PHYS1106 物理原理I第五次作□

董建宇

TOTAL POINTS

64 / 70

QUESTION 1

1 第一□ **15 / 15**

✓ **- 0 pts** *Correct*

- 4 pts □果

- 2 pts Click here to replace this description.

- 1 pts 交晚

QUESTION 2

2 第二□ **10 / 10**

✓ **- 0 pts** *Correct*

- 5 pts Click here to replace this description.

- 2 pts Click here to replace this description.

QUESTION 3

3 第三□ **13 / 15**

- 0 pts Correct

- 4 pts □程略减

✓ **- 2 pts** 乱 不全 □果□□ □程

- 7 pts □□太多 少□

- 1 pts □果化□

- 3 pts Click here to replace this description.

QUESTION 4

4 第四□ **11 / 15**

- 0 pts Correct

- 2 pts Click here to replace this description.

✓ **- 4 pts** *Click here to replace this description.*

- 1 pts Click here to replace this description.

- 13 pts Click here to replace this description.

- 6 pts Click here to replace this description.

- 7 pts □交作□

QUESTION 5

5 第五□ **15 / 15**

✓ **- 0 pts** *Correct*

- 4 pts Click here to replace this description.

- 1 pts Click here to replace this description.

- 2 pts Click here to replace this description.

- 3 pts Click here to replace this description.

- 5 pts Click here to replace this description.

1 第一□ **15 / 15**

✓ **- 0 pts** *Correct*

- 4 pts □果

- 2 pts Click here to replace this description.

- 1 pts 交晚

2 第二题 **10 / 10**

✓ **- 0 pts** *Correct*

- 5 pts Click here to replace this description.

- 2 pts Click here to replace this description.

3 第三□ **13 / 15**

- **- 0 pts** Correct
- **- 4 pts** □程略减
- ✓ **- 2 pts** 乱 不全 □果□□ □程
- **- 7 pts** □□太多 少□
- **- 1 pts** □果化□
- **- 3 pts** Click here to replace this description.

4 第四 **11 / 15**

- **- 0 pts** Correct
- **- 2 pts** Click here to replace this description.
- ✓ **- 4 pts** *Click here to replace this description.*
- **- 1 pts** Click here to replace this description.
- **- 13 pts** Click here to replace this description.
- **- 6 pts** Click here to replace this description.
- **- 7 pts** 交作

5 第五 **15 / 15**

✓ **- 0 pts** *Correct*

- 4 pts Click here to replace this description.

- 1 pts Click here to replace this description.

- 2 pts Click here to replace this description.

- 3 pts Click here to replace this description.

- 5 pts Click here to replace this description.

第一题：热力学定律练习题.

解 1. 由热力学第一定律 $\Delta U = Q - W$ 且 ΔU 只与始末状态有关

(1). $\Delta U = Q_1 - W_1$　　$\Delta U = Q_2 - W_2$

得 $Q_2 = 250J$ 即有 $250J$ 热量传入系统.

(2). $-\Delta U = Q_3 + |W_3|$ 得 $Q_3 = -292J$

即系统放热 $292J$.

2. $V = \frac{a}{\sqrt{p}}$ 得 $p = \frac{a^2}{V^2}$　　$W = \int_{V_1}^{V_2} p \cdot dV = \int_{V_1}^{V_2} \frac{a^2}{V^2} dV = a^2 \cdot -\frac{1}{V}\Big|_{V_1}^{V_2} = a^2 \left(\frac{1}{V_1} - \frac{1}{V_2}\right)$

由 $pV = \nu RT$ 可得 $T = \frac{a^2}{\nu RV}$　　$T_1 - T_2 = \frac{a^2}{\nu R}\left(\frac{1}{V_1} - \frac{1}{V_2}\right)$

即气体做功 $a^2\left(\frac{1}{V_1} - \frac{1}{V_2}\right)$　　$T_1 - T_2 = \frac{a^2}{\nu R}\left(\frac{1}{V_1} - \frac{1}{V_2}\right)$

3. 由于等温线与绝热线相交 则 $pV = pV^{\gamma} = K$ 得 $V = 1$

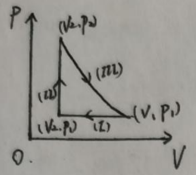
等温 $p_1 = \frac{K}{V}$　$\frac{dp_1}{dV} = -\frac{K}{V^2}$

绝热 $p_2 = \frac{K}{V^{\gamma}}$　$\frac{dp_2}{dV} = -\gamma \frac{K}{V^{1+\gamma}}$　　$\cancel{\frac{dp_2/dV}{dp_1/dV}}$

$\frac{dp_1/dV}{dp_2/dV} = \frac{1}{\gamma} = 0.714$　　即 $\frac{C}{C+R} = 0.714$ 得 $C = 20.7$

第二题：理想气体过程计算

解.



其中在(I)&(III)过程中气体有做功.

(I): $W_1 = -p_1(V_1-V_2)$

(III): $\Delta U_3 = C_V\cdot\frac{1}{\nu R}(V_1p_1-V_2p_2)$

由于 $Q_3=0$ 则 $W_3=-\Delta U_3=\frac{C_V}{\nu R}(V_2p_2-V_1p_1)$

(II)过程气体吸热 $\Delta U_2 = C_V\cdot\frac{V_2}{\nu R}(p_2-p_1)$

由于 $W_2=0$ 则 $Q_2=\Delta U_2=\frac{C_V V_2}{\nu R}(p_2-p_1)$

则 $\eta = \frac{W_1+W_3}{Q_2} = \frac{\frac{C_V}{\nu R}(V_2p_2-V_1p_1)-p_1(V_1-V_2)}{\frac{C_V}{\nu R}V_2(p_2-p_1)} = \frac{C_V(V_2p_2-V_1p_1)-(C_p-C_V)p_1(V_1-V_2)}{C_V V_2(p_2-p_1)}$ $\qquad \nu R = C_p-C_V$

$= \frac{C_V V_2(p_2-p_1)-C_p p_1(V_1-V_2)}{C_V V_2(p_2-p_1)}$

$= 1-\gamma\frac{(\frac{V_1}{V_2})-1}{(\frac{p_2}{p_1})-1} \qquad \gamma=\frac{C_p}{C_V}$

第三题：熵的计算

解 (1) (a). 液池：$\Delta Q = C\cdot\Delta T = 100\ \mathrm{kJ}$

$\Delta S_1 = \frac{\Delta Q}{T} = 1\ \mathrm{kJ/K}$

铅块：$\Delta S_2 = \int_1^2 \frac{dQ}{T} = C\int_{T_1}^{T_2}\frac{dT}{T} = -\ln 2\ (\mathrm{kJ/K})$

$\Delta S = \Delta S_1 + \Delta S_2 = (1-\ln 2)\ \mathrm{kJ/K}$

(b). 液池 $\Delta Q_1 = C\cdot\Delta T_1 = 50\ \mathrm{kJ}$

$\Delta S_1 = \frac{\Delta Q_1}{T_1} = \frac{1}{3}\ \mathrm{kJ/K}$

$\Delta Q_2 = C\cdot\Delta T_2 = 50\ \mathrm{kJ}$

$\Delta S_2 = \frac{\Delta Q_2}{T_2} = \frac{1}{2}\ \mathrm{kJ/K}$

$\Delta S = \Delta S_1 + \Delta S_2 = \frac{5}{6}\ \mathrm{kJ/K}$.

铅块. $\Delta S_1' = \int_1^2 \frac{dQ}{T} = C\int_{T_1}^{T_2}\frac{dT}{T} = -\ln\frac{4}{3}\ (\mathrm{kJ/K})$

$\Delta S_2' = \int_2^3 \frac{dQ}{T} = C\int_{T_2}^{T_3}\frac{dT}{T} = -\ln\frac{3}{2}\ \mathrm{kJ/K}$

$\Delta S' = \Delta S_1' + \Delta S_2' = -\ln 2\ \mathrm{kJ/K}$

$\Delta S_{总} = \Delta S + \Delta S' = (\frac{5}{6}-\ln 2)\ \mathrm{kJ/K}$

(c) 如果使用无穷多始终与铅块等温的液池进行热传导的准静态过程

则 液池 $dT_k = 0 \quad dQ_k = C\cdot dT_k = 0 \quad dS_k = \frac{dQ_k}{T_k} = 0$

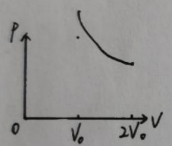
$\lim_{n\to\infty}\sum_{i=1}^{n}\Delta S_i = \lim_{n\to\infty}\sum_{i=1}^{n}\frac{1}{2n-i} = \ln 2\ \mathrm{kJ/K}$

~~则 $\sum_n dS_k = 0$~~

$\Delta S_{总} = \lim_{n\to\infty}\sum_{i=1}^{n}\frac{1}{2n-i} - \ln 2\ \mathrm{kJ/K} = 0$

即总熵变为0.

(2). (a).



由热力学第一定律 $\Delta U = Q - W$ 由理想气体状态方程 $pV = \nu RT \Rightarrow p = \frac{\nu RT}{V}$

$W = \int_{V_0}^{2V_0} p\,dV = \nu RT\int_{V_0}^{2V_0}\frac{1}{V}dV = \nu RT\ln 2$

$\Delta U = 0$ 则 $Q = \nu RT\ln 2$

$\Delta S_{系} = \frac{Q}{T} = \nu R\ln 2$

$\nu = 1\,\mathrm{mol}$ $\quad \Delta S_{系} = R\cdot\ln 2 \quad \Delta S_{系} + \Delta S_{环} = 0$ 得 $\Delta S_{环} = -R\cdot\ln 2$

(b). 由于气体经历可逆的绝热过程.

$dQ = 0 \qquad \Delta S = \int_{V_0}^{2V_0}\frac{dQ}{T} = 0$

即系统熵增为0 环境熵增为0.

(c). 由于气体向真空容器绝热膨胀. 则 $Q=0$ $W=0$ 由热力学第一定律 $\Delta U = Q - W = 0$

即气体始、末状态温度相等 则可设计气体经等温过程从 V 膨胀至 2V.

与(a)相同. $W = \int_{V_0}^{2V_0}\nu RT\frac{1}{V}dV = \nu RT\ln 2 \quad \Delta U = 0$ 得 $Q = \nu RT\ln 2$

$\Delta S_{系} = \frac{Q}{T} = \nu R\ln 2$ 当 $\nu = 1\,\mathrm{mol}$ 时 $\Delta S_{系} = R\cdot\ln 2$

$\Delta S_{系} + \Delta S_{环} = 0$ 得 $\Delta S_{环} = -R\ln 2$

第四题.

解 (1). $S_A=\left(\frac{R^2}{V_0\theta}\right)^{\frac{1}{3}}\cdot(N_AV_A\cdot U_A)^{\frac{1}{3}}$ $\qquad S_B=\left(\frac{R^2}{V_0\theta}\right)^{\frac{1}{3}}(N_BV_B\cdot U_B)^{\frac{1}{3}}$

$$S_A+S_B=\left(\frac{R^2}{V_0\theta}\right)^{\frac{1}{3}}\cdot\cancel{(U_A+U_B)}\cdot\left[(N_AV_A)^{\frac{1}{3}}\cdot\left(\frac{U_A}{U_A+U_B}\right)^{\frac{1}{3}}+(N_BV_B)^{\frac{1}{3}}\cdot\left(1-\frac{U_A}{U_A+U_B}\right)^{\frac{1}{3}}\right](U_A+U_B)^{\frac{1}{3}}$$

即 $S_A+S_B=\left(\frac{R^2}{V_0\theta}\right)^{\frac{1}{3}}\cdot\sqrt[3]{80}\cdot\left[3\times10^{-2}\cdot\left(\frac{U_A}{U_A+U_B}\right)^{\frac{1}{3}}+2\times10^{-2}\cdot\left(1-\frac{U_A}{U_A+U_B}\right)^{\frac{1}{3}}\right]$

若变为透热壁 则 $T_A'=T_B'$ $\quad P_A'=P_B'$

由 $\cancel{pV=NRT}$ $pV=NRT$ 则 $V_A':V_B'=N_A:N_B$

$V_A'=\frac{N_A}{N_A+N_B}(V_A+V_B)=7.8\times10^{-6}\,m^3$ $\qquad V_B'=\frac{N_B}{N_A+N_B}(V_A+V_B)=5.2\times10^{-6}\,m^3$

$U_A':U_B'=N_A:N_B$

$U_A'=\frac{N_A}{N_A+N_B}\cdot(U_A+U_B)=48J$ $\qquad U_B'=\frac{N_B}{N_A+N_B}(U_A+U_B)=32J.$

即平衡时 A系统内能48J B系统内能32J.

(2). $\frac{1}{T}=\left(\frac{\partial S}{\partial U}\right)_{V,N}=\left(\frac{R^2}{V_0\theta}\right)^{\frac{1}{3}}(NV)^{\frac{1}{3}}\cdot\frac{1}{3}U^{-\frac{2}{3}}$ $\qquad T=3U^{\frac{2}{3}}(VN)^{-\frac{1}{3}}\cdot\left(\frac{R^2}{V_0\theta}\right)^{-\frac{1}{3}}$

$$P=T\cdot\left(\frac{\partial S}{\partial V}\right)_{U,N}=T\cdot\left(\frac{R^2}{V_0\theta}\right)^{\frac{1}{3}}\cdot(NU)^{\frac{1}{3}}\cdot\frac{1}{3}V^{-\frac{2}{3}}$$

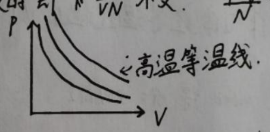
$$=\frac{U}{V}$$

$$\mu=-T\cdot\left(\frac{\partial S}{\partial N}\right)_{U,V}=-T\cdot\left(\frac{R^2}{V_0\theta}\right)^{\frac{1}{3}}(UV)^{\frac{1}{3}}\cdot\frac{1}{3}N^{-\frac{2}{3}}$$

$$=-\frac{U}{N}$$

$T_A=\cancel{3\sqrt[3]{}}\,3\left(\frac{R^2}{V_0\theta}\right)^{-\frac{1}{3}}\left(\frac{U_A'^2}{V_A'N_A}\right)^{\frac{1}{3}}$ $\qquad T_B=3\left(\frac{R^2}{V_0\theta}\right)^{-\frac{1}{3}}\cdot\left(\frac{U_B'^2}{V_B'N_B}\right)^{\frac{1}{3}}$ 代入数据可得 $T_A=T_B=3\left(\frac{R^2}{V_0\theta}\right)^{-\frac{1}{3}}\cdot\left(\frac{1280}{13\times10^{-6}}\right)^{\frac{1}{3}}$

温度不变时 即 $\frac{U^2}{VN}$ 不变. $\frac{P^2V}{N}$ 为常数. $P=\frac{k}{\sqrt{V}}$



(3). $\mu=\cancel{-\left(\frac{R^2}{V_0\theta}\right)^{\frac{1}{3}}}-\frac{U}{N}$ $\qquad T=3\cdot U^{\frac{2}{3}}\cdot(VN)^{-\frac{1}{3}}\cdot\left(\frac{R^2}{V_0\theta}\right)^{-\frac{1}{3}}$ 可得 $U=\left(\frac{T}{3}\right)^{\frac{3}{2}}\cdot(VN)^{\frac{1}{2}}\cdot\left(\frac{R^2}{V_0\theta}\right)^{\frac{1}{2}}$

即 $\mu=-\left(\frac{T}{3}\right)^{\frac{3}{2}}\cdot\left(\frac{V}{N}\right)^{\frac{1}{2}}\cdot\left(\frac{R^2}{V_0\theta}\right)^{\frac{1}{2}}$

第一问图。其中 x 表示 UA/(UA+UB)并把所有系数按 1 计算。

第五题. 熵表达式 L变换及热力学势

(1). 由 Gibbs - Duhem 关系. $d\left(\frac{\mu}{T}\right) = \frac{U}{N} d\left(\frac{1}{T}\right) + \frac{V}{N} d\left(\frac{P}{T}\right)$

则 $d\left(\frac{\mu}{T}\right) = -\frac{1}{T^2}\frac{U}{N} \cdot dT + \frac{V}{N}\left(\frac{1}{T}dP - \frac{P}{T^2}dT\right)$

$= \frac{V}{NT}dP - \frac{U+PV}{NT^2}dT$

$U = \frac{1}{2}PV$ $\quad T^2 = \frac{AU^{\frac{3}{2}}}{VN^{\frac{1}{2}}}$ 可得 $PV = 2U$ $\quad \frac{2UT^2N^{\frac{1}{2}}}{P} = A \cdot U^{\frac{3}{2}}$ $\quad U = \frac{4T^4N}{P^2A^2}$

$V = \frac{2U}{P} = \frac{8T^4N}{A^2P^3}$

即 $d\left(\frac{\mu}{T}\right) = \frac{V}{NT} \cdot dP - \frac{3U}{NT^2}dT = \frac{8T^3}{A^2P^3}dP - \frac{12T^2}{P^2A^2}dT = \frac{4}{A^2}\left(\frac{2T^3}{P^3}dP - \frac{3T^2}{P^2A^2}dT\right)$

$= \frac{4}{A^2}d\left(-\frac{T^3}{P^2}\right) = -\frac{4}{A^2}d\left(\frac{T^3}{P^2}\right)$

两侧积分 $\frac{\mu}{T} = -\frac{4}{A^2}\frac{T^3}{P^2} + C$ $\quad$ ~~$T=T_0$ 且~~ 初始条件: $T=T_0$ $P=P_0$ $\mu=\mu_0$

$C = \frac{\mu_0}{T_0} + \frac{4}{A^2}\frac{T_0^3}{P_0^2}$ $\quad \cancel{\frac{\mu}{T} - \frac{\mu_0}{T_0} = -\frac{4}{A^2}\left(\frac{T^3}{P^2} - \frac{T_0^3}{P_0^2}\right)}$

则 $\mu = -\frac{4}{A^2}\frac{T^4}{P^2} + \left(\frac{\mu_0}{T_0} + \frac{4}{A^2}\frac{T_0^3}{P_0^2}\right) \cdot T$ $\quad P^2 = \frac{4U^2}{V^2}$ $\quad T = \frac{A^{\frac{1}{2}} \cdot U^{\frac{3}{4}}}{V^{\frac{1}{2}}N^{\frac{1}{4}}}$

$\mu = -\frac{4}{A^2} \cdot \frac{A^2U}{4N} + \left(\frac{\mu_0}{T_0} + \frac{4}{A^2}\frac{T_0^3}{P_0^2}\right) \cdot \frac{A^{\frac{1}{2}} \cdot U^{\frac{3}{4}}}{V^{\frac{1}{2}} \cdot N^{\frac{1}{4}}}$

$= -\frac{U}{N} + \left(\frac{\mu_0}{T_0} + \frac{4}{A^2} \cdot \frac{T_0^3}{P_0^2}\right) \cdot \frac{A^{\frac{1}{2}} \cdot U^{\frac{3}{4}}}{V^{\frac{1}{2}} N^{\frac{1}{4}}}$

$S = \frac{1}{T} \cdot U + V \cdot \frac{P}{T} - N \cdot \frac{\mu}{T}$

$\Rightarrow 3\frac{V^{\frac{1}{2}} \cdot N^{\frac{1}{4}} \cdot U^{\frac{1}{4}}}{A^{\frac{1}{2}}} + \frac{V^{\frac{1}{2}}N^{\frac{1}{4}}}{A^{\frac{1}{2}} \cdot U^{\frac{3}{4}}} \cdot \left[-U + \left(\frac{\mu_0}{T_0} + \frac{4}{A^2}\frac{T_0^3}{P_0^2}\right) \cdot \frac{A^{\frac{1}{2}}U^{\frac{3}{4}}N^{\frac{3}{4}}}{V^{\frac{1}{2}}}\right]$

$= \frac{3}{A^{\frac{1}{2}}} \cdot V^{\frac{1}{2}}N^{\frac{1}{4}}U^{\frac{1}{4}} - \frac{1}{A^{\frac{1}{2}}}V^{\frac{1}{2}}N^{\frac{1}{4}}U^{\frac{1}{4}} + \left(\frac{\mu_0}{T_0} + \frac{4}{A^2}\frac{T_0^3}{P_0^2}\right) \cdot N$

$= \frac{2}{A^{\frac{1}{2}}}V^{\frac{1}{2}}N^{\frac{1}{4}}U^{\frac{1}{4}} + \left(\frac{\mu_0}{T_0} + \frac{4}{A^2}\frac{T_0^3}{P_0^2}\right)N$

(2). $\cancel{y=2e^{\frac{x}{2}} \quad y'=e^{\frac{x}{2}}=P(x)}$

$\cancel{\psi = y - P(x)x = 2\cdot e^{\frac{x}{2}} - x\cdot e^{\frac{x}{2}} = (2-x)e^{\frac{x}{2}}}$

$\cancel{\psi = y - P(x)x}$

(2). $y = A\cdot e^{Bx} \qquad y' = AB\cdot e^{Bx} = P(x)$

$\psi(x) = Y - Px = A\cdot e^{Bx} - ABx\cdot e^{Bx}$

$\psi(P) = \frac{P}{B} - Px = \frac{P}{B}(1-\ln\frac{P}{AB}) = \frac{P}{B} - \frac{P}{B}\cdot\ln\frac{P}{AB}$

反变换: $d\psi = dY - P\,d(x) - x\,dP = -x\,dP$

$x = -\frac{d\psi}{dP} = -(\frac{1}{B} - \frac{1}{B}\ln\frac{P}{AB} - \frac{1}{B})$

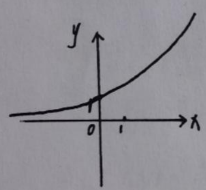
$= \frac{1}{B}\ln\frac{P}{AB} \Rightarrow P = ABe^{Bx}$

$Y = \psi + Px = \frac{P}{B} = \frac{ABe^{Bx}}{B} = A\cdot e^{Bx}$

$A=2\ B=\frac{1}{2}$时 $\cancel{y=2x}$ $y=2\cdot e^{\frac{x}{2}} \quad \psi(P) = 2P - 2P\ln P \quad P = e^{\frac{x}{2}}$

~~当$x=1$时 $y'=e$~~ 当$x=1$时 $y'=e^{\frac{1}{2}} \quad P=e^{\frac{1}{2}} \quad \psi(P) = 2\cdot e^{\frac{1}{2}} - 2e^{\frac{1}{2}}\cdot\ln e^{\frac{1}{2}} = e^{\frac{1}{2}}$

即 $\psi(P)$ 代表的曲线为 $y(x)$ 切线.



(3). $d(\frac{\mu}{T}) = u\, d(\frac{1}{T}) + v\cdot d(\frac{P}{T}) = - \frac{U}{NT^2}dT + \frac{V}{N}(\frac{1}{T}dP - \frac{P}{T^2}dT)$

$$= \frac{V}{NT}dP - \frac{U+PV}{NT^2}dT = \frac{V}{NT}dP - \frac{5U}{3T^2N}dT$$

$\frac{V}{N} = \frac{P}{AT^4}$ $\quad$ $\frac{U}{N} = \frac{3}{2}P\cdot\frac{V}{N} = \frac{3P^2}{2T^4A}$

故 $d(\frac{\mu}{T}) = \frac{P}{AT^5}dP - \frac{5P^2}{2T^6A}dT = \frac{1}{2A}(\frac{2P}{T^5}dP - \frac{5P^2}{T^6}dT) = \frac{1}{2A}d(P^2T^{-5})$

两侧积分 $\frac{\mu}{T} = \frac{1}{2A}P^2T^{-5}+C$ 初始条件 $T=T_0$ $P=P_0$ $\mu=\mu_0$

$C = \frac{\mu_0}{T_0} - \frac{P_0^2}{2AT_0^5}$ $\quad$ $\mu = \frac{1}{2A}\frac{P^2}{T^4} + (\frac{\mu_0}{T_0}-\frac{P_0^2}{2AT_0^5})\cdot T$

$S = \frac{1}{T}(U+PV-\mu N)$ $\quad$ $T = (\frac{2UN}{3AV^2})^{\frac{1}{4}}$ $\quad$ $PV=\frac{2}{3}U$

得热力学基本方程为: $S = \frac{5}{3}(\frac{3AV^2}{2N})^{\frac{1}{4}}\cdot U^{\frac{3}{4}} - (\frac{\mu_0}{T_0}-\frac{P_0^2}{2AT_0^5})\cdot N - \frac{2}{3}(\frac{3AV^2}{2N})^{\frac{1}{4}}\cdot U^{\frac{3}{4}}$

$$S = (\frac{3AV^2}{2N})^{\frac{1}{4}}U^{\frac{3}{4}} - (\frac{\mu_0}{T_0}-\frac{P_0^2}{2AT_0^5})N$$

$$U = \{(\frac{2N}{3AV^2})^{\frac{1}{4}}\cdot[S+(\frac{\mu_0}{T_0}-\frac{P_0^2}{2AT_0^5})N]\}^{\frac{4}{3}} = (\frac{2N}{3AV^2})^{\frac{1}{3}}\cdot[S+(\frac{\mu_0}{T_0}-\frac{P_0^2}{2AT_0^5})N]^{\frac{4}{3}}$$

Helmholtz势: ~~F=U-TS~~

$$F(T,V,N) = U-TS$$

$U=\frac{3}{2}PV = \frac{3}{2}V\cdot A\frac{V}{N}T^4 = \frac{3AV^2T^4}{2N}$

$S = (\frac{3AV^2}{2N})^{\frac{1}{4}}\cdot(\frac{3AV^2}{2N}T^4)^{\frac{3}{4}} - (\frac{\mu_0}{T_0}-\frac{P_0^2}{2AT_0^5})N$

$= \frac{3AV^2}{2N}\cdot T^3 - (\frac{\mu_0}{T_0}-\frac{P_0^2}{2AT_0^5})N$

$F(T,V,N) = \frac{3AV^2}{2N}T^4 - \frac{3AV^2}{2N}T^4 + (\frac{\mu_0}{T_0}-\frac{P_0^2}{2AT_0^5})NT = (\frac{\mu_0}{T_0}-\frac{P_0^2}{2AT_0^5})NT$

Gibbs势: ~~G=U~~ $G(T,V,N) = U-TS+PV$

$$= (\frac{\mu_0}{T_0}-\frac{P_0^2}{2AT_0^5})NT + \frac{AV^2}{N}T^4$$