# Aufgabe 1

[redacted]

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

$\dot{Q}_R = 100\,KW$

$m_{ges,1} = 5755\,Kg$

$\dot{m}_W = 0.3\,\frac{Kg}{s}$

$x_D = 0.005$

Energiebilanz: (Reaktor)

(Qaus positiv definiert in Strömungsrichtung K.F.)

$$0 = \dot{m}_W (h_e - h_a) + \dot{Q}_R - \dot{Q}_{aus} - \cancel{\dot{W}}^{0}$$

$h_f(70°C) = 292.98\,\frac{KJ}{Kg}$ (TAB A-2)

$h_g(70°C) = 2626.8\,\frac{KJ}{Kg}$

$$h_e = h_f(70°C) + x_D \cdot (h_g(70°C) - h_f(70°C))$$

$$\underline{h_e = 304.649\,\frac{KJ}{Kg}}$$

$h_f(100°C) = 419.04\,\frac{KJ}{Kg}$ (TAB A-2)

$h_g(100°C) = 2676.1\,\frac{KJ}{Kg}$

$$h_a = h_f(100°C) + x_D \cdot (h_g(100°C) - h_f(100°C))$$

$$\underline{h_a = 430.33\,\frac{KJ}{Kg}}$$

$$\dot{Q}_{aus} = 0.3\,\frac{Kg}{s} \cdot (304.649 - 430.33)\,\frac{KJ}{Kg} + 100\,KW$$

$$\underline{\underline{\dot{Q}_{aus} = 62.3\,KW}}$$

b) $$\bar{T}_{KF} = \frac{\int_1^2 T\,ds}{s_2 - s_1} = \frac{q_{rev}^{12}}{s_2 - s_1} = \frac{h_2 - h_1}{s_2 - s_1}$$

$T_1 = 288.15$

$T_2 = 298.15$

i.f.: $$h_2 - h_1 = \int_{T_1}^{T_2} c^{if}\,dT + v^{if}\,(\cancel{p_2 - p_1})^{0} = c^{if}\,(T_2 - T_1)$$

$$s_2 - s_1 = c^{if} \cdot \ln\left(\frac{T_2}{T_1}\right)$$

$$\underline{\underline{\bar{T}_{KF}}} = \frac{T_2 - T_1}{\ln\left(\frac{T_2}{T_1}\right)} = \frac{298.15 - 288.15}{\ln\left(\frac{298.15}{288.15}\right)} = \underline{\underline{293.12\,K}}$$

c)

Entropiebilanz am Reaktorwand:

$$0 = \frac{\dot{Q}_{zu}}{\overline{T}_{Reak}} - \frac{\dot{Q}_{aus}}{\overline{T}_{KF}} + \dot{S}_{erz}$$

$$\dot{S}_{erz} = \dot{Q}_{aus} \cdot \left( \frac{1}{\overline{T}_{KF}} - \frac{1}{\overline{T}_{Reak}} \right)$$

$$\overline{T}_{Reak} = 100°C = 373.15\ K$$

$$\dot{S}_{erz} = 62.3\ kW \cdot \left( \frac{1}{293.12} - \frac{1}{373.15} \right) = 0.570\ \frac{W}{K}$$

d)

$$T_{Reak1\to2} = 70°C$$

$$\Delta m_{12}\ ,\quad T_1 = 20°C$$

$$Q_{R,12} = 35\ MJ$$

Halboffenes System:

$$\Delta E = \Delta U = m_2 u_2 - m_1 u_1 = \Delta m_{12} \cdot (h_{ein}) - Q_{e,12}$$

Nassdampf:

$$m_2 = m_1 + \Delta m$$

$$u_1 = u_f(100°C) + x_D \cdot (u_g(100°C) - u_f(100°C))$$

$$u_2 = u_f(70°C) + x_D \cdot (u_g(70°C) - u_f(70°C))$$

$$h_{ein} = u_f(20°C) + x_D \cdot (u_g(20°C) - u_f(20°C))$$

e)

$$\Delta S = m_2 s_2 - m_1 s_1 = \left( \Delta m_{ein} s_{ein} - \frac{\check{Q}_{ein,12}}{\overline{T}} + S_{erz} \right)$$

$$s_2 = s_f(70°C) + x_D \cdot (s_g(70°C) - s_f(70°C))$$

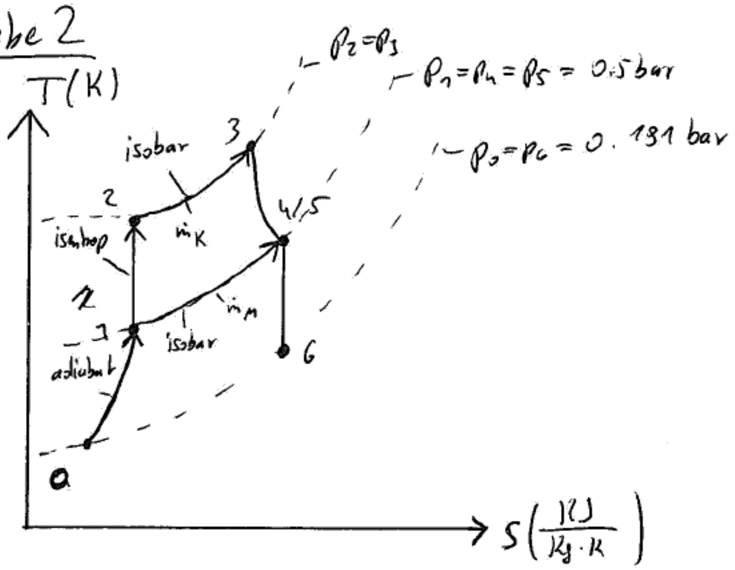
$$s_1 = s_f(100°C) + x_D \cdot (s_g(100°C) - s_f(100°C))$$

$$m_2 = m_1 + \Delta m_{12}$$

[redacted]

# Aufgabe 2

a)




b)

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

$T_5 = 431.9\ K$

isentrop: $s_5 = s_6 =$

$p_5 = 0.5$ bar

$p_6 = 0.191$ bar

$T_5 = 431.9\,K$

$n = \kappa = 1.4$

isentrop: $\underline{\underline{T_6}} = T_5 \cdot \left(\frac{p_6}{p_5}\right)^{\frac{n-1}{n}} = 431.9 \cdot \left(\frac{0.191}{0.5}\right)^{\frac{1.4-1}{1.4}} = \underline{\underline{328.1\ K}}$

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

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

$h_5 - h_6 = c_p \cdot (T_5 - T_6)$

$2(h_5 - h_6) + w_5^2 = w_6^2$

$w_6 = \sqrt{2 \cdot (c_p \cdot (T_5 - T_6)) + w_5^2} = \sqrt{2 \cdot 1.006\ \frac{kJ}{kgK} \cdot (431.9 - 328.1)K + (220)^2\ \frac{m^2}{s^2}}$

$w_6 =$

c) $w_6 = 510 \frac{m}{s}$

$T_6 = 340K$

$\Delta e_{x,str} = e_{x,str,6} - e_{x,str,0}$

$e_{x,str,6} = h_6 - h_u - T_u(s_6 - s_u) + \frac{w_6^2}{2}$

$e_{x,str,0} = h_0 - h_u - T_u(s_0 - s_u) + \frac{w_0^2}{2}$

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

$\frac{m^2}{s^2} =$

$J = Nm$

$N = \frac{kg\, m}{s^2}$

$J = \frac{kg \cdot m^2}{s^2}$

$T_u = T_0 = 243.15K$

$h_6 - h_0 = c_{p,Luft} \cdot (T_6 - T_0)$ (stoffges. IG)

$s_6 - s_0 = c_{p,Luft} \cdot \ln\left(\frac{T_6}{T_0}\right) - R \underbrace{\ln\left(\frac{p_6}{p_0}\right)}_{\to 0\ (p_6 = p_0)}$

$\Delta e_{x,str} = c_{p,Luft} \left( (T_6 - T_0) - T_0 \ln\left(\frac{T_6}{T_0}\right) \right) + \frac{w_6^2 - w_0^2}{2}$

$\Delta e_{x,str} = 1.006 \frac{kJ}{kg \cdot K} \cdot \left( (340 - 243.15) - 243.15 \cdot \ln\left(\frac{340}{243.15}\right) \right) + \frac{510^2 - 200^2}{2}$

$\Delta e_{x,str} = 125.42 \frac{kJ}{kg}$

d) $0 = -\Delta e_{x,str} + \underbrace{q_B \cdot \left(1 - \frac{T_0}{T_B}\right)}_{= e_{x,Q}} - \cancel{w_V}^{0} - \dot{e}_{x,verl}$

$\dot{e}_{x,verl} = -\Delta e_{x,str} + q_B \cdot \left(1 - \frac{T_0}{T_B}\right)$

$e_{x,verl} = -125.42 \frac{kJ}{kg} + 1195 \frac{kJ}{kg} \cdot \left(1 - \frac{243.15}{1283}\right) = 844.16 \frac{kJ}{kg}$

# Aufgabe 3

[redacted]

a)

$p_{g,1}$ ?

$m_g$ ?

$c_{v,gas} = 0.633 \frac{kJ}{kg\,K}$

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

$R_g = \frac{8.314}{M_g} = 0.16628 \frac{kJ}{kg \cdot K}$

$T_{g,1} = 500°C = 773.15K$

$V_{g,1} = 3.14L = 3.14 \cdot 10^{-3} m^3$

$\underline{A_K} = \pi \cdot \left(\frac{D}{2}\right)^2 = \pi \cdot \left(\frac{0.1}{2}\right)^2 = \underline{0.00785 m^3}$

$p_g = p_{amb} + m_K \cdot g \cdot \frac{1}{A_K} + m_{EW} \cdot g \frac{1}{A_K} = p_{amb} + \frac{g}{A_K} \cdot (m_K + m_{EW})$

$\underline{\underline{p_{g,1}}} = 1 bar + \frac{9.81}{A_K} \cdot (32 + 0.1) = \underline{\underline{1.4 bar}}$

$p \cdot V = mRT$

$\underline{\underline{m}} = \frac{p_1 V_1}{R_g \cdot T_1} = \frac{1.4 bar \cdot 3.14 \cdot 10^{-3} m^3}{0.16628 \frac{kJ}{kg \cdot K} \cdot 773.15K} = \underline{\underline{3.419 g}}$

b)

$pV = mRT$

$m_{1,g} = m_{2,g}$ $\underline{\underline{p_{1,g} = p_{2,g}}} = \underline{\underline{1.4 bar}}$ (Druck durch pamb und Gewicht bleibt unverändert)

$\underline{U_g = U_{EW}}$

c)

$T_{g,2} = 0.003°C$

$Q_{12}$!

E.B. um Gas:

$\Delta E = E_2 - E_1 = Q_{12} - \cancel{W_v} - W_L$

$\Delta E = \Delta U + \cancel{\Delta KE} + \cancel{\Delta E} + \Delta PE$

$\Delta U = m_g (u_2 - u_1) = m_g \cdot (c_v \cdot (T_2 - T_1)) = 3.419 \cdot 10^{-3} kg \cdot (0.633 \frac{kJ}{kgK} \cdot (0.003 - 500))$

$\Delta U = -1.082\ kJ$

$\cancel{W_{12}=}$

$\cancel{\Delta U = Q_{12} = -1.082\ kJ}$

$p_2 = p_1$

$m_2 = m_1$

$pV = mRT$

$V_2 = \frac{m_g R_g T_2}{p_1} = \frac{3.419 \cdot 10^{-3} \cdot R_g \cdot 273.153\ K}{1.4\ bar} = 1.109 L$

$W_v = p_i (V_2 - V_1) = 1.4\ bar \cdot (1.109 - 3.14) \cdot 10^{-3} m^3$

$W_L = -0.284\ kJ$

$\Delta PE = m_{K+EW} \cdot g \cdot \left( \frac{\Delta V}{A_K} \right) = -81.47 J$

$\Delta U + \Delta PE = Q_{12} - W_v$

$Q_{12} = \Delta U + \Delta PE + W_v = -1.082 - 81.47 \cdot 10^{-3} - 0.284 = 716.5 J$

[redacted]

# Aufgabe 3

d)

$$x_{Eis,2} = \frac{u_2 - u_{Fl}(1.4\,bar)}{u_{Fest}(1.4\,bar) - u_{Fl}(1.4\,bar)}$$

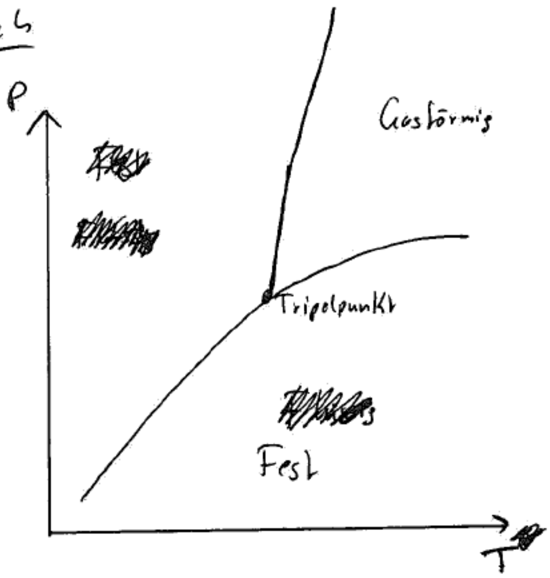
$u_{Fl}(1.4\,bar) = -0.045\ \frac{kJ}{kg}$

$u_{Fest}(1.4\,bar) = \cancel{333.458}\ -333.458\ \frac{kJ}{kg}$

[redacted]

Aufgabe 4

a)




b) $\dot{m}_{R134a}$

$x_2 = 1$

2–3 reversibel ($s_2 = s_3$) / isentrop

| | T | p | x |
|---|---|---|---|
| ~~1~~ 2 | | | ~~x~~ |
| ~~2~~ 3 | | | 1 |
| ~~3~~ 4 | | 8 | |
| 4 | | | |

$T_2 = \cancel{\quad} T_i - 6\,K$

$p_i = 1\,mbar = 10^{-3} \cdot 10^5\,Pa = 100\,Pa = 0.1\,KPa$

TAB A-6

$$\underline{\underline{T_{in}}} = \frac{\overset{T(0.0853\,KPa)}{-22} - \overset{T(0.1035\,KPa)}{(-20)}}{0.0853 - 0.1035} \cdot (0.1 - 0.1035) + (-20) = \underline{\underline{-20.385\,°C}}$$

$$\underline{\underline{T_2}} = -20.385 - 6K = \cancel{-26} \underline{\underline{-26.385\,°C}}$$

$h_2 = h_g(-26.385\,°C)$

$$0 = \dot{m}_{R134a} \cdot (h_2 - h_3) + \cancel{\dot{Q}}^0 - \underbrace{28W}_{=\dot{W}_K}$$

~~KZE~~

$$\dot{m}_{R134a} = \frac{28\,W}{h_2 - h_3}$$

$s_2 = s_3 = s(-26.385\,°C)$

$$x_3 = \frac{s_3 - s_f(8\,bar)}{s_g(8\,bar) - s_f(8\,bar)}$$

$s_f(8\,bar) = 0.3459\,\frac{KJ}{Kg\,K}$

$s_g(8\,bar) = 0.9066\,\frac{KJ}{Kg\,K}$ TAB A-11

$h_3 = h_f(8\,bar) + x_3 \cdot (h_g(8\,bar) - h_f(8\,bar))$

$h_f(8\,bar) = 93.42\,\frac{KJ}{Kg}$

$h_g(8\,bar) = 264.15\,\frac{KJ}{Kg}$ TAB A-11

c)

$p_1 = p_2 =$

$h_1 = h_4 = h_f(8\,bar) = 93.42\ \frac{kJ}{kg}$ TAB A-11

$x_1 = \frac{h_1 - h_f(p_2)}{h_g(p_2) - h_f(p_2)}$

d)

$\varepsilon_K = \frac{|\dot{Q}_{zu}|}{|\dot{Q}_{ab}| - |\dot{Q}_{zu}|} = \frac{|\dot{Q}_{zu}|}{|\dot{W}_V|}$

$\dot{Q}_{zu} = \dot{Q}_K$

$\varepsilon_K = \frac{|\dot{Q}_K|}{|\dot{Q}_{ab}| - |\dot{Q}_K|}$