$$\rightarrow \frac{u}{T} - \underline{\left(\frac{u_0}{T_0}\right)} = -cR\ln\underline{\frac{u}{u_0}} - R\ln\underline{\frac{v}{v_0}}$$

$$\rightarrow S = N\underset{\substack{\downarrow \\ \text{const:} \\ (c+1)R - \left(\frac{u}{T}\right)_0}}{s_0} + NR\ln\left[\left(\frac{U}{U_0}\right)^c\left(\frac{V}{V_0}\right)\left(\frac{N}{N_0}\right)^{-(c+1)}\right]$$

---

## 4-2 van der waals sys. (EOS)

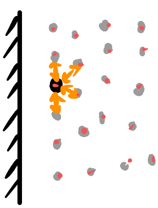
Ideal Gas : $PV = NRT$ or $P = \frac{RT}{v}$, $v = V/N$

- → Point mass : Does NOT occupy volume.
- → Do NOT interact w/ each other.

→ occupy volume.

$\rightarrow P = \frac{RT}{v-b}$ → occupancy of gas molecules.

→ Interactions ("turned on")



pull-back Force → reduce "P" (of ideal gas)

$\propto \frac{n}{V}$ (density)

$\propto \frac{n}{V}$

$\Big\} \propto \left(\frac{n}{V}\right)^2 = \frac{1}{v^2}$

$\downarrow$

$V/n$

$$\Rightarrow \boxed{P = \frac{RT}{v-b} - \frac{a}{v^2}}$$ vdW EOS

How about the Fundamental Eq for this?

# Entropy Form

$$ds = \overset{\nearrow F_{j=0}}{\frac{1}{T}} du + \overset{F_{j=1}\uparrow}{\frac{P}{T}} dv$$

$ds \to S/N$, $\frac{1}{T} \to ?$, $\frac{P}{T} \to ?$

1> $\frac{P}{T} = \frac{R}{v-b} - \frac{a}{v^2}\cdot\frac{1}{T}$ ✓

2> $\frac{1}{T} = T(u, v)$ ?

since $s = s(u, v)$. is a state function.

$$\to \left(\frac{\partial}{\partial v}\left(\frac{\partial s}{\partial u}\right)_v\right)_u = \left(\frac{\partial}{\partial u}\left(\frac{\partial s}{\partial v}\right)_u\right)_v$$

$$\longrightarrow \left(\frac{\partial}{\partial v}\left(\frac{1}{T}\right)\right)_u = \left(\frac{\partial}{\partial u}\left(\frac{P}{T}\right)\right)_v$$

$$F_{j=1} = -\frac{P_j}{T} \to -P$$

$$\left(\frac{\partial}{\partial v}\left(\frac{1}{T}\right)\right)_u = \left[\frac{\partial}{\partial u}\left(\underbrace{\frac{R}{v-b}}_{\text{const.}} - \frac{a}{v^2}\cdot\frac{1}{T}\right)\right]_v$$

$\frac{1}{T} \to T(u, v)$

$$= -\frac{a}{v^2}\frac{\partial}{\partial u}\left(\frac{1}{T}\right)_v$$

$$\to \frac{\partial}{\partial ?}\left(\frac{1}{T}\right)_u = \frac{\partial}{\partial ?}\left(\frac{1}{T}\right)_v$$

$$\to \boxed{\frac{\partial}{\partial(1/v)}\left(\frac{1}{T}\right)_u = \frac{\partial}{\partial(u/a)}\left(\frac{1}{T}\right)_v}$$

$\partial(1/v) \to -v^2\frac{\partial}{\partial v}$

✓

$\rightarrow$ simplest case: $\frac{1}{T} = \underline{T}(\underline{1/v + u/a})$ $\leftrightarrow f(x+y)$

For ideal gas: $\frac{1}{T} = \frac{cR}{\underline{u}} \leftarrow (U = cNRT)$

$\Rightarrow$ valid guess ✓

modify for vdW

$\rightarrow \frac{1}{T} = \frac{cR}{u/a + 1/v}$

since $\frac{P}{T} = \frac{R}{v-b} - \frac{a}{v^2} \cdot \frac{1}{T}$ & $\frac{1}{T} = \frac{cR}{u/a + 1/v}$

$ds = \frac{1}{T} du + \frac{P}{T} dv$ integrate

$$\Rightarrow \underline{S} = NR \ln[(v-b)(u+a/v)^c] + \underbrace{Ns_0}_{\text{const.}}$$

Molar

---

4-3. Stefan – Boltzman Law.

- Thermal radiation emitted by matter in terms of temperature.
- "Empty" vessel at T
  - ↳ $(N=0)$ $\quad U(S, V, \overset{0}{\overset{\shortparallel}{N}})$
- Although "Empty", But repository of E.M. Energy

For such EM cavity

1> $U = bVT^4$ ; 2> $P = U/(3V)$

$S = S(U, V) \quad (N=0)$

$\rightarrow S = \frac{1}{T}U + \frac{P}{T}V$ (Euler Eq.)

$$\left.\begin{aligned} \frac{1}{T} &= b^{1/4}\left(\frac{V}{U}\right)^{1/4} \\ \frac{P}{T} &= \frac{1}{3}b^{1/4}\left(\frac{U}{V}\right)^{3/4} \end{aligned}\right\} \rightarrow \underline{S = \frac{4}{3}b^{1/4}U^{3/4}V^{1/4}}.$$

---

4-4. Rubber Band.

Length of the band.

$S = S(U, V, N, L)$

Now. 1> Relaxed, length "$L_0$".

2> <u>$N$ is const. in the sys.</u>

3> <u>$V$ is approximately const.</u>

$\rightarrow S = S(U, L)$

$$dS = \underbrace{\left(\frac{\partial S}{\partial U}\right)_L}_{\frac{1}{T} = F_{j=0}} dU + \underbrace{\left(\frac{\partial S}{\partial L}\right)_U}_{F_j = -\frac{P_j}{T}\ \} -\frac{\tau}{T}} dL$$

tension.

"$-P$"

$$\rightarrow dS = \underbrace{\frac{1}{T}}_{?}dU - \underbrace{\frac{\tau}{T}}_{?}dL$$

$\Rightarrow S = S(U, L)$

$U = cL_0T$ , $\tau = b\cdot T\cdot \dfrac{L-L_0}{L_u-L_0}$ → variable

elastic length limit

$\rightarrow \frac{1}{T} = \cdots$
$\rightarrow -\frac{\tau}{T} = \cdots$

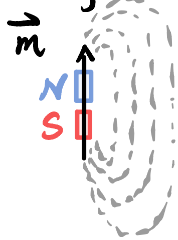
$$dS = \left(\frac{1}{T}\right)dU - \frac{\tau}{T}dL$$
$$= cL_0\frac{dU}{U} - \frac{b(L-L_0)}{L_u-L_0}dL$$

$\Rightarrow$ integrate: $S = S_0 + cL_0 \ln\dfrac{U}{U_0} - b\dfrac{(L-L_0)^2}{2(L_u-L_0)}$

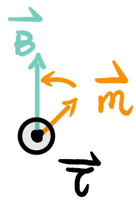
---

## 4-5. Magnetic Sys.

1> magnetic dipole moment




$$\vec{\tau} = \vec{m}\times\vec{B}$$



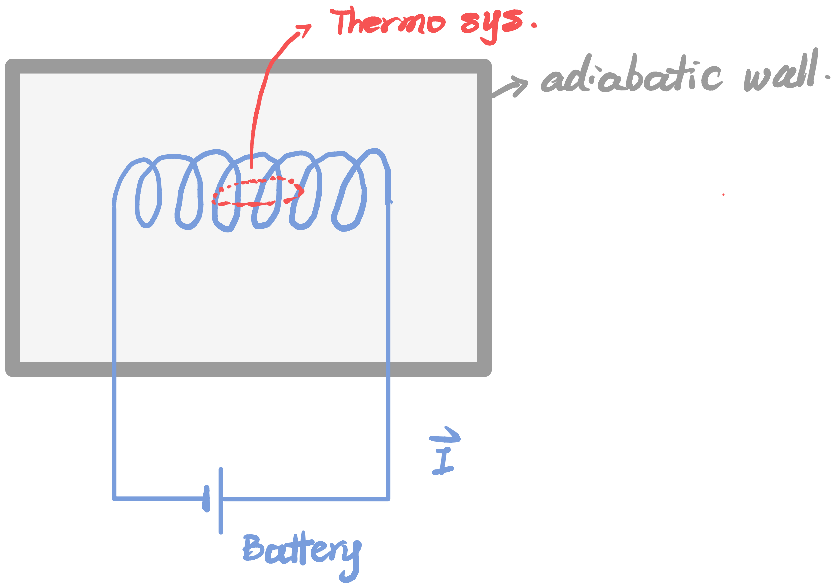

$\vec{M} = \dfrac{d\vec{m}}{dV}$ ↗ (x, y, z)

$\vec{M}$ ↓ magnetization

vector field describes the density of magnetic dipole moment in a magnetic material.

$$\vec{m} = \int \vec{M}\,dV = \vec{M}\cdot V$$

↓ * total magnetic moment of the sys.




$$U = U(S, V, N, \underline{m})$$

$$\rightarrow \quad \underline{\left(\frac{\partial U}{\partial m}\right)}_{S,V,N} = P_j$$

$$\downarrow$$

$$B_e \rightarrow \text{Tesla } [T]$$