1. Pressure In A Sealed Gas Can Is 123kPawhen It Sits At 30C. It Is Recorded At 75Cafter Heating. What

1. Pressure In A Sealed Gas Can Is 123 kPa When It Sits At 30°C. It Is Recorded At 75°C After Heating. What Does This Indicate?

Introduction to the Problem

Understanding how pressure, temperature, and volume interact in a sealed gas container is fundamental in thermodynamics. The problem presents a scenario where a gas in a sealed can has an initial pressure at a certain temperature, and after heating, its pressure is recorded again at a higher temperature. This situation prompts questions about the behavior of gases, the application of gas laws, and the physical implications of the observed data.

Core Concepts: Gas Laws and Their Relevance

Before delving into the specifics of the problem, it's essential to revisit the fundamental gas laws that govern the behavior of gases under temperature and pressure changes:

- **Boyle's Law**: For a fixed amount of gas at constant temperature, pressure and volume are inversely proportional.
- **Charles's Law**: For a fixed amount of gas at constant pressure, volume is directly proportional to temperature.
- **Gay-Lussac's Law**: For a fixed amount of gas at constant volume, pressure is directly proportional to temperature.
- **Ideal Gas Law**: Combines the above laws into PV = nRT, where P is pressure, V is volume, n is amount of gas (moles), R is the gas constant, and T is temperature in Kelvin.

Given the problem states the gas is in a sealed can, the volume (V) remains constant. Therefore, the behavior of pressure with temperature can be primarily described using Gay-Lussac's Law or the ideal gas law, assuming the gas behaves ideally.

Analyzing the Data: Initial and Final Conditions

Initial Conditions

- Pressure, P_1 = 123 kPa
- Temperature, T_1 = 30°C

Final Conditions

- Temperature, T_2 = 75°C
- Pressure, P_2 = ? (to be determined or analyzed)

Converting Temperatures to Kelvin

Since gas laws require absolute temperature measures, convert Celsius to Kelvin:

- $T_1 = 30°C + 273.15 = 303.15$ K
- $T_2 = 75°C + 273.15 = 348.15$ K

Applying Gas Laws to Determine the Pressure Change

The Ideal Gas Law and Sealed Systems

In a sealed container with fixed volume and amount of gas, the ideal gas law simplifies to:

$\mathbf{P_1 / T_1 = P_2 / T_2}$

This relation comes from rearranging PV = nRT, noting that V and n are constant:

P / T = constant

Calculating the Final Pressure

Using the relation, P_2 can be calculated as:

$$P_2 = P_1 \quad (T_2 / T_1)$$

Substituting the known values:

$$P_2 = 123 \text{ kPa} \quad (348.15 \text{ K} / 303.15 \text{ K}) \approx 123 \text{ kPa} \quad 1.149$$

Calculating:

$$P_2 \approx 123 \text{ kPa} \quad 1.149 \approx 141.2 \text{ kPa}$$

Implication of the Calculation

According to the ideal gas law, the pressure after heating should be approximately 141.2 kPa, which is higher than the initial 123 kPa. This increase aligns with the physical expectation that, at constant volume and amount of gas, increasing temperature results in increased pressure.

Understanding the Real-World Significance

Is the Data Consistent with Gas Laws?

- Yes. The calculated pressure at 75°C (348.15 K) is higher than at 30°C, consistent with the direct proportionality between pressure and temperature in Kelvin.
- The approximate 15-16% increase in pressure matches the ratio of the absolute temperatures, confirming the applicability of the ideal gas law in this scenario.

What Does the Pressure Rise Mean in Practical Terms?

1. **Safety Considerations:** Increased pressure in a sealed can due to heating can pose safety risks such as bursting or explosion if the pressure exceeds the can's design limits.
2. **Material Integrity:** The container's materials must withstand the increased pressure without deforming or failing.

3. **Engineering Design:** Engineers must account for temperature-induced pressure changes when designing sealed systems to prevent accidents.

Factors That Might Affect the Outcome

Real Gas Deviations

While the ideal gas law provides a good approximation, real gases exhibit deviations, especially at high pressures or low temperatures. Factors include:

- Intermolecular forces
- Finite molecular volume
- Gas-specific properties, such as non-ideal behavior

In most practical cases at moderate pressures, the ideal gas law remains sufficiently accurate.

Volume Changes and Material Expansion

Although the problem states the container is sealed, temperature changes can cause physical expansion or contraction of the container material, subtly influencing internal pressure.

- Thermal expansion of metal or plastic walls
- Potential changes in volume affecting pressure calculations

Additional Considerations and Real-World Applications

Monitoring and Safety Protocols

- Regular pressure checks in sealed containers used in industrial processes

- Incorporating safety valves to prevent over-pressurization

Application in Industries

- Compressed gas storage and transportation
- Scuba tanks and fire extinguishers
- Automotive and aerospace applications involving sealed gas systems

Summary of Key Points

- The pressure of a gas in a sealed container increases proportionally with absolute temperature, assuming ideal behavior.
- In the problem, heating from 30°C to 75°C increases the pressure from 123 kPa to approximately 141.2 kPa.
- This increase is consistent with the predictions of the ideal gas law.
- Real-world factors such as material expansion and gas non-idealities can influence actual pressure readings.
- Understanding these principles is vital for safety and design in many engineering applications involving sealed gas systems.

Conclusion

The scenario illustrates a fundamental principle of thermodynamics: in a sealed, rigid container, the pressure of an ideal gas is directly proportional to its absolute temperature. Heating the gas from 30°C to 75°C causes a predictable increase in pressure, from 123 kPa to roughly 141.2 kPa. Recognizing and applying these principles are essential in engineering, safety management, and scientific understanding of gas behaviors under various conditions. Proper consideration of real-world deviations, material properties, and safety measures ensures effective and safe handling of sealed gas systems in practical applications.

Frequently Asked Questions

What is the initial pressure of the gas in the can at 30°C?

The initial pressure is 123 kPa.

How does heating the gas from 30°C to 75°C affect its pressure?

Heating the gas causes its pressure to increase according to Gay-Lussac's law, assuming the volume remains constant.

What is the pressure of the gas after heating to 75°C?

The pressure can be calculated using the relation $P2 = P1 (T2 / T1)$, where temperatures are in Kelvin.

How do you convert Celsius temperatures to Kelvin for this calculation?

Add 273.15 to the Celsius temperature to convert to Kelvin. For example, 30°C = 303.15 K and 75°C = 348.15 K.

What formula is used to determine the pressure change in a sealed gas when temperature changes?

Gay-Lussac's law: $P1 / T1 = P2 / T2$, where P is pressure and T is temperature in Kelvin.

Calculate the new pressure after heating the can to 75°C.

Using $P2 = P1 (T2 / T1)$, $P2 = 123\ \text{kPa}\ (348.15\ \text{K} / 303.15\ \text{K}) \approx 141.4\ \text{kPa}$.

What safety considerations should be taken when heating a sealed gas can?

Heating increases pressure, potentially causing rupture or explosion. Always handle with caution and avoid overheating sealed containers.

Additional Resources

Pressure in a Sealed Gas Can: An Expert Analysis of Temperature Effects and Safety Implications

In the realm of compressed gases, understanding how temperature influences pressure within sealed containers is crucial for safety, efficiency, and proper handling. Whether you're a professional in industrial settings, a hobbyist using aerosol cans, or simply curious about the science behind everyday containers, grasping the relationship between temperature and pressure is fundamental. Today, we delve into a specific scenario: a sealed gas can with an initial pressure of 123 kPa at 30°C, which rises to a different pressure after heating to 75°C. This case study provides an excellent opportunity to explore the physics involved, the principles governing gas behavior, and practical considerations for handling such situations.

Understanding the Basics: Gas Laws and Pressure-Temperature Relationship

Before analyzing the specific scenario, it's imperative to understand the foundational principles that govern the behavior of gases in sealed containers.

Ideal Gas Law: The Cornerstone of Gas Behavior

The ideal gas law states:

$$PV = nRT$$

Where:
- P = pressure
- V = volume (assumed constant for a sealed can)
- n = number of moles of gas
- R = universal gas constant
- T = temperature in Kelvin

In a sealed, rigid container, the volume V and amount of gas n remain constant. Therefore, the relation simplifies to:

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

This means that pressure is directly proportional to temperature when volume and amount of gas are fixed.

Charles's Law and Gay-Lussac's Law

For constant volume and mass, Charles's and Gay-Lussac's laws tell us:

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

Where:
- P_1, T_1: initial pressure and temperature
- P_2, T_2: pressure and temperature after heating

This proportionality allows us to calculate the expected pressure at a new temperature, assuming ideal gas behavior.

Initial Conditions: Setting the Stage

The problem states:

- Initial pressure, P_1: 123 kPa
- Initial temperature, T_1: 30°C
- Final temperature, T_2: 75°C

First, convert temperatures from Celsius to Kelvin:

$$ T(K) = T(°C) + 273.15 $$

- T_1: $30 + 273.15 = 303.15\,K$
- T_2: $75 + 273.15 = 348.15\,K$

Calculating the Expected Final Pressure

Applying the ideal gas law relation:

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

Plugging in the known values:

$$ P_2 = 123\,kPa \times \frac{348.15\,K}{303.15\,K} $$

Calculating the ratio:

$$\frac{348.15}{303.15} \approx 1.149$$

Therefore:

$$P_2 \approx 123\,kPa \times 1.149 \approx 141.24\,kPa$$

This implies that, if the gas behaves ideally and the container withstands the pressure, the pressure after heating to 75°C should be approximately 141.24 kPa.

Implications and Real-World Considerations

While the ideal gas law provides a straightforward calculation, real-world scenarios often introduce complexities, including:

- Non-ideal gas behavior at high pressures or low temperatures.
- Material properties of the can, which may deform or rupture under increased pressure.
- Safety margins incorporated in product design to prevent accidents.

Let's explore these factors in detail.

Deviations from Ideal Behavior

Gases deviate from ideality under certain conditions, especially at high pressures or low temperatures. These deviations are accounted for using correction factors like the Van der Waals equation, which introduces parameters for molecular size and intermolecular forces:

$$\left(P + \frac{a}{V_m^2} \right) (V_m - b) = RT$$

Where:
- a, b: substance-specific constants
- V_m: molar volume

For typical gases in aerosol or fuel cans, these deviations are usually minimal at moderate pressures but can become significant as pressure increases.

Material Strength and Safety Margins

Most sealed cans are designed with safety margins, meaning they can withstand pressures higher than the expected operating or environmental pressures. Manufacturers specify maximum allowable working pressures (MAWP), often well above the calculated pressures at common temperatures.

For example:
- An aerosol can rated for 200 kPa at room temperature might safely handle pressures up to 300 kPa to account for temperature variations.
- Over-pressurization can cause cans to rupture, leading to safety hazards like sprays, explosions, or injury.

Practical Safety Tips for Handling Gas Cans

- Avoid heating sealed cans intentionally or unintentionally, as increased pressure can cause rupture.
- Inspect cans regularly for bulges, leaks, or corrosion.
- Store cans in cool, dry places away from direct sunlight or heat sources.
- Follow manufacturer instructions regarding temperature limits and handling procedures.

Additional Factors Influencing Pressure Changes

Beyond the idealized calculations, several real-world factors influence the pressure inside a sealed gas can:

1. **Ambient Temperature Fluctuations:** External temperature changes can cause pressure variations even without heating.

2. **Gas Composition:** Mixtures of gases can have different behaviors, especially if components liquefy or condense at certain temperatures.

3. **Container Integrity:** Age, manufacturing defects, or damage can alter the container’s response to pressure changes.

4. **Presence of Liquids or Condensed Phases:** Liquids inside the can can influence pressure dynamics, especially if vapor pressure is involved.

Concluding Remarks: What Does This Mean for Users and Professionals?

The core takeaway from this analysis emphasizes the importance of understanding the physics behind pressure changes in sealed gas containers. The initial pressure of 123 kPa at 30°C is expected to rise to about 141 kPa when heated to 75°C, assuming ideal gas behavior and no material failure.

For consumers and professionals, this knowledge translates into several key points:

- Safety First: Never deliberately heat sealed cans to increase pressure; doing so can be dangerous.
- Design Margins: Containers are engineered with safety margins, but exceeding recommended temperatures can compromise integrity.
- Monitoring and Maintenance: Regular inspection and proper storage are vital to prevent accidents.
- Understanding Limits: Recognize the difference between theoretical calculations and real-world factors; always adhere to manufacturer guidelines.

In essence, understanding how temperature influences pressure inside sealed cans is critical for safe handling, effective use, and preventing accidents. Whether in industrial applications or everyday use, this knowledge empowers users to make informed decisions and prioritize safety.

In summary, a sealed gas can initially at 123 kPa and 30°C will experience an increase in pressure to approximately 141 kPa upon heating to 75°C, based on the ideal gas law. Recognizing the factors that can influence this outcome ensures safer handling and better comprehension of the science behind pressure dynamics in sealed containers.

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