WileyPLUS Assignment 5

Chapters 11, 12, 14
Due Wednesday, December 9 at 11 pm

PHYS 1020 Final Exam

Friday, December 18, 1:30 - 4:30 pm
The whole course, 30 multiple choice questions
Formula sheet provided

Seating:

Frank Kennedy Brown Gym: A - S
Frank Kennedy Gold Gym: T - Z

Friday, Monday

Review of the course - send problems!

Wednesday next week

Available in office to answer problems

Ideal Gas Law

The behaviour of an ideal gas is described by the ideal gas law:

$$PV = nRT$$

n = number of moles of gas
R = universal gas constant = 8.314 J/(mol.K)
T in Kelvin

In terms of the number, N, of atoms or molecules of the gas:

$$PV = NkT$$

k = Boltzmann's constant = 1.38×10^{-23} J/K
$N = nN_A$, and $nRT = NkT = nN_AkT$, so

$$k = \frac{R}{N_A}$$

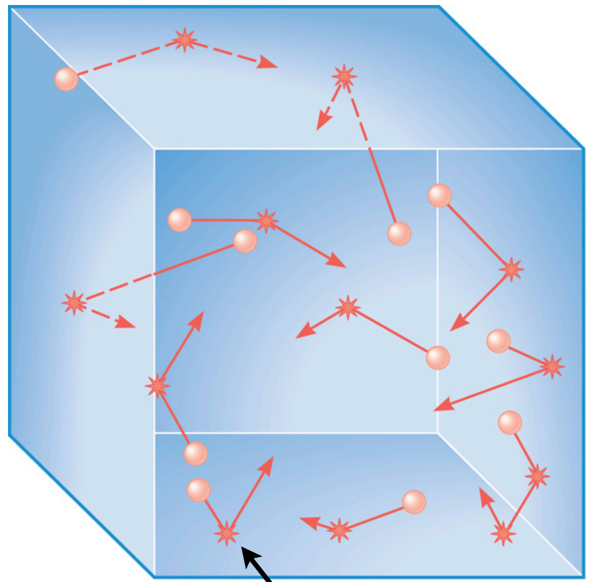
Prob. 14.28/22

A bubble, located 0.200 m beneath the surface in a glass of beer, rises to the top. The air pressure at the top is 1.01×10^5 Pa. Assume that the density of beer is the same as that of fresh water. If the temperature and number of moles of CO_2 in the bubble remain constant as the bubble rises, find the ratio of the bubble's volume at the top to its volume at the bottom.

Kinetic Theory of Gases

Ideal gas - particles (atoms or molecules) move freely and randomly in a container, impart an impulse to the walls of the container off which they bounce elastically.

The sum of the impulses of the particles bouncing off the walls generates the pressure force, which is proportional to the area of the walls.



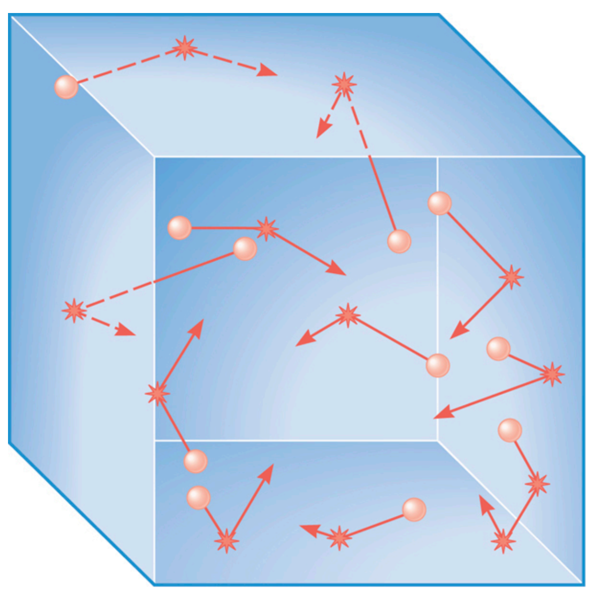
$$\text{Impulse} = \vec{F}\Delta t = \Delta\vec{p}$$

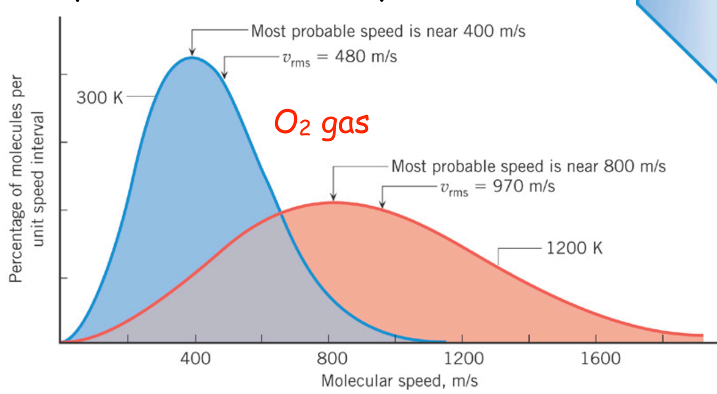
$$\boxed{\text{Pressure} = \frac{\text{Total impulse per second}}{\text{Area of wall}}}$$

Kinetic Theory of Gases

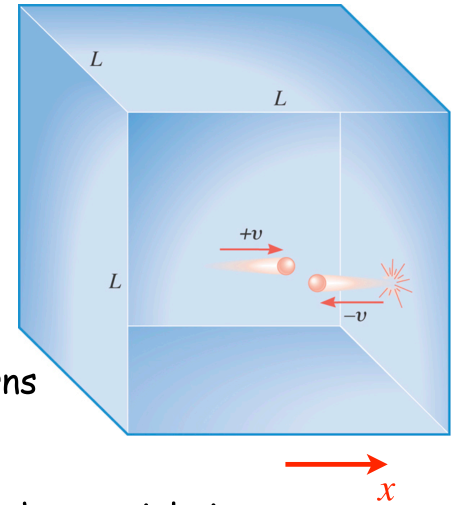
Even if the particles moved initially in the same direction at the same speed, in collisions with one another kinetic energy is shared between them.

After many such collisions, the particles end up with a distribution of speeds calculated by Maxwell.





Kinetic Theory of Gases



A particle: mass m, speed v in the x-direction, bounces off a wall. The particle recoils from the wall at speed −v.

Change in momentum of the particle is
$\Delta p = mv_f - mv_i = -2mv$.

A time $\Delta t = 2L/v$ later, the particle returns and bounces off the wall again.

The average force exerted on the wall by the particle is:

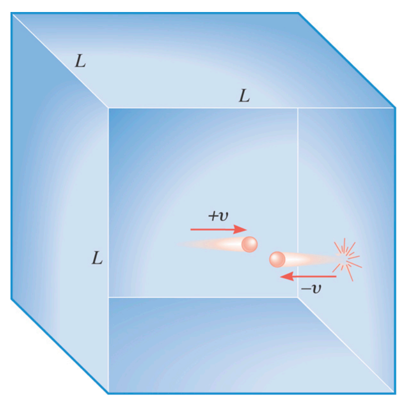
$$F = -\frac{\Delta p}{\Delta t} = \frac{2mv}{2L/v} = \frac{mv^2}{L}$$

The particles have a distribution of speeds. The average force is:

$$F = \frac{m\overline{v^2}}{L} \qquad \overline{v^2} = \text{mean square speed}$$

Kinetic Theory of Gases

$$\boxed{F = \frac{m\overline{v^2}}{L} \qquad \overline{v^2} = \text{mean square speed}}$$



If there are N particles in the box travelling in random directions, N/3 will be travelling in the x-direction.

So, the total force exerted on the wall is:

$$F = \left[\frac{N}{3}\right]\left[\frac{m\overline{v^2}}{L}\right] = \left[\frac{N}{3}\right]\left[\frac{mv_{rms}^2}{L}\right]$$

$$v_{rms} = \sqrt{\overline{v^2}} = \text{root mean square speed}$$

The pressure exerted on the wall is: $P = \frac{F}{A} = \left[\frac{N}{3}\right]\left[\frac{mv_{rms}^2}{L^3}\right]$

$$PV = \frac{N}{3}mv_{rms}^2 = \frac{2N}{3}\left(\frac{1}{2}mv_{rms}^2\right)$$

$A = L^2$ $\quad$ $L^3 = V$

Kinetic Theory of Gases

$$\boxed{PV = \frac{N}{3}mv_{rms}^2 = \frac{2N}{3}(\frac{1}{2}mv_{rms}^2)}$$

Looks like Boyle's law: PV = constant

$$PV = \frac{2N}{3}\overline{\mathrm{KE}} \quad \text{as} \quad \frac{1}{2}mv_{rms}^2 = \overline{\mathrm{KE}}$$

Average kinetic energy of the particles

Back to the ideal gas law:

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

Comparing: $\frac{2N}{3}\overline{\mathrm{KE}} = NkT$

Therefore: $\overline{\mathrm{KE}} = \frac{3}{2}kT$

$$\boxed{\overline{\mathrm{KE}} = \frac{1}{2}mv_{rms}^2 = \frac{3}{2}kT}$$

Suppose that the atoms in a container of helium have the same translational rms speed as the atoms in a container of argon. Treating each gas as an ideal gas which, if either, has the greater temperature?

$$\overline{\mathrm{KE}} = \frac{1}{2}mv_{rms}^2 = \frac{3}{2}kT$$

The rms speed of the He and Ar atoms is the same, but the mass is not the same.

So, T ∝ m

The mass of Ar is greater than the mass of He, so the Ar is at the higher temperature.

$$\frac{T_{Ar}}{T_{He}} = \frac{m_{Ar}}{m_{He}} = \frac{39.948}{4.0026} = 9.981$$

Q16, Final 2005: Consider two ideal gases, A and B, at the same temperature. The rms speed of the molecules of gas A is twice that of gas B. How does the molecular mass of A compare with that of B?

$$\overline{\mathrm{KE}} = \frac{1}{2}Mv_{rms}^2 = \frac{3}{2}kT$$

The gases have the same temperature, so

$$M_A(v_{rms}^2)_A = M_B(v_{rms}^2)_B$$

$$\text{If } (v_{rms})_A = 2(v_{rms})_B, \text{ then,}$$

$$\frac{M_A}{M_B} = \left[\frac{(v_{rms})_B}{(v_{rms})_A}\right]^2 = \frac{1}{2^2}$$

14.33/28: Near the surface of Venus, the rms speed of CO_2 molecules is 650 m/s. What is the temperature of the atmosphere?

14.-/34: What is the total kinetic energy of all of the molecules in 3 moles of a gas at 320 K?

Prob. 14.40/-

A container holds 2 moles of gas. The total average kinetic energy of the gas molecules in the container is equal to the kinetic energy of an 8 g bullet with a speed of 770 m/s.

What is the Kelvin temperature of the gas?

Prob. 14.35/51

Suppose a tank contains 680 m^3 of neon (Ne) at an absolute pressure of 1.01×10^5 Pa. The temperature is changed from 293.2 to 294.3 K. What is the increase in the internal energy of the neon?

14.62/35: Compressed air can be pumped underground into huge caverns as a form of energy storage. The volume of a cavern is 5.6×10^5 m^3 at a pressure of 7.7×10^6 Pa. Assume that the air is a diatomic ideal gas whose internal energy is given by:

$$U = \frac{5}{2} nRT$$ (molecules can rotate as well as move)

where n is the number of moles of gas.

If one home uses 30 kW.h of energy per day, how many homes could this internal energy serve for one day?

14.63/56: When perspiration on the human body absorbs heat, some of the perspiration turns into water vapour. The latent heat of vaporization at body temperature (37°C) is 2.42×10^6 J/kg.

The heat absorbed is approximately equal to the average energy E given to a single water molecule times the number of water molecules that are vaporized.

What is E?

Summary

Ideal gas law:

PV = nRT
n = number of moles

or

PV = NkT
N = number of atoms or molecules

Average kinetic energy of an atom or molecule:

$$\overline{\mathrm{KE}} = \frac{1}{2}mv_{rms}^2 = \frac{3}{2}kT$$