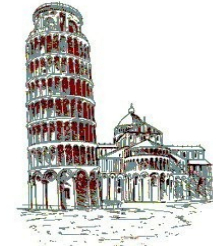


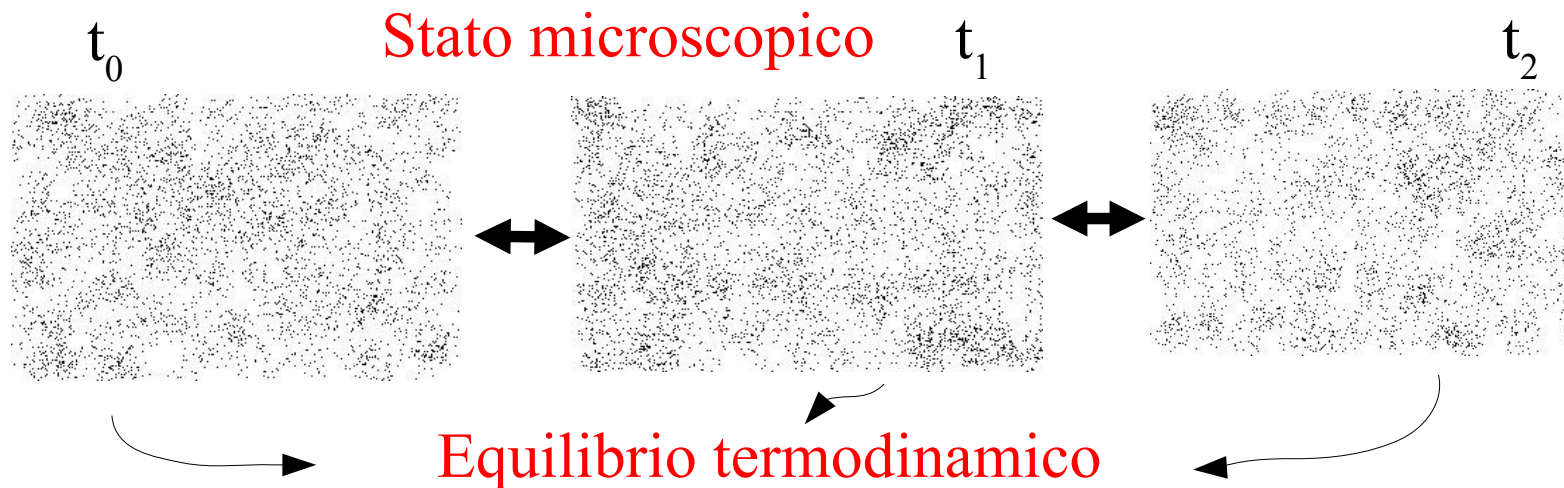
Termodinamica

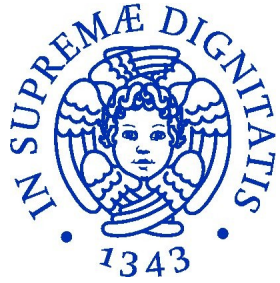
Cenni di teoria cinetica



Stato macroscopico

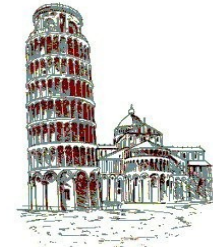
P V T





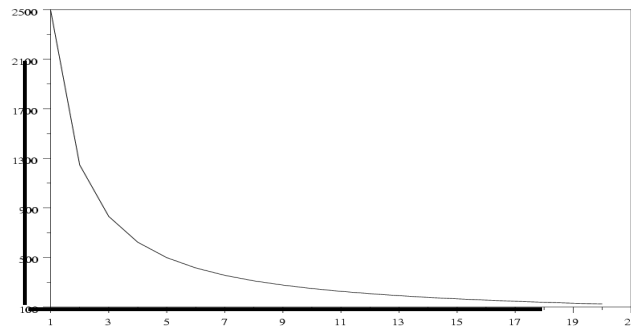
Termodinamica

Cenni di teoria cinetica



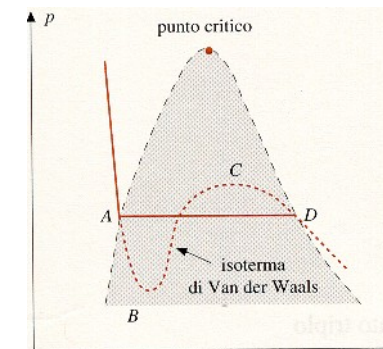
gas perfetto

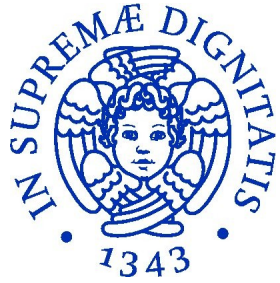
$$PV = nRT$$



gas reale

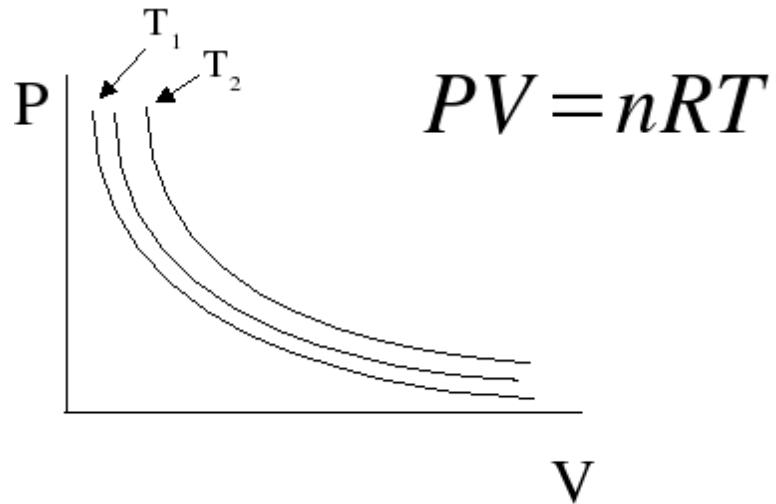
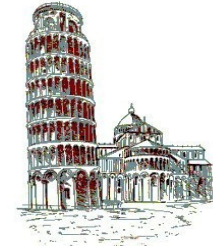
$$\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$$



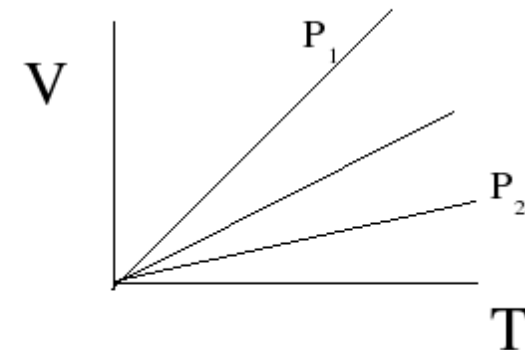
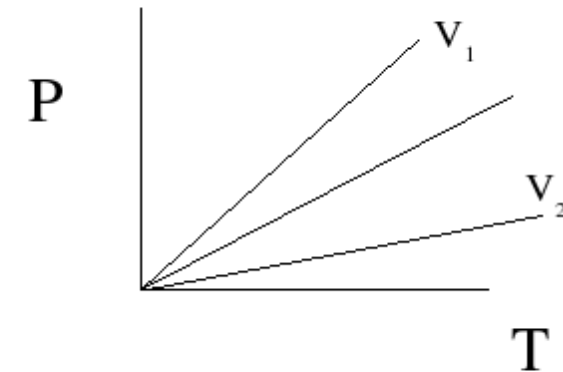


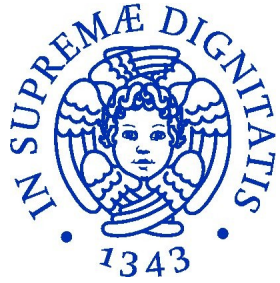
Termodinamica

Rappresentazione



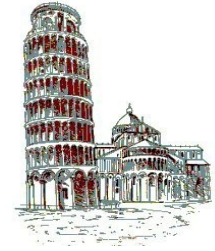
piano di Clapeyron





Termodinamica

Gas perfetto

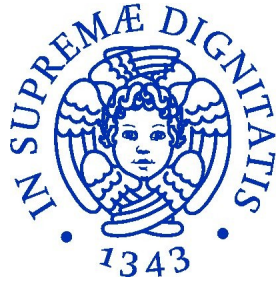


Modello di gas ideale

- particelle puntiformi
- uniformemente distribuite
- isotropicamente dirette
- energia maxwelliana

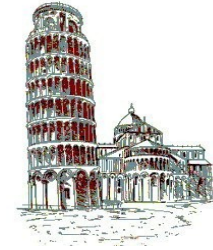


per continui urti e redistribuzione dell'energia
==> l' equilibrio termodinamico



Termodinamica

Distribuzione di Maxwell



$$\rho(v) = 4\pi \left(\frac{m}{2\pi KT} \right)^{3/2} v^2 e^{-mv^2/2KT}$$

distribuzione delle velocità'

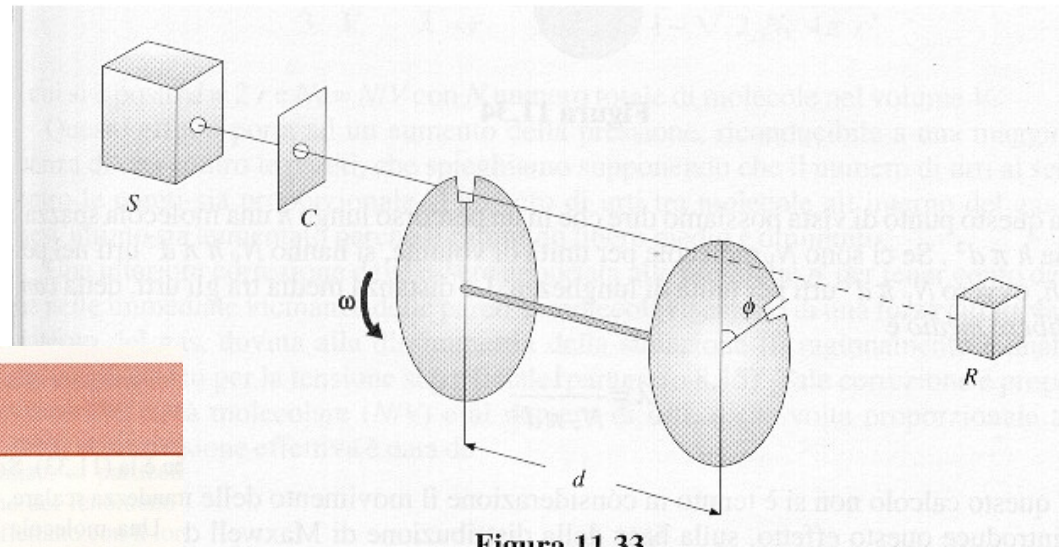
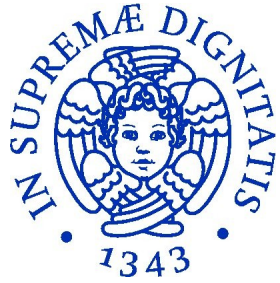


Figura 11.33

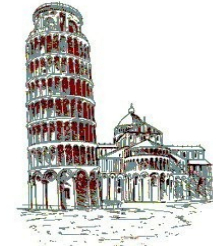
Tabella 11.3 Velocità medie quadratiche

gas	A (kg)	\bar{v} (m/s)
idrogeno	2	1934
elio	4	1368
vapor d'acqua	18	645
azoto	28	517
ossigeno	32	484



Termodinamica

Distribuzione di Maxwell



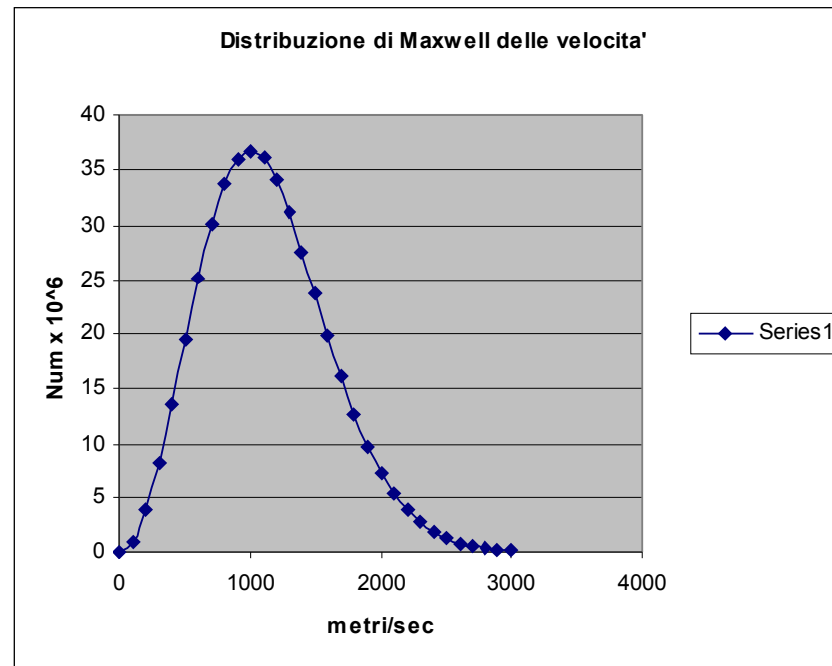
$$\rho(v, T) = 4\pi \left(\frac{m}{2\pi KT} \right)^{3/2} v^2 e^{-mv^2/2KT} \text{ distribuzione delle velocita'}$$

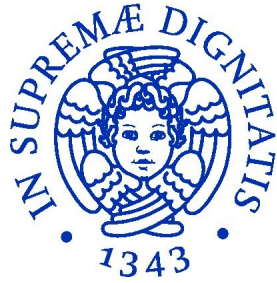
$$\Delta n_v = N \rho(v) dv$$

$$N = n N_A$$

Nota

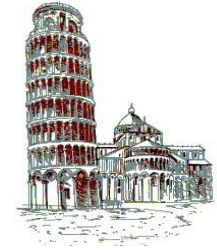
$\rho(v, T)$ lega la V a T





Termodinamica

Distribuzione di Maxwell



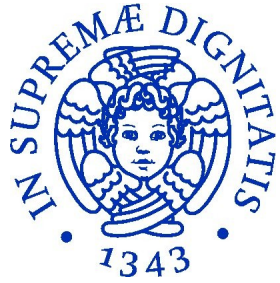
$$\bar{v} = \frac{1}{N} \int v \Delta n_v = \int v \rho(v) dv = \sqrt{\frac{8kT}{\pi m}}$$

La velocità media

$$\overline{v^2} = \frac{1}{N} \int v^2 \Delta n_v = \int v^2 \rho(v) dv = \frac{3kT}{m}$$

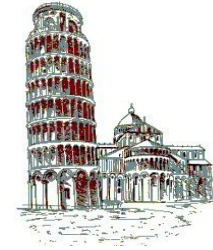
La velocità quadratica media

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



Termodinamica

Energia e temperatura



Agitazione termica $P = \frac{2}{3} \frac{N}{V} \overline{E}_c$

Equazione di stato

$$VP = NkT$$

$$\overline{E}_c = \frac{1}{2} m \overline{v^2} = \frac{3}{2} kT$$

una definizione della temperatura

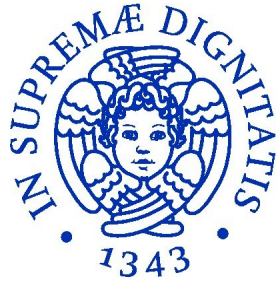
$$N_A * 1.5 * k * T = 3663 \text{ joule}$$

energia di una mole
 $\simeq 20^0$

$$k = 1.38 \cdot 10^{-23} \text{ JT}^{-1}$$

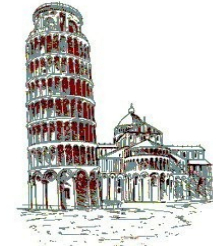
$$N_A = 6.0221 \cdot 10^{26}$$

Nota: $T = 0 \rightarrow$ tutto fermo!!



Termodinamica

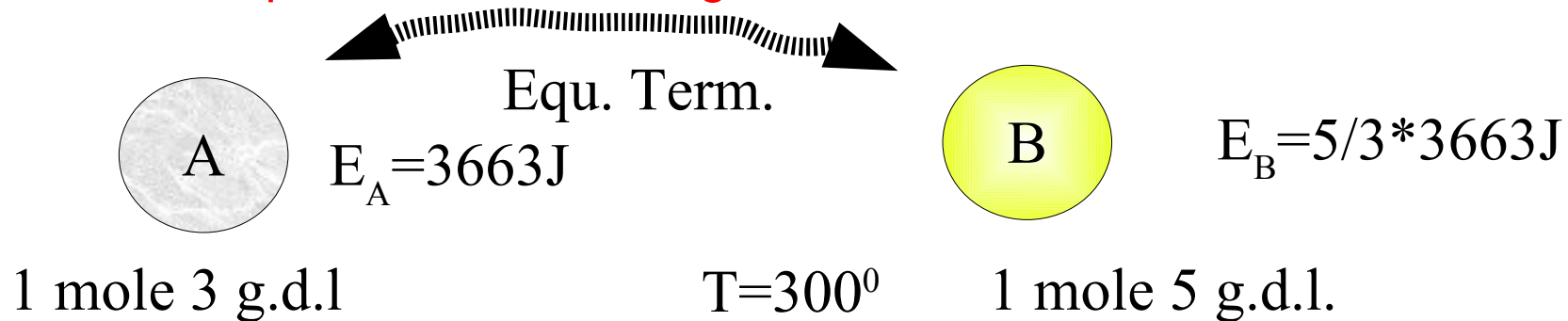
Particelle non puntiformi

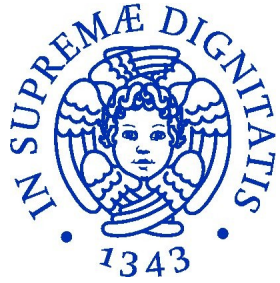


- Bisogna tener conto di:
- 3 gradi di liberta' di traslazione
- piu' gradi di liberta' di rotazione (O_2 ha 3+2 g.d.l. ma anche 7)
- ripartizione proporzionale ai gradi di liberta' (Boltzman)

se due sistemi sono all'equilibrio termico fra di loro, l'energia cinetica, quella di traslazione + rotazione, e' proporzionale al numero di gradi di liberta' delle molecole.

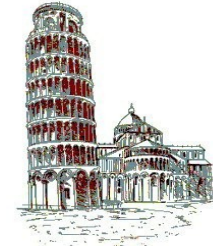
ma: temperatura \Leftrightarrow energia di traslazione!!





Termodinamica

Particelle non puntiformi



==> **unicita'** della equazione di stato per tutti i gas

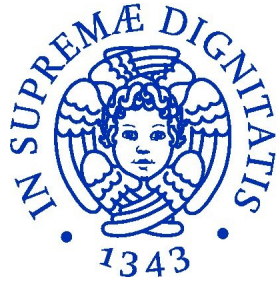
$$\overline{E}_c = \frac{3}{2} kT \quad ==>$$

Definizione

$$\overline{E}_{c \text{ per g.d.l}} = \frac{1}{2} kT$$

energia/g.d.l.

$$\overline{E}_{c \text{ per g.d.l}} = \frac{1}{2} 1.38 \cdot 10^{-23} \times 294^0 = 2.028 \cdot 10^{-21} \text{ J} \quad \text{!!!!?}$$



Termodinamica

Gas reali
Van der Waals



$$\left(P + \frac{n^2 a}{V^2}\right)(V - nb) = nRT$$

==> Forze di interazione

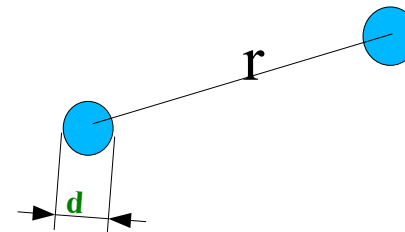
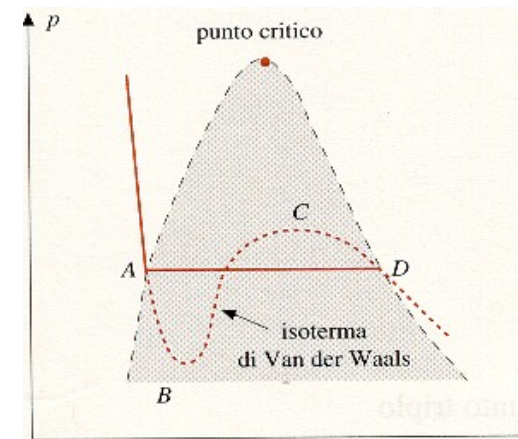
attrattiva a grande distanza $r > d$

repulsiva a breve distanza $r \approx d$

Parametri

a e' legato alle forze attrattive

b e' il covolume per mole





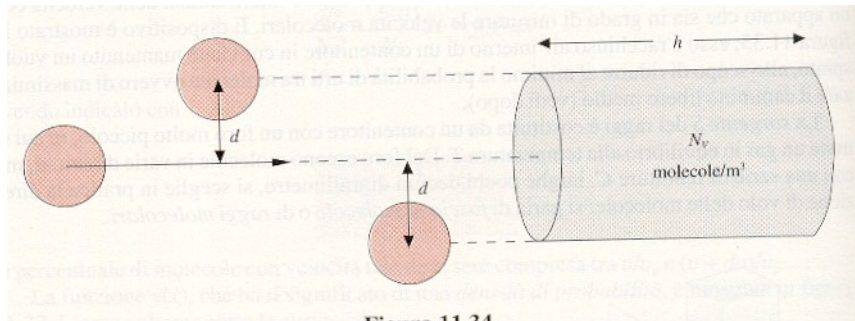
Termodinamica

Van der Waals



Prima correzione dovuta alla dimensione finita delle molecole

Dalla statistica $P = \frac{2}{3} \frac{N}{V} \overline{E}_c$ $P \propto v$ frequenza degli urti

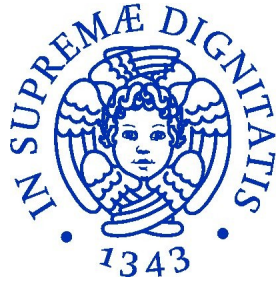


$$\lambda = \frac{1}{2N \pi 4 \sigma^2} \quad \text{caso ideale}$$

$$\lambda' = \lambda - r \quad \text{per molecole di raggio } r$$

$$P' = P \frac{\lambda}{\lambda - r}$$

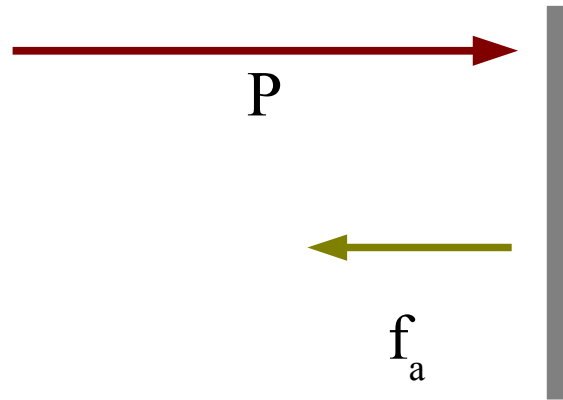
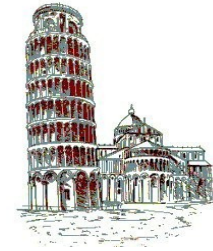
$$P' = \frac{2}{3} \frac{N}{V} \overline{E}_c \frac{\lambda}{\lambda - r} = \frac{2}{3} N \overline{E}_c \frac{1}{(V - 2N \pi 4r^3)} = \frac{2}{3} N \overline{E}_c \frac{1}{(V - nb)}$$



Termodinamica

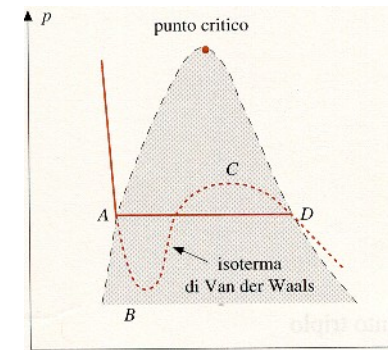
Van der Waals

Seconda correzione dovuta alle forze attrattive



$$\frac{f_a}{s} = a \frac{n}{V} * \frac{n}{V}$$

$$P = P' - a \frac{n^2}{V^2}$$



$$\left(P + a \frac{n^2}{V^2}\right)(V - nb) = \frac{2}{3} N \overline{E_c} = nRT$$

per il teorema
equiripartizione
energia