Aufgabe 1)

a)

$\Rightarrow$ st. fliessprozess $\quad ke = pe = 0$

$$0 = \dot{m}[he - ha] + \dot{Q}_R - \dot{Q}_{aus} - W \qquad W = 0$$

$$\dot{Q}_{aus} = \dot{m}_w[he - ha] + \dot{Q}_R = 0{,}3\,(292{,}98 - 419{,}04) + 100\,kW = \underline{62{,}182\,kW}$$

$\dot{m}_w = 0{,}3\ kg/s$

$he = h_f[70°C) = 292{,}98\ kJ/kg$, $ha = h_f(100°C) = 419{,}04\ kJ/kg$

TAB A-2

b)

$$T_{KF} = \frac{\int_1^2 T\,ds}{s_2 - s_1} = \frac{e^{if}(T_2 - T_1)}{e^{if}\ln\left(\frac{T_2}{T_1}\right)} = \frac{10}{\ln\left(\frac{298{,}15}{288{,}15}\right)} = \underline{288{,}12\,K}$$

$q_{12} = q_{12}$

$if \quad c\int_{T_1}^{T_2} \frac{1}{T}\,dT$

d)

~~Gesamt~~ halboffenes System

$$\Delta E = Q_E - Q_{aus} - W + \Delta m_{12}[he] = m_2 u_2 - m_1 u_1 = (m_1 + \Delta m_{12})u_2 - m_1 u_1$$

$Q_E - Q_{aus} = 0$ $\quad$ $W = 0$ $\quad$ $pe = ke = 0$ $\quad$ $m_2 = m_1 + \Delta m_{12}$ $\quad$ $m_1 = m_{gas,1}$

$$\Delta m_{12} = m_2$$

$$\Rightarrow \Delta m_{12}(he - u_2) = m_1(u_2 - u_1) \quad \Leftrightarrow \quad \Delta m_{12} = \frac{5755\,(292{,}95 - 418{,}94)}{83{,}96 - 292{,}95} = \underline{3469{,}41\,kg}$$

$he = h_c(20°C) = 83{,}96\ kJ/kg$

$u_2 = u_f(70°C) = 292{,}95\ kJ/kg$

$u_1 = u_f(100°C) = 418{,}94\ kJ/kg$

} TAB A-2

e) $\Delta S = m_2 s_2 - m_1 s_1 = \cancel{\Delta m_{12} s_e} + Q\left(\frac{1}{T_e} - \frac{1}{T_K}\right) + S_{irr}$

$= (5755 + 34(9,47)\,0,9549 - 5755\,1,3069 = 1287,18 \frac{kJ}{K}$

TAB A-2

$s_2 = s_f(70°C) = 0,9549$

$s_1 = s_f(400°C) = 1,3069$

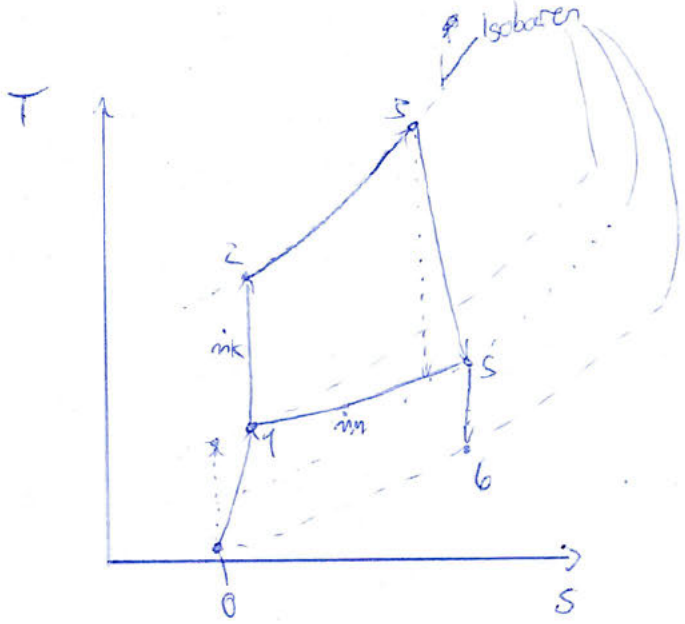
c) $\frac{dS}{dt} \to 0$

$\frac{dS}{dt} = \frac{\dot{Q}}{T_{KF}} + \dot{S}_{erz}$ $\quad \frac{\dot{Q}}{T_{KF}} = -\dot{S}_{erz}$ $\quad \frac{dS}{dt} = Q\left(\frac{1}{T_{KF}} + \frac{1}{T_R}\right) + \dot{S}_{erz}$

$\dot{S}_{erz} =$

Aufgabe 2)

a)



$T_0 = -30°C$

$p_0 = 0{,}191$

$p_1 > p_0$

$p_2 > p_1$

b) St. Fliessprozess

adiabat

$$0 = \dot{m}\left(h_e - h_a + \frac{(w_e^2 - w_a^2)}{2}\right) + \cancel{Q} - \cancel{W}$$

$$\Rightarrow \dot{m}\left[c_p(T_2 - T_1) + \frac{w_e^2}{2}\right] = \dot{m}\frac{w_a^2}{2}$$

$$h_e - h_a = \int_1^2 c_p dT = c_p(T_2 - T_1)$$

adiabat:

$$\frac{T_6}{T_5} = \left(\frac{p_6}{p_5}\right)^{\frac{\kappa-1}{\kappa}} \Rightarrow T_6 = 451{,}9 \cdot \left(\frac{0{,}191}{0{,}5}\right)^{\frac{0{,}4}{1{,}4}} = 328{,}75K$$

$$w_a^2 = 2\left[c_p(T_2 - T_1) + \frac{w_e^2}{2}\right] = 257{,}296$$

$w_a = 507{,}24\ m/s$

c)

$$\Delta e_{x,str} = h_6 - h_0 - T_0(s_6 - s_0) + \Delta ke = \underbrace{c_p\left[T_6 - T_0 - T_0 \ln\left(\frac{T_6}{T_0}\right)\right]}_{12{,}159\ kJ/kg} + \underbrace{\frac{w_6^2}{2} - \frac{w_0^2}{2}}_{108{,}646\ kJ/kg} = 120{,}805\ kJ/kg$$

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

$p_6 = p_0 \Rightarrow 0$

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

d)

stationär, adiabat

$$\frac{dE_x}{dt} = \sum \dot{E}_{x,str} + \sum \dot{E}_{x,Q} - \sum \left[\dot{V}_n - p_0 \frac{dV}{dt}\right] - \dot{E}_{x,verl} \quad // : \dot{m}_{ges}$$

$$e_{x,vel} = e_{x,str,0} - e_{x,str,6} = -\text{~~1000 kJ/kg~~} = -120{,}805 \text{ kJ/kg}$$

↑ vorgegeben

Aufgabe 3)

a)

$p_a = p_g$

↓ p_a

membran

↑ p_g

$$p_a = p_{amb} + \frac{m_K \cdot g}{A} + \frac{m_{EW} \cdot g}{A} = 1 \cdot 10^5 + 32 + 0{,}4 \cdot \frac{9{,}81}{\pi \cdot 0{,}05} = 140034\,Pa = 1{,}4\,bar$$

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

$$pV = nRT \qquad R = \frac{8{,}314}{50}$$

$$p = \frac{nRT}{V}$$

$$n = \frac{pV}{RT} = \frac{1{,}4 \cdot 10^5 \cdot 3{,}14 \cdot 10^{-3}}{(273{,}15+500) \cdot \frac{8{,}314}{50}} = 3{,}419\,g = 3{,}419 \cdot 10^{-3}\,kg = 3{,}419\,g$$

b)

$p_{g,2} \stackrel{!}{=} p_{g,1} = 1{,}4\,bar$ ⇐ von aussen immernoch dieselben Kräfte

$T_{g,2} \stackrel{!}{=} T_{EW} = 0°C$ ⇒ Wasser immernoch eis-wasser ⇒ befindet sich im fest-flüssig gebiet

→ T_{EW} fix ⇒ keine Wärmeübertragung: $T_g = T_{EW}$

c) Gas: $c_v (T_2 - T_1)$ geschl. system, $w = 0$

$\Delta E = Q = n_g (u_2 - u_1)$

$|Q| = 3{,}6 \cdot 0{,}633 (500°C - 0{,}005°C) = 1139{,}39\,J$

$Q = -|Q| = -1139{,}39\,J$

d)

$Q = 1{,}5\,kJ$ (aus Prüfung)

$\Delta E_{EW} = Q = m(u_2 - u_1)$

$u_2 = \frac{Q}{m} + u_1 = \frac{1{,}5}{0{,}1} - 133{,}41 = -118{,}41\ kJ/kg$

$u_{f,0}(0{,}000\,°C)$

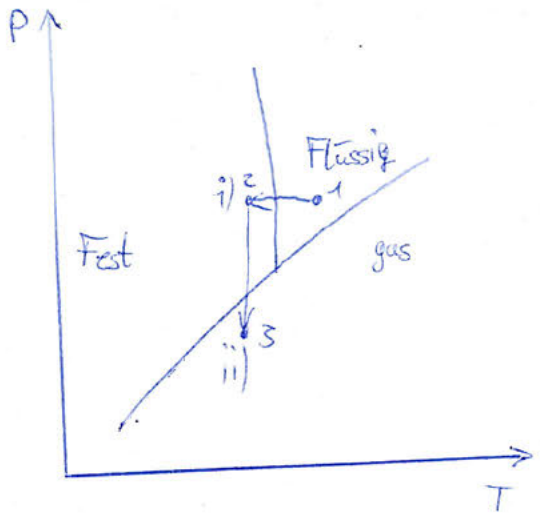
$u_1 = u_{f,0} + x(u_f - u_{Fest}) = -133{,}41\ kJ/kg$

$u_2 = u_{Fest} + x_2(u_f - u_{Fest}) \Rightarrow x_2 = \frac{u_2 - u_{Fest}}{u_f - u_{Fest}} = \frac{-118{,}41 + 333{,}442}{-0{,}033 + 333{,}442} = 0{,}645$

u_{Fest} bei $0{,}003\,°C$

Aufgabe 4)

a)



b)

$T_i = -10°C$

$T_{Verdampfer} = -16°C$

2 → 3

TAB A-11

$0 = \dot{m}[h_e - h_a] - \dot{W}_K$

$h_e = h_{gg}(-16°C) = \frac{237,97 - 236,04}{-15,62 + 18,8}(-16 + 18,8) + 236,04 =$

$\cdot(-16 + 18,8) + 236,04 = 237,74\ kJ/kg$

TAB A-12

$h_a = h(8bar, s_a = s_e) = \frac{275,66 - 264,15}{0,9374 - 0,9066}(0,9298 - 0,9066) + 264,15 = 271,31\ kJ/kg$

$s_e = \frac{0,9295 - 0,9322}{-15,62 + 18,8}(-16 + 18,8) + 0,9322 = 0,9298$

A-12

$\dot{m} = \frac{\dot{W}}{h_e - h_a} = 8,34 \cdot 10^{-4}\ kg/s$

c)

st. fliessprozess

$\dot{m}[h_e - h_a] = 0$

$h_a = h_e = h_f(8\,bar) = 93{,}42\ kJ/kg$

$T_4 = T_1 = -16\,°C$

$h_g = 237{,}74$

$h_f = \frac{29{,}78 - 25{,}77}{-15{,}62 + 18{,}8}(-16 + 18{,}8) + 25{,}77 = 29{,}3\ kJ/kg$

A-11

A-11

$x_4 = \frac{93{,}42 - 29{,}3}{237{,}74 - 29{,}3} = 0{,}3076$