## Boltzmann's constant and other stuff

$PV = nRT$ - ideal gas law.

- $R$ - ideal gas const.
  $R = 8.315\ J/mol\cdot K$

$N = nN_A$

# molecules

Avagadro's # $N_A = 6.02\times10^{23}\ \frac{\text{molecules}}{\text{mol}}$

$n = \frac{N}{N_A} \Rightarrow PV = \frac{N}{N_A}RT$

$k = 1.38\times10^{-23}\ J/K$

$= N\left(\frac{R}{N_A}\right)T$

$= NkT$

Boltzmann's constant

$PV = NkT$

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$P$ - pressure. $P = \frac{F}{A}$ in $\frac{N}{m^2}$

$1\frac{N}{m^2} = 1\ Pa$

$1\ atm = 101.325\ kPa$

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Kelvin $0K = -273.15°C$

$1C° = 1K°$

$1°C = 274.15\ K$

$1K = -272.15°C$

$T(K) = T(°C) + 273.15°C$

### Kinetic Theory

The idea that matter is made up of molecules in continuous motion is known as kinetic theory. We make four assumptions about molecules in a gas. This is an oversimplification, but real gases match these well under our previously defined conditions. A gas which matches these assumptions is an **ideal gas**.

→ P is not too high
T is not too low.

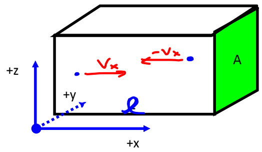
1. N is large - all molecules have same mass, m and $\vec{v}$ is random.
2. The separation of molecules is large ($\gg r_{molecule}$)
3. Classical physics - a billiard ball approach
4. All collisions are elastic. ($KE = KE'$)

A gas that meets these 4 requirements is called ideal

Derivation

1 molecule

$\vec{v} = v_x \hat{x} + v_y \hat{y} + v_z \hat{z}$




When it hits A

$\Delta p_x = -mv_x - mv_x$ ← true because KE is conserved

$= -2mv_x$

So $\Delta p$ of surface A must be

$\Delta p_x = 2mv_x$

Momentum-Impulse

$\Sigma F \Delta t = \Delta p$

$\Sigma F_{ave} = \frac{\Delta p}{\Delta t}$

$\Sigma F_{ave} = \frac{\cancel{2} m v_x}{\left(\frac{\cancel{2}\ell}{v_x}\right)}$

that molecule hits A once every

$t = \frac{d}{v_x} = \frac{2\ell}{v_x}$

$\Sigma F_{ave} = \frac{m v_x^2}{\ell}$ average force on A from a single particle.

But we have N molecules each with different $v_x$'s.

$\Sigma F_{total} = \sum_{i=1}^{N} \frac{m v_{x_i}^2}{\ell} = \frac{m}{\ell} \sum_{i=1}^{N} v_{x_i}^2$

average

$\overline{v_x^2} = \frac{\Sigma v_{x_i}^2}{N}$

$\Sigma F_{total} = \frac{m}{\ell} N \overline{v_x^2}$

$\overline{v^2} = \overline{v_x^2} + \overline{v_y^2} + \overline{v_z^2}$, but since $\vec{v}$ is random $\overline{v_x^2} = \overline{v_y^2} = \overline{v_z^2}$

$= \overline{v_x^2} + \overline{v_x^2} + \overline{v_x^2}$

$\overline{v_x^2} = \frac{1}{3}\overline{v^2}$

$\Sigma F_{total} = \frac{1}{3} \frac{mN}{\ell} \overline{v^2}$

$P = \frac{\Sigma F}{A} = \frac{\frac{1}{3}\frac{mN}{\ell}\overline{v^2}}{A}$

$= \frac{1}{3} \frac{mN}{\ell A} \overline{v^2}$

$P = \frac{\frac{1}{3} N m \overline{v^2}}{V}$

$PV = \frac{1}{3} N m \overline{v^2}$ $\qquad \frac{1}{2} m \overline{v^2} = \overline{KE}$

$= \underbrace{\frac{2}{3} N \overline{KE}}_{\Sigma \overline{KE}}$

$PV = \frac{2}{3} N \overline{KE} = NkT$

$kT = \frac{2}{3} \overline{KE}$

$T = \frac{2}{3} \frac{\overline{KE}}{k}$