What Volume Of 0.130 M HCl Is Required For The Complete Neutralization Of 1.30 G Of NaHCO3 (sodium Bicarbonate)?

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Understanding the precise volume of hydrochloric acid (HCl) needed to neutralize a specific amount of sodium bicarbonate ($NaHCO_3$) is fundamental in chemistry, especially in titration processes. This calculation not only helps in laboratory experiments but also has practical applications in industries such as pharmaceuticals, water treatment, and food production. In this comprehensive guide, we will explore the detailed steps to determine the volume of 0.130 M HCl required to completely neutralize 1.30 grams of sodium bicarbonate, ensuring clarity and precision in chemical calculations.

Fundamental Concepts and Chemical Reactions Involved

Understanding Sodium Bicarbonate ($NaHCO_3$)

Sodium bicarbonate, commonly known as baking soda, is a white crystalline powder with the chemical formula $NaHCO_3$. It acts as a weak base and is often used in neutralizations, baking, and medicinal applications.

Hydrochloric Acid (HCl) - The Strong Acid

Hydrochloric acid is a strong acid, fully ionizing in solution, and is frequently used in titrations to determine the amount of basic substances.

The Neutralization Reaction

When sodium bicarbonate reacts with hydrochloric acid, the following reaction occurs:

$NaHCO_3$ (s) + HCl (aq) → NaCl (aq) + H_2O (l) + CO_2 (g)

This reaction shows that one mole of sodium bicarbonate reacts with one mole of hydrochloric acid to produce sodium chloride, water, and carbon dioxide gas.

Step-by-Step Calculation Process

To find the required volume of 0.130 M HCl, we need to follow a systematic approach involving molar calculations, stoichiometry, and unit conversions.

Step 1: Calculate the molar mass of $NaHCO_3$

Element	Atomic Mass (g/mol)	Quantity in $NaHCO_3$	Total Mass Contribution (g/mol)
Sodium (Na)	22.99	1	22.99
Hydrogen (H)	1.008	1	1.008
Carbon (C)	12.01	1	12.01
Oxygen (O)	16.00	3	48.00

Total molar mass of $NaHCO_3$ = 22.99 + 1.008 + 12.01 + 48.00 = 84.008 g/mol

Step 2: Determine the number of moles of $NaHCO_3$ in 1.30 grams

Number of moles = mass / molar mass
Number of moles = 1.30 g / 84.008 g/mol ≈ 0.01548 mol

Step 3: Write the balanced chemical equation and determine the mole ratio

The reaction:

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

shows a 1:1 molar ratio between $NaHCO_3$ and HCl.

Thus, moles of HCl needed = moles of $NaHCO_3$ = 0.01548 mol

Step 4: Calculate the volume of HCl solution required

Given molarity of HCl = 0.130 mol/L

Using the relation:

Volume (L) = moles / molarity

Volume (L) = 0.01548 mol / 0.130 mol/L ≈ 0.1191 L

Convert liters to milliliters:

0.1191 L × 1000 = 119.1 mL

Therefore, approximately 119.1 milliliters of 0.130 M HCl are required for complete neutralization.

Additional Considerations and Practical Tips

Accuracy in Measurement

- Use precise volumetric equipment such as burettes for titration.
- Ensure the HCl solution is well-mixed and at the correct concentration.

Adjusting for Experimental Conditions

- If the concentration of HCl deviates from 0.130 M, recalculate accordingly.
- Always perform a titration with a small sample to confirm the theoretical calculations.

Safety Precautions

- Handle HCl with care; use gloves and eye protection.
- Conduct titrations in a well-ventilated area or fume hood, especially if CO_2 is released.

Real-World Applications of These Calculations

Understanding how to calculate the volume of acid needed for neutralization has several practical applications:

1. Laboratory Titrations: Accurate determination of unknown concentrations of acids or bases.
2. Industrial Processes: In manufacturing where precise chemical dosing is critical.
3. Environmental Monitoring: Neutralizing acidic waste streams before disposal.
4. Food Industry: Adjusting pH levels in products like baking or beverages.
5. Pharmaceuticals: Formulating medications with precise chemical balances.

Summary of the Calculation

- Mass of $NaHCO_3$: 1.30 g
- Molecular weight of $NaHCO_3$: 84.008 g/mol
- Moles of $NaHCO_3$: 0.01548 mol
- Moles of HCl required: 0.01548 mol (1:1 ratio)

- Concentration of HCl: 0.130 mol/L
- Volume of HCl needed: approximately 119.1 mL

In conclusion, to fully neutralize 1.30 grams of sodium bicarbonate, approximately 119.1 milliliters of 0.130 M hydrochloric acid are required.

Conclusion

Calculating the volume of acid needed for neutralization reactions is a fundamental skill in chemistry that combines concepts of molar mass, stoichiometry, and solution concentration. In this case, understanding the reaction between sodium bicarbonate and hydrochloric acid allows us to determine that about 119.1 mL of 0.130 M HCl is necessary for complete neutralization of 1.30 grams of $NaHCO_3$. This process underscores the importance of precise measurements and calculations in chemical processes, ensuring safety, efficiency, and accuracy in various scientific and industrial applications.

References and Further Reading

- Zumdahl, S. S., & Zumdahl, S. A. (2014). Chemistry: An Atoms First Approach. Cengage Learning.
- Tro, N. J. (2017). Chemistry: A Molecular Approach. Pearson.
- http://chemistry.about.com/od/stoichiometry/a/acid-base-reactions.htm
- Safety data sheets (SDS) for hydrochloric acid and sodium bicarbonate.

By mastering these calculations, students and professionals alike can confidently approach titration problems and chemical neutralizations with accuracy and understanding.

Frequently Asked Questions

How do you determine the volume of 0.130 M HCl needed to neutralize 1.30 g of $NaHCO_3$?

First, calculate the moles of $NaHCO_3$ using its molar mass, then use the stoichiometry of the neutralization reaction to find the moles of HCl required, and finally divide by the concentration of HCl to find the volume needed.

What is the balanced chemical equation for the reaction between $NaHCO_3$ and HCl?

The balanced equation is $NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$.

How many moles of $NaHCO_3$ are present in 1.30 g?

Moles of $NaHCO_3$ = 1.30 g / 84.01 g/mol ≈ 0.01548 mol.

What is the molarity of HCl used in the neutralization?

The concentration of HCl is 0.130 M, meaning 0.130 mol of HCl per liter.

How do you calculate the volume of HCl required in liters?

Use the formula Volume = moles of $NaHCO_3$ / molarity of HCl. So, Volume = 0.01548 mol / 0.130 mol/L ≈ 0.119 L.

What is the volume of HCl required in milliliters?

Convert liters to milliliters: 0.119 L × 1000 ≈ 119 mL.

Why is it important to use the correct molarity of HCl for this calculation?

Using the correct molarity ensures accurate calculation of the volume needed to fully neutralize the given amount of $NaHCO_3$, preventing under- or over-neutralization.

Can this calculation be applied to other similar neutralization problems?

Yes, by adjusting the molar masses, amounts, and concentrations, similar stoichiometric calculations can be used for other neutralization reactions involving different substances.

Additional Resources

What Volume Of 0.130 M HCl Is Required For The Complete Neutralization Of 1.30 G Of $NaHCO_3$ (sodium Bicarbonate)?

Understanding the precise quantities of chemicals needed for reactions is fundamental in chemistry, whether in laboratory settings or industrial processes. A common scenario involves determining how much hydrochloric acid (HCl) is required to completely neutralize a given amount of sodium bicarbonate ($NaHCO_3$). This calculation not only exemplifies core principles of stoichiometry but also illustrates how molarity, molar ratios, and mass relationships intertwine. In this article, we will explore the process step-by-step, providing a clear and detailed explanation suitable for students, educators, and professionals alike.

Basic Chemistry Background

Understanding Sodium Bicarbonate ($NaHCO_3$)

Sodium bicarbonate, commonly known as baking soda, is a chemical compound with the formula $NaHCO_3$. It is a white, crystalline solid that reacts with acids to produce carbon dioxide gas, water, and a salt. Its chemical properties make it valuable in baking, cleaning, and medical applications.

In terms of chemical behavior, $NaHCO_3$ is a weak base that reacts with strong acids like hydrochloric acid (HCl) to undergo neutralization:

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

This reaction is particularly important because it involves both acid-base chemistry and gas evolution, which can be observed as bubbling or foaming.

Molarity and Its Significance

Molarity (M) expresses the concentration of a solution in moles of solute per liter of solution. For example, a 0.130 M HCl solution contains 0.130 moles of HCl in every liter of solution. Knowing the molarity allows chemists to calculate the amount of reactant needed or produced in a reaction, which is fundamental for precise quantitative analysis.

Step-by-Step Calculation of Required HCl Volume

The goal is to determine how much 0.130 M HCl is necessary to fully neutralize 1.30 grams of $NaHCO_3$. The process involves several key steps:

1. Convert the mass of $NaHCO_3$ to moles.
2. Use the chemical reaction to relate moles of $NaHCO_3$ to moles of HCl.
3. Calculate the volume of HCl solution needed using molarity.

Let's explore each step in detail.

Step 1: Convert Mass of $NaHCO_3$ to Moles

The molar mass of $NaHCO_3$ is calculated by summing the atomic masses:

- Sodium (Na): approximately 22.99 g/mol
- Hydrogen (H): approximately 1.008 g/mol
- Carbon (C): approximately 12.01 g/mol
- Oxygen (O): approximately 16.00 g/mol, and there are three oxygens.

Calculating:

Molar mass of $NaHCO_3 = 22.99 + 1.008 + 12.01 + (3 \times 16.00)$

= 22.99 + 1.008 + 12.01 + 48.00
= 83.008 g/mol

Now, convert the given mass to moles:

Number of moles of $NaHCO_3$ = mass / molar mass
= 1.30 g / 83.008 g/mol
≈ 0.01566 mol

Step 2: Use the Reaction to Find Moles of HCl Needed

The balanced chemical equation for the neutralization is:

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

This shows a 1:1 molar ratio between $NaHCO_3$ and HCl, meaning:

- 1 mol of $NaHCO_3$ reacts with 1 mol of HCl

Therefore, the moles of HCl required are equal to the moles of $NaHCO_3$:

HCl needed = 0.01566 mol

Step 3: Calculate the Volume of HCl Solution Needed

Knowing the molarity of HCl allows us to determine the volume needed:

Molarity (M) = moles / volume (L)

Rearranged:

Volume (L) = moles / molarity

Plugging in the values:

Volume of HCl = 0.01566 mol / 0.130 mol/L
≈ 0.1205 L

Converting to milliliters:

0.1205 L × 1000 mL/L ≈ 120.5 mL

Final Result: Approximately 120.5 milliliters of 0.130 M HCl are required for complete neutralization of 1.30 grams of $NaHCO_3$.

Implications and Practical Considerations

Precision and Safety

While the calculation provides an exact volume under ideal conditions, practical laboratory procedures require careful measurement and safety precautions:

- Use calibrated volumetric equipment, such as burettes or graduated cylinders, for accuracy.
- Handle acids with appropriate personal protective equipment, including gloves and goggles.
- Perform titrations slowly to observe the endpoint accurately if conducting an experimental validation.

Adjustments for Real-World Conditions

In real scenarios, factors such as solution purity, temperature, and measurement errors can influence the results. It's often advisable to perform a small-scale titration to confirm calculations before scaling up.

Broader Applications of This Calculation

Understanding the volume of acid needed for neutralization reactions has several applications:

- Industrial processes: Precise acid-base neutralizations in manufacturing.
- Environmental science: Neutralizing acidic waste streams.
- Pharmaceuticals: Correct formulation of drug compounds involving acid-base chemistry.
- Educational demonstrations: Teaching stoichiometry through hands-on experiments.

Conclusion

Calculating the volume of hydrochloric acid required to neutralize a specific amount of sodium bicarbonate is a fundamental exercise that consolidates key chemical principles. Starting from the mass of $NaHCO_3$, converting to moles, applying the molar ratio, and then using molarity to find volume exemplifies the practical application of stoichiometry. In this case, approximately 120.5 mL of 0.130 M HCl is necessary to completely neutralize 1.30 grams of $NaHCO_3$.

This process underscores the importance of understanding molar relationships, solution concentrations, and careful measurement—skills that are essential for chemists across research, industry, and education. Whether for laboratory titrations or industrial processes, mastering such calculations enables precise control over chemical reactions, ensuring safety, efficiency, and accuracy.

References:

- Zumdahl, S. S., & Zumdahl, S. A. (2014). Chemistry: An Atoms First Approach. Cengage Learning.
- Harris, D. C. (2015). Quantitative Chemical Analysis. Macmillan Higher Education.
- Lide, D. R. (Ed.). (2004). CRC Handbook of Chemistry and Physics. CRC Press.

Note: Always verify calculations with experimental data when possible, and adhere to safety protocols when handling chemicals.

What Volume Of 0 130 M Hcl Is Required For The Complete Neutralization Of 1 30 G Of Nahco3 Sodium Bicarbonate

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