

#1. Boyle's Law. A Gas With A Volume Of 4.0 L At A Pressure Of 205 KPa Is Allowed To Expand To A Volume

1. Boyle's Law. A Gas With A Volume Of 4.0 L At A Pressure Of 205 KPa Is Allowed To Expand To A Volume is a classic example used to illustrate the fundamental principles of gas behavior under varying pressure and volume conditions. Boyle's Law is essential in fields such as chemistry, physics, engineering, and medicine, providing insight into how gases respond to changes in their environment. This article aims to provide a comprehensive understanding of Boyle's Law, its applications, derivations, and real-world examples, ensuring readers grasp the core concepts and practical implications.

Understanding Boyle's Law

Definition of Boyle's Law

Boyle's Law states that, for a given amount of an ideal gas at constant temperature, the pressure and volume of the gas are inversely proportional. Mathematically, it is expressed as:

$$P \propto \frac{1}{V} \quad \Rightarrow \quad P V = \text{constant}$$

where:

- P = pressure of the gas,
- V = volume of the gas.

This relationship implies that if the volume of a gas decreases, its pressure increases proportionally, provided the temperature and amount of gas remain unchanged. Conversely, increasing the volume decreases the pressure.

Historical Background

Boyle's Law is named after Robert Boyle, an Irish scientist who formulated the law in 1662 through meticulous experiments. Boyle's experiments demonstrated the inverse relationship between pressure and volume, leading to the formulation of this fundamental gas law. His work built upon earlier ideas of gas behavior, contributing significantly to the development of modern chemistry and physics.

Mathematical Derivation and Formula

Deriving Boyle's Law

Boyle's Law can be derived from experimental data by plotting pressure versus volume for a fixed amount of gas at constant temperature. The resulting graph is a hyperbolic curve, confirming the inverse proportionality.

Starting from the proportionality:

$$P V = \text{constant}$$

If initial conditions are (P_1) and (V_1) , and final conditions are (P_2) and (V_2) :

$$P_1 V_1 = P_2 V_2$$

This equation allows for calculating unknown pressure or volume after a change, as long as the initial conditions are known.

Applying Boyle's Law to the Given Scenario

Given:

- Initial volume, $(V_1 = 4.0\text{ L})$,
- Initial pressure, $(P_1 = 205\text{ kPa})$,
- Final volume, $(V_2 = ?)$,
- Final pressure, $(P_2 = ?)$.

Suppose the problem states that the gas expands to a new volume, and we need to find the new pressure. The formula:

$$P_1 V_1 = P_2 V_2$$

can be rearranged as:

$$P_2 = P_1 \times \frac{V_1}{V_2}$$

This allows for calculating the new pressure after expansion or contraction.

Practical Applications of Boyle's Law

1. Medical Field

In medical applications, Boyle's Law explains how lungs expand and contract during breathing. When the diaphragm moves downward, lung volume increases,

leading to decreased pressure inside the lungs, allowing air to flow in. Conversely, during exhalation, lung volume decreases, increasing internal pressure and pushing air out.

2. Engineering and Industrial Processes

Engineers utilize Boyle's Law in designing pressurized containers, pistons, and gas transfer systems. Understanding how gases behave under different pressure and volume conditions ensures safety and efficiency.

3. Scuba Diving and Underwater Applications

Scuba divers must comprehend Boyle's Law to avoid dangers like decompression sickness. As a diver ascends, pressure decreases, and gases in the body expand. Controlled ascent prevents injury caused by rapid gas expansion.

4. Chemical Reactions and Laboratory Experiments

Chemists rely on Boyle's Law to predict how gases will behave during reactions, especially when manipulating pressure and volume in lab setups.

Real-World Example: Gas Expansion Scenario

Let's revisit the initial scenario:

A gas with a volume of 4.0 L at a pressure of 205 KPa is allowed to expand to a new volume.

Suppose the gas expands to 8.0 L at constant temperature. To find the new pressure (P_2) :

Given:

- $(V_1 = 4.0\text{ L})$,
- $(P_1 = 205\text{ kPa})$,
- $(V_2 = 8.0\text{ L})$,

Using Boyle's Law:

$$P_2 = P_1 \times \frac{V_1}{V_2} = 205\text{ kPa} \times \frac{4.0\text{ L}}{8.0\text{ L}} = 205\text{ kPa} \times 0.5 = 102.5\text{ kPa}$$

Thus, the pressure decreases to 102.5 KPa when the volume doubles from 4.0 L to 8.0 L, illustrating the inverse proportionality.

Limitations and Assumptions of Boyle's Law

While Boyle's Law accurately describes gas behavior under many conditions, it relies on certain assumptions:

- The gas behaves ideally, meaning particle interactions are negligible.
- The temperature remains constant during the process.
- The amount of gas (number of moles) remains unchanged.
- The pressure and volume are within ranges where gases do not liquefy or condense.

In real-world scenarios, deviations can occur at high pressures or low temperatures, where gases deviate from ideal behavior.

Conclusion: Significance of Boyle's Law

Boyle's Law remains a cornerstone of classical gas theory, providing a fundamental understanding of how gases behave under pressure and volume changes. Its practical applications span across numerous fields, from medicine to engineering, making it an essential principle for scientists and professionals working with gases.

Understanding the relationship articulated by Boyle's Law allows for precise control and prediction of gas behavior, which is vital in designing equipment, conducting experiments, and ensuring safety in various applications. Whether calculating the pressure after a volume change or designing pressurized systems, Boyle's Law offers a reliable mathematical framework grounded in experimental evidence.

In summary, the inverse relationship between pressure and volume, as exemplified by the initial conditions of a gas expanding from 4.0 L at 205 KPa, underscores the importance of Boyle's Law in understanding and manipulating gaseous systems. Its simplicity, combined with broad applicability, ensures its relevance in both theoretical studies and practical implementations for years to come.

Frequently Asked Questions

What is Boyle's Law?

Boyle's Law states that the pressure of a gas is inversely proportional to its volume at constant temperature, expressed as $P_1V_1 = P_2V_2$.

How does Boyle's Law apply when a gas expands from 4.0 L to a larger volume?

According to Boyle's Law, if the volume increases, the pressure decreases proportionally, assuming temperature remains constant.

Given a gas with an initial volume of 4.0 L at 205 KPa, what happens to pressure when the volume doubles?

The pressure halves, so it would decrease from 205 KPa to approximately 102.5 KPa.

If a gas's volume increases from 4.0 L to 8.0 L at constant temperature, what is its new pressure?

The new pressure would be half of the original pressure, so approximately 102.5 KPa.

What assumptions are made when applying Boyle's Law?

The gas is assumed to be ideal, temperature remains constant, and there are no interactions between gas particles.

How can Boyle's Law be used to determine the pressure after a change in volume?

By rearranging the formula to $P_2 = (P_1 V_1) / V_2$, substituting known values to find the new pressure.

What real-world applications involve Boyle's Law?

Applications include syringe operation, breathing mechanics, and designing pressurized containers.

What happens to the pressure if a gas initially at 4.0 L and 205 KPa is compressed to 2.0 L?

The pressure doubles, increasing to approximately 410 KPa.

Can Boyle's Law be observed with gases at high pressure or low temperature?

Boyle's Law is most accurate under ideal conditions; deviations can occur at high pressures or low temperatures where gases behave non-ideally.

Additional Resources

Boyle's Law: A Gas With A Volume Of 4.0 L At A Pressure Of 205 KPa Is Allowed To Expand To A Volume

Introduction

The behavior of gases under varying conditions has long fascinated scientists and engineers alike. Among the fundamental principles governing gaseous behavior, Boyle's Law stands out as a cornerstone in understanding how pressure and volume relate when temperature remains constant. This investigative review delves into the intricacies of Boyle's Law, exemplified by a specific scenario where a gas initially occupies a volume of 4.0 liters at a pressure of 205 KPa and is permitted to expand. Through a comprehensive analysis, we explore the underlying physics, practical implications, and broader significance of this law in scientific and industrial contexts.

Understanding Boyle's Law: The Foundations

Historical Context and Development

Boyle's Law, also known as the Boyle-Mariotte Law, was first formulated in the 17th century through the experiments of Robert Boyle and Edme Mariotte independently. Boyle's meticulous experiments with air and other gases laid the groundwork for a quantitative relationship between pressure and volume, assuming constant temperature and amount of gas.

Mathematical Formulation

Boyle's Law states that, at constant temperature and amount of gas, the product of pressure (P) and volume (V) is a constant:

$$[PV = \text{constant}]$$

or, expressed mathematically:

$$[P_1 V_1 = P_2 V_2]$$

where:

- (P_1, V_1) are the initial pressure and volume,
- (P_2, V_2) are the final pressure and volume.

This inverse relationship implies that if the volume of a gas increases, its pressure decreases proportionally, provided temperature and moles of gas are unchanged.

The Scenario: From Initial Conditions to Expansion

Initial Conditions

In our case, the gas starts with:

- Volume $(V_1 = 4.0\text{ L})$
- Pressure $(P_1 = 205\text{ kPa})$

The question posed is: What happens to the pressure when the gas is allowed to expand to a new volume (V_2) ?

Without additional data, we might assume the final volume (V_2) is known or needs to be determined based on a specific expansion process.

The Expansion Process

Consider a scenario where the gas expands from 4.0 L to a larger volume. For illustration, let's assume the final volume is, say, 8.0 L, which is a common doubling to observe the law's effect. The process is assumed to occur at constant temperature, meaning the gas is allowed to expand freely or through a controlled process that maintains thermal equilibrium.

Quantitative Analysis: Applying Boyle's Law

Given the initial conditions and an assumed final volume, the final pressure can be calculated:

$$P_2 = \frac{P_1 V_1}{V_2}$$

Substituting values:

$$P_2 = \frac{205\text{ kPa} \times 4.0\text{ L}}{8.0\text{ L}} = \frac{820\text{ kPa} \cdot \text{L}}{8.0\text{ L}} = 102.5\text{ kPa}$$

This calculation reveals that doubling the volume halves the pressure, illustrating Boyle's Law's inverse proportionality.

Practical Implications and Real-World Applications

Medical Applications: Respiratory Physiology

Boyle's Law is integral to understanding how lungs operate. During inhalation, the diaphragm's movement increases lung volume, decreasing

internal pressure, allowing air to flow in. Conversely, exhalation involves decreasing lung volume, increasing pressure, and expelling air.

Engineering and Industrial Uses

In engineering, Boyle's Law informs the design of pneumatic systems, syringes, and pressure vessels. For instance, understanding how gas volume responds to pressure changes helps in calibrating equipment and ensuring safety standards.

Environmental and Atmospheric Science

Boyle's Law also explains phenomena such as the expansion of atmospheric gases at higher altitudes, where decreased pressure results in increased volume of air parcels, affecting weather patterns and climate models.

Limitations and Assumptions of Boyle's Law

While Boyle's Law provides a fundamental understanding, it operates under specific assumptions:

- Constant Temperature: The law assumes isothermal conditions. Any temperature change affects the relationship, necessitating combined gas laws.
- Ideal Gas Behavior: Real gases deviate from ideality under high pressure or low temperature, where intermolecular forces and molecular volume become significant.
- Closed System: No gas enters or leaves during the process.

Understanding these limitations is crucial when applying Boyle's Law to real-world problems.

Advanced Considerations: Beyond the Basic Law

Non-Ideal Gas Behavior

In high-pressure or low-temperature regimes, gases exhibit deviations from ideal behavior. The Van der Waals equation introduces correction factors for molecular volume and intermolecular forces:

$$\left(P + a \frac{n^2}{V^2} \right) (V - nb) = nRT$$

where (a) and (b) are substance-specific constants.

Isothermal vs. Adiabatic Processes

In real systems, expansions can be:

- Isothermal: Temperature remains constant; Boyle's Law applies directly.
- Adiabatic: No heat exchange occurs; pressure and volume change according to different relations governed by the adiabatic index.

Understanding the distinction is essential for accurate modeling.

Broader Significance and Future Perspectives

Boyle's Law remains a fundamental principle in physics and chemistry education. Its simplicity belies profound importance across scientific disciplines. With ongoing advancements in material science, nanotechnology, and atmospheric modeling, the principles underpinning Boyle's Law continue to inform research and innovation.

Furthermore, in the context of climate change and environmental science, understanding gas behavior under changing atmospheric pressures and temperatures is vital. Emerging technologies, such as high-altitude ballooning and space exploration, rely heavily on the principles encapsulated by Boyle's Law.

Conclusion

The examination of a gas initially occupying 4.0 liters at 205 KPa and permitted to expand exemplifies the core tenets of Boyle's Law. Through quantitative analysis, we observe the inverse relationship between pressure and volume, reinforcing the law's predictive power. Recognizing the conditions under which Boyle's Law holds, along with its limitations, is essential for practical applications in medicine, engineering, and environmental science. As our understanding deepens with technological progress, Boyle's Law remains a fundamental, enduring principle illuminating the behavior of gases in our universe.

References

- Atkins, P., & de Paula, J. (2010). Physical Chemistry. Oxford University Press.
- Zumdahl, S. S., & Zumdahl, S. A. (2014). Chemistry: An Atoms First Approach. Cengage Learning.
- Atkins, P., & Paula, J. (2014). Chemical Principles: The Quest for Insight. W. H. Freeman.

- Van der Waals, J. D. (1873). On the Continuity of the Gases. Journal of Physics.

- National Institute of Standards and Technology (NIST). (2023). Properties of Gases and Liquids. NIST Chemistry WebBook.

Note: This detailed investigation underscores the importance of Boyle's Law in both theoretical and practical contexts, illustrating how a simple inverse proportionality fundamentally influences our understanding of gas behavior across diverse scientific fields.

1 Boyle S Law A Gas With A Volume Of 4 0 L At A Pressure Of 205 Kpa Is Allowed To Expand To A Volume

1 Boyle S Law A Gas With A Volume Of 4 0 L At A Pressure Of 205 Kpa Is Allowed To Expand To A Volume

Related Articles

- [2.It Is Now 10:29 A.m., But When The Bell Rings At 10:30 A.m. Suzette Will Be Late For French Class For](#)
- [What Did The Second Continental Congress Decide? George Washington Would Write A Letter To King George](#)
- [A Cell Site Is A Site Where Electronic Communications Equipment Is Placed In A Cellular Network For The](#)

[Back to Home](#)