

BASIC EQUATION OF MOLECULAR-KINETIC THEORY

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Abstract:

This article discusses the basic equation, rules, brief history, and concept of ideal gas of molecular kinetic theory.

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Introduction

The branch of physics that studies matter and its properties is called molecular physics. Matter is made up of molecules, and molecules, in turn, are made up of atoms. The doctrine of the structure of matter was first founded by the Greek philosopher Democritus, who lived in the 5th-6th centuries BC. The theory that studies the structure and properties of matter by linking the motion of its constituent molecules and the existence of the force of interaction between molecules is called molecular-kinetic theory. The molecular-kinetic theory of the structure of matter began to develop as an integral theory in the 19th century. Russian scientists MV Lomonosov, DI Mendeleev, English scientists D. Dalton, J. Maxwell, and others contributed to the development of the molecular-kinetic theory.

The molecular-kinetic theory of the structure of matter is based on 3 basic laws. These are:

1. Absolutely all substances (regardless of whether they are liquid, solid or gaseous) have a complex structure, consisting of smaller particles: molecules and atoms.
2. All these elementary particles are constantly in a state of continuous and chaotic motion. For example, we have all seen that dust particles against the background of sunlight are constantly moving in a chaotic direction.
3. There are always attractive and repulsive forces between molecules, and these forces are electromagnetic in nature.

Another example of the second law, which can also be applied to the molecular-kinetic theory of gases, is diffusion. Diffusion is the mutual transfer of molecules of one substance into a second substance, and molecules of the second substance into the first substance.

Also, the molecules in a gas move freely over a considerable distance from each other and interact only at the moment of collision. Therefore, the molecule moves in a straight line for a short time between such collisions, only in cases where a sharp change in its direction occurs after the collision. The short distance over which a gas molecule moves in a straight line is called the mean free distance. The greater the density of the gas, the shorter the distance between its molecules. As a result of the efforts of a number of physicists, in the second half of the 19th century, the atomic-molecular theory of the structure of gases developed significantly and managed to become a universal theory. On the basis of the new and universal theory, the idea was put forward to study the macroscopic properties of gases, such as temperature, pressure and volume, in relation to the number, mass and speed of movement of the molecules that make up this gas, that is, their microscopic properties. Since molecules are in constant and regular motion, they must have molecular kinetic energy. Due to this assertion, the new theory is called the molecular-kinetic theory. Let us take pressure as an example. At any given moment, gas molecules collide with the walls of the container in which they are located. When each molecule collides, it imparts a certain impulse to the container wall, albeit a very small one, as a result of its impact. However, since there are millions of molecules carrying the gas, the total impulse they impart to the container wall when they collide with the container wall acts on the walls with a significant force. We perceive this force as the pressure of the gas molecules on the container wall. For example, by inflating a car tire, we introduce molecules of atmospheric air in addition to the molecules already present in the tire. As a result, a large number of air molecules accumulate in a dense closed volume inside the tire. The density inside is greater than the density of the atmospheric air outside. The large number of molecules in the narrow space also accelerates the collisions between each other and the tire walls. The tire remains taut and relaxed.

Within this theory, the concept of temperature is interpreted in the same way. The higher the temperature, the higher the average speed of the gas molecules. This relationship is expressed using the following formula:

$$\frac{1}{2}m_0v^2=kT$$

where m is the mass of one molecule of gas; v is the average speed of thermal motion of the molecule; T is the temperature of the gas (in Kelvin); and k is the Boltzmann constant, whose value is equal to:

$$k=1.38 \times 10^{-23} \frac{J}{K}$$

$$P = \frac{1}{3}nm_0v^2$$

This equation is the fundamental equation of molecular kinetic theory, and its left side represents the molecular properties, and the right side represents the macroscopic (measurable) properties. That is, the equation establishes a direct relationship between the microscopic and macroscopic properties of a gas. According to it, the temperature of a gas is inversely proportional to the square of the average velocity of the gas molecules.

If we expand the basic equation of molecular kinetic theory, we get the following equation:

$$P = \frac{1}{3}n m_0v^2 = \frac{1}{3} \frac{N}{V} m_0v^2 = \frac{1}{3} \frac{m}{V} v^2 = \frac{2}{3}nW_k$$

where, n is the concentration, m_0 - the mass of one molecule, P is the pressure, V is the volume, N is the number of molecules, W_k - the kinetic energy. From the last equation it follows that the kinetic energy of the forward motion of one gas molecule is equal to:

$$W_k = \frac{3}{2} \frac{P}{n}$$

The molecular-kinetic theory also provides a fairly detailed answer to the question of why the speed of individual molecules is lower than the average value. Each collision of molecules leads to a redistribution of energy between them. That is, as a result of the collision, the molecule with a higher speed slows down, and, conversely, the molecule with a lower speed accelerates. This leads to an

approximation of the speed to the average value. At each moment of time, such collisions of molecules in a gas occur countless millions of times. Nevertheless, according to this theory, it is determined that in a gas at a constant temperature, the average number of molecules with a speed v and an energy E does not change. This is because, from a statistical point of view, the probability that a molecule with energy E will change its energy and go to another energy level is equal to the probability that another molecule will change its energy and acquire exactly the same energy E . Accordingly, the number of molecules with energy E remains unchanged. This can be explained by an analogy: let's say the number of 10-year-olds in a high school this year is 100. However, none of the 10-year-olds this year will be 10 next year. All of them will be 11 next year. However, this does not change the total number of 10-year-olds in the school. Because next year, there will definitely be about the same number (in our example, one hundred) of 10-year-olds in the school.

We have touched on the field of physics such as molecular physics and thermodynamics, that is, molecular-kinetic theory, which expands our understanding of the ideal gas model. To consider the gas as ideal, the following changes are made:

1. A molecule should be considered as an elastic sphere that cannot be compressed or crushed.
2. The specific volume of the molecule should not be taken into account.
3. The potential energies of interactions between molecules should not be taken into account.
4. The forces of interaction between molecules should not be taken into account.
5. The number of collisions between molecules should be considered negligible compared to the number of collisions with the container wall.

The basic equation of the kinetic molecular theory states that the pressure of gases depends on the mass, concentration, and speed of their molecules. This theory helps explain the physical properties of gases from a microscopic point of view. Gas molecules are in constant motion and create pressure by hitting the walls of a container. As the temperature increases, the average speed and energy of the molecules increase, which affects the pressure and volume changes. The kinetic molecular theory is related to the ideal gas equation of state and also provides a basis for understanding the behavior of real gases.

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