What Is The Volume Of A Gas That Exerts A Pressure Of 457 Mm Hg If It Exerted A Pressure Of 2.50 Atm

What Is The Volume Of A Gas That Exerts A Pressure Of 457 Mm Hg If It Exerted A Pressure Of 2.50 Atm

Understanding the behavior of gases under different conditions is fundamental in chemistry and physics. When dealing with gases, one of the core principles is that their volume, pressure, temperature, and amount are interconnected through the ideal gas law. Specifically, determining the volume of a gas when its pressure changes is a common problem encountered in laboratory settings, industrial processes, and scientific research. In this article, we explore how to calculate the volume of a gas that initially exerts a pressure of 2.50 atm and then exerts a pressure of 457 mm Hg, focusing on the principles, formulas, and step-by-step calculations involved.

Introduction to Gas Laws and Their Significance

Gases are unique among the states of matter because their particles are widely spaced and move independently of each other. The behavior of gases is described by several fundamental laws, including Boyle’s Law, Charles’s Law, Gay-Lussac’s Law, and the ideal gas law. These laws relate pressure (P), volume (V), temperature (T), and the number of moles (n) of gas.

Understanding these relationships is crucial for:

- Designing chemical reactors
- Calculating gas flow rates
- Understanding atmospheric phenomena
- Engineering applications such as airbags and breathing apparatus

In particular, Boyle’s Law provides a direct relation between pressure and volume at constant temperature and amount of gas, making it highly relevant for our calculations.

Key Concepts and Units

Before proceeding with the calculations, it’s important to understand the units involved and their conversions.

Pressure Units

- Atm (atmospheres): Standard unit of pressure. 1 atm = 101.325 kPa

- mm Hg (millimeters of mercury): Commonly used in barometry. 1 atm = 760 mm Hg

Temperature

While temperature is not explicitly involved in the initial calculation, it's crucial to note that Boyle's Law applies at constant temperature.

Ideal Gas Law

The general form of the ideal gas law is:

$$PV = nRT$$

where:
- P = pressure
- V = volume
- n = number of moles
- R = universal gas constant (8.314 J/(mol·K))
- T = temperature in Kelvin

For calculations involving only pressure and volume at constant temperature and moles, Boyle's Law is sufficient.

Step-by-Step Calculation of Gas Volume Change

The problem involves two states of the same gas:

- Initial state: pressure $P_1 = 2.50 \text{ atm}$
- Final state: pressure $P_2 = 457 \text{ mm Hg}$
- Initial volume: V_1 (unknown)
- Final volume: V_2 (unknown, which we need to find)

Assuming temperature and the amount of gas remain constant, Boyle's Law states:

$$P_1 V_1 = P_2 V_2$$

Rearranged to solve for V_2:

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

Since V_1 is not specified, but typically in such problems, the initial volume is considered as a reference (say 1 liter), and the question asks for the final volume relative to the initial. Alternatively, if the initial volume is known, you can directly calculate the final.

Converting Pressures to a Common Unit

To use Boyle's Law correctly, both pressures must be in the same units.

- Convert $P_2 = 457 \text{ mm Hg}$ to atm:

$$
P_2 = \frac{457 \text{ mm Hg}}{760 \text{ mm Hg/atm}} \approx 0.6013 \text{ atm}
$$

Now, the pressures are:

- $P_1 = 2.50 \text{ atm}$
- $P_2 \approx 0.6013 \text{ atm}$

Calculating the Final Volume

Assuming the initial volume V_1 is 1 liter (or any unit), then:

$$
V_2 = \frac{P_1 V_1}{P_2} = \frac{2.50 \times V_1}{0.6013}
$$

For $V_1 = 1 \text{ L}$:

$$
V_2 \approx \frac{2.50}{0.6013} \approx 4.16 \text{ L}
$$

Thus, if the initial volume was 1 liter at 2.50 atm, after the pressure drops to 457 mm Hg, the volume would expand to approximately 4.16 liters, assuming constant temperature and amount of gas.

General Formula and Application

If the initial volume V_1 is different, the final volume V_2 can be found by:

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

This proportionality underscores Boyle’s Law: pressure and volume are inversely proportional at constant temperature.

Real-World Applications of Gas Volume Calculations

Calculating gas volume under varying pressures has numerous practical applications:

- Medical Fields: Understanding how gases expand or compress in respiratory treatments and anesthesia.
- Industrial Processes: Designing reactors, storage tanks, and pipelines that handle gases.

- Meteorology: Predicting atmospheric pressure changes and their effects on weather.
- Aerospace Engineering: Managing fuel and air supply systems under different altitudes.

Practical Example: Gas Storage Optimization

Suppose a gas storage tank initially contains 10 liters of gas at 2.50 atm. If the pressure is reduced to 457 mm Hg (0.6013 atm), the new volume would be:

$$
V_2 = 10 \times \frac{2.50}{0.6013} \approx 41.6 \text{ liters}
$$

This information helps engineers determine the necessary tank size and safety measures.

Factors Affecting Gas Behavior Beyond Boyle's Law

While Boyle's Law provides a good approximation for many situations, real gases exhibit deviations under certain conditions:

- High pressure: Intermolecular forces become significant.
- Low temperature: The gas particles move slower, and condensation may occur.
- Non-ideal conditions: Real gases do not behave perfectly like ideal gases, requiring correction factors such as those in the Van der Waals equation.

Understanding these factors is essential for precise calculations in advanced applications.

Conclusion

Determining the volume of a gas when its pressure changes is a fundamental problem in chemistry and physics, primarily governed by Boyle's Law for isothermal processes. In this scenario, converting pressure units to a common basis enables accurate calculations. The key takeaway is the inverse relationship between pressure and volume: as pressure decreases, volume increases proportionally, provided temperature and amount remain constant.

By applying the principles outlined here, scientists and engineers can predict gas behavior under various conditions, optimize storage solutions, and design systems that safely and efficiently handle gases across a wide range of applications. Mastery of these concepts is essential for anyone working with gases in scientific, industrial, or environmental contexts.

Meta Description: Learn how to calculate the volume of a gas exerting 457 mm Hg pressure when it was previously at 2.50 atm. Understand the principles of Boyle's Law, unit conversions, and real-world applications in this comprehensive guide.

Frequently Asked Questions

How do you convert pressure from atmospheres to mm Hg when calculating gas volume?

To convert pressure from atmospheres to mm Hg, multiply the pressure in atm by 760 mm Hg per atm. For example, 2.50 atm × 760 mm Hg/atm = 1900 mm Hg.

What is Boyle's Law and how is it used to find the volume of a gas under different pressures?

Boyle's Law states that for a fixed amount of gas at constant temperature, pressure and volume are inversely proportional ($P_1V_1 = P_2V_2$). It allows calculation of the new volume when pressure changes.

Given the initial pressure and volume of a gas, how can I find its volume at a new pressure?

Use Boyle's Law: $V_2 = (P_1 \times V_1) / P_2$, where P_1 and V_1 are initial pressure and volume, and P_2 is the new pressure.

What units should I use for pressure when calculating gas volume using Boyle's Law?

It's best to use consistent units, typically atmospheres or mm Hg, as long as both initial and final pressures are in the same units. In this case, convert all pressures to mm Hg for consistency.

How do I convert the given pressure from mm Hg to atm for calculations?

Divide the pressure in mm Hg by 760 mm Hg per atm. For example, 457 mm Hg ÷ 760 mm Hg/atm ≈ 0.601 atm.

If a gas exerts a pressure of 2.50 atm and a volume of 10 L, what is its volume if the pressure is 457 mm Hg at the same temperature?

First convert 457 mm Hg to atm: 457 ÷ 760 ≈ 0.601 atm. Then, use Boyle's Law: $V_2 = (P_1 \times V_1) / P_2 = (2.50 \text{ atm} \times 10 \text{ L}) / 0.601 \text{ atm} \approx 41.6 \text{ L}$.

Why is it important to keep temperature constant when

applying Boyle's Law?

Boyle's Law assumes temperature remains constant because temperature affects gas pressure and volume via the ideal gas law. Changing temperature would require using additional laws like Charles's Law.

What assumptions are made when calculating gas volume using Boyle’s Law?

Assumptions include that the gas behaves ideally, temperature remains constant, and the gas is at constant moles during the process.

Can Boyle’s Law be used for real gases under high pressure or low temperature?

Boyle's Law is most accurate for ideal gases at low pressure and high temperature. Under high pressure or low temperature, real gases deviate from ideal behavior, and corrections may be needed.

Additional Resources

Gas Volume Calculation: An Expert Analysis of Pressure and Volume Relationships

---

Introduction

Understanding the relationship between pressure and volume of gases is fundamental in fields ranging from chemistry and physics to engineering and environmental science. When dealing with gases, the core principle that governs their behavior is Boyle's Law, which states that, for a fixed amount of gas at constant temperature, the pressure and volume are inversely proportional. This means that if the pressure increases, the volume decreases, and vice versa, provided temperature remains unchanged.

Today, we delve into a practical application of this principle: determining the volume of a gas that exerts a specific pressure under different conditions. Specifically, we will explore how to calculate the volume of a gas that exerts a pressure of 457 mm Hg when its pressure is known to be 2.50 atm. This analysis not only demonstrates the application of Boyle's Law but also emphasizes the importance of unit conversions and accurate measurements in scientific calculations.

Understanding the Fundamental Concepts

Boyle's Law and Its Relevance

Boyle's Law is mathematically expressed as:

$$ P_1 V_1 = P_2 V_2 $$

Where:
- P_1 and V_1 are the initial pressure and volume,
- P_2 and V_2 are the final pressure and volume.

This inverse relationship allows us to find an unknown volume when the initial conditions and the final pressure are known, or vice versa.

Units of Pressure: The Need for Consistency

One of the critical aspects of gas law calculations is ensuring that pressure units are consistent. Gas pressure can be expressed in various units, including atmospheres (atm), millimeters of mercury (mm Hg), Pascals (Pa), and pounds per square inch (psi). Since Boyle's Law relies on proportional relationships, using consistent units is essential for accurate calculations.

In our case:
- The initial pressure is given in atmospheres (atm),
- The final pressure is in millimeters of mercury (mm Hg).

Therefore, we must convert one of these to match the other to maintain consistency.

The Conversion Process: Atmospheres to Millimeters of Mercury

Why Convert?

Using the same units for initial and final pressures ensures the proportional relationship remains valid. Since Boyle's Law depends on the ratio of pressures, both need to be expressed in the same units.

Conversion Factors

The standard conversion between atmospheres and mm Hg is:

$$ 1\, \text{atm} = 760\, \text{mm Hg} $$

Using this, we convert the initial pressure from atm to mm Hg:

$$
P_1 = 2.50\, \text{atm} \times 760\, \text{mm Hg/atm} = 1900\, \text{mm Hg}
$$

Now, the pressures are:
- $P_1 = 1900\, \text{mm Hg}$,
- $P_2 = 457\, \text{mm Hg}$.

Applying Boyle’s Law to Find the Unknown Volume

Assuming the initial volume V_1 is known or set as a reference (say 1 liter for simplicity), and the goal is to find the final volume V_2, the equation becomes:

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

If the initial volume is not specified, the typical approach is to determine the ratio of volumes directly, which is often sufficient in relative calculations. For the purpose of this analysis, let's assume an initial volume V_1 of 1 liter at the initial pressure P_1.

Plugging in the values:

$$
V_2 = 1\, \text{L} \times \frac{1900\, \text{mm Hg}}{457\, \text{mm Hg}} \approx 1\, \text{L} \times 4.154
$$

$$
V_2 \approx 4.15\, \text{L}
$$

Interpretation: When the pressure drops from 1900 mm Hg to 457 mm Hg, the volume of the gas increases from 1 liter to approximately 4.15 liters.

Real-World Significance and Practical Applications

This calculation exemplifies how gases respond to pressure changes, which is vital in numerous sectors:

- Chemical Manufacturing: Adjusting gas volumes in reactors based on pressure conditions.
- Medical Applications: Understanding gas volumes in respiratory devices where pressure variations are common.
- Environmental Monitoring: Predicting gas dispersal and volume changes in atmospheric studies.
- Engineering: Designing systems like compressed air tanks, where pressure-volume relationships are critical for safety and efficiency.

Additional Considerations: Temperature and Ideal Gas Assumption

While Boyle's Law provides a straightforward relationship, it assumes the gas behaves ideally and temperature remains constant. In real-world scenarios:

- Temperature fluctuations can affect gas behavior, necessitating the use of combined gas laws or Van der Waals equations for more accuracy.

- Non-ideal gases may deviate from the predictions of Boyle's Law, especially at high pressures or low temperatures.

In our calculation, we have implicitly assumed ideal behavior and constant temperature, which is typical for standard calculations unless specified otherwise.

Summary of Key Steps

To recap, here are the essential steps for solving similar problems:

1. Identify the known values: pressures, volumes, and units.
2. Convert all pressures into consistent units: in this case, convert atm to mm Hg.
3. Apply Boyle’s Law: $P_1 V_1 = P_2 V_2$.
4. Solve for the unknown volume: $V_2 = V_1 \times \frac{P_1}{P_2}$.
5. Interpret the result: understand the physical implications of the volume change.

Final Thoughts: The Power of Gas Law Calculations

Understanding the interplay between pressure and volume of gases not only enhances scientific literacy but also empowers practical decision-making in technical fields. The ability to accurately convert units and apply fundamental laws like Boyle's Law ensures precise calculations, which are crucial for safety, efficiency, and innovation.

In our specific scenario, recognizing that decreasing pressure from 2.50 atm to 457 mm Hg causes the gas volume to increase approximately fourfold illustrates the sensitivity of gases to pressure changes. Such insights are invaluable for designing systems ranging from industrial reactors to medical devices.

Whether you're a student, scientist, or engineer, mastering these principles provides a solid foundation for exploring the dynamic behavior of gases and leveraging their properties in real-world applications.

References

- Atkins, P., & de Paula, J. (2014). Physical Chemistry. Oxford University Press.
- Zumdahl, S. S., & Zumdahl, S. A. (2013). Chemistry. Cengage Learning.
- Boyle's Law. (2023). In Chemistry LibreTexts. https://chemistry.libretexts.org/

In conclusion, calculating the volume of a gas based on pressure involves understanding the principles of gas laws, performing accurate unit conversions, and applying mathematical relationships correctly. This process underscores the importance of precision and comprehension in scientific calculations—a cornerstone of effective scientific practice.

What Is The Volume Of A Gas That Exerts A Pressure Of 457 Mm Hg If It Exerted A Pressure Of 2 50 Atm

What Is The Volume Of A Gas That Exerts A Pressure Of 457 Mm Hg If It Exerted A Pressure Of 2 50 Atm

Related Articles

- A Clothing Designer Determines That The Number Of Shirts She Can Sell Is Given By The Formula S = 4x2
- 25 POINTS!!! Please Correctly Answer The Questions Below.Choisis La Meilleure Rponse Pour Complter La
- Curfews For Children Discusses Opinions And Reasons Both For And Against Curfews. "ChildrenDon't Need

Back to Home