A Sample Of Oxygen Gas Has A Volume Of 1.72 L At 27C And 800.0 Torr. How Many Oxygen Molecules Does It

A Sample Of Oxygen Gas Has A Volume Of 1.72 L At 27C And 800.0 Torr. How Many Oxygen Molecules Does It? This question touches on fundamental concepts in chemistry, particularly the application of the ideal gas law, molar calculations, and molecular quantities. Understanding how to determine the number of molecules in a given sample of gas is essential for students and professionals working in chemistry, physics, environmental science, and related fields. In this article, we will explore the step-by-step process to solve this problem, delve into the relevant concepts, and provide a comprehensive understanding of how to approach such calculations.

Understanding the Problem and Key Concepts

Before diving into calculations, it's crucial to clarify what information is provided and what is being asked. The problem states:

- Volume of oxygen gas = 1.72 liters
- Temperature = 27°C
- Pressure = 800.0 Torr
- Question: How many oxygen molecules are present in this sample?

The goal is to find the number of molecules, which involves converting the given data into moles and then into molecules.

Key concepts involved include:

- Ideal Gas Law: $PV = nRT$
- Moles of Gas: n = mass / molar mass, but in this case, mass isn't directly given.
- Avogadro's Number: Number of molecules per mole = 6.022×10^{23} molecules/mol
- Conversions: Pressure units, temperature units, and gas law constants.

Converting Units and Preparing Data

To accurately apply the ideal gas law, all units must be consistent.

1. Pressure Conversion

The pressure is given in Torr, but the ideal gas law requires pressure in atmospheres (atm).

- 1 atm = 760 Torr
- Therefore, $P = 800.0 \text{ Torr} \times (1 \text{ atm} / 760 \text{ Torr}) \approx 1.0526 \text{ atm}$

2. Temperature Conversion

Temperature must be in Kelvin (K).

- $T = 27°C + 273.15 = 300.15$ K

3. Gas Constant (R)

Use the ideal gas constant in appropriate units:

- $R = 0.082057$ L·atm/(mol·K)

Summary of converted data:

Parameter	Value
Volume (V)	1.72 L
Temperature (T)	300.15 K
Pressure (P)	1.0526 atm
Gas constant (R)	0.082057 L·atm/(mol·K)

Applying the Ideal Gas Law to Find Moles of Oxygen

The ideal gas law relates pressure, volume, temperature, and amount of gas:

$$PV = nRT$$

Rearranged to find n (number of moles):

$$n = PV / RT$$

Plugging in the known values:

$$n = (1.0526 \text{ atm} \times 1.72 \text{ L}) / (0.082057 \text{ L·atm/(mol·K)} \times 300.15 \text{ K})$$

Calculating numerator:

- $1.0526 \times 1.72 \approx 1.809$ L·atm

Calculating denominator:

- $0.082057 \times 300.15 \approx 24.612$ mol·K

Now:

$$n \approx 1.809 / 24.612 \approx 0.0735 \text{ mol}$$

This means the sample contains approximately 0.0735 moles of oxygen gas.

Converting Moles to Molecules

To find the number of molecules, multiply the moles by Avogadro's number:

Number of molecules = $n \times$ Avogadro’s number

- Avogadro’s number = 6.022×10^{23} molecules/mol

Therefore:

Number of molecules = 0.0735 mol $\times$ 6.022×10^{23} molecules/mol

Calculating:

- $0.0735 \times 6.022 \times 10^{23} \approx 4.422 \times 10^{22}$ molecules

Result: The sample contains approximately 4.42×10^{22} oxygen molecules.

Additional Considerations and Real-World Applications

While the calculations above assume ideal gas behavior, real gases may deviate slightly, especially under high pressure or low temperature conditions. For most practical purposes at standard conditions, the ideal gas law provides a reliable approximation.

Applications of such calculations include:

- Determining the amount of gas in chemical reactions
- Calculating gas exchange in biological systems
- Designing industrial processes involving gases
- Environmental monitoring and modeling atmospheric gases

Summary of the Calculation Process

To summarize, here are the key steps to determine the number of molecules in a gas sample:

1. Convert all units to appropriate SI or standard units.
2. Use the ideal gas law to find the number of moles.
3. Convert moles to molecules using Avogadro’s number.

Applying these steps to the given data results in an estimated 4.42×10^{22} oxygen molecules in the sample.

Conclusion

Understanding how to calculate the number of molecules in a given volume of gas is fundamental in chemistry. By carefully converting units, applying the ideal gas law, and utilizing Avogadro's number, we can accurately determine molecular quantities from observable parameters like volume, temperature, and pressure. This approach is essential for experiments, industrial applications, and environmental science, providing a bridge between macroscopic measurements and microscopic realities.

Whether you are a student tackling chemistry homework or a scientist designing experiments, mastering these calculations enhances your ability to interpret and manipulate gaseous systems effectively.

Frequently Asked Questions

How do you calculate the number of molecules in a sample of oxygen gas given its volume, temperature, and pressure?

You can use the ideal gas law (PV = nRT) to find the number of moles (n), then multiply by Avogadro's number to find the number of molecules.

What is the first step to determine the number of oxygen molecules in a 1.72 L sample at 27°C and 800.0 Torr?

Convert all given values to SI units: pressure in atmospheres, volume in liters, and temperature in Kelvin, then apply the ideal gas law to find moles.

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

R = 0.0821 L·atm/(mol·K) is commonly used for calculations involving gases at standard conditions.

How do you convert the pressure from Torr to atmospheres for the calculation?

Divide the pressure in Torr by 760 to convert it to atmospheres (e.g., 800.0 Torr / 760 ≈ 1.0526 atm).

Once you find the number of moles of oxygen, how do you determine the number of molecules?

Multiply the number of moles by Avogadro's number (6.022×10^{23} molecules/mol) to find the total number of oxygen molecules.

What is the approximate number of oxygen molecules in the sample described?

Using the ideal gas law, the sample contains approximately 4.4×10^{21} molecules of oxygen.

Additional Resources

Oxygen Gas Molecules: Unlocking the Molecular Mystery in a 1.72 L Sample

In the realm of chemistry, understanding the behavior of gases and their molecular constituents is fundamental. Whether you're a student deciphering the intricacies of molar calculations or a scientist working on atmospheric studies, grasping how to determine the number of molecules in a given sample is crucial. Today, we delve into a fascinating problem: "A sample of oxygen gas has a volume of 1.72 L at 27°C and 800.0 Torr. How many oxygen molecules does it contain?" This question not only challenges our understanding of gas laws but also exemplifies the elegance of molecular calculations.

Understanding the Scenario: The Basics of Gaseous Oxygen

Before diving into calculations, it's essential to understand the context and the parameters provided:

- Volume (V): 1.72 liters
- Temperature (T): 27°C (which needs to be converted to Kelvin)
- Pressure (P): 800.0 Torr
- Substance: Oxygen gas (O_2) molecules

This scenario is typical in experimental chemistry and atmospheric science. The key to solving the problem lies in applying the ideal gas law, converting units appropriately, and understanding the relationship between moles and molecules.

Converting Units: From Torr to Atmospheres and Celsius to Kelvin

Why is unit conversion necessary?
The ideal gas law, PV = nRT, requires pressure in atmospheres (atm), volume in liters (L), temperature in Kelvin (K), and the gas constant R in compatible units. Therefore, the initial parameters must be converted accordingly.

1. Converting Torr to Atmospheres

- 1 atm = 760 Torr

Given pressure: 800.0 Torr

$$
P = \frac{800.0\, \text{Torr}}{760\, \text{Torr/atm}} \approx 1.0526\, \text{atm}
$$

2. Converting Celsius to Kelvin

Temperature in Celsius: 27°C

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

Note: For precision, we retain three decimal places, but for most calculations, two decimal places suffice.

Applying the Ideal Gas Law: Calculating Moles of Oxygen

The ideal gas law provides a straightforward way to determine the number of moles (n):

$$
PV = nRT
$$

Where:
- P = pressure in atm
- V = volume in L
- n = number of moles
- R = ideal gas constant = 0.082057 L·atm/(mol·K)
- T = temperature in Kelvin

Step 1: Plugging in the known values

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

$$
n = \frac{(1.0526\, \text{atm}) \times (1.72\, \text{L})}{(0.082057\, \text{L·atm/(mol·K)}) \times (300.15\, \text{K})}
$$

Step 2: Performing the calculation

Numerator:

$$
1.0526 \times 1.72 \approx 1.8102
$$

Denominator:

$$
0.082057 \times 300.15 \approx 24.624
$$

Therefore:

$$
n \approx \frac{1.8102}{24.624} \approx 0.0735\, \text{mol}
$$

This value indicates that the sample contains approximately 0.0735 moles of oxygen molecules.

From Moles to Molecules: The Molecular Count

To determine the total number of molecules in the sample, we use Avogadro's number:

$$
N_A = 6.022 \times 10^{23}\, \text{molecules/mol}
$$

Calculation:

$$
\text{Number of molecules} = n \times N_A
$$

$$
= 0.0735 \times 6.022 \times 10^{23}
$$

$$
\approx 4.425 \times 10^{22}\, \text{molecules}
$$

Final Result:

> The sample contains approximately 4.43×10^{22} oxygen molecules.

Deeper Insights: Significance and Applications

Understanding the number of molecules in a given volume of gas is not merely an academic exercise; it has real-world applications:

- Atmospheric Chemistry: Quantifying oxygen molecules helps in modeling oxygen availability in different environmental conditions.
- Industrial Processes: Precise calculations are vital in processes like oxygen therapy, welding, and chemical manufacturing.
- Research and Development: Molecular counts assist in designing experiments involving gas reactions or diffusion studies.

Additional Considerations and Common Pitfalls

While the above calculations are straightforward, there are common challenges and nuances to keep in mind:

- Non-ideal Behavior: Real gases deviate from ideal behavior under high pressure or low temperature. In such cases, corrections or real gas models are necessary.
- Unit Consistency: Always ensure units are compatible; mixing Torr with atm or Celsius with Kelvin leads to errors.
- Significant Figures: Maintain appropriate precision, especially in scientific contexts, to ensure accuracy.

Summary: Step-by-Step Procedure

To recap, here's a concise guide to solving similar problems:

1. Convert pressure to atm:
$\text{Pressure (atm)} = \frac{\text{Pressure (Torr)}}{760}$

2. Convert temperature to Kelvin:
$T(K) = T(°C) + 273.15$

3. Use the ideal gas law to find moles:
$n = \frac{PV}{RT}$

4. Calculate molecules:

$\text{Number of molecules} = n \times N_A$

Applying this method ensures accurate and reliable results.

Conclusion: The Power of Molecular Quantification

The journey from a simple volume, temperature, and pressure to the count of oxygen molecules exemplifies the power of gas laws and fundamental constants. Through careful unit conversion, methodical calculations, and an understanding of molecular theory, we can unveil the microscopic world within a modest 1.72-liter sample.

Whether you’re a student, educator, or researcher, mastering these calculations enhances your ability to interpret experimental data and develop insights into the molecular universe. The oxygen molecules in this sample—around 4.43×10^{22}—represent an astonishing number of particles, each contributing to the vital processes that sustain life and drive technological advancements.

In essence, understanding the number of molecules in a gas sample bridges the macroscopic world we observe with the microscopic reality that underpins all of chemistry and physics.

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