The Ka For Benzoic Acid Is 6.5 105. Calculate The PH Of A 0.12 M Benzoic Acid Solution.

The Ka For Benzoic Acid Is 6.5 × 10^5. Calculate The pH Of A 0.12 M Benzoic Acid Solution.

Understanding the pH of a benzoic acid solution is essential in fields ranging from chemistry laboratories to industrial applications. When working with acids like benzoic acid, knowing how to calculate the pH based on their acid dissociation constant (Ka) and molarity is fundamental. This article provides a comprehensive guide to calculating the pH of a 0.12 M benzoic acid solution, explains the significance of the Ka value, and explores related concepts such as acid strength, dissociation, and practical applications.

Introduction to Benzoic Acid and Its Acid Dissociation Constant (Ka)

Benzoic acid is a simple aromatic carboxylic acid with the chemical formula C_6H_5COOH. It is widely used as a food preservative, in the manufacture of plastics, and in various pharmaceutical products. The acidity of benzoic acid stems from its ability to donate protons (H^+) in aqueous solutions.

The acid dissociation constant, Ka, measures the strength of an acid in solution. It quantifies the extent to which an acid dissociates into its ions in water. A higher Ka indicates a stronger acid, while a lower Ka suggests a weaker acid.

In this context, the provided Ka value for benzoic acid is 6.5×10^{-5}, which indicates a weak acid. Knowing this value allows chemists to calculate the pH of solutions with known concentrations.

Understanding the Given Data

Before proceeding to calculations, let's review the key data:

- Ka for benzoic acid: 6.5×10^{-5}
- Concentration of benzoic acid (initial): 0.12 M

The goal is to find the pH of this solution, which depends on the concentration of hydrogen ions (H^+) in the solution.

Theoretical Background for pH Calculation

pH is a measure of the acidity of a solution, defined by the negative base-10 logarithm of the hydrogen ion concentration:

$$pH = -\log[H^+]$$

To determine $[H^+]$, we analyze the dissociation of benzoic acid in water:

$C_6H_5COOH \rightleftharpoons C_6H_5COO^- + H^+$

Since benzoic acid is weak, it does not dissociate completely, and an equilibrium is established. The dissociation can be represented by the expression:

$Ka = [C_6H_5COO^-][H^+] / [C_6H_5COOH]$

Step-by-Step Calculation of the pH

1. Set Up the ICE Table

Let’s define:

- Initial concentration of benzoic acid: 0.12 M
- Change in concentration: x (amount dissociated)
- Equilibrium concentrations:

	Initial (M)	Change (M)	Equilibrium (M)
C_6H_5COOH	0.12	−x	0.12 − x
$C_6H_5COO^-$	0	+x	x
H^+	0	+x	x

Because benzoic acid is weak, x is small relative to 0.12 M, allowing us to use the approximation that $0.12 - x \approx 0.12$.

2. Write the Expression for Ka

Using the equilibrium concentrations:

$Ka = x^2 / (0.12)$

Plugging in the known Ka value:

$6.5 \times 10^{-5} = x^2 / 0.12$

3. Solve for x

$x^2 = 6.5 \times 10^{-5} \times 0.12$

$x^2 = 7.8 \times 10^{-6}$

$x = \sqrt{(7.8 \times 10^{-6})} \approx 0.00279$ M

This x represents the concentration of H^+ ions in the solution.

4. Calculate the pH

$pH = -\log[H^+] = -\log(0.00279)$

$pH \approx 2.55$

Therefore, the pH of the 0.12 M benzoic acid solution is approximately 2.55.

Significance of the Calculated pH

The pH value of approximately 2.55 indicates that the benzoic acid solution is acidic, but not strongly so. It falls within the typical pH range of weak acids and demonstrates the moderate acidity of benzoic acid in aqueous solutions.

Key points:

- The weak dissociation of benzoic acid results in a pH above 2, reflecting its weak acid nature.
- The calculation validates the importance of the Ka value in predicting solution acidity.
- Such pH calculations are crucial in industries where precise acidity levels are necessary, such as food preservation and pharmaceutical formulation.

Factors Influencing pH in Benzoic Acid Solutions

Understanding the factors that influence pH helps in controlling and optimizing processes involving benzoic acid:

- **Concentration:** Increasing concentration decreases pH (more H^+ ions).
- **Temperature:** Elevated temperatures can affect dissociation and pH.
- **Presence of other ions:** Interfering ions can shift dissociation equilibria.

Applications of Benzoic Acid and pH Calculations

Benzoic acid's weak acidity and predictable pH are exploited in various applications:

1. Food Industry

- Used as a preservative due to its antimicrobial properties.
- pH control is essential to ensure food safety and effectiveness.

2. Pharmaceutical Industry

- Formulating drugs with specific pH levels to optimize stability and absorption.
- pH calculations guide proper dosage and formulation.

3. Chemical Manufacturing

- In manufacturing plastics and resins, controlling acidity influences product quality.

Additional Insights into Acid Dissociation and pH Calculations

For more complex solutions or higher concentrations, the approximation used in the calculation might not hold, necessitating the use of quadratic equations to solve for x explicitly. Advanced calculations may involve:

- Quadratic solution for precise $[H^+]$.
- Consideration of activity coefficients in non-ideal solutions.
- Impact of ionic strength on dissociation constants.

Summary and Key Takeaways

- The Ka for benzoic acid is 6.5×10^{-5}, indicating it is a weak acid.
- To calculate the pH of a 0.12 M benzoic acid solution, use the dissociation

equilibrium and approximate that x ≈ √(Ka × concentration).
- The pH of this solution is approximately 2.55, reflecting moderate acidity.
- Understanding the relationship between Ka, concentration, and pH is vital in practical applications across various industries.

Conclusion

Calculating the pH of a benzoic acid solution is a fundamental skill in analytical chemistry, essential for quality control, industrial processes, and research. By knowing the Ka value and initial concentration, chemists can accurately predict acidity levels. The example provided demonstrates how to perform such calculations step-by-step, emphasizing the importance of understanding acid dissociation and equilibrium concepts. Whether in the lab or industry, mastering these calculations ensures better control over chemical processes and product formulations.

Related Topics for Further Study

- Differences between strong and weak acids.
- Effect of temperature on Ka and pH.
- Buffer solutions containing benzoic acid.
- Titration methods for determining acid strength.
- Role of activity coefficients in real-world solutions.

Optimized for SEO Keywords:

- Benzoic acid pH calculation
- Ka of benzoic acid
- How to calculate pH of weak acids
- Benzoic acid solution properties
- Acid dissociation constant
- Weak acid pH formula
- Industrial applications of benzoic acid
- Food preservative pH levels
- Pharmaceutical formulation pH

By understanding these concepts, students, researchers, and industry professionals can better manipulate and utilize benzoic acid solutions for their specific needs.

Frequently Asked Questions

What is the significance of the Ka value in

calculating the pH of benzoic acid solutions?

The Ka value indicates the acid dissociation constant, reflecting the strength of the acid. It helps determine the degree of ionization in solution, which is essential for calculating the pH of benzoic acid solutions.

How do you calculate the pH of a 0.12 M benzoic acid solution using its Ka value?

You set up an expression for the dissociation of benzoic acid, use the Ka = 6.5×10^-5 to find the concentration of H+ ions, and then calculate pH as -log[H+].

What assumptions are made when calculating the pH of weak acids like benzoic acid?

The calculation assumes that the initial concentration of the acid is much greater than the amount that dissociates, so the change in concentration is negligible, allowing the use of the approximation [H+] ≈ sqrt(Ka × initial concentration).

What is the step-by-step method to find the pH of a 0.12 M benzoic acid solution with Ka = 6.5×10^-5?

Step 1: Write the dissociation expression. Step 2: Set up the equilibrium expression with x = [H+]. Step 3: Use the approximation [H+] ≈ sqrt(Ka × initial concentration). Step 4: Calculate pH as -log[H+].

What is the approximate pH of a 0.12 M benzoic acid solution with Ka = 6.5×10^-5?

Using the approximation, [H+] ≈ sqrt(6.5×10^-5 × 0.12) ≈ 0.0028 M, so the pH ≈ -log(0.0028) ≈ 2.55.

Additional Resources

The Ka for Benzoic Acid Is 6.5 x 10^{-5}: Calculating the pH of a 0.12 M Benzoic Acid Solution

---

Introduction

Benzoic acid, a widely studied aromatic carboxylic acid, holds significance in both industrial applications and academic research. Known for its preservative qualities and role in organic synthesis, understanding its acid-base properties remains crucial. The dissociation constant (Ka) of benzoic acid is a key parameter in predicting its behavior in aqueous solutions. With a Ka of 6.5 x 10^{-5}, chemists can determine the acidity and pH of solutions with specified concentrations.

This article explores the fundamental principles behind calculating the pH of a 0.12 M benzoic acid solution, emphasizing the importance of Ka, the dissociation process, and the step-by-step solution methodology. We will delve into the theoretical background, detailed calculations, and implications of these findings for both laboratory practice and chemical theory.

Understanding Acid Dissociation Constant (Ka)

Definition and Significance

The acid dissociation constant, Ka, quantifies the strength of an acid in solution. It reflects the degree to which an acid donates protons (H^+) to the solvent:

$$ \text{HA} \leftrightarrow \text{H}^+ + \text{A}^- $$

Where:

- HA = weak acid (benzoic acid)
- A^- = conjugate base

A larger Ka indicates a stronger acid, which dissociates more extensively in water. Conversely, a smaller Ka signifies a weaker acid with less dissociation.

The Ka for Benzoic Acid

Given:

$$ \text{Ka} = 6.5 \times 10^{-5} $$

This value positions benzoic acid as a weak acid—more potent than acetic acid but significantly less so than strong acids like HCl or sulfuric acid.

Theoretical Framework for pH Calculation

Acid Dissociation in Aqueous Solution

Benzoic acid's dissociation can be represented as:

$$ \text{C}_6\text{H}_5\text{COOH} \leftrightarrow \text{C}_6\text{H}_5\text{COO}^- + \text{H}^+ $$

Initially, the concentration of benzoic acid is 0.12 M. Upon dissociation, let:

- x = concentration of H^+ ions produced at equilibrium
- The concentration of undissociated benzoic acid remaining = $0.12 - x$

Since the acid is weak, x is expected to be small relative to initial concentration, allowing the assumption $0.12 - x \approx 0.12$ for initial approximation.

The Expression for Ka

At equilibrium:

$$\text{Ka} = \frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]}$$

Given that:

$$[\text{H}^+] = x$$
$$[\text{A}^-] = x$$
$$[\text{HA}] \approx 0.12 - x$$

we get:

$$6.5 \times 10^{-5} = \frac{x^2}{0.12 - x}$$

Since x is small, approximate:

$$6.5 \times 10^{-5} \approx \frac{x^2}{0.12}$$

Step-by-Step Calculation

Step 1: Solving for x

$$x^2 = 6.5 \times 10^{-5} \times 0.12$$
$$x^2 = 7.8 \times 10^{-6}$$
$$x = \sqrt{7.8 \times 10^{-6}}$$

Calculating:

$$x \approx 0.00279 \text{ M}$$

This is the concentration of hydrogen ions in solution.

Step 2: Calculating pH

pH is defined as:

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

Substituting x:

$$\text{pH} = -\log 0.00279$$

Calculating:

$$\text{pH} \approx -(-2.55)$$
$$\text{pH} \approx 2.55$$

Validation of Approximation

The assumption $x \ll 0.12$ is justified because:

$$\frac{x}{0.12} \approx \frac{0.00279}{0.12} \approx 0.023$$

which is below 5%, confirming the approximation's validity.

Implications of the pH Calculation

Acid Strength and Solution Behavior

A pH of approximately 2.55 indicates a moderately acidic solution, consistent with weak acids. This pH level influences various processes, including preservation efficacy, chemical reactivity, and biological interactions.

Industrial Relevance

Understanding the pH of benzoic acid solutions is crucial in food preservation, where maintaining specific acidity levels ensures microbial stability. Additionally, in organic synthesis, pH control impacts reaction pathways and yields.

Factors Affecting the pH of Benzoic Acid Solutions

While the calculation above assumes ideal conditions, several factors can influence the actual pH:

- Temperature: Elevating temperature generally increases dissociation, lowering pH.
- Purity of the acid: Impurities can alter dissociation behavior.
- Ionic strength: High ionic strength can affect activity coefficients, influencing the effective Ka and pH.
- Concentration: At very high concentrations, deviations from ideal behavior may occur due to activity effects.

Advanced Considerations

Using the Quadratic Equation for Precise Calculation

When higher accuracy is required, solving the full quadratic expression is necessary:

$$ x^2 + \text{Ka} \times x - \text{Ka} \times [\text{initial concentration}] = 0 $$

Plugging in the values:

$$ x^2 + (6.5 \times 10^{-5}) x - (6.5 \times 10^{-5}) \times 0.12 = 0 $$

This yields:

$$ x^2 + (6.5 \times 10^{-5}) x - 7.8 \times 10^{-6} = 0 $$

Applying quadratic formula:

$$ x = \frac{ -b \pm \sqrt{b^2 - 4ac} }{2a} $$

where:

- $a = 1$
- $b = 6.5 \times 10^{-5}$
- $c = -7.8 \times 10^{-6}$

Calculating the discriminant:

$$ \Delta = (6.5 \times 10^{-5})^2 - 4 \times 1 \times (-7.8 \times 10^{-6}) $$
$$ \Delta = 4.225 \times 10^{-9} + 3.12 \times 10^{-5} $$
$$ \Delta \approx 3.1204 \times 10^{-5} $$

Calculating x:

$$ x = \frac{ -6.5 \times 10^{-5} \pm \sqrt{3.1204 \times 10^{-5}} }{2} $$

The positive root yields:

$$ x \approx \frac{ -6.5 \times 10^{-5} + 0.00559 }{2} $$
$$ x \approx \frac{0.005525}{2} $$
$$ x \approx 0.00276 \text{ M} $$

which closely aligns with the previous estimate.

Real-World Application and Significance

Understanding how to calculate the pH of benzoic acid solutions directly impacts various fields:

- Food Industry: Optimizing preservative concentrations to maintain safety and quality.
- Pharmaceuticals: Designing formulations with precise pH values for stability.
- Chemical Manufacturing: Controlling reaction conditions in synthesis and purification processes.
- Academic Research: Fundamental understanding of weak acid equilibria.

Conclusion

The calculation of the pH of a 0.12 M benzoic acid solution, given its Ka of 6.5 x 10^{-5}, exemplifies core principles of acid-base chemistry and equilibrium. Through assumptions grounded in the weak acid approximation, the pH is approximately 2.55, reflecting moderate acidity. More refined calculations confirm this estimate, illustrating the importance of mathematical rigor in chemical analysis.

This investigation underscores the significance of dissociation constants in predicting solution behavior and informs practical applications across scientific disciplines. Mastery of these calculations not only enhances theoretical understanding but also contributes to effective laboratory practice and industrial process optimization.

References

- Atkins, P. & de Paula, J. (2014). Physical Chemistry. Oxford University Press.
- Zumdahl, S. S., & Zumdahl, S. A. (2013). Chemistry. Cengage Learning.
- Lide, D. R. (Ed.). (2004). CRC Handbook of Chemistry and Physics. CRC

```
Press.
- Online resources such as Khan Academy and Chemguide for additional
tutorials on weak acids and p
```

The Ka For Benzoic Acid Is 6 5 105 Calculate The Ph Of A 0 12 M Benzoic Acid Solution

The Ka For Benzoic Acid Is 6 5 105 Calculate The Ph Of A 0 12 M Benzoic Acid Solution

Related Articles

- (If A(2, -3), B(3,-2) And Point C Divides The Line Segment AB In The Ratio Of 1: 2, Find OC.)
- What Was The Biggest Benefit To Kraft From Their Social Media "Cheesepocalypse" Campaign?
- Please Help Me Today's The Last Day To Turn It In Any Help Would Be Greatly Appreciated

Back to Home