Ministry of Higher Education and Scientific Research
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Physical chemistry

Lecture 4

Kinetic theory of gases, Assumption

By

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The Kinetic Molecular Theory of Matter

Describe each word to define:

Kinetic

Molecular

Theory

Matter

- The Kinetic Molecular Theory of Matter states that the particles in all matter are in a constant state of motion.
- The theory is used to explain the properties of solids, liquids and gases.

Five Assumptions of the Kinetic Molecular Theory

1. Gases consist of large numbers of tiny particles that are far apart relative to their size.

   - Most of the volume occupied by a gas is empty space.

   - Accounts for lower density compared to solid and liquids.

2. Collisions between gas particles and between particles and container walls are **elastic** collisions with NO loss of energy.

3. Gas particles are in constant, rapid, random motion—

4. There are no forces of attraction or repulsion between gas particles.

Think of ideal gas molecules as behaving like small billiard balls. When they collide, they do not stick together but immediately bounce apart.

5. The average kinetic energy of gas particles depends on the temperature of the gas.

$$KE = \frac{1}{2} MV^2$$

M= mass

V= velocity

All gases at the same temperature have the same average kinetic energy. Therefore, at the same temperature, lighter gas particles, such as hydrogen molecules, have higher average speeds than do heavier gas particles, such as oxygen molecules.

The average Kinetic Energy of gas particles depends on Temperature of the gas

The Kinetic Molecular Theory and the Nature of Gases

The kinetic molecular theory applies only to ideal gases. Although ideal gases do not actually exist, many gases behave nearly ideally if pressure is not very high or temperature is not very low.

The theory accounts for the physical properties of gases.

Physical Properties of Gases

<u>Expansion</u>

- Gases do not have a definite shape.
- Gases do not have a definite volume.
- They expand to take the shape of their container because they are in rapid, random, constant motion.

Fluidity

- Because the attractive forces between gas particles are slight, gas particles glide past one another.
- **They flow just like liquids.**

Low Density

The density of a substance in the gaseous state is about 1/1000 the density of the same substance in the liquid or solid state.

That is because their particles are so spread out and far apart from each other.

Compressibility

-In compression, gas particles are pressed close together.

- This greatly decreases the volume making transport much easier

Diffusion and Effusion

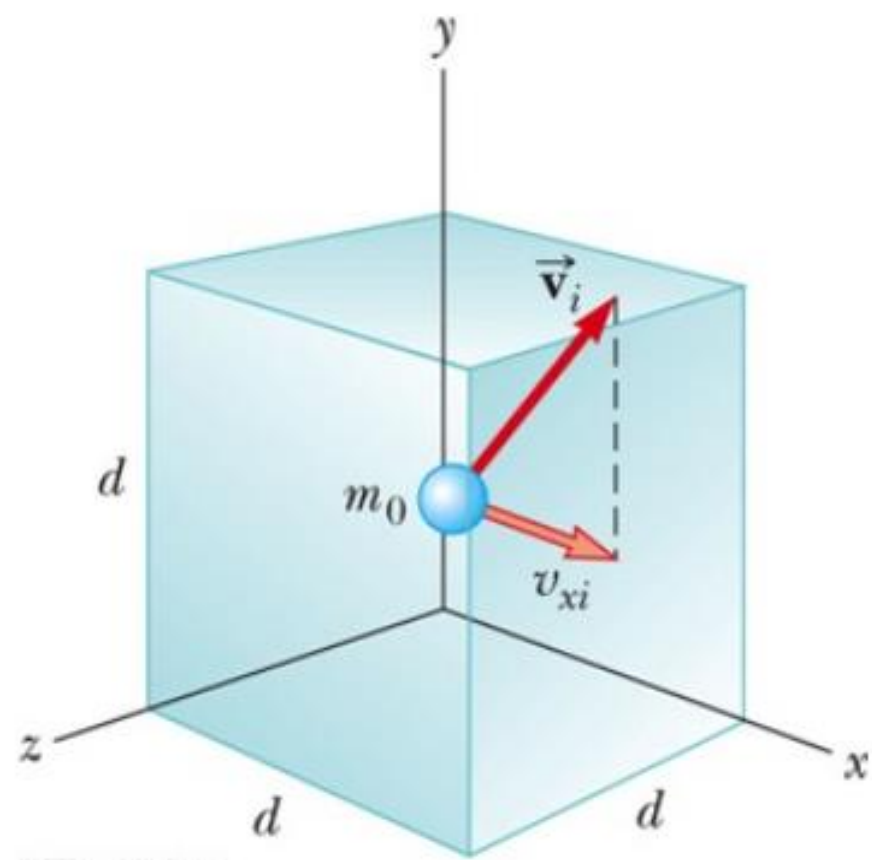
Diffusion is the mixing of particles of two substances caused by their random motion.

Effusion is the process by which gas particles under **pressure** pass through a **tiny opening.**

Symbol:	Name:	Unit/Conversion:
P	Pressure	1 atm = 760 torr = 760 mmHg = 101.3 kPa
T	Temperature	Kelvin (K) = °C + 273
M	Molar Mass	1.429 g/mol
V	Volume	1 L = 1000 mL
n	Amount of Substance	g/mol^{-1}

Pressure and Kinetic Energy

- Assume a container is a cube
  - Edges are length *d*
- Look at the motion of the molecule in terms of its velocity components
- Look at its momentum and the average force



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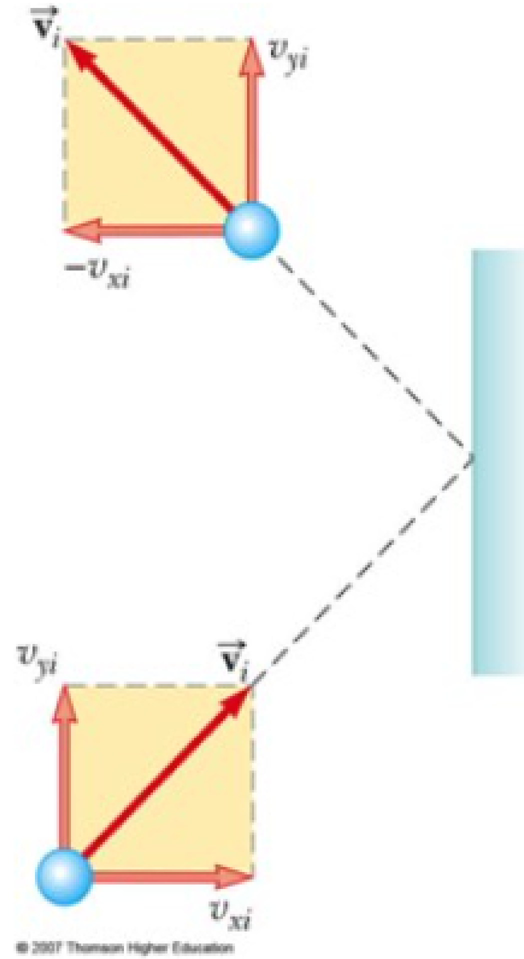
Pressure and Kinetic Energy, 2

- Assume perfectly elastic collisions with the walls of the container
- The relationship between the pressure and the molecular kinetic energy comes from momentum and Newton's Laws
- Use the active figure to observe collisions



Pressure and Kinetic Energy, 3

- The relationship is

$$P = \frac{2}{3}\left(\frac{N}{V}\right)\left(\frac{1}{2}m_o\overline{v^2}\right)$$

- This tells us that pressure is proportional to the number of molecules per unit volume (*N*/*V*) and to the average translational kinetic energy of the molecules

Pressure and Kinetic Energy, final

- This equation also relates the macroscopic quantity of pressure with a microscopic quantity of the average value of the square of the molecular speed
- One way to increase the pressure is to increase the number of molecules per unit volume
- The pressure can also be increased by increasing the speed (kinetic energy) of the molecules

Molecular Interpretation of Temperature

- We can take the pressure as it relates to the kinetic energy and compare it to the pressure from the equation of state for an ideal gas

$$P = \frac{2}{3}\left(\frac{N}{V}\right)\left(\frac{1}{2}m\overline{v^2}\right) = Nk_BT$$

- Therefore, the temperature is a direct measure of the average molecular kinetic energy

Molecular Interpretation of Temperature, cont

- Simplifying the equation relating temperature and kinetic energy gives

$$\frac{1}{2} m_o \overline{v^2} = \frac{3}{2} k_B T$$

- This can be applied to each direction,

$$\frac{1}{2} m \overline{v_x^2} = \frac{1}{2} k_B T$$

  - with similar expressions for v_y and v_z

Total Kinetic Energy

- The total kinetic energy is just N times the kinetic energy of each molecule

$$K_{\text{tot trans}} = N\left(\frac{1}{2}m\overline{v^2}\right) = \frac{3}{2}Nk_B T = \frac{3}{2}nRT$$

- If we have a gas with only translational energy, this is the internal energy of the gas
- This tells us that the internal energy of an ideal gas depends only on the temperature

Root Mean Square Speed

- The root mean square (rms) speed is the square root of the average of the squares of the speeds
  - Square, average, take the square root
- Solving for v_{rms} we find

$$v_{rms} = \sqrt{\frac{3k_B T}{m}} = \sqrt{\frac{3RT}{M}}$$

- M is the molar mass and $M = mN_A$

2.3 Differences Between the Ideal Gases and The Real Gases?

To make you understand how ideal gas and real gas are different from each other, here are the some of the major differences between ideal gas and real gas:

Difference between Ideal gas and Real gas:

Ideal Gases	Real Gases
• No definite volume	• Definite volume
• Elastic collision of particles	• Non elastic collision of particles
• No intermolecular attraction forces	• Intermolecular attraction forces
• Does not really exists in environment and is a hypothetical gas	• It really exists in the environment
• High pressure	• Pressure is less when compared to Ideal gas
• Does not obey gas laws at all conditions of pressure and temperature	• Obeys gas laws at high temperature and
	• low pressure
• Independent	• Interacts with others
• Obey this eq. $Pv = nRT$	• Obey this eq. $p + ((n^2 \mathbf{a})/V^2)(V - n\mathbf{b}) = nRT$

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Thank you