熱力学　4回目

[1] (1) 開いた系のエネルギ式より,

$E_I = \boxed{m(h_I + \frac{1}{2}w_I^2 + gz_I)}$

(2) $m(h_I + \frac{1}{2}w_I^2 + gz_I) - Q_L = m(h_{II} + \frac{1}{2}w_{II}^2 + gz_{II}) + W_t$

$\therefore W_t = \boxed{m\{(h_I - h_{II}) + \frac{1}{2}(w_I^2 - w_{II}^2) + g(z_I - z_{II})\} - Q_L}$

(3) 絞り前後ではエンタルピの変化はないので, $dh = 0$

$dh = c_p dT + [v - T(\partial v/\partial T)_p] dP = 0$

$\frac{dT}{dP} = -\frac{1}{c_p}\{v - T(\frac{\partial v}{\partial T})_p\}$

ジュール・トムソン効果より, 逆転温度の際には

$\mu = \frac{dT}{dp} = 0$

$v - T(\frac{\partial v}{\partial T})_p = 0$ —①

$pv = aRPT^2 - bT + Cp$

$v = aRT^2 - \frac{b}{p}T + C$ —②

$(\frac{\partial v}{\partial T})_p = 2aRT - \frac{b}{p}$

①に代入

$v - T(2aRT - \frac{b}{p}) = 0$

②より,

$aRT^2 - \frac{b}{p}T + C - 2aRT^2 + \frac{b}{p}T = 0$

$aRT^2 = C$

$\therefore T = \boxed{\sqrt{\frac{C}{aR}}}$

(4) 等エンタルピ変化より, $dh = 0$

$dh = c_p dT + [v - T(\partial v/\partial T)_p] dP = 0$

$\frac{dT}{dP} = -\frac{1}{c_p}\{v - T(\frac{\partial v}{\partial T})_p\}$ —①

理想気体の状態方程式より, $pv = RT \rightarrow v = RT/p$

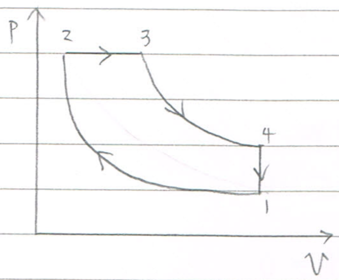
また, Pが一定ならば,

$(\frac{\partial v}{\partial T})_p = \frac{R}{P}$

①に代入

$\frac{dT}{dP} = -\frac{1}{c_p}(\frac{RT}{P} - T\cdot\frac{R}{P}) = 0 \rightarrow$ 温度変化なし//

[2] (1)



(2) ・2 → 3；定圧変化より，$dP = 0$

$dq = dh - v dP$ より，$dq = dh = c_p dT$

∴吸熱量：$Q_{23} = \int_2^3 m\beta T\,dT = \boxed{\frac{1}{2} m\beta (T_3^2 - T_2^2)}$

・1 → 2；断熱変化より，

$Q_{12} = \boxed{0}$

・4 → 1；定容変化より，$dv = 0$

$dq = du + p dv$ より，$dq = du = c_v dT$

∴放熱量：$Q_{41} = \int_4^1 m\alpha T\,dT = \boxed{\frac{1}{2} m\alpha (T_1^2 - T_4^2)}$

・3 → 4；断熱変化より，

$Q_{34} = \boxed{0}$

(3) ・定圧変化のとき，$dP = 0$

$dq = dh - v dp$ より，$dq = dh$

$dq = T ds$ より，

$$ds = \frac{dq}{T} = \frac{dh}{T} = \frac{c_p dT}{T} = m\beta\, dT$$

$S = m\beta T + S_0$

$S = 0$ のとき，$T = T_0$ より，

$S = m\beta T_0 + S_0 = 0 \rightarrow S_0 = -m\beta T_0$

∴ $S = m\beta T - m\beta T_0 \rightarrow$ ∴ $\boxed{T = \frac{S}{m\beta} + T_0}$

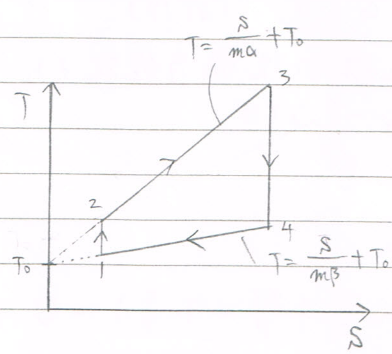
・定容変化も同様に，

$S = m\alpha T - m\alpha T_0 \rightarrow$ ∴ $\boxed{T = \frac{S}{m\alpha} + T_0}$

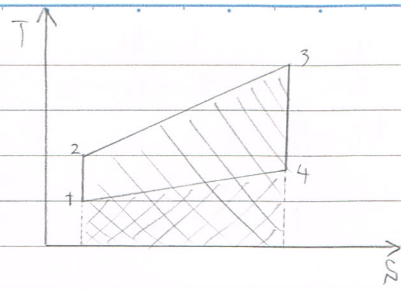
(4) (3)より，$T = \frac{S}{m\beta} + T_0$

$T = \frac{S}{m\alpha} + T_0$

$C_v < C_p$ より，$\alpha < \beta \rightarrow \frac{1}{\alpha} > \frac{1}{\beta}$



(5) TS線図より、2−3間と4−1間のエントロピ変化量は等しいので、エントロピ変化量をΔSとおくと、



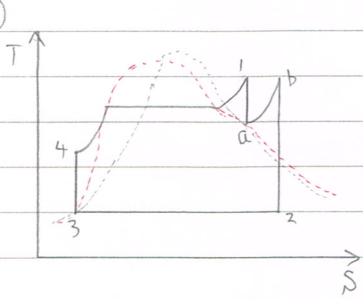
$$Q_1 = (T_2 + T_3)\cdot\Delta S\cdot\frac{1}{2} = \frac{1}{2}\Delta S(T_2 + T_3)$$

$$Q_2 = (T_1 + T_4)\cdot\Delta S\cdot\frac{1}{2} = \frac{1}{2}\Delta S(T_1 + T_4)$$

$$\eta = \frac{W}{Q} = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1} = 1 - \frac{\frac{1}{2}\Delta S(T_1 + T_4)}{\frac{1}{2}\Delta S(T_2 + T_3)}$$

$$= \boxed{1 - \frac{T_1 + T_4}{T_2 + T_3}}$$

[3] (1)



(2) $q_1 = (h_1 - h_4) - (h_b - h_a) = \boxed{h_1 - h_4 + h_a - h_b}$

$q_2 = -(h_3 - h_2) = \boxed{h_2 - h_3}$

(3) $$\eta_a = \frac{w}{q_1} = \frac{q_1 - q_2}{q_1} = 1 - \frac{q_2}{q_1} = \boxed{1 - \frac{h_2 - h_3}{h_1 - h_4 + h_a - h_b}}$$

(4) 状態3は圧縮液より、$h_3 = h_2' = h_c'$

$$h_2 = h_2' + x_2 r = h_3 + x_2 r$$

$$h_c = h_c' + x_c r = h_3 + x_c r$$

$$q_1' = h_1 - h_4,\quad q_2' = h_c - h_3$$

$$\eta_b = \frac{w}{q_1'} = \frac{q_1' - q_2'}{q_1'} = 1 - \frac{q_2'}{q_1'} = 1 - \frac{h_c - h_3}{h_1 - h_4}$$

$\eta_a > \eta_b$ のとき、

$$1 - \frac{h_2 - h_3}{h_1 - h_4 + h_a - h_b} > 1 - \frac{h_c - h_3}{h_1 - h_4}$$

$$\cancel{1} - \frac{(\cancel{h_3} + x_2 r) - \cancel{h_3}}{h_1 - h_4 + h_a - h_b} > \cancel{1} - \frac{(\cancel{h_3} + x_c r) - \cancel{h_3}}{h_1 - h_4}$$

$$\frac{x_c}{x_2} > \frac{h_1 - h_4}{h_1 - h_4 + h_a - h_b}$$

乾き度 $: x < 1$ より, $\frac{x_c}{x_2} < 1$

$$\therefore \boxed{\frac{h_1 - h_4}{h_1 - h_4 + h_a - h_b} < \frac{x_c}{x_2} < 1}$$