ist. ~~Und~~ ~~zusätzl~~ muss $T_{g,2}$ dieselbe Temperatur haben wie das Eis als $\underline{T = 0°C}$.

Da der Kolben gegen oben isoliert ist, ~~entweicht dort keine Temp oder kommt dazu!~~

$T_{g,2} = 0°C$

c) Q_{12}

$\boxed{x_{Eis,1} = \frac{m_{Eis}}{m_{EW}} = 0{,}6}$

~~$m_g = 3kg$~~

~~x_{E1}~~

Energiebilanz: $\dot{m} = 0!$

$$\frac{dE}{dt} = \cancel{\Sigma \dot{m} (\quad)} + \Sigma \dot{Q} - \Sigma \dot{W}$$

$$\Delta U_{12} = \Sigma Q - \cancel{\Sigma W_v}^{\,0}$$

vernachlässigen?
↳ Kinetische, pot Energie vernachlässigen!

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

$T_2 = 0°C = 273{,}15K$

$T_1 = 500°C = 773{,}15K$

$$m_g \cdot (u_2 - u_1) = Q_{12}$$

$$↳ \int_{T_1}^{T_2} c_v \, dt = c_v (T_2 - T_1)$$

~~m_g~~

$c_v = 0{,}633 \frac{kJ}{kgK}$

$$m_g \cdot c_v (T_2 - T_1) = Q_{12} = \cancel{1082{,}9}$$

$\underline{\underline{1083 \, kJ}}$

3 d

[redacted]

$X_{Eis,2}$

$$\underline{X_{Eis,1} = 0{,}6}$$

~~Eh~~ Oben gibt Q_{ab} → wir nehmen $\underline{1500 J}$ aus $\underline{\text{Aufgabe}}$

Energie:

$$\Delta U_{21} = \cancel{\dot m [\ ]}^{0} + Q_{12} - \cancel{W_n}^{0}$$

abgegebene Wärme: $Q_{12}^{Eis} = -Q_{12}$

$$\Delta U_{21} = -Q_{12}$$

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

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

Werte aus gegebener Tabelle

$x = 0{,}6$

$$\underline{u_1 = u_{fest} + x(u_{flüssig} - u_{fest})}$$

$\underline{p = 1{,}4\ bar}$

$$u_1 = -13{,}4102\ \frac{kJ}{kg}$$

$$u_2 = -\frac{1500 \cdot 10^{-3} kJ}{m_{EW}} + u_1 = \boxed{-28{,}4102\ \frac{kJ}{kg}}$$

→ Interpolieren mit der gegebenen Tabelle $\boxed{p_2 = p_1}$

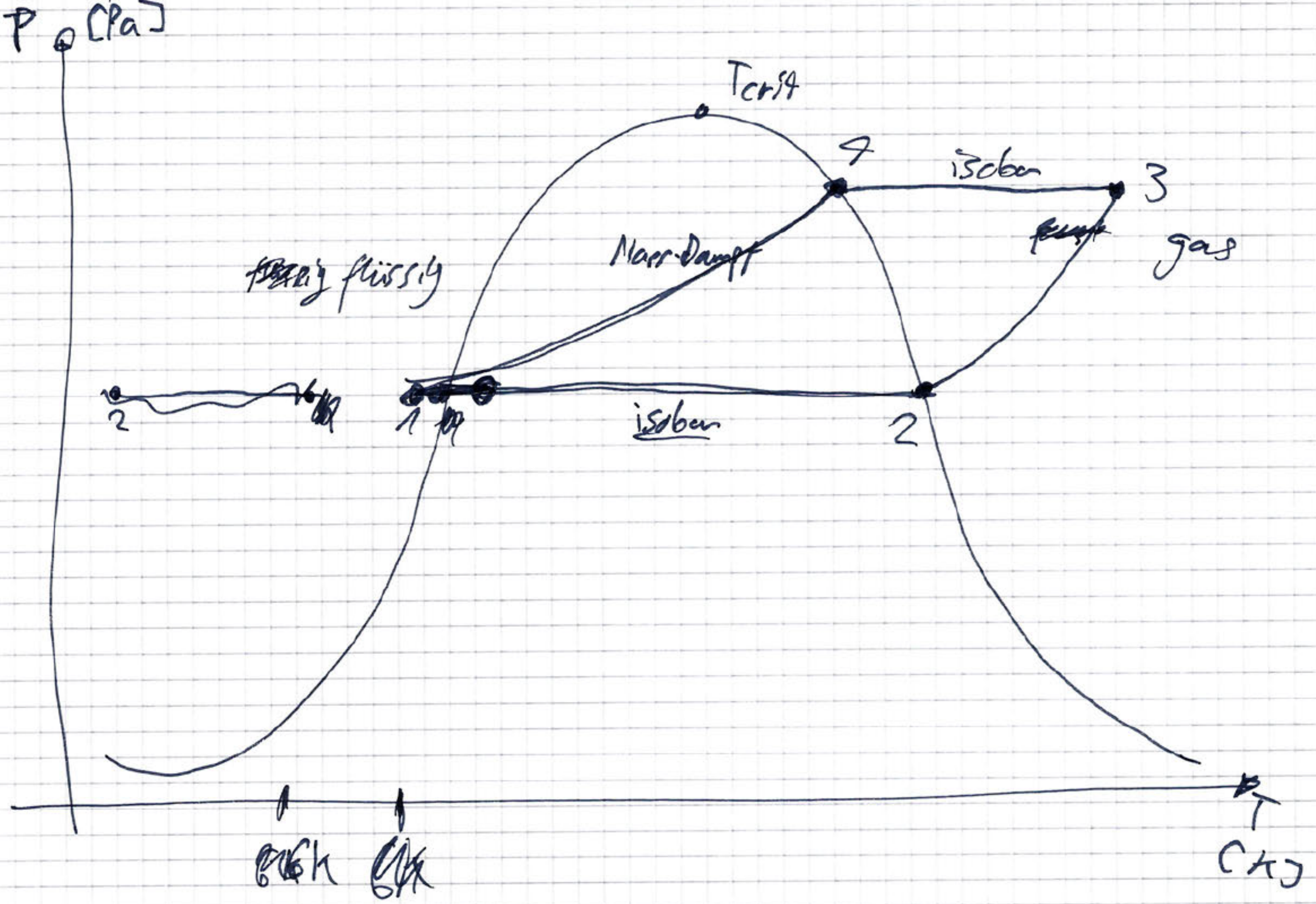
$$X_{Eis,2} = \cancel{\frac{-333{,}958 - (-0{,}045)}{1 - 0}}$$

$$\underline{X_{Eis,2} = 0{,}085}$$

$$X_{Eis,2} = \frac{1 - 0}{-333{,}958 - (-0{,}045)}\left(-28{,}4102 - (-0{,}045)\right) + (-0{,}045)$$

[redacted]

4 (a)



(b)

~~$\dot{m}_{R134a}$:~~

~~Energiebilanz~~

Energiebilanz: stationär

$$0 = \dot{m}_{R134a} [h_2 - h_3] + \cancel{\dot{Q}}^{0} - W_t$$