A Mixture Of O2 And He Gas Is 92.3% By Mass O2. What Is The Partial Pressure Of O2 If The Total Pressure

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Understanding gas mixtures and calculating partial pressures are fundamental concepts in chemistry, especially in fields such as respiratory physiology, chemical engineering, and environmental science. When dealing with a mixture of oxygen (O_2) and helium (He), knowing the mass composition allows us to determine the partial pressure of each component, which in turn influences various physical and chemical behaviors of the gases. In this article, we will explore how to calculate the partial pressure of oxygen in a gas mixture that is 92.3% by mass O_2 when the total pressure is known. We will break down the problem step-by-step, ensuring clarity and thoroughness.

Understanding the Problem

Before diving into calculations, it is essential to understand the key data and what is being asked.

Given Data

- The gas mixture contains oxygen (O_2) and helium (He).
- Mass percent of O_2 in the mixture: 92.3%

- Mass of the entire mixture: typically assumed or specified (we will assume a basis of 1 kg for simplicity).
- Total pressure of the gas mixture: denoted as \(P_{total} \), a known value.

What Is Being Asked?

- Calculate the partial pressure of O_2 in the mixture, given the total pressure.

Key Concepts and Formulas

To solve this problem, we need to understand several fundamental concepts: molar mass, mole fraction, Dalton's law of partial pressures, and the relationship between mass, molar mass, and moles.

Molar Masses of Gases

- Oxygen (O_2): approximately 32.00 g/mol
- Helium (He): approximately 4.00 g/mol

Dalton's Law of Partial Pressures

- States that the partial pressure of a gas in a mixture is proportional to its mole fraction and the total pressure:

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

- Where X_{gas} is the mole fraction of the gas.

Calculating Mole Fractions

- Mole fraction of a component:

$$
X_{gas} = \frac{\text{moles of gas}}{\text{total moles of mixture}}
$$

- Moles are calculated from mass and molar mass:

$$
n = \frac{m}{M}
$$

- Total moles:

$$
n_{total} = n_{O_2} + n_{He}
$$

With these concepts, we can proceed to the step-by-step solution.

Step-by-Step Solution

Step 1: Assume a Basis for Calculations

To simplify calculations, assume the total mass of the mixture is 1 kg (1000 g). This is a common approach in chemistry to work with basis quantities.

Step 2: Determine Mass of O_2 and He in the Mixture

Given the mass percentage:

$$
\text{Mass of } O_2 = 0.923 \times 1000\, g = 923\, g
$$

$$
\text{Mass of } He = 1000\, g - 923\, g = 77\, g
$$

Step 3: Calculate Moles of O_2 and He

Using molar masses:

$$
n_{O_2} = \frac{923\, g}{32.00\, g/mol} \approx 28.84\, mol
$$

$$
n_{He} = \frac{77\, g}{4.00\, g/mol} \approx 19.25\, mol
$$

Step 4: Calculate Total Moles

$$
n_{total} = n_{O_2} + n_{He} = 28.84 + 19.25 = 48.09\, mol
$$

Step 5: Determine Mole Fraction of O_2

$$
X_{O_2} = \frac{n_{O_2}}{n_{total}} = \frac{28.84}{48.09} \approx 0.599
$$

Similarly, the mole fraction of helium:

$$
X_{He} = 1 - X_{O_2} \approx 0.401
$$

Step 6: Calculate Partial Pressure of O_2

Using Dalton's law:

$$
P_{O_2} = X_{O_2} \times P_{total}
$$

Suppose the total pressure P_{total} is given (say, 1 atm for simplicity). To express the partial pressure:

$$
P_{O_2} = 0.599 \times P_{total}
$$

\]

If the total pressure is, for example, 1 atm:

$$
P_{O_2} \approx 0.599\, atm
$$

Note: If the total pressure differs, simply multiply the mole fraction of O_2 by the actual total pressure.

Practical Applications and Considerations

Understanding how to compute the partial pressure of oxygen in gas mixtures has several practical applications:

Medical and Respiratory Science
- Determining oxygen delivery in medical therapies.
- Assessing gas exchange efficiency in lungs.

Chemical Engineering
- Designing industrial processes involving oxygen and inert gases.
- Controlling reaction environments where partial pressures influence reaction rates.

Environmental Science
- Modeling atmospheric compositions and their effects on climate.

Additional Factors to Consider
- Temperature dependence: Partial pressures are influenced by temperature via gas laws.
- Non-ideal gases: Real gases may deviate from ideal behavior, requiring correction factors.

- Changes in total pressure: The calculation scales linearly with the total pressure.

Summary

In summary, calculating the partial pressure of oxygen in a mixture of O_2 and helium involves understanding the composition of the mixture, converting mass to moles, determining the mole fraction, and then applying Dalton's law.

Key steps include:

1. Assume a basis for total mass.
2. Calculate individual masses based on mass percentages.
3. Convert masses to moles using molar masses.
4. Find the mole fraction of O_2.
5. Multiply the mole fraction by the total pressure to find the partial pressure.

By mastering these calculations, chemists and scientists can accurately determine the behavior of gas mixtures, enabling precise control in various scientific and industrial applications.

Final Notes

Always ensure that the units are consistent throughout your calculations. When the total pressure is provided in units other than atmospheres (such as kPa or mmHg), convert accordingly before calculating partial pressures. Understanding these fundamental principles enhances your comprehension of gas behaviors and their practical implications in science and engineering.

Frequently Asked Questions

What is the significance of knowing the partial pressure of O2 in a mixture of O2 and He gases?

Knowing the partial pressure of O2 helps determine its individual contribution to the total pressure, which is important in respiratory physiology, industrial processes, and gas mixture calculations.

How do you calculate the partial pressure of O2 in a gas mixture if the total pressure is known?

The partial pressure of O2 can be calculated using Dalton's Law: P_O2 = (mass fraction of O2) × (total pressure).

What information do you need to find the partial pressure of O2 in the mixture?

You need the total pressure of the gas mixture and the mass percentage or mole fraction of O2 in the mixture.

Given the mixture is 92.3% by mass O2, how do you find the mole fraction of O2?

Convert the mass percentage to moles by dividing the mass of each component by its molar mass, then calculate the mole fraction of O2.

If the total pressure of the gas mixture is 1 atm, what is the partial pressure of O2?

First, find the mole fraction of O2 using the given mass percentage, then multiply by the total pressure. For example, with 92.3% by mass O2, the partial pressure P_O2 □ 0.923 × 1 atm = 0.923 atm.

Why is it important to convert mass percentages to mole fractions when calculating partial pressures?

Because gases obey Dalton's Law based on mole fractions, converting mass percentages to mole fractions ensures accurate calculation of each gas's partial pressure.

What is the molar mass of O2 and He, and why are these important in calculations?

The molar mass of O2 is approximately 32 g/mol, and He is about 4 g/mol. These values are used to convert between mass and moles, essential for calculating mole fractions.

How does Dalton's Law relate to calculating partial pressures in a gas mixture?

Dalton's Law states that the total pressure is the sum of the partial pressures of individual gases, which are proportional to their mole fractions in the mixture.

Can the partial pressure of O2 be directly calculated from mass percentage without converting to moles?

No, because partial pressure depends on mole fraction, which requires converting mass percentages to mole fractions, not just using mass percentages directly.

What assumptions are made when calculating partial pressures in gas mixtures?

Assumptions include ideal gas behavior, uniform mixing, and that the gases do not react chemically with each other.

Additional Resources

A Mixture Of O_2 And He Gas Is 92.3% By Mass O_2. What Is The Partial Pressure Of O_2 If The Total Pressure is a classic problem in gas law calculations, combining concepts of partial pressures, molar fractions, and the composition of gas mixtures. Understanding how to determine the partial pressure of a specific gas component in a mixture is fundamental in fields ranging from chemical engineering to atmospheric science. This guide aims to break down the problem step-by-step, providing clear explanations, relevant formulas, and practical insights to help you master this important topic.

Introduction to Gas Mixtures and Partial Pressures

When dealing with gases, it's common to encounter mixtures – for example, the Earth's atmosphere, which is primarily nitrogen and oxygen, or industrial gas mixtures used for various applications. Each component in a mixture exerts its own pressure, known as its partial pressure, which collectively sums to the total pressure of the mixture.

Why Is Partial Pressure Important?

- It determines how gases behave in reactions.
- It influences gas transfer processes like diffusion.
- It helps in calculating gas concentrations in various applications, including medical and industrial settings.

The Role of Molar and Mass Fractions

In gas mixtures problems, understanding the difference between mass fractions and molar fractions is crucial:

- Mass fraction: The ratio of the mass of a component to the total mass.
- Molar fraction: The ratio of the number of moles of a component to the total moles.

Since gases are often analyzed in molar terms due to ideal gas behavior, converting mass fractions to molar fractions is a key step.

Step 1: Understanding the Composition of the Gas Mixture

Given data:

- The mixture contains oxygen (O_2) and helium (He).
- The mixture is 92.3% by mass O_2.

This implies:

- Mass of O_2 in the mixture: 92.3%
- Mass of He in the mixture: 100% - 92.3% = 7.7%

Step 2: Calculating the Molar Fractions

To find the partial pressure of O_2, we need its molar fraction within the mixture because Dalton's law expresses partial pressure in terms of molar ratios.

Step 2.1: Find the number of moles of each gas per unit total mass

Molar masses:

- O_2: approximately 32 g/mol
- He: approximately 4 g/mol

Assuming a total mass of 100 grams for simplicity:

- Mass of O_2 = 92.3 g
- Mass of He = 7.7 g

Number of moles:

- Moles of O_2: $n_{O_2} = \frac{92.3 \text{ g}}{32 \text{ g/mol}} \approx 2.884 \text{ mol}$

- Moles of He: $n_{He} = \frac{7.7 \text{ g}}{4 \text{ g/mol}} = 1.925 \text{ mol}$

Step 2.2: Calculate molar fractions

Total moles in the mixture:

$$n_{total} = n_{O_2} + n_{He} \approx 2.884 + 1.925 = 4.809 \text{ mol}$$

- Molar fraction of O_2:

$$X_{O_2} = \frac{n_{O_2}}{n_{total}} \approx \frac{2.884}{4.809} \approx 0.599$$

- Molar fraction of He:

$$X_{He} = \frac{n_{He}}{n_{total}} \approx \frac{1.925}{4.809} \approx 0.401$$

Step 3: Applying Dalton’s Law to Find Partial Pressure

Dalton’s Law states:

$$
P_{O_2} = X_{O_2} \times P_{total}
$$

Where:

- P_{O_2}: Partial pressure of oxygen
- X_{O_2}: Molar fraction of oxygen
- P_{total}: Total pressure of the gas mixture

To proceed, you need to know the total pressure P_{total}. For example, if the problem states that the total pressure is 1 atmosphere (atm), then:

$$
P_{O_2} = 0.599 \times 1\, \text{atm} = 0.599\, \text{atm}
$$

or approximately 599 mm Hg.

Step 4: Generalized Calculation

If the total pressure is different, say P_{total} (which could be given or assumed), the partial pressure can be directly calculated as:

$$
\boxed{
P_{O_2} = X_{O_2} \times P_{total}
}
$$

This formula underscores the importance of molar fractions derived from mass data and how they relate to partial pressures.

Additional Considerations and Practical Insights

1. Effect of Temperature

- Though temperature doesn't directly affect the calculation of partial pressures via Dalton’s law, it influences the total pressure if the gas is not in a rigid container.
- For ideal gases, the partial pressure is proportional to temperature at constant volume and moles, according to the ideal gas law.

2. Non-Ideal Gas Effects

- At high pressures or low temperatures, deviations from ideality can occur.
- Real gas corrections (using Van der Waals equation, for example) may be required for precise calculations.

3. Real-World Applications

- Medical oxygen supply systems depend on partial pressure calculations.
- Industrial processes like welding gases or inert atmospheres rely on accurate gas mixture compositions.
- Environmental sciences analyze atmospheric compositions using similar principles.

Summary of the Calculation Steps

1. Identify the mass fractions of each component.
2. Convert mass fractions to molar fractions using molar masses.
3. Determine the molar fraction of the gas of interest (here, O_2).
4. Multiply the molar fraction by the total pressure to find the partial pressure.

In our example:

- Molar fraction of $O_2 \approx 0.599$
- Total pressure (assumed at 1 atm) = 1 atm
- Partial pressure of $O_2 \approx 0.599$ atm

Final Thoughts

Understanding how to compute the partial pressure of a gas in a mixture based on its mass percentage is a fundamental skill in physical chemistry and engineering. The key steps involve converting mass fractions to molar fractions, applying Dalton's Law, and considering the total pressure. Whether working with ideal gases or real gases, mastering these concepts enables accurate analysis of gas systems in scientific and industrial contexts.

References

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By understanding these principles, you can confidently approach problems involving gas mixtures, partial pressures, and their practical applications in diverse scientific fields.

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