How Many Moles Of Water Vapor Are In 12510 L Of Gas Over Water At 27c? (in A Hotel Pool Room, For Example.)

How Many Moles Of Water Vapor Are In 12510 L Of Gas Over Water At 27°C? (in A Hotel Pool Room, For Example.)

Understanding the amount of water vapor present in a given volume of air is an important concept in fields ranging from meteorology to HVAC systems, and even in everyday scenarios like relaxing in a hotel pool room. Imagine walking into a hotel pool area on a warm day, and noticing the humidity in the air. But how do scientists quantify this humidity? Specifically, how many moles of water vapor are present in a certain volume of air at a given temperature? This article explores the calculation of the number of moles of water vapor in 12,510 liters of gas over water at 27°C, providing a comprehensive understanding of the underlying principles and calculations involved.

Fundamental Concepts: Gas Laws and Water Vapor

Before diving into the calculations, it's essential to understand some fundamental concepts related to gases and water vapor.

Ideal Gas Law

The ideal gas law relates the pressure (P), volume (V), temperature (T), and number of moles (n) of a gas:
\[PV = nRT \]
where R is the universal gas constant (8.314 J/mol·K).

Water Vapor and Humidity

Water vapor is the gaseous phase of water. The amount of water vapor in the air depends on temperature and pressure, and it can be described using concepts like vapor pressure and relative humidity. The saturation vapor pressure (SVP) indicates the maximum pressure exerted by water vapor at a specific temperature when the air is fully saturated.

Step-by-Step Calculation of Moles of Water

Vapor

To determine how many moles of water vapor are in the 12,510 liters of gas over water at 27°C, we need to follow a systematic approach involving the vapor pressure of water at the given temperature and the ideal gas law.

Step 1: Determine the Saturation Vapor Pressure at 27°C

The first key parameter is the saturation vapor pressure (SVP) at 27°C. According to standard tables:

- SVP of water at 27°C ≈ 26.7 mm Hg

This value indicates the maximum partial pressure of water vapor that can exist at 27°C before condensation occurs.

Step 2: Convert Vapor Pressure to Atmospheric Pressure Units

To work seamlessly with the ideal gas law, it's best to convert the vapor pressure into atmospheres (atm):

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

Thus,

$$
P_{H_2O} = \frac{26.7\, \text{mm Hg}}{760\, \text{mm Hg}} \approx 0.0351\, \text{atm}
$$

This is the partial pressure of water vapor in the air at saturation.

Step 3: Establish Total Pressure of the Gas Mixture

In most indoor environments, the total atmospheric pressure is approximately 1 atm. Since the gas over water includes water vapor and dry air, the partial pressure of water vapor is a component of the total pressure.

Assuming the room is at standard atmospheric pressure (which is typical for a hotel pool room), the partial pressure of water vapor is about 0.0351 atm at saturation.

Step 4: Use the Ideal Gas Law to Calculate Moles of Water Vapor

The ideal gas law can be rearranged to find the number of moles:

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

where:
- $P = 0.0351\, \text{atm}$ (partial pressure of water vapor),
- $V = 12510\, \text{L}$,
- $R = 0.082057\, \text{L·atm/(mol·K)}$,
- $T = 27°C = 300.15\, \text{K}$.

Plugging in the numbers:

$$
n = \frac{(0.0351\, \text{atm}) \times 12510\, \text{L}}{0.082057\, \text{L·atm/(mol·K)} \times 300.15\, \text{K}}
$$

Calculating numerator:

$$
0.0351 \times 12510 \approx 439.4
$$

Calculating denominator:

$$
0.082057 \times 300.15 \approx 24.623
$$

Therefore:

$$
n = \frac{439.4}{24.623} \approx 17.86\, \text{moles}
$$

Result: Approximately 17.86 moles of water vapor are present in 12,510 liters of gas over water at 27°C when the vapor pressure is at saturation.

Additional Considerations: Real-World Implications

While the calculation above assumes the air is saturated with water vapor, in reality, humidity levels vary. The actual amount of water vapor in the air depends on the relative humidity (RH). For instance, if the air is only 50% saturated, then the actual moles of water vapor would be half of the calculated value.

How to adjust for relative humidity?

1. Obtain the relative humidity percentage (e.g., 50% RH).
2. Multiply the saturation vapor pressure by the RH to get the actual vapor pressure:

$$
P_{actual} = P_{SVP} \times \frac{\text{RH}}{100}
$$

3. Repeat the mole calculation with this actual vapor pressure.

Example:

If the RH is 50%:

$$
P_{H_2O} = 0.0351\, \text{atm} \times 0.5 = 0.01755\, \text{atm}
$$

$$
n = \frac{0.01755 \times 12510}{0.082057 \times 300.15} \approx 8.93\, \text{moles}
$$

This highlights how humidity levels significantly influence the amount of water vapor in a given volume.

Practical Applications and Significance

Understanding the amount of water vapor in indoor environments like hotel pool rooms has several practical implications:

- Comfort and Safety: High humidity levels can lead to discomfort, mold growth, and structural issues.
- HVAC Design: Proper ventilation systems rely on accurate humidity calculations to maintain optimal indoor air quality.
- Chemical and Biological Control: Controlling moisture is vital in preventing mold, bacteria, and other biological growths.
- Weather and Climate Studies: Indoor humidity measurements often mirror

broader atmospheric conditions.

Summary of Key Points

- The saturation vapor pressure of water at 27°C is approximately 26.7 mm Hg.
- Converting vapor pressure into atmospheres gives about 0.0351 atm.
- Using the ideal gas law, the number of moles of water vapor in 12,510 liters of air at saturation is approximately 17.86 moles.
- Actual water vapor content depends on relative humidity; at 50% RH, the amount drops to roughly half.
- These calculations help in understanding and managing indoor air quality in various settings, including hotel pool rooms.

Conclusion

Calculating how many moles of water vapor are in a given volume of air involves understanding the principles of gas laws, vapor pressure, and environmental conditions. In a typical scenario like a hotel pool room, knowing these values can aid in maintaining comfortable humidity levels and ensuring safety. Whether for scientific research, environmental management, or everyday comfort, mastering these calculations provides valuable insight into the behavior of water vapor in our environment.

By applying the ideal gas law and vapor pressure data, we can accurately estimate the amount of water vapor present, which is crucial for designing better ventilation systems, preventing mold growth, and enhancing indoor air quality. Ultimately, understanding the microscopic details of water vapor in the air enriches our appreciation of the complex interplay between temperature, pressure, and humidity in indoor environments.

Frequently Asked Questions

How do I determine the number of moles of water vapor in 12510 L of gas at 27°C?

Use the ideal gas law (PV = nRT) by converting the volume to liters, temperature to Kelvin, and using the appropriate R value; then solve for n to find moles.

What is the ideal gas constant R, and what units should I use in calculations?

The ideal gas constant R is 0.0821 L·atm/(mol·K); ensure volume is in liters, pressure in atm, and temperature in Kelvin for consistent units.

How do I convert 27°C to Kelvin?

Add 273.15 to 27°C, so 27 + 273.15 = 300.15 K.

What pressure should I assume for the gas over water in a hotel pool room?

Assuming atmospheric pressure at sea level, use approximately 1 atm unless otherwise specified; remember that water vapor contributes to total pressure.

How does water vapor pressure at 27°C affect the calculation?

If the gas is saturated with water vapor, subtract the vapor pressure of water at 27°C (around 26.7 mmHg) from the total pressure to find the partial pressure of dry gas.

What is the vapor pressure of water at 27°C, and why is it important?

The vapor pressure of water at 27°C is approximately 26.7 mmHg; it’s important because it influences the partial pressure of water vapor in the gas sample.

Can I directly apply the ideal gas law to find moles of water vapor in this scenario?

Yes, if you account for the partial pressure of water vapor and use the volume and temperature, the ideal gas law can be applied to find the moles of water vapor.

How do I adjust the total pressure to account for water vapor in the room?

Subtract the vapor pressure of water at 27°C from the total atmospheric pressure to get the partial pressure of the dry gas; then use this in your calculations.

What is the approximate number of moles of water vapor in 12510 L of gas at 27°C and 1 atm total pressure?

First, subtract water vapor pressure (about 26.7 mmHg ≈ 0.035 atm) from 1 atm to get dry gas pressure (~0.965 atm). Using PV = nRT, n ≈ (0.965 atm × 12510

L) / (0.0821 L·atm/(mol·K) × 300.15 K) ≈ 491 mol of water vapor.

Additional Resources

How Many Moles Of Water Vapor Are In 12,510 L Of Gas Over Water At 27°C? (In A Hotel Pool Room, For Example.)

Understanding the amount of water vapor present in a given volume of gas at a specific temperature is a fundamental concept in chemistry, atmospheric science, and everyday life—like in a hotel pool room. Whether you're a student preparing for exams, a scientist measuring humidity, or just curious about the moisture in your environment, grasping how to determine the number of moles of water vapor in a gas volume is essential. This detailed exploration will guide you through the principles, calculations, and practical implications of determining water vapor content, specifically focusing on a scenario where 12,510 liters of gas are over water at 27°C.

Fundamental Concepts and Definitions

Before diving into calculations, it's important to familiarize yourself with key concepts:

- Moles (mol): The standard unit in chemistry representing a specific number of particles—Avogadro's number (6.022×10^{23} particles).

- Gas Volume: The space occupied by the gas, usually measured in liters (L).

- Temperature (T): The measure of the thermal energy of the gas, influencing vapor pressure and saturation.

- Pressure (P): The force exerted by the gas per unit area, often measured in atmospheres (atm), pascals (Pa), or millimeters of mercury (mm Hg).

- Water Vapor: The gaseous phase of water, which can coexist with other gases in an air mixture.

- Saturation Vapor Pressure (SVP): The maximum pressure exerted by water vapor at a given temperature when the air is saturated.

The Relevance of Temperature and Vapor Pressure

Temperature plays a pivotal role in determining the amount of water vapor a gas can contain. As temperature increases, water's vapor pressure rises, meaning the air can hold more moisture before reaching saturation. Conversely, cooler air holds less water vapor.

- At 27°C (approximately 80.6°F):
The saturation vapor pressure for water is approximately 26.7 mm Hg (or about 3.56 kPa). This value indicates the maximum partial pressure of water vapor in the air when it's saturated at this temperature.

Understanding the saturation vapor pressure is crucial because it sets an upper limit on the water vapor content under equilibrium conditions.

Applying the Ideal Gas Law

The ideal gas law is a cornerstone in calculating the amount of gas in a given volume:

$$PV = nRT$$

where:
- P = pressure in atm
- V = volume in liters
- n = number of moles
- R = ideal gas constant = 0.08206 L·atm/(mol·K)
- T = temperature in Kelvin (K)

Key Point:
When calculating water vapor content over water, the partial pressure of water vapor is the relevant pressure in the ideal gas law, not the total pressure.

Scenario Setup: Gas Over Water in a Hotel Pool Room

Imagine you're in a hotel pool room where the ambient conditions induce moisture-laden air above a water surface. The total volume of the gas is 12,510 liters at 27°C.

Assumptions for the Calculation:

- The gas is in equilibrium with water at 27°C.
- The total pressure is standard atmospheric pressure: 1 atm.
- The gas is an ideal mixture of dry air and water vapor.
- The air is saturated with water vapor at 27°C (i.e., maximum possible water vapor content at this temperature).

Calculating the Moles of Water Vapor

To determine the number of moles of water vapor in the gas volume, follow these steps:

Step 1: Determine the Partial Pressure of Water Vapor

Since the air is saturated at 27°C, the partial pressure of water vapor (P_{H_2O}) equals the saturation vapor pressure at this temperature:

$$P_{H_2O} \approx 26.7 \text{ mm Hg}$$

Convert mm Hg to atm:

$$
P_{H_2O} = \frac{26.7 \text{ mm Hg}}{760 \text{ mm Hg/atm}} \approx 0.0351 \text{ atm}
$$

Step 2: Determine the Partial Pressure of Dry Air

Assuming the total pressure is 1 atm:

$$
P_{dry\,air} = P_{total} - P_{H_2O} = 1 - 0.0351 = 0.9649 \text{ atm}
$$

Step 3: Calculate the Moles of Water Vapor Using the Ideal Gas Law

Apply the ideal gas law to the water vapor:

$$
n_{H_2O} = \frac{P_{H_2O} \times V}{R \times T}
$$

Where:
- $P_{H_2O} = 0.0351 \text{ atm}$
- $V = 12,510 \text{ L}$
- $R = 0.08206 \text{ L·atm/(mol·K)}$

- $T = 27°C = 273 + 27 = 300 \text{ K}$

Plugging in the values:

$$
n_{H_2O} = \frac{0.0351 \times 12510}{0.08206 \times 300}
$$

Calculating numerator:

$$
0.0351 \times 12510 \approx 439.7
$$

Calculating denominator:

$$
0.08206 \times 300 \approx 24.618
$$

Final calculation:

$$
n_{H_2O} \approx \frac{439.7}{24.618} \approx 17.87 \text{ mol}
$$

Result:

Approximately 17.87 moles of water vapor are present in 12,510 liters of gas over water at 27°C when saturated.

Implications and Practical Considerations

- Humidity Level:
The calculation assumes saturation. In real-world scenarios, the actual humidity may be less, meaning fewer moles of water vapor are present.

- Partial vs. Total Pressure:
If the total pressure differs from 1 atm (e.g., in a pressurized room), adjust the partial pressure accordingly.

- Temperature Variations:
Slight changes in temperature significantly affect the saturation vapor pressure and thus the water vapor content.

- Non-Ideal Behavior:
For higher pressures or specific conditions, deviations from ideal gas

behavior might need to be considered, possibly requiring correction factors or more advanced models.

Additional Factors to Consider in Real-Life Settings

While the calculations above provide a theoretical maximum under ideal conditions, real environments like a hotel pool room involve additional factors:

- Room Ventilation:
Fresh air exchange can reduce vapor content.

- Water Temperature Variability:
The temperature of the pool water and air may vary, influencing vapor pressure.

- Presence of Other Gases:
Humidity interacts with other gases, and the mixture's behavior can be complex.

- Condensation Risks:
If the air becomes supersaturated (exceeds saturation vapor pressure), condensation occurs, affecting the actual vapor content.

Broader Applications and Related Topics

Understanding the quantity of water vapor in a gas has numerous applications:

- Meteorology:
Predicting weather patterns, cloud formation, and humidity levels.

- HVAC Engineering:
Designing ventilation systems to control indoor humidity.

- Industrial Processes:
Managing moisture for manufacturing, drying, or chemical reactions.

- Environmental Science:
Monitoring atmospheric moisture and its effects on climate.

- Health and Comfort:

Maintaining optimal indoor humidity levels for comfort and health.

Summary and Key Takeaways

- The number of moles of water vapor in a given volume of gas depends on temperature, pressure, and whether the air is saturated.

- At 27°C, the saturation vapor pressure of water is approximately 26.7 mm Hg, which corresponds to about 0.0351 atm.

- Using the ideal gas law, the calculation yields roughly 17.87 moles of water vapor in 12,510 liters of saturated air at this temperature and pressure.

- Real-world conditions may vary, and factors such as ventilation, actual humidity, and temperature fluctuations influence the actual water vapor content.

- Understanding these principles helps in managing indoor environments, predicting weather, and designing systems involving humidification or dehumidification.

In conclusion, determining the amount of water vapor in a volume of gas is a straightforward application of the ideal gas law combined with vapor pressure data. Whether in a hotel pool room or in atmospheric studies, these calculations provide vital insights into moisture content, helping us better understand and control our environment.

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