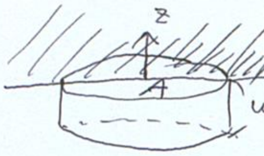


$\vec{c} = (u, v, w)$

\# of collisions on A

$= n_0 A w dt$

rate of collisions on A

$$= \frac{n_0 A w dt}{dt} = n_0 A w \ [\#/s]$$

$$P = (\dot{P}_+ + \dot{P}_-)/A = \frac{1}{3} n m \overline{c^2}$$

$$PV = \frac{1}{3} n V m \overline{c^2} = \frac{1}{3} N m \overline{c^2}$$

$$\boxed{\frac{1}{2} m \overline{c^2}} = \bar{E}_k = \frac{3}{2N} \frac{1}{3} N m \overline{c^2} = \frac{3}{2N} \mathscr{g} R T$$

$$= \frac{3}{2N} \frac{N}{N_A} R T = \frac{3}{2} \frac{R}{N_A} T = \boxed{\frac{3}{2} k T}$$

$$\left(\begin{array}{l} R = 8.31\ J/mole, \quad N_A = 6.02 \times 10^{23}\ /mole \\ k = 1.38 \times 10^{-23}\ J/K \end{array} \right)$$

* molecule partial current

$$J_+ = (n_1 w_1 + n_2 w_2 + \cdots) A = n_+ \bar{w}_+ A$$

$\circledast$ $\bar{w}_+ = \dfrac{n_1 w_1 + n_2 w_2 + \cdots}{n_1 + n_2 + \cdots} = \dfrac{n_1 w_1 + n_2 w_2 + \cdots}{n_+}$

$\circledast$ $n_+ = n_- = \frac{1}{2} n$, $\bar{w}_+ = \frac{1}{2} \bar{c}$

$$\therefore J_+ = \frac{1}{4} n \bar{c} A \ [\#/s]$$

* momentum partial current $[(kg \cdot m/s)/s]$

$$n_w A w m w = n_w A m w^2$$

$$\dot{P}_+ = (n_1 w_1^2 + n_2 w_2^2 + \cdots) A m = n_+ \overline{w_+^2} A m = \frac{1}{6} n m \overline{c^2} A$$

$$\overline{w_+^2} = \frac{n_1 w_1^2 + n_2 w_2^2 + \cdots}{n_1 + n_2 + \cdots} = \frac{n_1 w_1^2 + n_2 w_2^2 + \cdots}{n_+}$$

$$c^2 = u^2 + v^2 + w^2, \quad \overline{u^2} = \overline{v^2} = \overline{w^2} = \frac{1}{3} \overline{c^2}$$

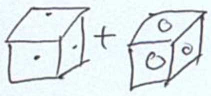
$$\overline{w^2} = \overline{w_+^2} = \overline{w_-^2}$$

$$\therefore \dot{P}_+ = \frac{1}{6} n m \overline{c^2} A \ [kg \cdot m/s^2]$$

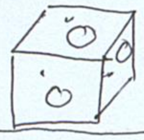
$$PV = \frac{1}{3} N m \overline{c^2} = \frac{1}{3} N 3 k T = N k T$$

$$\therefore \frac{PV}{T} = N k$$

$$PV = NkT \rightarrow P = \frac{N}{V} kT = nkT$$



$$= P_1 + P_2 = n_1 kT + n_2 kT = (n_1 + n_2) kT$$



$$= P = \frac{N_1 + N_2}{V} kT = (n_1 + n_2) kT = P_1 + P_2$$

* number density

$$P = nkT \qquad \text{space } 10^4\ \#/m^3$$

$$n = \frac{P}{kT} \qquad \text{KSTAR } 10^{20}\ \#/m^3$$

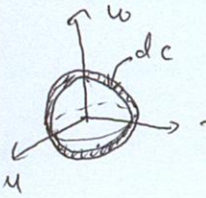
$$n\,[\#/m^3] = 2.45 \times 10^{25} P\,[atm] \quad \text{at } 300K$$

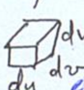
* molecular speed

$$\frac{1}{2} m \overline{c^2} = \frac{3}{2} kT$$

H_2 : $1.93 \times 10^3 m/s$ (at 300K)

Maxwell's speed distribution





$$\boxed{dn} = A \exp\left(-\frac{\frac{1}{2}mc^2 + P.E.}{kT}\right) du\, dv\, dw$$

큐빅 미소

다름

충돌 있다.

P.E. 일정

전체 E 일정

구각 미소

이 안에 n이 포함

$$\boxed{dn} = \boxed{A} \exp\left(-\frac{\frac{1}{2}mc^2 + P.E.}{kT}\right) 4\pi c^2 dc$$

$$= n B c^2 \exp\left(-\frac{\frac{1}{2}mc^2}{kT}\right) dc$$

밀도 (공간 적분 안 함)

$$= n \underbrace{f(c)} dc$$

$$\int_0^\infty f(c) dc = 1$$

$$\Downarrow$$

$$B = \sqrt{\frac{2}{\pi}} \left(\frac{m}{kT}\right)^{\frac{3}{2}}$$

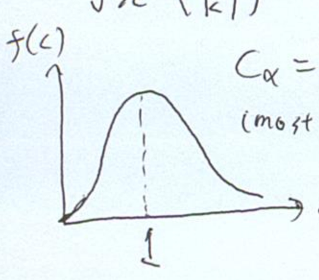
f(c) 미분해서 0

$$C_\alpha = \sqrt{\frac{2kT}{m}}$$

(most probable speed)

$$\bar{c} = \int_0^\infty c f(c) dc = \sqrt{\frac{8kT}{\pi m}}$$

$$\sqrt{\overline{c^2}} = \left\{\int_0^\infty c^2 f(c) dc\right\}^{\frac{1}{2}} = \sqrt{\frac{3kT}{m}} \Rightarrow \frac{1}{2} m \overline{c^2} = \frac{3}{2} kT$$



$$\left(* \int_0^\infty c^{2n} e^{-ac^2} dc = \frac{1 \cdot 3 \cdot 5 \cdots (2n-1)}{2^{n+1} a^n} \sqrt{\frac{\pi}{a}}, \quad \int_0^\infty c^{2n+1} e^{-ac^2} dc = \frac{n!}{2 a^{n+1}} \ (a > 0) \right)$$

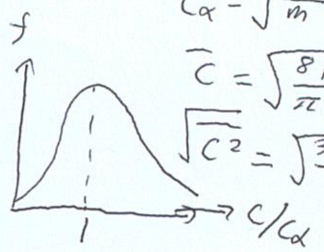
$$P = \frac{1}{3} n m \overline{c^2}$$

$$PV = \frac{1}{3} N m \overline{c^2} = \mathcal{R} R T$$

$$\frac{1}{2} m \overline{c^2} = \frac{3}{2} k T$$

$$\boxed{dn = A \exp\left(-\frac{\frac{1}{2}mc^2 + P.E.}{kT}\right) 4\pi c^2 dc} \quad ①$$

$$= n \beta c^2 \exp\left(-\frac{\frac{1}{2}mc^2}{kT}\right) dc = n f(c) dc$$

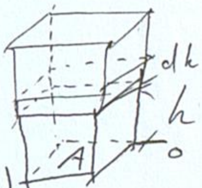


$$c_\alpha = \sqrt{\frac{2kT}{m}}$$

$$\bar{c} = \sqrt{\frac{8kT}{\pi m}}$$

$$\sqrt{\overline{c^2}} = \sqrt{\frac{3kT}{m}}$$

※ Effect of potential energy - Isothermal atmosphere

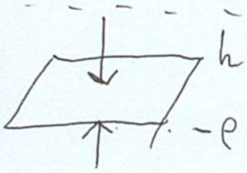


① $$4\pi A \exp\left(-\frac{P.E.}{kT}\right) c^2 \exp\left(-\frac{\frac{1}{2}mc^2}{kT}\right) dc$$

$$= n \qquad B \qquad c^2 \exp\left(-\frac{\frac{1}{2}mc^2}{kT}\right) dc$$

$$\Rightarrow n = \frac{4\pi A}{B} \exp\left(-\frac{P.E.}{kT}\right)$$

$$= \frac{4\pi A}{B} \exp\left(-\frac{mgh}{kT}\right) = n_0 \exp\left(-\frac{mgh}{kT}\right)$$



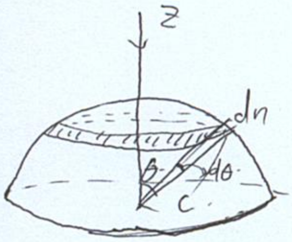
$$-\rho g\, dh A = A dP$$

$$-n m g\, dh A = A kT dn$$

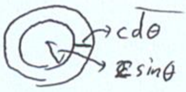
$$\int \quad \frac{dn}{n} = -\frac{mg}{kT} dh$$

$$\int_{n_0}^{n} \frac{dn}{n} = -\int_0^h \frac{mg}{kT} dh \Rightarrow \ln\frac{n}{n_0} = -\frac{mgh}{kT}$$

$$\therefore n = n_0 \exp\left(-\frac{mgh}{kT}\right)$$



$$dn = n f(c) dc \frac{d\Omega}{4\pi}$$



$$\underset{\text{띠의 넓이}}{dS} = 2\pi c \sin\theta\, c\, d\theta = c^2 d\Omega$$

$$\therefore d\Omega = 2\pi \sin\theta\, d\theta$$

$$dJ_+ = dn\, c \cos\theta\, A$$

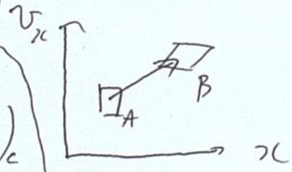
$$= n f(c) dc \frac{2\pi}{4\pi} \sin\theta\, d\theta\, c \cos\theta\, A$$

$$= \frac{1}{2} \sin\theta \cos\theta\, d\theta\, A\, c\, n f(c) dc$$

$$\therefore J_+ = \int_0^{\frac{\pi}{2}} \frac{A}{2} \sin\theta \cos\theta \int_0^\infty c\, n f(c) dc\, d\theta = \frac{A}{2} n \bar{c} \int_0^{\frac{\pi}{2}} \sin\theta \cos\theta\, d\theta = \frac{A}{4} n \bar{c} \left[-\frac{1}{2}\cos 2\theta\right]_0^{\frac{\pi}{2}}$$

$$= \frac{1}{4} n \bar{c} A$$

※ Boltzmann equation



$$0 = \frac{dN}{dt} = \frac{d}{dt} \int f(x, v_x, t)\, dx\, dv_x = \int \frac{df}{dt} dx\, dv_x$$

$$\boxed{\overset{\text{phase space}}{f(x, v_x, t)}}$$

$$\frac{df}{dt} = \frac{\partial f}{\partial t} + \frac{\partial f}{\partial x}\frac{dx}{dt} + \frac{\partial f}{\partial v_x}\frac{dv_x}{dt}$$

$$\frac{df}{dt} = \frac{\partial f}{\partial t} + \vec{v} \cdot \nabla f + \vec{a} \cdot \frac{\partial f}{\partial \vec{v}} = 0$$

$$= \frac{\partial f}{\partial t} + \vec{v} \cdot \nabla f + \frac{q(\vec{E} + \vec{v} \times \vec{B})}{m} \cdot \frac{\partial f}{\partial \vec{v}} = 0$$

if there is collision

$$\frac{\partial f}{\partial t} + \vec{v} \cdot \nabla f + \vec{a} \cdot \frac{\partial f}{\partial \vec{v}} = \left(\frac{\partial f}{\partial t}\right)_c$$

$\left(\frac{\partial f}{\partial t}\right)_c = 0$; Vlasov equation

$\left(\frac{\partial f}{\partial t}\right)_c = \frac{f_n - f}{\tau}$; Krook collision term

f_n → neutral atoms의 분포함수

τ → collision time

$$\sigma = \sum_j n_j q_j = \sum_j q_j \int f_j\, dv_j$$

$$\vec{j} = \sum_j n_j q_j \vec{u}_j = \sum_j q_j \int \vec{v}_j f_j\, d\vec{v}_j$$

$$(\vec{v} = \underset{\text{단체속도}}{\vec{u}} + \underset{\text{열운동}}{\vec{w}})$$

$$\varepsilon_0 \nabla \cdot \vec{E} = \sigma \qquad \nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\nabla \cdot \vec{B} = 0 \qquad \nabla \times \vec{B} = \mu_0 \vec{j} + \frac{1}{c^2}\frac{\partial \vec{E}}{\partial t}$$

Perrin의 실험