

[TP] The rms speed, u_{rms}, of O_2 at 25 °C is about ("Use units, Luke!") ...

25% 1. 250 m/s
25% 2. 500 m/s
25% 3. 750 m/s
25% 4. 1000 m/s

Response Counter 10

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Lecture 8 CH102 A2 (MWF 11:15 am)

Monday, February 5, 2018

- Review: Practice with particle picture of gases
- Units of pressure and of the gas constant, R
- Molecular speeds and their distribution, CDF https://goo.gl/VkRrsg

Next: Real gases (attraction and size)

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?

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

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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[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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Units of pressure and of gas constant *R*

In CH101 Fall 2017 (lecture 13) 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

Convert R = 8.314 J / (K mol) to L atm / (K mol).

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[TP] The rms speed, u_{rms}, of O_2 at 25 °C is about ...
(“Use units, Luke!” $R = 8.314\,\frac{\text{J}}{\text{K mol}} = 8.314\,\frac{\text{kg m}^2\text{/s}^2}{\text{K mol}}$)

25% 1. 250 m/s
25% 2. 500 m/s
25% 3. 750 m/s
25% 4. 1000 m/s

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Calculate rms speed of O_2 at 25 °C

$$u^2_{avg} = \frac{3RT}{M}$$

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

$$R = 8.314\,\frac{\text{J}}{\text{K mol}} = 8.314\,\frac{\text{kg m}^2\text{/s}^2}{\text{K mol}}$$

Answer: 482 m/s ≈ 500 m/s

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Distribution of molecular speeds

Distribution of speeds is a plot of the number of particles (y axis) at each speed (x axis).

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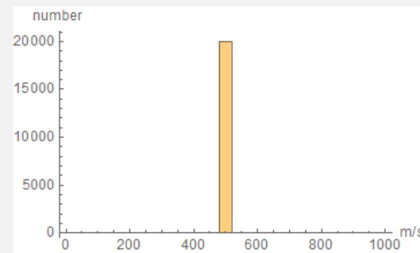
Distribution of molecular speeds

Say we 20,000 particles, all with the same speed $u = 500$ m/s.

Make a sketch of the corresponding distribution of speeds.



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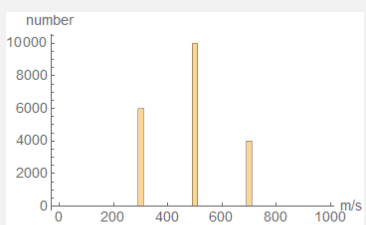
Distribution of molecular speeds

We have said that collisions between gas particles results in the particles having different speeds.

Make a sketch of a possible distribution of just three speeds, 300, 500, and 700 m/s, of the 20,000 particles.



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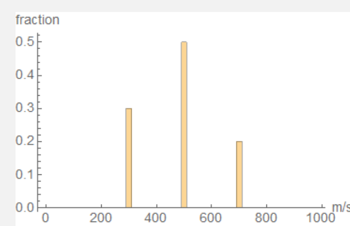
Distribution of molecular speeds

We have said that collisions between gas particles results in the particles having different speeds.

It is convenient to express the distribution in terms of fractional number of particles rather than number of particles.



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Distribution of molecular speeds

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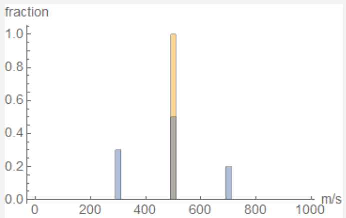
It is convenient to express the distribution in terms of fractional number of particles rather than number of particles.



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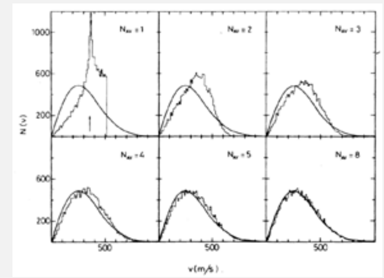
Distribution of molecular speeds

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)
http://dx.doi.org/10.1119/1.13809



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Distribution of molecular speeds

At 300 K, the rms speed of O_2 is $u_{rms} = 500$ m/s.

Sketch the Maxwell-Boltzmann distribution of speeds of O_2 at 300 K, from 0 m/s to 4000 m/s, marking the position of u_{rms} on the x axis.

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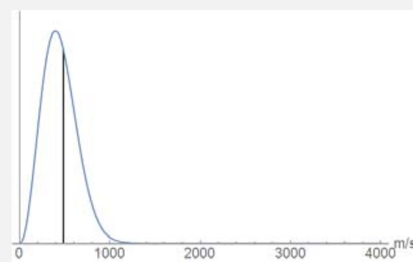

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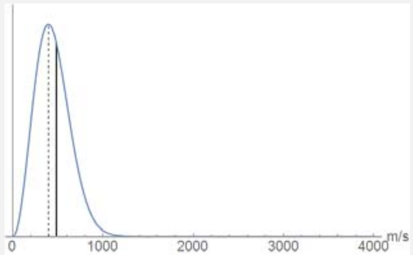
Distribution of molecular speeds

The rms speed, u_{rms}, is slightly higher than the most probable speed, u_{mp}, because of the exponential tail extending to very high speeds.

$$u_{\text{mp}} = \sqrt{2/3}\ u_{rms} \approx 0.82\ u_{rms}$$



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