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Understanding the thermodynamic properties of gases is essential in various engineering applications, including chemical processing, aerospace, and environmental engineering. When dealing with gases like oxygen in confined containers, it is often necessary to determine the temperature based on given parameters such as volume, mass, and pressure. This article provides a comprehensive guide to calculating the temperature of oxygen in a 3-ft3 container filled with 2-lbm of oxygen at a pressure of 80 Psia.

Fundamentals of Gas Behavior

Before delving into the calculations, it is important to review the basic principles that govern the behavior of gases.

Ideal Gas Law

The ideal gas law is the primary relation used to relate pressure (P), volume (V), temperature (T), and amount of gas (n or m). It is expressed as:

$$PV = nRT$$

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

Alternatively, using the molar form:

$$PV = m/M\ R\ T$$

Where:
- m = mass of gas
- M = molar mass of gas

Real vs. Ideal Gas

While oxygen can deviate from ideal behavior under high pressures or low temperatures, for typical conditions like those specified (80 Psia), the ideal gas law provides a sufficiently accurate approximation.

Given Data and Conversion Factors

Let's identify and convert the provided data into SI units for consistency and ease of calculation.

- **Volume (V):** 3 ft^3
- **Mass (m):** 2 lbm
- **Pressure (P):** 80 Psia

Unit Conversions

- Volume:

Since 1 ft3 = 0.0283168 m3,

$V = 3\ ft^3 = 3 \times 0.0283168\ m^3 \approx 0.08495\ m^3$

- Mass:

1 lbm ≈ 0.45359237 kg,

m = 2 × 0.45359237 kg ≈ 0.90718474 kg

- Pressure:

1 Psia ≈ 6894.76 Pa,

P = 80 × 6894.76 Pa ≈ 551580.8 Pa

- Molar mass of oxygen (O2):

Approximately 32 g/mol or 0.032 kg/mol.

Calculating the Temperature of Oxygen in the Container

The goal is to find the temperature, T, in Kelvin. The process involves applying the ideal gas law:

PV = (m/M) R T

Rearranged as:

T = (PV M) / (m R)

Where:
- P = 551580.8 Pa
- V = 0.08495 m3
- m = 0.90718474 kg
- M = 0.032 kg/mol
- R = 8.314 J/(mol·K)

Let's proceed step-by-step.

Step 1: Calculate the number of moles (n)

Since n = m / M:

n = 0.90718474 kg / 0.032 kg/mol ≈ 28.35 mol

Step 2: Apply the ideal gas law to find T

Using:

T = (P × V) / (n × R)

Substituting known values:

T = (551580.8 Pa × 0.08495 m^3) / (28.35 mol × 8.314 J/(mol·K))

Calculating numerator:

551580.8 Pa × 0.08495 m^3 ≈ 46,872.2 J

Calculating denominator:

28.35 mol × 8.314 J/(mol·K) ≈ 236.0 J/K

Finally:

T ≈ 46,872.2 J / 236.0 J/K ≈ 198.7 K

Therefore, the temperature of the oxygen in the container is approximately 199 Kelvin.

Additional Considerations and Real-World Factors

While the ideal gas law provides a solid approximation, real-world scenarios sometimes require adjustments. Here are factors to consider:

1. Deviations from Ideal Behavior

At high pressures or low temperatures, gases deviate from ideality. For oxygen at 80 Psia, deviations are minimal but can be accounted for using real gas equations of state like the Van der Waals equation.

2. Effect of Temperature on Gas Properties

Temperature influences gas density, pressure, and potential phase changes. The calculated temperature indicates the gas is well above its liquefaction point, confirming it remains gaseous under these conditions.

3. Safety and Practical Implications

Handling oxygen at high pressures necessitates safety measures. Knowing the temperature helps assess risks such as thermal expansion or potential ignition sources.

Summary of Key Steps to Determine Gas Temperature

- Convert all given parameters to SI units for consistency.

- Calculate the number of moles using the molar mass and mass provided.
- Apply the ideal gas law to solve for temperature.
- Verify units and approximate results, considering real gas effects if necessary.

Conclusion

Using the ideal gas law, the temperature of oxygen contained in a 3-ft3 volume with a mass of 2 lbm at 80 Psia is approximately 199 Kelvin. This calculation underscores the importance of unit conversions and understanding gas laws in engineering contexts. Whether designing pressure vessels, conducting safety assessments, or performing process calculations, accurately determining the temperature based on pressure, volume, and mass is fundamental.

For more complex scenarios or higher precision, engineers may utilize real gas equations, computational tools, or experimental data. Nonetheless, the ideal gas law remains a vital starting point for thermodynamic analysis of gases such as oxygen in practical applications.

Keywords: oxygen temperature calculation, ideal gas law, pressure-volume-temperature, engineering thermodynamics, gas properties, pressure container analysis

Frequently Asked Questions

What is the initial temperature of the oxygen in the 3-ft³ container at 80 psia and 2 lbm mass?

Using the ideal gas law, the temperature can be calculated as T = (P V) / (m R). Converting units and applying the gas constant for oxygen, the temperature is approximately 608 R.

How do you convert the given pressure and volume into a temperature for the oxygen in the container?

Convert the pressure to absolute units (psia to psf), volume to cubic feet, and use the specific gas constant for oxygen. Then, apply the ideal gas law T = (P V) / (m R) to find the temperature.

What assumptions are made when calculating the temperature of oxygen in this container?

Assumptions include that the oxygen behaves as an ideal gas, the system is at steady state, and the pressure and temperature are uniform throughout the container.

If the pressure in the container increased to 100 psia while maintaining the same mass and volume, what would be the new temperature?

The temperature would increase proportionally. Using the ideal gas law, the new temperature would be T = (100 psia V) / (m R), resulting in approximately 760 R.

What is the importance of knowing the temperature of oxygen in a pressurized container like this?

Knowing the temperature is crucial for safety, performance, and design considerations, including avoiding exceeding material limits, ensuring proper operation, and preventing hazards related to high-pressure gases.

Additional Resources

A 3-ft^3 Container Is Filled With 2-lbm Of Oxygen At A Pressure Of 80 Psia: What Is The Temperature?

Understanding the thermal state of gases within confined spaces is a foundational aspect of thermodynamics, with profound implications across engineering, safety, and scientific research. When a 3-ft^3 container is filled with 2 pounds-mass (lbm) of oxygen at a pressure of 80 psia, determining the temperature of the gas involves a detailed analysis rooted in the fundamental principles of gas behavior, property relations, and the ideal or real gas models.

This article provides a comprehensive investigation into this problem, elucidating the underlying physics, calculation steps, assumptions, and practical considerations. Such an exploration is essential for engineers, researchers, and safety professionals who must accurately predict the state of gases under various conditions.

Fundamental Concepts and Problem Overview

Before diving into calculations, it is crucial to clarify the parameters and assumptions:

- Container volume (V): 3 cubic feet (ft^3)
- Mass of oxygen (m): 2 pounds-mass (lbm)
- Pressure (P): 80 pounds per square inch absolute (psia)
- Objective: Find the temperature (T) of the oxygen within this confined space.

Key Assumptions and Considerations

1. Ideal Gas Behavior:
For most practical purposes at moderate pressures and temperatures, oxygen behaves approximately as an ideal gas. This simplifies calculations but warrants validation based on the pressure and temperature ranges involved.

2. Units Consistency:
To perform calculations accurately, all units should be consistent, preferably converting to absolute SI units or using specific gas constants.

3. State of the Gas:
The gas is assumed to be uniform and in thermodynamic equilibrium, with no phase changes or significant interactions affecting the behavior.

4. Container Conditions:
The container is rigid and closed, with no gas exchange or leakage during the process.

Key Properties of Oxygen and Relevant Data

Molecular and Gas Constants

- Molecular weight of oxygen (O_2): approximately 32.00 g/mol or 0.0703 lbm/mol.
- Universal gas constant (R): 8.314 J/(mol·K).
For imperial units, the specific gas constant for oxygen (R_specific) is often used:

\[
R_{O_2} = \frac{R}{M} \approx \frac{1545 \text{ ft·lb}_f/ (lbm·°R)}{1} \text{ (see below for units)}
\]

Specific Gas Constant for Oxygen

In imperial units, the specific gas constant R for oxygen is:

\[
R_{O_2} = \frac{1545 \text{ ft·lb}_f/ (lbm·°R)}{32 \text{ g/mol} / 453.592 \text{ g/lb}} \approx 53.35 \text{ ft·lb}_f/(lbm·°R)
\]

Alternatively, a commonly used value:

\[
R_{O_2} \approx 0.257 \text{ Btu/(lbm·°R)}
\]

which can be converted to ft·lb units as needed.

Conversion of Volume and Pressure

- Volume (V): 3 ft^3 (already in imperial units)
- Pressure (P): 80 psia (pounds per square inch absolute)
- Temperature (T): in Rankine (°R)

Calculating the Temperature of Oxygen

The ideal gas law relates pressure, volume, temperature, and amount of gas:

$$
PV = m R_{specific} T
$$

Where:

- P = absolute pressure (psia)
- V = volume (ft^3)
- m = mass (lbm)
- $R_{specific}$ = specific gas constant for oxygen ($ft·lb_f/(lbm·°R)$)
- T = temperature in Rankine (°R)

Step 1: Convert Units

Given:

- $V = 3 \text{ ft}^3$
- $m = 2 \text{ lbm}$
- $P = 80 \text{ psia}$
- $R_{O_2} \approx 53.35 \text{ ft·lb}_f/(lbm·°R)$

Step 2: Apply Ideal Gas Law

Rearranged to solve for T:

$$
T = \frac{PV}{m R_{O_2}}
$$

Plugging in the numbers:

$$
T = \frac{80 \text{ psia} \times 3 \text{ ft}^3}{2 \text{ lbm} \times 53.35 \text{ ft·lb}_f/(lbm·°R)}
$$

Note: To ensure units are compatible, pressure in psia and R in $ft \cdot lb_f/(lbm \cdot {}^\circ R)$ are acceptable, provided volume is in ft^3 and mass in lbm.

Step 3: Calculation

Calculating numerator:

$$
80 \times 3 = 240 \text{ psia·ft}^3
$$

Calculating denominator:

$$
2 \times 53.35 = 106.7 \text{ ft·lb}_f/°R
$$

Therefore:

$$
T = \frac{240}{106.7} \approx 2.25 \times 10^0 \text{ (unitless)}
$$

But this is incomplete because the units of pressure and R need to be consistent with the ideal gas law.

Ensuring Proper Units and Correct Calculation

To avoid unit inconsistency, it is often best to convert all quantities into SI units or use the version of the ideal gas law with pressure in absolute units, volume in cubic feet, molar quantities, and the universal gas constant.

Alternative Approach: Use Moles and Molar Gas Constant

- Calculate number of moles (n):

$$
n = \frac{m}{M} = \frac{2 \text{ lbm}}{32 \text{ g/mol} \times 0.00220462 \text{ lbm/g}} \approx 0.0353 \text{ mol}
$$

- Use ideal gas law in SI units:

$$
PV = n R T
$$

Where:

- $P = 80 \text{ psia} = 80 \times 144 \text{ psf} = 11520 \text{ psf}$

But it's more straightforward to convert pressure into absolute SI units:

$$
1 \text{ psia} = 6894.76 \text{ Pa}
$$

Thus:

$$
P = 80 \times 6894.76 \text{ Pa} \approx 551580.8 \text{ Pa}
$$

- Volume:

$$
V = 3 \text{ ft}^3 = 3 \times 0.0283168 \text{ m}^3 \approx 0.08495 \text{ m}^3
$$

- Universal gas constant:

$$
R = 8.314 \text{ J/(mol·K)}
$$

- Calculate T:

$$
T = \frac{PV}{n R} = \frac{551580.8 \times 0.08495}{0.0353 \times 8.314}
$$

Numerator:

$$
551580.8 \times 0.08495 \approx 46,878.4 \text{ J}
$$

Denominator:

$$
0.0353 \times 8.314 \approx 0.2937 \text{ J/K}
$$

Thus:

$$
T \approx \frac{46,878.4}{0.2937} \approx 159,678 \text{ K}
$$

This clearly indicates an inconsistency—such a high temperature is physically impossible under normal circumstances, highlighting the importance of verifying assumptions.

Reconciling Discrepancies and Validating Assumptions

The enormous temperature obtained suggests that the initial assumption of ideal behavior at 80 psia and the given mass in such a small volume is invalid or that the problem is ill-posed without additional context.

Alternative Explanation

- Is the gas initially at or near standard conditions?

Possibly, the problem aims to find the temperature under the given pressure and volume, assuming ideal gas behavior, but the mass supplied might be inconsistent with the volume at standard conditions.

- Check the gas density:

- The density (ρ):

$$
\rho = \frac{m}{V} = \frac{2 \text{ lbm}}{3 \text{ ft}^3} \approx 0.6667 \text{ lbm/ft}^3
$$

For oxygen, the standard density at STP (~14.7 psia, 59°F) is approximately 0.0824 lbm/ft^3, indicating the gas is more compressed under the given pressure.

Practical Interpretation

Given the high-pressure and small-volume context, the problem likely aims to determine the temperature assuming

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