

[TP] The distribution of speeds in a gas is due to …

13% 1. collisions of gas particles with the walls of the container.
13% 2. collisions of gas particles with one another
13% 3. attractions between the particles of the gas and the particles of the walls of the container.
13% 4. attractions between the particles of the gas.
13% 5. 1 and 2
13% 6. 1 and 3
13% 7. 1, 2 and 3
13% 8. 1, 2, 3 and 4

Response Counter 10

Lecture 6 CH102 A1 (MWF 9:05 am)

Wednesday, February 1, 2017

- Complete: Kinetic molecular theory of gases
- Practice with particle picture of gases

Next: Continue ch11: Molecular speeds and their distribution; real gases (attraction and size)

Kinetic-molecular theory of gases

Force due to j^{th} particle of mass m and speed u_j

$\Delta p = 2\ m\ u_j$ (elastic collision)

$\Delta t = 2\ L\ /\ u_j$ (travel to opposite wall and back)

$F = \Delta p\ /\ \Delta t = m\ u_j^2\ /\ L$

Pressure due to j^{th} particle of mass m and speed u_j

$P_j = F\ /\ \text{area} = F\ /\ L^2 = m\ u_j^2\ /\ L^3$

$P_j = m\ u_j^2\ /\ V$

Kinetic-molecular theory of gases

A single particle j exerts a pressure

$P_j = m\ u_j^2\ /\ V$

The total pressure P due to all of the N particles in the container is

$P = (m\ /\ V\ )\ (u_1^2 + u_2^2 + \ldots + u_j^2 + \ldots + u_N^2\ )$

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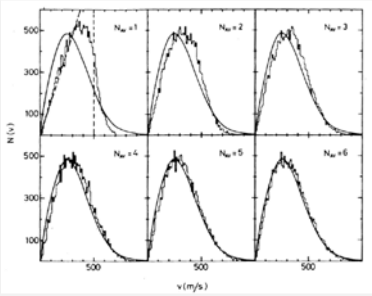
Distribution of molecular speeds

Here is what happens to the speeds of 20,000 particles, all initially at the same speed, after they each have undergone successive numbers of collisions.

Bonomo & Riggi,
Am. J. Phys. ,Vol 52, p 54 (1984)



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Kinetic-molecular theory of gases

In terms of the average squared speed

$u^2_{avg} = (u_1^2 + u_2^2 + \ldots + u_j^2 + \ldots + u_N^2) / N$

N particles exert a pressure

$P = (m / V)\, N\, (u_1^2 + u_2^2 + \ldots + u_j^2 + \ldots + u_N^2) / N$

$= (m / V)\, N\, u^2_{avg}$

$= (m / V)\, n N_A\, u^2_{avg}$

$= (M / V)\, n\, u^2_{avg}$

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Kinetic-molecular theory of gases

The expression for pressure,

$P = (n M / V)\, u^2_{avg}$ (motion in one dimension)

assumes the particle moves back and forth between opposite walls, say the walls perpendicular to the x axis.

A more detailed treatment that takes into account motion in all three dimensions shows that the pressure on any one wall is only ⅓ as great,

$P = (n M / V)\, \frac{1}{3}\, u^2_{avg}$ (motion in three dimensions)

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Calculation of molecular speeds

We now have two expressions for pressure:

The microscopic expression $P = (n\,M / V)\,⅓\,u^2_{\text{avg}}$

and the macroscopic expression $P = n\,R\,T / V$

Comparing these, we get that …

Calculation of molecular speeds

$u^2_{\text{avg}} = 3\,R\,T / M$

is the fundamental connection between …
microscopic motion , u^2_{avg},
macroscopic concept temperature , T, and
molar mass, M.

$$u_{\text{rms}} \equiv \sqrt{u^2{}_{avg}} = \sqrt{3\,R\,T/M}$$

Practice with particle picture of gases

Let's consider some questions to help us develop a particle-level understanding of why gases behave the way they do.

[Quiz] Gas pressure is due to …

13% 1. collisions of gas particles with the walls of the container.
13% 2. collisions of gas particles with one another
13% 3. attractions between the particles of the gas and the particles of the walls of the container.
13% 4. attractions between the particles of the gas.
13% 5. 1 and 2
13% 6. 1 and 3
13% 7. 1, 2 and 3
13% 8. 1, 2, 3 and 4

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[TP] A container of volume V is filled with a gas at 20 ºC. If V is decreased (while keeping T constant), the pressure P exerted by the gas on the walls of the container goes up ($P = n\,R\,T\,/\,V$). Why?

17% 1. The particles move faster
17% 2. The particles move slower
17% 3. The particles hit the walls harder
17% 4. The particles hit the walls less hard
17% 5. The particles hit the walls more often
17% 6. The particles hit the walls less often

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[TP] When more particles are added to the same V at the same T, P goes up ($P = n\,R\,T\,/\,V$). Why?

17% 1. The particles move faster
17% 2. The particles move slower
17% 3. The particles hit the walls harder
17% 4. The particles hit the walls less harder
17% 5. More particles hit the walls in a given time
17% 6. Fewer particles hit the wall in a given time

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[TP] When a gas is heated, if the P is to remain constant, then volume V must go up ($V = n\,R\,T\,/\,P$). Why?

17% 1. The particles move faster
17% 2. The particles move slower
17% 3. The particles hit the walls harder
17% 4. The particles hit the walls less harder
17% 5. The distance travelled between collisions must increase
17% 6. The distance travelled between collisions must decrease

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[TP] Two 1 L containers, A and B, each contain equal numbers of particles at 20 ºC. The particles of gas in A are twice as heavy as those in B, $m_A = 2\ m_B$. Therefore ...

33% 1. particles of gas A move faster than those of gas B
33% 2. particles of gas A move slower than those of gas B
33% 3. particles of gas A move at the same average speed as those of gas B

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[Quiz] Two 1 L containers, A and B, each contain equal numbers of particles at 20 °C. The particles of gas in A are twice as heavy as those in B.
What are the relative pressures in the two containers?

25% 1. Pressure of A is half the pressure of B
25% 2. Pressure of A equals the pressure of B
25% 3. Pressure of A is twice the pressure of B
25% 4. Pressure of A is four times the pressure of B

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Practice with particle picture of gases

Two 1 L containers, A and B, each contain equal numbers of particles at 20 °C.
The particles of gas in A are twice as heavy as those in B, $m_A = 2\ m_B$.
The pressure in the two containers is the same.

How can this be?

$P = (n\,M\,/\,V)\ ⅓\ u^2_{avg} = (n\,M\,/\,V)\ ⅓\ 3\,R\,T\,/\,M$

Pressure depends on speed AND mass

Heavy particles move s l o w l y ! ! !

Light particles move q u I c k l y !!!

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[TP] Equal amounts of gases A and B are in a single container. The mass of a molecule of gas in A is twice that of the gas in B, $m_A = 2\ m_B$. The container is pierced with a hole 0.003 mm in diameter.

When 5 minutes has elapsed after the piercing, the container will contain …

25% 1. more A than B
25% 2. equal amounts of each gas
25% 3. less A than B
25% 4. Further information needed

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