

[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?

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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Lecture 5 CH102 A2 (MWF 11:15 am)

Friday, February 1, 2019

- Review: Kinetic molecular theory, PDF: http://goo.gl/njf3em
- Practice with particle picture of gases
- Units of pressure and of the gas constant R

Next: Molecular speeds and their distribution, CDF https://goo.gl/VkRrsg ; Real gases: Effect of molecular attraction; Real gases: Effect of molecular size; van der Waals equation; Phase diagrams

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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,

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

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

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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 …

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

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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.

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[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

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[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?

17% 1. The particles hit the walls with more force
17% 2. The particles hit the walls less force
17% 3. The particles hit the walls with more momentum
17% 4. The particles hit the walls less momentum
17% 5. 1 and 3
17% 6. 2 and 4

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

25% 1. The particles move faster
25% 2. The particles move slower
25% 3. More particles hit the walls in a given time
25% 4. 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 ($V = nRT/P$). Why?

25% 1. The particles move faster
25% 2. The particles move slower
25% 3. The distance travelled between collisions with the walls must increase
25% 4. The distance travelled between collisions with the walls must decrease

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[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

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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 ...

0% 1. more A than B
0% 2. equal amounts of each gas
0% 3. less A than B
0% 4. Further information needed

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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, $m_A = 2\ m_B$. 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

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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?

$$P = \frac{nM}{3V} u_{\text{avg}}^2 = \frac{nM}{3V}\frac{3RT}{M} = \frac{nRT}{V}$$

Pressure depends on both speed and mass, but in opposite ways that cancel one another.

Greater mass contributes greater momentum.

Greater mass means lower speed and so offsets greater momentum

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Units of pressure and of the gas constant *R*

In CH101 Fall 2018 (lecture 14) we discussed units of pressure

$$1\ \text{Pa} = \frac{\text{force}}{\text{area}} = 1\frac{\text{kg m/s}^2}{\text{m}^2} = 1\frac{\text{kg m}^2/\text{s}^2}{\text{m}^3} = 1\frac{\text{J}}{\text{m}^3}$$

1 bar = 100 kPa = 100000 Pa (exactly)

1 atm = 101.325 kPa = 101325 Pa (exactly)

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Pressure = Force/Area

Pa = J/m^3

1 atm = 101325 Pa

m^3 = 1000 L

Use dimensional analysis to convert R = 8.314 J / (K mol) to L atm / (K mol).

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