A Rigid Ylinder With A Movable Piston Ontains 50.0 Liters Of A Gass At 30.0 C With A Pressure Of 1.00

A Rigid Ylinder With A Movable Piston Ontains 50.0 Liters Of A Gass At 30.0 C With A Pressure Of 1.00

Understanding the behavior of gases within a confined system is fundamental in fields such as thermodynamics, physics, engineering, and chemistry. The scenario of a rigid cylinder with a movable piston containing a specified amount of gas offers an excellent case study to explore these principles. In this article, we will analyze the properties of the gas, the relevant gas laws, and the implications of changes within such a system.

Introduction to Gas Laws and the System Setup

What is a Rigid Cylinder with a Movable Piston?

A rigid cylinder is a container designed to hold gases under controlled conditions. The presence of a movable piston allows the volume of the gas to change in response to pressure and temperature variations, while the cylinder's walls are rigid and do not deform. This setup is commonly used in laboratory experiments and industrial applications to study gas behaviors.

Initial Conditions of the Gas

In our scenario, the gas within the cylinder has the following initial parameters:

- Volume (V): 50.0 liters
- Temperature (T): 30.0°C (which converts to 303.15 K)
- Pressure (P): 1.00 atm

Understanding these initial conditions is vital for applying the gas laws and predicting the system's response to changes.

Fundamental Gas Laws Relevant to the System

Ideal Gas Law

The ideal gas law forms the foundation for analyzing gases in this context:

$$ PV = nRT $$

Where:
- P = pressure in atm
- V = volume in liters
- n = number of moles of gas
- R = ideal gas constant ($0.0821 \, \text{L·atm/(mol·K)}$)
- T = temperature in Kelvin

Using this law, we can determine the amount of gas present and predict how the system will respond to temperature or pressure changes.

Boyle's Law and Charles's Law

- Boyle's Law: For a fixed amount of gas at constant temperature, the pressure and volume are inversely proportional:

$$ P_1 V_1 = P_2 V_2 $$

- Charles's Law: For a fixed amount of gas at constant pressure, the volume and temperature are directly proportional:

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

These laws are instrumental when considering how the piston moves in response to temperature or pressure adjustments.

Calculating the Amount of Gas in the Cylinder

Given the initial conditions, let's determine the number of moles of gas inside the cylinder.

Step 1: Convert temperature to Kelvin:

$$ T = 30.0^\circ C + 273.15 = 303.15\, K $$

Step 2: Use the ideal gas law to find n:

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

$$ n = \frac{(1.00\, atm)(50.0\, L)}{(0.0821\, L\cdot atm/(mol\cdot K))(303.15\, K)} $$

$$ n \approx \frac{50.0}{(0.0821)(303.15)} $$

$$ n \approx \frac{50.0}{24.86} $$

$$ n \approx 2.01\, mol $$

Thus, approximately 2.01 moles of gas are contained within the system initially.

Implications of a Rigid Cylinder with a Movable Piston

The phrase "rigid cylinder with a movable piston" appears to be contradictory at first glance. Typically, a "rigid" container implies a fixed volume, while a "movable piston" suggests the volume can change. To clarify, in many thermodynamic systems, the container walls are rigid, but the piston can move to change the volume, effectively making the entire system flexible in volume but constrained within a rigid outer shell.

Scenario Clarification:
- If the outer cylinder is truly rigid and immovable, the volume remains constant.
- If the piston is movable, the volume can change, implying the outer shell may be flexible or the system is not strictly rigid.

For this analysis, we'll assume the "rigid cylinder" is a fixed outer shell, and the piston movement is possible within the constraints of the system—meaning the volume can change but is limited by the system's design.

Implication: The movable piston allows the gas to expand or compress, changing its pressure and temperature, obeying the relevant gas laws.

Predicting System Behavior Under Different Conditions

Scenario 1: Heating the Gas at Constant Volume

If the temperature increases while the volume remains constant, the pressure will increase proportionally, according to Gay-Lussac's law:

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

Suppose the temperature is increased to 60.0°C (333.15 K):

$$ P_2 = P_1 \times \frac{T_2}{T_1} = 1.00\, atm \times \frac{333.15}{303.15} \approx 1.10\, atm $$

The piston would experience an increase in pressure, potentially causing it to move, depending on the system's design.

Key Point: Heating the gas increases pressure at constant volume; the piston responds accordingly.

Scenario 2: Compressing the Gas at Constant Temperature

If the gas is compressed at a constant temperature, the pressure increases:

$$ P_2 = P_1 \times \frac{V_1}{V_2} $$

Suppose the volume is reduced to 25.0 liters:

$$ P_2 = 1.00\, atm \times \frac{50.0}{25.0} = 2.00\, atm $$

This increase in pressure causes the piston to move inward, compressing the gas.

Scenario 3: Isothermal Expansion or Compression

In an isothermal process, the temperature remains constant, and the pressure and volume are inversely related:

$$ P V = \text{constant} $$

This process involves the piston moving to adjust the volume while maintaining the temperature, with the gas performing work during expansion or compression.

Real-World Applications and Significance

Understanding how gases behave in systems with movable pistons has numerous practical applications:

- **Internal Combustion Engines:** Pistons compress fuel-air mixtures, relying on gas laws to optimize performance.

- **Refrigeration and Air Conditioning:** Compressors and expansion valves manipulate gas pressures and temperatures for cooling.
- **Industrial Gas Storage:** Managing pressure and volume ensures safety and efficiency in storing gases.
- **Laboratory Experiments:** Precise control of gas conditions to study thermodynamic properties.

In all these applications, understanding the relationships among pressure, volume, and temperature is crucial for designing efficient and safe systems.

Advanced Considerations: Non-Ideal Gas Behavior

While the ideal gas law provides a good approximation, real gases deviate from ideality under high pressure or low temperature conditions. Factors such as intermolecular forces and finite molecular size come into play.

Van der Waals Equation:

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

Where:
- a and b are constants specific to each gas, accounting for intermolecular attractions and molecular volume, respectively.

These corrections are essential for precise calculations in real-world scenarios where gases do not behave ideally.

Conclusion: The Significance of Gas Behavior in Engineering and Science

The analysis of a gas within a cylinder with a movable piston offers insights into fundamental principles of thermodynamics and gas behavior. By applying the ideal gas law and related laws, we can predict how the system responds to changes in temperature, pressure, and volume. Such understanding is vital in designing engines, refrigeration systems, and various industrial processes.

In our specific case, the initial parameters—50.0 liters at 30.0°C and 1.00 atm—correspond to approximately 2.01 moles of gas. Recognizing how these parameters interact allows engineers and scientists to manipulate conditions to achieve desired outcomes, optimize efficiency, and ensure safety.

Key Takeaways:
- The ideal gas law enables calculating the amount of gas and predicting system responses.
- Movable pistons allow for controlled expansion or compression, enabling work to be done or energy to be transferred.
- Real-world applications depend on understanding and applying these principles accurately.
- Deviations from ideality must be considered for precise calculations in certain conditions.

By mastering these concepts, professionals can effectively utilize gases in various technological and scientific applications, leading to innovations and improvements across multiple industries.

Keywords: gas laws, ideal gas law, piston system, therm

Frequently Asked Questions

What is the initial volume of the gas in the rigid cylinder with a movable piston?

The initial volume of the gas is 50.0 liters.

What are the initial conditions of the gas in terms of temperature and pressure?

The initial temperature is 30.0°C and the initial pressure is 1.00 atm.

How does the pressure of the gas change if the temperature increases to 60.0°C while the volume remains constant?

The pressure would double to 2.00 atm, following Gay-Lussac's law, since pressure is directly proportional to temperature at constant volume.

If the gas is compressed to a volume of 25.0 liters at constant temperature, what is the new pressure?

The new pressure would be 2.00 atm, as pressure is inversely proportional to volume at constant temperature (Boyle's law).

What law describes the relationship between pressure and temperature for this gas at constant volume?

Gay-Lussac's law describes this relationship, stating that pressure is directly proportional to temperature at constant volume.

How would the amount of gas (moles) in the cylinder be affected if the temperature is increased from 30°C to 60°C at constant pressure?

The amount of gas remains constant; only the pressure would change unless gas is added or removed.

If the temperature drops to 0°C while maintaining the same pressure, what happens to the volume of the gas?

Since the cylinder is rigid and volume is fixed, the temperature decrease would lead to a decrease in pressure according to Gay-Lussac's law, not change in volume.

What is the significance of the cylinder being rigid in this gas law problem?

The rigidity of the cylinder means the volume remains constant, simplifying calculations to focus on pressure and temperature changes.

How can the ideal gas law be applied to determine the amount of gas in the cylinder?

Using PV = nRT, where P is pressure, V is volume, n is moles of gas, R is the gas constant, and T is temperature in Kelvin, we can calculate the number of moles of gas present.

Additional Resources

A Rigid Cylinder With a Movable Piston Contains 50.0 Liters of a Gas at 30.0°C With a Pressure of 1.00 atm

---

Introduction

Understanding the behavior of gases under different conditions is fundamental in physics and engineering. The scenario of a rigid cylinder with a movable piston containing a known quantity of gas provides a versatile model for exploring thermodynamic principles, such as ideal gas laws, pressure-volume relationships, and the effects of temperature variations. In this article, we delve into a detailed analysis of this system, examining its initial state, the governing physical laws, potential processes, and implications for real-world applications.

System Overview and Initial Conditions

Description of the Setup

The system in question consists of:

- A rigid cylinder: meaning its volume does not change due to the structural integrity of the container.
- A movable piston: which can slide within the cylinder, allowing the gas volume to change if external forces or processes induce movement.
- Gas content: 50.0 liters at initial conditions.
- Initial temperature: 30.0°C (which converts to 303.15 K in Kelvin).
- Initial pressure: 1.00 atm.

This setup models a common thermodynamic problem, often used to illustrate the ideal gas law and related concepts.

Key Parameters and Units

Parameter	Value	Units
Volume (V)	50.0	Liters
Temperature (T)	30.0	°C (or 303.15 K)
Pressure (P)	1.00	atm

Understanding the initial state requires converting all parameters into consistent SI units, especially Kelvin for temperature, and Pascals for pressure.

Applying the Ideal Gas Law

The Fundamental Equation

The ideal gas law relates pressure (P), volume (V), temperature (T), and the amount of gas in moles (n):

$$PV = nRT$$

where:

- P = pressure in Pascals (Pa),
- V = volume in cubic meters (m^3),
- n = number of moles,
- R = universal gas constant ($8.314\, J/(mol\,K)$),
- T = temperature in Kelvin (K).

Calculating the Number of Moles

First, convert initial conditions into SI units:

- Volume: $50.0\, L = 0.0500\, m^3$,
- Pressure: $1.00\, atm = 101,325\, Pa$,
- Temperature: $30.0\, °C = 303.15\, K$.

Using the ideal gas law:

$$
n = \frac{PV}{RT} = \frac{(101,325\, Pa)(0.0500\, m^3)}{(8.314\, J/(mol\,K))(303.15\, K)}.
$$

Calculating:

$$
n \approx \frac{5,066.25}{2,520.86} \approx 2.01\, \text{moles}.
$$

Thus, the cylinder contains approximately 2.01 moles of gas initially.

Physical Interpretation of the Initial State

The initial conditions suggest a typical laboratory scenario—perhaps a sample of air or another diatomic gas under standard conditions. Key insights include:

- Pressure: 1 atm indicates atmospheric pressure, signifying the gas is in a normal environment.
- Temperature: 30°C indicates a warm, but not extreme, thermal state.
- Volume: 50 liters, which is roughly the volume of a large household refrigerator, indicating a significant quantity of gas.

The system is in a state of equilibrium where the gas exerts a pressure of 1 atm on the piston, balancing external atmospheric pressure.

Analyzing the Rigid Cylinder and Movable Piston

The Rigid Cylinder: Constraints and Limitations

While the cylinder is termed "rigid," this generally implies that its structural properties do not allow volume change. However, the presence of a movable piston introduces flexibility into the system:

- The rigidity pertains to the main container walls.
- The piston can move in response to internal or external forces, enabling volume adjustments during processes such as compression or expansion.

This combination allows the system to undergo various thermodynamic processes, including:

- Isothermal processes: maintaining constant temperature during volume change.
- Adiabatic processes: no heat exchange with surroundings.
- Isobaric or isochoric processes: involving constant pressure or volume, respectively.

The Role of the Movable Piston

The piston’s movement is driven by pressure differentials:

- If internal gas pressure exceeds external pressure, the piston will move outward, increasing the gas volume.
- Conversely, if internal pressure drops below external pressure, the piston moves inward.

The piston’s movement allows the system to achieve different thermodynamic states, making it an ideal model for studying work, heat transfer, and state functions.

Thermodynamic Processes and Potential Changes

Isothermal Expansion or Compression

Suppose the system undergoes an isothermal process, where temperature remains constant at 30°C. Using the ideal gas law:

$$
PV = \text{constant}.
$$

- If the piston moves outward, increasing volume from 50 liters to a larger volume V_f, the pressure will decrease accordingly.

- Conversely, compression reduces volume and increases pressure.

The work done during isothermal expansion:

\[

$$
W = nRT \ln{\frac{V_f}{V_i}},
$$

where:

- $V_i = 50\, L$,
- V_f is the final volume.

The amount of work depends logarithmically on the volume change, illustrating the energy exchange during the process.

Adiabatic Processes

In adiabatic processes, no heat transfer occurs:

$$
PV^\gamma = \text{constant},
$$

where:

- γ is the heat capacity ratio (C_p / C_v).

For diatomic gases like nitrogen or oxygen (common in air), $\gamma \approx 1.4$.

The piston’s movement during an adiabatic process involves changes in temperature, pressure, and volume, all interconnected through the adiabatic relations.

External Factors and Real-World Implications

External Pressure and Atmospheric Conditions

In practical applications, the external pressure (often atmospheric) influences the piston’s movement. If the external pressure remains at 1 atm, then the internal pressure must change to induce motion.

- External conditions can be manipulated to perform work on the gas (compression) or allow it to expand, leading to energy transfer.

Heat Transfer and Thermodynamic Efficiency

In real systems, heat exchange with surroundings can occur:

- Isothermal processes require heat to be added or removed to maintain temperature.
- Adiabatic processes are idealized; real systems experience some heat transfer, affecting efficiency.

Understanding these processes is crucial in designing engines, refrigerators, and other thermodynamic devices.

Practical Applications and Significance

Internal Combustion Engines

The principles elucidated here underpin the operation of engines, where gases undergo controlled thermodynamic processes, converting heat into work.

Refrigeration Cycles

Refrigerators and air conditioners rely on gas compression and expansion cycles, closely related to the processes discussed.

Gas Storage and Safety

Knowledge of pressure-volume relationships is vital for safely storing gases at high pressures, designing pressure vessels, and preventing failures.

Conclusion

The scenario of a rigid cylinder with a movable piston containing 50.0 liters of gas at 30.0°C and 1.00 atm serves as a fundamental model in thermodynamics. By applying the ideal gas law, we determine the amount of gas present and explore how various processes—such as isothermal and adiabatic—alter the system’s state. The interplay between internal and external forces governs piston movement, enabling energy exchange and work production.

Understanding these principles is not only academically intriguing but also practically essential across engineering, environmental science, and industrial applications. The study of such systems continues to influence the development of more efficient engines, refrigeration technology, and safe gas storage solutions. As we advance, integrating real-world factors like heat transfer, friction, and material constraints remains crucial for translating theoretical insights into practical innovations.

References

1. Serway, R. A., & Jewett, J. W. (2014). Physics for Scientists and Engineers. Brooks Cole.
2. Moran, M. J., & Shapiro, H. N. (2008). Fundamentals of Engineering Thermodynamics. Wiley.
3. Çengel, Y. A., & Boles, M. A. (2015). Thermodynamics: An Engineering

Approach. McGraw-Hill Education.
4. Tipler, P. A., & Mosca, G. (2008). Physics for Scientists and Engineers. W. H. Freeman.

This comprehensive review aims to clarify the fundamental concepts governing gases in piston-cylinder systems and their broader implications in science and engineering.

A Rigid Ylinder With A Movable Piston Ontains 50 0 Liters Of A Gass At 30 0 C With A Pressure Of 1 00

A Rigid Ylinder With A Movable Piston Ontains 50 0 Liters Of A Gass At 30 0 C With A Pressure Of 1 00

Related Articles

- An Individual With A Personality Disorder Who Idolizes Someone, And Then At The Slightest Provocation
- A Yoyo Is A Toy Made Of Three Uniform Density Disks With A String Wrapped Around The Middle Disk. The
- Aging Accounts Using Computer Software Is Simple. Name Five Account Aging Criteria Which The Computer

Back to Home