7.2 Litters Of An Ideal Gas Are Contained At 4.0 Atm And 27C. Using The Ideal Gas Law, Calculate How

7.2 Litters Of An Ideal Gas Are Contained At 4.0 Atm And 27°C. Using The Ideal Gas Law, Calculate How to determine the volume, pressure, temperature, or amount of gas involved in various scenarios is a fundamental aspect of understanding chemistry and physics. The Ideal Gas Law provides a straightforward way to relate these variables and solve for unknowns, making it an essential tool for students, scientists, and engineers alike. This article will explore how to apply the Ideal Gas Law in practical calculations, starting with the provided conditions: 7.2 liters of an ideal gas at 4.0 atm and 27°C, and extending to various related questions.

Understanding the Ideal Gas Law

The Ideal Gas Law is expressed as:

PV = nRT

where:

- **P** = pressure (in atmospheres, atm)
- **V** = volume (in liters, L)
- **n** = number of moles of gas
- **R** = ideal gas constant (0.0821 L·atm/(mol·K))
- **T** = temperature (in Kelvin, K)

This equation links the four main variables of a gas sample, allowing us to calculate any one of them if the others are known.

Converting Temperature to Kelvin

Since the Ideal Gas Law uses Kelvin, the first step is to convert the given temperature:

Temperature Conversion

1. Given temperature: 27°C
2. Conversion formula: T(K) = T(°C) + 273.15
3. Calculation: 27 + 273.15 = 300.15 K

For simplicity, this is often rounded to 300.15 K or 300 K in calculations.

Calculating the Number of Moles of Gas

Suppose we want to determine how many moles of gas are present in the 7.2 liters under the given conditions.

Applying the Ideal Gas Law

Using the formula:

$PV = nRT$

Rearranged to solve for n:

$n = PV / RT$

Input Values

- $P = 4.0$ atm
- $V = 7.2$ L
- $R = 0.0821$ L·atm/(mol·K)
- $T = 300$ K

Calculation

$n = (4.0 \text{ atm})(7.2 \text{ L}) / (0.0821 \text{ L·atm/(mol·K)} \times 300 \text{ K})$

$n = 28.8 / 24.63 \approx 1.17$ mol

Result: Approximately 1.17 moles of gas are contained within the 7.2 liters at 4.0 atm and 27°C.

Exploring Variations: How Changing Conditions Affect the Gas

The versatility of the Ideal Gas Law allows for various calculations depending on what variable you want to find. Here are some common scenarios:

1. What is the volume if the number of moles, pressure, and temperature are known?

Suppose the number of moles is 1.17 mol, pressure remains at 4.0 atm, and temperature is 300 K. To find volume:

$V = nRT / P$

Plugging in the values:

$V = (1.17\ \text{mol})(0.0821\ \text{L·atm/(mol·K)})(300\ \text{K}) / 4.0\ \text{atm}$

$V \approx (1.17)(0.0821)(300) / 4.0$

$V \approx 28.8 / 4.0 = 7.2\ \text{L}$

This confirms the initial volume, illustrating consistency in calculations.

2. How does pressure change if volume and temperature are fixed?

If volume and temperature are constant, increasing the number of moles increases pressure proportionally:

$P = nRT / V$

For example, doubling the moles to 2.34 mol:

$P = (2.34\ \text{mol})(0.0821)(300) / 7.2 \approx 8.0\ \text{atm}$

Key insight: Pressure is directly proportional to the number of moles when other variables are held constant.

3. How does temperature influence the pressure at constant volume and moles?

If the volume and moles are fixed, increasing temperature increases pressure:

$P = nRT / V$

Suppose temperature rises from 300 K to 600 K:

$P_{new} = (1.17\ \text{mol})(0.0821)(600) / 7.2 \approx 8.0\ \text{atm}$

Observation: Doubling the temperature doubles the pressure.

Practical Applications of the Ideal Gas Law

Understanding how to manipulate and interpret the Ideal Gas Law is crucial in various real-world contexts:

Chemical Reactions and Gas Stoichiometry

The law assists in predicting the amount of gas produced or consumed during reactions, essential in laboratory and industrial chemistry.

Engineering and Design of Gas Containers

Designers use these calculations to determine safe pressure limits and optimal storage conditions for gases.

Environmental Science

Scientists model atmospheric gases, pollution dispersion, and greenhouse effects using the law.

Limitations and Real-World Considerations

While the Ideal Gas Law is a powerful tool, it has limitations:

- It assumes gases are ideal, meaning particles do not interact and occupy no volume, which isn't accurate at very high pressures or low temperatures.
- Real gases deviate from ideality near liquefaction points or under extreme conditions.
- For precise calculations under such conditions, real gas equations like the Van der Waals equation are used.

Conclusion: Applying the Ideal Gas Law Effectively

Starting with the initial conditions—7.2 liters of an ideal gas at 4.0 atm and 27°C—you can determine the number of moles, predict how volume changes with pressure and temperature, or understand how different variables influence each other. Mastering these calculations enhances your comprehension of gases and their behaviors in various scientific and engineering contexts.

By understanding the core principles and practicing different scenarios, you can confidently utilize the Ideal Gas Law to solve real-world problems efficiently and accurately.

Frequently Asked Questions

What is the ideal gas law formula used to calculate the number of moles in a gas sample?

The ideal gas law formula is $PV = nRT$, where P is pressure, V is volume, n is number of moles, R is the gas constant, and T is temperature in Kelvin.

How do you convert Celsius temperature to Kelvin for gas law calculations?

Add 273.15 to the Celsius temperature to convert it to Kelvin. For example, 27°C = 300.15 K.

Given a volume of 7.2 liters, pressure of 4.0 atm, and temperature of 27°C,

how many moles of an ideal gas are present?

Using PV = nRT, n = (PV) / (RT). Substituting the values: n = (4.0 atm 7.2 L) / (0.0821 L·atm/(mol·K) 300.15 K) ≈ 1.17 moles.

What is the value of the gas constant R used in the ideal gas law calculations?

The gas constant R is 0.0821 L·atm/(mol·K).

How does changing the pressure or temperature affect the number of moles in a fixed volume of gas?

In a fixed volume, increasing pressure or temperature will affect the number of moles if the gas is not ideal, but for an ideal gas, the number of moles remains proportional to PV/RT, so changes in P or T will alter n accordingly.

If the temperature increases to 37°C, how does that impact the calculation of moles in the same gas sample?

Converting 37°C to Kelvin gives 310.15 K. Recalculating n with this temperature will typically result in a slightly different value, showing the relationship between temperature and the amount of gas, assuming pressure and volume are constant.

Can the ideal gas law be used accurately at high pressures or low temperatures?

The ideal gas law becomes less accurate at high pressures and low temperatures where real gas behavior deviates from ideality due to intermolecular forces and volume occupied by gas particles.

What steps are involved in calculating the number of moles of gas in a 7.2 L container at 4.0 atm and 27°C?

First, convert temperature to Kelvin (27°C = 300.15 K). Then, apply PV = nRT: n = (P V) / (R T). Substitute the known values and solve for n to find the number of moles.

Additional Resources

Ideal Gas Law: An In-Depth Analysis of Volume, Pressure, and Temperature Relationships

The ideal gas law is a cornerstone of modern chemistry and physics, providing fundamental insights into how gases behave under various conditions. In this detailed exploration, we will analyze a specific scenario: a container holding 7.2 liters of an ideal gas at a pressure of 4.0 atm and a temperature of 27°C. Our goal is to understand the relationships involved, perform precise calculations, and appreciate the significance of the law in real-world applications.

Understanding the Ideal Gas Law

What Is the Ideal Gas Law?

The ideal gas law is expressed mathematically as:

$$PV = nRT$$

Where:
- P = Pressure (atm)
- V = Volume (liters)
- n = Number of moles of gas
- R = Ideal gas constant (8.314 J/mol·K or 0.0821 L·atm/mol·K)
- T = Temperature (Kelvin)

This equation relates the four variables—pressure, volume, temperature, and amount of gas—assuming the gas behaves ideally, meaning particles do not interact and occupy negligible volume.

Scenario Overview: Gas in a Container

Let's examine the given parameters:

- Volume (V) = 7.2 liters
- Pressure (P) = 4.0 atm
- Temperature (T) = 27°C

Our goal is to determine:
- The number of moles (n) of gas present
- How the volume would change if the temperature or pressure varies
- Additional insights into the behavior of the gas under these conditions

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Converting Temperature to Kelvin

Since the ideal gas law requires temperature in Kelvin, we convert:

$$T(K) = T(°C) + 273.15$$

$$T = 27 + 273.15 = 300.15\, \text{K}$$

For simplicity, we often round to 300 K in calculations unless very high precision is required.

Calculating the Number of Moles of Gas

Using the ideal gas law:

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

Step-by-step calculation:

- Substitute known values:

$$ n = \frac{(4.0\, \text{atm}) \times (7.2\, \text{L})}{(0.0821\, \text{L·atm/mol·K}) \times 300\, \text{K}} $$

- Calculate numerator:

$$ 4.0 \times 7.2 = 28.8\, \text{L·atm} $$

- Calculate denominator:

$$ 0.0821 \times 300 = 24.63\, \text{L·atm/mol} $$

- Final calculation:

$$ n = \frac{28.8}{24.63} \approx 1.17\, \text{mol} $$

Result: The container holds approximately 1.17 moles of the ideal gas.

Analyzing the Implications of the Moles Calculated

This quantity of gas, roughly 1.17 mol, corresponds to a specific mass depending on the gas's molar mass. For example:

- For nitrogen (N_2), molar mass ≈ 28 g/mol:

$$ \text{Mass} = 1.17 \times 28 \approx 32.8\, \text{g} $$

- For oxygen (O_2), molar mass ≈ 32 g/mol:

$$ \text{Mass} = 1.17 \times 32 \approx 37.4\, \text{g} $$

This contextual understanding enables practical applications, such as estimating the weight of gases in industrial processes.

Exploring Variations: How Changes in Conditions Affect the Gas

The ideal gas law allows us to predict how the gas's behavior will change with variations in pressure, temperature, or volume. Let's explore some scenarios.

1. Increasing the Temperature at Constant Pressure and Volume

Suppose the temperature increases from 27°C (300 K) to 50°C (323 K). How does the number of moles or volume change?

- Since n and V are constant, the law simplifies to:

$$ \frac{P \times V}{T} = \text{constant} $$

- The volume, under constant pressure, is directly proportional to temperature:

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

- Therefore:

$$ V_2 = V_1 \times \frac{T_2}{T_1} = 7.2\, \text{L} \times \frac{323}{300} \approx 7.75\, \text{L} $$

Conclusion: The volume expands slightly to approximately 7.75 liters when heated from 27°C to 50°C at constant pressure.

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2. Increasing Pressure at Constant Temperature and Volume

If the pressure increases from 4.0 atm to 5.0 atm while temperature and volume remain unchanged:

- The number of moles n increases proportionally:

$$ n_2 = \frac{P_2 V}{RT} = \frac{5.0 \times 7.2}{0.0821 \times 300} \approx 1.46\, \text{mol} $$

- This indicates more gas particles are introduced, or the existing particles are compressed, increasing the number of moles in the same volume.

Real-World Applications of the Ideal Gas Law

Understanding and calculating gas behavior via the ideal gas law has numerous applications across industries and scientific research:

- Chemical manufacturing: Precise control of gas reactions
- Aerospace engineering: Designing pressurized cabins and fuel systems
- Environmental science: Predicting pollutant dispersion
- Medical field: Gas exchange in respiratory therapies
- Everyday life: Estimating gas quantities in cooking, diving, or inflation

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Limitations and Real-World Deviations

While the ideal gas law provides a robust approximation, real gases deviate under certain conditions:

- High pressures: Particles are forced closer, and intermolecular forces become significant
- Low temperatures: Molecular interactions influence behavior more markedly
- Complex gases: Polarity and molecular structure can alter ideal assumptions

Real gases are better modeled with equations like the Van der Waals equation, which accounts for particle volume and intermolecular forces.

Conclusion: The Power of the Ideal Gas Law

This comprehensive analysis underscores the utility and elegance of the ideal gas law. From calculating the precise number of moles in a given volume to predicting how gases respond to changing conditions, the law remains indispensable in scientific and industrial contexts.

In our specific scenario—7.2 liters of an ideal gas at 4.0 atm and 27°C—we determined the gas contains approximately 1.17 moles. This foundational calculation exemplifies how a simple formula can unlock detailed insights into the microscopic world, enabling scientists and engineers to design, optimize, and innovate across countless fields.

Whether adjusting conditions to achieve desired reactions or ensuring safety in pressurized systems, mastering the ideal gas law continues to be a fundamental skill, bridging theoretical principles with practical applications.

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