Thermische Zustandsgrößen ($m = 10\,kg$)

① $p_1 = 20\,bar$ $T_1 = 1000\,K$ $V_1 = \frac{m R_i T_1}{p_1} = 1.435\,m^3$

① → ② isotherm

$p_2 = 10\,bar$, $T_2 = T_1 = 1000\,K$, $V_2 = \frac{p_1}{p_2} V_1 = 2,870\,m^3$

② → ③ isentrop

$p_3 = 2\,bar$ $T_3 = \left(\frac{p_3}{p_2}\right)^{\frac{\kappa-1}{\kappa}} T_2 = 631.4\,K$ $V_3 = \left(\frac{p_2}{p_3}\right)^{\frac{1}{\kappa}} V_2 = 9,060\,m^3$

③ → ④ isotherm, ④ → ① isentrop

$T_4 = T_3 = 631,4\,K$ $p_4 = \left(\frac{T_4}{T_1}\right)^{\frac{\kappa}{\kappa-1}} p_1 = 4\,bar$ $V_4 = \left(\frac{p_1}{p_4}\right)^{\frac{1}{\kappa}} V_1 = 4.530\,m^3$

Volumen änderungsarbeiten:

$$W_{V12} = p_1 V_1 \ln \frac{p_2}{p_1} = -1989\ \text{kJ}$$

$$W_{V23} = m c_V (T_3 - T_2) = -2645\ \text{kJ} \quad \text{mit} \quad c_V = \frac{1}{\kappa - 1} R_i = 0{,}7175\ \frac{\text{kJ}}{\text{kg K}}$$

$$W_{V34} = 1256\ \text{kJ}$$

$$W_{V41} = 2645\ \text{kJ}$$

$$\Rightarrow W_k = \sum_i W_{V_i} = -773{,}7\ \text{kJ}$$

Wärmen:

$$Q_{12} = -W_{V12} = 1989\ \text{kJ}$$

$$Q_{23} = 0$$

$$Q_{34} = -W_{V34} = -1256\ \text{kJ}$$

$$Q_{41} = 0$$

$$\Rightarrow \sum Q_i = 773{,}7\ \text{kJ} \quad \checkmark$$

$$\eta = \frac{-W_k}{Q_{zu}} = \frac{-W_k}{Q_{12}} = 0{,}3686$$

Entropien:

Isentrope: $\Delta S = 0$

Isotherme (rev.!) $\quad dS = \frac{dQ}{T} \Rightarrow S_2 - S_1 = \frac{Q_{12}}{T_1}$

$S_2 - S_1 = \frac{Q_{12}}{T_1} = 1.98\,\mathrm{J}\,\frac{\mathrm{kJ}}{\mathrm{K}}$ $\qquad S_3 - S_2 = 0$

$S_4 - S_3 = \frac{Q_{34}}{T_4} = -1.98\,\frac{\mathrm{kJ}}{\mathrm{K}}$ $\qquad S_1 - S_4 = 0$

b) $\Delta S_A = \frac{-Q_{12}}{T_1} = -1.98\,\mathrm{J}\,\frac{\mathrm{kJ}}{\mathrm{K}}$

$\Delta S_C = \frac{-Q_{34}}{T_4} = 1.98\,\mathrm{J}\,\frac{\mathrm{kJ}}{\mathrm{K}}$

$\Delta S_B = 0\ \frac{\mathrm{kJ}}{\mathrm{K}}$

$\Delta S = \Delta S_A + \Delta S_B + \Delta S_C = 0\,\frac{\mathrm{kJ}}{\mathrm{K}}$

# Aufgabe 2

a.) Bestimmung der Energien

$W_{v12} = -1989\ kJ$ $\qquad$ $W_{v34} = 1256\ kJ$

$W_{diss12} = 0.1\,|W_{v12}| = 198{,}9\ kJ$ $\qquad$ $W_{diss34} = 0.1\,|W_{v34}| = 125.6\ kJ$

$0 = U_2 - U_1 = W_{v12} + Q_{12} + W_{diss12}$

$Q_{12} = -W_{v12} - W_{diss12} = 1790\ kJ$ $\qquad$ $Q_{34} = -W_{v34} - W_{diss34} = -1782\ kJ$

$W_k = \sum_i W_{s,i} = \sum_i W_{v,i} + \sum_i W_{diss,i}$

$= W_{k,rev} + W_{diss12} + W_{diss34} = -408.8\ kJ$

$\eta = \frac{-W_k}{Q_{12}} = 0.228$

h) Berechnen der Entropien

$$s_2 - s_1 = \frac{q_{12}}{T_1} + \frac{w_{diss,12}}{T_1} = 1.893 \frac{kJ}{K}$$

$$s_4 - s_3 = -1.893 \frac{kJ}{K}$$

$$s_3 - s_2 = 0 = s_1 - s_4$$

$\Delta s_B = 0$ Kreisprozess (s ist Zustandsgröße!)

$$\Delta s_A = \frac{-q_{12}}{T_1} = -1.790 \frac{kJ}{K}$$

$$\Delta s_C = -\frac{q_{34}}{T_4} = 2.188 \frac{kJ}{K}$$

$$\Delta s = \Delta s_A + \underbrace{\Delta s_B}_{=0} + \Delta s_C = 0.3979 \frac{kJ}{K} > 0$$

irreversibel!