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What Volume Of 0.140M HCl Is Required For The Complete Neutralization Of 1.40g Of NaHCO3 (sodium Bicarbonate)? What

Understanding the precise volume of hydrochloric acid (HCl) needed to neutralize a given amount of sodium bicarbonate ($NaHCO_3$) is fundamental in chemistry, especially in titration processes and chemical reaction calculations. This article explores how to determine the volume of 0.140M HCl required to completely neutralize 1.40 grams of sodium bicarbonate, providing clear explanations, step-by-step calculations, and relevant insights to enhance your understanding of acid-base reactions.

Introduction to Acid-Base Neutralization

What Is Neutralization?

Neutralization is a chemical reaction where an acid and a base react to form water and a salt. In the case of hydrochloric acid and sodium bicarbonate, the reaction results in the formation of sodium chloride, water, and carbon dioxide.

Significance of Knowing the Required Volume of HCl

Calculating the required volume of HCl for neutralization is crucial in various applications, including titration experiments, industrial processes, and pharmaceutical formulations. Accurate measurements ensure safety, efficiency, and precision in chemical procedures.

Understanding the Chemical Reaction

Balanced Chemical Equation

The reaction between hydrochloric acid and sodium bicarbonate can be represented as:

$$
\mathrm{NaHCO_3\, (s)} + \mathrm{HCl\, (aq)} \rightarrow \mathrm{NaCl\, (aq)} + \mathrm{H_2O\, (l)} + \mathrm{CO_2\, (g)}
$$

This balanced equation indicates a 1:1 molar ratio between $NaHCO_3$ and HCl.

Molar Ratios and Their Importance

The molar ratio tells us that one mole of sodium bicarbonate reacts with one mole of hydrochloric acid. Therefore, knowing the number of moles of $NaHCO_3$ allows us to determine the moles of HCl required for complete neutralization.

Calculating Moles of Sodium Bicarbonate ($NaHCO_3$)

Step 1: Find the molar mass of $NaHCO_3$

The molar mass of sodium bicarbonate is calculated by summing atomic masses:

- Sodium (Na): 22.99 g/mol
- Hydrogen (H): 1.01 g/mol
- Carbon (C): 12.01 g/mol
- Oxygen (O): 16.00 g/mol (there are 3 oxygen atoms)

$$
\text{Molar mass of NaHCO}_3 = 22.99 + 1.01 + 12.01 + (3 \times 16.00) = 22.99 + 1.01 + 12.01 + 48.00 = 84.01\, \text{g/mol}
$$

Step 2: Calculate moles of $NaHCO_3$ in 1.40g

Using the formula:

$$
\text{Moles} = \frac{\text{Mass}}{\text{Molar mass}}
$$

$$
\text{Moles of NaHCO}_3 = \frac{1.40\, \text{g}}{84.01\, \text{g/mol}} \approx 0.01667\, \text{mol}
$$

This means there are approximately 0.01667 moles of sodium bicarbonate present.

Determining the Moles of HCl Needed

Step 1: Use the molar ratio from the balanced equation

Since the reaction ratio is 1:1, the moles of HCl required are equal to the moles of $NaHCO_3$:

$$
\text{Moles of HCl} = 0.01667\, \text{mol}
$$

Step 2: Find the volume of HCl solution needed

Given the molarity (concentration) of HCl:

$$
\text{Concentration} = 0.140\, \text{mol/L}
$$

\]

The volume (V) needed is calculated by rearranging the molarity formula:

$$
V = \frac{\text{Moles of solute}}{\text{Concentration}}
$$

$$
V = \frac{0.01667\, \text{mol}}{0.140\, \text{mol/L}} \approx 0.119\, \text{L}
$$

Converting liters to milliliters:

$$
0.119\, \text{L} \times 1000 = 119\, \text{mL}
$$

Therefore, approximately 119 mL of 0.140M HCl is required to completely neutralize 1.40 grams of sodium bicarbonate.

Summary of the Calculation Steps

To summarize, here are the key steps involved in calculating the required volume:

1. Determine the molar mass of sodium bicarbonate ($NaHCO_3$): 84.01 g/mol
2. Calculate moles of $NaHCO_3$ in 1.40g: approximately 0.01667 mol
3. Use the molar ratio (1:1) to find moles of HCl needed: 0.01667 mol
4. Calculate the volume of 0.140M HCl solution required: approximately 119 mL

Additional Considerations and Practical Tips

Precision in Titration

When performing actual titrations, it's essential to use precise measuring tools like burettes and pipettes to measure solution volumes accurately. This ensures your calculated values closely match experimental results.

Safety Precautions

Handling acids such as HCl requires proper safety equipment including gloves, goggles, and lab coats. Always add acid to water, not the other way around, to prevent splashing.

Environmental and Waste Disposal

Neutralized solutions should be disposed of according to local regulations. Avoid pouring acids directly

down the drain without proper neutralization.

Applications of This Calculation

Educational Demonstrations

Understanding the volume of acid needed for neutralization is fundamental in teaching titration techniques and acid-base chemistry.

Industrial Processes

Accurate calculations ensure the correct amount of acid is used in manufacturing processes, minimizing waste and optimizing costs.

Pharmaceutical Formulations

Precise neutralization calculations are critical in preparing medications and solutions with exact pH levels.

Conclusion

Determining the volume of 0.140M HCl needed to neutralize 1.40 grams of sodium bicarbonate involves understanding the chemical reaction, calculating moles, and applying molarity principles. By following the outlined steps, you can accurately calculate that approximately 119 mL of HCl is required for complete neutralization. Mastery of these calculations enhances your chemical proficiency, supports safe laboratory practices, and underpins various scientific and industrial applications.

In summary:

- Molar mass of $NaHCO_3$: 84.01 g/mol
- Moles of $NaHCO_3$ in 1.40 g: approximately 0.01667 mol
- Moles of HCl required: 0.01667 mol
- Volume of 0.140M HCl needed: approximately 119 mL

Understanding these principles empowers you to perform accurate titrations and chemical calculations, essential skills in chemistry and related fields.

Frequently Asked Questions

How do you determine the volume of 0.140 M HCl needed to neutralize 1.40 g of $NaHCO_3$?

First, calculate the moles of $NaHCO_3$ using its molar mass, then use the molar ratio from the balanced equation to find the moles of HCl required, and finally divide by the concentration of HCl to find the volume needed.

What is the molar mass of sodium bicarbonate ($NaHCO_3$)?

The molar mass of $NaHCO_3$ is approximately 84.01 g/mol.

What is the balanced chemical equation for the neutralization of $NaHCO_3$ with HCl?

$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$

How many moles of $NaHCO_3$ are present in 1.40 g?

Number of moles = 1.40 g ÷ 84.01 g/mol ≈ 0.01667 mol.

What is the molar ratio of HCl to $NaHCO_3$ in the reaction?

The ratio is 1:1; one mole of HCl neutralizes one mole of $NaHCO_3$.

How do you calculate the volume of HCl solution needed for complete neutralization?

Use the formula: Volume = moles of HCl ÷ concentration of HCl; since moles of HCl = moles of $NaHCO_3$, substitute the values accordingly.

What is the final calculation for the volume of 0.140 M HCl required?

Volume = 0.01667 mol ÷ 0.140 mol/L ≈ 0.119 L or 119 mL.

Why is it important to convert grams to moles in titration calculations?

Because titrations are based on molar ratios, converting grams to moles allows for accurate stoichiometric calculations.

What assumptions are made in this calculation?

Assumptions include pure $NaHCO_3$ sample, complete reaction without side reactions, and accurate concentration of HCl solution.

How can this calculation be applied in a laboratory setting?

It helps determine the precise volume of acid needed to neutralize a known amount of base, essential for titration experiments and solution preparation.

Additional Resources

Neutralization: The Key to Understanding Acid-Base Reactions

When considering chemical reactions, particularly those involving acids and bases, the concept of neutralization is fundamental. In this detailed exploration, we will analyze the precise volume of 0.140 M hydrochloric acid (HCl) required to completely neutralize 1.40 grams of sodium bicarbonate ($NaHCO_3$). This problem exemplifies core principles of molarity, molar ratios, and stoichiometry, providing a comprehensive understanding suitable for students, educators, and chemistry enthusiasts alike.

Understanding the Chemical Background

The Nature of Sodium Bicarbonate ($NaHCO_3$)

Sodium bicarbonate, popularly known as baking soda, is an odorless, crystalline compound with widespread applications—from baking to medical uses. Chemically, $NaHCO_3$ is classified as a bicarbonate, serving as a basic compound that can neutralize acids.

Molecular Formula: $NaHCO_3$
Molar Mass: Approximately 84.01 g/mol (calculated as Na: 22.99, H: 1.01, C: 12.01, O_3: 3×16.00)

Properties & Reactions:
$NaHCO_3$ reacts with acids to produce carbon dioxide (CO_2), water (H_2O), and a corresponding salt. For example, with hydrochloric acid:

$$\text{NaHCO}_3 + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{O} + \text{CO}_2$$

The Role of Hydrochloric Acid (HCl)

Hydrochloric acid is a strong, monoprotic acid, meaning each molecule supplies one proton (H^+) in reactions:

Molecular Formula: HCl
Molarity: 0.140 M (moles per liter)

In neutralization reactions, HCl reacts with basic compounds like $NaHCO_3$ in a 1:1 molar ratio, owing to its monoprotic nature.

Step-by-Step Calculation of the Required Volume

The goal is to determine how much 0.140 M HCl is needed to completely react with a given amount of sodium bicarbonate.

Step 1: Calculate the Moles of Sodium Bicarbonate ($NaHCO_3$)

Given:
Mass of $NaHCO_3$ = 1.40 g

Using molar mass:
$$\text{Moles of NaHCO}_3 = \frac{\text{Mass}}{\text{Molar mass}} = \frac{1.40\,g}{84.01\,g/mol}$$

\]

\[
\text{Moles of NaHCO}_3 \approx 0.01667\, \text{mol}
\]

This is the amount of bicarbonate that needs to be neutralized.

Step 2: Write the Balanced Chemical Equation

The reaction between $NaHCO_3$ and HCl is:

\[
\text{NaHCO}_3 + \text{HCl} \rightarrow \text{NaCl} + \text{H}_2\text{O} + \text{CO}_2
\]

This indicates a 1:1 molar ratio, meaning 1 mole of $NaHCO_3$ reacts with 1 mole of HCl.

Step 3: Determine Moles of HCl Needed

Since the molar ratio is 1:1:

\[
\text{Moles of HCl required} = \text{Moles of NaHCO}_3 = 0.01667\, \text{mol}
\]

Step 4: Calculate the Volume of HCl Solution Needed

Using the molarity of the HCl solution:

\[
\text{Molarity} (M) = \frac{\text{moles of solute}}{\text{volume in liters}}
\]

Rearranged for volume:

\[
\text{Volume} = \frac{\text{moles of solute}}{\text{molarity}}
\]

\[
\text{Volume of HCl} = \frac{0.01667\, \text{mol}}{0.140\, \text{mol/L}}
\]

\[
\text{Volume} \approx 0.119\, \text{L}
\]

Expressed in milliliters:

$$
0.119\, \text{L} \times 1000\, \text{mL/L} = 119\, \text{mL}
$$

Summary of Findings

To completely neutralize 1.40 grams of sodium bicarbonate, approximately 119 milliliters of 0.140 M hydrochloric acid are required. This precise calculation underscores the importance of stoichiometry and molarity in quantitative chemical analysis.

Additional Insights and Practical Considerations

Factors Affecting the Reaction and Measurement Accuracy

While the calculation provides an idealized figure, several practical aspects can influence the actual volume needed:

- Purity of Reagents: Commercial reagents may contain impurities affecting molar ratios.
- Measurement Precision: Accurate weighing and volume measurement tools are essential.
- Reaction Completeness: Ensuring the reaction proceeds to completion, possibly by monitoring pH.
- Temperature Effects: Temperature can influence molar volume and reaction rate, though minimal in dilute solutions.

Safety Precautions in Laboratory Settings

Handling acids like HCl requires proper safety measures:

- Use of gloves, goggles, and lab coats.
- Conducting reactions in a fume hood.
- Proper disposal of acid waste.

Conclusion: The Significance of Quantitative Analysis

This detailed exploration exemplifies the power of stoichiometry in predicting and controlling chemical reactions. Understanding how to calculate the volume of acid needed for neutralization not only enhances laboratory proficiency but also deepens comprehension of fundamental chemical principles. Whether in research, industry, or education, mastery of these calculations is indispensable for accurate and safe chemical handling.

In essence, approximately 119 mL of 0.140 M HCl is required to achieve complete neutralization of 1.40 grams of sodium bicarbonate—a testament to the precision and predictability that define chemistry's analytical

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