2.2 L Of Hydrogen At 6.5 Atm Pressure Is Used To Fill A Balloon At A Final Pressure Of 1.15 Atm. What

Understanding the Problem: Hydrogen Gas and Balloon Inflation

2.2 L Of Hydrogen At 6.5 Atm Pressure Is Used To Fill A Balloon At A Final Pressure Of 1.15 Atm. What happens to the volume of the hydrogen, and how can we calculate it? This question involves fundamental principles of gas behavior, specifically the relationship between pressure and volume, governed by the ideal gas law. Whether you're a student studying chemistry or a science enthusiast curious about gas laws, understanding this problem provides valuable insights into the behavior of gases under changing conditions.

In this article, we will explore the concepts involved, including Boyle’s Law, and walk through a step-by-step process to determine the final volume of hydrogen when the pressure changes. We will also discuss real-world applications of these principles, such as balloon filling, gas storage, and industrial processes.

The Fundamentals of Gas Laws

Boyle’s Law Explained

Boyle's Law is a fundamental principle in chemistry that describes the inverse relationship between the pressure and volume of a gas at constant temperature. Mathematically, it is expressed as:

$$
P_1 V_1 = P_2 V_2
$$

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

This law implies that if the temperature remains unchanged, increasing the

pressure will decrease the volume proportionally, and vice versa.

Assumptions and Conditions

When applying Boyle's Law to real-world problems, certain conditions should be assumed:
- The gas behaves ideally.
- Temperature remains constant throughout the process.
- The gas is confined in a rigid, closed container during the process.

In the context of filling a balloon, the temperature is typically assumed to be constant during the process, especially over short durations.

Applying Boyle's Law to the Hydrogen Balloon Problem

Given Data

Let's outline the given information:
- Initial volume of hydrogen, $V_1 = 2.2\, \text{L}$
- Initial pressure, $P_1 = 6.5\, \text{atm}$
- Final pressure, $P_2 = 1.15\, \text{atm}$
- Final volume, $V_2 = ?$

Our goal is to find the final volume of hydrogen, V_2, after the pressure drops from 6.5 atm to 1.15 atm.

Step-by-Step Calculation

Applying 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:

$$
V_2 = \frac{6.5\, \text{atm} \times 2.2\, \text{L}}{1.15\, \text{atm}}
$$

Calculating numerator:

$$
6.5 \times 2.2 = 14.3
$$

Now, dividing:

$$
V_2 = \frac{14.3}{1.15} \approx 12.43\, \text{L}
$$

Result: The hydrogen gas will occupy approximately 12.43 liters when the pressure decreases to 1.15 atm.

Implications of the Calculation

Volume Expansion in Balloon Filling

This significant increase in volume—from 2.2 L to approximately 12.43 L—illustrates how gas expands as the pressure drops, assuming temperature remains constant. When filling a balloon, this expansion causes the balloon to inflate, increasing its size proportionally.

Real-World Applications

Understanding the relationship between pressure and volume is crucial in various fields:
- Aerospace Engineering: Designing pressurized cabins and fuel tanks.
- Medical Industry: Managing gas flow in devices like ventilators.
- Industrial Gas Storage: Ensuring safety and efficiency in storing gases at different pressures.
- Environmental Science: Modeling gas exchange processes in the atmosphere.

Additional Considerations and Limitations

While Boyle’s Law is a powerful tool, it’s important to recognize its limitations:
- It assumes ideal gas behavior, which may not hold at very high pressures or

low temperatures.
- Real gases exhibit deviations from ideality, especially under extreme conditions.
- Temperature changes during the process can affect calculations; in such cases, other gas laws like Charles' Law or the combined gas law are more appropriate.

When to Use the Combined Gas Law

If temperature varies, the combined gas law offers a more comprehensive approach:

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

Where T_1 and T_2 are the initial and final temperatures in Kelvin.

Conclusion: Practical Insights into Gas Behavior

The problem of determining the final volume of hydrogen when the pressure decreases from 6.5 atm to 1.15 atm demonstrates fundamental principles of gas behavior. By applying Boyle’s Law, we see how gases expand proportionally to pressure reductions, which is essential knowledge in scientific and industrial applications.

Understanding these concepts helps in designing safer storage systems, optimizing processes that involve gases, and predicting how gases will behave under different environmental conditions. Whether filling a balloon or managing complex industrial systems, the principles of gas laws remain a cornerstone of scientific understanding and technological innovation.

Summary of Key Points

- Boyle’s Law relates pressure and volume at constant temperature.
- When pressure decreases, volume increases proportionally.
- The calculated volume for the hydrogen after pressure reduction is approximately 12.43 liters.
- Real-world applications include balloon inflation, gas storage, and process engineering.
- Always consider limitations and deviations from ideal behavior in practical scenarios.

By mastering these principles, you can confidently analyze various gas-related problems and appreciate the fascinating dynamics of gases in everyday life.

Frequently Asked Questions

What is the initial volume of hydrogen used to fill the balloon?

The initial volume of hydrogen is 2.2 liters.

What were the initial and final pressures of the hydrogen gas?

The initial pressure was 6.5 atm, and the final pressure after filling the balloon is 1.15 atm.

Which gas law can be used to determine the change in volume or other parameters in this problem?

Boyle's Law is applicable, as it relates pressure and volume at constant temperature.

How would you calculate the final volume of hydrogen in the balloon after the pressure change?

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

What is the final volume of hydrogen in the balloon after the pressure change?

$V2 = (6.5 \text{ atm} \times 2.2 \text{ L}) / 1.15 \text{ atm} \approx 12.43$ liters.

Why does the volume of hydrogen increase when the pressure decreases?

According to Boyle's Law, at constant temperature, volume and pressure are inversely related; decreasing pressure causes volume to increase.

What assumptions are made in solving this problem using Boyle's Law?

The main assumptions are that the temperature remains constant and the gas behaves ideally during the process.

Additional Resources

2.2 L of Hydrogen at 6.5 atm pressure is used to fill a balloon at a final pressure of 1.15 atm. What is the final volume of the balloon? This question encapsulates fundamental principles of gas laws, particularly Boyle's Law, which describes the inverse relationship between pressure and volume for a fixed amount of gas at constant temperature. Understanding how to approach such problems is essential for students and professionals working in chemistry, physics, and engineering fields. In this comprehensive guide, we will break down the problem step-by-step, explore the underlying principles, and provide practical tips for solving similar questions.

Understanding the Problem

Before delving into calculations, it's crucial to understand what the problem asks and the data provided:

- Initial volume of hydrogen (V_1): 2.2 liters
- Initial pressure (P_1): 6.5 atm
- Final pressure (P_2): 1.15 atm
- Final volume (V_2): ? (what we need to find)

The problem assumes the temperature remains constant (isothermal process), which allows us to apply Boyle's Law directly. Boyle's Law states:

> For a fixed amount of gas at constant temperature, the pressure of the gas times its volume is constant:

$$ P_1 \times V_1 = P_2 \times V_2 $$

Fundamental Principles: Boyle's Law

Boyle's Law is fundamental to understanding how gases behave under changing pressure and volume conditions. It 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 relationship tells us that if the temperature and the amount of gas

remain constant, increasing the pressure will decrease the volume proportionally, and vice versa.

Step-by-Step Solution Approach

Below is a detailed step-by-step process to determine the final volume of the balloon after it is filled with hydrogen:

Step 1: Write down the known data

Variable	Value	Units
Initial volume (V_1)	2.2	liters
Initial pressure (P_1)	6.5	atm
Final pressure (P_2)	1.15	atm
Final volume (V_2)	?	liters

Step 2: Recognize the assumption of constant temperature

Since the problem involves pressure and volume changes, and no mention of temperature change is made, we assume an isothermal process. This allows us to apply Boyle’s Law directly.

Step 3: Rearrange Boyle’s Law to solve for V_2

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

Step 4: Plug in the known values

$$ V_2 = \frac{6.5\, \text{atm} \times 2.2\, \text{L}}{1.15\, \text{atm}} $$

Step 5: Calculate

$$ V_2 = \frac{14.3\, \text{atm·L}}{1.15\, \text{atm}} $$

$$ V_2 \approx 12.43\, \text{L} $$

Conclusion: Final Volume of the Balloon

The final volume of the balloon after filling with hydrogen at a pressure of 1.15 atm is approximately 12.43 liters. This indicates that as the pressure decreased from 6.5 atm to 1.15 atm, the volume expanded proportionally,

consistent with Boyle’s Law.

Practical Implications and Real-World Applications

Understanding how gases expand or compress under varying pressures is essential in many fields:

- Balloon and Airship Design: Engineers use these principles to determine how much gas is needed to achieve desired buoyancy.
- Industrial Gas Storage: Properly calculating volume and pressure ensures safety and efficiency.
- Respiratory Therapy: Calculations involving gas volumes and pressures are critical for ventilator design and usage.
- Chemical Reactions: Gas law principles help predict how gases behave under different conditions, affecting yields and reaction rates.

Additional Tips for Gas Law Problems

- Always identify whether the process is isothermal, adiabatic, or involves other conditions. This determines which law applies.
- Check units carefully. Consistency avoids calculation errors.
- Remember the assumptions: Boyle’s Law applies only when temperature and amount of gas are constant.
- Use ratios to simplify calculations. For example, pressure and volume ratios directly relate in Boyle’s Law.

Common Mistakes to Avoid

- Forgetting that temperature remains constant: Applying Boyle’s Law only under the assumption of constant temperature.
- Mixing units: Ensure all pressures are in atm, all volumes in liters, etc.
- Misreading the problem: Confirm which variables are known and what is being asked.
- Ignoring the physical context: Understand that gases expand when pressure decreases, which aligns with intuitive expectations.

Summary

- The problem involves applying Boyle’s Law to find the final volume of hydrogen in a balloon.
- Using the formula $V_2 = \frac{P_1 V_1}{P_2}$, we find that the balloon’s volume expands from 2.2 L to approximately 12.43 L when the pressure drops from 6.5 atm to 1.15 atm.
- Recognizing the assumptions and conditions of the gas laws ensures accurate application.
- Mastery of these principles enables effective problem-solving in science and engineering contexts involving gases.

In conclusion, understanding how to manipulate and apply Boyle’s Law is fundamental for anyone working with gases. This problem exemplifies the straightforward yet powerful relationship between pressure and volume, providing insight into practical scenarios where gases expand or compress under changing pressures. With careful analysis and attention to detail, similar problems can be approached confidently and accurately, reinforcing core scientific principles.

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