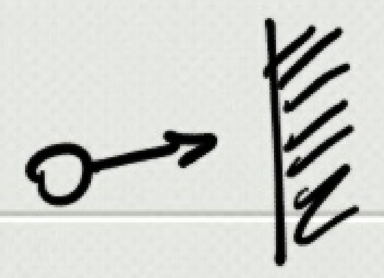
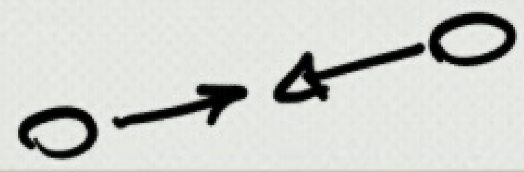
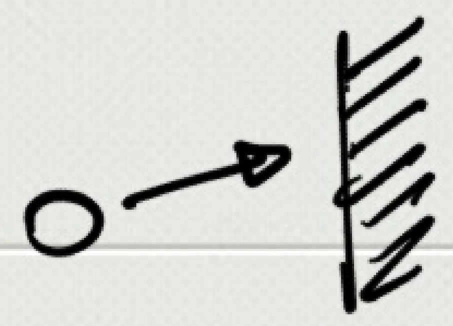
1. Molecole uguali, moto caotico
2. Urti elastici  
3. Forze intermolecolari solo negli urti
   (no forze "a distanza")
4. $D << L$

1 $\Rightarrow$ $\bar{U}$ $\quad \langle v_U \rangle = 0 \quad [\,\bar{P} = 0\,]$

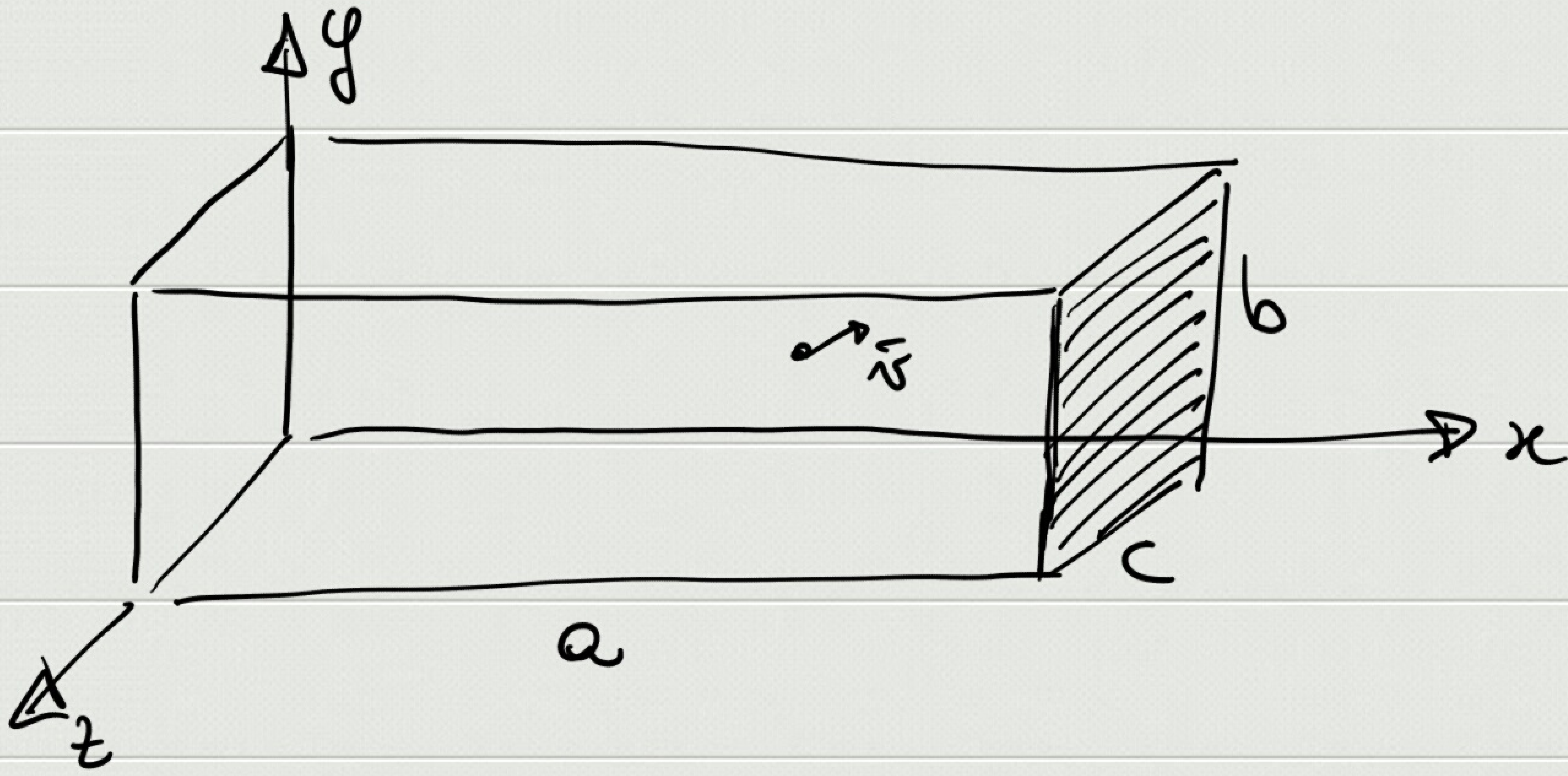
ρ = costante

2. $\Rightarrow$  $E_k = cost \quad \bar{P} = cost$

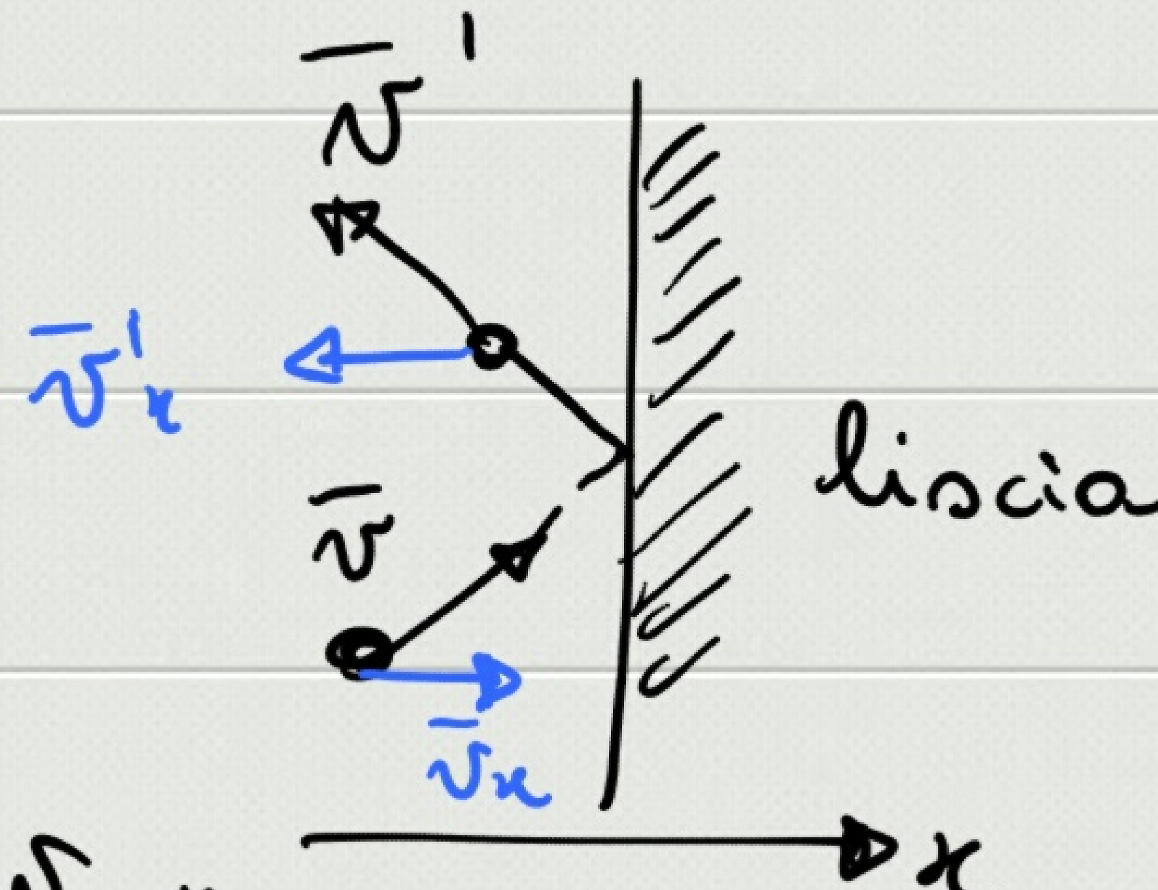
 $E_k = cost \quad \bar{P} \neq cost$

3. $\Rightarrow$ $E_p = cost \Rightarrow \Delta E_m = \Delta E_k$

4 $\Rightarrow$ $V_{mol} << V_{recipiente}$



$V = abc \quad , \quad N \quad , \quad m$



$\bar{p} = m\bar{v}$

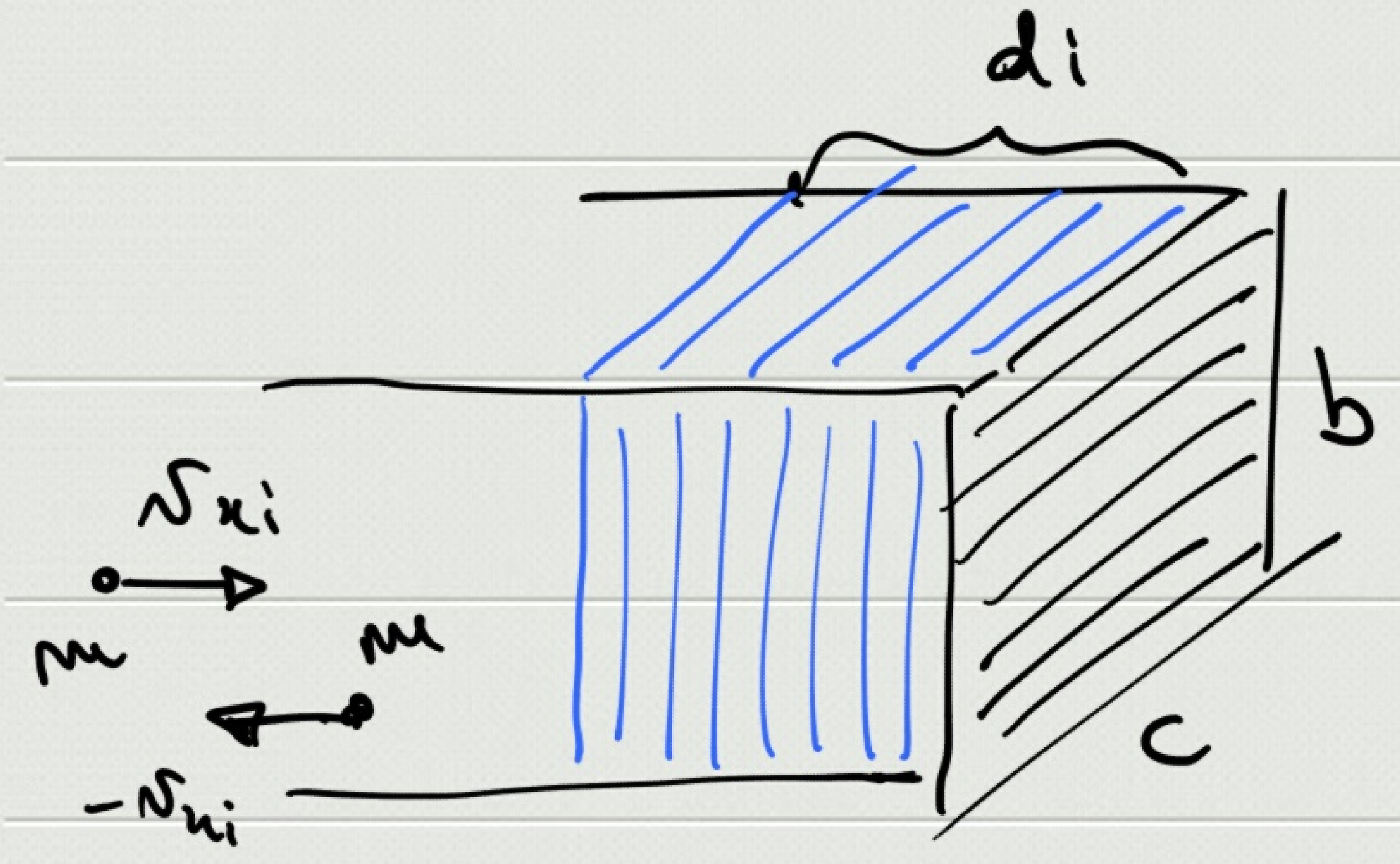
$|\bar{v}'| = |\bar{v}|$

$$\Delta \bar{p} = m\bar{v}' - m\bar{v} = -m v'_x \hat{u}_x - m v_x \hat{u}_x =$$

$$= -2 m v_x \hat{u}_x \quad \Rightarrow \quad J_{x,mol} = \Delta p = -2 m v_x$$

$$\boxed{J_{x,parete} = 2 m v_x}$$

$v_{xi} \, , \, N_i$



$$\underline{\underline{\Delta t}}$$

$$d_i = v_{xi}\,\Delta t$$

$$N_i' = \frac{1}{2} N_i \frac{V_i}{V} = \frac{1}{2} N_i \frac{\cancel{bc}\, v_{xi}\,\Delta t}{a\cancel{bc}}$$

$$J_{x_i} = N_i' \, J_x = \frac{1}{\cancel{2}} \frac{N_i \,\Delta t\, v_{xi}}{a} \cdot \cancel{2} m v_{xi} =$$

$$= \frac{1}{a} m N_i \,\Delta t\, v_{xi}^2$$

$$\bar{J} = \int \bar{F} dt = \langle \bar{F} \rangle \Delta t \quad \Rightarrow \quad \langle F_{x_i} \rangle = \frac{m}{a} N_i v_{xi}^2$$

$$p_i = \frac{\langle F_{xi} \rangle}{bc} = \frac{m}{abc} N_i v_{xi}^2 = \frac{m}{V} N_i v_{xi}^2$$

$$p = \Sigma_i p_i = \frac{m}{V} \Sigma_i N_i v_{xi}^2$$

$$\langle v_x^2 \rangle = \frac{1}{N} \Sigma_i N_i v_{xi}^2 \quad \Rightarrow \boxed{p = \frac{m}{V} N \langle v_x^2 \rangle}$$

$$p = \frac{m}{V} N \langle v_x^2 \rangle$$

$$\langle v_x^2 \rangle = \langle v_y^2 \rangle = \langle v_z^2 \rangle$$

$$v^2 = v_x^2 + v_y^2 + v_z^2 \Rightarrow \langle v^2 \rangle = 3 \langle v_x^2 \rangle$$

$$p = \frac{m}{3V} N \langle v^2 \rangle = \frac{2}{3} \frac{N}{V} \langle \frac{1}{2} m v^2 \rangle$$

$$\boxed{pV = \frac{2}{3} N \langle E_k \rangle}$$

$$\boxed{\langle E_k \rangle = l \cdot \frac{1}{2} k_B T}$$

$l \rightarrow$ numero gradi di libertà

$$\langle E_k \rangle = \frac{3}{2} k_B T$$

$$k_B = \frac{R}{N_A}$$

$$\Rightarrow \underline{pV} = \frac{\cancel{2}}{\cancel{3}} N \cdot \frac{\cancel{3}}{\cancel{2}} k_B T = \underline{nRT}$$

$$\left.\begin{aligned} \langle E_k \rangle &= \frac{3}{\cancel{2}} k_B T \\ &= \frac{1}{\cancel{2}} m \langle v^2 \rangle \end{aligned}\right\} \Rightarrow \langle v^2 \rangle = \frac{3 k_B T}{m}$$

$$\Rightarrow \quad \sqrt{\langle v^2 \rangle} = \sqrt{\frac{3 k_B T}{m}}$$

He : $v \sim 1400$ m/s

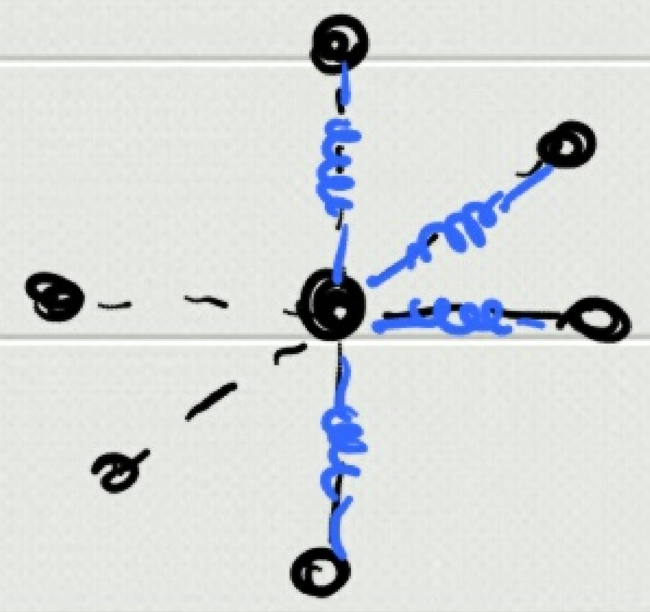
H_2O : $v \sim 650$ m/s

$$\langle E_k \rangle = \frac{1}{2} k_B T$$ (per ogni grado di libertà)

monoatomica $\quad l = 3$

biatomica $\quad l = 5$

$$E_k = \frac{1}{2} m \underset{(v_x, v_y, v_z)}{v^2} + \frac{1}{2} \underbrace{I \omega^2}_{I_x \omega_x^2 + I_y \omega_y^2 + I_z \omega_z^2}$$



$$\langle E \rangle = \frac{1}{2} m v^2 + \frac{1}{2} k x^2 + \frac{1}{2} k y^2 + \frac{1}{2} k z^2$$

\# g.d.l. della molecola

$$U = \langle E_k \rangle = N \langle E_{k,mol} \rangle = N \, l \, \frac{1}{2} k_B T$$

mono : $l = 3$ $\qquad$ biatomico : $l = 5$

$$\Delta U = \Delta\left(N\, l\, \frac{1}{2} k_B T\right) = N\, l\, \frac{k_B}{2} \Delta T =$$

$$k_B \to \frac{R}{N_A}$$

$$= n \frac{l R}{2} \Delta T$$

$$\Delta U = n c_V \Delta T$$

$$c_V = \frac{l R}{2}$$

mono : $l = 3 \Rightarrow c_V = \frac{3}{2} R$

biato : $l = 5 \Rightarrow c_V = \frac{5}{2} R$