The Volume Of Gas Changes From 5L To 3L, What Will Be The New Pressure? What Law Did You Use And Why?

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Understanding how gases behave under different conditions is essential in fields ranging from chemistry and physics to engineering and environmental science. When the volume of a gas changes, its pressure and temperature often change as well, according to the fundamental principles governing gases. In this article, we explore the scenario where a gas's volume decreases from 5 liters to 3 liters and seek to determine the new pressure, understanding which gas law applies and why.

Introduction to Gas Laws

Gases are unique in their ability to expand and compress easily, making their behavior predictable under certain conditions. The relationships between pressure, volume, temperature, and amount of gas are described by various gas laws.

The three most fundamental laws are:
- Boyle's Law
- Charles's Law
- Gay-Lussac's Law

When combined, they lead to the ideal gas law, which provides a comprehensive model for understanding gas behavior.

The Scenario: Changing Volume and Its Effect on Pressure

Suppose you have a contained gas at a specific initial state — for example, 5L volume at a certain pressure and temperature. When the volume is decreased to 3L, what happens to the pressure? To analyze this, we need to understand the properties of the gas and the conditions under which it is contained.

Initial Conditions and Assumptions

- Initial volume (V_1): 5 liters
- Final volume (V_2): 3 liters
- Initial pressure (P_1): known or assumed

- Temperature (T): assumed to be constant for simplicity
- Amount of gas (n): remains unchanged

Assuming the temperature remains constant during the process (no heating or cooling), the problem simplifies to a pressure-volume relationship, making Boyle's Law applicable.

Which Gas Law Is Used and Why?

Boyle’s Law

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

$$ P_1 V_1 = P_2 V_2 $$

Why Boyle’s Law? Because in the scenario described, the temperature is assumed constant, and the amount of gas doesn't change. Under these conditions, Boyle's Law is the most appropriate because it directly relates pressure and volume at a fixed temperature.

When to Use Boyle’s Law:
- When temperature is held constant (isothermal process).
- When the amount of gas remains unchanged.
- When analyzing pressure-volume relationships.

Limitations: If temperature or amount of gas changes, Boyle's Law alone isn't sufficient, and the ideal gas law or other laws must be used.

Applying Boyle’s Law to Find the New Pressure

Given the initial and final volumes, and knowing the initial pressure, we can calculate the final pressure using Boyle's Law:

$$ P_1 V_1 = P_2 V_2 $$

Rearranged as:

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

Example Calculation:

Suppose the initial pressure (P_1) is 1 atm (atmosphere). Then,

$$ P_2 = 1\, \text{atm} \times \frac{5\, \text{L}}{3\, \text{L}} = 1\, \text{atm} \times \frac{5}{3} \approx 1.67\, \text{atm} $$

Thus, when the volume decreases from 5L to 3L, the pressure increases from 1 atm to approximately 1.67 atm, assuming constant temperature.

Understanding the Assumptions and Conditions

While Boyle's Law provides an elegant and straightforward way to calculate the new pressure, it relies on several assumptions:

- **Temperature remains constant:** The process is isothermal. If the temperature changes, a different law or the combined gas law must be used.
- **No gas leaks:** The amount of gas remains unchanged.
- **Ideal gas behavior:** The gas behaves ideally, meaning interactions between molecules are negligible, and the molecules occupy no volume.

In real-world applications, deviations may occur due to non-ideal interactions or temperature fluctuations, but Boyle's Law provides a reliable approximation under controlled conditions.

The Combined Gas Law: When Conditions Change

If, in addition to volume, temperature or the amount of gas change, Boyle's Law alone may not suffice. Instead, the Combined Gas Law is used:

$$ \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} $$

This law combines Boyle's, Charles's, and Gay-Lussac's laws, allowing for more complex scenarios.

Why Use the Combined Gas Law?
- When temperature varies during the process.
- When the amount of gas changes.

In our specific case, since temperature and amount are assumed constant, Boyle's Law remains the most straightforward and appropriate.

Real-World Applications and Examples

Understanding how pressure varies with volume has numerous practical applications:

- Syringes: When you pull or push the plunger, volume changes, affecting pressure inside.

- Scuba Diving: As a diver descends, water pressure increases, and understanding gas laws helps in calculating safe ascent rates.
- Industrial Gas Storage: Designing tanks and pipelines requires predicting pressure changes due to volume adjustments.
- Respiratory Physiology: Lung expansion and contraction follow principles similar to Boyle's Law.

Example in Practice:
Suppose a scuba tank contains air at 200 atm and 5L volume at room temperature. If the tank is emptied to a volume of 3L (say, through a regulator), what is the pressure, assuming temperature remains constant?

Applying Boyle's Law:

$$ P_2 = 200\, \text{atm} \times \frac{5\, \text{L}}{3\, \text{L}} = 200 \times \frac{5}{3} \approx 333.33\, \text{atm} $$

This illustrates how pressure increases significantly with decreasing volume, emphasizing safety considerations.

Conclusion

In summary, when the volume of a gas decreases from 5L to 3L at constant temperature and amount, the pressure increases proportionally, as described by Boyle's Law. The law’s mathematical simplicity makes it ideal for straightforward calculations under isothermal conditions, which is why it was used in this scenario.

Understanding which gas law to apply depends on the specific conditions of the process—particularly whether temperature or the amount of gas changes. Recognizing these conditions allows scientists and engineers to accurately predict how gases will behave, design safe storage systems, and understand natural phenomena.

Key Takeaways:
- Boyle's Law states $ P \propto \frac{1}{V} $ at constant T and n.
- To find the new pressure after volume change, use $ P_2 = P_1 \times \frac{V_1}{V_2} $.
- Always verify the assumptions: constant temperature, no gas loss, ideal gas behavior.
- For more complex scenarios involving temperature or gas amount variations, use the combined gas law or ideal gas law.

By mastering these principles, you can confidently analyze and predict gas behaviors in various scientific and practical contexts.

Frequently Asked Questions

If a gas's volume decreases from 5L to 3L at constant temperature, what will be its new pressure?

The new pressure will be 5/3 times the original pressure, assuming temperature remains constant, following Boyle's Law.

Which law explains the relationship between the change in gas volume and pressure in this scenario?

Boyle's Law explains this relationship, stating that pressure and volume are inversely proportional at constant temperature.

How do you calculate the new pressure when the volume of a gas changes according to Boyle's Law?

Use the formula $P1 \times V1 = P2 \times V2$; rearranged to $P2 = (P1 \times V1) / V2$.

Why is Boyle's Law applicable when the volume of a gas changes from 5L to 3L?

Because Boyle's Law applies when temperature and amount of gas are constant, relating pressure and volume inversely.

What assumptions are made when applying Boyle's Law to this problem?

Assumptions include constant temperature, fixed amount of gas, and that the gas behaves ideally.

If the initial pressure was 2 atm at 5L, what is the new pressure after volume decreases to 3L?

Using $P2 = (P1 \times V1)/V2$, $P2 = (2 \text{ atm} \times 5L)/3L = 10/3 \text{ atm} \approx 3.33 \text{ atm}$.

Can Boyle's Law be used if the temperature changes during the volume change?

No, Boyle's Law assumes temperature remains constant; if temperature varies, other laws like Charles's Law are applicable.

What is the significance of understanding how gas volume and pressure are related in real-world applications?

It helps in designing pressurized systems, respiratory devices, and understanding natural

phenomena involving gases.

Additional Resources

The volume of gas changes from 5L to 3L, what will be the new pressure? What law did you use and why?

This question is a classic example of applying fundamental principles in gas laws to determine how a change in the volume of a gas affects its pressure. Understanding the relationship between these variables is crucial in fields such as chemistry, physics, engineering, and even meteorology. In this article, we'll explore the concepts behind this problem, identify the appropriate law to use, and walk through the calculation step-by-step, providing clarity for learners and professionals alike.

Introduction to Gas Laws

Gases are unique among the states of matter because their particles are widely spaced and free to move. This characteristic allows their properties—pressure, volume, temperature, and amount—to be interconnected in predictable ways. To describe these relationships, scientists have developed several gas laws, which help us understand how changing one variable influences others.

The Importance of Gas Laws

- Predicting behavior: Gas laws allow us to forecast how gases will react under different conditions.
- Designing equipment: Engineers use these laws to design containers, engines, and safety systems.
- Scientific research: Accurate modeling of atmospheric and environmental phenomena depends on understanding these relationships.

Understanding the Key Variables

Before diving into the law, it's essential to understand the primary variables involved:

- Pressure (P): The force exerted by gas particles per unit area (typically measured in atmospheres, atm, or pascals, Pa).
- Volume (V): The space occupied by the gas (liters, L).
- Temperature (T): The average kinetic energy of gas particles (Kelvin, K).
- Amount of gas (n): The number of moles of gas present.

In the problem presented, temperature and amount of gas are assumed to be constant unless specified otherwise.

Which Gas Law to Use?

Given the change in volume and the desire to find the corresponding change in pressure, the most relevant law is Boyle’s Law.

Boyle’s Law: The Relationship Between Pressure and Volume

Boyle’s Law states that, at constant temperature and amount of gas, the pressure of a gas is inversely proportional to its volume. Mathematically, it can be 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 law applies well to situations where temperature and amount remain unchanged, making it ideal for our scenario.

Why Boyle’s Law?

- The problem specifies a change in volume from 5L to 3L.
- There's no mention of temperature change or gas addition/removal.
- The relationship between pressure and volume under these conditions is inversely proportional, aligning perfectly with Boyle’s Law.

Step-by-Step Calculation

Let’s walk through the calculation using Boyle’s Law:

Given Data
- Initial volume, $V_1 = 5\, \text{L}$
- Final volume, $V_2 = 3\, \text{L}$
- Initial pressure, $P_1 = \text{unknown}$ (or it could be given in a specific problem)
- Final pressure, $P_2 = ?$

Note: If the initial pressure P_1 is provided, plug it into the formula directly. If not, for demonstration, assume a typical initial pressure, such as 1 atm.

Example Assumption:
- $P_1 = 1\, \text{atm}$

Applying Boyle’s Law:

$$
P_1 V_1 = P_2 V_2
$$

Rearranged to solve for P_2:

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

Calculation:

$$
P_2 = \frac{(1\, \text{atm}) \times (5\, \text{L})}{3\, \text{L}} = \frac{5}{3}\, \text{atm} \approx 1.67\, \text{atm}
$$

Result:

The new pressure is approximately 1.67 atm when the volume decreases from 5L to 3L, assuming the initial pressure was 1 atm.

Additional Considerations

1. Temperature Constancy
Boyle’s Law assumes temperature remains constant. If the problem involves temperature change, the combined gas law or ideal gas law must be used.

2. Units Consistency
Ensure pressure units are consistent throughout. If initial pressure is given in pascals (Pa), convert to atmospheres or vice versa.

3. Real-World Applications
- Scuba diving: Understanding how pressure increases as a diver descends.
- Syringe mechanics: How exerting pressure affects volume.
- Industrial processes: Gas compression and expansion.

When to Use the Ideal Gas Law

If the problem involved changes in temperature or the amount of gas, the ideal gas law would be more appropriate:

$$
PV = nRT
$$

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

This law encompasses Boyle’s Law as a special case when n and T are constant.

Summary of Key Points

- The problem involves a change in the volume of a gas and asks for the new pressure, assuming constant temperature and amount.
- The appropriate law is Boyle’s Law, which states $P_1 V_1 = P_2 V_2$.
- To find the new pressure, rearrange the equation and substitute known values.
- Always verify the assumptions (constant temperature, amount of gas) before choosing the law.
- Convert all units to be consistent to avoid errors.

Final Thoughts

Understanding the relationship between pressure and volume in gases is fundamental in many scientific and engineering applications. Recognizing the correct law to apply simplifies calculations and enhances comprehension of gas behavior. Remember, Boyle’s Law is a powerful tool when temperature and amount are held constant, providing clear insights into how gases respond to volume changes.

By mastering these principles, you'll be better equipped to analyze real-world scenarios, perform laboratory experiments, and solve complex problems involving gases.

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