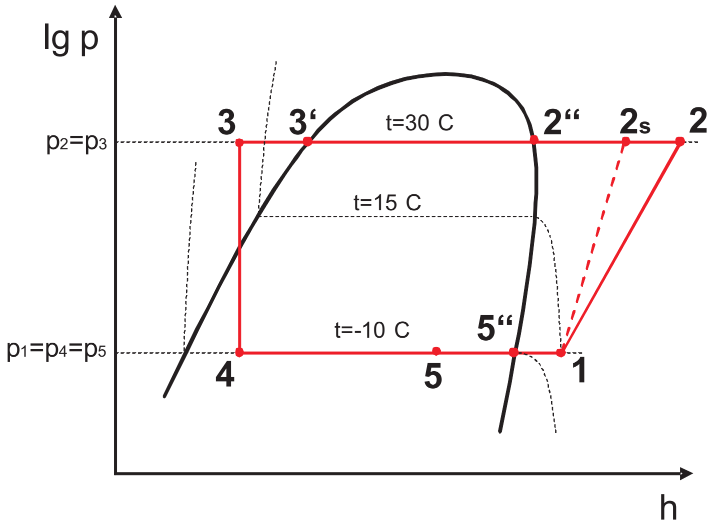
Musterlösung Aufgabe 1: «Kompressionskälteprozess»

I. TEILAUFGABE A) ⇒ 4 PUNKTE



II. TEILAUFGABE B) ⇒ 5 PUNKTE

$$P_{12} = \dot{m} \cdot w_{t12}$$

$$w_{t12} = \frac{w_{t12s}}{\eta_{s,v}} = \frac{h_{2s} - h_1}{\eta_{s,v}}$$

$$h_1 = h_{5''} + c_p \cdot (T_1 - T_{5''}) = 307,8 \left(\frac{kJ}{kg}\right) + 0,7360 \left(\frac{kJ}{kg \cdot K}\right) \cdot (15 - (-10))K = 326,2 \ \left(\frac{kJ}{kg}\right)$$

$$s_{2s} = s_1 = s_{5''} + \Delta s_{5'',1} = s_{5''} + c_p \cdot ln \left(\frac{T_1}{T_{5''}}\right) =$$

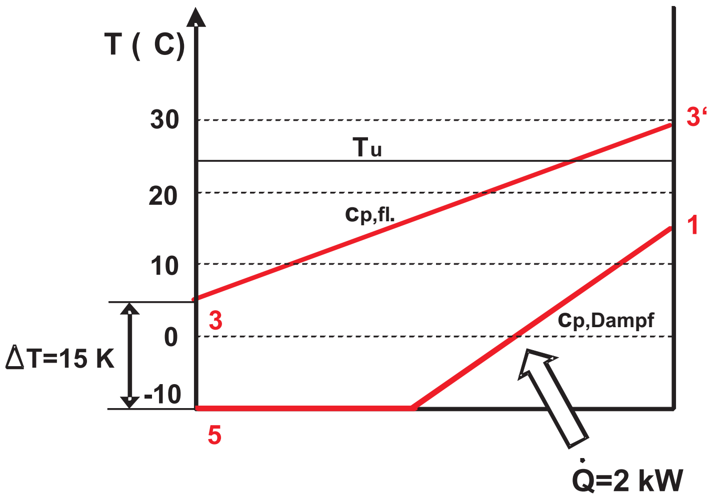
$$= 1,411 \left(\frac{kJ}{kg \cdot K}\right) + 0,7360 \left(\frac{kJ}{kg \cdot K}\right) \cdot ln \left(\frac{288,15}{263,15}\right) = 1,478 \left(\frac{kJ}{kg \cdot K}\right)$$

$$s_{2s} = s_{2''} + \Delta s_{2'',2s} = s_{2''} + c_p \cdot ln \left(\frac{T_{2s}}{T_{2''}}\right) \Rightarrow ln \left(\frac{T_{2s}}{T_{2''}}\right) = \frac{s_{2s} - s_{2''}}{c_p} \Rightarrow$$

$$T_{2s} = T_{2''} \cdot exp \left(\frac{s_{2s} - s_{2''}}{c_p}\right) = 303,15(K) \cdot exp \left(\frac{1,478 \left(\frac{kJ}{kg \cdot K}\right) - 1,449 \left(\frac{kJ}{kg \cdot K}\right)}{0,8363 \left(\frac{kJ}{kg \cdot K}\right)}\right) = 313,47 \ K = 40,32 \ ^\circ C$$

$$h_{2s} = h_{2''} + c_p \cdot (T_{2s} - T_{2''}) = 332,4 \left(\frac{kJ}{kg}\right) + 0,8363 \left(\frac{kJ}{kg \cdot K}\right) \cdot (40,32 - 30)K = 341,03 \ \left(\frac{kJ}{kg}\right)$$

$$P_{12} = 2,5 \left(\frac{kg}{s}\right) \cdot \frac{\left(341,03 (\frac{kJ}{kg}) - 326,2 \left(\frac{kJ}{kg}\right)\right)}{0,75} = \boxed{49,43 \ kW}$$



III. TEILAUFGABE C) $\Rightarrow$ 4 PUNKTE

$$\dot{Q}_{3',3} = \dot{m} \cdot \Delta h = \dot{m} \cdot c_{p_{fl.}} \cdot \Delta T = \frac{2,5\left(\frac{kg}{s}\right)}{10} \cdot 1,127\left(\frac{kJ}{kg \cdot K}\right) \cdot (-25K) = -7,044\ kW$$

$$\dot{Q}_{51} = \dot{Q} - \dot{Q}_{3',3} = (2 - (-7,044))\,(kW) = 9,044\ kW$$

$$\dot{Q}_{51} = \dot{m} \cdot \Delta h_{51}$$

$$\Rightarrow \Delta h_{51} = \frac{\dot{Q}_{51}}{\dot{m}} = \frac{9,044(kW)}{0,25\left(\frac{kg}{s}\right)} = 36,176\left(\frac{kJ}{kg}\right)$$

$$h_5 = h_1 - \Delta h_{51} = 326,2\left(\frac{kJ}{kg}\right) - 36,176\left(\frac{kJ}{kg}\right) = 290,024\left(\frac{kJ}{kg}\right)$$

$$h_4 = h_3 = h_{3'} - c_p \cdot \Delta T_{3,3'} = 232,7\left(\frac{kJ}{kg}\right) - 1,127\left(\frac{kJ}{kg \cdot K}\right) \cdot 25K = 204,525\left(\frac{kJ}{kg}\right)$$

$$\dot{Q}_{zu} = \dot{m} \cdot \Delta h_{45} = 0,25\left(\frac{kg}{s}\right) \cdot \left(290,024\left(\frac{kJ}{kg}\right) - 204,525\left(\frac{kJ}{kg}\right)\right) = \boxed{21,375\ kW}$$

$$x_5 = \frac{h_5 - h_5'}{h_5'' - h_5'} = \frac{290,024\left(\frac{kJ}{kg}\right) - 189,6\left(\frac{kJ}{kg}\right)}{307,8\left(\frac{kJ}{kg}\right) - 189,6\left(\frac{kJ}{kg}\right)} = \boxed{85\%}$$

IV. TEILAUFGABE D) $\Rightarrow$ 1 PUNKTE

$$\epsilon_{KM} = \frac{Nutzen}{Aufwand} = \frac{k \cdot \dot{Q}_{zu}}{P_{12}} = \frac{10 \cdot 21,375}{49,43} = \boxed{4,32}$$

Musterlösung Aufgabe 2: ≪*Entsalzungsanlage*≫

I. TEILAUFGABE B) ⇒ 3 PUNKTE

$h_{1+x,L1} = 1400 kJ/kg (aus Diagramm)$

$h_{1+x,L2} = h_{1+x,L3} + \Delta x \cdot h_w = 130 + (0,5 - 0,037) \cdot c_{pw} \cdot t_w = (130 + 67,8) \frac{kJ}{kg} = 197,8 \frac{kJ}{kg}$

II. TEILAUFGABE C) ⇒ 3 PUNKTE

$\dot{m}_{w1} \cdot \Delta h_w = -\dot{m}_{tr} \cdot \Delta h_{1+x,L1-L2}$

$\dot{m}_{w1} = \dot{m}_{trL} \cdot \frac{1400 - 198}{4,192 \cdot 45} = 6,377 \cdot \dot{m}_{trL} = \frac{6,377}{0,925} \frac{kg}{m^3} \cdot \dot{V} = 6,894 \frac{kg}{m^3} \cdot \dot{V}$

$\dot{m}_{trL} = \frac{\dot{V}}{v_{1+x}} = 1,081 \frac{kg}{m^3} \cdot \dot{V}$

$v_{1+x} = \frac{T \cdot R_m}{p} \cdot (\frac{1}{M_L} + \frac{x}{M_D}) = \frac{308,15K \cdot 8,314472 \frac{J}{molK}}{1,01325 bar} \cdot (\frac{1}{28,96} + \frac{0,037}{18,015}) = 0,925 \frac{m^3}{kg}$

$\dot{m}_{W1,mitHeatpipe} = \frac{1}{4} \cdot 6,894 \frac{kg}{m^3} \cdot \dot{V} = 1,724 \frac{kg}{m^3} \cdot \dot{V}$

$\dot{m}_{Kond} = \dot{m}_{trL} \cdot \Delta x = \frac{\dot{V}}{v_{1+x}} \cdot \Delta x = \frac{0,463 kg/kg}{0,925 m^3/kg} \cdot \dot{V} = 0,5005 \frac{kg}{m^3} \cdot \dot{V}$

III. TEILAUFGABE D) ⇒ 4 PUNKTE

Massebilanz: $\dot{m}_{W_3} = \dot{m}_{W_4} + \Delta \dot{m}_W; \quad wobei: \Delta \dot{m}_W = \dot{m}_{trL} \cdot \Delta x$

Enthalpiebilanz:

$\dot{H}_{W_3} - \dot{H}_{W_4} + Q + \dot{H}_{L3} - \dot{H}_{L1} = 0$

$\dot{m}_{W_3} \cdot h_{W_3} - \dot{m}_{W_4} \cdot h_{W_4} + Q + \dot{m}_L \cdot (h_{1+x,3} - h_{1+x,1}) = 0$

$\dot{m}_{W_3} \cdot h_{W_3} - (\dot{m}_{W_3} - \Delta x \cdot \dot{m}_{trL}) \cdot h_{W_4} + \dot{m}_{trL} \cdot (h_{1+x,3} - h_{1+x,1}) + Q = 0$

$$h_3 = \frac{1}{\dot{m}_{W3}} \cdot [(\dot{m}_{W_3} - \dot{m}_{trL} \cdot \Delta x) \cdot h_{W_4} - \dot{m}_{trL} \cdot (h_{1+x,3} - h_{1+x,1}) - Q]; \quad wobei: Q = 3/4 \cdot \dot{m}_{trL} \cdot \Delta h_{1+x,1-2}$$
$$= \frac{1}{1,724} \cdot [(1,724 - 0,5005) \cdot 4,192 \cdot 45 - 1,081 \cdot (130 - 1400) - 1,081 \cdot (1400 - 198)]$$
$$= \frac{1,224}{1,724} \cdot 4,192 \cdot 45 + \frac{1,081}{1,724} \cdot (1270 - \frac{3}{4} \cdot 1202) = 365 \frac{kJ}{kg}$$

$$h_3 = c_p \cdot t_{W_3} \rightarrow t_{W_3} = \frac{365 kJ/kg}{4,192 kJ/kgK} = 87,07 \circ C$$

IV. TEILAUFGABE E) ⇒ 2 PUNKTE

$$\dot{Q}_{Kollektor} = \dot{m}_{W_3} \cdot c_p \Delta t_{W2,W_3} = 1,724 \frac{kg}{m^3} \cdot \dot{V} \cdot 4,192 \cdot 17,074 = 123,4 \frac{kJ}{m^3} \cdot \dot{V}$$

$$\frac{\dot{Q}_{Kollektor}}{\dot{m}_{Dest}} = \frac{123,4}{0,5005} = 246,5 \frac{kJ}{kg}$$

V. TEILAUFGABE F) ⇒ 6 PUNKTE

L1:

$$p_{S,L1} = exp[11,93255 - \frac{3970,148}{353,15 - 40,052}] = 0,4735 bar$$

$$p_{H2O,L1} = \varphi_{L1} \cdot p_{S,L1} = 0,4498 bar$$

$$x_{L1} = \frac{p_{H2O,L1}}{(p_{ges} - p_{H2O,L1})} \cdot \frac{M_{H2O}}{M_L} = \frac{0,4498}{(1,01325 - 0,4498)} \cdot \frac{18,015}{28,96} = 0,497 \frac{kg}{kg}$$

$$h_{1+x,L1} = (1,004 \cdot 80) \frac{kJ}{kg} + 0,497 \cdot (2500 + 1,86 \cdot 80) \frac{kJ}{kg} = 1395,7 \frac{kJ}{kg}$$

L2:

$$p_{S,L2} = exp[11,93255 - \frac{3970,148}{308,15 - 40,052}] = 0,0564 bar$$

$$p_{H2O,L2} = \varphi_{L2} \cdot p_{S,L2} = 0,0564 bar$$

$$x_{L2} = \frac{p_{H2O,L2}}{(p_{ges} - p_{H2O,L2})} \cdot \frac{M_{H2O}}{M_L} = \frac{0,0564}{(1,01325 - 0,0564)} \cdot \frac{18,015}{28,96} = 0,0366 \frac{kg}{kg}$$

$$h_{1+x,L1} = (1,004 \cdot 35) \frac{kJ}{kg} + 0,0366 \cdot (2500 + 1,86 \cdot 35) \frac{kJ}{kg} + (0,497 - 0,0366) \cdot (4,192 \cdot 35) \frac{kJ}{kg} = 196,51 \frac{kJ}{kg}$$

Musterlösung Aufgabe 3: «Verbrennung» $\Rightarrow$ 15 Punkte

$$\Delta^U h_{[pro\ \ kg]} = 5\frac{kW\cdot h}{kg_{HP}} = 5\cdot 3600\frac{kW\cdot s}{kg_{HP}} = 18\frac{MJ}{kg_{HP}}$$

$$\nu_{HP,i} = \frac{\dot{n}_{HP,i}}{\dot{m}_{HP}} \quad \text{mit} \quad \dot{n}_{HP,i} = \frac{\dot{m}_{HP,i}}{M_i} \quad \Rightarrow \nu_{HP,i} = \frac{\frac{\dot{m}_{HP,i}}{M_i}}{\dot{m}_{HP}}$$

$$\text{mit} \quad \dot{m}_{HP,i} = \zeta_{HP,i}\cdot\dot{m}_{HP} \quad \Rightarrow \nu_{HP,i} = \frac{\frac{\zeta_{HP,i}\cdot\dot{m}_{HP}}{M_i}}{\dot{m}_{HP}} = \frac{\zeta_{HP,i}}{M_i}$$

$$\Rightarrow \nu_{HP,C} = \frac{\zeta_{HP,C}}{M_C} = \frac{0,5\frac{kg_C}{kg_{HP}}}{12\frac{g_C}{mol_C}} = 41,6667\frac{mol_C}{kg_{HP}} \quad ;$$

$$\nu_{HP,H_2} = 29,8954\frac{mol_{H_2}}{kg_{HP}} \quad ; \quad \nu_{HP,O_2} = 13,125\frac{mol_{O_2}}{kg_{HP}} \quad ; \quad \nu_{HP,N_2} = 0,357\frac{mol_{N_2}}{kg_{HP}} \quad ; \quad \nu_{HP,K} = 0,2558\frac{mol_K}{kg_{HP}}$$

Vollständige Verbrennung der einzelnen Komponenten der Holzpellets:

K+0,5 C+0,75 $O_2 \longrightarrow 0,5\ K_2CO_3$

Für die Umwandlung von $0,2558\frac{mol_K}{kg_{HP}}$ K zu $(0,2558\frac{mol_K}{kg_{HP}}\cdot 0,5\frac{mol_{K_2CO_3}}{mol_K} = 0,1279\frac{mol_{K_2CO_3}}{kg_{HP}})$ K_2CO_3 wird $(0,2558\frac{mol_K}{kg_{HP}}\cdot 0,5\frac{mol_C}{mol_K} = 0,1279\frac{mol_C}{kg_{HP}})$ C und $(0,2558\frac{mol_K}{kg_{HP}}\cdot 0,75\frac{mol_{O_2}}{mol_K} = 0,1919\frac{mol_{O_2}}{kg_{HP}})$ O_2 benötigt.

Das übrige C reagiert zu CO_2:

$$\nu*_{HP,C} = \nu_{HP,C} - 0,1279\frac{mol_C}{kg_{HP}} = 41,5388\frac{mol_C}{kg_{HP}}$$

$\nu*_{HP,C} = 41,5388:\ C + O_2 \longrightarrow CO_2$

$\nu_{HP,H_2} = 29,8954:\ H_2 + 0,5\ O_2 \longrightarrow H_2O$

$\nu_{HP,O_2} = 13,125:\ O_2 \longrightarrow O_2$

$\nu_{HP,N_2} = 0,357:\ N_2 \longrightarrow N_2$

Es verbrennen C, K und H_2. Hierfür wird O_2 benötigt:

$$\Rightarrow O_{2,V} = (41,5388 + 29,8954\cdot 0,5 + 0,2558\cdot 0,75)\ O_2 = 56,6784\ O_2$$

In den Holzpellets befindet sich bereits O_2:

$$\Rightarrow O_{2,HP} = 13,125\ O_2$$

Das fehlende O_2 wird durch $O_{2,L}$ aus der Luft geliefert:

$$\Rightarrow O_{2,V} = O_{2,HP} + O_{2,L} \quad \Rightarrow O_{2,L} = O_{2,V} - O_{2,HP} = 43,5534\ O_2$$

$\Rightarrow\ (41,5388\ [Verbrennung\ von\ C\ zu\ CO_2] + 0,1279\ [Verbrennung\ von\ C\ und\ K\ zu\ K_2CO_2])\ C + 29,8954\ H_2 + (13,125\ [Holzpellets] + 43,5534\ [Luft])\ O_2 + 0,357\ N_2 + 0,2558\ K$

$\longrightarrow\ 41,5388\ CO_2 + 29,8954\ H_2O + 0,357\ N_2 + 0,1279\ K_2CO_3$

$$N_{2,L} = 43,5534 \frac{mol_{O_2}}{kg_{HP}} \cdot \frac{0,79 \frac{mol_{N_2}}{mol_L}}{0,21 \frac{mol_{O_2}}{mol_L}} = 163,8437 \frac{mol_{N_2}}{kg_{HP}}$$

$\Rightarrow\ 41,6667\ C + 29,8954\ H_2 + (13,125[HP] + 43,5534[L])\ O_2 + (0,357[HP] + 163,8437[L])\ N_2 + 0,2558\ K$

$\longrightarrow\ 41,5388\ CO_2 + 29,8954\ H_2O + (0,357[HP] + 163,8437[L])\ N_2 + 0,1279\ K_2CO_3$

I. TEILAUFGABE A) $\Rightarrow$ 3 PUNKTE

gesucht: $\psi_{HP,i},\ \Delta^U h_{[pro\ mol]}$

$$\psi_{HP,i} = \frac{\dot{n}_{HP,i}}{\dot{n}_{HP}} = \frac{\nu_{HP,i} \cdot \dot{m}_{HP}}{\Sigma(\dot{n}_{HP,i})} = \frac{\nu_{HP,i} \cdot \dot{m}_{HP}}{\Sigma(\nu_{HP,i} \cdot \dot{m}_{HP})} = \frac{\nu_{HP,i} \cdot \dot{m}_{HP}}{\Sigma(\nu_{HP,i}) \cdot \dot{m}_{HP}} = \frac{\nu_{HP,i}}{\Sigma(\nu_{HP,i})}$$

$\Sigma(\nu_{HP,i}) = \nu_{HP,C} + \nu_{HP,H_2} + \nu_{HP,O_2} + \nu_{HP,N_2} + \nu_{HP,K}$

$\Rightarrow\ \Sigma(\nu_{HP,i}) = 41,6667 \frac{mol_C}{kg_{HP}} + 29,8954 \frac{mol_{H_2}}{kg_{HP}} + 13,125 \frac{mol_{O_2}}{kg_{HP}} + 0,357 \frac{mol_{N_2}}{kg_{HP}} + 0,2558 \frac{mol_K}{kg_{HP}}$

$\Rightarrow\ \Sigma(\nu_{HP,i}) = 85,2999 \frac{mol_{HP}}{kg_{HP}}$

$$\Rightarrow\ \psi_{HP,C} = \frac{\nu_{HP,C}}{\Sigma(\nu_{HP,i})} = \frac{41,6667 \frac{mol_C}{kg_{HP}}}{85,2999 \frac{mol_{HP}}{kg_{HP}}} = 0,4885 \frac{mol_C}{mol_{HP}} \quad ;$$

$\psi_{HP,H_2} = 0,3505 \frac{mol_{H_2}}{mol_{HP}}\ ;\ \psi_{HP,O_2} = 0,1539 \frac{mol_{O_2}}{mol_{HP}}\ ;\ \psi_{HP,N_2} = 0,0042 \frac{mol_{N_2}}{mol_{HP}}\ ;\ \psi_{HP,K} = 0,003 \frac{mol_K}{mol_{HP}}$

$$\Delta^U h_{[pro\ mol]} = \frac{\Delta^U h_{[pro\ kg]}}{\Sigma(\nu_{HP,i})} = \frac{18 \frac{MJ}{kg_{HP}}}{85,2999 \frac{mol_{HP}}{kg_{HP}}} = 211,0202 \frac{MJ}{mol_{HP}}$$

II. TEILAUFGABE B) $\Rightarrow$ 2 PUNKTE

$\lambda = 1,2$

$\Rightarrow\ 41,6667\ C + 29,8954\ H_2 + (13,125[HP] + 1,2 \cdot 43,5534[L])\ O_2 + (0,357[HP] + 1,2 \cdot 163,8437[L])\ N_2 + 0,2558\ K$

$\longrightarrow\ 41,5388\ CO_2 + 29,8954\ H_2O + (0,357[HP] + 1,2 \cdot 163,8437[L])\ N_2 + 0,1279\ K_2CO_3$

$+((1,2 - 1) \cdot 43,5534[L])\ O_2$

$\Rightarrow\ 41,6667\ C + 29,8954\ H_2 + (13,125[HP] + 52,2641[L])\ O_2 + (0,357[HP] + 196,6124[L])\ N_2 + 0,2558\ K$

$\longrightarrow\ 41,5388\ CO_2 + 29,8954\ H_2O + 196,9694\ N_2 + 0,1279\ K_2CO_3 + 8,7107\ O_2$

ablesen:

Edukte: $\nu_C = 41,6667\frac{mol_C}{kg_{HP}}$; $\nu_{H_2} = 29,8954\frac{mol_{H_2}}{kg_{HP}}$; $\nu_{O_2} = 13,125\frac{mol_{O_2}}{kg_{HP}}$; $\nu_{N_2} = 0,357\frac{mol_{N_2}}{kg_{HP}}$; $\nu_K = 0,2558\frac{mol_K}{kg_{HP}}$; $\nu_{O_2,Luft} = 52,2641\frac{mol_{O_2}}{kg_{HP}}$; $\nu_{N_2,Luft} = 196,6124\frac{mol_{N_2}}{kg_{HP}}$

Produkte: $\nu_{CO_2} = 41,5388\frac{mol_{CO_2}}{kg_{HP}}$; $\nu_{H_2O} = 29,8954\frac{mol_{H_2O}}{kg_{HP}}$; $\nu_{Pottasche} = 0,1279\frac{mol_{K_2CO_3}}{kg_{HP}}$; $\nu_{O_2,Rest} = 8,7107\frac{mol_{O_2}}{kg_{HP}}$; $\nu_{N_2,Rest} = 196,9694\frac{mol_{N_2}}{kg_{HP}}$

Abgase: $\psi_{AG,i} = \frac{\nu_{AG,i}}{\Sigma(\nu_{AG,i})}$

$\Sigma(\nu_{AG,i}) = \nu_{AG,CO_2} + \nu_{AG,H_2O} + \nu_{AG,N_2} + \nu_{AG,K_2CO_3} + \nu_{AG,O_2}$

$\Rightarrow\ \Sigma(\nu_{AG,i}) = 41,5388\frac{mol_{CO_2}}{kg_{HP}} + 29,8954\frac{mol_{H_2O}}{kg_{HP}} + 8,7107\frac{mol_{O_2}}{kg_{HP}} + 196,9694\frac{mol_{N_2}}{kg_{HP}} + 0,1279\frac{mol_{K_2CO_3}}{kg_{HP}}$

$\Rightarrow\ \Sigma(\nu_{AG,i}) = 277,2422\frac{mol_{AG}}{kg_{HP}}$

$$\Rightarrow\ \psi_{AG,CO_2} = \frac{\nu_{AG,CO_2}}{\Sigma(\nu_{AG,i})} = \frac{41,5388\frac{mol_{CO_2}}{kg_{HP}}}{277,2422\frac{mol_{AG}}{kg_{HP}}} = 0,1498\frac{mol_{CO_2}}{mol_{AG}}\ ;\ \psi_{AG,H_2O} = 0,1078\frac{mol_{H_2O}}{mol_{AG}}$$

$$\psi_{AG,N_2} = 0,7105\frac{mol_{N_2}}{mol_{AG}}\ ;\ \psi_{AG,K_2CO_3} = 0,0005\frac{mol_{K_2CO_3}}{mol_{AG}}\ ;\ \psi_{AG,O_2} = 0,0314\frac{mol_{O_2}}{mol_{AG}}$$

III. TEILAUFGABE C) $\Rightarrow$ 3 PUNKTE

gesucht: t_{max}

$$(Edukte, t_\Theta) \overset{A}{\Longrightarrow} (Produkte, t_\Theta)$$

$$C \Downarrow \qquad\qquad\qquad \Downarrow B$$

$$(Edukte, t_{ein}) \overset{D}{\Longrightarrow} (Produkte, t_{max})$$

$$B = \Sigma(\nu_{P,i} \cdot c_{p,i}|_{t_\Theta}^{t_{max}} \cdot (t_{max} - t_\Theta) + r_{0,i}) \qquad |\ r_{0,i} = 0$$

$$\Rightarrow\ t_{max} = \frac{B}{\Sigma(\nu_{P,i} \cdot c_{p,i}|_{t_\Theta}^{t_{max}})} + t_\Theta \qquad \text{mit: } t_\Theta = 25°C$$

$A + B = C + D \quad \Rightarrow \quad B = C + D - A$

$A = \Delta^R h_{\Theta[pro\ \ kg]}$

$\Delta^R h_{\Theta[pro\ kg]} = -\Delta^U h_{[pro\ kg]} = -18 \frac{MJ}{kg_{HP}} \quad \Rightarrow \quad A = -18 \frac{MJ}{kg_{HP}}$

$C = \Sigma(\nu_{E,i} \cdot c_{p,i}|_{t_\Theta}^{t_{ein}} \cdot (t_{ein} - t_\Theta) + r_{0,i})$ mit: $(t_{ein} - t_\Theta) = 0\ K \quad \Rightarrow \quad C = 0 \frac{J}{kg_{HP}}$

$D = \Delta^R h \qquad \Delta^R h = 0 \frac{J}{kg_{HP}}$ (maximale Temperatur = adiabater Brenner)

$\Rightarrow \quad D = 0 \frac{J}{kg_{HP}} \qquad \Rightarrow \quad B = 18 \frac{MJ}{kg_{HP}}$

$$\Rightarrow \quad t_{max} = \frac{B}{\nu_{P,CO_2} \cdot c_{p,CO_2}|_{t_\Theta}^{t_{max}} + \nu_{P,H_2O} \cdot c_{p,H_2O,(g)}|_{t_\Theta}^{t_{max}} + \nu_{P,N_2} \cdot c_{p,N_2}|_{t_\Theta}^{t_{max}} + \nu_{P,O_2} \cdot c_{p,O_2}|_{t_\Theta}^{t_{max}}} + t_\Theta$$

$$\Rightarrow \quad t_{max} = \frac{18 \frac{MJ}{kg_{HP}}}{10,4374 \frac{kJ}{kg_{HP} \cdot K}} + 25^\circ C = 1749,5674^\circ C$$

IV. TEILAUFGABE D) $\Rightarrow$ 4 PUNKTE

gesucht: $\Delta *^R h$ mit $t_{Abgas} = 110^\circ C$

$(Edukte, t_\Theta) \overset{A}{\Longrightarrow} (Produkte, t_\Theta)$

$C \Downarrow \qquad\qquad\qquad\qquad \Downarrow B*$

$(Edukte, t_{ein}) \overset{D*}{\Longrightarrow} (Produkte, t_{max})$

$\Delta *^R h = D*$

$A + B* = C + D* \quad \Rightarrow D* = A + B * -C$

$B* = \Sigma(\nu_{P,i} \cdot c_{p,i}|_{t_\Theta}^{110^\circ C} \cdot (110^\circ C - t_\Theta) + r_{0,i})$

Annahme: Enthalpie der Asche wird vernachlässigt

$\Rightarrow \quad B* = (\nu_{P,CO_2} \cdot c_{p,CO_2}|_{t_\Theta}^{110^\circ C} + \nu_{P,H_2O} \cdot c_{p,H_2O}|_{t_\Theta}^{110^\circ C} + \nu_{P,N_2} \cdot c_{p,N_2}|_{t_\Theta}^{110^\circ C} + \nu_{P,O_2} \cdot c_{p,O_2}|_{t_\Theta}^{110^\circ C}) \cdot (110^\circ C - t_\Theta)$

$B* = 9,1926 \frac{kJ}{kg_{HP}\ K} \cdot (110^\circ C - 25^\circ C) = 781,3698 \frac{kJ}{kg_{HP}}$

$\Rightarrow \quad D* = -17,2186 \frac{MJ}{kg_{HP}} \quad \Rightarrow \quad \Delta *^R h = -17,2186 \frac{MJ}{kg_{HP}}$