A Reaction Requires 22.4 L Of Gas At STP. You Have 45.0 L Of Gas At 100 KPa And 373 K. Which Of The Following

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Understanding gas laws and their applications is fundamental in chemistry, especially when dealing with reactions involving gases. This scenario presents a practical problem that combines concepts such as molar volume at Standard Temperature and Pressure (STP), ideal gas law calculations, and gas behavior under different conditions. It is essential to analyze this problem step-by-step to determine which options are correct when comparing the given gas volume to the required volume at STP, considering the different pressure and temperature conditions.

In this comprehensive guide, we will explore the relationship between gas volumes under various conditions, revisit fundamental gas laws, and apply these principles to solve the problem efficiently. Whether you're a student preparing for exams or a professional chemist reviewing gas principles, understanding this case study will improve your grasp of gas behavior in chemical reactions.

Understanding the Fundamental Concepts of Gas Laws

Before diving into calculations, it’s crucial to understand the fundamental gas laws that underpin the problem. These laws describe how gases behave under different conditions of pressure, volume, temperature, and amount (moles). The key laws involved here include:

1. Ideal Gas Law

- Equation: $PV = nRT$
- Variables:
- P = pressure
- V = volume
- n = number of moles
- R = universal gas constant
- T = temperature (Kelvin)

This law relates all four variables and allows us to calculate unknowns when the other three are known.

2. Molar Volume at STP

- Standard Conditions:
- Temperature = 273.15 K (0°C)
- Pressure = 1 atm (101.3 kPa)
- Molar Volume:
- One mole of an ideal gas occupies approximately 22.4 liters at STP.

This value is crucial for converting between volume and moles at standard conditions.

3. Gas Law Adjustments for Different Conditions

- When conditions deviate from STP, the volume of a gas changes accordingly, following the combined gas law:

$$
\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}
$$

- This law allows us to compare the volume of a gas at different pressures and temperatures.

Analyzing the Given Data

The problem provides specific data:

- Standard Volume for Reaction: 22.4 L at STP
- Given Volume of Gas: 45.0 L
- Pressure of Given Gas: 100 kPa
- Temperature of Given Gas: 373 K

Our goal is to determine how much gas at the given conditions relates to the standard molar volume and to decide among potential options (which are typically about the amount of gas needed or produced in a reaction).

Step-by-Step Approach to the Solution

To analyze this problem, we will follow these steps:

1. Convert the Given Gas Volume to Moles

Using the ideal gas law, we can calculate the number of moles of gas present under the given conditions.

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

- Convert units appropriately:
- Pressure (P): 100 kPa (already in SI units)
- Volume (V): 45.0 L = 0.045 m^3 (if needed, but we can keep in liters with R in appropriate units)
- Temperature (T): 373 K
- R: 8.314 J/(mol·K) (when using SI units)

Alternatively, since R can be expressed as 8.314 L·kPa/(mol·K) when working with liters and kPa, it's often easier to use this form directly.

Using R = 8.314 L·kPa/(mol·K):

$$
n = \frac{P \times V}{R \times T} = \frac{100 \text{ kPa} \times 45.0 \text{ L}}{8.314 \text{ L·kPa/(mol·K)} \times 373 \text{ K}}
$$

Calculating:

$$
n = \frac{4,500}{3,103.222} \approx 1.45 \text{ mol}
$$

This indicates that 45.0 liters of gas at 100 kPa and 373 K corresponds to approximately 1.45 moles.

2. Convert Moles to Volume at STP

Given that 1 mol of gas occupies 22.4 L at STP, the volume of this amount of gas at STP is:

$$
V_{STP} = n \times 22.4 \text{ L} = 1.45 \times 22.4 \approx 32.5 \text{ L}
$$

Thus, 45.0 L of the gas under the given conditions corresponds to roughly 32.5 L at STP.

3. Determine the Relationship Between Given Gas Volume and Standard Volume for Reaction

The reaction requires 22.4 L of gas at STP, but we have approximately 32.5 L at STP equivalent. This suggests:

- The given gas volume (45.0 L at 100 kPa and 373 K) is sufficient for the reaction requiring 22.4 L at STP.
- The excess volume indicates more than enough gas is present for the reaction, or that the amount (in moles) exceeds the stoichiometric requirement.

Considering Gas Behavior Under Different Conditions

While the calculations above assume ideal behavior, real gases may deviate slightly. However, for most gases at moderate pressures and temperatures, the ideal gas law provides a reliable approximation.

Adjustments for Non-Ideal Behavior

- At higher pressures (>100 kPa), gases can deviate from ideality.
- Corrections such as the Van der Waals equation can be applied for more precise calculations, but for this scenario, the ideal gas law suffices.

Final Analysis and Conclusion

Based on the calculations:

- The 45.0 liters of gas at 100 kPa and 373 K corresponds to approximately 1.45 mols of gas.
- At STP, this amount would occupy roughly 32.5 liters.
- Since the reaction requires 22.4 liters at STP, the available gas at the given conditions is more than enough to complete the reaction.

Implication: If the question asks which of the following options is correct—such as "the gas is sufficient," "the gas is insufficient," or "the gas is in excess"—the answer would be that the given volume exceeds the standard molar volume needed for the reaction.

Practical Applications and Real-World Relevance

Understanding how to convert between different states of gases is vital in various fields:

- Chemical Manufacturing: Ensuring sufficient reactant gases are available.
- Environmental Science: Calculating pollutant quantities under different atmospheric conditions.

- Engineering: Designing systems that involve gas flow and reactions under variable pressures and temperatures.

Summary of Key Points

- Gas Law Fundamentals: The ideal gas law is essential for converting between volume, pressure, temperature, and moles.
- Molar Volume at STP: 22.4 L per mole provides a basis for standard comparisons.
- Calculations: Convert given volumes to moles, then to standard conditions for comparison.
- Relevance: These principles help determine the sufficiency of gases for reactions under varying conditions.

Conclusion

In conclusion, understanding the relationship between gas volume, pressure, and temperature enables chemists and students to analyze reaction feasibility effectively. In this scenario, 45.0 L of gas at 100 kPa and 373 K corresponds to approximately 32.5 liters at STP, which is more than enough for a reaction requiring 22.4 liters at STP. Mastery of these calculations is fundamental for accurate experimental planning, safety considerations, and optimizing chemical processes.

Whether you are preparing for exams or performing laboratory calculations, applying the principles of gas laws with confidence will enhance your problem-solving skills and deepen your understanding of gaseous systems in chemistry.

Frequently Asked Questions

What is the volume of gas required at STP according to the reaction?

The reaction requires 22.4 L of gas at STP.

Given 45.0 L of gas at 100 kPa and 373 K, how does it compare to the required 22.4 L at STP?

Since 45.0 L is greater than 22.4 L, there is enough gas to meet the requirement under the given conditions.

How do you convert gas volume from non-STP conditions to STP?

Use the combined gas law or ideal gas law to account for pressure and temperature differences, converting the volume accordingly.

What is the significance of the 22.4 L volume at STP in gas reactions?

22.4 L at STP is the molar volume of an ideal gas, representing the volume occupied by one mole of gas at standard conditions.

How does temperature affect the volume of gas in this scenario?

Higher temperature increases the gas volume at constant pressure, according to Charles's law.

What is the impact of pressure differences on the gas volume in this problem?

Higher pressure compresses the gas, reducing volume; lower pressure expands it, following Boyle's law.

Which gas law is most relevant for calculating the amount of gas at different conditions in this problem?

The ideal gas law (PV=nRT) or combined gas law, which relates pressure, volume, and temperature.

If the gas is at 100 kPa instead of 101.3 kPa (standard pressure), how does that affect the calculation?

You can adjust the volume using the ideal gas law to account for the pressure difference, as volume is inversely proportional to pressure.

Based on the given data, is the available gas sufficient for the reaction requiring 22.4 L at STP?

Yes, since 45.0 L at 100 kPa and 373 K provides more than the 22.4 L needed at STP, assuming proper calculations are made to adjust for conditions.

Additional Resources

A Reaction Requires 22.4 L Of Gas At STP. You Have 45.0 L Of Gas At 100 KPa And 373 K. Which Of The Following?

Introduction: Understanding Gas Laws and Their Relevance in Chemical Reactions

Gases play a pivotal role in countless chemical reactions, whether as reactants, products, or mediums facilitating processes. A fundamental aspect of chemistry involves understanding how gases behave under different conditions. The statement "A reaction requires 22.4 L of gas at STP" serves as a cornerstone in stoichiometry involving gases, highlighting the significance of molar volume at standard temperature and pressure (STP). This article delves into the principles underpinning such reactions, particularly focusing on the relationships between volume, pressure, and temperature, guided by the ideal gas law. We will analyze a scenario where an individual has a specific volume of gas at non-standard conditions and needs to determine its potential to participate in a reaction demanding a known volume at STP.

Fundamental Concepts: Gas Laws and Molar Volumes

1. Standard Temperature and Pressure (STP)

Standard Temperature and Pressure (STP) is a set of conditions widely used as a reference point for gas measurements. Historically, STP is defined as:

- Temperature: 0°C (273.15 K)
- Pressure: 1 atmosphere (atm)

At STP, one mole of an ideal gas occupies approximately 22.4 liters. This molar volume is crucial because it allows chemists to convert between volume and amount (moles) directly, simplifying stoichiometric calculations.

2. The Ideal Gas Law

The ideal gas law provides a comprehensive relationship among pressure (P), volume (V), temperature (T), and the amount of gas in moles (n):

$$ PV = nRT $$

where:

- P = pressure (atm or Pa)
- V = volume (L or m^3)
- n = number of moles
- R = universal gas constant ($0.0821\, L\, atm\, mol^{-1}\, K^{-1}$ or $8.314\, J\, mol^{-1}\, K^{-1}$)
- T = temperature (Kelvin)

This law allows us to predict how changing one variable affects others, which is essential in reaction calculations involving gases.

3. Molar Volume at STP

At STP, the molar volume of an ideal gas is approximately 22.4 liters per mole. This means:

- 1 mol of gas occupies 22.4 L at 0°C and 1 atm pressure.

This conversion factor simplifies stoichiometric calculations. For example, if a reaction requires 22.4 L of gas, it involves exactly 1 mol of that gas under STP conditions.

Analyzing the Scenario: From Given Data to Reaction Potential

The scenario presents a common problem in chemical calculations:

- The reaction requires 22.4 L of gas at STP.
- The available gas volume is 45.0 L.
- The gas is at a pressure of 100 KPa and a temperature of 373 K.

The question is: "Which of the following?" — which suggests that multiple options or conclusions might be offered, but here, we focus on understanding the implications of the data provided.

Step-by-Step Analytical Approach

1. Convert the Given Gas Conditions to STP Equivalent

Since the available gas is not at STP, we need to determine its molar quantity at its current conditions and then relate it to the amount needed for the reaction at STP.

Given data:

- Volume $V_{available} = 45.0\, L$
- Pressure $P = 100\, KPa$
- Temperature $T = 373\, K$

Note: Standard pressure in atm is 1 atm □ 101.3 KPa.

Convert pressure to atm:

\[
P_{atm} = \frac{100\, KPa}{101.3\, KPa/atm} \approx 0.987\, atm
\]

Calculate moles of gas at current conditions using the ideal gas law:

\[
n = \frac{PV}{RT}
\]

\[
n_{current} = \frac{(0.987\, atm)(45.0\, L)}{(0.0821\, L\, atm\, mol^{-1}\, K^{-1})(373\, K)}
\]

Calculate numerator:

\[
0.987 \times 45.0 \approx 44.4\, L\, atm
\]

Calculate denominator:

\[
0.0821 \times 373 \approx 30.6\, L\, atm\, mol^{-1}
\]

Compute:

\[

$$
n_{current} \approx \frac{44.4}{30.6} \approx 1.45\, \text{moles}
$$

Interpretation: The available gas corresponds to approximately 1.45 mol at the current conditions.

---

2. Determine the Volume of the Same Gas at STP

Using the molar quantity, we can find the volume this amount of gas would occupy at STP:

$$
V_{STP} = n \times 22.4\, L\, \text{per mol}
$$

$$
V_{STP} = 1.45 \times 22.4 \approx 32.5\, L
$$

Conclusion: The 45.0 L of gas at 100 KPa and 373 K corresponds to approximately 32.5 L at STP.

Implications for the Reaction: Is There Enough Gas?

The reaction requires 22.4 L at STP, which equates to 1 mol of gas. Our calculations show:

- The available gas, when converted to STP conditions, corresponds to about 32.5 L.
- Since 32.5 L > 22.4 L, there is more than enough gas to complete the reaction.

Key insight: The quantity of gas available exceeds the amount needed at STP, indicating that the reaction can proceed using the available gas volume.

Additional Considerations: Non-Ideal Conditions and Practical Aspects

While the ideal gas law provides a solid approximation, real gases might deviate slightly under certain conditions, especially at high pressures or low temperatures. In this scenario:

- The pressure (100 KPa) is close to atmospheric pressure.
- The temperature (373 K, or 100°C) is relatively high, but still within a range where ideal gas assumptions are reasonable.
- Therefore, the calculations are reliable for most practical purposes.

However, in more precise applications, corrections for non-ideal behavior might be necessary, employing equations like Van der Waals or other real gas models.

Broader Applications and Significance

Understanding how to convert between different conditions of gases is central to many fields:

- Industrial Chemistry: Designing reactors, calculating reactant quantities, and optimizing yields.
- Environmental Science: Modeling atmospheric gases and pollutant dispersion.
- Pharmacology: Preparing gaseous drugs and ensuring correct dosages.

- Education: Teaching fundamental principles of chemistry and physics.

The ability to convert volumes, pressures, and temperatures accurately allows scientists and engineers to predict outcomes, optimize processes, and innovate effectively.

Summary and Final Remarks

In conclusion, the scenario underscores the importance of the ideal gas law and molar volume concepts in chemical calculations involving gases. By converting the given volume at specific conditions to the standard conditions, we find that:

- The available gas volume (45.0 L at 100 KPa and 373 K) corresponds to approximately 32.5 L at STP.
- Since the reaction requires only 22.4 L at STP (equivalent to 1 mol), the available gas is more than sufficient to drive the reaction forward.

This analytical approach highlights the importance of understanding the relationships between pressure, volume, temperature, and molar quantities in practical chemistry. It also emphasizes that, with the right calculations, chemists can predict and manipulate reactions efficiently, ensuring optimal yields and safety.

In essence, mastering the gas laws and their applications enables a deeper comprehension of chemical behavior and enhances the ability to solve complex problems involving gaseous reactants and products, contributing to advancements across scientific disciplines.

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