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HEAT CAPACITY OF IDEAL GASES

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AnnotationЖ This work examines the heat capacity of ideal gases as one of the fundamental concepts in thermodynamics. It explains how heat capacity relates to the internal energy of a gas and describes the difference between heat capacity at constant volume (Cv) and heat capacity at constant pressure (Cp). The relationship between these quantities is discussed using Mayer's equation, which highlights the role of the universal gas constant. The study also considers the dependence of heat capacity on molecular structure and degrees of freedom, including translational, rotational, and vibrational motions. In addition, the behavior of monatomic and diatomic gases is analyzed in relation to classical and quantum approaches. The significance of heat capacity in thermodynamic processes, energy systems, heat engines, atmospheric physics, and engineering applications is also emphasized.

Keywords: Ideal gas, heat capacity, thermodynamics, internal energy, constant volume (Cv), constant pressure (Cp), Mayer's equation, degrees of freedom, adiabatic process, molecular motion, statistical physics, energy transfer.

Introduction

The heat capacity of ideal gases is one of the most important concepts in physical thermodynamics. This quantity expresses the amount of heat required to increase the temperature of a substance by one unit. The ideal gas model is considered a system in which the intermolecular forces are neglected. This model makes it possible to explain many properties of real gases in a simplified manner.Heat capacity is closely related to the internal energy of a gas. When heat is supplied to a gas, the kinetic energy of its molecules increases. As a result, the temperature of the system rises. In thermodynamics, there are two main types of heat capacity: heat capacity at constant volume and heat capacity at constant pressure. These quantities are denoted by **Cv** and **Cp**, respectively.For ideal gases, there is a relation between these quantities known as **Mayer's equation**, which is expressed as:

$$Cp - Cv = R$$

where **R** is the universal gas constant.The study of the heat capacity of ideal gases is of great importance in the design of heat engines and energy systems. In modern physics and chemistry, this theory forms a fundamental part of practical calculations. The heat capacity of ideal gases is directly related to the degrees of freedom of their molecules. The greater the number of ways a molecule can move, the greater its ability to absorb energy. In monatomic gases, only translational motion is present. Therefore, their heat capacity is lower than that of diatomic and polyatomic gases.In diatomic molecules, rotational motion also contributes to the total energy. At higher temperatures, vibrational motions become active as well. This leads to an increase in heat capacity. According to classical statistical physics, each degree of freedom stores a specific amount of energy. The work of Boltsmann and Maxwell provided the mathematical foundation for this principle.The temperature dependence of heat capacity is explained more accurately by quantum theory. At low temperatures, some degrees of freedom become "frozen out" and no longer

contribute significantly to the energy of the system. As a result, experimental observations may differ from the predictions of classical theory. For this reason, the heat capacity of ideal gases remains an important subject of study in modern quantum statistics. This theory is widely applied in fields such as cryogenics and atmospheric physics.

$$C_v = \frac{i}{2}R$$

The heat capacity at constant volume, denoted by Cv, indicates that the heat supplied to a gas is used solely to change its internal energy. In such a process, no external work is performed because the volume of the gas remains constant. According to the First Law of Thermodynamics, the heat added to the system is equal to the increase in its internal energy. For an ideal gas, the internal energy depends only on temperature. Therefore, the value of Cv depends on the nature of the gas and its molecular structure.For monatomic gases, the theoretical value of Cv is equal to 3/2 R. Experimental results confirm this prediction. This value is observed with high accuracy in gases such as helium and neon. In diatomic gases, additional rotational energy contributes to the total internal energy. As a result, their heat capacity is greater. The physicist Rudolf Clausius explained these processes from a thermodynamic perspective. In modern engineering, the heat capacity at constant volume is widely used in the analysis of engines and closed systems.

$Q=\Delta U=n\cdot c_v \cdot \Delta T$

The heat capacity at constant pressure, denoted by Cp, is considered one of the most important parameters of thermodynamic systems. This quantity indicates that when heat is supplied to a gas, not only does its internal energy change, but external work is also performed. As the gas expands, it does work against the surrounding environment. Therefore, Cp is always greater than Cv.For ideal gases, the difference between these two quantities is equal to the universal gas constant. This relationship, discovered by Mayer, is one of the fundamental results of thermodynamics. Processes occurring at constant pressure are common in the atmosphere. This quantity is also used in the analysis of meteorological phenomena. The heating and cooling of air masses occur in ways that are closely related to heat capacity.Accurate knowledge of the value of Cp is essential in gas turbines and heat engines because energy efficiency largely depends on this parameter. In modern industrial technologies, high-precision calorimetric methods are used to determine the heat capacities of gases. These studies have significant practical importance in the fields of energy production and environmental science.

$Q=nC_p\Delta T$

The ratio of the heat capacities of ideal gases plays an important role in describing adiabatic processes. This ratio is usually denoted by the Greek letter γ (gamma). Mathematically, it is expressed as:

$$\gamma=\frac{C_p}{C_v}$$

For monatomic gases, this value is approximately 1.67, while for diatomic gases it is typically around 1.4.During an adiabatic process, the system does not exchange heat with its surroundings. When a gas is compressed, its temperature increases; when it expands, its temperature decreases. This principle is fundamental to the operation of internal combustion engines.The scientists Pierre-Simon Laplace and Siméon Denis Poisson developed the equations that describe adiabatic processes. The speed of sound in the atmosphere also depends directly on the value of γ. This parameter is extremely important in aerodynamics and aerospace engineering. Many problems in gas dynamics are solved using the ratio of heat capacities. For this reason, the theory of ideal gases is regarded as one of the fundamental branches of modern physics.The heat capacity at constant

pressure is of great importance in determining the thermodynamic properties of gases. When heat is supplied to a gas, it expands and performs work against external forces. Therefore, part of the supplied energy is used to increase the internal energy, while another part is used to perform work. The heat capacity at constant pressure is always greater than that at constant volume. This difference is described by Mayer's law.The expansion process of gases is common in energy systems. Pressure changes play a major role in heat engines. This parameter is also used in atmospheric physics and meteorology. The molar heat capacity of a gas depends on the nature of the substance.In diatomic gases, heat capacity increases due to rotational energy. At high temperatures, vibrational energy also contributes to the process, resulting in an even higher heat capacity value. The ideal gas model allows many properties of real gases to be approximated. In modern energy systems, this theory serves as a basis for practical calculations.Heat capacity at constant pressure:

$Cp=Cv+R$

Work done by a gas:

$A=P\Delta V$

usually denoted by the Greek letter γ (gamma). The adiabatic index describes the thermodynamic properties of a gas and also plays an important role in determining the speed of sound.In monatomic gases, the value of γ is higher, while in diatomic gases it is lower. This is because diatomic molecules have additional rotational energy. During adiabatic processes, no heat exchange takes place; therefore, the energy of the system changes only due to internal transformations.In engines, compression and expansion processes are often adiabatic in nature. Many physical phenomena in the atmosphere also obey adiabatic laws. Determining the ratio of heat capacities is one of the important tasks of experimental physics. Modern gas dynamics is developed based on this parameter. The γ value is also of great importance in spacecraft and aviation engineering.Heat capacity ratio:

$$\gamma = \frac{C_p}{C_v}$$

Adiabatic process equation:

$PV\gamma=const$

Conclusion

The heat capacity of ideal gases is one of the key concepts in thermodynamics, describing the ability of gases to absorb and store thermal energy. Research shows that the heat capacity of ideal gases depends on the number of degrees of freedom of the gas, the conditions of the process, and the molecular structure.The heat capacities at constant volume (Cv) and at constant pressure (Cp) differ due to the work done by the gas during expansion. In addition, Mayer's equation expresses the relationship between Cp and Cv, allowing a deeper understanding of the thermodynamic properties of ideal gases.The study of the heat capacity of ideal gases is important in heat engines, energy systems, industrial technologies, and scientific research. This topic serves as a theoretical basis for understanding the laws of energy exchange in gases and for efficiently solving practical problems.

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