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Understanding how gases dissolve in liquids is fundamental in fields such as chemistry, environmental science, and engineering. When dealing with gases like helium in water, Henry's Law provides a crucial relationship between the solubility of the gas and the partial pressure exerted by the gas above the liquid. This article explores the calculation of the mass of helium gas dissolved in water at a specific temperature, given Henry's Law constant, and provides a comprehensive explanation of the concepts involved.

Introduction to Henry's Law and Its Significance

Henry's Law states that the amount of a gas that dissolves in a liquid at a constant temperature is directly proportional to the partial pressure of the gas above the liquid. Mathematically, it is expressed as:

$$ C = k_H \times P $$

where:
- C = concentration of the gas in the liquid (mol/L)
- k_H = Henry's Law constant (mol/(L·atm))
- P = partial pressure of the gas (atm)

This relationship is vital for:
- Designing gas-liquid systems such as scuba diving equipment, gas exchange in biological systems, and industrial processes.
- Predicting how gases behave under different pressure conditions.
- Environmental modeling, such as understanding the dissolution of atmospheric gases in bodies of water.

Understanding the Parameters in the Problem

In the given scenario:
- Temperature (T) = 25.0°C
- Henry's Law constant for helium in water (k_H) = 3.7 × 10^{-4} M/atm

Note on Henry's Law Constant Units:
- The value provided (3.7×10^{-4} M/atm) indicates that at 1 atm partial pressure, the molar concentration of helium in water is 3.7×10^{-4} mol/L.

Calculating the Mass of Helium Dissolved in Water

The goal is to determine the mass of helium gas dissolved in a certain volume of water at a specified pressure. To do this, follow these steps:

Step 1: Determine the molar concentration of helium in water

Using Henry's Law:

$$C = k_H \times P$$

where P is the partial pressure of helium in atm.

Step 2: Convert molar concentration to moles

Once the molar concentration (C) is known, multiply by the volume of water to find the total moles of helium dissolved:

$$\text{Moles of He} = C \times V$$

where:
- V = volume of water in liters (L)

Step 3: Convert moles to mass

Using the molar mass of helium:

$$M_{He} = 4.00 \, \text{g/mol}$$

calculate the mass:

$$\text{Mass} = \text{Moles} \times M_{He}$$

Practical Example: Calculating Helium Mass in Water

Suppose we want to find the mass of helium dissolved in 1 liter of water at a partial pressure of helium of 1 atm.

Given:
- $P = 1 \, \text{atm}$
- $V = 1 \, \text{L}$
- $k_H = 3.7 \times 10^{-4} \, \text{mol/(L·atm)}$
- $M_{He} = 4.00 \, \text{g/mol}$

Calculation:

1. Molar concentration:

$$C = 3.7 \times 10^{-4} \, \text{mol/(L·atm)} \times 1 \, \text{atm} = 3.7 \times 10^{-4} \, \text{mol/L}$$

2. Total moles in 1 L:

$$\text{Moles} = 3.7 \times 10^{-4} \, \text{mol}$$

3. Mass of helium:

$$\text{Mass} = 3.7 \times 10^{-4} \, \text{mol} \times 4.00 \, \text{g/mol} = 1.48 \times 10^{-3} \, \text{g}$$

Result: Approximately 1.48 milligrams of helium is dissolved in 1 liter of water at 1 atm partial pressure.

Factors Influencing Helium Solubility

While Henry's Law provides a basis for calculating gas solubility, several factors can influence the actual amount dissolved:

- **Temperature:** Solubility of gases generally decreases with increasing temperature.
- **Pressure:** Higher partial pressures increase the amount of gas dissolved.
- **Salinity:** Salt presence can reduce gas solubility (salting-out effect).
- **Nature of the gas and solvent:** Molecular interactions affect solubility

levels.

Understanding these factors is essential for accurate modeling in real-world applications.

Applications of Helium Solubility Calculations

Calculating the mass of helium dissolved in water has numerous practical applications:

Environmental Science and Marine Biology

- Predicting how helium and other inert gases behave in aquatic environments.
- Monitoring gas exchange processes in lakes and oceans.

Industrial Processes

- Designing systems for helium extraction or removal.
- Managing gas solubility in cooling systems or chemical reactors.

Medical and Research Fields

- Developing inhalation therapies involving helium.
- Conducting experiments involving gas solubility and diffusion.

Engineering and Safety

- Ensuring safe handling of helium in pressurized systems.
- Calculating gas release or absorption rates in various engineering designs.

Conclusion: The Importance of Accurate Gas Solubility Calculations

In conclusion, understanding how to calculate the mass of helium gas dissolved in water based on Henry's Law constant is vital across multiple disciplines. By knowing the Henry's Law constant at a specific temperature, scientists and engineers can predict solubility, design efficient systems, and analyze environmental processes. The example provided demonstrates a straightforward approach to such calculations, emphasizing the importance of knowing the parameters and applying fundamental chemical principles. As gas-liquid interactions continue to be relevant in technological and scientific advancements, mastering these calculations remains essential for accurate modeling and safe practices.

Key Takeaways

- Henry's Law relates gas solubility to partial pressure and temperature.
- The Henry's Law constant must be used with the correct units for accurate calculations.
- Calculating the mass involves converting molar concentration to total moles and then to grams.
- Environmental and industrial applications rely heavily on understanding gas solubility principles.

If you want to explore more about gas solubility, Henry’s Law applications, or related chemical calculations, numerous resources and scientific literature are available to deepen your understanding.

Meta Description:
Learn how to calculate the mass of helium dissolved in water at 25°C using Henry's Law constant 3.7×10^{-4} M/atm. Detailed explanation and practical examples included.

Frequently Asked Questions

What is Henry's Law constant for helium in water at 25.0°C?

The Henry's Law constant for helium at 25.0°C is 3.7×10^{-4} M/atm.

How do you calculate the mass of helium dissolved in

water using Henry's Law?

You first determine the molarity (concentration in mol/L) using Henry's Law, then multiply by the molar mass of helium and the volume of water to find the mass.

What additional information is needed to calculate the mass of helium in water?

You need the partial pressure of helium over the water and the volume of water to perform the calculation.

How is Henry's Law constant expressed and what does it signify?

Henry's Law constant is expressed in mol/(L·atm) or M/atm, indicating how much gas dissolves in water per unit pressure at a given temperature.

Can the Henry's Law constant for helium change with temperature?

Yes, Henry's Law constant varies with temperature; typically, solubility decreases as temperature increases.

What is the molar mass of helium used in these calculations?

The molar mass of helium is approximately 4.00 g/mol.

If the partial pressure of helium in a container is 2 atm, what is the concentration of helium in water at 25°C?

Using Henry's Law, concentration = (Henry's Law constant) × pressure = 3.7×10^{-4} M/atm × 2 atm = 7.4×10^{-4} M.

Additional Resources

Henry's Law Constant for Helium in Water: An In-Depth Analysis and Calculation

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Introduction: Understanding the Significance of Henry’s Law Constant

Henry’s Law is a fundamental principle in chemistry that describes how gases dissolve in liquids. It states that at a constant temperature, the amount of a gas that dissolves in a liquid is directly proportional to the partial pressure of that gas above the liquid. This relationship is mathematically expressed by Henry's Law:

$$C = k_H \times P$$

where:
- C is the concentration of the gas in the liquid (mol/L),
- k_H is the Henry's Law constant (mol/(L·atm)),
- P is the partial pressure of the gas (atm).

In real-world applications, understanding and calculating the mass of a gas dissolved in a liquid under specific conditions is crucial across fields like environmental science, chemical engineering, and even medicine.

In this article, we focus on helium (He) and its solubility in water at 25.0°C, with a given Henry's Law constant of $3.7 \times 10^{-4} \, \text{M/atm}$. Our goal is to compute the mass of helium gas that would dissolve in a specified volume of water under a given pressure.

The Henry's Law Constant for Helium: An Overview

What does the value $3.7 \times 10^{-4} \, \text{M/atm}$ signify?

This Henry's Law constant indicates that at 25.0°C, for each atmosphere of partial pressure of helium above water, approximately 3.7×10^{-4} mol of helium dissolves per liter of water.

- Units Explained: M (molarity) is mol/L, so the constant relates partial pressure (P) in atm to molar concentration (C) in mol/L.
- Implication: Helium has relatively low solubility in water, consistent with its inertness and small atomic size.

Step-by-Step Calculation: From Concentration to Mass

To determine the actual mass of helium gas dissolved, we need to follow a structured process:

1. Define the parameters:
- Volume of water (V)
- Partial pressure of helium (P)
- Temperature ($T = 25.0^\circ C$)
- Henry's Law constant ($k_H = 3.7 \times 10^{-4} \text{ mol/(L·atm)}$)

2. Calculate the molar concentration (C):

Using Henry’s Law:

$$ C = k_H \times P $$

3. Determine the total moles of helium in the water:

$$ n = C \times V $$

where V is in liters.

4. Convert moles to mass:

Using the molar mass of helium ($M_{He} = 4.0026 \, \text{g/mol}$):

$$ \text{Mass} = n \times M_{He} $$

Practical Scenario: Example Calculation

Suppose we have a scenario where:
- Volume of water: 1 liter
- Partial pressure of helium: 1 atm

Let's perform the calculation step-by-step.

Step 1: Calculate molar concentration:

$$
C = 3.7 \times 10^{-4} \, \text{mol/(L·atm)} \times 1\, \text{atm} = 3.7 \times 10^{-4} \, \text{mol/L}
$$

Step 2: Total moles in 1 liter:

$$
n = 3.7 \times 10^{-4} \, \text{mol}
$$

Step 3: Convert to mass:

$$
\text{Mass} = 3.7 \times 10^{-4} \, \text{mol} \times 4.0026 \, \text{g/mol} \approx 1.481 \times 10^{-3} \, \text{g}
$$

Result: Approximately 1.48 milligrams of helium gas dissolves in 1 liter of water at 25°C and 1 atm partial pressure.

Exploring Different Conditions

The calculation scales linearly with pressure and volume. For example:

- Doubling the pressure to 2 atm doubles the dissolved mass.
- Increasing the water volume proportionally increases the total helium mass.

Table: Helium Dissolution at Various Pressures

Pressure (atm)	Moles of He in 1L	Mass of He (g)
0.5	1.85×10^{-4}	7.4×10^{-4}
1.0	3.7×10^{-4}	1.48×10^{-3}
2.0	7.4×10^{-4}	2.96×10^{-3}
5.0	1.85×10^{-3}	7.41×10^{-3}

This table demonstrates how sensitive helium's solubility is to pressure changes at constant temperature.

Factors Influencing Helium Solubility

While Henry’s Law provides a straightforward relationship, real-world scenarios can be affected by various factors:

- Temperature: Henry’s Law constant varies with temperature. Typically, solubility decreases as temperature increases.
- Water Purity: Impurities can alter gas solubility.
- Salinity: Saltwater generally decreases gas solubility relative to freshwater.
- Gas Partial Pressure: Higher partial pressures increase the amount dissolved, up to saturation limits.

Understanding these factors is essential for accurate predictions in practical applications like scuba diving, gas extraction, or environmental monitoring.

Applications and Significance

1. Medical Applications

Helium is used in medical treatments, such as in respiratory therapies, where precise knowledge of its solubility ensures safety and effectiveness.

2. Environmental Science

Helium's low solubility impacts its behavior in aquatic environments, influencing models of gas exchange and water quality assessments.

3. Industrial Processes

In industries utilizing helium, such as cryogenics or leak detection, understanding its solubility in water assists in designing efficient systems.

Conclusion: The Importance of Accurate Calculations

The ability to accurately determine the mass of helium dissolved in water under specific conditions hinges on understanding Henry's Law and applying it correctly. Our detailed calculation illustrates that at 25.0°C and 1 atm partial pressure, approximately 1.48 milligrams of helium dissolves in a liter of water.

This calculation not only emphasizes the importance of the Henry's Law constant but also highlights how fundamental principles of chemistry underpin practical applications across various fields. Whether for environmental modeling, industrial design, or medical applications, mastering these calculations ensures precision and informed decision-making.

Final Thoughts

Henry's Law remains a cornerstone in the study of gas-liquid interactions. By grasping its principles and applying precise calculations, scientists and engineers can predict gas behavior in complex systems, ensuring safety, efficiency, and environmental responsibility. The specific case of helium in water exemplifies how a seemingly simple constant can unlock a wealth of understanding about gas solubility at the molecular level, reinforcing the interconnectedness of chemical theory and real-world application.

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