[redacted]

A 1)

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

stationärer Fliessprozess im Reaktor

$$0 = \dot{m}_{ein}(h_{ein} - h_a) + \dot{Q}_R - \cancel{\dot{W}_t}^{\,0} - \dot{Q}_{aus}$$

$$\dot{Q}_{aus} = \dot{m}_{ein}(h_e - h_a) + \dot{Q}_R = \underline{\underline{62{,}182\,kW}}$$

Tab A-2

$h_e = h_f(70°C) = 292{,}98\ kJ/kg$

$h_a = h_f(100°C) = 419{,}04\ kJ/kg$

b) $$\overline{T} = \frac{\int_e^a T\,ds}{s_a - s_e} = \frac{h_a - h_e}{s_a - s_e} = \frac{126{,}06}{0{,}352} = \underline{\underline{358{,}125\,K}}$$

~~$s_a = s_f(70$~~ Tab A-2

$s_e = s_f(70°C) = 0{,}9545\ kJ/kgK$

$s_a = s_f(100°C) = 1{,}3069\ kJ/kgK$

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

9,5

$\dot{S}_{erz} = \dot{m}(s_a - s_e) - \frac{\dot{Q}}{T_a} = 0,1056 - \frac{\dot{Q}_{aus}}{T_a} = 0,1056 + \frac{61,182}{295}$

$= 0,3164 \text{ kJ/kgK}$

$= 316,39 \text{ J/kgK}$

auf zweiten Blatt

d) Halboffenes System

$\Delta E = m_2 u_2 - m_1 u_1 = \Delta m (h)_{ein} + Q - \cancel{W}^{\,0}$

Tab A.2

$h_{ein} = h_f(20°C) = 83,96 \text{ kJ/kg}$

$u_1 = u(100°C, x = 0,005)$

$= u_f(100°C) + x(u_g - u_f) = \cancel{430,33}\ 423,38 \text{ kJ/kg}$

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

$Q = 35 \cdot 10^3 \text{ kJ}$

$(m_1 + \Delta m) u_2 - m_1 u_1 = \Delta m\, h_{ein} + Q$

$m_1 u_2 - m_1 u_1 - Q = \Delta m (h_{ein} - u_2)$

$\Delta m = \frac{m_1 u_2 - m_1 u_1 - Q}{h_{ein} - u_2} = 572,4 \text{ kg}$

[redacted]

A1)

e) $\Delta m_{12} = 3600 kg$

Halboffnes Sys.

$$\Delta S_{12} = m_2 s_2 - m_1 s_1 = (m_1 + \Delta m_{12}) s_2 - m_1 s_1 = \underline{\underline{1237{,}84 kJ}}$$

Tab A-2 bei 100°C

$$s_1 = s(100°C, x = 0{,}005) = s_f + x(s_g - s_f) = 1{,}33714 \ kJ/kg\,K$$

$$s_2 = s_f(70°) = 0{,}9549$$

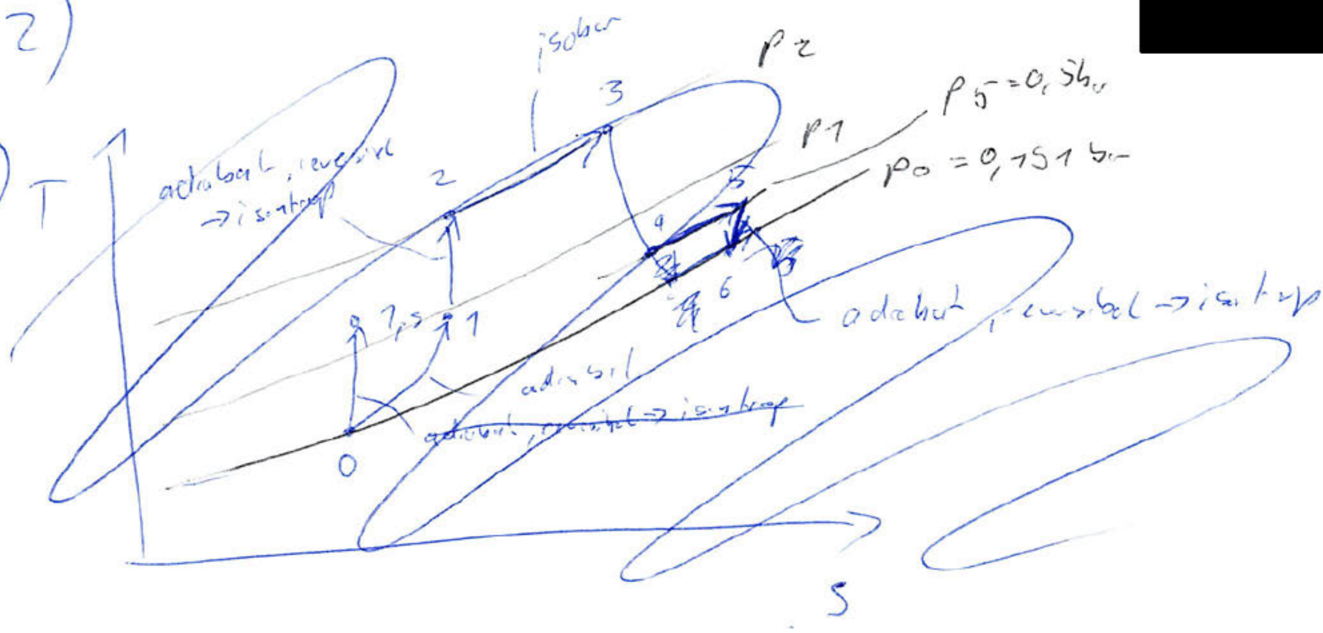
c) $$\bar{T} = \frac{\int_e^a T\,ds}{s_a - s_e} = \frac{\int_e^a T\,ds}{\int_{T_e}^{T_a} \frac{c}{T}\,dT} = \frac{\int_e^a T\,ds}{c^{if} \ln\left(\frac{T_a}{T_e}\right)}$$

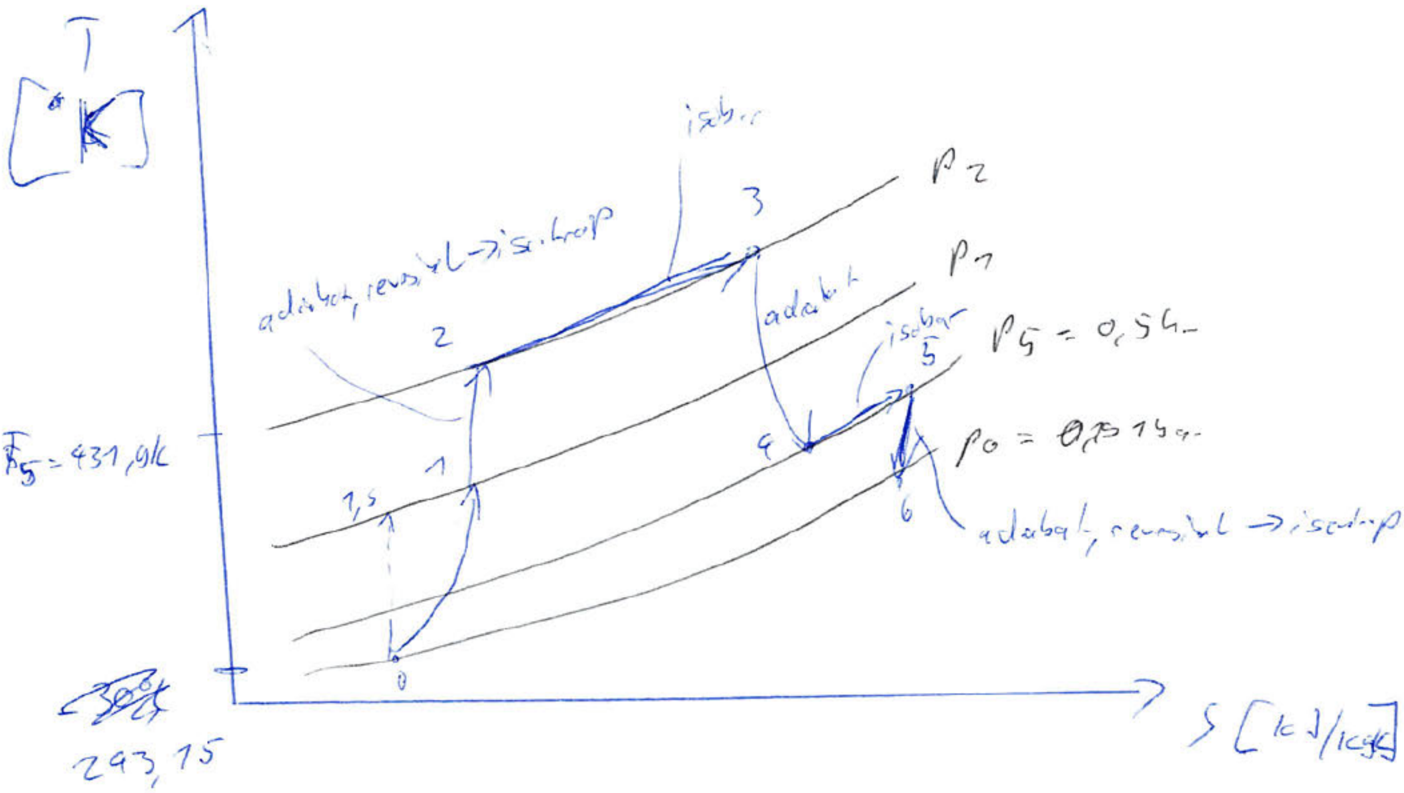
$$= \frac{Q}{c \ln\left(\frac{T_a}{T_e}\right)} = \frac{c(T_a - T_e)}{c \ln\left(\frac{T_a}{T_e}\right)} = \frac{T_a - T_e}{\ln\left(\frac{T_a}{T_e}\right)} =$$

A2)

[redacted]

a)





b) $w_6 = ?$ $\quad T_6 = ?$

$w_5 = 220\,m/s$, $T_5 = 431{,}5\,K$, $p_5 = 0{,}5\,bar$

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

isentrop $\quad s_5 = s_6$

stationärer Fließprozess

adiabat

reversibel

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

$$h_5 - h_6 = c_p(T_5 - T_6) = +146{,}228\,kJ/kg$$

$$c_p = \kappa \cdot c_v = n \cdot c_v = 1{,}4084\,kJ/kgK$$

$$\rightarrow R = c_p - c_v = 0{,}4024\,kJ/kgK$$

$$h_5 - h_6 + \frac{w_5^2 - w_6^2}{2} = 0$$

$$\underbrace{2(h_5 - h_6) + w_5^2}_{} = w_6^2$$

$$w_6 = \sqrt{\dots}$$

~~$= 219{,}334\,m/s$~~

$$= 1729{,}98\,m/s$$

isentrop $\quad s_5 = s_6$

$$0 = c_p \ln\left(\frac{T_6}{T_5}\right) - R \cdot \ln\left(\frac{p_6}{p_5}\right)$$

$$R \cdot \ln\left(\frac{p_6}{p_5}\right) = c_p \ln\left(\frac{T_6}{T_5}\right) \quad | e^1$$

$$e^{R \cdot \ln\left(\frac{p_6}{p_5}\right)} = e^{c_p \ln\left(\frac{T_6}{T_5}\right)}$$

$$\left(\frac{p_6}{p_5}\right)^R = \left(\frac{T_6}{T_5}\right)^{c_p} \rightarrow T_6 = T_5 \left(\frac{p_6}{p_5}\right)^{\frac{R}{c_p}} = 328{,}075\,K$$

[redacted]

c)

$$\Delta e_{x,str} = e_{x,str6} - e_{x,str0} = h_6 - h_0 - T_0(s_6 - s_0) + \frac{w_6^2}{2} - \frac{w_0^2}{2}$$

$$h_6 - h_0 = c_p (T_6 - T_0) = 119,608 \, kJ/kg$$

$$s_6 - s_0 = c_p \ln\left(\frac{T_6}{T_0}\right) - R \ln\cancel{\left(\frac{p_6}{p_0}\right)}^{0} = 0,4219051 \, kJ/kg$$

$$\frac{w_0^2}{2} = 20 \, kJ/kg$$

$$\frac{w_6^2}{2} = 1487,8 \, kJ/kg$$

$$\Delta e_{x,str} = 1499,21 \, kW/kg$$

d)

$$\dot{E}_{xvel} = T_0 \cdot \dot{S}_{erz}$$

stationärer Fliessprozess

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

$$s_{erz} = \overbrace{s_6 - s_0}^{c} - \frac{q}{T_G} = 0,421905 \, kJ/kg - \frac{1195}{1283} \, kJ/kg$$

$$= 0,505 \, kJ/kg$$

$$e_{x,v,l} = T_0 \cdot s_{erz} = 243,15 \cdot 0,505 = 122,832 \, kW/kg$$

[redacted]

A3)

a) $R = \frac{\bar{R}}{M} = \frac{8319}{50} = 166,38\ J/kg$

$\frac{\downarrow p_0 \quad \downarrow F}{\uparrow p_{EW}}$

$p_{EW} = p_0 + F \cdot A = 1bar + m \cdot g \cdot \pi \left(\frac{D}{2}\right)^2 = 1,247\ bar$

$p_{g,1} = p_G = p_{ew} = \underline{\underline{1,247\ bar}}$

$\frac{\downarrow p_{EW}}{\uparrow p_G}$

perfekten Gas:

$V_1 = 3,19 \cdot 10^{-3} m^3$

$pV = mRT$

$T_1 = 773,15\ K$

$m = \frac{p_1 V_1}{R T_1} = \underline{\underline{0,0312\ kg}}$

b) Da sich an den Umgebungsbedingungen nichts ändert, drücken immer noch 32kg + 1bar atmosphären Druck, dadurch ist $p_{g,2} = p_{g,1} = \underline{\underline{1,247\ bar}}$.

$\Delta E = 0 = m_{EW}(u_{2g} - u_{1g}) + m_G (u_2 - u_1)$

$= m_{EW}(u_{2g} - u_{1s}) + m_g (c_v (T_2 - T_1))$

c)

$m_1 = m_2$

$\Delta E = m_2 u_2 - m_1 u_1 = Q - \cancel{W}^{\nearrow 0}$

$\cancel{Q = m_{EW}(u_2 - u_1)}$

inkompressibel

$\cancel{u_1 = u(1{,}247\,bar,\ 0°C) = u(T = 0°C) =}$

$\cancel{u_2 = u(1{,}247\,bar,\ 0{,}003°) = u(T = 0{,}003°C)}$

$Q = m_g(u_2 - u_1) = m_g c_v (T_2 - T_1) = \underline{\underline{-9{,}873\,kJ}}$

d)

$x_1 = 0{,}6$ $0°C$

$u_1 = u(T = 0°C,\ x = 0{,}6) = u_{fest} + x(u_{flüssig} - u_{fest}) = -133{,}4702$

$\cancel{u_2}$

$Q = m_{EW}(u_2 - u_1) = \cancel{9{,}873\,kJ}$

$u_2 = \frac{Q}{m_{EW}} + u_1 = 98{,}73\,kJ/kg + (-133{,}4702)\,kJ/kg = -34{,}6802\,kJ/kg$

$T_2 = 0{,}003\,°C$

$x = \frac{u_2 - u_{Fest}}{u_{Flüssig} - u_{Fest}} = \underline{\underline{0{,}896081}}$

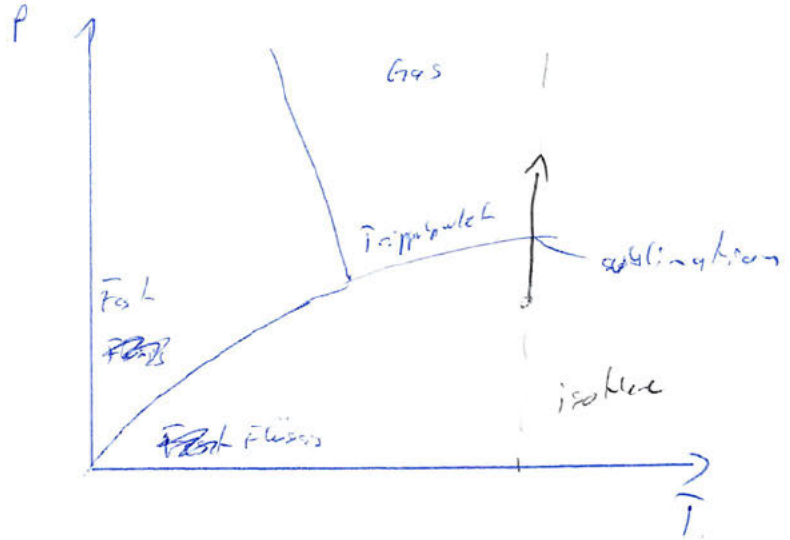
[redacted]

A4)

a) ~~$T_{tripel} = 0°C$~~

$T_{tripel} = 0°C$ $\qquad$ $T_{subl}(1bar) = -20°C$

somit liegt T_i mit 10K über T_{sub} bei $\underline{T_i = -10°C}$



b) stationärer Fliessprozess beim Verdichter

$$0 = \dot{m}(h_2 - h_3) + \cancel{\dot{Q}}^{\,0 \text{ adiabat}} - \dot{W}_t$$

$$\dot{W}_k = \dot{m}(h_2 - h_3) \longrightarrow \dot{m}_{134} = \frac{\dot{W}_k}{|h_2 - h_3|} = \frac{28 \cdot 10^{-3}}{|237{,}79 - 271{,}314|}$$

$$= 8{,}34 \cdot 10^{-4}\ kg/s$$

$$\underline{= 0{,}834\, g/s}$$

$1 \to 2$ isobare Verdampfung

$T_V = T_i - 6 = -16°C = T_2$

Tab A-11

$h_2 = h(x_2 = 1, T_2 = -16°C) = 237{,}79\, kJ/kg$

adiabat reversibel $3 \to 4 \Rightarrow$ isentrop $s_3 = s_4 = s_g(-16°C) = 0,9298$ Tab A-11

$p_3 = 8$ bar

Tab A-12 8 bar

$$h_3 = h(8 bar, s = 0,9298) = h_{sat} + \frac{0,9298 - 0,9379}{0,9066 - 0,9379}(h_{40} - h_{sat}) = 271,314 kJ/kg$$

c) $x_4 = 0$ $p_3 = p_4 = 8$ bar

Tab A 11

$s_4 = s_1 = s_f(8 bar) = 0,3459$

$p_2 = 1,5748$ bar $\Leftarrow$ abgelesen aus Tab A-10 bei $T_2 = -16°C$

$p_1 = p_2 = 1,5709$ bar, da isobar

Tab A-11 interpolieren

p	s_f	s_g	h_f	h_g
1,4	0,1035	0,9322	25,77	$23\cancel{8},69$
1,5709	0,1194	0,929894	29,1945	237,6882
1,6	0,1211	0,9295	29,78	237,97

$$x_1 = \frac{s - s_f}{s_g - s_f} = \underline{\underline{0,2795}}$$

[redacted]

A4)

d) $\varepsilon_K = \frac{Q_{zu}}{\cancel{Q} \cdot W_t} = \frac{\dot{Q}_K}{W_t} = \frac{129{,}3}{28} = \underline{\underline{4{,}476}}$

beim Kondensator

$\cancel{\dot{Q}_{Kon}}$ $0 = \dot{m}(h_1 - h_2) + \dot{Q} - \cancel{\dot{W}_t}^{\,0}$

$\dot{Q}_K = \dot{m}(h_2 - h_1) = 0{,}125\,3\,kg/s = 125{,}3\,W$

Aufgabe c

$h_1 = h(1{,}5\,7084\,bar, x = 0{,}2\,795) = h_f + x(h_g - h_f) = 87{,}4684$

$h_2 = 237{,}79\ kJ/kg$ ⟸ Aufgabe b

e) Die Temperatur im innen würde isochor weiter fallen.