Ch. 17 & 18-1

(You will not be tested on rest of Ch. 18.)

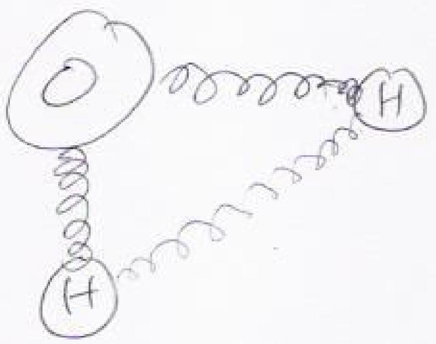
↑ Today

(Simulations due Thursday.)

What is temperature?

Matter is made of particles (molecules) moving randomly (translational, rotational, vibrational).

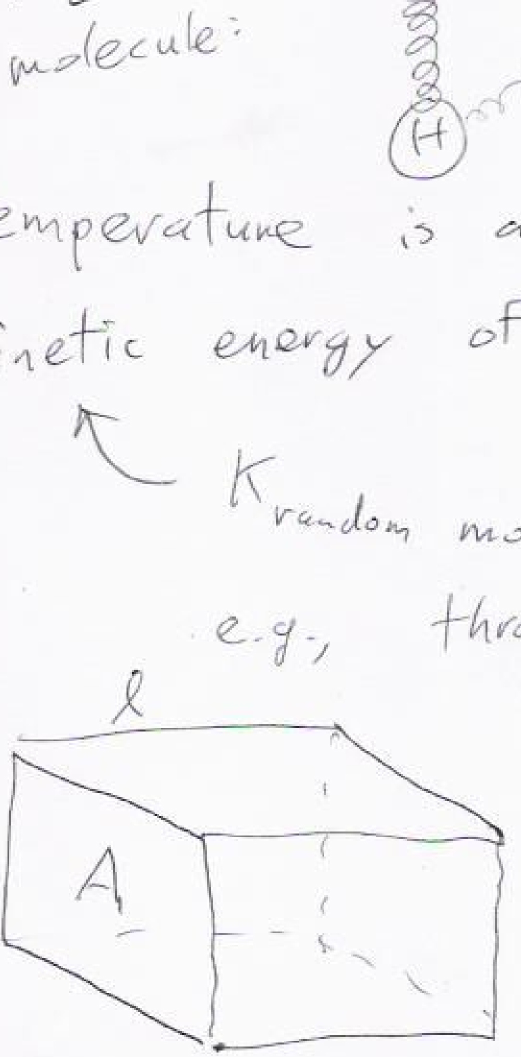
H_2O molecule:



Essentially 3 balls & springs.

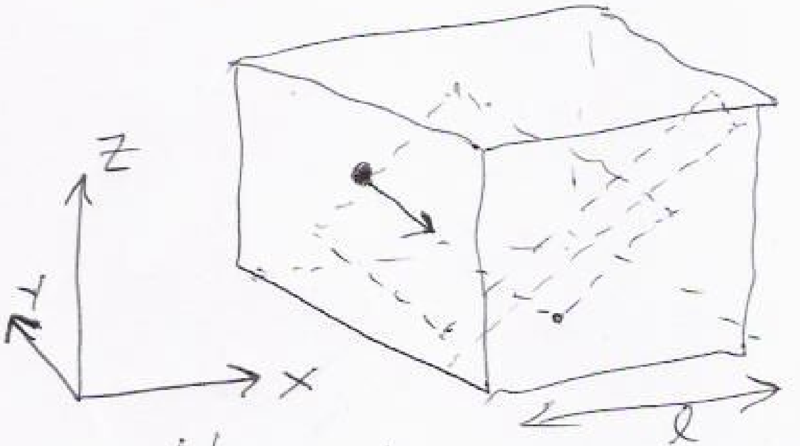
Temperature is a measure of average kinetic energy of molecules.

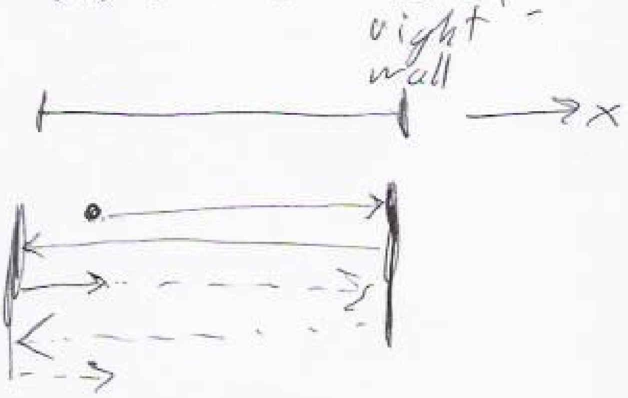
$K_{\text{random motion}}$, not the K from, e.g., throwing a ball.



box ℓ long, face area A.

Ideal gas: Particles (like He atoms) that bounce around the box with negligible interaction with eachother, nor have rotational or vibrational motion.





How does one particle affect the box?

Just look at x-direction at first:

Time to cross box & and get back to original x position: $\Delta t = 2\ell / v_x$

Changes in momentum: switch from $m v_x$ to $-m v_x$ & back to $m v_x$.

Force on right wall (averaged over time interval Δt) is $\underbrace{2 m v_x}_{\Delta p_{\text{right wall}, x} = -\Delta p_x} / \Delta t$.

$F_{avg} = \frac{\Delta p}{\Delta t}$; $F = \frac{dp}{dt}$

$$F_{\substack{\text{right}\\\text{wall}}} = \frac{2mv_x}{2\ell/v_x} = \frac{mv_x^2}{\ell}$$

Go from one particle to many.

$$\sum F_{\text{right wall}} = \frac{mv_{x1}^2 + mv_{x2}^2 + \cdots + mv_{xN}^2}{\ell}$$

(Assume all particles have same mass)

$\overline{v_x^2}$ = average of $v_{x1}^2, \ldots, v_{xN}^2$

$$\overline{v_x^2} = \frac{1}{N}\left(v_{x1}^2 + \cdots + v_{xN}^2\right)$$

$$N\overline{v_x^2} = v_{x1}^2 + \cdots + v_{xN}^2$$

$$\sum F = mN\overline{v_x^2}/\ell$$

Assume motion is random enough

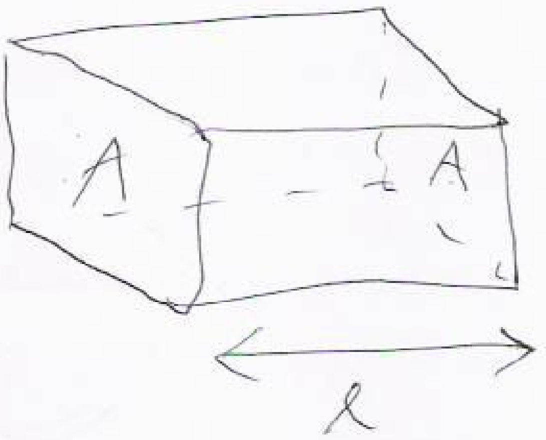
that $\overline{v_x^2} \approx \overline{v_y^2} \approx \overline{v_z^2}$

$$\overline{v^2} = \overline{v_x^2} + \overline{v_x^2} + \overline{v_z^2} = 3\overline{v_x^2}$$

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

$$\sum F_{\text{right wall}} = \frac{m N \overline{v^2}}{3\ell}.$$

Pressure on right wall:



$$P = \frac{F}{A} = \frac{m N \overline{v^2}}{3 \underbrace{\ell A}_{V = \text{volume}}}$$

$\longrightarrow x$

mass of particle

$$PV = m N \overline{v^2}/3 = \frac{2}{3} N \underbrace{\left(\frac{1}{2} m \overline{v^2}\right)}_{\overline{K}}$$

\# of particle

average kinetic energy

$$PV = \underline{nRT}\ ?$$

Definition: temperature of ideal gas:

$$T = \frac{2}{3}\frac{\overline{K}}{k} \quad \text{(in Kelvins)}$$

k = Boltzmann constant

$$k = 1.38 \times 10^{-23}\ \mathrm{J/Kelvin}$$

Ice at $0^\circ C$ has $T = 273.15$ Kelvins

$$x^\circ C = (x + 273.15)\ \text{Kelvins}$$

300 Kelvins $\approx$ room temperature

$$T = \frac{2}{3}\frac{\overline{K}}{k} \qquad PV = \frac{2}{3} N \overline{K}$$

$$PV = NkT = nRT$$ Ideal gas law

$$\#\text{moles} = n = \frac{N}{N_A} \qquad R = \text{gas constant} = kN_A$$

$$N_A = \#\text{particle/mole} = 6.02 \times 10^{23}$$

$$R = \frac{8.314\ \mathrm{J}}{\mathrm{mol \cdot Kelvin}}$$

1 mole of ^{12}C has mass 12.000 grams

periodic table gives ~~the~~ grams/mole.

H_2O molecule mass: ~~$2\cdot 1.00794 + 15.9994$~~

$$\frac{(2\times 1.00794)+15.9994}{6.02\times 10^{23}} \text{ grams}$$

N_A

$$\approx 3.00\times 10^{-23}\,g$$