[redacted]

(1)

a) Energiebilanz:

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

$$\dot{Q}_{aus} = \dot{m}(h_{ein} - h_{aus}) + \dot{Q}_R$$

h_{ein} (70°C $x=0$): 292,98 $\frac{kJ}{kg}$

h_{aus} (100°C $x=0$) = 419,04 $\frac{kJ}{kg}$

$$\Rightarrow Q_{aus} = 0,3\,(292,98 - 419,04) + 700$$

$$= 62,18\ kW$$

b) $$\bar{T} = \frac{\int_0^q T\,ds}{s_a - s_e} = \frac{\Delta h}{\Delta s}$$

s_{ein} (70°C, $x=0$): 0,9549

s_{aus} (100°C, $x=0$) = 1,3069

$$\bar{T} = \frac{419,04 - 292,98}{1,3069 - 0,9549} = 358,125\ K$$

c) $0 = \dot{m}(s_{ein} - s_{aus}) + \frac{\dot{Q}_R}{T} - \frac{\dot{Q}_{aus}}{T} + \dot{S}_{er,2}$

$\dot{S}_{er,2} = \dot{m}(s_{aus} - s_{ein}) + \frac{\dot{Q}_{aus}}{T} - \frac{\dot{Q}_R}{T}$

s_{ein}, s_{aus} aus Teil b:

$\dot{S}_{er,2} = 0{,}3(1{,}3069 - 0{,}9549) + \frac{65}{295} - \frac{100}{295}$

$= -0{,}013 \frac{kJ}{K}$

d) $m_2 u_2 - m_1 u_1 = \Delta m_{12} h_{12} + Q_R$

$m_1 = 5755\,kg$

$m_2 = 5755 + \Delta m$

$u_1 = u_F + x(u_g - u_F)$

$u_1(100°C) = 418{,}94 + 0{,}005($

$2506{,}5 - 418{,}94)$

$= 429{,}3778 \frac{kJ}{kg}$

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

$h_{12} = h(20°, x=0) = 83{,}95$

$\Rightarrow (m_1 + \Delta m)u_2 - m_1 u_1 = \Delta m h_{12} + Q_R$

$\Delta m(h_{12} - u_2) = -m_1 u_1 + m_1 u_2 - Q_R$

$\Delta m = \frac{-m_1 u_1 + m_1 u_2 - Q_R}{h_{12} - u_2}$

[redacted]

① d) weiter:

$$\Delta u = -5775(4,29,377) + 5775(292,95) - 35\cdot10^7$$

$$83,95 - 292,95$$

$$= 3937\,kg$$

e)

s_1 (400°C) aus: $1,3069 \frac{kJ}{kgK}$

$s_1 = 1,3069 \cdot 5775 = 7547,3 \frac{kJ}{K}$

s_2 (70°C) $= 0,9549$

$s_2 = 0,9549\,(5775 + 3600) = 8952,2 \frac{kJ}{K}$

$$s_{erz} = \left(+\frac{35\cdot10^3}{\frac{70-20}{2}}\right) \Rightarrow s_{erz} = 1400 \frac{kJ}{K} = \frac{Q_{B,12}}{T}$$

$$\Delta S = -s_1 + (s_2 + s_{erz})$$

$$= 7547 - 7547,3 + (8952,2 + 1400)$$

$$= 2804,9 \frac{kJ}{K}$$

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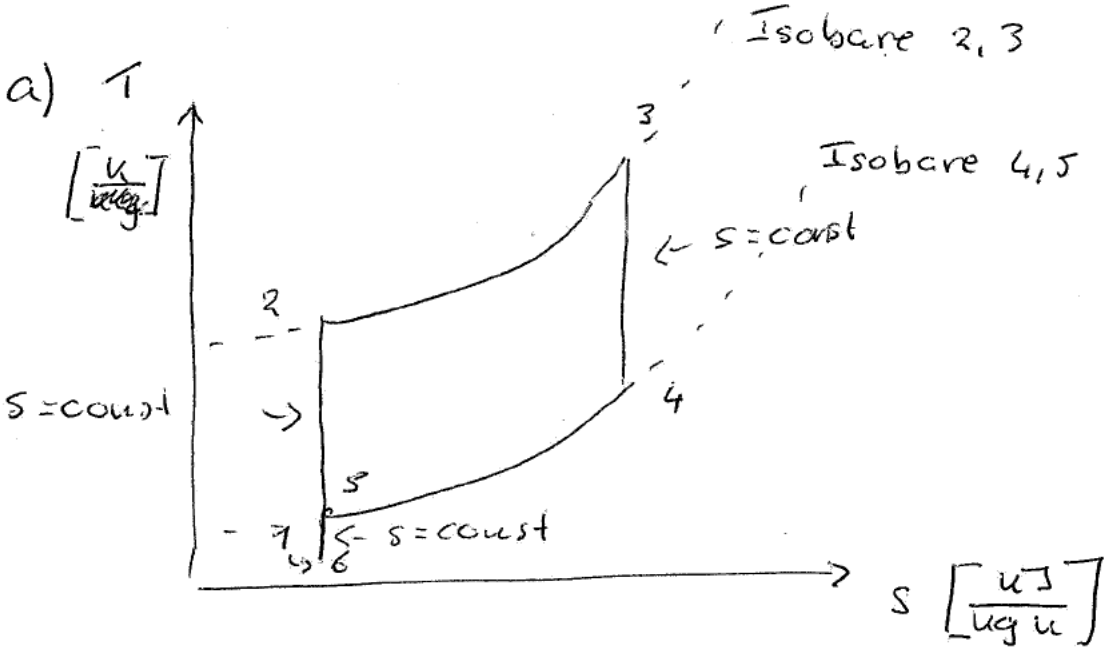
② a) T



b) ω_6, T_6 = ?

Adiabat, reversibel => s = const

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

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

$$= 431{,}9 \left(\frac{0{,}5\,\text{bar}}{0{,}1971\,\text{bar}}\right)^{\frac{1{,}4-1}{1{,}4}}$$

$$= \underline{568{,}6\,\text{K}}$$

~~s = const~~

Energiebilanz:

$$0 = \dot{m}\left(h_5 - h_6 + \frac{\omega_5^2 - \omega_6^2}{2}\right)$$

$$2\dot{m}(h_5 - h_6) + \dot{m}\left(\frac{\omega_5^2}{2}\right) = \dot{m}\,\omega_6^2$$

$$h_5(431{,}9,\ 0{,}5\text{bar}) = \frac{h(305) - h(300)}{305 - 300}(\quad$$

$$h_5(431{,}9,\ 0{,}5) = \frac{h(440) - h(430)}{440 - 430}(431{,}9 - 430) + h(430)$$

$$= \frac{(441{,}61 - 431{,}43)}{10}(1{,}9) + 431{,}43$$

$$= 433{,}36$$

$$h_6(-30°C,\ 0{,}19\text{T}) = \frac{h(250) - h(240)}{250 - 240}(247{,}15 - 240) + h(240)$$

$$= \frac{250{,}05 - 240{,}02}{250 - 240}(3{,}15) + 240{,}02$$

Ideales Gas: $h(T_2) - h(T_1) = c_p(T_2 - T_1)$

$$\Rightarrow \omega_6^2 = 2 \cdot c_p(T_6 - T_5) + \omega_5^2$$

$$\omega_6 = \sqrt{2 \cdot 1.006 \cdot 10^3 (568{,}6 - 431{,}9) + (220)^2}$$

$$= 220{,}6\ \text{m/s}$$

$$= 568{,}71\ \frac{\text{m}}{\text{s}}$$

[redacted]

(2)

c)

$\dot{m} e_{x,6} = \dot{m}_{gas}((h_6 - h_3) - T_0 (s_6 - s_3) + \frac{1}{2} \dot{w}_6^2)$

~~$\dot{m} e_{x,0} = \dot{m}_{gas}(h_1 - h_0 - T_0(s_1 - s_0) + \frac{1}{2}$~~

$\dot{m} e_{x\,str,0} = \dot{m} (-h_0 - T_0(-s_0) + \frac{1}{2} w_0^2)$

$\uparrow w_{lokal}$

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

[redacted]

(3)

a) $p_{g,1}$, m_g

Perfektes gas: $p_1 V_1 = m_g R T_1$

Kräftegleichgewicht: $A p_{amb} + m_{Kg} + m_{EG} = p_1 A$ (Inkompressibel)

$p_{amb} \cdot \pi \cdot 5^2_{cm} + 32g + 0{,}1g = p_{EIS} \cdot \pi 5^2_{cm} = p_{g,1} \cdot \pi \cdot 5^2_{cm}$

$$\Rightarrow p_{g,1} = p_{amb} + \frac{32 \cdot 9{,}81 + 0{,}1 \cdot 9{,}81}{\pi \cdot (5 \cdot 10^{-2})^2}$$

$$= 1 \cdot 10^5 + \frac{32 \cdot 9{,}81 + 0{,}1 \cdot 9{,}81}{\pi (5 \cdot 10^{-2})^2}$$

$$= 41{,}096\,bar = 1{,}40094\,bar$$

$$\Rightarrow m_g = \frac{p_1 V_1}{R T_1} \quad \text{mit} \quad R = \frac{8{,}314}{50 \cdot 10^{-3}}$$

$$= \frac{1{,}400 \cdot 10^5}{\frac{8{,}314}{50 \cdot 10^{-3}} \cdot 773{,}15} \cdot 3{,}14 \cdot 10^{-3}$$

$$= 3{,}421\,g$$

b) Nächste seite

b) $T_{g,2}$, $p_{g,2}$ $x_{Eis,1} = 0,6$ $T_{EW,1} = 0°C$

$T_{g,2} = T_{eis,2}$

~~Energiebilanz von 1 → 2~~

~~$m_{g,1} u_{g,1} + m_{EW,1} u_{EW} = m_{g,2} u_{g,2} + m_{EW,1} u_{EW}$~~

~~$\Rightarrow m_g c_v (T_{g,1}) + m_{EW} c_w = m_{g,2} c_v (T_{g,2}) +$~~

Die Temperatur $T_{g,2} = T_{eis,2} = 0°C$ da $x > 0$

wäre die Temperatur über 0°C wäre $x_{eis} = 0$

~~$\Rightarrow kg\ p_{g,2} V_{g,2} = m R T_{g,2}$~~

$$p_{g,2} = \frac{m R T_{g,2}}{V_{g,2}}$$

$$= 3,6 \cdot 10^{-3} \cdot \frac{8,314}{50 \cdot 10^{-3}} \cdot 273,15$$

Das Eis + Wasser ist Inkompressibel

also ist $p_{g,2} = p_{g,1} = 1,5\,bar$

[redacted]

(3)

(3) (c)

$$|Q_{1,2}| = |m_{g,1}\, c_V\, (\Delta T)|$$

$$= 3{,}6 \cdot 10^{-3} \cdot 0{,}633\,(500°C - 0°C)$$

$$= 1{,}139\ kJ$$

(d) $T_{g,2} = T_{E,2} = 0{,}003°C$

$$\Delta u = \frac{Q_{1,2}}{m} = \frac{1500}{0{,}1} = 150\ \frac{kJ}{kg} = 0{,}150\ \frac{MJ}{kg}$$

$$x = \frac{u_{tot} - u_{fest}}{u_{flüss} - u_{fest}} \qquad \Delta x = \frac{\Delta u - \Delta u_{fest}}{\Delta u_{flüss} - \Delta u_{fest}}$$

~~$u_{tot} = 0{,}150$~~

$\Delta u_{fest,\,flüss} = u_L(0°C) - u_L(0{,}003) = |-0{,}045 - -0{,}033| = -0{,}012$

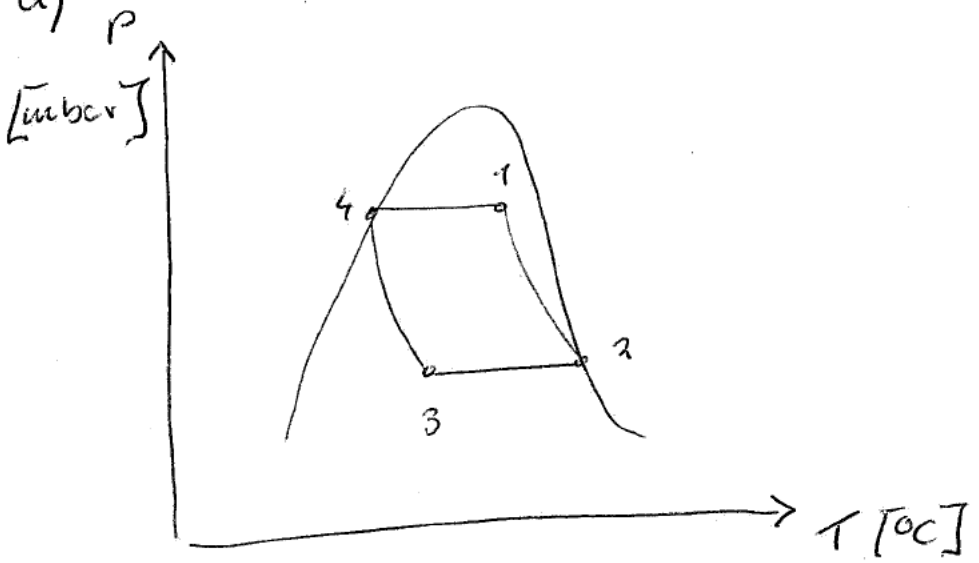
$\Delta u_{fest}^{flüss} = |-333{,}458_1 - -333{,}442| =$

$= +333{,}16$

$$\Delta x = \frac{0{,}150 - 333{,}16}{-0{,}012 - 333{,}16} = 0{,}999$$

[redacted]

④ a)



Energiebilanz

b) $\dot{m}_{R134a}(h_2 - h_1) + \dot{Q}_K = 0$

$T_V = T_i - 6K$

$\Rightarrow \dot{m}_{R134} = \frac{-\dot{Q}_K}{h_2 - h_1}$

Energiebilanz

h_2 ✓

$\dot{m}_{R134}(h_3 - h_2) + \dot{W}_K = 0$

$\dot{m}_{R134} = \frac{\dot{W}_K}{h_2 - h_3}$

~~h_2 (8bar,~~

$\dot{Q}_K$: $h_2(8\,bar, x=1) = 255{,}05 \frac{kJ}{kg}$

(TAB A8) $T_{h_2} = 15{,}45\,°C$

ΔT von 2 → 1 = 6°C $\Rightarrow T_1 = 9{,}45\,°C$

Energie bilanz

$$\dot{m}\,(h_3 - h_2) + \dot{Q}_K = 0$$

$$\dot{m} = \frac{\dot{Q}_K}{h_2 - h_3}$$

$4 \to 1 \quad s = \text{const}$

$$s_4\,(x = 0{,}8\ p_{ab}) = 0{,}2419$$

$$s_4 = s_3 = s_{3,F} + x\,(s_{3,g} - s_{3,F})$$

$$x = \frac{s_4 - s_{3F}}{s_{3g} - s_{3F}}$$

$$h_3 = h_{3,F} + x\,(h_{3,g} - h_{3,F})$$

$$= h_{3,F} + \left(\frac{s_4 - s_{3F}}{s_{3g} - s_{3F}}\right)(h_{3,g} - h_{3,F})$$

[redacted]

④

c) Δx von $2 \to 1 = 6°C$

Bei 3,8 bar, $x = 1$ $h_2 = 255,05$, $T = 15,45$

$\therefore T_1 = 15,45°C$

$p_4 = p_1 = p(s_3$

d) $\varepsilon_K = \frac{|\dot{Q}_{zu}|}{|\dot{Q}_{ab}| - |\dot{Q}_{zu}|} = \frac{|\dot{Q}_{zu}|}{|\dot{W}_t|}$ $\quad 0 = \dot{m}(h_2 - h_1) + \dot{Q}_K$

$= ?$

$= \frac{\dot{Q}_K}{\dot{W}_K} = \frac{\dot{m}_{Kälte}(h_1 - h_2)}{\dot{W}_K}$