

[TP] The different speeds, u_1, u_2, etc., 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

BOSTON UNIVERSITY

Response Counter 10

Lecture 7 CH102 A2 (MWF 11:15 am)

Friday, February 2, 2018

- Kinetic molecular theory, PDF: http://goo.gl/njf3em
- Practice with particle picture of gases;

Next: Molecular speeds and their distribution; Real gases (attraction and size)

BOSTON UNIVERSITY

Kinetic-molecular theory of gases

Force due to j^{th} particle of mass m and speed u_j is $\Delta p/\Delta t$ …

$\Delta p = 2mu_j$ (elastic collision)

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

$F = \Delta p/\Delta t = mu_j^2/L$

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

$$P_j = \frac{F}{\text{area}} = \frac{F}{L^2} = \frac{mu_j^2}{L^3} = \frac{mu_j^2}{V}$$

BOSTON UNIVERSITY

Kinetic-molecular theory of gases

A single particle j exerts a pressure

$$P_j = \frac{mu_j^2}{V}$$

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

$$P = \frac{m}{V}(u_1^2 + u_2^2 + \cdots + u_j^2 + \cdots + u_N^2)$$

BOSTON UNIVERSITY

Lecture 7 CH102 A2 (MWF 11:15 am) Spring 2018

[TP] The different speeds, u_1, u_2, etc., in a gas is due to …

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

BOSTON UNIVERSITY

Response Counter 10

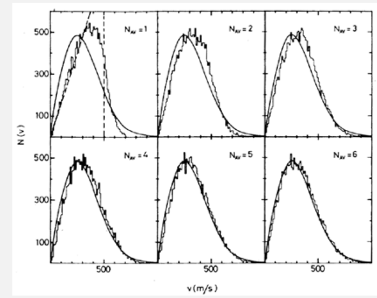
8

Lecture 7 CH102 A2 (MWF 11:15 am) Spring 2018

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)



BOSTON UNIVERSITY

9

Lecture 7 CH102 A2 (MWF 11:15 am) Spring 2018

Kinetic-molecular theory of gases

We can rewrite the total pressure due to the N particles,

$$P = \frac{m}{V}(u_1^2 + u_2^2 + \cdots + u_j^2 + \cdots + u_N^2)$$

in terms of the average squared speed

$$u_{\text{avg}}^2 = (u_1^2 + u_2^2 + \cdots + u_j^2 + \cdots + u_N^2)/N$$

by multiplying and dividing P by N,

$$P = \frac{m}{V}N(u_1^2 + u_2^2 + \cdots + u_j^2 + \cdots + u_N^2)/N$$

$$= \frac{m}{V}Nu_{\text{avg}}^2 = \frac{m}{V}N_{\text{A}}nu_{\text{avg}}^2 = \frac{M}{V}nu_{\text{avg}}^2$$

BOSTON UNIVERSITY

11

Lecture 7 CH102 A2 (MWF 11:15 am) Spring 2018

Kinetic-molecular theory of gases

The expression for pressure,

$$P = \frac{nM}{V}u_{\text{avg}}^2 \text{ (one dimension)}$$

assumes the particle moves in just one dimension, 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,

$$P = \frac{nM}{3V}u_{\text{avg}}^2 \text{ (three dimensions)}$$

BOSTON UNIVERSITY

13

Calculation of molecular speeds

We now have two expressions for pressure:

The microscopic expression $P = \frac{nMu_{\text{avg}}^2}{3}/V$

and the macroscopic expression $P = nRT/V$

Comparing these, we get that $\frac{Mu_{\text{avg}}^2}{3} = RT$ ...

and so that the average squared speed is $u_{\text{avg}}^2 = \frac{3RT}{M}$

BOSTON UNIVERSITY

Lecture 7 CH102 A2 (MWF 11:15 am) Spring 2018 Copyright © 2018 Dan Dill dan@bu.edu

Calculation of molecular speeds

$u_{\text{avg}}^2 = \frac{3RT}{M}$

is the connection between...

microscopic motion, quantified as u_{avg}^2, and ...

the macroscopic concept temperature, T, and molar mass, M.

The square root of the mean (average) squared speed is the rms speed ...

$u_{\text{rms}} = \sqrt{u_{\text{avg}}^2} = \sqrt{\frac{3RT}{M}}$

BOSTON UNIVERSITY

Lecture 7 CH102 A2 (MWF 11:15 am) Spring 2018 Copyright © 2018 Dan Dill dan@bu.edu

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.

BOSTON UNIVERSITY

Lecture 7 CH102 A2 (MWF 11:15 am) Spring 2018 Copyright © 2018 Dan Dill dan@bu.edu

[Quiz] Gas pressure is due to ...

0% 1. collisions of gas particles with the walls of the container.
0% 2. collisions of gas particles with one another
0% 3. attractions between the particles of the gas and the particles of the walls of the container.
0% 4. attractions between the particles of the gas.
0% 5. 1 and 2
0% 6. 1 and 3
0% 7. 1, 2 and 3
0% 8. 1, 2, 3 and 4

BOSTON UNIVERSITY

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

0% 1. The particles move faster
0% 2. The particles move slower
0% 3. The particles hit the walls harder
0% 4. The particles hit the walls less hard
0% 5. The particles hit the walls more often
0% 6. The particles hit the walls less often

BOSTON UNIVERSITY 19

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

0% 1. The particles move faster
0% 2. The particles move slower
0% 3. The particles hit the walls harder
0% 4. The particles hit the walls less harder
0% 5. More particles hit the walls in a given time
0% 6. Fewer particles hit the wall in a given time

BOSTON UNIVERSITY 21

[TP] When a gas is heated, if the P is to remain constant, then volume V must go up ($V = nRT/P$). 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 with the walls must increase
17% 6. The distance travelled between collisions with the walls must decrease

BOSTON UNIVERSITY 23

[TP] 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, $m_A = 2\ m_B$. Therefore …

0% 1. particles of gas A move faster than those of gas B
0% 2. particles of gas A move slower than those of gas B
0% 3. particles of gas A move at the same average speed as those of gas B

BOSTON UNIVERSITY 24

Lecture 7 CH102 A2 (MWF 11:15 am) Spring 2018

[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, $m_A = 2\ m_B$. What are the relative pressures in the two containers?

0% 1. Pressure of A is half the pressure of B
0% 2. Pressure of A equals the pressure of B
0% 3. Pressure of A is twice the pressure of B
0% 4. Pressure of A is four times the pressure of B

BOSTON UNIVERSITY

25