Thermo I 2024

[redacted]

Aufgabe 1

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

1 HS: $0 = \dot{m}(h_e - h_a) + \sum \dot{Q} - \dot{W}^{0}$

$\dot{Q}_{aus} = \dot{m}(h_a - h_e) \triangleq \dot{Q}_R$

$h_e = h_f(70°C, x=0) = 292,98\ kJ/kg$ ← siedend

$h_a = h_f(100°C, x=0) = 419,04\ kJ/kg$ — Tab. A-2

$\dot{Q}_{aus} = 0,3\,kg/s\,(419,04 - 292,98)\,kJ/kg - 100\,kJ/s$

$= -62,18\ kJ/s\ (kW)$

b) $\bar{T}_{KF} = \frac{\int_e^a T\,ds}{s_a - s_e}$ $\qquad \int_e^a T\,ds = h_a - h_e$ (1. HS)

$= \frac{h_a - h_e}{s_a - s_e}$ → KF = ideale Flüssigkeit

$h_a - h_e = c_{KF}(T_2 - T_1)$

$s_a - s_e = c_{KF} \cdot \ln\left(\frac{T_2}{T_1}\right)$

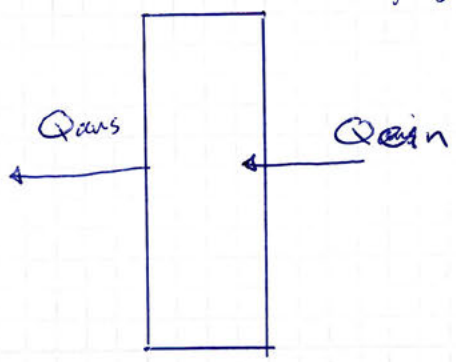
$\bar{T}_{KF} = \frac{c_{KF}(T_2 - T_1)}{c_{KF} \ln\left(\frac{T_2}{T_1}\right)} = \frac{(298,15K - 288,15K)}{\ln\left(\frac{298,15}{288,15}\right)}$

$= 293,12K$

c) $\dot{S}_{erz}$

○ Wärmeübertragung über Kühlwand ?

○ adiabat



$$0 = \sum \dot{m}_i s_i + \sum \frac{\dot{Q}_i}{T_i} + \dot{S}_{erz}$$

$Q_{aus} = Q_{ein} = 65\,kW$

$T_{m\,in\ reaktor} = 100°C = 373{,}15\,K$

$T_{Kf} = 293{,}12\,K$

$$\dot{S}_{erz} = \frac{Q_{aus}}{T_{KF}} - \frac{Q_{ein}}{T_{reaktor}} = 65\,kW\left(\frac{1}{293{,}12K} - \frac{1}{373{,}15K}\right)$$

$$= 0{,}04\ kJ/K\cdot s$$

d) 1: 5755 kg / 0,005 / 100°C
2: 70°C / x=0

$\Delta m_{12} = 20$ / x=0

$Q_{aus,12}$ 35 MJ

Halb offenes System:

$$\Delta E = m_2 u_2 - m_1 u_1 = \Delta m_i\, h_i + Q_j - W_n$$

$m_2 = m_1 + \Delta m$

$u_2 = u(70°C, x=0) = 292{,}95\ kJ/kg$ [TAB A2]

$m_1 = 5755\,kg$

$u_1 = u(100°C, x=0{,}005) = u_f + x(u_g - u_f)$

$= 418{,}96\ kJ/kg + 0{,}005\,(2506{,}5 - 418{,}94)$

$= 429{,}37\ kJ/kg$ [TAB A2]

$h_i = h(20°C, x=0) = h_f = 83{,}96\ kJ/kg$

$\sum \dot{Q}_j = Q_{R12} - Q_{aus,12} = 0$

next page

d continuous

$$(m_1 + \Delta m)\, u_2 - \Delta m\, h_i = m_1 u_1$$

$$m_1 u_2 + \Delta m u_2 - \Delta m h_i = m_1 u_1$$

$$\Delta m = \frac{m_1 u_1 - m_1 u_2}{u_2 - h_i}$$

$$= \frac{5755\,kg\,(429{,}3778 - 292{,}95\,kJ/kg)}{292{,}95 - 83{,}96\,kJ/kg}$$

$$= 3765{,}1\,kg$$

e) calc of ΔS

$$\Delta S_{12} = m_2 s_2 - m_1 \cdot s_1 \qquad \rightarrow \Delta m_{12} = 3600\,kg$$

$m_2 = 9355\,kg$

$m_1 = 5755\,kg$

$s_2 = s(70°C, x=0) = 0{,}9549\,kJ/kg\cdot K$

$s_1 = s(100°C, x=0{,}005) = s_f + x(s_g - s_f)$

$= 1{,}3069\,\frac{kJ}{kg\cdot K} + 0{,}005\,(7{,}3549 - 1{,}3069)$

$= 1{,}337\,kJ/kg\cdot K$

$\Delta S_{12} = 9355\,kg \cdot 0{,}9549\,kJ/kg\cdot K - 5755\,kg \cdot 1{,}337\,kJ/kg\,k$

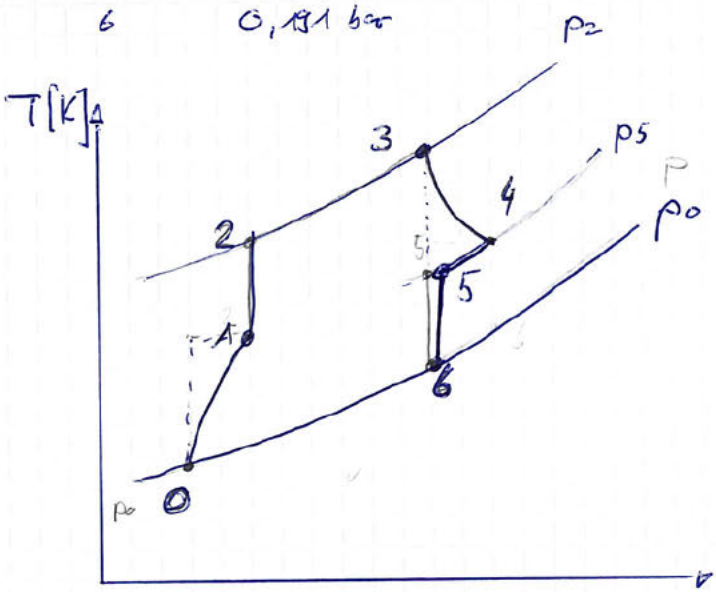
$= 1238{,}65\,kJ/k$

Aufgabe 2 (ideales Gas, Luft)

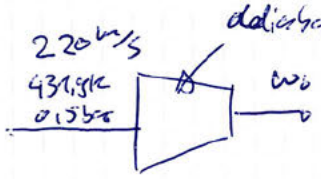
[redacted]

a)

0	0,191 bar	−30 °C	
1			$s_1 = s_2$
q_B ↓ 2	$p_2 = p_3$		$s_2 = s_1$
3	$p_5 = p_2$		
4			
5	0,5 bar	431,9 K	
6	0,191 bar		



b)



$c_p = 1{,}006\ \left[\frac{kJ}{kg \cdot K}\right]$

1 HS:

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

$$w_a^2 = h_e - h_a + \frac{w_e^2}{2}$$

$$w_a = \sqrt{h_5 - h_6 + \frac{w_e^2}{2}} = \sqrt{c_p (T_5 - T_6) + \frac{w_e^2}{2}}$$

$$\frac{T_6}{T_5} = \left(\frac{p_6}{p_5}\right)^{\frac{n-1}{n}} \cdot T_5 = \left(\frac{p_6}{p_5}\right)^{\frac{\kappa-1}{\kappa}} \cdot T_5 = \left(\frac{0{,}191}{0{,}5}\right)^{\frac{0{,}4}{1{,}4}} \cdot 431{,}9\,K$$

$$= 328{,}07\,K$$

$$w_a = \sqrt{1{,}006 \frac{kJ}{kg \cdot K}\,(431{,}9 - 328{,}07) + \frac{220^2\ m^2/s^2}{2}} = 682{,}79\ m/s$$

[redacted]

c) $\Delta Exst$

$$0 = \dot{m}\left(h_e - h_a - T_0(s_e - s_a) + \frac{w_e^2}{2} - \frac{w_a^2}{2}\right) = -\Delta\dot{E}xst$$

$T_0 = 243{,}15\,K$, $T_6 = 340\,K$,

$h_0 - h_6 = c_p\,(T_0 - T_6) = 1{,}006\,\frac{kJ}{kg\,K} \cdot 96{,}85\,K = 97{,}43\,\frac{kJ}{kg}$

$(s_e - s_a) = c_p \cdot \ln\left(\frac{T_0}{T_6}\right) - R\ln\left(\frac{p_6}{p_0}\right)$

$= c_p \cdot \ln\left(\frac{T_0}{T_6}\right) = 1{,}006\,\frac{kJ}{kg\,K} \cdot \ln\left(\frac{243{,}15}{340}\right) = -0{,}33$

$$\Delta ex,st = -\dot{m}\left(c_p(h_0 - h_6) - T_0\left(c_p \ln\left(\frac{T_0}{T_6}\right) + \frac{w_e^2}{2} - \frac{w_a^2}{2}\right)\right.$$

d) Ex verl:

$$0 = \underbrace{\dot{m}\left(-\Delta Ex\right)}_{100\,kJ/kg \rightarrow \text{Aufgabe c}} + \left(1 - \frac{T_0}{T_J}\right)\dot{Q}_J - Ex\,verl$$

$$Ex\,verl = 100\,kJ/kg + \left(1 - \frac{243{,}15\,K}{1289\,K}\right) 1195\,\frac{kJ}{kg}$$

$$= 1069{,}58\,kJ/kg$$

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Aufgabe 3

a) $F_1 = m_K \cdot g + m_{ew} \cdot g + p_0$

$= 32\,kg \cdot 9{,}81\,m/s^2 + 0{,}1\,kg \cdot 9{,}81\,m/s^2$

$= 314{,}901\,\frac{kg \cdot m}{s^2} + 1 \cdot 10^5\,Pa$

$p_g \cdot A = F_1$ $\qquad A = r^2 \pi = 0{,}05m^2 \cdot \pi = 0{,}00785m$

$p_g = \frac{314{,}901 + 1 \cdot 10^5\,Pa}{A} = 1{,}4\,bar$

$m_g = \frac{pV}{RT}$ $\qquad p_g = 1{,}5\,bar$

$T = 773\,K$

$= \frac{1{,}5 \cdot 10^5 \cdot 3{,}14 \cdot 10^{-3}}{1662{,}8 \cdot 773\,K}$ $\qquad V = 3{,}14 \cdot 10^{-3}\,m^3$

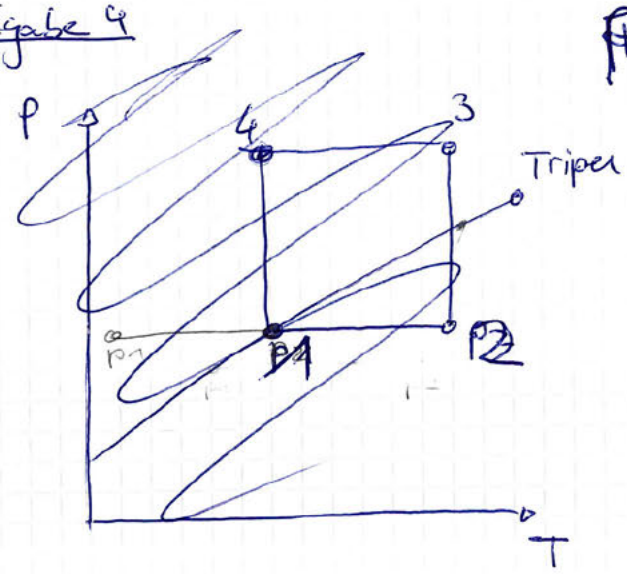
$= 3{,}664\,g$

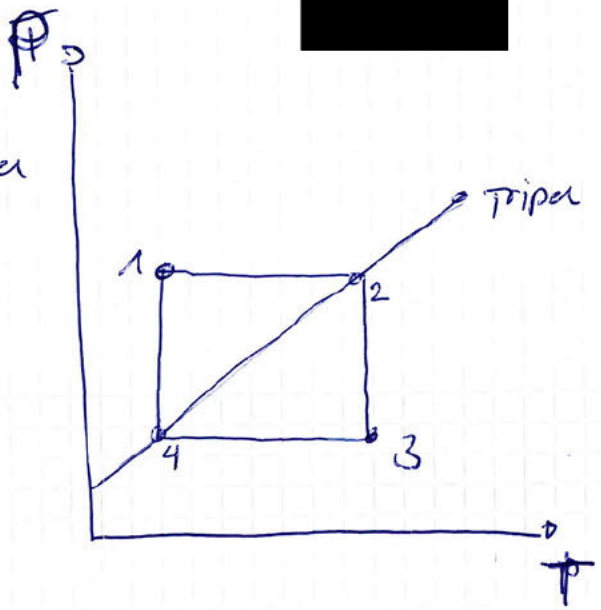
$R = \frac{R}{M} = \frac{8{,}314\,kJ/kmol}{50\,\frac{kg}{kmol}} = 166{,}28\,J/kmol$

b)

Aufgabe 4

a)





$T_1 = 5°C$

1	$p_2 = p_1$		
2	$p_2 = p_1$	$x_2 = 1$	
3	8 bar		$w = 28\ w$
4	8 bar	$x = 0$	

b) $\dot{m}$

c) $x_1 = \frac{m_D}{m_D + m_f}$

d) $\varepsilon_K = \frac{|\dot{Q}_{zu}|}{\dot{w}_E} = \frac{|\dot{Q}_K|}{\dot{w}_K}$