The Solubility Of A Gas Is 0.584 G/L At A Pressure Of 109 KPa. What Is The Solubility Of The Gas If The

The Solubility Of A Gas Is 0.584 G/L At A Pressure Of 109 KPa. What Is The Solubility Of The Gas If The question prompts a fundamental exploration into the relationship between gas solubility and pressure. Understanding how gases dissolve in liquids under varying pressures is essential in fields ranging from chemistry and environmental science to industrial processes and engineering. This article delves into the principles governing gas solubility, particularly focusing on Henry's Law, methods to calculate solubility changes with pressure variations, and real-world applications. Whether you're a student, researcher, or industry professional, grasping these concepts enhances your ability to predict and manipulate gas-liquid interactions effectively.

Understanding Gas Solubility and Henry's Law

What Is Gas Solubility?

Gas solubility refers to the maximum amount of a specific gas that can dissolve in a liquid at a given temperature and pressure. It is usually expressed in units such as grams per liter (g/L), molarity, or molality. Solubility is influenced by various factors including temperature, pressure, and the nature of both the gas and the solvent.

Henry's Law: The Foundation of Gas Solubility

Henry's Law is a fundamental principle describing how gas solubility in liquids depends on pressure. It states that:

The amount of a gas that dissolves in a liquid is directly proportional to the partial pressure of that gas above the liquid at constant temperature.

Mathematically, Henry's Law is expressed as:

$$ C = k_H \times P $$

Where:
- C = solubility of the gas (e.g., g/L)
- k_H = Henry's law constant (depends on the gas, solvent, and temperature)
- P = partial pressure of the gas (e.g., in KPa or atm)

This linear relationship implies that increasing the pressure increases the solubility, and vice versa, assuming temperature remains constant.

Calculating Gas Solubility at Different Pressures

The Basic Formula

Given the initial solubility at a known pressure, you can determine the solubility at a new pressure using Henry's Law:

$$ \frac{C_1}{P_1} = \frac{C_2}{P_2} $$

Where:
- C_1 = initial solubility
- P_1 = initial pressure
- C_2 = new solubility
- P_2 = new pressure

Rearranged to find the new solubility:

$$C_2 = C_1 \times \frac{P_2}{P_1}$$

Applying the Formula: An Example

Suppose a gas has:
- Solubility $C_1 = 0.584\, \text{g/L}$
- At pressure $P_1 = 109\, \text{kPa}$

If the pressure changes to $P_2 = 150\, \text{kPa}$, the new solubility C_2 can be calculated as:

$$C_2 = 0.584\, \text{g/L} \times \frac{150\, \text{kPa}}{109\, \text{kPa}} \approx 0.584 \times 1.376 \approx 0.804\, \text{g/L}$$

This calculation demonstrates how solubility increases with pressure, following Henry's Law.

Factors Affecting Gas Solubility Beyond Pressure

While pressure is a significant factor, other elements influence how gases dissolve:

Temperature

- Increasing temperature generally decreases gas solubility.
- Gas molecules gain kinetic energy, making it easier for them to escape from the liquid.

Nature of the Gas and Solvent

- Polar gases tend to be more soluble in polar solvents.
- Non-polar gases are more soluble in non-polar solvents.

Presence of Other Substances

- Salts and other solutes can either increase or decrease gas solubility (salting out/in effect).

Real-World Applications of Gas Solubility Principles

Understanding gas solubility and its dependence on pressure has numerous practical applications:

1. Carbonation in Beverages

- The amount of CO_2 dissolved in soft drinks depends on pressure.
- Bottling under high pressure ensures adequate carbonation; releasing pressure causes bubbles to form.

2. Aquatic Life and Oxygen Levels

- Oxygen solubility in water affects aquatic ecosystems.
- Scientists manipulate pressure and temperature to maintain optimal oxygen levels for marine life.

3. Industrial Gas Absorption

- Industries use pressure-based methods to capture and purify gases.
- These processes rely on precise calculations based on Henry's Law.

4. Environmental Monitoring

- Understanding how pollutants dissolve in water under varying pressures helps in assessing environmental impacts.

Limitations and Considerations

While Henry's Law provides a reliable model for ideal solutions and low concentrations, several factors can cause deviations:

- Non-ideality: At high pressures or concentrations, interactions between molecules may invalidate linear relationships.
- Temperature Variations: Changes in temperature alter Henry's law constant, affecting solubility calculations.
- Chemical Reactions: Some gases react with the solvent, complicating the solubility behavior.

Summary and Key Takeaways

- The solubility of a gas is directly proportional to its partial pressure above the liquid, as described by Henry's Law.
- Given initial solubility and pressure, you can determine the solubility at a new pressure using a simple proportional calculation.
- Factors such as temperature, gas and solvent properties, and chemical interactions influence gas solubility.
- Practical applications of gas solubility principles are widespread, impacting industries and environmental science.
- Always consider potential deviations from ideal behavior when applying Henry's Law in real-world situations.

Final Thoughts

Understanding the relationship between gas solubility and pressure is essential for scientists, engineers, and industry professionals. Whether designing carbonated beverages, managing aquatic ecosystems, or developing industrial gas processes, applying Henry's Law enables accurate predictions and efficient control of gas-liquid systems. As you explore further, remember that while Henry's Law provides a foundational model, real-world conditions may require adjustments and considerations for accurate results.

By mastering these concepts, you can optimize processes, improve environmental management, and deepen your comprehension of the dynamic interactions between gases and liquids across various scientific and industrial domains.

Frequently Asked Questions

What is the solubility of the gas at a pressure of 109 kPa?

The solubility of the gas at 109 kPa is 0.584 g/L.

How does increasing pressure affect the solubility of a gas?

According to Henry's law, increasing pressure generally increases the solubility of a gas in a liquid.

If the pressure changes from 109 kPa to 200 kPa, what is the new solubility assuming linear behavior?

Assuming Henry's law applies, the new solubility would be (200 kPa / 109 kPa) × 0.584 g/L ≈ 1.07 g/L.

What assumptions are made when applying Henry's law to this problem?

The assumptions include that the temperature remains constant and that the gas-solvent system behaves ideally with a linear relationship between pressure and solubility.

Why is understanding gas solubility important in industrial applications?

Understanding gas solubility helps in designing processes like carbonation in beverages, gas absorption in chemical manufacturing, and controlling emissions, ensuring safety and efficiency.

Additional Resources

The Solubility Of A Gas Is 0.584 G/L At A Pressure Of 109 KPa. What Is The Solubility Of The Gas If The pressure changes? This question taps into fundamental principles of gas solubility and Henry's Law, offering a window into how gases behave under different conditions. Understanding how solubility varies with pressure is crucial in numerous scientific and industrial applications—from designing efficient carbonated beverages to predicting gas exchange in biological systems and environmental modeling. In this comprehensive guide, we will explore the concepts behind gas solubility, delve into Henry's Law, and provide a step-by-step approach to determine the new solubility of a gas when the pressure changes.

Understanding Gas Solubility and Henry's Law

What Is Gas Solubility?

Gas solubility refers to the maximum amount of a gas that can dissolve in a liquid at a specific temperature and pressure, typically expressed in units like grams per liter (g/L) or molarity. It is influenced by various factors, including temperature, pressure, and the nature of both the gas and the solvent.

The Role of Pressure in Gas Solubility

One of the key factors affecting gas solubility is pressure. Generally, as pressure increases, the solubility of a gas in a liquid also increases, assuming constant temperature. This relationship is well described by Henry's Law.

Henry's Law: The Foundation for Gas Solubility Calculations

Henry's Law 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. Mathematically, it can be expressed as:

$C = k_P P$

Where:
- C = solubility of the gas (e.g., g/L)
- k_P = Henry's Law constant (depends on the gas, solvent, and temperature)
- P = partial pressure of the gas (e.g., kPa)

This relationship implies that if the pressure doubles, the solubility doubles (assuming the temperature remains constant), and so on.

Key Assumptions of Henry's Law
- The system is at equilibrium.
- Temperature remains constant.
- The gas behaves ideally.
- The solubility is low enough that interactions between dissolved gas molecules are negligible.

Applying Henry's Law to the Given Data

Given Data:
- Initial solubility, $C_1 = 0.584$ g/L
- Initial pressure, $P_1 = 109$ kPa
- Final pressure, $P_2 = ?$ (to be determined)

Goal:
- Find the new solubility C_2 when the pressure changes from P_1 to P_2.

Step 1: Determine Henry's Law constant (k_P)

Since Henry's Law states:

$C_1 / P_1 = C_2 / P_2 = k_P$

At the initial pressure and solubility:

$k_P = C_1 / P_1 = 0.584$ g/L / 109 kPa ≈ 0.00536 g/(L·kPa)

This constant remains the same regardless of pressure, assuming temperature remains unchanged.

Calculating Solubility at a New Pressure

Scenario: The pressure increases to, say, 200 kPa

Suppose we want to find the solubility of the gas at $P_2 = 200$ kPa.

Using the proportionality:

$C_2 = k_P P_2$

Plugging in the values:

$C_2 = 0.00536$ g/(L·kPa) 200 kPa ≈ 1.072 g/L

Interpretation:
The solubility roughly doubles when the pressure nearly doubles, aligning with Henry's Law's linearity.

General Formula for Solubility at Any Pressure

Putting it all together, the general formula becomes:

$C_2 = (C_1 / P_1) P_2$

Or, explicitly:

$C_2 = C_1 (P_2 / P_1)$

This simple ratio allows you to compute the new solubility at any given pressure, provided the temperature remains constant and Henry's Law applies.

Practical Examples and Applications

Example 1: Decreasing Pressure

Suppose the pressure drops to 50 kPa. The solubility:

$C_2 = 0.584$ g/L (50 kPa / 109 kPa) ≈ 0.268 g/L

This indicates that lowering the pressure reduces the gas's solubility proportionally.

Example 2: Increasing Pressure

For a pressure of 300 kPa:

$C_2 = 0.584$ g/L (300 kPa / 109 kPa) ≈ 1.605 g/L

Higher pressure increases solubility, which is essential in processes like carbonated beverage production.

Limitations and Considerations

While Henry's Law provides a straightforward method to relate pressure and solubility, there are important caveats:

- Temperature Dependence: Henry's constant varies with temperature; the calculations assume constant temperature.
- Non-Ideal Behavior: At very high pressures or with gases that interact strongly with the solvent, deviations occur.
- Gas and Liquid Interaction: Some gases may react chemically with the solvent, invalidating Henry's Law assumptions.

Summary and Key Takeaways

- Henry's Law establishes a direct proportionality between a gas's solubility and its partial pressure.
- The proportionality constant, k_P, can be calculated from initial conditions and used to find solubility at different pressures.

- The formula for solubility at a new pressure:

$C_2 = C_1 (P_2 / P_1)$

- Changes in pressure significantly influence gas solubility, with higher pressures increasing solubility.
- Always verify the assumptions, especially temperature consistency and ideality, when applying Henry's Law.

Final Thoughts

Understanding how the solubility of a gas varies with pressure is vital in fields such as chemical engineering, environmental science, and food technology. By mastering the application of Henry's Law, you can predict and manipulate gas-liquid interactions effectively, leading to optimized processes and innovative solutions. Whether you're designing a soda carbonation system or modeling atmospheric gas exchange, grasping these principles provides a solid foundation for tackling real-world challenges involving gas solubility.

Remember: Always consider the context and limitations of Henry's Law, and ensure that the assumptions hold true for your specific scenario.

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