A Gas Occupies 11.2 Liters At 0.860 Atm. What Is The Pressure If The Volume Is Doubled?

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Understanding how gases behave under different conditions is fundamental in chemistry and physics. When dealing with gases, the relationship between pressure, volume, temperature, and amount of gas is described by the ideal gas law. In this article, we explore a common problem: a gas initially occupies a certain volume and pressure, and we want to determine its new pressure after its volume is doubled, assuming temperature and amount of gas remain constant. This scenario illustrates the practical application of Boyle’s Law, one of the key principles governing gases.

Introduction to Gas Laws

Before diving into the specific problem, it’s important to understand the foundational gas laws that describe the behavior of gases under changing conditions.

Boyle’s Law

Boyle’s Law states that, at constant temperature and amount of gas, the pressure of a gas is inversely proportional to its volume:

$$P_1 V_1 = P_2 V_2$$

Where:
- P_1 = initial pressure
- V_1 = initial volume
- P_2 = final pressure
- V_2 = final volume

This relationship means that if you double the volume of a gas, its pressure halves, provided temperature and moles of gas stay the same.

Ideal Gas Law

The ideal gas law combines pressure, volume, temperature, and moles:

$$PV = nRT$$

Where:
- P = pressure
- V = volume
- n = number of moles
- R = universal gas constant
- T = temperature in Kelvin

For this problem, since temperature and moles are constant, Boyle’s Law suffices.

Given Data and Problem Setup

Let's analyze the problem step by step.

Initial Conditions

- Initial volume, $V_1 = 11.2\, \text{liters}$
- Initial pressure, $P_1 = 0.860\, \text{atm}$
- Temperature and number of moles remain constant throughout the process.

Final Conditions

- Final volume, $V_2 = 2 \times V_1 = 2 \times 11.2\, \text{liters} = 22.4\, \text{liters}$
- Final pressure, $P_2 = ?$

The goal is to find P_2.

Applying Boyle’s Law to Find the Final Pressure

Since temperature and amount of gas are constant, Boyle’s Law applies directly:

$$P_1 V_1 = P_2 V_2$$

Rearranged to solve for P_2:

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

Substituting the known values:

$$P_2 = \frac{0.860\, \text{atm} \times 11.2\, \text{liters}}{22.4\, \text{liters}}$$

Calculating numerator:

$$ 0.860 \times 11.2 = 9.632\, \text{atm} \cdot \text{liters} $$

Dividing by the new volume:

$$ P_2 = \frac{9.632}{22.4} \approx 0.43\, \text{atm} $$

Result: When the volume is doubled, the pressure drops to approximately 0.43 atm.

Understanding the Implications of the Result

This problem exemplifies Boyle’s Law in action and highlights the inverse relationship between pressure and volume.

Key Takeaways

- Doubling the volume halves the pressure.
- The pressure decreases proportionally as volume increases.
- The initial pressure was 0.860 atm, and after doubling the volume, it reduces to approximately 0.43 atm.

Real-World Applications

Understanding these relationships is crucial in numerous fields:

- Scuba Diving: Gas volume and pressure change with depth.
- Chemical Engineering: Designing reactors that involve gas compression.
- Meteorology: Atmospheric pressure changes with altitude.
- Aerospace: Behavior of gases in spacecraft and aircraft.

Additional Considerations

While Boyle’s Law provides a straightforward calculation, real gases can deviate from ideal behavior under certain conditions.

Non-Ideal Gas Behavior

- At high pressures or low temperatures, gases may not follow Boyle's Law precisely.
- Intermolecular forces and molecular volume influence gas behavior.
- Corrections are made using Van der Waals equation for real gases.

Temperature Stability Assumption

In this problem, temperature is assumed constant. If temperature varies, the ideal gas law must be used to account for changes:

$$ P V = n R T $$

- If temperature increases, pressure tends to increase.
- If temperature decreases, pressure tends to decrease.

Summary of Key Steps to Solve Similar Problems

To approach similar gas law problems, follow these steps:

1. Identify Known Variables: Initial pressure, volume, temperature, and moles.
2. Determine What Is Being Asked: Final pressure, volume, temperature, or moles.
3. Select Appropriate Law: Boyle's Law if temperature and moles are constant.
4. Write the Equation and Rearrange: Solve for the unknown.
5. Substitute Values and Calculate: Be careful with units.
6. Interpret Results: Consider physical meaning and real-world implications.

Conclusion

The relationship between pressure and volume for gases is fundamental in understanding their behavior. In the specific scenario where a gas initially occupies 11.2 liters at 0.860 atm, and its volume is doubled, the pressure decreases to approximately 0.43 atm. This inverse proportionality exemplifies Boyle's Law, illustrating how gases respond to changes in volume under constant temperature conditions. Whether in scientific research, engineering, or everyday applications, mastering these principles enables a deeper understanding of the gaseous state and its practical implications.

Meta Description:

Learn how to calculate the new pressure of a gas when its volume is doubled, given initial conditions of 11.2 liters at 0.860 atm. Explore Boyle's Law with detailed explanations and practical insights.

Frequently Asked Questions

What is the initial pressure of the gas if it occupies 11.2 liters at 0.860 atm?

The initial pressure is given as 0.860 atm.

If the volume of the gas is doubled while temperature remains constant, what is the new volume?

The new volume is 2×11.2 liters = 22.4 liters.

Which gas law applies to determine the new pressure after doubling the volume?

Boyle's Law applies, which states that $P_1V_1 = P_2V_2$ at constant temperature.

Calculate the new pressure of the gas when its volume is doubled?

Using Boyle's Law: $P_2 = P_1V_1 / V_2 = (0.860 \text{ atm} \times 11.2 \text{ L}) / 22.4 \text{ L} = 0.430 \text{ atm}$.

What is the final pressure of the gas after doubling the volume at constant temperature?

The final pressure is 0.430 atm.

Additional Resources

A Gas Occupies 11.2 Liters At 0.860 Atm. What Is The Pressure If The Volume Is Doubled?

Understanding the behavior of gases under different conditions is fundamental to the fields of chemistry, physics, and engineering. This question, which involves calculating the new pressure of a gas when its volume doubles, draws upon core principles of gas laws—particularly Boyle's Law. Delving into this problem provides not only a practical application of theoretical concepts but also a window into the importance of these laws in real-world scenarios such as industrial processes, meteorology, and even space exploration. In this comprehensive analysis, we will explore the foundational principles, step-by-step calculations, and broader implications of this scenario, ensuring a thorough grasp of the subject matter.

Foundational Principles: The Behavior of Gases

Understanding Gas Laws

Gases are characterized by their high compressibility and ability to expand to fill their containers. Their behavior is governed by a set of empirical laws that describe relationships between pressure (P), volume (V), temperature (T), and amount of gas (n). The most relevant laws for this particular problem are:

- Boyle's Law: States that at constant temperature and amount of gas, the pressure of a gas is inversely proportional to its volume:

$$
P \propto \frac{1}{V}
$$

or

$$
P_1 V_1 = P_2 V_2
$$

- Charles's Law: Describes how volume varies directly with temperature at constant pressure.
- Gay-Lussac's Law: Describes how pressure varies directly with temperature at constant volume.
- Combined Gas Law: Integrates Boyle's, Charles's, and Gay-Lussac's laws, useful when multiple variables change.

Since the problem specifies a change in volume at constant temperature and amount of gas, Boyle's Law is the primary principle to apply.

Ideal Gas Law as a Framework

The Ideal Gas Law combines these relationships into a single equation:

$$
PV = nRT
$$

Where:
- P = pressure (atm)
- V = volume (liters)
- n = amount of gas (moles)
- R = ideal gas constant (0.082057 L·atm/(mol·K))
- T = temperature (Kelvin)

In scenarios where the temperature and amount of gas remain constant, the law simplifies to Boyle's

Law.

Given Data and Objective

Initial conditions:
- Initial volume, $V_1 = 11.2$ liters
- Initial pressure, $P_1 = 0.860$ atm

Change:
- The volume is doubled: $V_2 = 2 \times V_1 = 2 \times 11.2 = 22.4$ liters

Question:
- What is the new pressure, P_2, after the volume doubles?

Step-by-Step Calculation Using Boyle's Law

Applying Boyle's Law

Since temperature and the number of moles are assumed constant, Boyle's Law applies:

$$
P_1 V_1 = P_2 V_2
$$

Rearranged to solve for P_2:

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

Substituting the known values:

$$
P_2 = \frac{0.860\, \text{atm} \times 11.2\, \text{L}}{22.4\, \text{L}}
$$

Calculating numerator:

$$
0.860 \times 11.2 = 9.632
$$

Dividing:

$$
P_2 = \frac{9.632}{22.4} \approx 0.43\, \text{atm}
$$

Result:

$$
\boxed{
P_2 \approx 0.43\, \text{atm}
}
$$

This indicates that doubling the volume halves the pressure, which aligns with the inverse relationship described by Boyle's Law.

Understanding the Implications and Broader Context

Theoretical Significance

The calculation succinctly demonstrates a fundamental property of gases: their pressure is inversely proportional to their volume at constant temperature. This inverse relationship is critical in various scientific and engineering applications:

- Industrial Gas Storage: Ensuring safety and efficiency when storing gases under different pressures and volumes.
- Respiratory Physiology: Understanding how lung volume and pressure relate during breathing.
- Aerospace Engineering: Designing pressurized cabins that can withstand volume changes due to altitude variations.

Practical Considerations and Limitations

While Boyle's Law provides an idealized model, real gases exhibit deviations under certain conditions:

- High Pressures: Molecules interact more, leading to deviations from ideal behavior.
- Low Temperatures: Molecules move slower, and condensation or liquefaction may occur.
- Non-constant Temperature or Moles: Real systems often involve simultaneous changes, requiring the use of the combined gas law or ideal gas law for accurate calculations.

Thus, in practical applications, corrections and more complex models (such as Van der Waals Equation) may be necessary.

Influence of Temperature and Moles

In this specific problem, temperature and moles are held constant, simplifying the analysis. However, in real-world scenarios, changes in temperature or the amount of gas can alter the pressure-volume relationship significantly. For example:

- Heating the gas: Increases kinetic energy, which can increase pressure if volume is constant.
- Adding more gas: Increases the number of molecules, thereby increasing pressure if volume and temperature are held constant.

Extensions and Related Concepts

Calculating Other Properties

The approach used here can be extended to compute other properties:

- Work Done by Gas: When volume changes, work is performed or absorbed, calculated as $W = P \Delta V$.
- Change in Internal Energy: For an ideal gas at constant temperature, internal energy remains unchanged, but at different temperatures, it varies with heat capacity.

Real-World Examples

1. Balloon Expansion: When a hot air balloon ascends, the external pressure decreases, and the gas inside expands, illustrating Boyle's Law in action.
2. Industrial Gas Compression: Compressors increase pressure by decreasing volume, following similar principles.
3. Vacuum Systems: Creating a low-pressure environment involves increasing volume or removing gas molecules.

Conclusion

The problem of determining the new pressure of a gas when its volume doubles, given initial conditions, exemplifies the foundational principles of gas behavior. Applying Boyle's Law, we find that the pressure decreases proportionally with the increase in volume, resulting in a new pressure of approximately 0.43 atm. This straightforward calculation not only reinforces core scientific concepts but also underscores their significance across diverse fields—from medical ventilation to aerospace engineering. Understanding these relationships equips scientists and engineers with the predictive tools necessary to design safe, efficient, and innovative systems that leverage the unique properties of gases.

By appreciating the nuances and limitations of ideal gas laws, professionals can better interpret real-world data, anticipate deviations, and develop more sophisticated models. Ultimately, mastering these principles enhances our ability to manipulate and utilize gases effectively, a testament to the enduring importance of fundamental scientific laws in advancing technology and understanding our environment.

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