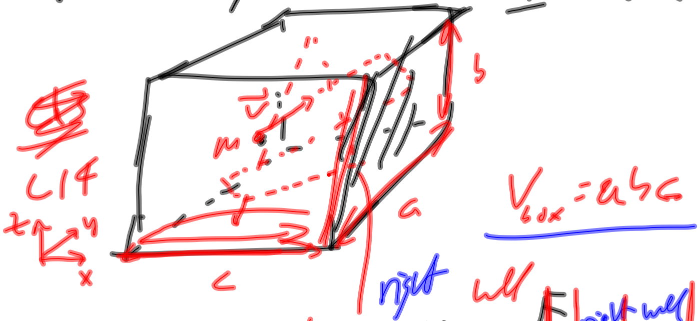
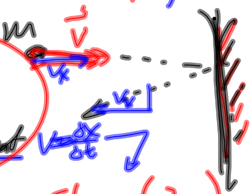
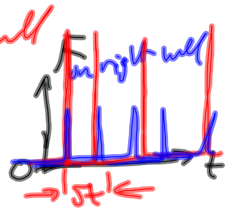
premise: $P \doteq \vec{F}/A$ empty box w/ 1 atom



$V_{box} = abc$

right wall





Assumption: speed ~ constant

$v_x = \frac{\delta x}{\delta t}$

transit time $\delta t = \frac{(2c)}{v_x}$

N2L: $F_{W\to x} = m\frac{\Delta v_x}{\delta t} = m\frac{(-v_x - v_x)}{\delta t} = \frac{-2mv_x}{\delta t}$

time averaged $\langle F_{W\to x}\rangle = \frac{-2mv_x}{\delta t} = \frac{-2mv_x}{(2c/v_x)}$

$= \frac{-mv_x^2}{c}$

$P_{\text{right wall}} = \frac{F}{A} = \frac{mv_x^2/c}{ab} = \frac{mv_x^2}{abc} = \frac{mv_x^2}{V}$

$P\cdot V = mv_x^2$

N atoms in box

$$\boxed{P\cdot V = N\langle mv_x^2\rangle = N\tfrac{2}{3}\langle K\rangle}$$

1 mol =

$N_A = 6.02E23$ things ~ chemist's dozen

Avogadro

$K = \frac{1}{2}mv^2 = \frac{1}{2}m(v_x^2+v_y^2+v_z^2)$

$\langle K\rangle = \frac{m}{2}\langle v_x^2+v_y^2+v_z^2\rangle = \frac{m}{2}(\langle v_x^2\rangle+\langle v_y^2\rangle+\langle v_z^2\rangle)$

$= \frac{m}{2}\,3\langle v_x^2\rangle$

$PV = N\frac{2}{3}\langle K\rangle \overset{*}{=} N k_B T$

Boltzmann

$k_B = 1.381E-23$ J/K

$PV = nRT$

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

$$\frac{1}{2} m v_{rms}^2 = \frac{3}{2} k_B T$$

$$\hookrightarrow V_{rms} = \sqrt{\frac{3 k_B T}{m}}$$

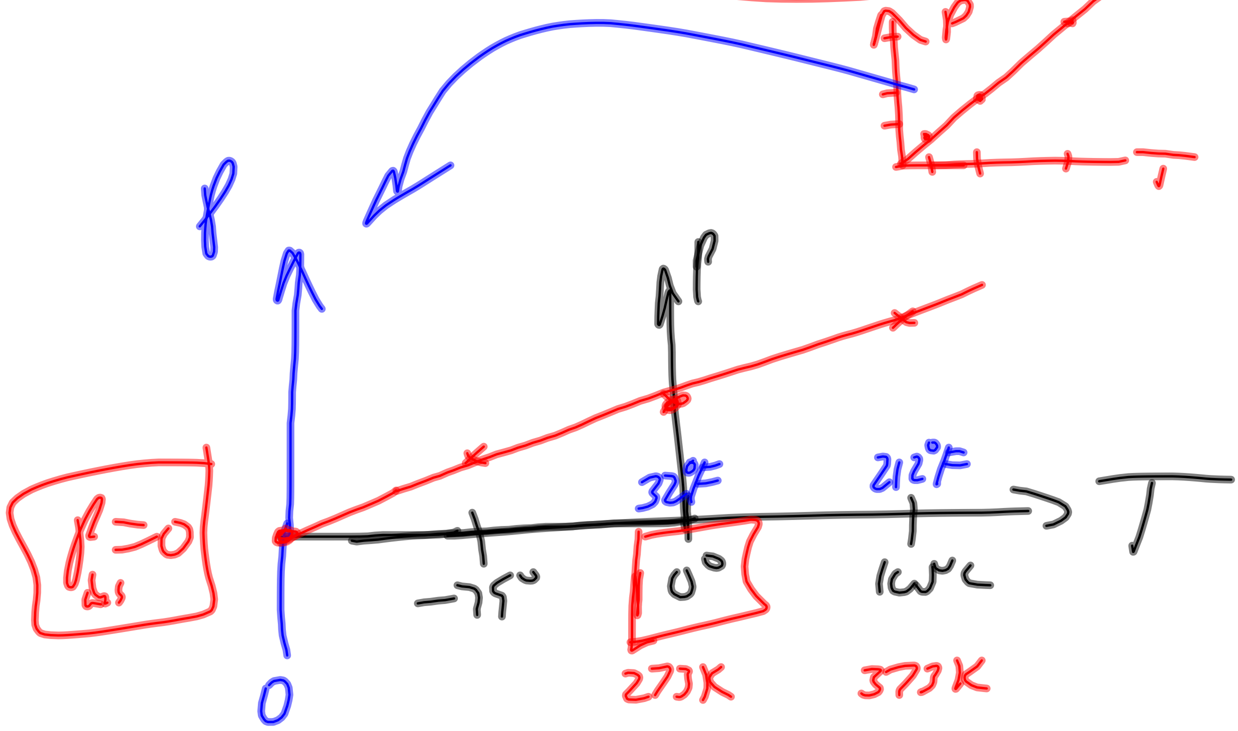
300 mph

air molecule @ R.T. —— $v \sim 150$ m/s

$$v_{sound} = \frac{1\,\text{mile}}{5\,s} = \frac{1609\,m}{5\,s} \approx \underline{340\,m/s}$$

$$V_{rms} = \sqrt{\frac{3(1.38E{-}23\,J/\cancel{K})(20°C + 273\,\cancel{K})}{\left(.029\,\frac{kg}{mol} \cdot \frac{mol}{6E23\,atm}\right)}} = \underline{501}\sqrt{\frac{J}{kg}}$$

Check, expts, $P \propto T$



$\Delta 1°C = \Delta 1K$

Heat Transfer   ball ~ energy, players ~ atoms

- conduction – hand-off
- convection – carrying   (requires fluid < gas, liquid)
- radiation – throw or kick or toss

$$\rightarrow PV = \underline{Nk_B}T \quad (T \text{ in } K)$$

$$PV = \underline{n}RT$$

Avogadro $N_A = 6.022E23$ things

$n = 1\,\text{mol}$ $N \sim \#\text{ atoms}$ $R = 8.314\,\frac{J}{\text{mol}\cdot K}$

$$(1\,\cancel{\text{mol}})\left(8.314\,\frac{J}{\cancel{\text{mol}}\,K}\right) = (6.022E23\,\#)\,k_B$$

$$k_B = 1.381E{-23}\,\frac{J}{\#\,K}$$

$$\cancel{N}k_BT = \cancel{N}\frac{2}{3}\langle K\rangle \qquad \underline{\underline{\langle K\rangle = \frac{3}{2}k_BT}}$$

$$\left\langle \frac{1}{2}mv^2 \right\rangle = \frac{3}{2}k_BT$$

$$\hookrightarrow V_{rms} = \sqrt{\frac{3k_BT}{m}}$$

use $PV = NkT = nRT$ to compute ρ_{He}.

$$\rho_{He} \doteq \frac{M_{He}}{V_{He}} = \frac{4\ \text{gm/mol}}{}$$

Helios

L sun

$T > T_{room} = 20°C = 293\ K$

$$V = \frac{NkT}{P} = \frac{nRT}{P} \to \frac{(1\ \cancel{\text{mol}})(8.31\ \frac{J}{\cancel{\text{mol}}\ \cancel{K}})(293\ \cancel{K})}{(82400\ Pa)}$$

$$\frac{(6.022E23)(1.381E{-}23\ \frac{J}{K})(293\ K)}{82900\ Pa}$$

$=$

$$= .0295\ \frac{\cancel{N} \cdot m}{(\cancel{N}/m^2)} = m^3$$

$= 29.5\ L = 29500\ cm^3$

$$\rho_{He} = \frac{4\ gm}{29500\ cm^3} = .00014\ gm/cm^3 \qquad \rho_{air} = .00098\ gm/cm^3$$

Dec 5-8:08 AM