If 22.5 L Of Nitrogen At 748.3 Mm Hg Is Changed To A Pressure Of 1294.6 Mm Hg At Constanttemperature.

If 22.5 L Of Nitrogen At 748.3 Mm Hg Is Changed To A Pressure Of 1294.6 Mm Hg At Constanttemperature. This scenario involves understanding the fundamental principles of gas laws, specifically Boyle's Law, which describes how the pressure and volume of a gas relate when temperature remains constant. In this article, we explore the underlying concepts, derive the necessary calculations, and discuss the implications of changing the pressure conditions on a fixed amount of nitrogen gas.

Understanding Gas Laws: Boyle's Law and Its Significance

What Is Boyle's Law?

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. Formally, 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 relationship indicates that if the pressure increases, the volume decreases proportionally, assuming temperature and the amount of gas remain unchanged.

Importance of Boyle's Law in Real-World Applications

Boyle's Law is fundamental in various fields:
- Engineering: Designing pressurized vessels and syringes.
- Medicine: Understanding how lungs expand and contract.
- Meteorology: Studying atmospheric pressure changes.
- Chemistry: Calculating gas behavior in reactions.

In the context of our problem, Boyle's Law allows us to determine how the volume of nitrogen gas changes when the pressure varies, provided the temperature remains constant.

Given Data and Objective

To analyze the problem, let's clarify the given data:
- Initial volume of nitrogen gas, $V_1 = 22.5$ liters
- Initial pressure, $P_1 = 748.3$ mm Hg
- Final pressure, $P_2 = 1294.6$ mm Hg
- Temperature remains constant (isothermal process)

Our primary goal is to find the new volume V_2 of nitrogen when the pressure changes from P_1 to P_2.

Applying Boyle’s Law to the Scenario

Since temperature is constant, Boyle’s Law simplifies to:

$$P_1 V_1 = P_2 V_2$$

Rearranged to find the unknown volume V_2:

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

Plugging in the known values:

$$V_2 = \frac{748.3 \text{ mm Hg} \times 22.5 \text{ L}}{1294.6 \text{ mm Hg}}$$

Calculating numerator and denominator:

$$V_2 = \frac{16,837.425}{1294.6}$$

$$V_2 \approx 13.0 \text{ L}$$

Thus, the new volume of nitrogen gas under the increased pressure is approximately 13.0 liters.

Interpreting the Results and Real-World Implications

Volume Change Due to Pressure Increase

The initial volume of 22.5 liters decreases to about 13.0 liters when the pressure increases from 748.3 mm Hg to 1294.6 mm Hg. This demonstrates the inverse relationship between pressure and volume:

- Initial State: 748.3 mm Hg at 22.5 L

- Final State: 1294.6 mm Hg at 13.0 L

This significant volume reduction (roughly 42%) underscores how gases compress under increased pressure when temperature remains constant.

Practical Examples and Applications

Understanding this principle is essential in:
- Industrial Gas Storage: Ensuring safe storage at high pressures.
- Diving Physics: Calculating how volume of air in tanks decreases with increasing depth.
- Chemical Reactions: Adjusting conditions to manipulate gas volumes without changing temperature.

Additional Considerations in Gas Law Calculations

Units and Conversion

Always ensure unit consistency:
- Pressure in mm Hg (millimeters of mercury) is common in laboratory settings.
- Volume in liters is standard; conversions may be necessary if pressure is given in other units like atm or Pa.

To convert mm Hg to atm:

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

So,

$$ P_1 = \frac{748.3}{760} \approx 0.985 \text{ atm} $$

$$ P_2 = \frac{1294.6}{760} \approx 1.705 \text{ atm} $$

Using these in calculations can sometimes simplify understanding, especially when working with the ideal gas law.

Ideal Gas Law and Its Relevance

While Boyle’s Law suffices here, the ideal gas law provides a broader context:

$$ PV = nRT $$

where:
- P = pressure
- V = volume
- n = number of moles
- R = ideal gas constant
- T = temperature

Given that temperature and moles are constant, Boyle’s Law is a direct consequence of the ideal gas law.

Summary and Key Takeaways

- Boyle’s Law explains the inverse relationship between pressure and volume at constant temperature.
- When nitrogen gas's pressure increases from 748.3 mm Hg to 1294.6 mm Hg, its volume decreases from 22.5 liters to approximately 13.0 liters.
- Understanding these relationships is critical in various scientific and engineering applications, from designing pressurized systems to understanding natural phenomena.
- Always pay attention to units and conditions (like temperature) to accurately apply gas laws.

Conclusion

In conclusion, the problem of changing nitrogen gas pressure while maintaining constant temperature exemplifies the practical application of Boyle’s Law. By understanding the relationship between pressure and volume, scientists and engineers can predict and manipulate gas behaviors effectively. Whether in laboratory experiments, industrial processes, or natural systems, mastering these fundamental principles allows for precise control and safety in handling gases.

Remember: Always verify conditions and units before calculations, and consider the broader context of the ideal gas law when dealing with real-world scenarios.

Frequently Asked Questions

What is the initial volume of nitrogen gas in the problem?

The initial volume of nitrogen gas is 22.5 liters.

What are the initial and final pressures of the nitrogen gas?

The initial pressure is 748.3 mm Hg, and the final pressure is 1294.6 mm Hg.

Is the temperature of the nitrogen gas changing in this process?

No, the temperature remains constant as stated in the problem.

Which gas law applies to find the new volume of

nitrogen gas?

The Boyle's Law applies, which relates pressure and volume at constant temperature.

How do you calculate the new volume of nitrogen gas after pressure change?

Using Boyle's Law: P1 × V1 = P2 × V2, solve for V2: V2 = (P1 × V1) / P2.

What is the calculated volume of nitrogen gas at the new pressure?

The new volume is approximately 13.07 liters, calculated as V2 = (748.3 mm Hg × 22.5 L) / 1294.6 mm Hg.

Additional Resources

Understanding the Behavior of Gases Under Changing Pressure Conditions

Gas laws are fundamental principles in chemistry that describe how gases respond to changes in variables such as pressure, volume, and temperature. Among these, Boyle’s Law stands out as a cornerstone in understanding how the volume of a gas varies inversely with pressure when temperature remains constant. In this context, analyzing the transformation of a given volume of nitrogen gas from one pressure to another offers a clear illustration of these principles. This article delves into the specifics of such a transformation, explaining the underlying concepts, calculations, and implications in detail.

Fundamentals of Gas Laws Relevant to the Problem

Boyle’s Law: The Foundation

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

$$
P_1 V_1 = P_2 V_2
$$

where:
- P_1 and P_2 are the initial and final pressures,
- V_1 and V_2 are the initial and final volumes.

- Implication: If the pressure on a gas increases, its volume decreases proportionally, and vice versa, provided the temperature remains unchanged.

Ideal Gas Law and Its Application

- While Boyle’s Law is sufficient for this particular problem due to constant temperature, the Ideal Gas Law offers a more comprehensive framework:

$$
PV = nRT
$$

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

- Since the problem involves changing pressure at constant temperature and assuming the amount of gas remains unchanged, Boyle’s Law provides a straightforward approach.

Given Data and Objective

Parameter	Value
Initial Volume (V_1)	22.5 L
Initial Pressure (P_1)	748.3 mm Hg
Final Pressure (P_2)	1294.6 mm Hg
Temperature	Constant (unspecified, but constant)

Objective: Determine the final volume (V_2) of nitrogen gas after the pressure change, assuming no change in temperature or amount of gas.

Step-by-Step Calculation

Applying Boyle’s Law

Given:

- $P_1 = 748.3\, \text{mm Hg}$
- $V_1 = 22.5\, \text{L}$
- $P_2 = 1294.6\, \text{mm Hg}$
- $V_2 = ?$

Using Boyle’s Law:

$$
P_1 V_1 = P_2 V_2
$$

Rearranged to solve for V_2:

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

Plugging in the known values:

$$
V_2 = \frac{748.3\, \text{mm Hg} \times 22.5\, \text{L}}{1294.6\, \text{mm Hg}}
$$

Calculating numerator:

$$
748.3 \times 22.5 = 16,837.425
$$

Dividing:

$$
V_2 = \frac{16,837.425}{1294.6} \approx 13.0\, \text{L}
$$

Result: The volume of nitrogen gas decreases from 22.5 L to approximately 13.0 liters when the pressure increases from 748.3 mm Hg to 1294.6 mm Hg at constant temperature.

Physical Interpretation and Significance

Inverse Relationship Between Pressure and Volume

- The calculation vividly demonstrates Boyle’s Law: as pressure increases, the volume decreases proportionally, provided the temperature remains unchanged. In this case, the pressure nearly doubles, and the volume nearly halves.

- Specifically:

$$
\frac{V_2}{V_1} \approx \frac{P_1}{P_2} \approx \frac{748.3}{1294.6} \approx 0.578
$$

indicating the final volume is approximately 57.8% of the initial volume.

Implications in Practical Scenarios

- Industrial Applications: Understanding how gases compress or expand under varying pressure conditions is vital in industries such as chemical manufacturing, aerospace, and medical gas supply.

- Safety Considerations: Recognizing how gases behave under pressure changes helps in designing safer storage tanks and pipelines.

- Environmental Impact: Accurate modeling of gas behavior is crucial in atmospheric science and climate modeling, especially for gases like nitrogen that dominate the Earth's atmosphere.

Additional Considerations and Limitations

Assumption of Ideal Gas Behavior

- The calculations assume nitrogen behaves as an ideal gas, which is a good approximation under many conditions but can deviate at high pressures or low temperatures.

- Real gases exhibit interactions and finite molecular sizes, leading to deviations from ideality, especially at extreme conditions.

Temperature Constancy

- The problem presumes constant temperature, a key assumption for Boyle’s Law. In real-world scenarios, pressure changes often involve temperature fluctuations, requiring combined gas laws or the Van der Waals equation for more precise modeling.

Measurement Accuracy

- Variations in pressure measurement or volume calibration can influence the calculated values, emphasizing the importance of precise instrumentation.

Broader Context and Related Concepts

Relationship with Other Gas Laws

- Charles's Law: Describes volume change with temperature at constant pressure.

- Gay-Lussac's Law: Describes pressure change with temperature at constant volume.

- Combined Gas Law: Integrates Boyle's, Charles's, and Gay-Lussac's laws to handle simultaneous variations in pressure, volume, and temperature.

Real-World Applications

- Scuba Diving: Gas compression and decompression are critical to avoid issues like decompression sickness.

- Engine Design: Internal combustion engines rely on understanding gas compression ratios.

- Atmospheric Science: Climate models depend on understanding how atmospheric gases respond to temperature and pressure variations.

Conclusion

The transformation of 22.5 liters of nitrogen gas from an initial pressure of 748.3 mm Hg to a final pressure of 1294.6 mm Hg exemplifies the core principles of Boyle's Law. Through straightforward calculations, we observe that the gas's volume reduces significantly under increased pressure, demonstrating the inverse relationship predicted by the law. This analysis not only reinforces foundational concepts in gas behavior but also underscores their importance across scientific, industrial, and environmental contexts. Recognizing these fundamental relationships enables scientists and engineers to predict, manipulate, and control gas systems effectively, ensuring safety, efficiency, and innovation in various fields.

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