技術系専門試験問題演習講座
記述　熱力学・熱機関

2019年　国家総合職　2次記述　No.16

（熱力学・熱機関）

(3)

(3)(a)(i)

$M_{He} = 4\ kg/kmol \Rightarrow 1kmol = 4kg$

$0.25kmol \Leftarrow 1kg$

$n_{He} = \dfrac{m_{He}}{M_{He}} = \dfrac{1}{4}\ kmol$ //

$n_{O2} = \dfrac{m_{O2}}{M_{O2}} = \dfrac{2}{32} = \dfrac{1}{16}\ kmol$ //

$n_{N2} = \dfrac{m_{N2}}{M_{O2}} = \dfrac{1}{4}\ kmol$ //

$n = n_{He} + n_{O2} + n_{N2} = \dfrac{9}{16}\ kmol$ //

(ii)

$X_{He} = \dfrac{\frac{1}{4}}{\frac{9}{16}} = \dfrac{4}{9}$ //

$X_{O2} = \dfrac{1}{9}$ //

$X_{N2} = \dfrac{4}{9}$ //

(iii)

$m = m_{He} + m_{O2} + m_{N2} = 10\ kg$

$\therefore M = \dfrac{m}{n} = \dfrac{160}{9}\ kg/kmol$ //

(iv)

$R = 8.31\ [kJ/(kmol \cdot K)]$ ← 1kmol あたり

⇓

$R\ [J/(kg \cdot K)]$ ← $1kg = \dfrac{9}{160}\ kmol$ あたり

$R = 8.31 \times 10^3 \times \dfrac{9}{160} = 467.4\ [J/(kg \cdot K)]$ //

$8.31\ [kJ/(kmol \cdot K)] = \dfrac{8.31 \times 10^3}{\frac{160}{9}}\ [J/(kg \cdot K)]$ //

(v) 混合気体の状態方程式

$$p_1V_1 = mRT_1$$

hPa

$$1\times10^2\times V_1 = 10\times467.4\times300$$

10^3

$$V_1 = 14.0\,[m^3]$$

⑨ $p_1V_1 = nRT_1$

$$1\times\cancel{10^2}\times V_1 = \frac{9}{16}\times8.31\times3\cancel{00}$$

$$V_1 = 14.0\ m^3$$

(b)

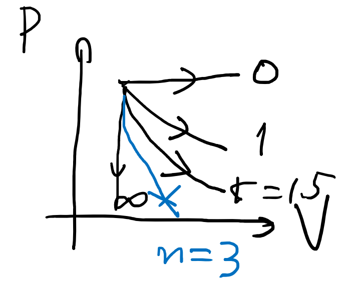
$pV^n =$ 一定

$n=0$ 定圧

$n=1$ 等温

$n=\kappa$ 断熱

$n\to\infty$ 定積



(i)

$pV^n =$ 一定 $\Rightarrow$ $TV^{n-1} =$ 一定

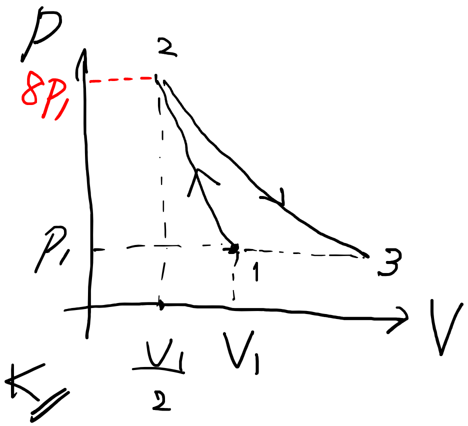
$1\to2$

$$T_1V_1^2 = T_2\left(\frac{V_1}{2}\right)^2$$

$$\therefore\ T_2 = 4T_1 = 1.2\times10^3\ \mathrm{K}$$

圧力は、

$$p_1V_1^3 = p_2\left(\frac{V_1}{2}\right)^3 \Rightarrow p_2 = 8p_1$$



(ii)

2→3について、

$$8p_1\left(\frac{V_1}{2}\right)^{1.5} = p_1V_3^{1.5}$$

$$\therefore 64\left(\frac{V_1}{2}\right)^3 = 8V_1^3 = (2V_1)^3 = V_3^3$$

$$\therefore V_3 = 2V_1$$

$$= 28.0\ \mathrm{m^3}$$

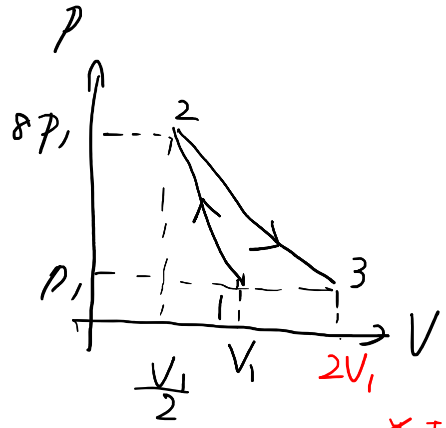
(iii)

ポリトロープ変化の仕事

$$W = \frac{p_1V_1 - p_2V_2}{n-1}$$

断熱変化

$$W = \frac{p_1V_1 - p_2V_2}{\kappa - 1}$$



$$W_{13} = \underbrace{W_{12}}_{\text{ポリトロープ}(n=3)} + \underbrace{W_{23}}_{\text{断熱}}$$

$$= \frac{p_1V_1 - 8p_1\frac{V_1}{2}}{2} + \frac{8p_1\frac{V_1}{2} - p_1 2V_1}{0.5}$$

$$= -\frac{3}{2}p_1V_1 + 4p_1V_1$$

$$= \frac{5}{2}p_1V_1 = 1.40\times10^6\ \mathrm{J}$$

◎

$$W = \int_1^2 p\,dV = C\int_1^2 V^{-n}dV \qquad pV^n = C$$

$$= C\left[\frac{V^{1-n}}{1-n}\right]_1^2 = \frac{CV_1^{1-n} - CV_2^{1-n}}{n-1}$$

$$p_1V_1^n \qquad p_2V_2^n$$

(iv) (1) ポリトロープのQ

(2) 1→3 のQ

熱力学I　$\Delta U = Q - W$

$$\therefore Q_{13} = Q_{12} = W_{12} + \Delta U_{12}$$

$$= -\frac{3}{2}p_1V_1$$

$$\Delta U = nC_v\Delta T = \begin{cases} \frac{3}{2}nR\Delta T & (\text{単原子}) \\ \frac{5}{2}nR\Delta T & (\text{2原子}) \end{cases}$$

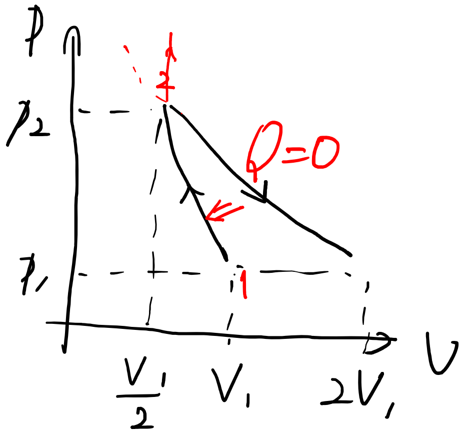
単　$n = n_{He} = \frac{1}{4}$ kmol

二　$n = n_{O_2} + n_{N_2} = \frac{5}{16}$ kmol

$(\Delta T_{12} = 1200 - 300 = 900)$

よって　$\Delta U = \frac{3}{2} \times \frac{1}{4} \times R \times 900 + \frac{5}{2} \times \frac{5}{16} \times R \times 900$

$$= \left(\frac{3}{8} + \frac{25}{32}\right) \times 900R$$



$$= \frac{37}{32} \times 900 \times 8.31 = 8647 \text{ kJ}$$

$$W_{12} = -\frac{3}{2}p_1V_1$$

$$= -\frac{3}{2} \times 1 \times 10^2 \times 14 = -2100 \text{ kJ}$$

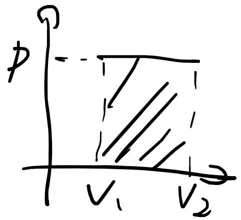
よって

$$Q_{13} = 6547 \text{ kJ}$$

$$= 6.55 \times 10^6 \text{ J}$$

(v) 定圧変化を考える。

$$\Delta U = nC_v\Delta T$$
$$Q = nC_p\Delta T$$
$$W = p(V_2 - V_1) = p\Delta V = nR\Delta T$$



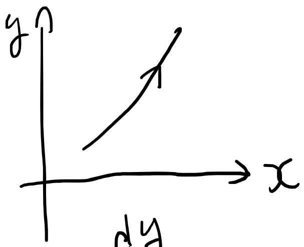
$$pV = nRT$$
$$\Downarrow$$
$$p\Delta V = nR\Delta T$$

$$\Downarrow$$

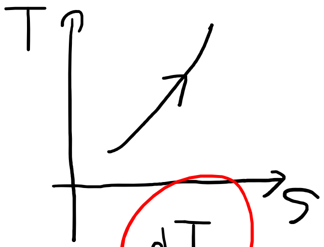
熱力学I $\Delta U = Q - W$

$$c_v = c_p - R$$

(vi)



$$\frac{dy}{dx}$$



$$\frac{dT}{dS}$$

比熱

$$dQ = c\,dT$$

$$dS = \frac{dQ}{T} = c\frac{dT}{T}$$

$c_p, c_v > 0$

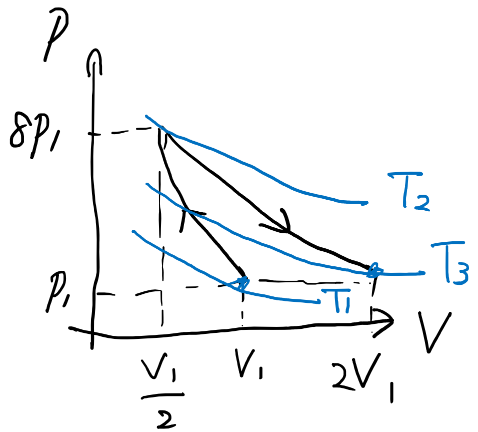
$$\therefore \frac{dT}{dS} = \frac{T}{c} > 0$$

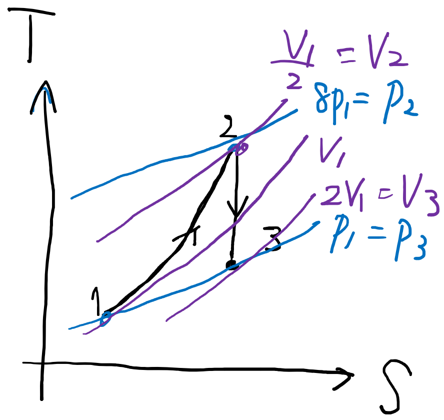
$c_p > c_v$ (vより)

よって $\dfrac{T}{c_v} > \dfrac{T}{c_p}$

傾き大

(vii)





$$dS = \frac{dQ}{T} > 0$$ (吸熱)