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A Mixture Contains 50.0% O2, 25% N2 And 25.0% Cl2 By Volume At A Total Pressure Of 1.40 Atm. Which Of

Understanding gas mixtures is fundamental in chemistry, especially in fields such as environmental science, industrial manufacturing, and chemical engineering. When analyzing a gas mixture, it’s essential to interpret the given data accurately to determine properties like partial pressures, mole fractions, and potential chemical reactions. In this article, we will explore the scenario where a mixture contains 50.0% oxygen (O_2), 25% nitrogen (N_2), and 25% chlorine (Cl_2) by volume at a total pressure of 1.40 atm. We will examine how to analyze such a mixture, understand the significance of the given percentages, and address the implications for chemical reactions, safety considerations, and applications.

Understanding Gas Mixtures and Dalton’s Law of Partial Pressures

Dalton’s Law of Partial Pressures

Dalton’s Law states that in a mixture of non-reacting gases, the total pressure exerted is equal to the sum of the partial pressures of individual gases:

- $\mathbf{P_{total}} = P_{O_2} + P_{N_2} + P_{Cl_2}$

Each partial pressure can be calculated based on the mole fraction of the gas and the total pressure:

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

Where:

- **Xgas** = Mole fraction of the gas
- **Ptotal** = Total pressure of the mixture

Because volume percentages are given, and assuming ideal gas behavior, the volume percentages are equivalent to mole fractions at constant temperature and pressure, simplifying calculations.

Calculating Partial Pressures of Each Gas

Given the volume percentages:

- O_2: 50.0%
- N_2: 25.0%
- Cl_2: 25.0%

Since the gases are measured at the same temperature and pressure, their mole fractions are directly proportional to their volume percentages.

Therefore:

1. Mole fraction of O_2 (XO_2) = 0.50
2. Mole fraction of N_2 (XN_2) = 0.25
3. Mole fraction of Cl_2 (XCl_2) = 0.25

Using Dalton's Law:

- $PO_2 = 0.50 \times 1.40$ atm = 0.70 atm
- $PN_2 = 0.25 \times 1.40$ atm = 0.35 atm
- $PCl_2 = 0.25 \times 1.40$ atm = 0.35 atm

Summary of Partial Pressures:

Gas	Volume %	Mole Fraction	Partial Pressure (atm)
O_2	50.0%	0.50	0.70
N_2	25.0%	0.25	0.35
Cl_2	25.0%	0.25	0.35

Implications of Gas Composition

1. Chemical Reactivity and Safety Considerations

The presence of chlorine gas (Cl_2) in the mixture is significant due to its toxic and corrosive nature. Chlorine is a strong oxidizer and can react with organic compounds, moisture, or other gases under certain conditions.

- Reactivity with Organic Materials: Chlorine can produce hazardous compounds upon contact with organic materials.
- Health Risks: Breathing in chlorine gas can cause respiratory issues, eye irritation, and other health problems.
- Storage and Handling: Such mixtures require careful handling, appropriate ventilation, and safety

equipment.

Note: The mixture's composition suggests it is not suitable for inhalation without proper safety protocols.

2. Potential for Chemical Reactions

Given the mixture's composition, certain reactions may occur:

- Chlorine with Oxygen: Under high energy conditions (like UV light or heat), Cl_2 can react with O_2 to form various reactive species such as chlorates or other oxychlorides.
- Chlorine with Nitrogen: Typically, Cl_2 and N_2 do not react under normal conditions but can produce nitrogen trichloride (NCl_3) under specific conditions, which is highly explosive.
- Industrial Applications: Such mixtures could be used in processes like chlorination, oxychlorination, or other chemical synthesis, but only with controlled conditions.

Application of Gas Mixture Data in Industry

Understanding the composition and partial pressures of gases is crucial in various industrial contexts:

- **Respiratory Gas Mixtures:** Analyzing oxygen content for medical purposes or diving mixtures.
- **Chemical Manufacturing:** Designing reactors where precise gas ratios are required for optimal reactions.
- **Environmental Monitoring:** Assessing the presence of toxic gases like Cl_2 in the environment.
- **Safety Protocols:** Establishing safe thresholds for exposure based on partial pressures and concentrations.

Calculations Related to Moles and Volume

In chemistry, it’s often necessary to convert between volume, moles, and mass:

1. Calculating Moles of Each Gas

Using the ideal gas law:

$PV = nRT$

Where:

- P = partial pressure (atm)
- V = volume (L)
- n = number of moles
- R = ideal gas constant (0.0821 L·atm/(mol·K))
- T = temperature in Kelvin

Suppose the total volume of the mixture is known; for simplicity, assume V = 1 L.

- Moles of O_2:

$n_{O_2} = (P_{O_2} \times V) / (R \times T) = (0.70 \text{ atm} \times 1 \text{ L}) / (0.0821 \times T)$

- Similarly for N_2 and Cl_2.

This allows for precise calculations of molar quantities, which are important for stoichiometric calculations in reactions.

2. Mass of Each Gas in the Mixture

Once moles are known:

- Mass = moles × molar mass

Using approximate molar masses:

- O_2: 32 g/mol
- N_2: 28 g/mol
- Cl_2: 71 g/mol

Example:

- Mass of Cl_2 in 1 L volume at the given conditions:

$m_{Cl_2} = n_{Cl_2} \times 71$ g/mol

This information is vital for industrial applications where precise quantities of gases are needed.

Conclusion: Analyzing and Utilizing Gas Mixture Data

In conclusion, understanding a gas mixture with specified volume percentages and total pressure allows chemists and engineers to determine partial pressures, mole ratios, and potential reactions. The mixture containing 50.0% O_2, 25% N_2, and 25% Cl_2 at 1.40 atm exemplifies how gas law principles are applied in real-world scenarios. Proper safety measures are essential given the presence of chlorine gas, which poses health risks and can engage in hazardous reactions. Accurate calculations of partial pressures and molar quantities are fundamental for designing industrial processes, environmental assessments, and medical applications.

By mastering the analysis of such gas mixtures, professionals can optimize chemical reactions, ensure safety, and develop innovative solutions across various scientific and industrial fields.

Frequently Asked Questions

What is the partial pressure of O_2 in the mixture?

The partial pressure of O_2 is 50.0% of 1.40 atm, which is 0.50 × 1.40 = 0.70 atm.

How do you calculate the partial pressure of N_2 in the mixture?

The partial pressure of N_2 is 25% of 1.40 atm, so 0.25 × 1.40 = 0.35 atm.

What is the partial pressure of Cl_2 in the mixture?

The partial pressure of Cl_2 is 25% of 1.40 atm, which is 0.25 × 1.40 = 0.35 atm.

How can you determine the mole fraction of each gas in the mixture?

Since the volume percentages are given, the mole fraction of each gas equals its volume fraction: O_2 = 0.50, N_2 = 0.25, Cl_2 = 0.25.

What is the total pressure of the mixture, and how does it relate to Dalton's Law?

The total pressure is 1.40 atm, which equals the sum of the partial pressures of all gases, consistent with Dalton's Law.

If the gases behave ideally, how can we find the number of moles of each gas?

Using the ideal gas law (PV = nRT), the moles of each gas can be calculated as n = (P × V) / (R × T). Since volume and temperature are not specified, mole ratios are based on volume fractions.

What is the significance of knowing the partial pressures in this mixture?

Partial pressures help determine the individual gas behaviors, reaction tendencies, and are essential for calculating partial molar quantities and reaction rates.

How does the composition of this mixture affect its properties, such as reactivity or toxicity?

The high O_2 content makes the mixture potentially reactive and supporting combustion, while the presence of Cl_2 adds toxicity and reactivity, impacting safety and chemical processes.

Can this mixture be considered an ideal gas mixture? Why or why not?

Yes, assuming gases behave ideally under the given conditions, the mixture can be considered ideal since the gases are non-interacting and follow Dalton's Law.

Additional Resources

Understanding the Composition and Behavior of a Gas Mixture Containing O_2, N_2, and Cl_2 at 1.40 atm

Analyzing gas mixtures is fundamental in fields ranging from industrial chemistry to environmental science. When dealing with a mixture of oxygen (O_2), nitrogen (N_2), and chlorine (Cl_2), each component's proportion, behavior under pressure, and chemical interactions become essential for applications such as respiratory systems, chemical manufacturing, and environmental monitoring. This detailed review explores the key aspects of such a mixture, breaking down its composition, partial pressures, mole fractions, and potential chemical behaviors.

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1. Composition of the Gas Mixture

The mixture’s composition is specified by volume percentages at a given total pressure:

- O_2: 50.0%
- N_2: 25.0%
- Cl_2: 25.0%

This indicates that, by volume, half of the total mixture is oxygen, a quarter nitrogen, and a quarter chlorine gas.

Key Points:
- The percentages are given by volume, which, under ideal gas assumptions, are equivalent to mole fractions.
- The total pressure is 1.40 atm, which influences the partial pressures of each component.

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2. Fundamental Concepts in Gas Mixture Analysis

Before delving into calculations, it is vital to understand the foundational principles:

Mole Fraction and Volume Percentage

- In ideal gases, the volume ratio directly correlates with mole ratio because gases obey Avogadro's law.
- Therefore, the mole fraction X_i of each component equals its volume percentage expressed as a decimal.

Dalton’s Law of Partial Pressures

- The partial pressure of each gas component in a mixture is proportional to its mole fraction:

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

- Total pressure is the sum of partial pressures:

$$
P_{total} = P_{O_2} + P_{N_2} + P_{Cl_2}
$$

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3. Calculating Partial Pressures and Mole Fractions

Given the volume percentages and total pressure, the partial pressures of each component are:

Step 1: Convert volume percentages to mole fractions

$$
X_{O_2} = 0.50, \quad X_{N_2} = 0.25, \quad X_{Cl_2} = 0.25
$$

Step 2: Calculate partial pressures

$$
P_{O_2} = X_{O_2} \times P_{total} = 0.50 \times 1.40\, \text{atm} = 0.70\, \text{atm}
$$
$$
P_{N_2} = 0.25 \times 1.40\, \text{atm} = 0.35\, \text{atm}
$$
$$
P_{Cl_2} = 0.25 \times 1.40\, \text{atm} = 0.35\, \text{atm}
$$

Step 3: Determine the mole ratios

Using the ideal gas law, the number of moles of each gas (n_i) relates to their partial pressures:

$$
PV = nRT
$$

Assuming constant temperature and volume, the ratio of moles is proportional to the partial pressure:

$$
n_i \propto P_i
$$

Thus,

- Mole fraction $X_i = \frac{n_i}{n_{total}}$

which aligns with the volume percentages in ideal conditions.

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4. Chemical and Physical Properties of the Components

Understanding each component's properties is crucial for assessing reactivity, safety, and potential applications.

Oxygen (O_2)

- Physical State: Colorless, odorless, tasteless gas.
- Reactivity: Supports combustion; essential for respiration.
- Use Cases: Medical oxygen, industrial processes, combustion support.
- Safety Note: High concentrations can cause oxygen toxicity; supports rapid combustion.

Nitrogen (N_2)

- Physical State: Colorless, odorless, inert under most conditions.
- Reactivity: Chemically inert at room temperature; used as an inert atmosphere.
- Use Cases: Preservation, inerting, food packaging.
- Safety Note: Non-reactive, but can displace oxygen leading to asphyxiation in confined spaces.

Chlorine (Cl_2)

- Physical State: Greenish-yellow gas with a pungent odor.
- Reactivity: Highly reactive, toxic, and corrosive.

- Use Cases: Disinfectants, chemical manufacturing (e.g., PVC production).
- Safety Note: Toxic and corrosive; inhalation can cause severe respiratory issues. Handling requires strict safety protocols.

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5. Potential Chemical Interactions and Safety Considerations

While O_2 and N_2 are relatively inert, Cl_2 is reactive and can form various compounds depending on the environment.

Chemical Reactions and Risks:

- Chlorine’s Reactivity: Cl_2 can react with organic compounds and metals, forming chlorinated products.
- Oxidation Reactions: In the presence of oxygen, certain reactions could produce reactive chlorine oxides, especially under UV light or heat.
- Disinfection and Sterilization: Cl_2's strong oxidizing property makes it effective for killing bacteria and viruses but poses health risks if inhaled.

Safety Concerns:

- Toxicity of Cl_2: Proper ventilation and protective equipment are essential.
- Asphyxiation risk: High oxygen concentration supports combustion, but in combination with Cl_2, risks of toxic exposure increase.
- Environmental Impact: Leakage can contaminate water sources, forming hydrochloric acid or other chlorinated compounds.

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6. Practical Applications of the Gas Mixture

Understanding this mixture's composition provides insights into its potential applications:

- Industrial Processes: Such mixtures may be used in chemical manufacturing, especially in processes involving oxidation or chlorination.
- Medical and Laboratory Use: Controlled oxygen and nitrogen blends are used in respiration therapy or as inert atmospheres, but Cl_2 is typically avoided due to toxicity.
- Environmental Monitoring: The presence of Cl_2 requires careful handling due to its toxicity and environmental impact.

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7. Environmental and Health Perspectives

The mixture's composition raises important environmental and health considerations:

- Possible Exposure: Handling or accidental leaks can expose workers or the environment to toxic chlorine gas.
- Disposal Measures: Gas mixtures containing Cl_2 should be neutralized or safely vented under controlled conditions.
- Regulatory Standards: Occupational safety guidelines specify permissible exposure limits for Cl_2 and oxygen-rich environments.

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8. Summary and Final Thoughts

This detailed overview underscores the importance of understanding gas mixture composition, behavior, and safety implications.

- Composition: The mixture contains 50% O_2, 25% N_2, and 25% Cl_2 by volume, with partial pressures directly proportional to their volume fractions at 1.40 atm.
- Chemical Behavior: O_2 supports combustion, N_2 is inert, and Cl_2 is a highly reactive toxin.
- Applications: The mixture could be utilized in industrial processes, provided safety and environmental precautions are strictly observed.
- Safety: Handling such a mixture necessitates rigorous safety protocols due to chlorine's toxicity and the fire-supporting nature of oxygen.

In conclusion, a thorough understanding of each component’s properties, partial pressures, and potential reactions ensures safe and effective use of this gas mixture across various scientific and industrial applications. Proper storage, handling, and disposal are paramount to mitigate health and environmental risks associated with chlorine gas, especially when mixed with oxygen and nitrogen under pressure.

Note: Always adhere to local regulations and safety guidelines when working with or manipulating gas mixtures, especially those containing toxic and reactive gases like chlorine.

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