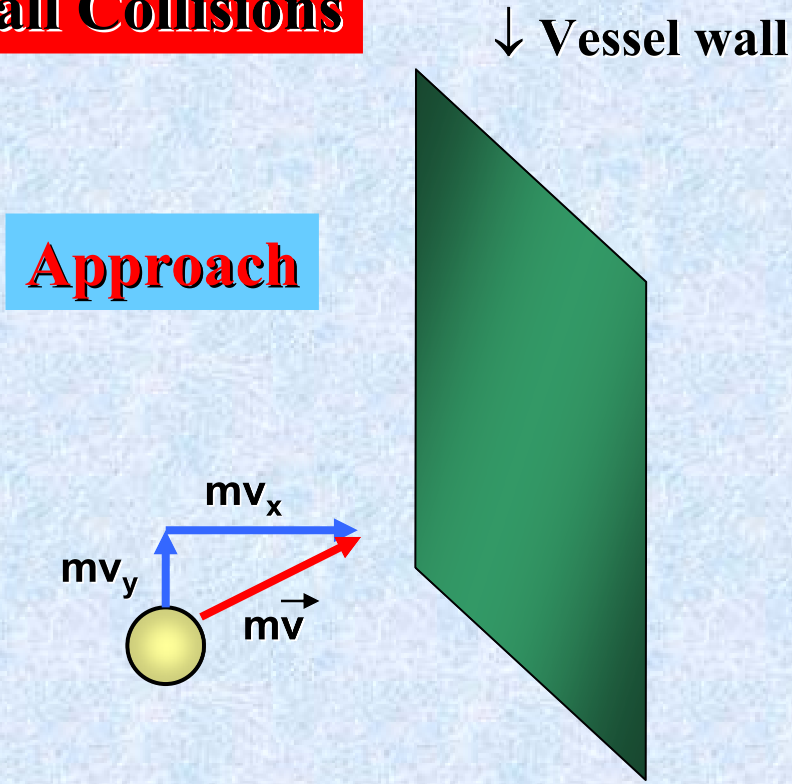
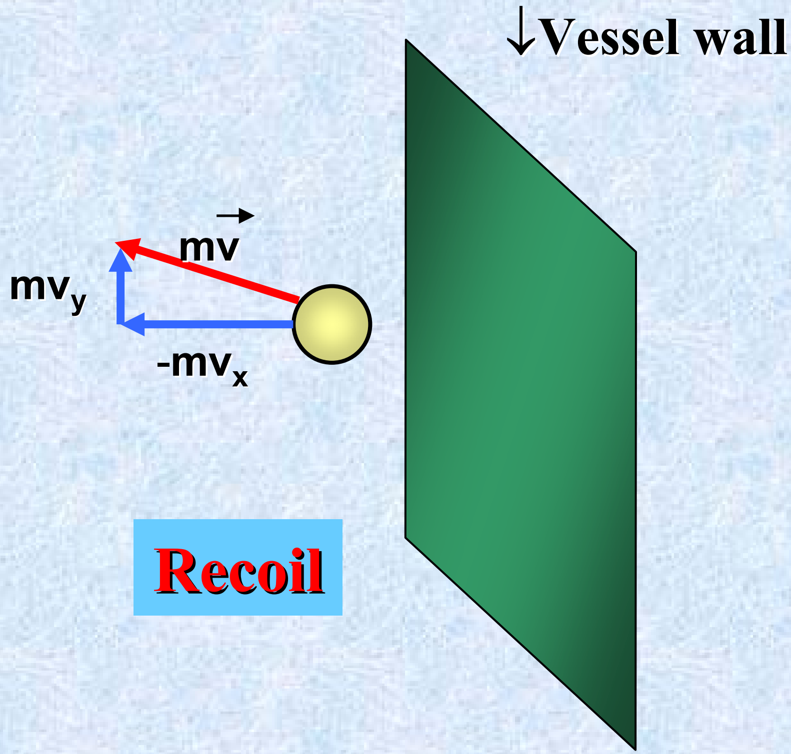
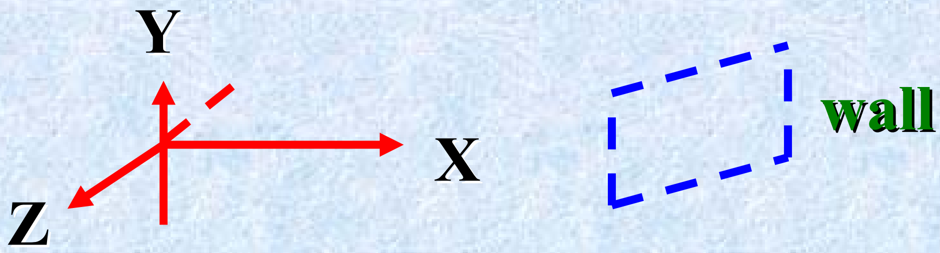
Wall Collisions

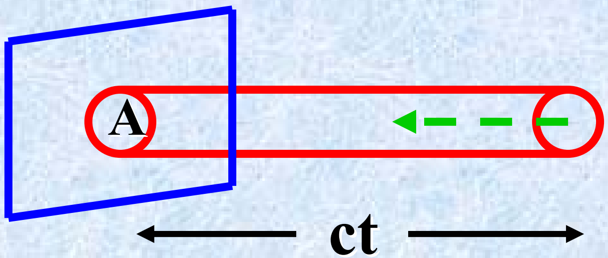


Before Collision with wall

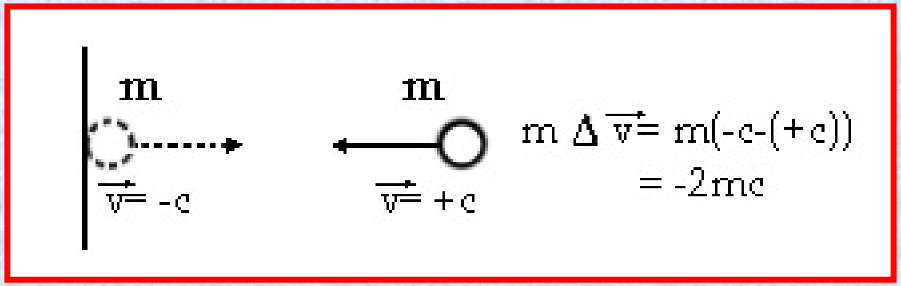


After Collision with wall





This cylinder contains all the atoms which will strike A in a time t (It also contains quite a few atoms that will not collide with the wall during t).

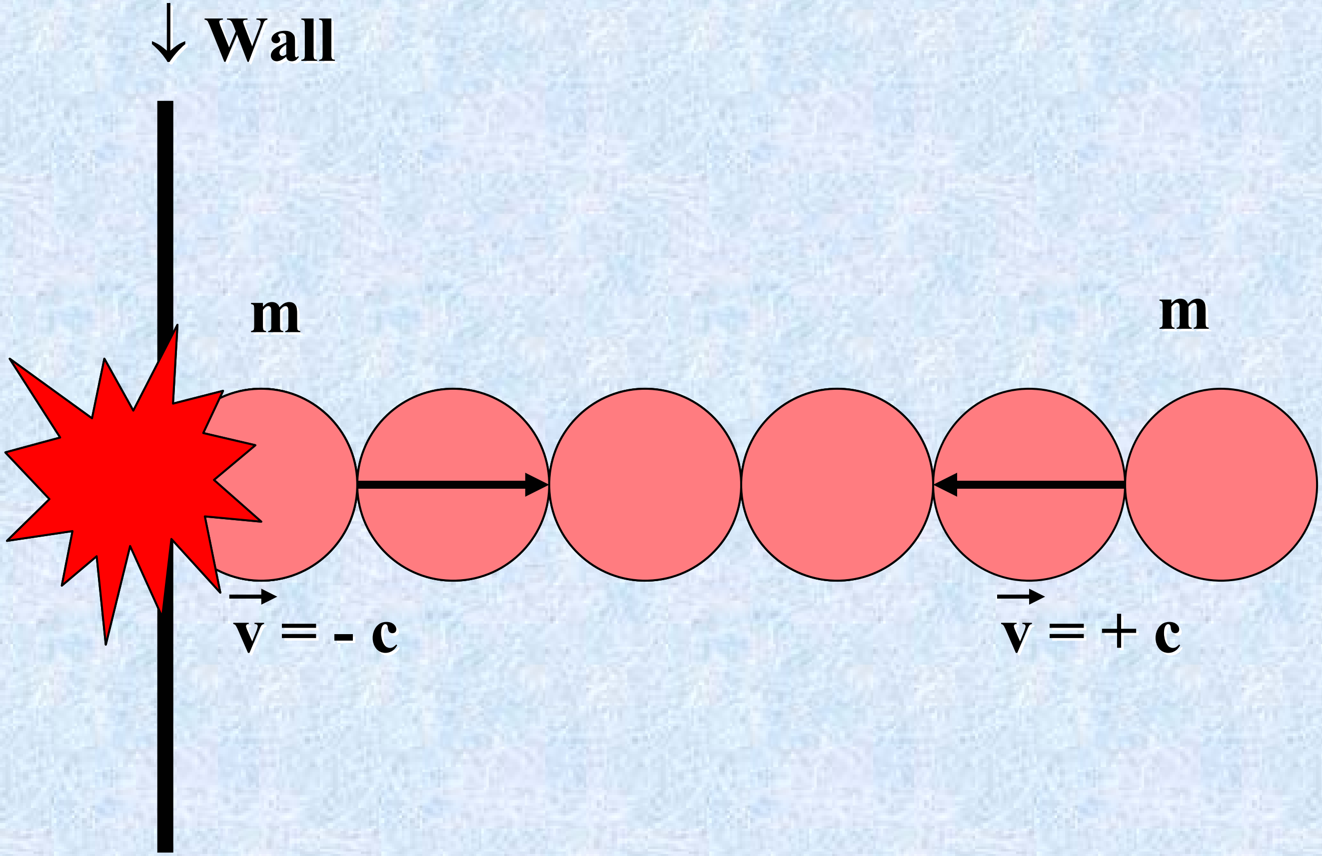


$\vec{F}_{atom}$/atom = (-2mc)/Δt

This is the force exerted ON an atom due to a single collision.

Since the momentum change for the wall is the negative of that for the atom:

One Particle Momentum Change for Elastic Wall Collision



$$m\Delta\vec{v} = m(-c - (+c))$$

$$= -2mc$$

Our problem now is to determine Δt. There is no easy way to do this so we resort to a trick:

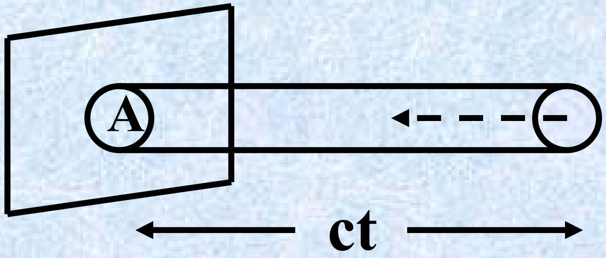
Then:

[(Momentum change) / sec] =

$(\Delta \vec{P}_{wall} / \text{impact}) \times (\text{impacts / sec}) = (\Delta \vec{P}_{wall} / \text{sec})$

$\vec{F} = (2mc) \times I = (\Delta \vec{P}_{wall} / \text{sec})$

Calculating I



Total atoms in collision cylinder = (N / V) (Act)

(1/3)(1/2)(N / V) (Act) = (1/6) (N / V) (Act)

Directions/axis

# of axes

$\vec{F}_{wall}$ = [(2mc)][(1 / 6)(N / V)(Ac)] = (1 / 3)(N / V)mc^2A

$P = (1/3)\ (N / V) mc^2$ or →

$PV = (2/3)\ N\ [(1/2)\ mc^2]$

Let N_0 = Avogadro's #; n = # moles in V = N / N_0

$PV = N\ (RT / N_0) = (2/3)\ N\ [(1/2)\ mc^2]$ or →

$$\frac{1}{2}mc^2 = \frac{3}{2}(R / N_0)T$$

$$\boxed{\frac{1}{2}mc^2 = \frac{3}{2}kT}$$

Kool result!!

$N_0\left(\frac{1}{2}mc^2\right)$ **is the kinetic energy of one mole of gas atoms**

Units:

PV ~ [pressure] [volume]

PV ~ force × length

Bonus * Bonus * Bonus * Bonus * Bonus * Bonus

Bonus * Bonus * Bonus * Bonus * Bonus * Bonus

Typical Molecular Speeds

Understand that $c = \sqrt{\overline{c^2}} = c_{rms}$ [Root Mean Square Speed]

$(1/2)mc^2 = (3/2)kT$ → $c = (3kT/m)^{1/2}$

$c = (3RT/M)^{1/2}$ → $c^2 = 3RT/M$

$c^2 = 3RT/M = 7.47 \times 10^6$ Joules/Kg $= 7.47 \times 10^6\ (\text{m/sec})^2$

$c = 2.73 \times 10^3$ m/sec (Fast Moving Particle)

Why do Light and Heavy Gases Exert Same Pressure at Constant V,T, n (# moles)? (p = nRT/V)

wall collision frequency/unit area = (1/6) (N/V) (Ac t)/(At) = (1/6) (N/V) c

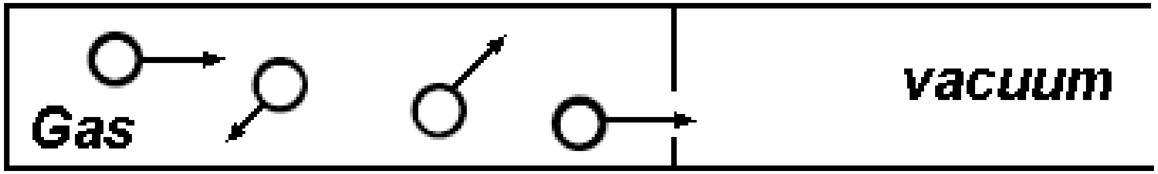
However, since

BUT momentum change per collision ~ mc, with

Two effects cancel since $(1/m^{1/2})$ x $(m^{1/2})$ is independent of m

Experimental Evidence for Kinetic Theory: Effusion

Put very small hole in box and measure # of molecules coming through. If hole is really small , molecules won't know it's there and will collide with hole at same rate as they collide with the wall.

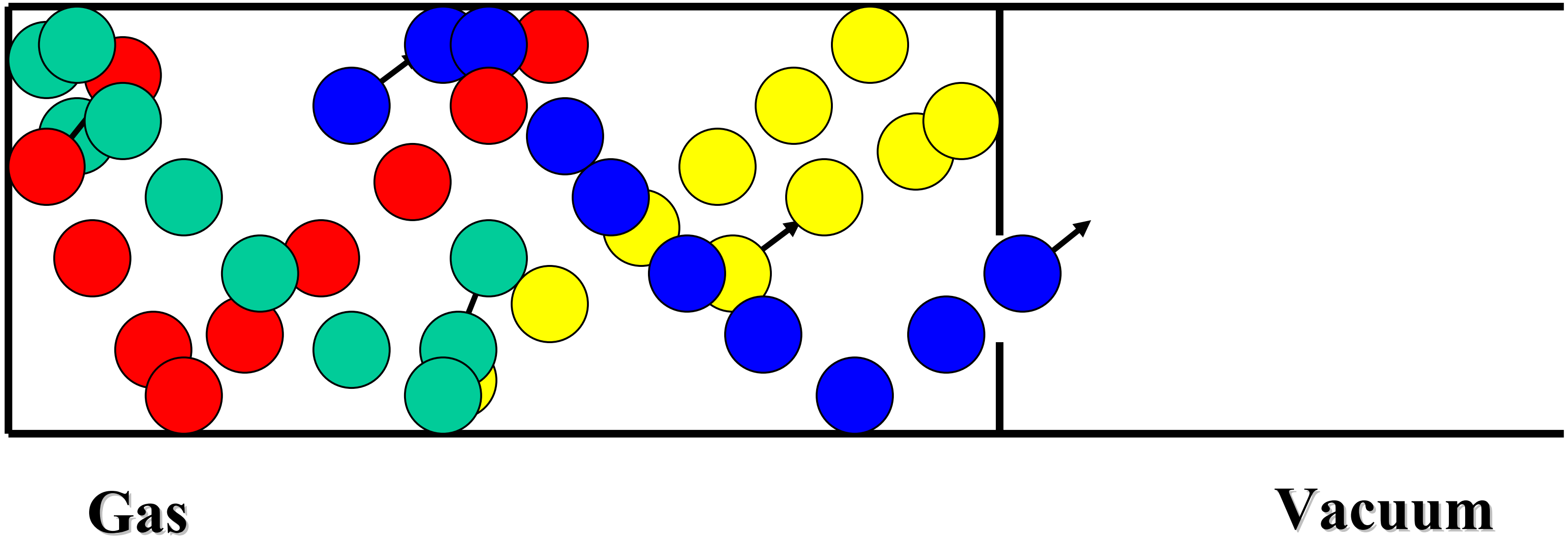


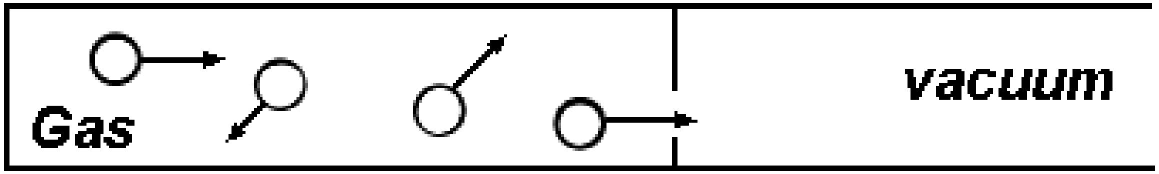
Effusion of Gases: The Movie

QuickTime™ and a
Video decompressor
are needed to see this picture.

Note:
← Hole
Must be very small!

Effusion of a Gas through a Small Hole





If hole area = A, rate at which molecules leave = (1/6) (N / V) Ac = R

$$\frac{R_1}{R_2} = \left[\left(\frac{N_1}{V}\right) / \left(\frac{N_2}{V}\right)\right]\left(\frac{c_1}{c_2}\right)$$

$$\frac{R_1}{R_2} = \left(\frac{c_1}{c_2}\right) = \frac{\sqrt{\frac{3kT}{m_1}}}{\sqrt{\frac{3kT}{m_2}}} \rightarrow$$

Find experimentally that light gases escape more quickly than heavy ones!

Experimental Evidence for Kinetic Theory: Heat Capacities

Two kinds: C_p **(add heat at constant pressure)**

C_v **(add heat at constant volume)**