The distribution of speeds 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. Attractions between the particles of the gas and the particles of the walls of the container.
6. Attractions between the particles of the gas and the particles of the walls of the container.
7. Attractions between the particles of the gas and the particles of the walls of the container.
8. Attractions between the particles of the gas and the particles of the walls of the container.

The force due to the jth particle of mass $m$ and speed $u_j$ is:

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

$$\Delta t = \frac{2L}{u_j} \text{(travel to opposite wall and back)}$$

$$F = \frac{\Delta p}{\Delta t} = \frac{m u_j^2}{L}$$

The pressure due to the jth particle of mass $m$ and speed $u_j$ is:

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

$$P_j = \frac{m u_j^2}{V}$$

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

$$P = \left(\frac{m}{V}\right) \left( u_1^2 + u_2^2 + \ldots + u_N^2 \right)$$
The distribution of speeds 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

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.


Kinetic-molecular theory of gases

In terms of the average squared speed

$$u^2_{\text{avg}} = (u_1^2 + u_2^2 + ... + u_i^2 + ... + u_N^2) / N$$

N particles exert a pressure

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

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

$$= \frac{(m / V)}{N} n N_u u^2_{\text{avg}}$$

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

The expression for pressure,

$$P = \frac{(n M / V)}{u^2_{\text{avg}}}$$ (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 \(\frac{1}{3}\) as great,

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

We now have two expressions for pressure:

- The **microscopic expression** \( P = \frac{n M}{V} \frac{1}{2} u_{avg}^2 \)
- and the **macroscopic expression** \( P = \frac{n R T}{V} \)

Comparing these, we get that ...

\[
\begin{align*}
\text{Calculation of molecular speeds} \\
\text{We now have two expressions for pressure:} \\
&\text{The microscopic expression } P = \frac{n M}{V} \frac{1}{2} u_{avg}^2 \\
&\text{and the macroscopic expression } P = \frac{n R T}{V} \\
\text{Comparing these, we get that ...}
\end{align*}
\]

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.

\[
\begin{align*}
\text{Practice with particle picture of gases} \\
\text{Let's consider some questions to help us develop a particle-level understanding of why gases behave the way they do.}
\end{align*}
\]
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 ($P = n R T / V$). Why?

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

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

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

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

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

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 ...

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

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

Practice with particle picture of gases

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 ...

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