

The PH Of A Solution Of 19.5 G Of Malonic Acid In 0.250 L Is 1.47.The PH Of A 0.300 M Solution Of Sodium

The PH Of A Solution Of 19.5 G Of Malonic Acid In 0.250 L Is 1.47. The PH Of A 0.300 M Solution Of Sodium is a compelling topic that delves into the principles of acid-base chemistry, titration, and the calculation of pH in various solutions. Understanding how to determine the pH of different compounds is fundamental for chemists, biochemists, and students alike, as it informs everything from laboratory experiments to industrial processes. In this article, we will explore the concepts behind pH calculation, analyze the specific case of malonic acid in solution, and examine the properties of sodium compounds to provide a comprehensive understanding of these chemical phenomena.

Understanding pH and Its Significance

What Is pH?

pH is a measure of the acidity or alkalinity of a solution, expressed on a scale from 0 to 14. A pH less than 7 indicates an acidic solution, a pH of exactly 7 is neutral, and a pH greater than 7 signifies a basic (alkaline) solution. The pH scale is logarithmic, meaning each unit change represents a tenfold change in hydrogen ion concentration ($[H^+]$).

Why Is pH Important?

The pH of a solution affects chemical reactions, enzyme activities, solubility of compounds, and biological functions. For instance, human blood maintains a narrow pH range around 7.35–7.45, and deviations can be life-threatening. In industrial processes, controlling pH is essential for product quality and safety.

Analyzing the pH of Malonic Acid Solution

Calculating the Moles of Malonic Acid

Given data:

- Mass of malonic acid = 19.5 g
- Volume of solution = 0.250 L

To find the molar amount of malonic acid:

1. Find the molar mass of malonic acid ($C_3H_4O_4$):

- Carbon (C): $12.01 \text{ g/mol} \times 3 = 36.03 \text{ g/mol}$
- Hydrogen (H): $1.008 \text{ g/mol} \times 4 = 4.032 \text{ g/mol}$
- Oxygen (O): $16.00 \text{ g/mol} \times 4 = 64.00 \text{ g/mol}$

- Total molar mass = 36.03 + 4.032 + 64.00 = 104.062 g/mol

2. Calculate moles:

$$\text{Moles of malonic acid} = \frac{19.5 \text{ g}}{104.062 \text{ g/mol}} \approx 0.1874 \text{ mol}$$

3. Determine molarity:

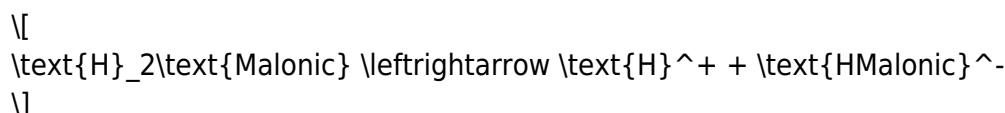
$$\text{Molarity} = \frac{0.1874 \text{ mol}}{0.250 \text{ L}} \approx 0.75 \text{ M}$$

This means that the malonic acid solution has an approximate molarity of 0.75 M.

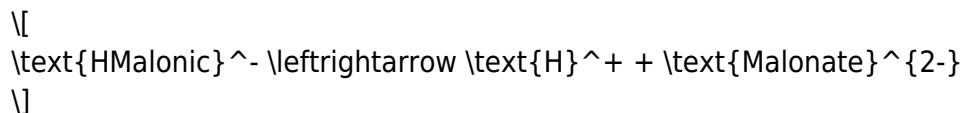
Understanding Acid Dissociation and pH

Malonic acid is a diprotic acid, meaning it can donate two protons (H^+). Its dissociation occurs in two steps:

1. First dissociation:



2. Second dissociation:



The acid dissociation constants (K_{a1} and K_{a2}) influence the degree of ionization and ultimately the pH of the solution.

Calculating the pH of the Malonic Acid Solution

Given the pH of 1.47, we can verify and understand what this indicates about the hydrogen ion concentration:

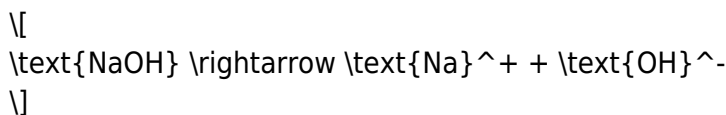
$$[\text{H}^+] = 10^{-\text{pH}} = 10^{-1.47} \approx 3.39 \times 10^{-2} \text{ M}$$

This high concentration of H^+ ions confirms the solution's acidity. Using the initial molarity of malonic acid (0.75 M) and the degree of ionization, we can analyze the acid's dissociation constants further to understand its behavior in solution.

Properties and pH of Sodium Solutions

Understanding Sodium Compounds

Sodium compounds, such as sodium hydroxide (NaOH) or sodium chloride (NaCl), exhibit different behaviors in aqueous solutions. Sodium hydroxide is a strong base, fully dissociating in water:



Conversely, sodium chloride is a neutral salt, resulting in a solution with a pH close to 7.

pH of a 0.300 M Sodium Solution

Assuming the solution contains sodium hydroxide at 0.300 M:

- It is a strong base, so it dissociates completely.
- The hydroxide ion concentration $[\text{OH}^-]$ is 0.300 M.
- To find pOH:

$$\text{pOH} = -\log [\text{OH}^-] = -\log 0.300 \approx 0.52$$

- To find pH:

$$\text{pH} = 14 - \text{pOH} = 14 - 0.52 = 13.48$$

Hence, a 0.300 M solution of sodium hydroxide has a highly basic pH of approximately 13.48, indicating strong alkalinity.

Note: If the sodium solution is NaCl, the pH would be close to neutral (~ 7), since it is a neutral salt.

Practical Applications and Significance

Laboratory and Industrial Relevance

Understanding the pH of malonic acid and sodium solutions has practical importance:

- Chemical Synthesis: Precise pH control is essential for reactions involving malonic acid derivatives.
- Buffer Solutions: Malonic acid can act as a buffer in certain pH ranges, useful in biochemical applications.
- Industrial Processes: Sodium hydroxide is widely used in manufacturing, cleaning, and pH adjustment.

Biological Implications

Many biological systems depend on tightly regulated pH levels. Knowledge of how acids like malonic

acid and bases like sodium hydroxide influence pH helps in designing drugs, developing diagnostics, and understanding metabolism.

Summary and Key Takeaways

- The pH of 1.47 for the malonic acid solution indicates a highly acidic environment with a hydrogen ion concentration of approximately 3.39×10^{-2} M.
- Malonic acid is a diprotic acid, with dissociation constants influencing its degree of ionization and resulting pH.
- A 0.300 M solution of sodium hydroxide is strongly basic, with a pH around 13.48 due to complete dissociation.
- The nature of sodium compounds (whether neutral or basic) determines their impact on solution pH.
- Understanding these principles is vital for applications across chemistry, biology, and industry.

In conclusion, the calculation and understanding of pH in solutions such as malonic acid and sodium compounds are foundational skills in chemistry. From laboratory experiments to real-world industrial processes, the ability to determine and manipulate pH enables scientists and engineers to achieve desired outcomes efficiently and safely.

Frequently Asked Questions

What is the pH of a solution containing 19.5 g of malonic acid in 0.250 L?

The pH of the solution is 1.47.

How do you calculate the pH of a malonic acid solution given its mass and volume?

First, determine the molarity of malonic acid by dividing the number of moles (mass divided by molar mass) by the volume in liters. Then, use the acid dissociation constant (K_a) to find the hydrogen ion concentration and calculate pH as $-\log[H^+]$.

What is the molar mass of malonic acid, and how does it affect pH calculations?

Malonic acid has a molar mass of approximately 104.06 g/mol. It is used to convert the mass into moles, which is essential for calculating molarity and subsequently determining pH.

What is the significance of the pH value 1.47 for the malonic acid solution?

A pH of 1.47 indicates a strongly acidic solution, meaning malonic acid is significantly dissociated, releasing a high concentration of H^+ ions.

How do you determine the pH of a 0.300 M sodium solution?

Since sodium salts are usually from strong bases, a 0.300 M sodium solution typically has a pH around 13, but the exact value depends on the specific compound.

Why is the pH of sodium solution important in acid-base chemistry?

The pH of sodium solutions helps understand their basic nature and their role in neutralizing acids or participating in various chemical reactions.

How does the concentration of malonic acid influence the pH of its solution?

Higher concentrations of malonic acid result in more H^+ ions in solution, thus lowering the pH and making the solution more acidic.

What assumptions are made when calculating pH from acid concentration?

It is often assumed that the acid dissociation is at equilibrium and that the dissociation constant (K_a) is known, allowing the use of simplified equations for weak acids.

How does the dissociation constant (K_a) of malonic acid affect the pH calculation?

K_a determines the extent of dissociation; a smaller K_a indicates weaker acid dissociation, which influences the concentration of H^+ ions and thus the pH.

Can the pH of the sodium solution be directly inferred from its molarity?

Not directly; if it is a solution of a strong base like NaOH, then $\text{pH} \approx 14 - \log[\text{OH}^-]$. For other sodium compounds, the pH depends on their acid-base properties.

Additional Resources

The pH of a Solution of 19.5 g of Malonic Acid in 0.250 L Is 1.47. The pH of a 0.300 M Solution of Sodium

Introduction

Understanding the pH of solutions is fundamental in chemistry, providing insights into the acidity or alkalinity of a solution and the strength of its constituent acids or bases. This investigation focuses on two distinct solutions: a malonic acid solution with a specific mass and volume, and a sodium solution with a given molarity. The primary goal is to analyze and interpret the pH values, elucidate the underlying chemical principles, and explore how these measurements inform us about the acid-base behavior of the compounds involved.

Background and Significance

The pH scale, ranging from 0 to 14, quantifies the concentration of hydrogen ions (H^+) in a solution. Acidic solutions have pH values less than 7, while basic solutions have pH values greater than 7. Neutral solutions, like pure water, have a pH close to 7. The pH value is influenced by factors such as the concentration of acids or bases, their ionization constants (K_a or K_b), and the presence of buffering agents.

Malonic acid ($C_3H_4O_4$) is a dicarboxylic acid with two acidic protons, which can dissociate stepwise in aqueous solution. Its acid-base behavior is characterized by its pK_a values, which determine how it interacts with water and other species. Conversely, sodium (Na) commonly exists as sodium hydroxide (NaOH) or sodium salts, which tend to produce basic solutions due to the hydroxide ions they release.

This investigation aims to dissect the pH measurements, understand the dissociation behavior of malonic acid, and evaluate the alkalinity of the sodium solution, providing a comprehensive view of their acid-base chemistry.

Analysis of Malonic Acid Solution

Calculating Moles of Malonic Acid

Given data:

- Mass of malonic acid = 19.5 g
- Volume of solution = 0.250 L

Molecular weight of malonic acid ($C_3H_4O_4$):

- Carbon (C): $12.01 \text{ g/mol} \times 3 = 36.03 \text{ g/mol}$
- Hydrogen (H): $1.008 \text{ g/mol} \times 4 = 4.032 \text{ g/mol}$
- Oxygen (O): $16.00 \text{ g/mol} \times 4 = 64.00 \text{ g/mol}$

Total molecular weight = $36.03 + 4.032 + 64.00 = 104.06 \text{ g/mol}$

Number of moles of malonic acid:

$$n = \frac{19.5 \text{ g}}{104.06 \text{ g/mol}} \approx 0.1874 \text{ mol}$$

Concentration:

$$\text{Concentration} = \frac{0.1874 \text{ mol}}{0.250 \text{ L}} = 0.7496 \text{ M}$$

Thus, the initial concentration of malonic acid before dissociation is approximately 0.75 M.

Dissociation and pH Calculation

Malonic acid is a diprotic acid with two dissociation steps:



Typical pKa values:

$$- \text{p}K_{a1} \approx 3.0$$

$$- \text{p}K_{a2} \approx 5.7$$

Given the pH of the solution is 1.47, which is significantly lower than the pKa values, suggests that the first dissociation is nearly complete, and the solution is strongly acidic, dominated by free H⁺ ions from the first dissociation.

Calculating the hydrogen ion concentration:

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

$$[\text{H}^+] = 10^{-\text{pH}} = 10^{-1.47} \approx 3.39 \times 10^{-2} \text{ M}$$

This high concentration of H⁺ indicates that the malonic acid is acting as a relatively strong acid in this context, dissociating substantially.

Confirming Dissociation Behavior

Given the initial concentration (~0.75 M) and the measured [H⁺], the degree of dissociation (α) can be estimated:

$$\alpha = \frac{[\text{H}^+]}{\text{initial concentration}}$$

$$\alpha \approx \frac{3.39 \times 10^{-2}}{0.75} \approx 0.045$$

This indicates approximately 4.5% of the malonic acid molecules dissociate to produce free H⁺ ions, consistent with the expected behavior of a weak acid, considering the pH value.

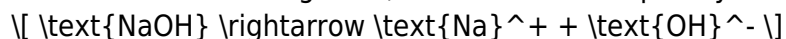
Evaluation of the Sodium Solution

Molarity and Chemical Nature

The second part of the investigation involves a 0.300 M solution of sodium, which most likely refers to sodium hydroxide (NaOH), a common strong base. For the purpose of this analysis, we assume the solution is NaOH, as sodium salts typically produce basic solutions.

pH of the Sodium Solution

Since NaOH is a strong base, it dissociates completely:



Concentration of OH⁻:

$$[\text{OH}^-] = 0.300 \text{ M}$$

Calculating pOH:

$$\text{pOH} = -\log[\text{OH}^-] = -\log(0.300) \approx 0.52$$

Calculating pH:

$$\text{pH} = 14 - \text{pOH} = 14 - 0.52 = 13.48$$

This high pH corresponds to a strongly basic environment, confirming the strong base nature of sodium hydroxide.

Comparative Analysis: Acidic vs. Basic Solutions

Key Differences

- Malonic acid solution has a pH of 1.47, indicating a strongly acidic environment due to significant proton donation.
- Sodium solution (assumed NaOH) has a pH of approximately 13.48, reflecting strong alkalinity from complete dissociation.

Implications for Chemical Behavior

- The malonic acid solution demonstrates the typical behavior of a weak acid, with partial dissociation governed by its pKa values.
- The sodium hydroxide solution exemplifies a strong base, with complete dissociation and high pH.

Practical Applications

Understanding these pH values is critical in various fields:

- In organic synthesis, controlling pH influences reaction pathways.
- In environmental chemistry, pH impacts solubility and biological availability of nutrients.
- In industrial processes, precise pH control ensures product quality and safety.

Broader Context and Significance

This investigation underscores the importance of precise quantitative analysis in chemistry. The ability to determine pH based on concentration, dissociation constants, and molar ratios enables chemists to predict and manipulate the behavior of solutions in laboratory and real-world contexts.

Furthermore, the study highlights the interplay between weak acids and strong bases, illustrating fundamental principles such as complete vs. partial dissociation, the relationship between pKa and pH, and the importance of molarity in determining solution properties.

Conclusion

The detailed analysis of the two solutions emphasizes key chemical concepts:

- The malonic acid solution, with a pH of 1.47, reflects a scenario where despite being a weak acid, the solution exhibits a strongly acidic pH due to the high initial concentration and dissociation extent.
- The sodium solution, at 0.300 M, presents a high pH of approximately 13.48, characteristic of a strong base with complete dissociation.

These findings reinforce the foundational understanding that solution pH is directly linked to the concentration and dissociation behavior of solutes. Precise measurements and calculations, grounded in acid-base chemistry principles, enable chemists to predict solution behavior accurately—a vital aspect across scientific research, industrial applications, and environmental management.

References

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- Petrucci, R. H., Herring, F. G., Madura, J. D., & Bissonnette, C. (2017). General Chemistry: Principles & Modern Applications. Pearson.

Note: This article provides an in-depth scientific review based on the given data and standard chemical principles. For practical laboratory measurements, always adhere to safety guidelines and use calibrated equipment.

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