If I Have 2,90 L. Sample Of Gas At A Pressure Of 5.00 KPa And A Temperature Of 50.0 0C.Assume The Container

If I Have 2.90 L. Sample Of Gas At A Pressure Of 5.00 KPa And A Temperature Of 50.0°C. Assume The Container

Understanding the behavior of gases under various conditions is fundamental in chemistry and physics. The given scenario presents a sample of gas with specific initial parameters: volume, pressure, and temperature. To analyze and predict the properties or changes of this gas sample, it is essential to apply the fundamental gas laws and concepts such as the Ideal Gas Law, real gas behavior, and the impact of varying conditions. This article explores these principles in-depth, providing a comprehensive understanding of how gases behave under the specified conditions and how to manipulate these parameters for practical applications.

Fundamental Concepts of Gas Behavior

Properties of Gases

Gases are one of the three primary states of matter, characterized by their ability to expand to fill their containers, compressibility, and low density. The main properties of gases include:

- **Pressure (P)**: The force exerted by gas molecules per unit area on the walls of the container, measured in units such as kilopascals (kPa), atmospheres (atm), or pascals (Pa).
- **Volume (V)**: The amount of space occupied by the gas, typically in liters (L) or cubic meters (m^3).
- **Temperature (T)**: A measure of the average kinetic energy of gas molecules, expressed in Kelvin (K) or Celsius (°C).
- **Amount of gas (n)**: The quantity of gas, usually given in moles (mol).

Understanding how these properties are interrelated allows us to predict how a gas will respond to changes in its environment.

Ideal Gas Law

The Ideal Gas Law combines the four properties into a single equation:

$PV = nRT$

Where:

- **P** = pressure in kilopascals (kPa)
- **V** = volume in liters (L)
- **n** = amount of gas in moles (mol)
- **R** = universal gas constant (8.314 J/(mol·K)) or 8.314 L·kPa/(mol·K))
- **T** = temperature in Kelvin (K)

This law is applicable under ideal conditions, where gas molecules are considered point particles with no intermolecular forces.

Converting and Calculating Initial Conditions

Converting Temperature to Kelvin

Since the initial temperature is given as 50.0°C, it needs to be converted to Kelvin:

T(K) = T(°C) + 273.15

T = 50.0 + 273.15 = 323.15 K

Calculating the Number of Moles (n)

Using the ideal gas law with the initial parameters:

- P = 5.00 kPa
- V = 2.90 L
- T = 323.15 K
- R = 8.314 L·kPa/(mol·K)

Rearranged for n:

n = PV / RT

Calculating:

n = (5.00 kPa 2.90 L) / (8.314 L·kPa/(mol·K) 323.15 K)

n = (14.5 kPa·L) / (2688.6 L·kPa/mol)

n ≈ 0.00539 mol

This indicates a very small amount of gas in the sample, typical for laboratory or analytical settings.

Predicting Gas Behavior Under Changing Conditions

Impact of Temperature Variations

Temperature influences the kinetic energy of gas particles. Increasing temperature generally increases pressure or volume, assuming other variables remain constant, according to Gay-Lussac's law or Charles's law.

Impact of Pressure Changes

Applying pressure changes impacts the volume of the gas if temperature and amount of gas are held constant, as described by Boyle's law:

- At constant temperature and moles, **PV = constant**

Impact of Volume Changes

Similarly, altering the volume affects pressure at constant temperature:

- At constant n and T, $\mathbf{V \propto 1/P}$

Applying Gas Laws to the Scenario

Suppose we want to determine how the gas behaves if the temperature is increased or the pressure is altered.

Example 1: Increasing Temperature to 100°C

Convert 100°C to Kelvin:

$T_2 = 100 + 273.15 = 373.15$ K

Using the combined gas law:

$(P_1 V_1) / T_1 = (P_2 V_2) / T_2$

If the pressure remains constant, the volume will change proportionally with temperature:

$V_2 = V_1 (T_2 / T_1) = 2.90 \text{ L} (373.15 / 323.15) \approx 2.90 \text{ L } 1.154 \approx 3.347 \text{ L}$

This means the volume will expand from 2.90 L to approximately 3.35 L when heating from 50°C to 100°C at constant pressure.

Example 2: Applying Increased Pressure to 10.00 KPa

Assuming the temperature remains at 50°C (or 323.15 K), and initial volume is 2.90 L, find the new volume V_2 when pressure doubles to 10.00 KPa:

Using Boyle's law:

$P_1V_1 = P_2V_2$

So,

$V_2 = (P_1 V_1) / P_2 = (5.00 \text{ KPa } 2.90 \text{ L}) / 10.00 \text{ KPa} = 14.5 / 10.00 = 1.45 \text{ L}$

The volume halves when pressure doubles, illustrating the inverse relationship.

Real Gas Considerations and Deviations from Ideal Behavior

While the ideal gas law provides a good approximation under many conditions, real gases exhibit deviations at high pressures and low temperatures due to intermolecular forces and finite molecular sizes.

Van der Waals Equation

The Van der Waals equation adjusts the ideal gas law to account for these factors:

$[P + a(n/V)^2] [V - nb] = nRT$

Where:

- **a** and **b** are substance-specific constants representing intermolecular attractions and molecular volume, respectively.

At the given low pressure (5.00 kPa), deviations are minimal, and the ideal gas law remains a valid approximation.

Practical Applications and Implications

Understanding the behavior of gases under these conditions is crucial in various fields:

- **Industrial Gas Storage:** Determining optimal storage conditions to prevent overpressure or volume expansion.
- **Respiratory Physiology:** Analyzing how gases like oxygen behave in the lungs at different pressures and temperatures.
- **Chemical Reactions:** Controlling gas parameters to optimize reaction conditions and yields.
- **Environmental Science:** Assessing how atmospheric gases respond to temperature and pressure changes due to climate variations.

Conclusion

Analyzing a gas sample with a volume of 2.90 L, at a pressure of 5.00 KPa, and a temperature of 50.0°C involves understanding the fundamental principles of gas laws and their applications. Converting temperature to Kelvin, calculating the number of moles, and applying the ideal gas law allows for precise predictions of how the gas will behave under different conditions. Recognizing the limitations of the ideal gas law and the potential for deviations in real-world scenarios ensures more accurate modeling. Whether adjusting temperature, pressure, or volume, the interplay of these parameters dictates the behavior of gases, essential knowledge in scientific research, engineering, and environmental management.

Frequently Asked Questions

What is the initial volume of the gas sample?

The initial volume of the gas sample is 2.90 liters.

What is the initial pressure of the gas sample?

The initial pressure of the gas sample is 5.00 kPa.

What is the initial temperature of the gas in Celsius?

The initial temperature of the gas is 50.0°C.

How can I convert the temperature from Celsius to

Kelvin?

Add 273.15 to the Celsius temperature, so 50.0°C equals 323.15 K.

Which gas law should I use if I want to find the new pressure after changing temperature or volume?

You should use the Ideal Gas Law: PV = nRT, or combined gas law if only temperature and pressure change.

How do I calculate the number of moles of gas in the sample?

Use the ideal gas law rearranged as n = PV / RT, substituting the initial conditions and R = 8.314 J/(mol·K).

What assumptions are made in applying the ideal gas law to this sample?

It assumes the gas behaves ideally, with negligible interactions between molecules and point-like particles.

If the container is assumed rigid and closed, how does changing temperature affect pressure?

According to Gay-Lussac's Law, increasing temperature at constant volume increases pressure proportionally.

Can I determine the final pressure if I change the temperature, assuming volume and amount of gas stay constant?

Yes, using P1/T1 = P2/T2, you can calculate the final pressure after temperature change.

Additional Resources

Gas Behavior Analysis: An Expert Review of Sample Conditions and Theoretical Implications

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Introduction

Understanding the behavior of gases under various conditions is fundamental to fields ranging from chemical engineering to environmental science. When examining a sample of gas, parameters such as volume, pressure, temperature, and the properties of the container itself critically influence the gas's state and its potential applications. In this detailed analysis, we explore a specific scenario: a 2.90-liter sample of gas held at a pressure of 5.00 kPa and a temperature of 50.0°C, with assumptions about the container's nature. This case provides an excellent opportunity to delve into the principles of ideal gas behavior, the use of the ideal gas law, and the real-world implications of these calculations.

Fundamental Concepts in Gas Laws

Before analyzing the specific sample, it is essential to review the core principles governing gases:

- Pressure (P): The force exerted per unit area by gas particles colliding with container walls.
- Volume (V): The space occupied by the gas.
- Temperature (T): A measure of the average kinetic energy of gas particles.
- Number of moles (n): The amount of substance, directly related to mass and molar mass.
- Ideal Gas Law: $PV = nRT$, where R is the universal gas constant.

These parameters are interconnected, and understanding their relationships allows for the prediction and manipulation of gas behavior in various contexts.

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1. Container Assumptions and Their Significance

Adopting the container as a rigid, sealed vessel simplifies analysis by assuming:

- Constant Volume: The container's volume does not change during the process.
- Impermeability: No gas leakage occurs.
- Thermal Isolation or Controlled Temperature: The temperature remains stable or varies predictably.

This assumption allows us to focus primarily on how pressure, temperature, and the amount of gas relate, using well-established gas laws. It also means that any changes in one parameter directly influence the others, provided the container remains unaltered.

Implications of container assumptions:

- Rigid containers prevent volume fluctuations, making calculations straightforward.
- Sealed environments eliminate the need to consider gas exchange with surroundings.
- Material properties (e.g., whether the container is metallic, glass, or polymeric) influence thermal conduction and pressure tolerance but are secondary for ideal gas calculations.

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2. Analyzing the Given Data

a. Volume and Its Role

The sample volume is specified as 2.90 liters. This volume is crucial because:

- It determines the space available for the gas particles.

- It influences the pressure and temperature relationships via the ideal gas law.
- For practical applications, knowing the volume helps in designing containers and predicting gas behavior under different conditions.

b. Pressure

The pressure is 5.00 kPa. Compared to atmospheric pressure (~101.3 kPa), this is relatively low, indicating a near-vacuum or a low-pressure situation. Low-pressure gases tend to behave more ideally, as interactions between particles are minimized.

c. Temperature

The temperature is 50.0°C, which converts to Kelvin as:

$$
T(K) = 50.0 + 273.15 = 323.15\, \mathrm{K}
$$

Temperature impacts the kinetic energy of particles, affecting pressure and volume if the container is flexible.

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3. Applying the Ideal Gas Law

The ideal gas law provides a framework to understand and calculate the amount of gas present and predict how the gas will behave under different conditions.

$$
PV = nRT
$$

Where:

- P = pressure in pascals (Pa)
- V = volume in cubic meters (m^3)
- n = number of moles
- R = universal gas constant ($8.314\, \mathrm{J\,mol^{-1}\,K^{-1}}$)
- T = temperature in Kelvin (K)

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4. Calculating the Moles of Gas

To determine the number of moles, convert given parameters to SI units:

- Volume: $2.90\, \mathrm{L} = 2.90 \times 10^{-3}\, \mathrm{m^3}$
- Pressure: $5.00\, \mathrm{kPa} = 5.00 \times 10^{3}\, \mathrm{Pa}$

Plugging into the ideal gas law:

$$
n = \frac{PV}{RT}
$$

\[

$$
n = \frac{(5.00 \times 10^{3}) \times (2.90 \times 10^{-3})}{8.314 \times 323.15}
$$

Calculating numerator:

$$
5.00 \times 10^{3} \times 2.90 \times 10^{-3} = 14.5
$$

Calculating denominator:

$$
8.314 \times 323.15 \approx 2687.4
$$

Result:

$$
n \approx \frac{14.5}{2687.4} \approx 0.0054\, \text{moles}
$$

Interpretation: The sample contains approximately 0.0054 moles of gas, which is a very small amount, consistent with the low pressure and volume.

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5. Implications of the Calculations

a. Gas Density

The molar density (n/V) is:

$$
\frac{0.0054\, \text{mol}}{2.90 \times 10^{-3}\, \text{m}^3} \approx 1.86\, \text{mol/m}^3
$$

This low density aligns with the low pressure, indicating the gas particles are sparsely distributed.

b. Potential for Gas Compression or Expansion

If the container were flexible, increasing temperature or decreasing pressure could result in volume changes, in accordance with the ideal gas law.

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6. Real-World Applications and Considerations

a. Gas Storage and Safety

Understanding the amount of gas at specific conditions aids in designing safe storage containers, especially for gases under low or high pressures and temperatures.

b. Gas Behavior in Industrial Processes

Accurate calculations of gas quantities inform processes such as:

- Chemical reactions involving gaseous reactants.
- Gas transport in pipelines.
- Environmental modeling, such as atmospheric gas behavior.

c. Limitations of the Ideal Gas Law

While the ideal gas law offers valuable approximations, real gases deviate at high pressures and low temperatures due to intermolecular forces and finite particle volume. For this scenario:

- The low pressure suggests ideal behavior.
- At higher pressures, correction factors (van der Waals equation) may be necessary.

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7. Additional Considerations

a. Effect of Temperature Change

Suppose the temperature increases:

- At constant volume and moles, pressure increases proportionally.
- At constant pressure, volume would expand with temperature.

b. Effect of Adding or Removing Gas

- Increasing the number of moles (\(n \)) raises pressure or volume, depending on constraints.
- Removing gas decreases pressure directly.

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8. Conclusion

This comprehensive analysis underscores the importance of understanding fundamental gas laws and assumptions about container properties. The sample's low pressure, modest volume, and moderate temperature characterize a dilute, ideal gas scenario, allowing straightforward calculations and predictions. Such insights are invaluable for designing experiments, industrial processes, and safety protocols involving gases.

Key takeaways:

- Precise parameter conversion is essential for accurate calculations.
- Assumptions about the container influence the applicability of models.
- The ideal gas law serves as a powerful tool for estimating gas quantities under specified conditions.
- Real-world applications require considering deviations from ideality, especially at extreme conditions.

In sum, this case study exemplifies the intersection of theoretical principles and practical considerations, reinforcing the vital role of gas law fundamentals in scientific and engineering pursuits.

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