A Gas Mixture Contains 20.0 G He Gas And 6.0 G Hydrogen Gas At A Total Pressure Of 800 Torr. What Is

A Gas Mixture Contains 20.0 G He Gas And 6.0 G Hydrogen Gas At A Total Pressure Of 800 Torr. What Is this mixture's molar composition, partial pressures, and other relevant properties? Understanding the behavior of gas mixtures is fundamental in chemistry and physics, especially for applications involving gas laws, mixtures, and partial pressures. This article explores how to analyze such a mixture systematically, calculating the number of moles, mole fractions, partial pressures, and related properties.

Understanding the Composition of the Gas Mixture

Before diving into calculations, it's crucial to interpret the given data correctly. The mixture contains helium (He) and hydrogen (H_2) gases, with specified masses and a total pressure. We will use this information to determine the number of moles of each gas, their mole fractions, and the partial pressures contributing to the total pressure.

Calculating Moles of Each Gas

The first step involves converting the given masses into moles, using the molar masses of helium and hydrogen.

Molar Mass of Helium (He)

- Atomic mass of He ≈ 4.00 g/mol

Molar Mass of Hydrogen (H_2)

- Molecular mass of H_2 ≈ 2.02 g/mol (since atomic hydrogen ≈ 1.008 g/mol, and H_2 is diatomic)

Number of Moles of Helium

$$
n_{He} = \frac{\text{mass of He}}{\text{molar mass of He}} = \frac{20.0\, \text{g}}{4.00\, \text{g/mol}} = 5.00\, \text{mol}
$$

Number of Moles of Hydrogen

$$
n_{H_2} = \frac{\text{mass of H}_2}{\text{molar mass of H}_2} = \frac{6.0\, \text{g}}{2.02\, \text{g/mol}} \approx 2.97\, \text{mol}
$$

Note: The slight approximation here is due to rounding.

Calculating Total Moles in the Mixture

The total number of moles in the mixture is simply the sum of the moles of each component:

$$
n_{total} = n_{He} + n_{H_2} = 5.00 + 2.97 \approx 7.97\, \text{mol}
$$

This total will be useful for calculating mole fractions and partial pressures.

Mole Fractions of Each Gas

Mole fraction (X) indicates the proportion of each gas in the mixture:

$$
X_{He} = \frac{n_{He}}{n_{total}} = \frac{5.00}{7.97} \approx 0.628
$$

$$
X_{H_2} = \frac{n_{H_2}}{n_{total}} = \frac{2.97}{7.97} \approx 0.373
$$

These fractions help determine each gas's contribution to the total pressure.

Calculating Partial Pressures

Dalton’s Law states that each gas in a mixture exerts a partial pressure proportional to its mole fraction:

$$
P_{gas} = X_{gas} \times P_{total}
$$

Given:
- Total pressure, $P_{total} = 800\, \text{Torr}$

Partial Pressure of Helium

$$
P_{He} = X_{He} \times P_{total} = 0.628 \times 800\, \text{Torr} \approx 502.4\, \text{Torr}
$$

Partial Pressure of Hydrogen

$$
P_{H_2} = X_{H_2} \times P_{total} = 0.373 \times 800\, \text{Torr} \approx 298.4\, \text{Torr}
$$

These partial pressures are crucial for understanding the behavior of each component within the mixture.

Additional Properties and Applications

Knowing the moles and partial pressures, several other properties and applications can be analyzed:

1. Gas Behavior and Ideal Gas Law

- The ideal gas law, $PV = nRT$, can be used to determine the volume of the mixture at a given temperature.
- For example, assuming a temperature T (say, 298 K), the volume V can be calculated as:

$$
V = \frac{nRT}{P}
$$

where $R = 0.08206\, \text{L·atm/(mol·K)}$. To use this, convert pressure from Torr to atm:

$$
800\, \text{Torr} \times \frac{1\, \text{atm}}{760\, \text{Torr}} \approx 1.0526\, \text{atm}
$$

2. Molar Ratios and Composition

- The molar ratio of He to H_2 is approximately 5.00:2.97, or about 1.68:1, which can be relevant in chemical reactions or processes where specific ratios are needed.

3. Applications in Industry and Research

- Gas mixtures like this are common in laboratories, welding (helium-hydrogen mixtures), and gas chromatography.
- Understanding partial pressures helps optimize conditions for reactions or processes like gas separation.

Summary of Key Calculations

- Helium moles: 5.00 mol
- Hydrogen moles: 2.97 mol
- Total moles: 7.97 mol
- Mole fraction of He: 0.628
- Mole fraction of H_2: 0.373
- Partial pressure of He: approximately 502.4 Torr
- Partial pressure of H_2: approximately 298.4 Torr

Conclusion

Analyzing a gas mixture involves converting given masses into moles, calculating mole fractions, and applying Dalton's Law to find partial pressures. In this example, the mixture contains about 5.00 mol of helium and 2.97 mol of hydrogen, with partial pressures of approximately 502.4 Torr and 298.4 Torr, respectively. Such calculations are essential in various scientific and industrial applications, providing insight into the behavior and properties of gas mixtures under different conditions.

Understanding these principles allows chemists and engineers to design processes, interpret experimental data, and optimize conditions for reactions involving multiple gases. Whether in laboratory settings or large-scale industrial operations, mastery of gas mixture analysis remains a fundamental skill in the physical sciences.

Frequently Asked Questions

What is the mole fraction of helium in the gas mixture?

First, calculate moles of helium: 20.0 g / 4.00 g/mol = 5.0 mol. For hydrogen: 6.0 g / 2.02 g/mol ≈ 2.97 mol. Total moles = 5.0 + 2.97 ≈ 7.97 mol. Mole fraction of helium = 5.0 / 7.97 ≈ 0.628.

What is the partial pressure of helium in the mixture?

Using Dalton's Law: Partial pressure of helium = mole fraction × total pressure = 0.628 × 800 Torr ≈ 502.4 Torr.

How do you determine the partial pressure of hydrogen in the mixture?

Partial pressure of hydrogen = mole fraction of hydrogen × total pressure. Mole fraction of hydrogen = 2.97 / 7.97 ≈ 0.373. Therefore, partial pressure = 0.373 × 800 Torr ≈ 298.4 Torr.

What is the total number of moles of gases in the mixture?

Total moles = (mass of helium / molar mass of helium) + (mass of hydrogen / molar mass of hydrogen) = 20.0 g / 4.00 g/mol + 6.0 g / 2.02 g/mol ≈ 5.0 + 2.97 = 7.97 mol.

How can you find the average molar mass of the gas mixture?

Average molar mass = (total mass of gases) / (total moles) = (20.0 g + 6.0 g) / 7.97 mol ≈ 26.0 g / 7.97 mol ≈ 3.26 g/mol.

If the temperature is constant, how does Dalton's Law help determine individual gas pressures?

Dalton's Law states that each gas exerts pressure proportional to its mole fraction. Knowing total pressure and mole fractions allows calculation of each gas's partial pressure at constant temperature and volume.

Additional Resources

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Understanding the behavior of gas mixtures is fundamental in fields ranging from chemical engineering to atmospheric science. When gases are combined, their individual properties influence the overall characteristics of the mixture, such as pressure, molar composition, and partial pressures. In this article, we explore a specific scenario involving a mixture of helium and hydrogen gases, analyze the key parameters, and perform detailed calculations to uncover the underlying properties of this mixture.

Introduction: The Significance of Gas Mixture Analysis

Gas mixtures are ubiquitous in both natural and industrial processes. From the Earth's atmosphere to specialized laboratory environments, understanding how different gases interact and contribute to overall system behavior is crucial. Accurate calculations of molar quantities, partial pressures, and mole fractions enable scientists and engineers to design better equipment, predict reactions, and control conditions effectively.

In the present case, a mixture comprises helium (He) and hydrogen (H_2) gases, with known masses and a total pressure. Determining properties like molar amounts, mole fractions, partial pressures, and other thermodynamic parameters provides insights into the composition and behavior of this specific mixture.

Key Concepts and Definitions

Before diving into calculations, it is essential to clarify some fundamental concepts:

- Mole (mol): The amount of substance containing exactly 6.022×10^{23} particles (Avogadro's number).
- Partial Pressure: The pressure exerted by an individual gas in a mixture, proportional to its molar fraction.
- Mole Fraction (X_i): The ratio of moles of a component to the total moles in the mixture.
- Ideal Gas Law: $PV = nRT$, relating pressure (P), volume (V), number of moles (n), gas constant (R), and temperature (T).

Given that the total pressure and masses are known, the goal is to compute:

- The number of moles of each gas
- The total moles in the mixture
- The mole fraction of each component
- The partial pressure of each component

Calculating Moles of Helium and Hydrogen

The initial step involves converting the given masses into moles. The molar masses are:

- Helium (He): approximately 4.00 g/mol
- Hydrogen (H_2): approximately 2.02 g/mol

Using the formula:

$$
n = \frac{\text{mass}}{\text{molar mass}}
$$

we find:

1. Moles of Helium (He):

$$
n_{He} = \frac{20.0 \text{ g}}{4.00 \text{ g/mol}} = 5.00 \text{ mol}
$$

\]

2. Moles of Hydrogen (H_2):

$$
n_{H_2} = \frac{6.0 \text{ g}}{2.02 \text{ g/mol}} \approx 2.97 \text{ mol}
$$

Total moles in the mixture:

$$
n_{total} = n_{He} + n_{H_2} = 5.00 + 2.97 \approx 7.97 \text{ mol}
$$

Determining Mole Fractions

Mole fractions indicate the proportion of each gas in the mixture:

$$
X_{He} = \frac{n_{He}}{n_{total}} = \frac{5.00}{7.97} \approx 0.628
$$

$$
X_{H_2} = \frac{n_{H_2}}{n_{total}} = \frac{2.97}{7.97} \approx 0.372
$$

These mole fractions are critical in calculating partial pressures, as they directly influence the distribution of pressure among the components.

Calculating Partial Pressures

According to Dalton’s Law of Partial Pressures, the partial pressure of each gas is proportional to its mole fraction:

$$
P_i = X_i \times P_{total}
$$

Given:

- Total pressure $P_{total} = 800 \text{ Torr}$

Calculations:

1. Helium partial pressure:

$$
P_{He} = 0.628 \times 800 \text{ Torr} \approx 502.4 \text{ Torr}
$$

2. Hydrogen partial pressure:

$$
P_{H_2} = 0.372 \times 800 \text{ Torr} \approx 297.6 \text{ Torr}
$$

These partial pressures reveal the contribution of each gas to the total pressure, which is valuable in processes sensitive to specific gas concentrations.

Implications and Applications

Understanding the composition and partial pressures of gas mixtures like this has multiple practical applications:

- Industrial Gas Production: Precise calculations enable optimal separation and utilization of gases in manufacturing processes.
- Environmental Monitoring: Composition analysis helps in assessing atmospheric pollution levels and greenhouse gas contributions.
- Laboratory Experiments: Accurate molar and partial pressure data are crucial for reproducibility and safety in chemical reactions.
- Design of Gas Handling Equipment: Knowledge of partial pressures informs the design of pressure vessels, piping, and safety protocols.

Additionally, knowing the molar quantities allows for further thermodynamic calculations, such as enthalpy or entropy changes, which are essential in process engineering.

Conclusion: Synthesis of Findings

The analysis of this specific gas mixture reveals that:

- The mixture contains approximately 5.00 mol of helium and 2.97 mol of hydrogen.
- The total molar content is around 7.97 mol.
- Helium accounts for about 62.8% of the molar composition, while hydrogen makes up about 37.2%.
- The partial pressure exerted by helium is roughly 502.4 Torr, and hydrogen contributes

approximately 297.6 Torr to the total of 800 Torr.

These calculations exemplify the importance of fundamental principles of gas laws and molar relationships in understanding and predicting the behavior of gas mixtures. Whether in designing industrial processes or conducting scientific research, such detailed analysis provides a foundation for informed decision-making and innovation in the realm of gases.

Final note: While this analysis assumes ideal gas behavior, real gases may deviate slightly depending on temperature, pressure, and intermolecular interactions. Nonetheless, the ideal gas law offers a robust approximation for most practical purposes within typical conditions.

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