

Lösung 10.4

$$\dot{m}_C = 12 \frac{\text{t}}{\text{h}}$$

$$\vartheta_{H_2O} = 327^\circ\text{C}$$

$$p_{H_2O} = p_{O_2} = 30 \text{ bar}$$

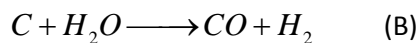
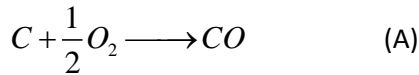
$$M_C = 12 \frac{\text{kg}}{\text{kmol}}$$

$$\vartheta_{CO} = \vartheta_{H_2} = 627^\circ\text{C}$$

$$\vartheta_{O_2} = \vartheta_C = \vartheta_u = 25^\circ\text{C}$$

isobare, vollständige Reaktion

a) $\dot{n}_{H_2O,I}$ $\dot{n}_{O_2,I}$ $\dot{n}_{CO,II}$ $\dot{n}_{H_2,II}$



$$\dot{n}_{C,I} = \frac{\dot{m}_C}{M_C} = 10^3 \frac{\text{kmol}}{\text{h}}$$

$$\dot{n}_{O_2,I} = \frac{1}{2} \dot{n}_{C,A}$$

$$\dot{n}_{CO,II} = \dot{n}_{CO,A} + \dot{n}_{CO,B} = \dot{n}_{C,A} + \dot{n}_{C,B} = \dot{n}_{C,I}$$

$$\dot{n}_{H_2O,I} = \dot{n}_{C,B} = \dot{n}_{C,I} - \dot{n}_{C,A}$$

$$\dot{n}_{H_2,II} = \dot{n}_{C,B} = \dot{n}_{C,I} - \dot{n}_{C,A}$$

1. Hauptsatz:

$$\underbrace{\dot{Q}_{I,II}}_{=0} + \underbrace{\dot{W}_{I,II}}_{=0} = \dot{H}_{II} - \dot{H}_I \Rightarrow$$

$$0 = \dot{n}_{CO,II} \cdot h_{m_{CO}} + \dot{n}_{H_2,II} \cdot h_{m_{H_2}} - \dot{n}_{C,I} \cdot h_{m_C} - \dot{n}_{O_2,I} \cdot h_{m_{O_2}} - \dot{n}_{H_2O,I} \cdot h_{m_{H_2O}}$$

$$0 = \dot{n}_{C,I} \cdot h_{m_{CO}} + (\dot{n}_{C,I} - \dot{n}_{C,A}) \cdot h_{m_{H_2}} - \dot{n}_{C,I} \cdot h_{m_C} - \frac{1}{2} \cdot \dot{n}_{C,A} \cdot h_{m_{O_2}} - (\dot{n}_{C,I} - \dot{n}_{C,A}) \cdot h_{m_{H_2O}}$$

$$\Rightarrow \dot{n}_{C,A} = \frac{\dot{n}_{C,I} \cdot (h_{m_{CO}} + h_{m_{H_2}} - h_{m_C} - h_{m_{H_2O}})}{h_{m_{H_2}} + \frac{1}{2} \cdot h_{m_{O_2}} - h_{m_{H_2O}}} = 630 \frac{\text{kmol}}{\text{h}}$$

$$\Rightarrow \dot{n}_{H_2O,I} = (1000 - 630) \frac{\text{kmol}}{\text{h}} = 370 \frac{\text{kmol}}{\text{h}}$$

$$\dot{n}_{O_2,I} = 1/2 \cdot 630 \frac{\text{kmol}}{\text{h}} = 315 \frac{\text{kmol}}{\text{h}}$$

$$\dot{n}_{CO,II} = 1000 \frac{\text{kmol}}{\text{h}}$$

$$\dot{n}_{H_2,II} = (1000 - 630) \frac{\text{kmol}}{\text{h}} = 370 \frac{\text{kmol}}{\text{h}}$$

b) $\dot{E}_{V_{I,II}}$

$$\dot{E}_{V_{I,II}} = T_u \cdot \dot{S}_{irr_{I,II}}$$

$$\dot{S}_{irr_{I,II}} = \dot{S}_{II} - \dot{S}_I, \text{ da adiabat}$$

$$\begin{aligned} \dot{S}_{II} - \dot{S}_I = & \dot{n}_{CO,II} \cdot \left(s_{m_{CO}} - R_m \cdot \ln \frac{p_{CO}}{p_0} \right) + \dot{n}_{H_2,II} \cdot \left(s_{m_{H_2}} - R_m \cdot \ln \frac{p_{H_2}}{p_0} \right) - \dot{n}_{C,I} \cdot s_{m_C} \\ & - \dot{n}_{O_2,I} \cdot \left(s_{m_{O_2}} - R_m \cdot \ln \frac{p_{O_2}}{p_0} \right) - \dot{n}_{H_2O,I} \cdot \left(s_{m_{H_2O}} - R_m \cdot \ln \frac{p_{H_2O}}{p_0} \right) \end{aligned}$$

$$p_{CO} = \frac{\dot{n}_{CO,II}}{\dot{n}_{CO,II} + \dot{n}_{H_2,II}} \cdot p_A = 21,9 \text{ bar}$$

$$p_{H_2} = p_A - p_{CO} = 8,1 \text{ bar}$$

$$p_{O_2} = p_{H_2O} = 30 \text{ bar}$$

$$\text{mit } R_m = 8,3134 \cdot 10^{-3} \frac{\text{MJ}}{\text{kmol} \cdot \text{K}} \Rightarrow \dot{S}_{irr_{I,II}} = 129,8 \frac{\text{MJ}}{\text{h} \cdot \text{K}}$$

$$\Rightarrow \dot{E}_{V_{I,II}} = 298 \text{ K} \cdot 129,8 \frac{\text{MJ}}{\text{h} \cdot \text{K}} = 36,68 \cdot 10^3 \frac{\text{MJ}}{\text{h}} = 10,74 \text{ MW}$$

Lösung 10.5

Zustandsänderungen:

1 → 2 adiabate, isobare Verbrennung von H_2 mit Luft mit $\lambda = 1$

3 → 4 vollständige, isobare Verdampfung von siedendem Wasser

$$M_L = 28,96 \frac{\text{kmol}}{\text{kg}} \quad M_{H_2} = 2 \frac{\text{kmol}}{\text{kg}} \quad M_{H_2O} = 18 \frac{\text{kmol}}{\text{kg}}$$

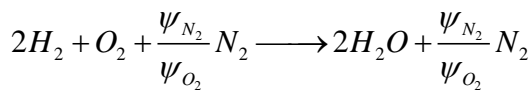
$$\dot{m}_L = 28,96 \frac{\text{kg}}{\text{h}} \quad \psi_{O_2} = 0,21 \quad \psi_{N_2} = 0,79$$

$$p_{L,I} = 1 \text{ bar} \quad T_{L,I} = 298 \text{ K} \quad p_{H_2,I} = 1 \text{ bar}$$

$$p_{Abg,II} = 1 \text{ bar} \quad T_{Abg,II} = 1100 \text{ K} \quad \Delta e_a = 0$$

$$M_{N_2} = 28 \frac{\text{kmol}}{\text{kg}} \quad p_W = 120 \text{ bar} \quad T_{H_2,I} = 298 \text{ K}$$

a) $\dot{n}_{O_2,I} \quad \dot{n}_{N_2,I} \quad \dot{n}_{H_2,I} \quad \dot{n}_{N_2,II} \quad \dot{n}_{H_2O,II}$



$$\dot{n}_{L,I} = \frac{\dot{m}_L}{M_L} = 1 \frac{\text{kmol}}{\text{h}} \quad \dot{n}_{O_2,I} = \psi_{O_2} \cdot \dot{n}_{L,I} = 0,21 \frac{\text{kmol}}{\text{h}}$$

$$\dot{n}_{N_2,I} = \psi_{N_2} \cdot \dot{n}_{L,I} = 0,79 \frac{\text{kmol}}{\text{h}} \quad \dot{n}_{H_2,I} = 2 \cdot \dot{n}_{O_2,I} = 0,42 \frac{\text{kmol}}{\text{h}}$$

$$\dot{n}_{H_2O,II} = \dot{n}_{H_2,I} = 0,42 \frac{\text{kmol}}{\text{h}} \quad \dot{n}_{N_2,II} = \dot{n}_{N_2,I} = 0,79 \frac{\text{kmol}}{\text{h}}$$

b) \dot{m}_d

1. Hauptsatz Gesamtsystem:

$$\dot{Q}_{I,II} + \dot{W}_{t,II} = \dot{H}_{aus} - \dot{H}_{ein} = \dot{H}_2 - \dot{H}_1 + \dot{H}_4 - \dot{H}_3$$

$$\Rightarrow \dot{H}_2 - \dot{H}_1 = -\dot{H}_4 + \dot{H}_3 = -\dot{m}_d \cdot (h_4 - h_3) = -\dot{m}_d \cdot \Delta h_v(p_W)$$

$$\begin{aligned} \Rightarrow -\dot{m}_d \cdot \Delta h_v(p_W) &= \dot{n}_{H_2O,II} \cdot h_{m_{H_2O}}(T_2) + \dot{n}_{N_2,II} \cdot h_{m_{N_2}}(T_2) \\ &\quad - \dot{n}_{O_2,I} \cdot h_{m_{O_2}}(T_1) - \dot{n}_{N_2,I} \cdot h_{m_{N_2}}(T_1) - \dot{n}_{H_2,I} \cdot h_{m_{H_2}}(T_1) \end{aligned}$$

mit den Beträgen aus der Tabelle molarer Enthalpien

$$\Rightarrow -\dot{m}_d \cdot 1,194 \frac{\text{MJ}}{\text{kg}} = (-0,42 \cdot 198,8 + 0,79 \cdot 33,43 - 0,21 \cdot 8,68 - 0,79 \cdot 8,67 - 0,42 \cdot 8,45) \frac{\text{MJ}}{\text{h}}$$

$$\Rightarrow -\dot{m}_d = \frac{69,3074}{1,1974} \frac{\text{kg}}{\text{h}} = 57,88 \frac{\text{kg}}{\text{h}}$$

$$c) \dot{S}_{irr} \quad \dot{E}_v$$

2. Hauptsatz

$$\dot{S}_{irr} = \dot{S}_{aus} - \dot{S}_{ein} = \sum \dot{S}_{Gase} + \sum \dot{S}_d$$

$$\sum \dot{S}_d = \dot{m}_d \cdot (s'' - s') \text{ bei } p = 120 \text{ bar}$$

$$\Rightarrow \sum \dot{S}_d = 57,88 \frac{\text{kg}}{\text{h}} \cdot (5,5002 - 3,4972) \frac{\text{kJ}}{\text{kg} \cdot \text{K}} = 115,93 \frac{\text{kJ}}{\text{h} \cdot \text{K}}$$

$$\sum \dot{S}_{Gase} = \dot{n}_{H_2O,II} \cdot s_{m_{H_2O,II}} + \dot{n}_{N_2,II} \cdot s_{m_{N_2,II}} - \dot{n}_{O_2,I} \cdot s_{m_{O_2,I}} - \dot{n}_{N_2,I} \cdot s_{m_{N_2,I}} - \dot{n}_{H_2,I} \cdot s_{m_{H_2,I}}$$

Bestimmung der Partialdrücke zur Berechnung der S_m :

$$p_{O_2,I} = 0,21 \text{ bar} \quad p_{N_2,I} = 0,79 \text{ bar} \quad p_{H_2,I} = 1 \text{ bar}$$

$$\dot{n}_{Abg,II} = \dot{n}_{H_2O,II} + \dot{n}_{N_2,II} = 1,21 \frac{\text{kmol}}{\text{h}}$$

$$p_{H_2O,II} = \frac{\dot{n}_{H_2O,II}}{\dot{n}_{Abg,II}} \cdot p_{II} = \frac{0,42}{1,21} \cdot 1 \text{ bar} = 0,347 \text{ bar}$$

$$p_{N_2,II} = \frac{\dot{n}_{N_2,II}}{\dot{n}_{Abg,II}} \cdot p_{II} = \frac{0,79}{0,21} \cdot 1 \text{ bar} = 0,653 \text{ bar}$$

$$s_{m_{H_2O,II}} = s_{m_{H_2O}}(T_{II}, p_0) - R_m \cdot \ln \frac{p_{H_2O,II}}{p_0}$$

$$s_{m_{H_2O,II}} = (236,8 - 8,314 \cdot \ln 0,347) \frac{\text{kJ}}{\text{kmol} \cdot \text{K}} = 245,6 \frac{\text{kJ}}{\text{kmol} \cdot \text{K}}$$

$$s_{m_{N_2,II}} = (231,3 - 8,314 \cdot \ln 0,653) \frac{\text{kJ}}{\text{kmol} \cdot \text{K}} = 234,86 \frac{\text{kJ}}{\text{kmol} \cdot \text{K}}$$

$$s_{m_{N_2,I}} = (191,6 - 8,314 \cdot \ln 0,79) \frac{\text{kJ}}{\text{kmol} \cdot \text{K}} = 193,57 \frac{\text{kJ}}{\text{kmol} \cdot \text{K}}$$

$$s_{m_{O_2,I}} = (205,15 - 8,314 \cdot \ln 0,21) \frac{\text{kJ}}{\text{kmol} \cdot \text{K}} = 218,13 \frac{\text{kJ}}{\text{kmol} \cdot \text{K}}$$

$$s_{m_{N_2,II}} = (130,63 - 8,314 \cdot \ln 1) \frac{\text{kJ}}{\text{kmol} \cdot \text{K}} = 130,63 \frac{\text{kJ}}{\text{kmol} \cdot \text{K}}$$

$$\sum \dot{S}_{Gase} = (0,42 \cdot 245,6 + 0,79 \cdot 234,86 - 0,21 \cdot 218,13 - 0,79 \cdot 193,57 - 0,42 \cdot 130,63) \frac{\text{kJ}}{\text{h} \cdot \text{K}}$$

$$= 35,01 \frac{\text{kJ}}{\text{h} \cdot \text{K}}$$

$$\Rightarrow \dot{S}_{irr} = \sum \dot{S}_{Gase} + \sum \dot{S}_d = 150,94 \frac{\text{kJ}}{\text{h} \cdot \text{K}}$$

$$\Rightarrow \dot{E}_v = T_u \cdot \dot{S}_{irr} = 298 \text{ K} \cdot 150,94 \frac{\text{kJ}}{\text{h} \cdot \text{K}} = 44,98 \cdot 10^3 \frac{\text{kJ}}{\text{h}} = 12,5 \text{ kW}$$

$$d) \mathcal{G}_{H_2O}$$

$$p_{H_2O} = 0,347 \text{ bar} \Rightarrow \text{aus h,s-Diagramm: } \mathcal{G}_{H_2O} \geq 72,3 \text{ } ^\circ\text{C}$$