Sample Of Gas In A Balloon Has An Initial Temperature Of 42 C And A Volume Of 1.47103 L . If The Temperature

Sample Of Gas In A Balloon Has An Initial Temperature Of 42 °C And A Volume Of 1.47103 L. If The Temperature change, how does it affect the gas's volume? This question is fundamental in understanding the behavior of gases under varying temperature conditions, which is essential in fields ranging from physics and chemistry to various engineering applications. Whether you're a student studying the ideal gas law, a scientist conducting experiments, or an enthusiast curious about how gases behave, grasping the relationship between temperature and volume of gases is crucial. In this article, we will explore the principles governing these relationships, examine the relevant gas laws, and analyze how temperature variations impact the volume of a gas trapped in a balloon.

Understanding the Behavior of Gases: Basic Concepts

What Is a Gas?

A gas is one of the four fundamental states of matter, characterized by particles that are widely spaced and move freely. Unlike solids or liquids, gases have no fixed shape or volume, instead adapting to the container they occupy. The behavior of gases can be described mathematically through various gas laws that relate pressure, volume, temperature, and amount of gas.

The Ideal Gas Law

The ideal gas law succinctly summarizes the relationships among the key variables:
$$PV = nRT$$

Where:
- P = pressure of the gas (atm, Pa, etc.)
- V = volume (L, m^3)
- n = number of moles of gas
- R = ideal gas constant (8.314 J/mol·K or 0.0821 L·atm/mol·K)
- T = temperature in Kelvin (K)

This law assumes gases behave ideally, meaning particles do not interact and occupy negligible volume. While real gases deviate under certain conditions, the ideal gas law provides a strong approximation for many scenarios.

The Relationship Between Temperature and Volume: Charles's Law

Charles's Law Explained

One of the fundamental principles describing the relationship between temperature and volume of a gas at constant pressure and amount is Charles's Law. It states:

The volume of a fixed amount of gas is directly proportional to its absolute temperature (in Kelvin) when pressure remains constant.

Mathematically:
$$ \frac{V_1}{T_1} = \frac{V_2}{T_2} $$

Where:
- V_1, T_1 = initial volume and temperature
- V_2, T_2 = final volume and temperature

Key Points:
- Temperatures must be in Kelvin to avoid negative values and ensure proportionality.
- The law implies that increasing temperature causes the gas to expand, while decreasing temperature causes it to contract, assuming constant pressure.

Applying the Concept: Calculating Changes in Gas Volume with Temperature Variations

Given Data

- Initial temperature, T_1 = 42°C
- Initial volume, V_1 = 1.47103 L

Convert Celsius to Kelvin:
$$ T_1(K) = 42 + 273.15 = 315.15\,K $$

Suppose the problem involves changing the temperature to a new value, T_2. Our goal is to determine the new volume V_2.

Sample Calculation Scenarios

Scenario 1: Heating the balloon to 60°C

- Final temperature, $T_2 = 60 + 273.15 = 333.15\,K$

Using Charles's Law:

$$V_2 = V_1 \times \frac{T_2}{T_1}$$

$$V_2 = 1.47103\,L \times \frac{333.15\,K}{315.15\,K}$$

$$V_2 \approx 1.47103\,L \times 1.057$$

$$V_2 \approx 1.556\,L$$

Result: Heating the balloon to 60°C increases its volume to approximately 1.556 liters.

Scenario 2: Cooling the balloon to 20°C

- Final temperature, $T_2 = 20 + 273.15 = 293.15\,K$

Applying Charles's Law:

$$V_2 = 1.47103\,L \times \frac{293.15\,K}{315.15\,K}$$

$$V_2 \approx 1.47103\,L \times 0.931$$

$$V_2 \approx 1.369\,L$$

Result: Cooling to 20°C reduces the volume to about 1.369 liters.

Factors Affecting Gas Behavior in a Balloon

While temperature plays a central role, other factors can influence the volume of gas in a balloon:

1. Pressure Changes

- Variations in external pressure can compress or expand the gas.
- Boyle's Law ($P_1 V_1 = P_2 V_2$) describes this behavior at constant temperature.

2. Amount of Gas (Number of Moles)

- Adding or removing gas changes the total amount (n).
- The combined gas law integrates pressure, volume, and temperature.

3. Material Constraints of the Balloon

- The elasticity and stretchability limit how much the balloon can expand.
- Beyond certain limits, the balloon may burst or deform.

Real-World Applications and Implications

Understanding how temperature influences the volume of gases in balloons has practical applications across various fields:

1. Weather Balloons

- Used in meteorology to collect atmospheric data.
- As the balloon ascends, external temperatures decrease, causing the gas volume to shrink unless the gas escapes or pressure adjusts.

2. Hot Air Balloons

- The pilot heats the air inside the balloon to increase volume and reduce density, causing it to rise.
- Cooling causes descent.

3. Engineering and Design

- Designing containers or systems that operate under temperature fluctuations require knowledge of gas laws to ensure safety and functionality.

Limitations and Deviations from Ideal Behavior

While the ideal gas law provides a useful approximation, real gases exhibit deviations due to interactions between particles and finite particle volume, especially at high pressures or low temperatures. Corrections such as Van der Waals equation can account for these effects, but for most practical purposes involving moderate conditions, ideal gas assumptions suffice.

Conclusion

The relationship between temperature and volume in gases is a cornerstone of thermodynamics and physical chemistry. As demonstrated through Charles's Law, when the amount of gas and pressure are held constant, an increase in temperature results in a proportional increase in volume, and vice versa. This principle explains everyday observations, such as the expansion of a hot air balloon or the contraction of a balloon in cold weather.

In the specific case where a gas sample in a balloon starts at 42°C and a volume of 1.47103 L, understanding how changes in temperature affect its size allows for precise control and prediction of its behavior. Whether adjusting for environmental conditions or designing systems that rely on gas expansion or contraction, applying these fundamental laws ensures safety, efficiency, and scientific accuracy.

Remember:
- Always convert temperatures to Kelvin when applying gas laws.
- Consider the constraints of your system, including pressure, material limits, and gas amount.
- Use the appropriate gas law or combined law for complex scenarios involving multiple variables.

By mastering these concepts, you gain deeper insight into the dynamic world of gases and their practical applications across science and engineering disciplines.

Frequently Asked Questions

What is the initial temperature of the gas sample in the balloon?

The initial temperature of the gas sample is 42°C.

What is the initial volume of the gas in the balloon?

The initial volume of the gas is 1.47103 liters.

Which gas law can be used to determine the change in volume or temperature of the gas in the balloon?

The combined gas law or Charles's law can be used to relate temperature and volume changes of the gas.

If the temperature of the gas increases, what happens to the volume assuming pressure remains constant?

The volume of the gas will increase if the temperature increases while pressure remains constant, according to Charles's law.

How do you convert the initial temperature from Celsius to Kelvin?

Add 273.15 to the Celsius temperature: 42°C + 273.15 = 315.15 K.

What additional information is needed to determine the new volume if the temperature changes?

The new temperature in Celsius or Kelvin and confirmation that pressure remains constant are needed to calculate the new volume using the gas laws.

Additional Resources

Sample Of Gas In A Balloon Has An Initial Temperature Of 42°C And A Volume Of 1.47103 L — These types of problems are common in chemistry and physics, especially when exploring the relationships between temperature, volume, and pressure of gases. Understanding how to analyze and solve such problems is essential for students and professionals alike. In this comprehensive guide, we'll walk through the principles behind gas law calculations, provide step-by-step instructions, and explore practical applications of these concepts, ensuring you gain a thorough understanding of how temperature influences the behavior of gases in a balloon.

Understanding the Basics of Gas Laws

Before diving into calculations, it's essential to grasp the fundamental principles governing gases. The behavior of gases is primarily described by the Ideal Gas Law, which combines several individual gas laws into a single equation:

$PV = nRT$

Where:
- P = Pressure of the gas (atm, Pa, etc.)
- V = Volume of the gas (L, m^3, etc.)
- n = Number of moles of gas (mol)
- R = Ideal gas constant (8.314 J/(mol·K) or 0.0821 L·atm/(mol·K))
- T = Temperature of the gas (Kelvin)

Key Concepts:
- Temperature (T): Must be in Kelvin for calculations.
- Volume (V): The space occupied by the gas.
- Pressure (P): The force exerted by the gas on its container.
- Moles (n): The amount of gas present.

The Relationship Between Temperature and Volume
One of the simplest forms of the ideal gas law, when pressure and moles are constant, is Charles's Law:

$V_1 / T_1 = V_2 / T_2$

This law states that at constant pressure and amount of gas, the volume of a gas is directly proportional to its temperature measured in Kelvin.

Step-by-Step Guide to Analyzing the Gas Sample

Let's consider the problem context: a sample of gas in a balloon with an initial temperature of 42°C and an initial volume of 1.47103 L.

Step 1: Convert Temperatures to Kelvin
Since gas law calculations require temperatures in Kelvin:

$T(K) = T(°C) + 273.15$

- Initial temperature:
$T_1 = 42 + 273.15 = 315.15$ K

- If the problem involves a change in temperature (say, T_2), convert accordingly.

Step 2: Clarify the Data and What is Being Asked
Depending on the problem, you might need to determine:
- The new volume after a temperature change.
- The change in pressure if temperature changes.
- The number of moles if conditions change.

Suppose the problem states: "If the temperature of the gas increases to 60°C, what will be the new volume of the balloon, assuming pressure remains constant?"

- New temperature, $T_2 = 60 + 273.15 = 333.15$ K

Step 3: Apply Charles's Law
Given that pressure and moles are constant, Charles's Law relates initial and final states:

$V_1 / T_1 = V_2 / T_2$

Rearranged to solve for V_2:

$V_2 = V_1 \times (T_2 / T_1)$

Plug in the known values:

$V_2 = 1.47103 \text{ L} \times (333.15 \text{ K} / 315.15 \text{ K})$

Calculate:

$V_2 \approx 1.47103 \times 1.0571 \approx 1.556$ L

Result: The volume of the balloon expands to approximately 1.556 liters when the temperature increases to 60°C.

Exploring Different Scenarios

Scenario 1: Decreasing Temperature
If the temperature drops, the volume decreases proportionally (assuming constant pressure and moles). For example, at 20°C:

- $T_3 = 20 + 273.15 = 293.15$ K

$V_3 = 1.47103 \text{ L} \times (293.15 / 315.15) \approx 1.371 \text{ L}$

Scenario 2: Changing Pressure
If pressure is not constant, Boyle's Law applies:

$P_1V_1 = P_2V_2$

When temperature is constant, but pressure changes, you can find the new volume.

Scenario 3: Changing Moles
If the amount of gas changes, the ideal gas law can be rearranged to solve for n:

$n = PV / RT$

Knowing initial conditions, you can determine moles and analyze how the addition or removal of gas affects the system.

Practical Applications and Considerations

Understanding the relationship between temperature and volume in gases has numerous real-world applications:

- Balloon and Airship Design: Engineers account for temperature changes to prevent overexpansion or contraction.
- Weather Balloons: Predict their ascent and expansion at different altitudes.
- Industrial Gas Storage: Ensuring safety when gases are subjected to temperature fluctuations.

Limitations of Ideal Gas Law
While the ideal gas law provides a good approximation, real gases deviate under high pressures or low temperatures due to intermolecular forces. For precise calculations, corrections like Van der Waals equations may be employed.

Additional Tips for Gas Law Problems

- Always convert temperatures to Kelvin before calculations.
- Keep track of units throughout.
- Understand the conditions of your problem: are pressure, temperature, or moles held constant?
- Use appropriate gas constants based on units to ensure consistency.
- For multi-step problems, write down each known and unknown clearly.

Summary

In this guide, we've explored the fundamental concepts behind the behavior of gases, especially in relation to temperature and volume changes. Starting with the initial data — a sample of gas in a balloon with an initial temperature of 42°C and volume of 1.47103 L — we've demonstrated how to convert temperatures to Kelvin, apply Charles's Law for volume changes, and interpret the results in practical contexts. Mastering these principles enables you to analyze a wide array of problems involving gases, ensuring you can approach them with confidence and clarity.

Final Thoughts
Gas law problems like the one involving Sample Of Gas In A Balloon Has An Initial Temperature Of 42°C And A Volume Of 1.47103 L are foundational in understanding thermodynamics and physical chemistry. Whether you're a student preparing for exams or a professional working in fields related to gases, mastering these calculations opens the door to deeper insights into the physical world around us. Keep practicing with different scenarios, and you'll develop a strong intuition for how gases behave under various conditions.

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