An Aqueous Solution Has A Hydrogen Ion Contamination Of 1.15x10^−2M (1)What Is The Hydroxide Ion Concentration

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Understanding the relationship between hydrogen ion (H^+) concentration and hydroxide ion (OH^-) concentration in aqueous solutions is fundamental in chemistry, especially in the context of acids, bases, and pH calculations. In this article, we will explore how to determine the hydroxide ion concentration when given the hydrogen ion concentration, using principles rooted in the ion product constant of water (Kw). We will delve into the concepts of pH, pOH, and the equilibrium of water autoionization, providing an in-depth explanation suitable for students, educators, and chemistry enthusiasts alike.

Understanding Aqueous Solutions and Ion Concentrations

What Are Aqueous Solutions?

An aqueous solution is a solution where water (H_2O) acts as the solvent. These solutions are ubiquitous in chemistry because water is a universal solvent, capable of dissolving many substances, including salts, acids, and bases. The behavior of ions in aqueous solutions is vital for understanding phenomena such as acidity, alkalinity, and chemical reactivity.

Hydrogen Ions and Hydroxide Ions in Water

In pure water and aqueous solutions, water molecules undergo a process called autoionization:

$$\text{H}_2\text{O} \leftrightarrow \text{H}^+ + \text{OH}^-$$

This equilibrium results in a small but significant concentration of hydrogen ions (H^+) and hydroxide ions (OH^-) in water, both typically around 10^{-7} M at 25°C.

Given Data: Hydrogen Ion Concentration

The problem states:

> An aqueous solution has a hydrogen ion contamination of 1.15×10^{-2} M.

This indicates that the H^+ concentration in the solution is $[\text{H}^+] = 1.15 \times 10^{-2} \, \text{M}$.

What does this tell us?
- The solution is acidic because the H^+ concentration is higher than the neutral value of 1×10^{-7} M.
- To find the hydroxide ion concentration, we need to understand the relationship governed by Kw.

The Ion Product of Water (Kw) and Its Significance

Definition of Kw

At 25°C, the ion product constant of water (Kw) is:

$$K_w = [\text{H}^+][\text{OH}^-] = 1.0 \times 10^{-14}$$

This constant reflects the equilibrium between water molecules dissociating into H^+ and OH^- ions.

Implication for pH and pOH

- pH is defined as:

$$\text{pH} = -\log [\text{H}^+]$$

- pOH is:

$$\text{pOH} = -\log [\text{OH}^-]$$

- The relationship between pH and pOH is:

$$\text{pH} + \text{pOH} = 14$$

Calculating the Hydroxide Ion Concentration

Given $[\text{H}^+] = 1.15 \times 10^{-2} \, \text{M}$, we can determine $[\text{OH}^-]$ using the Kw relationship:

$$[\text{OH}^-] = \frac{K_w}{[\text{H}^+]}$$

Substituting the known values:

$$[\text{OH}^-] = \frac{1.0 \times 10^{-14}}{1.15 \times 10^{-2}}$$

Calculating this:

$$ [\text{OH}^-] = \frac{1.0 \times 10^{-14}}{1.15 \times 10^{-2}} \approx 8.70 \times 10^{-13} \, \text{M} $$

This extremely low hydroxide ion concentration confirms the solution's acidity.

Step-by-Step Calculation Summary

1. Identify the hydrogen ion concentration: $ [\text{H}^+] = 1.15 \times 10^{-2} \, \text{M} $.
2. Recall Kw at 25°C: $ 1.0 \times 10^{-14} $.
3. Calculate hydroxide ion concentration:

$$ [\text{OH}^-] = \frac{1.0 \times 10^{-14}}{1.15 \times 10^{-2}} \approx 8.70 \times 10^{-13} \, \text{M} $$

Understanding pH and pOH in This Context

Calculating pH

Using the definition:

$$ \text{pH} = -\log [\text{H}^+] $$

$$ \text{pH} = -\log (1.15 \times 10^{-2}) $$

$$ \text{pH} \approx -(\log 1.15 + \log 10^{-2}) $$

$$ \text{pH} \approx -(0.0607 - 2) = 1.939 $$

This indicates a strongly acidic solution.

Calculating pOH

Using the relation:

$$ \text{pOH} = 14 - \text{pH} = 14 - 1.939 \approx 12.061 $$

Alternatively:

$$ \text{pOH} = -\log [\text{OH}^-] $$

$$ \text{pOH} = -\log (8.70 \times 10^{-13}) $$

$$ \text{pOH} \approx 12.06 $$

This confirms the hydroxide ion concentration's consistency with the pOH.

Key Points for Chemistry Students and Enthusiasts

- The relationship between H^+ and OH^- concentrations in water is inversely proportional, governed by Kw.
- Acidic solutions have high H^+ concentrations and correspondingly low OH^- concentrations.
- The pH scale provides an intuitive measure of acidity; values below 7 indicate acidity, above 7 indicate alkalinity.
- Precise calculations of ion concentrations are crucial in various applications, including titrations, buffer solutions, and biochemical processes.

Practical Applications and Implications

In Laboratory Settings

Knowing how to calculate hydroxide ion concentration from hydrogen ion contamination helps chemists:
- Determine the acidity or alkalinity of a solution.
- Prepare solutions with desired pH levels.
- Understand the behavior of acids and bases in reactions.

In Industry and Environmental Science

Accurate ion concentration measurements are vital for:
- Water treatment processes.
- Monitoring environmental water quality.
- Designing pharmaceuticals and biochemical solutions.

In Educational Contexts

Students learning about acids and bases can reinforce their understanding of equilibrium principles and the pH scale through such calculations.

Summary

- The given hydrogen ion concentration in the aqueous solution is $1.15 \times 10^{-2} \, \text{M}$.
- Using the water ion product constant $K_w = 1.0 \times 10^{-14}$, the hydroxide ion concentration is approximately $8.70 \times 10^{-13} \, \text{M}$.
- The solution is highly acidic, with a pH of approximately 1.94.
- Understanding these calculations enhances comprehension of acid-base chemistry and solution behavior.

Conclusion

Determining the hydroxide ion concentration from hydrogen ion contamination is straightforward once the fundamental principles of water autoionization and the ion product constant are understood. Such calculations are essential in various scientific and industrial applications, emphasizing the importance of mastering pH and ion concentration concepts. Whether you're a student, researcher, or industry professional, knowing how to navigate these calculations enables accurate analysis and effective solution design in aqueous chemistry.

Keywords: aqueous solution, hydrogen ion concentration, hydroxide ion concentration, pH, pOH, Kw, acid-base chemistry, water autoionization, solution chemistry, ion concentrations, pH calculation

Frequently Asked Questions

What is the given hydrogen ion concentration in the aqueous solution?

The hydrogen ion concentration is 1.15 x 10^−2 M.

How do you calculate the pH of the solution from the hydrogen ion concentration?

pH = −log[H^+], so pH = −log(1.15 x 10^−2) ≈ 1.94.

What is the relationship between hydrogen ion concentration and hydroxide ion concentration in water?

They are related through the ion product of water: [H^+][OH^-] = 1.0 x 10^−14 at 25°C.

How do you determine the hydroxide ion concentration from the hydrogen ion concentration?

Use the relation [OH^-] = (1.0 x 10^−14) / [H^+].

What is the calculated hydroxide ion concentration in this solution?

[OH^-] = (1.0 x 10^−14) / (1.15 x 10^−2) ≈ 8.70 x 10^−13 M.

Is the solution acidic, basic, or neutral based on the hydrogen ion concentration?

Since [H^+] = 1.15 x 10^-2 M (> 1 x 10^-7 M), the solution is acidic.

Why is it important to know the hydroxide ion concentration in aqueous solutions?

It helps determine the solution's pH, alkalinity, and overall chemical behavior, which are crucial in many applications and reactions.

What assumptions are made in calculating the hydroxide ion concentration from hydrogen ion concentration?

The calculation assumes the temperature is 25°C and that the water ion product (Kw) is 1.0 x 10^-14, with the solution being dilute and at equilibrium.

Additional Resources

An aqueous solution has a hydrogen ion contamination of 1.15×10^{-2} M — what is the hydroxide ion concentration? This question lies at the core of understanding acid–base chemistry and the fundamental principles of pH and pOH in aqueous solutions. Determining the hydroxide ion concentration from the given hydrogen ion concentration (or [H^+]) is a common task in chemistry, especially when analyzing the acidity or basicity of a solution. In this guide, we will explore the principles behind this calculation, walk through the step-by-step process, and discuss related concepts that deepen your understanding of aqueous equilibria.

Understanding the Basics: Hydrogen Ions, Hydroxide Ions, and Water’s Autoionization

Before diving into calculations, it’s essential to grasp the underlying chemistry.

The Autoionization of Water

Pure water undergoes a small degree of autoionization:

$$ \text{H}_2\text{O} \rightleftharpoons \text{H}^+ + \text{OH}^- $$

This equilibrium is characterized by the ion product constant for water (K_w):

$$ K_w = [\text{H}^+][\text{OH}^-] $$

At standard laboratory temperature (25°C),

$$ K_w = 1.0 \times 10^{-14} $$

This value is crucial because it links the concentrations of hydrogen and

hydroxide ions in any aqueous solution at equilibrium.

pH and pOH: The Logarithmic Measures

The acidity or basicity of a solution is often expressed in terms of pH and pOH:

- pH is defined as:

$$\text{pH} = -\log [\text{H}^+]$$

- pOH is:

$$\text{pOH} = -\log [\text{OH}^-]$$

And these are related by:

$$\text{pH} + \text{pOH} = 14 \quad \text{(at 25°C)}$$

Step-by-Step Calculation: From Hydrogen Ion Concentration to Hydroxide Ion Concentration

Given:

$$[\text{H}^+] = 1.15 \times 10^{-2} \, \text{M}$$

Our goal:

$$[\text{OH}^-] = ?$$

Step 1: Calculate pH

Applying the definition:

$$\text{pH} = -\log [\text{H}^+]$$

$$\text{pH} = -\log (1.15 \times 10^{-2})$$

Using logarithm properties:

$$\text{pH} = -[\log 1.15 + \log 10^{-2}]$$

$$\text{pH} = -[\log 1.15 - 2]$$

Calculating:

$$\log 1.15 \approx 0.0607$$

So:

$$\text{pH} = -[0.0607 - 2] = -(-1.9393) = 1.9393$$

Step 2: Find pOH

Since:

$$\text{pH} + \text{pOH} = 14$$

$$ \text{pOH} = 14 - \text{pH} $$

$$ \text{pOH} = 14 - 1.9393 = 12.0607 $$

Step 3: Calculate Hydroxide Ion Concentration

From pOH:

$$ [\text{OH}^-] = 10^{-\text{pOH}} $$

$$ [\text{OH}^-] = 10^{-12.0607} $$

$$ [\text{OH}^-] \approx 8.69 \times 10^{-13} \, \text{M} $$

Confirming with Water's Ion Product Constant

Alternatively, verify the calculation using K_w:

$$ [\text{OH}^-] = \frac{K_w}{[\text{H}^+]} $$

$$ [\text{OH}^-] = \frac{1.0 \times 10^{-14}}{1.15 \times 10^{-2}} $$

$$ [\text{OH}^-] \approx 8.70 \times 10^{-13} \, \text{M} $$

This matches closely with our previous calculation, confirming consistency.

Deeper Insights and Related Concepts

The Significance of Hydrogen Ion Contamination

The term "hydrogen ion contamination" here refers to the presence of free H^+ ions in the solution, which can arise from acids, dissolved gases, or impurities. A concentration of $1.15 \times 10^{-2} \, \text{M}$ indicates a solution that is mildly acidic, with a pH around 1.94, quite acidic compared to neutral water.

How pH Influences Hydroxide Concentration

In acidic solutions:

- The higher the $[H^+]$, the lower the $[OH^-]$.
- The relationship is strictly governed by the water ion product constant, K_w.

In basic solutions:

- $[H^+]$ is very low, and $[OH^-]$ is correspondingly high.

Real-World Applications

Understanding how to derive hydroxide concentrations from hydrogen ion levels is vital in:

- Pharmaceutical formulations: Ensuring solutions are within safe pH ranges.
- Environmental chemistry: Monitoring acid rain or contamination.

- Industrial processes: Managing corrosion or chemical reactions that depend on pH.

Summary and Key Takeaways

- The hydrogen ion concentration directly influences the hydroxide ion concentration via the water ion product constant, K_w.
- To find $[OH^-]$, you can either:

1. Calculate pH from $[H^+]$, then derive pOH, and finally find $[OH^-]$.

2. Use the relation:

$$[\text{OH}^-] = \frac{K_w}{[\text{H}^+]}$$

- At 25°C, $K_w = 1.0 \times 10^{-14}$, which simplifies calculations.
- The solution's pH indicates its acidity; in this case, a pH of about 1.94 suggests a strongly acidic environment.

Final Note

Mastering these calculations enhances your ability to analyze aqueous solutions' behavior and pH dynamics accurately. Whether in academic research, industrial chemistry, or environmental science, understanding the interplay between hydrogen and hydroxide ions is fundamental to controlling and predicting chemical reactions in water.

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