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熱力学　4回目

[1](1)・定容変化のとき, $dv=0$

熱力学第一法則より, $dq = du + pdv$

$\rightarrow dq = du$

$$C_v = \left(\frac{dq}{dT}\right)_v = \left(\frac{du}{dT}\right)_v \rightarrow \boxed{du = C_v dT}$$

・定圧変化のとき, $dp=0$

熱力学第一法則より, $dq = du + pdv$

エンタルピの関係式より, $h = u + pv \longrightarrow dh = du + pdv + vdp$

$$-)\begin{cases} dq = du + pdv \\ dh = du + pdv - vdp \end{cases}$$

$dq = dh - vdp$ より,

$dq = dh$

$$C_p = \left(\frac{dq}{dT}\right)_p = \left(\frac{dh}{dT}\right)_p \longrightarrow \boxed{dh = C_p dT}$$

(2) 理想気体の状態方程式より,

$pv = RT$

エンタルピの関係式より, $h = u + pv = u + RT$

$\rightarrow dh = du + RdT$

$dh = C_p dT$, $du = C_v dT$ より,

$C_p dT = C_v dT + RdT$

$C_p = C_v + R$

$\therefore C_p - C_v = \boxed{R}$

(3) (i) 定容変化 ; $dv = 0$

$dq = du + pdv$ より,

$dq = du$

$dq = Tds$ より,

$$ds = \frac{dq}{T} = \frac{du}{T} = \frac{C_v dT}{T}$$

$$s = \boxed{C_v \ln T + s_1}$$

(ii) 定圧変化 ; $dp = 0$

$dq = dh - vdp$ より, $dq = dh$

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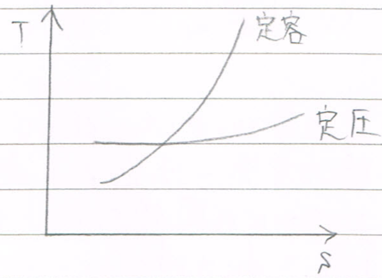
$dq = Tds$ より、

$$ds = \frac{dq}{T} = \frac{C_p dT}{T} \longrightarrow s = \boxed{C_p \ln T + s_2}$$

(4) $\begin{cases} s = C_p \ln T + s_1 \longrightarrow T = \frac{1}{C_p} \exp[s - s_1] \\ s = C_v \ln T + s_2 \longrightarrow T = \frac{1}{C_v} \exp[s - s_2] \end{cases}$

$C_p > C_v \longrightarrow \frac{1}{C_p} < \frac{1}{C_v}$ より、



(5) (i) $ds = \frac{dq}{T} = \frac{C_v dT}{T} = \frac{(a + bT + cT^2)}{T} dT$

$$\therefore s = \boxed{a \ln T + bT + \frac{1}{2} cT^2 + s_1}$$

(ii) $ds = \frac{dq}{T} = \frac{C_p dT}{T} = \frac{a + R + bT + cT^2}{T} dT$

$$\therefore s = \boxed{(a+R) \ln T + bT + \frac{1}{2} cT^2 + s_2}$$

[2] (1) 液体熱：$Q_\ell = mc\Delta T = 1 \cdot 4.0 \cdot (450 - 300) = 600$ (kJ/kg)

水：1，周囲：2

$$\Delta s_1 = -\int \frac{dq}{T}, \quad \Delta s_2 = \frac{Q_2}{T_2}$$

$$\Delta s = \Delta s_1 + \Delta s_2 = -\int \frac{dq}{T} + \frac{Q_2}{T_2} \geqq 0 \longrightarrow Q_2 \geqq T_2 \int \frac{dq}{T}$$

$$\therefore Q_0' = Q_{2min} = T_2 \int \frac{dq}{T} = 300 \cdot \int \frac{mcdT}{T} = 300 \cdot 1 \cdot 4.0 \cdot \ln \frac{450}{300}$$

$$= 1200 \cdot 0.4 = \boxed{480 \text{ (kJ/kg)}}$$

$$Q_a' = Q_\ell - Q_a = \boxed{120 \text{ (kJ/kg)}}$$

(2) $\Delta s_1 = -\frac{Q}{T_1}, \quad \Delta s_2 = \frac{Q_2'}{T_2}$

$$\Delta s = \Delta s_1 + \Delta s_2 = -\frac{Q}{T_1} + \frac{Q_2'}{T_2} \geqq 0 \longrightarrow Q_2' \geqq \frac{T_2}{T_1} Q$$

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$\therefore Q_0'' = Q_{2min} = \frac{T_2}{T_1} Q = \frac{300}{450} \cdot 1800 = \boxed{1200\,(\mathrm{kJ/kg})}$

$Q_a'' = Q - Q_0'' = \boxed{600\,(\mathrm{kJ/kg})}$

(3) $Q_a = Q_a' + Q_a'' = \boxed{720\,(\mathrm{kJ/kg})}$

$Q_0 = Q_0' + Q_0'' = \boxed{1680\,(\mathrm{kJ/kg})}$

[3] (1) $h_2'' = 2600\,(\mathrm{kJ/kg})$, $h_2' = h_3 = 150\,(\mathrm{kJ/kg})$

$h_2 = h_2' + x(h_2'' - h_2') = 150 + 0.8(2600 - 150) = 2110\,(\mathrm{kJ/kg})$

$\therefore W_T = h_1 - h_2 = 3300 - 2110 = \boxed{1190\,(\mathrm{kJ/kg})}$

(2) $q = h_1 - h_3 = 3300 - 150 = 3150\,(\mathrm{kJ/kg})$

$\therefore \eta_{th} = \frac{W_T}{q} = \frac{1190}{3150} \fallingdotseq \boxed{0.38}$

(3) ・蒸気の流動による損失（摩擦・渦・絞り）

・周囲への熱損失

・蒸気の周囲への漏れ出し

・復水器などの周辺空気への漏れ込み

(4) $W_T' = 0.8 \cdot W_T = 0.8 \cdot 1190 = 952\,(\mathrm{kJ/kg})$

$\eta_{th}' = \frac{W_T'}{q} = \frac{952}{3150} \fallingdotseq \boxed{0.302}$