A 10.0 L Container Of NH3 Gas At 25.8C And 0.85 Atm, Is Heated To 70.4C And A Pressure Of 1.35 Atm. Calculate

A 10.0 L Container Of NH3 Gas At 25.8°C And 0.85 Atm, Is Heated To 70.4°C And A Pressure Of 1.35 Atm. Calculate

---

Introduction

Understanding the behavior of gases under changing conditions is fundamental in chemistry and physics. In this scenario, a container of ammonia (NH_3) gas undergoes a temperature increase while its pressure and volume are monitored. Calculating the change in properties such as temperature, pressure, and volume involves applying the ideal gas law, combined with principles like Gay-Lussac's and Charles's laws. This article will provide an in-depth analysis of the problem, elucidate the relevant equations, and walk through the step-by-step calculations to determine the unknown parameters based on the given initial and final conditions.

Initial Conditions and Data Summary

Initial State:
- Volume, $V_1 = 10.0\, \text{L}$
- Temperature, $T_1 = 25.8^\circ C$
- Pressure, $P_1 = 0.85\, \text{atm}$

Final State:
- Temperature, $T_2 = 70.4^\circ C$
- Pressure, $P_2 = 1.35\, \text{atm}$

The problem involves calculating either the final volume, the number of moles, or verifying the consistency of the data using the ideal gas law $PV = nRT$.

Converting Temperatures to Kelvin

Since gas law calculations require absolute temperatures, convert Celsius to Kelvin:

$$
T(K) = T(^\circ C) + 273.15
$$

Initial Temperature:

$$
T_1 = 25.8 + 273.15 = 298.95\, \text{K}
$$

Final Temperature:

$$
T_2 = 70.4 + 273.15 = 343.55\, \text{K}
$$

Applying the Ideal Gas Law

The ideal gas law is expressed as:

$$
PV = nRT
$$

where:
- P = pressure
- V = volume
- n = number of moles
- R = ideal gas constant ($0.082057\, \text{L·atm·mol}^{-1}\text{·K}^{-1}$)
- T = temperature in Kelvin

Objective:
Based on the initial state, determine the number of moles n. Then, using this n, find the final volume V_2 at the new temperature and pressure.

Step 1: Calculating the Number of Moles of NH_3 Initially

Using the initial conditions:

$$
n = \frac{P_1 V_1}{RT_1}
$$

Plugging in the values:

$$
n = \frac{0.85\, \text{atm} \times 10.0\, \text{L}}{0.082057\, \text{L·atm·mol}^{-1}\text{·K}^{-1} \times 298.95\, \text{K}}
$$

Calculating numerator:

$$
0.85 \times 10.0 = 8.5\, \text{L·atm}

\]

Calculating denominator:

\[
0.082057 \times 298.95 \approx 24.52\, \text{L·atm·mol}^{-1}
\]

Thus,

\[
n = \frac{8.5}{24.52} \approx 0.3469\, \text{mol}
\]

This is the number of moles of NH_3 in the container initially.

Step 2: Calculating Final Volume \(V_2 \)

Assuming the amount of substance remains constant (no gas escapes), the number of moles \(n \) stays the same. Using the ideal gas law again for the final state:

\[
V_2 = \frac{nRT_2}{P_2}
\]

Substituting known values:

\[
V_2 = \frac{0.3469\, \text{mol} \times 0.082057\, \text{L·atm·mol}^{-1}\text{·K}^{-1} \times 343.55\, \text{K}}{1.35\, \text{atm}}
\]

Calculating numerator:

\[
0.3469 \times 0.082057 \approx 0.02845
\]
\[
0.02845 \times 343.55 \approx 9.78
\]

Now, dividing by the final pressure:

\[
V_2 = \frac{9.78}{1.35} \approx 7.24\, \text{L}
\]

Result:
The volume of the NH_3 gas at 70.4°C and 1.35 atm is approximately 7.24 liters.

Additional Analysis: Comparing Initial and Final States

1. Volume Change:

- Initial volume: 10.0 L
- Final volume: 7.24 L

The decrease in volume is consistent with the increase in pressure and temperature when the amount of gas is constant. This indicates that the gas was compressed or that the container's volume changed if the container was flexible.

2. Consistency Check:

Applying the combined gas law:

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

Substituting known values:

$$
\frac{0.85 \times 10.0}{298.95} = \frac{1.35 \times V_2}{343.55}
$$

Calculating the left side:

$$
\frac{8.5}{298.95} \approx 0.02845
$$

Rearranged for V_2:

$$
V_2 = \frac{0.02845 \times 343.55}{1.35} \approx \frac{9.78}{1.35} \approx 7.24\,\text{L}
$$

This matches the previous calculation, confirming the consistency of the data and calculations.

Implications and Practical Considerations

Effects of Temperature and Pressure Changes

- Heating the gas from 25.8°C to 70.4°C, while increasing the pressure from 0.85 atm to 1.35 atm, results in a decrease in volume in this scenario. This reflects the behavior of gases under such conditions, aligning with the ideal gas law.

Real-World Applications

- Understanding these calculations is essential in chemical manufacturing, where gases are often heated or compressed.
- Accurate predictions of volume changes help in designing containers and safety protocols.

Limitations and Assumptions

- The calculations assume ideal gas behavior; real gases may deviate at high pressures or low temperatures.
- The container is presumed rigid or flexible depending on the scenario, but the calculations focus on the case where the amount of gas remains constant.

Summary of Key Points

- The number of moles of NH_3 initially present is approximately 0.347 mol.
- The final volume of NH_3 at 70.4°C and 1.35 atm is approximately 7.24 L.
- The calculations are based on the ideal gas law, assuming ideal behavior and no gas loss.
- The application of combined gas law confirms the internal consistency of the data.

Conclusion

By applying fundamental principles of gas laws, we have successfully calculated the final volume of ammonia gas under specified conditions. This exercise demonstrates the importance of unit conversions, understanding the relationships between pressure, volume, and temperature, and the utility of the ideal gas law in solving real-world chemistry problems. Mastery of these principles enables chemists and engineers to predict and control the behavior of gases in various applications, ensuring safety, efficiency, and accuracy in scientific and industrial processes.

Frequently Asked Questions

How do you calculate the initial and final moles of NH3 gas in the container?

Using the ideal gas law (PV = nRT), initial moles $n_1 = (P_1V) / (RT_1)$ and final moles $n_2 = (P_2V) / (RT_2)$, where P is pressure, V is volume, R is the ideal gas constant, and T is temperature in Kelvin.

What is the step-by-step process to determine the change in the amount of substance or other properties during heating?

First, convert temperatures to Kelvin. Then, calculate initial moles using initial P, V, and T. Next, calculate final moles using final P, V, and T. If the volume is constant, the change in pressure and temperature can be related through the ideal gas law to find the new properties.

How do you convert temperatures from Celsius to Kelvin for these calculations?

Add 273.15 to the Celsius temperature: $T(K) = T(°C) + 273.15$. For 25.8°C, $T \approx 298.95$ K; for 70.4°C, $T \approx 343.55$ K.

What is the significance of using the ideal gas law in this problem, and are there any limitations?

The ideal gas law allows us to relate pressure, volume, temperature, and moles of gas, assuming ideal behavior. Its limitations include deviations at high pressures or low temperatures where real gas behavior differs from ideality.

How can you calculate the final number of moles of NH3 after heating and pressure change?

Assuming no leakage or chemical reaction, the number of moles remains constant. Using the initial conditions, you can verify this by calculating $n = PV / RT$ at both states; if volume is constant, the moles should be the same, confirming the gas quantity remains unchanged.

Additional Resources

Understanding the Behavior of Ammonia Gas Under Changing Conditions: A Detailed Thermodynamic Analysis

The study of gases and their responses to variations in temperature, pressure, and volume forms a cornerstone of chemical thermodynamics. Among industrial and laboratory applications, ammonia (NH_3) stands out as a crucial compound, both as a fertilizer component and as a refrigerant. When analyzing how ammonia behaves in a confined environment, such as a 10.0-liter container subjected to temperature and pressure changes, it becomes vital to understand the principles governing its behavior. This article offers a comprehensive, detailed exploration of a scenario where ammonia gas, initially at a specified temperature and pressure, is heated, resulting in altered thermodynamic properties. Through careful calculations and in-depth explanations, we aim to elucidate the underlying principles and provide insights into the gas’s behavior.

Introduction to the Scenario

Imagine a sealed, rigid container holding ammonia gas with a volume of 10.0 liters. At the initial state, the gas is at 25.8°C and 0.85 atm. The system is then heated to 70.4°C, and during this process, the pressure increases to 1.35 atm. The central question revolves around understanding how the properties of ammonia change under these conditions. Specifically, what are the changes in the molar amount of gas, and how do temperature and pressure relate through the ideal gas law?

This scenario exemplifies real-world processes where gases are subject to temperature fluctuations, affecting their pressure and volume, and by extension, their thermodynamic state. The calculations involved provide insights into the behavior of ammonia and serve as a foundation for understanding more complex thermodynamic systems.

Fundamental Concepts and Principles

Before delving into calculations, it is essential to establish the fundamental principles that guide our analysis.

Ideal Gas Law

The ideal gas law is the cornerstone for calculating the state variables of gases under many conditions:

$$ PV = nRT $$

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

While real gases exhibit deviations from ideal behavior under certain conditions, ammonia at moderate temperatures and pressures often behaves sufficiently close to an ideal gas for most calculations.

Conversions and Units

- Temperatures in Celsius must be converted to Kelvin: $T(K) = T(°C) + 273.15$
- Pressures are given in atmospheres and are compatible with the gas constant R.
- Volumes are in liters, aligning with the units of R.

Assumptions in Calculations

- The container volume remains constant; thus, the process is at constant volume.
- The gas behaves ideally.
- The amount of gas (number of moles) may change if the process involves addition or removal, but in a sealed container, it remains constant unless gas leaks.

Initial State Analysis

The initial state of the ammonia gas provides the baseline for our calculations.

Initial Conditions

- Volume $V_1 = 10.0\, \text{L}$
- Temperature $T_1 = 25.8°C = 25.8 + 273.15 = 298.95\, \text{K}$
- Pressure $P_1 = 0.85\, \text{atm}$

Calculating Moles of Ammonia Initially

Using the ideal gas law:

$$n_1 = \frac{P_1 V_1}{R T_1}$$

Plugging in the known values:

$$n_1 = \frac{0.85\, \text{atm} \times 10.0\, \text{L}}{0.082057\, \text{L·atm/(mol·K)} \times 298.95\, \text{K}}$$

Calculating numerator:

$$0.85 \times 10.0 = 8.5$$

Calculating denominator:

$$ 0.082057 \times 298.95 \approx 24.525 $$

Thus:

$$ n_1 = \frac{8.5}{24.525} \approx 0.3467\, \text{mol} $$

This initial molar amount represents the quantity of ammonia in the container before heating.

Final State Analysis

Post-heating, the system's parameters have changed:

- Temperature $T_2 = 70.4^\circ C = 70.4 + 273.15 = 343.55\, \text{K}$
- Pressure $P_2 = 1.35\, \text{atm}$

Since the container volume is constant, we can analyze how the molar amount or other properties change.

Calculating the Number of Moles After Heating

Applying the ideal gas law again:

$$ n_2 = \frac{P_2 V_1}{R T_2} $$

Substituting known values:

$$ n_2 = \frac{1.35\, \text{atm} \times 10.0\, \text{L}}{0.082057\, \text{L·atm/(mol·K)} \times 343.55\, \text{K}} $$

Calculating numerator:

$$ 1.35 \times 10.0 = 13.5 $$

Calculating denominator:

$$ 0.082057 \times 343.55 \approx 28.21 $$

Thus:

$$ n_2 = \frac{13.5}{28.21} \approx 0.4787\, \text{mol} $$

Interpretation: The molar quantity appears to increase from approximately 0.3467 mol to 0.4787 mol, which suggests either gas addition, leakage, or an inconsistency in assumptions.

Reconciling the Apparent Discrepancy: Sealed System Analysis

In a real sealed container, the number of moles should remain constant unless gas leaks or is added. The apparent increase in moles indicates that the initial assumption of an ideal, closed system may not be entirely valid in this context. Alternatively, the difference may arise from experimental uncertainties or the need for a more refined model accounting for non-ideal behavior.

However, for the purposes of this analysis, we can consider the process as happening in a sealed, rigid container, where the number of moles remains constant. Under this assumption, the initial and final moles are equal:

$$ n_1 = n_2 = n $$

Given the initial value:

$$ n \approx 0.3467\, \text{mol} $$

and the known volume and initial conditions, we can verify the consistency of the process.

Thermodynamic Insights and Calculations

Having established the initial molar amount, we proceed to analyze the thermodynamic implications of heating the ammonia gas.

Work Done and Heat Transfer

In a rigid, sealed container, there is no work done by the gas because the volume remains constant:

$$ W = P \Delta V = 0 $$

The change in the internal energy ΔU of the gas is related to heat transfer Q:

$$ \Delta U = Q $$

Assuming ideal gas behavior, the internal energy change depends solely on temperature:

$$ \Delta U = n C_v \Delta T $$

Where:
- C_v = molar heat capacity at constant volume for NH_3 (approximate value: 35 J/(mol·K))
- $\Delta T = T_2 - T_1 = 343.55 - 298.95 = 44.6\, \text{K}$

Calculating:

$$\Delta U = 0.3467\, \text{mol} \times 35\, \text{J/(mol·K)} \times 44.6\, \text{K}$$

$$\Delta U \approx 0.3467 \times 35 \times 44.6 \approx 544\, \text{J}$$

This indicates approximately 544 Joules of heat energy must be supplied to raise the temperature of the ammonia from 25.8°C to 70.4°C in this rigid container.

Pressure-Temperature Relationship

Using the ideal gas law, we see that:

$$P \propto T$$

at constant molar amount and volume. The ratio:

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

Calculates as:

$$\frac{1.35}{0.85} \approx 1.588$$

and

$$\frac{T_2}{T_1} = \frac{343.55}{298.95} \approx 1.149$$

The discrepancy here indicates that the molar amount of gas is not constant, or real gas deviations are significant. If the molar amount is conserved, then the pressure increase is less than proportional to the temperature increase, which suggests non-ideal behavior or other external influences.

Practical

[A 10 0 L Container Of Nh3 Gas At 25 8c And 0 85 Atm Is Heated To 70 4c And A Pressure Of 1 35 Atm Calculate]

A 10 0 L Container Of Nh3 Gas At 25 8c And 0 85 Atm Is Heated To 70 4c And A Pressure Of 1 35 Atm Calculate

Related Articles

- [Total Assets Equal $1.000.000. Tot Owners' Equity Totals 5650,000. Total Current Liabilities Total $300,000.]
- [Deborah Tannen's Research On The Speech Habits Of Men And Women Has Revealed ThatCalls Demonstrate Linguistic]
- [Select All The Correct Answers. Kelly Holds A Fast-paced And High-pressure Job As A Stockbroker And Regularly]

[Back to Home]