Gas Is Confined In A Tank At A Pressure Of 11.0 Atm And A Temperature Of 25.0C. If Two Thirds Of The

Gas Is Confined In A Tank At A Pressure Of 11.0 Atm And A Temperature Of 25.0C. If Two Thirds Of The the gas is removed from the tank, what will be the new pressure and temperature of the remaining gas? This question involves fundamental principles of gas behavior, thermodynamics, and the ideal gas law, all of which are essential concepts in chemistry and physics. Understanding how gases respond to changes in quantity, pressure, and temperature is crucial for various applications, from industrial processes to scientific research.

In this comprehensive article, we will explore the principles governing gases in confined spaces, analyze the specific scenario described, and explain the calculations needed to determine the new conditions of the gas after part of it is removed. We will also discuss real-world applications and important considerations related to gas behavior in confined environments.

Understanding the Behavior of Gases in Confined Spaces

Gases are characterized by their ability to expand to fill their containers, and their behavior is well described by the ideal gas law, which relates pressure (P), volume (V), temperature (T), and amount of gas (n). The ideal gas law is expressed as:

$$PV = nRT$$

where:
- P = pressure (atm)
- V = volume (L)
- n = number of moles (mol)
- R = ideal gas constant (0.0821 L·atm/(mol·K))
- T = temperature (Kelvin)

Understanding how these variables interact allows us to predict how a gas will respond to changes such as the removal of a portion of it, temperature variations, or alterations in volume.

Scenario Breakdown: Initial Conditions and Changes

Before diving into calculations, it’s critical to understand the initial conditions and the specific change occurring:

- Initial Conditions:
- Pressure (P_1) = 11.0 atm
- Temperature (T_1) = 25.0°C = 298.15 K
- Gas amount (n_1) = unknown but proportional to initial conditions
- Volume (V) = constant, assuming the tank's volume remains unchanged

- Change:
- Two-thirds of the gas is removed from the tank, leaving one-third of the initial amount.

The core question: What will be the new pressure (P_2) and temperature (T_2) of the remaining gas?

Effects of Removing Gas on Pressure and Temperature

Removing part of the gas reduces the number of moles (n) in the tank. According to the ideal gas law, when volume and temperature are held constant:

$$ \frac{P}{n} = \text{constant} $$

This means that pressure is directly proportional to the number of moles of gas at constant volume and temperature.

Key points:
- If the temperature remains constant, reducing the amount of gas decreases the pressure proportionally.
- If the temperature changes, both temperature and pressure can vary depending on the process.

In our scenario, unless otherwise specified, we assume that the removal of gas is an instantaneous process that does not alter the temperature of the remaining gas, and the tank is perfectly insulated (no heat exchange). This is a reasonable approximation for many practical situations.

Calculating the New Pressure After Gas Removal

Given that two-thirds of the gas is removed, the remaining amount of gas is one-third of the original:

$$ n_2 = \frac{1}{3} n_1 $$

Since the volume and temperature are unchanged, and assuming ideal gas behavior, the pressure after removal (P_2) can be calculated as:

$$ P_2 = P_1 \times \frac{n_2}{n_1} $$

$$ P_2 = 11.0\, \text{atm} \times \frac{1}{3} $$

$$ P_2 = 3.67\, \text{atm} $$

Therefore, the pressure of the remaining gas is approximately 3.67 atm.

Considering Temperature Changes: Is T_2 Equal to T_1?

In many real-world scenarios, removing gas rapidly can cause temperature changes due to various processes:

- Adiabatic process: No heat exchange, and removal of gas can cause cooling or heating depending on the process specifics.
- Isothermal process: The temperature remains constant, often achieved by allowing heat exchange with surroundings.

In our initial assumption, we consider the process to be isothermal (constant temperature), which is common in many laboratory conditions where the system is in thermal equilibrium with its surroundings.

Thus, $T_2 = T_1 = 25.0°C = 298.15$ K.

Summary of Results

Parameter	Initial	Final	Calculation/Comments
Pressure	11.0 atm	3.67 atm	proportional to amount of gas remaining
Temperature	25.0°C	25.0°C	assumed constant in an isothermal process
Moles of gas remaining	N/A	one-third of initial	proportional to the remaining gas volume and pressure

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Real-World Applications of Gas Behavior Principles

Understanding how gases respond to changes in quantity, pressure, and temperature is fundamental to many industries and scientific fields. Here are some notable applications:

1. Industrial Gas Storage and Safety

- Storage tanks often contain gases under high pressure.
- Removing or adding gas affects pressure and temperature.
- Proper calculations ensure safety and efficiency during transfer and usage.

2. Chemical Reaction Engineering

- Reactions involving gases depend on initial concentrations and pressures.
- Controlling gas quantities and conditions optimizes yields and safety.

3. Environmental Monitoring and Atmospheric Science

- Gases in the atmosphere respond to temperature and pressure variations.
- Modeling these responses helps in understanding climate phenomena.

4. Medical and Respiratory Technologies

- Gas delivery systems (e.g., oxygen tanks) rely on precise pressure and temperature control.
- Removing or adding gases affects patient safety.

Additional Considerations and Advanced Topics

While the ideal gas law provides a solid foundation, real gases often deviate from ideal behavior under certain conditions, such as high pressure or low temperature.

1. Van der Waals Equation

- Accounts for intermolecular forces and finite molecular size.
- Useful for more accurate calculations when gases are non-ideal.

2. Isothermal vs. Adiabatic Processes

- The nature of the process (with or without heat exchange) significantly impacts temperature and pressure changes during gas removal or compression.

3. Thermodynamic Cycles Involving Gases

- Engines and refrigerators operate based on cycles involving compression, expansion, heating, and cooling of gases.

Conclusion

In summary, when two-thirds of the gas in a confined tank are removed under the assumption of constant temperature and volume, the pressure of the remaining gas decreases proportionally. Starting from an initial pressure of 11.0 atm, the new pressure becomes approximately 3.67 atm. The temperature remains unchanged at 25.0°C if the process is isothermal, which is a common assumption in many practical scenarios.

Understanding these principles allows scientists and engineers to design safer storage systems, optimize chemical processes, and predict the behavior of gases in various environments. Mastery of the ideal gas law and related thermodynamic concepts provides essential tools for analyzing and solving real-world problems involving gases.

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Frequently Asked Questions

What is the initial pressure and temperature of the gas in the tank?

The initial pressure is 11.0 atm and the temperature is 25.0°C.

How does the pressure of the gas change if two-thirds of the gas is removed?

Removing two-thirds of the gas reduces the number of moles, which, at constant volume and temperature, decreases the pressure proportionally, resulting in a new pressure of approximately 3.67 atm.

What law can be used to relate the initial and final states of the gas when some of it is removed?

The ideal gas law (PV = nRT) can be used, assuming temperature and volume remain constant, to relate initial and final states.

If the temperature remains constant, how does the number of moles of gas change after removing two-thirds of it?

The number of moles decreases to one-third of its original amount, since two-thirds of the gas is removed.

How would the pressure change if the temperature were increased instead of removing gas?

If the temperature increases while the amount of gas and volume remain constant, the pressure would increase proportionally according to Gay-Lussac's law.

What is the significance of the initial pressure being 11.0 atm in terms of safety and tank design?

An initial pressure of 11.0 atm indicates high pressure, which requires robust tank design and safety measures to prevent rupture or leaks.

How can the ideal gas law be applied to calculate the final pressure after removing two-thirds of the gas?

Using PV = nRT, with constant volume and temperature, the final pressure is proportional to the number of moles remaining. Since only one-third remains, the final pressure is one-third of the initial pressure, approximately 3.67 atm.

What assumptions are made when applying the ideal gas law in this scenario?

Assumptions include that the gas behaves ideally, the volume and temperature are constant, and that the gas particles do not interact significantly.

How does temperature influence gas behavior in confined systems like this tank?

Temperature affects the kinetic energy of gas molecules; increasing temperature increases pressure if volume and amount of gas are constant, according to Gay-Lussac's law.

Additional Resources

Gas Behavior in Confined Tanks: A Comprehensive Analysis

Understanding the behavior of gases under different conditions is fundamental in fields ranging from chemical engineering to environmental science. When a gas is confined within a tank at a specific pressure and temperature, its properties—such as volume, density, and energy—are governed by the principles of thermodynamics and the ideal gas law. This article delves into the detailed analysis of such a scenario, examining the implications of pressure and temperature settings, the effects of volume changes, and the practical applications of these principles in real-world systems.

Fundamental Concepts: The Ideal Gas Law and Its Relevance

At the core of understanding gases in a confined space is the Ideal Gas Law, expressed as:

$$PV = nRT$$

where:
- P = pressure
- V = volume
- n = number of moles
- R = universal gas constant
- T = temperature in Kelvin

This equation provides a straightforward relationship between the thermodynamic variables for an ideal gas, assuming negligible interactions between molecules and that particles occupy no volume.

Why is the ideal gas law important?
It allows us to predict how a gas will respond to changes in pressure, volume, or temperature, which is essential for designing and optimizing storage systems, reactors, and transportation mechanisms for gases.

Scenario Overview: Confined Gas at 11.0 atm and 25.0°C

Let's consider a specific case:

- Initial pressure (P_1): 11.0 atm
- Initial temperature (T_1): 25.0°C (which converts to 298.15 K)
- Initial volume (V_1): To be analyzed based on the problem's context

Suppose this gas is confined in a tank with a fixed amount of substance n. The key parameters influence the gas's behavior, especially when a change occurs in the system, such as removing a portion of the gas or altering the temperature.

Impact of Removing Two-Thirds of the Gas

The phrase "If two thirds of the" suggests an analysis involving the removal of two-thirds of the gas from the tank, which is a common scenario in processes like gas extraction, leak modeling, or controlled venting.

Effect on Gas Properties

- Initial state:
- Moles of gas: n_1
- Volume: V_1
- Pressure: 11.0 atm
- Temperature: 25.0°C

- After removing two-thirds of the gas:
- Remaining moles: $n_2 = \frac{1}{3} n_1$

If the volume and temperature are held constant during removal (e.g., the tank's volume cannot change, and temperature is maintained by an external environment), the pressure will decrease proportionally, owing to the ideal gas law:

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

Given that $n_2 = \frac{1}{3} n_1$, the new pressure becomes:

$$P_2 = \frac{1}{3} P_1$$

which is approximately 3.67 atm.

Key Points:
- Removing gas at constant volume and temperature reduces the pressure proportionally.
- The remaining gas exerts less force on the tank walls.
- This process illustrates how gas quantity directly influences pressure in a confined space.

Calculating the Remaining Gas Properties

Assuming the initial amount of gas n_1 is known, and the initial volume V_1 is fixed, we can analyze the state before and after the removal:

Parameter	Initial	After removing two-thirds
Moles of gas	n_1	$\frac{1}{3} n_1$
Pressure	11.0 atm	approximately 3.67 atm
Temperature	25.0°C	remains at 25.0°C (assuming isothermal process)
Volume	V_1	V_1 (constant)

Volume and Temperature Considerations

If, instead, the process involves changing the volume or temperature, the calculations become more complex:

- Constant temperature (isothermal process):
$P_2 V_2 = P_1 V_1$

- Constant volume (isochoric process):
$P_2 / T_2 = P_1 / T_1$

Understanding these relationships is vital in designing systems where gases are manipulated for storage, transport, or chemical reactions.

Energy and Thermodynamic Implications

Beyond pressure and volume, the removal of gas affects the thermodynamic state variables, especially energy-related parameters such as internal energy and enthalpy.

Internal Energy (U)
- For an ideal gas, internal energy depends solely on temperature:

$$U = \frac{3}{2} nRT$$ (for monoatomic gases)

- Since temperature remains constant in an isothermal process, internal energy remains unchanged during gas removal. However, if temperature varies, energy exchange occurs.

Work Done During Gas Removal
- If the removal process involves changing volume or pressure, work is done by or on the system.
- For a fixed volume, no work is performed; for a process involving volume change, work can be expressed as:

$$W = P \Delta V$$

- In the case of removing gas at constant volume, the primary energy transfer is through heat exchange or changes in internal energy.

Real-World Applications and Practical Considerations

Understanding how gases behave under confinement and removal is critical in various industries:

Storage and Transportation
- Industrial gases (oxygen, nitrogen, argon) are stored in high-pressure tanks.
- Managing pressure drops during gas withdrawal helps ensure safety and efficiency.
- Design considerations include tank material strength, pressure relief systems, and monitoring equipment.

Chemical Processing
- In reactors, precise control over gas quantities influences reaction rates and yields.
- Removing fractions of gases can shift equilibria or optimize process conditions.

Environmental Control
- Leak detection involves monitoring pressure drops to estimate gas loss.
- Controlled venting during safety procedures depends on understanding gas behavior.

Safety Measures
- Knowledge of pressure and volume relationships prevents tank rupture.
- Pressure relief valves are calibrated based on anticipated pressure reductions or increases.

Advanced Topics: Non-Ideal Gas Behavior and Real-World Deviations

While the ideal gas law provides an excellent approximation under many conditions, real gases exhibit deviations, especially at high pressures or low temperatures:

- Van der Waals Equation:
Adjusts for molecular volume and intermolecular forces:

$$ \left(P + a \frac{n^2}{V^2} \right) (V - nb) = nRT $$

where a and b are substance-specific constants.

- Implications for Confined Gases:
- At 11 atm and 25°C, the gas behavior is close to ideal for many gases, but precise applications require correction factors.
- Accurate modeling enhances safety margins and system efficiency.

Conclusion: Harnessing Gas Behavior for Engineering Excellence

The analysis of gases confined within tanks at specified pressures and temperatures reveals a complex interplay of thermodynamic variables that underpin many industrial and scientific processes. Removing a significant fraction of the gas, such as two-thirds, dramatically alters the system's pressure and energy profile, emphasizing the importance of precise calculations and considerations for safety and efficiency.

By applying fundamental principles like the ideal gas law, understanding the thermodynamic implications, and accounting for real-gas deviations, engineers and scientists can design optimized systems for storage, transportation, and processing of gases. Whether managing high-pressure storage tanks or controlling chemical reactions, a deep comprehension of gas behavior ensures operational success and safety.

In essence, grasping the nuances of confined gases at various pressures and temperatures is not just an academic exercise but a practical necessity that drives innovation and safety in countless applications worldwide.

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