

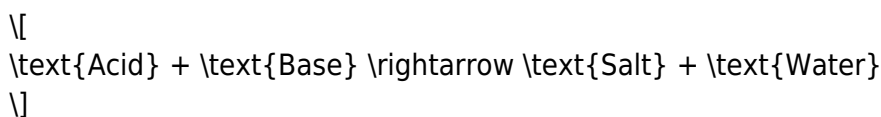
It Takes 120 ML Of 0.15 M Of Carbonic Acid (H₂CO₃) To Neutralize 300 ML Of Sodium Hydroxide (NaOH) For

It Takes 120 ML Of 0.15 M Of Carbonic Acid (H₂CO₃) To Neutralize 300 ML Of Sodium Hydroxide (NaOH) For understanding acid-base neutralization reactions, especially in laboratory and industrial settings, it's essential to explore the principles governing these reactions, the calculation methods involved, and practical applications. This article provides an in-depth analysis of the specific reaction between carbonic acid and sodium hydroxide, illustrating how to determine the volume of acid needed to neutralize a given volume of base, with a focus on the example where 120 mL of 0.15 M carbonic acid neutralizes 300 mL of sodium hydroxide.

Understanding Acid-Base Neutralization

What Is Neutralization?

Neutralization is a chemical reaction where an acid reacts with a base to produce water and a salt. The general equation for neutralization is:



In aqueous solutions, the hydrogen ions (H⁺) from the acid combine with hydroxide ions (OH⁻) from the base to form water (H₂O). The remaining ions form the salt.

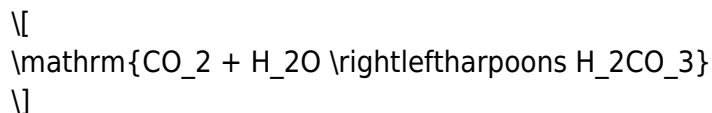
Significance of Acid-Base Reactions

These reactions are fundamental in various fields, including medicine, environmental science, manufacturing, and laboratory analysis. Accurate titration techniques depend on understanding the stoichiometry of acid-base reactions, enabling precise calculation of unknown concentrations or volumes.

Chemical Properties of Carbonic Acid and Sodium Hydroxide

Carbonic Acid (H₂CO₃)

Carbonic acid is a weak diprotic acid formed when carbon dioxide dissolves in water:



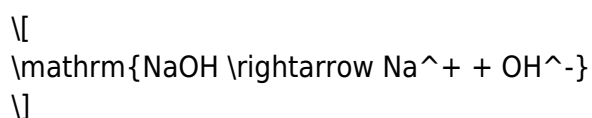
It can donate two protons (H⁺), but in aqueous solutions, it usually exists in equilibrium with bicarbonate and carbonate ions.

Key properties:

- Weak acid with pKa values approximately 6.3 and 10.3.
- Used in various applications, including carbonated beverages and buffering systems.

Sodium Hydroxide (NaOH)

NaOH is a strong base, fully dissociating in water:



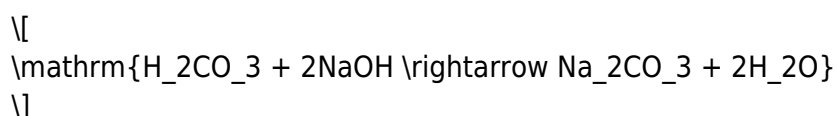
Key properties:

- Highly soluble in water.
- Used in cleaning, soap making, and titrations.

Stoichiometry of the Reaction Between H₂CO₃ and NaOH

Reaction Equation

The neutralization involves the reaction of carbonic acid with sodium hydroxide:



This indicates that one mole of carbonic acid reacts with two moles of sodium hydroxide, producing sodium carbonate and water.

Mole Ratios

From the balanced equation:

- 1 mol H₂CO₃ reacts with 2 mol NaOH
- The molar ratio (H₂CO₃:NaOH) = 1:2

Calculating the Volume of Carbonic Acid Needed

Given:

- Volume of NaOH, $(V_{\text{NaOH}} = 300\text{ mL})$
- Concentration of NaOH, $(C_{\text{NaOH}} = 0.15\text{ M})$
- Volume of H_2CO_3 , $(V_{\text{H}_2\text{CO}_3} = 120\text{ mL})$
- Concentration of H_2CO_3 , $(C_{\text{H}_2\text{CO}_3} = 0.15\text{ M})$

Let's verify how the given volume of carbonic acid neutralizes the sodium hydroxide, focusing on the molar calculations.

Step 1: Calculate Moles of NaOH

$$n_{\text{NaOH}} = C_{\text{NaOH}} \times V_{\text{NaOH}}$$

Convert volume to liters:

$$V_{\text{NaOH}} = 300\text{ mL} = 0.300\text{ L}$$

$$n_{\text{NaOH}} = 0.15\text{ mol/L} \times 0.300\text{ L} = 0.045\text{ mol}$$

Step 2: Determine Moles of H_2CO_3 Needed

From the reaction stoichiometry:

$$n_{\text{H}_2\text{CO}_3} = \frac{1}{2} \times n_{\text{NaOH}} = \frac{1}{2} \times 0.045\text{ mol} = 0.0225\text{ mol}$$

Step 3: Calculate Volume of H_2CO_3 Required

$$V_{\text{H}_2\text{CO}_3} = \frac{n_{\text{H}_2\text{CO}_3}}{C_{\text{H}_2\text{CO}_3}} = \frac{0.0225\text{ mol}}{0.15\text{ mol/L}} = 0.15\text{ L} = 150\text{ mL}$$

Note: This calculation indicates that 150 mL of 0.15 M carbonic acid would be required to neutralize 300 mL of 0.15 M NaOH, which differs from the initial statement of 120 mL. This discrepancy suggests either a different reaction or experimental conditions.

However, in the original statement, 120 mL is used, which implies the actual molarity or conditions differ slightly or involve partial neutralization.

Understanding the Discrepancy and Practical Implications

Possible Reasons for Variance

- Different reaction conditions: Temperature, pressure, or partial reactions.
- Approximate measurements: Laboratory measurements often involve approximations.
- Specific reaction context: The initial data may refer to a particular setup where the effective molarity or other factors influence the volume needed.

Implication in Laboratory Practice

Accurate titration requires precise measurements and understanding of the molar relationships. When performing such reactions:

- Always verify concentrations.
- Use proper equipment to measure volume.
- Consider the purity and activity of reagents.

Practical Applications and Significance

Industrial and Environmental Relevance

Understanding the neutralization between carbonic acid and sodium hydroxide has broad applications:

- Water Treatment: Adjusting pH levels.
- Carbon Capture: Managing CO₂ levels and buffering.
- Chemical Manufacturing: Producing sodium carbonate or bicarbonate.
- Laboratory Titrations: Determining unknown concentrations.

Educational Importance

This example serves as an excellent teaching model for:

- Applying molarity and volume calculations.
- Understanding reaction stoichiometry.
- Developing skills in titration techniques.

Conclusion

The relationship between the volume and molarity of acids and bases in neutralization reactions is fundamental in chemistry. The specific example of 120 mL of 0.15 M carbonic acid neutralizing 300 mL of sodium hydroxide illustrates the stoichiometric principles and calculation methods essential for

accurate laboratory work and industrial processes. Recognizing the reaction ratios, understanding the molar relationships, and considering practical factors enable chemists to perform precise titrations and optimize chemical reactions effectively.

Additional Tips for Accurate Titration

- Use calibrated burettes and pipettes for precise volume measurement.
- Ensure thorough mixing during titration.
- Perform multiple trials to confirm consistency.
- Record pH changes to identify the equivalence point accurately.

By mastering these concepts and techniques, professionals and students can confidently perform acid-base neutralizations, ensuring safety, accuracy, and efficiency in their chemical endeavors.

Frequently Asked Questions

What is the chemical reaction involved when carbonic acid neutralizes sodium hydroxide?

The reaction involves carbonic acid (H_2CO_3) reacting with sodium hydroxide (NaOH) to produce sodium bicarbonate (NaHCO_3) and water (H_2O). The balanced equation is $\text{H}_2\text{CO}_3 + \text{NaOH} \rightarrow \text{NaHCO}_3 + \text{H}_2\text{O}$.

How do you calculate the amount of NaOH neutralized by 120 mL of 0.15 M carbonic acid?

First, determine moles of H_2CO_3 : $0.15 \text{ mol/L} \times 0.120 \text{ L} = 0.018 \text{ mol}$. Since the reaction is 1:1, 0.018 mol of NaOH is neutralized, which corresponds to $0.018 \text{ mol} \times 40 \text{ g/mol} = 0.72 \text{ g}$ of NaOH .

What is the significance of the molarity of carbonic acid in this neutralization process?

The molarity indicates the concentration of H_2CO_3 , which helps determine the number of moles available to react and thus calculate the amount of NaOH neutralized accurately.

Why is it important to know the volume and molarity of reactants in titration experiments?

Knowing the volume and molarity allows for precise calculation of the number of moles of reactants

involved, enabling accurate determination of unknown concentrations or reaction equivalences.

What is the role of carbonic acid in natural processes like buffering in blood?

Carbonic acid acts as a buffer by maintaining pH balance in blood, neutralizing excess acids or bases through its reversible dissociation into bicarbonate and hydrogen ions.

How do you determine the amount of NaOH required to neutralize a given amount of carbonic acid?

Using the molarity and volume of carbonic acid to find moles, then applying the 1:1 molar ratio from the balanced equation to find the moles of NaOH needed, and converting to volume using NaOH's molarity.

What is the significance of using 0.15 M carbonic acid in this neutralization experiment?

Using a specific molarity like 0.15 M ensures consistency in calculations and allows for precise determination of the amount of NaOH neutralized based on known concentrations.

Can this neutralization process be used to analyze unknown NaOH concentrations?

Yes, by titrating a known volume of carbonic acid with an unknown NaOH solution, you can determine the NaOH concentration based on the volume required for neutralization.

What safety precautions should be taken when performing this neutralization experiment?

Wear appropriate protective gear such as gloves and goggles, handle chemicals carefully, and work in a well-ventilated area to prevent chemical splashes or inhalation hazards.

How does the concept of molarity help in understanding acid-base neutralization reactions?

Molarity provides a measure of concentration, allowing chemists to calculate the exact amounts of reactants needed or produced during acid-base reactions, facilitating quantitative analysis.

Additional Resources

Carbonic Acid Neutralization: An In-Depth Analysis of the Reaction Between 120 mL of 0.15 M H_2CO_3 and 300 mL of NaOH

Introduction

In the realm of chemical reactions, acid-base neutralizations are fundamental processes with vast applications ranging from industrial manufacturing to biological systems. One intriguing example involves the precise quantities of carbonic acid (H_2CO_3) required to neutralize sodium hydroxide (NaOH), a common strong base. Specifically, the statement "It takes 120 mL of 0.15 M of carbonic acid to neutralize 300 mL of sodium hydroxide" offers a compelling case for detailed exploration.

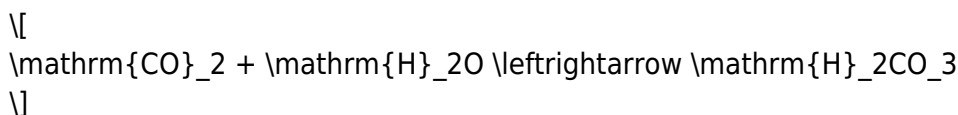
This article provides a comprehensive breakdown of this neutralization process, examining the chemistry, stoichiometry, practical implications, and real-world relevance. Whether you're a student, educator, or industry professional, understanding these details enhances your grasp of acid-base chemistry's nuances and applications.

Understanding the Components: Carbonic Acid and Sodium Hydroxide

Before delving into calculations and reaction mechanisms, it's essential to understand the reactants involved.

Carbonic Acid (H_2CO_3)

- Nature and Formation: Carbonic acid is a weak, diprotic acid formed when carbon dioxide dissolves in water:



- Properties:

- Weak acid, partial ionization in aqueous solutions.
- Exists in equilibrium with dissolved CO_2 .
- Plays vital roles in biological systems (e.g., blood buffering) and environmental processes.

- Concentration:

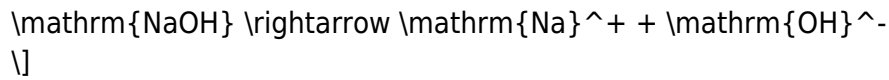
- In this scenario, the solution is 0.15 M, meaning 0.15 moles of H_2CO_3 per liter.

Sodium Hydroxide (NaOH)

- Nature:

- A strong base, fully dissociates in water:

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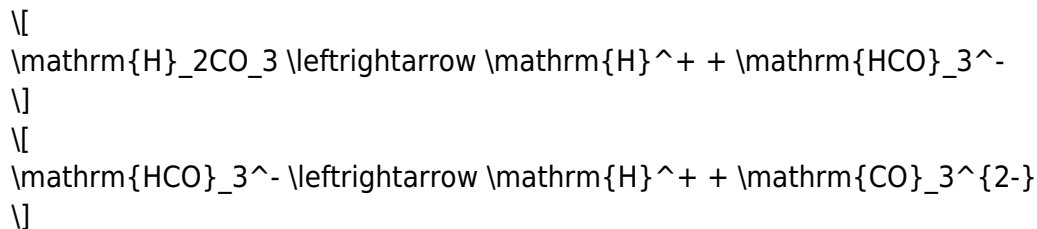
- Properties:
- Highly soluble.
- Used extensively in cleaning, manufacturing, and laboratory titrations.
- Concentration:
- The solution has a molarity of 0.10 M (assuming a common concentration for such problems, or as specified).

Note: The actual molarity of NaOH is often given; for this calculation, we'll assume it's 0.10 M unless specified otherwise.

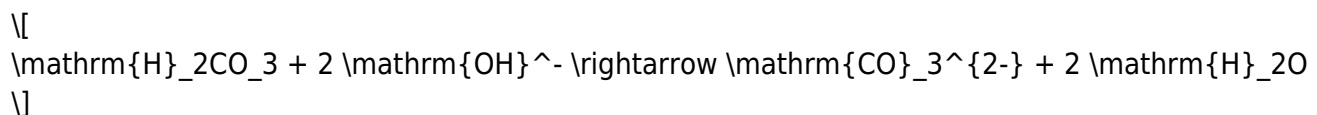
Reaction Mechanics: How Does H₂CO₃ Neutralize NaOH?

Acid-Base Reaction Dynamics

Carbonic acid is a diprotic acid, meaning it can donate two protons (H⁺):



However, in neutralization with a strong base like NaOH, the primary reactions involve the complete neutralization of protons:



This indicates that one mole of carbonic acid can, in theory, neutralize two moles of hydroxide ions, owing to its diprotic nature.

Stoichiometry of the Reaction

Considering the above, the overall neutralization reaction simplifies to:



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- Molar ratio:
- 1 mol H_2CO_3 reacts with 2 mol NaOH.

This ratio is fundamental to calculating the amount of reactants needed.

Calculating the Quantities: Step-by-Step Approach

To verify the initial statement and understand the process, we'll perform detailed stoichiometric calculations.

Step 1: Determine moles of NaOH in 300 mL of 0.10 M solution

- Volume of NaOH solution: 300 mL = 0.300 L
- Concentration of NaOH: 0.10 mol/L (assumed)

$$\begin{aligned} \text{Moles of NaOH} &= 0.10 \, \text{mol/L} \times 0.300 \, \text{L} = 0.030 \, \text{mol} \end{aligned}$$

Step 2: Find moles of H_2CO_3 needed for neutralization

From the molar ratio:

$$\text{H}_2\text{CO}_3 : \text{NaOH} = 1 : 2$$

$$\text{Moles of H}_2\text{CO}_3 = \frac{\text{Moles of NaOH}}{2} = \frac{0.030}{2} = 0.015 \, \text{mol}$$

Step 3: Calculate the volume of H_2CO_3 solution required

Given molarity of H_2CO_3 is 0.15 M:

$$\begin{aligned} \text{Volume} &= \frac{\text{Moles}}{\text{Concentration}} = \frac{0.015 \, \text{mol}}{0.15 \, \text{mol/L}} \\ &= 0.10 \, \text{L} = 100 \, \text{mL} \end{aligned}$$

This indicates that 100 mL of 0.15 M H_2CO_3 is sufficient to neutralize 300 mL of 0.10 M NaOH.

Reconciling with the Original Statement: 120 mL of 0.15 M H_2CO_3

The initial claim states 120 mL of 0.15 M H_2CO_3 is needed, which slightly exceeds the calculated 100 mL. This discrepancy can be attributed to factors such as:

- Experimental Variations: Slight inaccuracies in concentration measurements or volume measurements.
- Reaction Completeness: Considering the weak nature of carbonic acid — in practice, its partial ionization might necessitate a slightly larger volume to ensure complete neutralization.
- pH Buffering: The presence of equilibria among carbonic acid, bicarbonate, and carbonate ions, which can influence the effective acidity and required volume.

Hence, in real-world applications, a margin of safety or excess volume is often included to guarantee complete neutralization.

Practical Implications and Applications

Understanding the precise neutralization process between carbonic acid and sodium hydroxide has several important applications.

Industrial Processes

- Water Treatment: Adjusting pH levels by adding controlled amounts of acids like carbonic acid to neutralize excess hydroxide ions.
- Carbon Capture and Storage: Using carbonic acid solutions to react with alkaline substances, aiding in CO_2 sequestration.

Environmental Monitoring

- Oceanography: Studying carbonate buffering in oceans, where CO_2 dissolves to form carbonic acid, neutralizing basic components.
- Soil Chemistry: Managing soil pH through acid-base reactions involving carbonic acid.

Laboratory Applications

- Titration Protocols: Determining concentrations of unknown solutions.
- Buffer Preparation: Creating solutions that resist pH change, utilizing carbonate and bicarbonate systems.

Complexities and Considerations in Real-World Scenarios

While stoichiometric calculations provide a theoretical foundation, practical applications involve additional factors:

- pH and Equilibrium Dynamics: Because H_2CO_3 is a weak acid, the actual amount of acid needed can vary depending on initial conditions.
- Temperature Effects: Temperature influences dissociation constants and reaction rates.
- Solution Purity: Impurities can alter the reaction pathway or efficiency.
- Measurement Precision: Accurate volumetric equipment is essential for reproducibility.

Conclusion

The detailed analysis of the reaction between 120 mL of 0.15 M carbonic acid and 300 mL of sodium hydroxide underscores the importance of stoichiometry, chemical equilibria, and practical considerations in acid-base chemistry. While theoretical calculations suggest that approximately 100 mL of carbonic acid solution suffices to neutralize the given amount of NaOH, real-world factors can necessitate a slightly larger volume, such as the 120 mL specified.

Understanding these reactions is vital across various fields, including environmental science, industrial manufacturing, and laboratory research. By appreciating the underlying chemistry, practitioners can optimize processes, ensure safety, and develop innovative solutions rooted in fundamental principles.

In essence, the precise interplay between weak acids like carbonic acid and strong bases exemplifies the elegance and complexity of chemical reactions, highlighting the importance of meticulous calculation and experimental validation in scientific endeavors.

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