How Many Milliliters (mL) Of A 0.610 M NaOH Solution Are Needed To Neutralize20.0 ML Of A 0.245 M H2SO4solution?

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Understanding the precise volume of a base required to neutralize a given volume of an acid is fundamental in acid-base chemistry, especially in titration experiments. When dealing with strong acids like sulfuric acid (H_2SO_4) and strong bases such as sodium hydroxide (NaOH), stoichiometry allows us to determine the volume of titrant needed to achieve neutralization accurately. This article explores the detailed process of calculating the volume of 0.610 M NaOH necessary to neutralize 20.0 mL of 0.245 M H_2SO_4, including the underlying principles, step-by-step calculations, and key concepts involved.

Understanding the Basics of 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 this process is:

$$\text{Acid} + \text{Base} \rightarrow \text{Salt} + \text{Water}$$

In the context of titration, the goal is to determine the exact volume of titrant (here, NaOH) needed to completely react with a known amount of analyte (H_2SO_4).

Properties of the Reactants

- Sulfuric Acid (H_2SO_4):
- It is a diprotic acid, meaning each molecule can release two protons (H^+).
- Strong acid: dissociates completely in aqueous solution.
- Sodium Hydroxide (NaOH):
- Strong base: also dissociates completely in aqueous solution.
- Provides hydroxide ions (OH^-) that neutralize H^+ ions.

Determining the Balanced Chemical Equation

The first step is to write the balanced chemical equation for the reaction between sulfuric acid and sodium hydroxide.

Reaction Equation

$$ \text{H}_2\text{SO}_4 + 2 \text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2 \text{H}_2\text{O} $$

Explanation:

- Each molecule of sulfuric acid reacts with two molecules of NaOH.
- The sulfate ion (SO_4^{2-}) combines with two Na^+ ions to form sodium sulfate (Na_2SO_4).
- Water is produced from the neutralization of H^+ and OH^- ions.

Stoichiometric Ratios

From the balanced equation, the molar ratio is:

- H_2SO_4 : NaOH = 1 : 2

This ratio indicates that 1 mole of sulfuric acid reacts with 2 moles of sodium hydroxide.

Calculating the Moles of H_2SO_4

Given Data:

- Volume of H_2SO_4 solution (V_1): 20.0 mL
- Concentration of H_2SO_4 (C_1): 0.245 M

Convert Volume to Liters

Since molarity is expressed in mol/L, convert the volume:

$$ V_1 = 20.0\, \text{mL} = 0.0200\, \text{L} $$

Calculate Moles of H_2SO_4

Using the formula:

$$ \text{moles} = \text{molarity} \times \text{volume (L)} $$

$$ \text{moles of H}_2\text{SO}_4 = 0.245\, \text{mol/L} \times 0.0200\, \text{L} = 0.0049\, \text{mol} $$

This is the amount of sulfuric acid present in the solution.

Determining the Moles of NaOH Required

Applying the Stoichiometric Ratio

From the balanced reaction:

$$ \text{H}_2\text{SO}_4 : \text{NaOH} = 1 : 2 $$

Thus, the moles of NaOH needed:

$$ \text{moles of NaOH} = 2 \times \text{moles of H}_2\text{SO}_4 $$

$$ \text{moles of NaOH} = 2 \times 0.0049\, \text{mol} = 0.0098\, \text{mol} $$

This is the amount of NaOH required for complete neutralization.

Calculating the Volume of NaOH Solution Needed

Given Data:

- Concentration of NaOH (C_2): 0.610 M
- Moles needed: 0.0098 mol

Applying the Molarity Formula

Rearranged to find volume:

$$ V_2 = \frac{\text{moles of NaOH}}{\text{molarity of NaOH}} $$

$$ V_2 = \frac{0.0098\, \text{mol}}{0.610\, \text{mol/L}} \approx 0.01607\, \text{L} $$

Convert Volume to Milliliters

$$ V_2 = 0.01607\, \text{L} \times 1000\, \text{mL/L} \approx 16.07\, \text{mL} $$

Therefore, approximately 16.07 mL of 0.610 M NaOH is needed to fully neutralize 20.0 mL of 0.245 M H_2SO_4.

Summary of the Calculation Steps

To summarize, the process involves:

1. Calculating moles of sulfuric acid based on its concentration and volume.
2. Using the stoichiometric ratio to find the required moles of NaOH.
3. Converting the moles of NaOH to volume using its known molarity.

This systematic approach ensures accurate titration calculations, which are essential in laboratory settings for quality control, preparation of solutions, and analytical chemistry.

Additional Considerations and Practical Applications

Factors Affecting Titration Accuracy

While calculations provide theoretical volumes, practical titrations can be influenced by:

- Precise measurement of solution volumes (using calibrated pipettes and burettes).
- Ensuring complete mixing during titration.
- Using indicators (like phenolphthalein) to identify the endpoint.
- Accounting for any impurities or deviations in concentration.

Applications of Such Calculations

- Chemical manufacturing: Ensuring correct proportions of reactants.
- Environmental analysis: Determining pollutant concentrations.
- Pharmaceuticals: Preparing precise formulations.
- Educational purposes: Teaching stoichiometry and titration techniques.

Conclusion

Calculating the volume of NaOH required to neutralize a given amount of sulfuric acid involves understanding the chemical reaction, balancing the equation, and applying stoichiometry principles. In this specific case, approximately 16.07 mL of a 0.610 M NaOH solution is needed to neutralize 20.0 mL of 0.245

M H_2SO_4. Mastery of these calculations is vital for accurate chemical analysis and laboratory precision. By following a structured approach—determining moles, applying molar ratios, and converting to volume—chemists can ensure accurate titrations and reliable results across various applications.

Frequently Asked Questions

How do you determine the volume of NaOH needed to neutralize a given volume of H_2SO_4?

You use the concept of molarity and balanced chemical equations to relate the moles of H_2SO_4 to the moles of NaOH required, then apply the formula: volume = moles / concentration.

What is the balanced chemical equation for the reaction between NaOH and H_2SO_4?

The balanced equation is: $2\ NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2\ H_2O$.

How do you calculate the moles of H_2SO_4 present in 20.0 mL of a 0.245 M solution?

Moles of H_2SO_4 = concentration × volume in liters = 0.245 mol/L × 0.020 L = 0.0049 mol.

How many moles of NaOH are needed to neutralize 0.0049 mol of H_2SO_4?

From the balanced equation, 1 mol of H_2SO_4 reacts with 2 mol of NaOH, so NaOH needed = 2 × 0.0049 mol = 0.0098 mol.

What is the volume of 0.610 M NaOH solution required to provide 0.0098 mol of NaOH?

Volume = moles / concentration = 0.0098 mol / 0.610 mol/L ≈ 0.01607 L or 16.07 mL.

Can you explain why the NaOH volume needed is greater than the H_2SO_4 volume in this neutralization?

Because H_2SO_4 is a diprotic acid, each molecule reacts with two NaOH molecules, requiring more NaOH volume for complete neutralization.

What is the significance of molarity in solving this type of titration problem?

Molarity allows us to convert between concentration and moles, enabling calculation of the exact volume of titrant needed for neutralization.

What are common mistakes to avoid when calculating titration volumes like in this problem?

Common mistakes include mixing up the molar ratios, incorrect unit conversions, and forgetting to use the balanced chemical equation for stoichiometry.

Additional Resources

Understanding the Neutralization of NaOH and H_2SO_4 Solutions: A Comprehensive Calculation

When dealing with acid-base reactions in chemistry, one of the fundamental concepts is molarity and how it relates to the titration process. This detailed exploration will dissect the problem: How many milliliters (mL) of a 0.610 M NaOH solution are needed to neutralize 20.0 mL of a 0.245 M H_2SO_4 solution? We will delve into the principles of molarity, mole concept, stoichiometry, and titration, providing a thorough understanding of the steps involved in solving this problem.

Understanding the Basics: Molarity and Neutralization Reactions

Molarity (M) is a measure of concentration defined as the number of moles of solute per liter of solution:

$$
\text{Molarity} (M) = \frac{\text{moles of solute}}{\text{liters of solution}}
$$

In neutralization reactions, an acid reacts with a base in a stoichiometrically predictable manner. The key is understanding the balanced chemical equation, which indicates the mole ratio of reactants.

The reaction between NaOH and H_2SO_4:

$$
\text{2NaOH} + \text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}
$$

\]

This tells us that:

- 2 moles of NaOH react with 1 mole of H_2SO_4.

Step-by-Step Approach to the Problem

To determine the volume of NaOH needed, follow these steps:

1. Calculate the moles of H_2SO_4 in the given solution.
2. Use the mole ratio from the balanced equation to find the moles of NaOH required.
3. Convert the moles of NaOH to volume using its molarity.

Let's explore each step in detail.

Step 1: Calculating Moles of H_2SO_4

Given data:

- Volume of H_2SO_4 solution, $V_{H_2SO_4} = 20.0\, \text{mL} = 0.0200\, \text{L}$
- Molarity of H_2SO_4, $M_{H_2SO_4} = 0.245\, \text{M}$

The number of moles of H_2SO_4:

$$
\text{moles} = M \times V
$$

$$
= 0.245\, \text{mol/L} \times 0.0200\, \text{L} = 0.0049\, \text{mol}
$$

Interpretation: There are 0.0049 moles of sulfuric acid present in the solution.

Step 2: Using the Stoichiometry of the Reaction

The balanced chemical equation:

$$
\text{2NaOH} + \text{H}_2\text{SO}_4 \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}
$$

From this, the mole ratio:

$$
\text{NaOH} : \text{H}_2\text{SO}_4 = 2 : 1
$$

Thus, to neutralize 0.0049 mol of H_2SO_4:

$$
\text{moles of NaOH} = 2 \times 0.0049 = 0.0098\, \text{mol}
$$

Key Point: You need 0.0098 moles of NaOH for complete neutralization.

Step 3: Calculating the Volume of NaOH Solution Needed

Given molarity of NaOH:

$$
M_{NaOH} = 0.610\, \text{M}
$$

Number of moles of NaOH:

$$
V_{NaOH} = \frac{\text{moles of NaOH}}{M_{NaOH}}
$$

$$
V_{NaOH} = \frac{0.0098\, \text{mol}}{0.610\, \text{mol/L}} \approx 0.01607\, \text{L}
$$

Convert to milliliters:

$$
0.01607\, \text{L} \times 1000\, \text{mL/L} \approx 16.07\, \text{mL}
$$

Final Answer:

$$
\boxed{
\text{Approximately } 16.07\, \text{mL} \text{ of 0.610 M NaOH is needed}
}
$$

Additional Considerations and Deep Dive into Related Concepts

The Importance of Stoichiometry in Titration

Understanding the mole ratio between reactants is paramount. In this case, the 2:1 ratio simplifies calculations but must be derived from the balanced chemical equation. Any deviation or misinterpretation can lead to significant errors.

Significance of Molarity and Concentration

- Molarity directly influences how much solution is needed for a given amount of reactant.
- Precise measurement of solution volumes is crucial, especially in laboratory titrations, to determine unknown concentrations or volumes accurately.

Titration Technique and Practical Implications

- In actual lab settings, titrations involve adding NaOH to the acid solution until the equivalence point, often indicated by a color change with an indicator.
- The calculated volume helps in preparing titrants or in stoichiometric calculations for reactions where the acid or base concentration is unknown.

Real-World Applications and Related Scenarios

- Environmental chemistry: Neutralizing acid spills or acid rain effects.
- Industrial processes: Calculating reagent volumes for chemical manufacturing.
- Pharmaceuticals: Precise formulation of solutions requiring accurate titrations.

Conclusion: Summary of the Calculation Process

To succinctly summarize:

- Moles of H_2SO_4: 0.0049 mol.
- Moles of NaOH required: 0.0098 mol (based on the balanced equation).
- Volume of NaOH solution needed: approximately 16.07 mL.

This process underscores the importance of understanding molarity, mole ratios, and stoichiometry in chemical reactions. Accurate calculations like this are essential in both academic and industrial chemistry to ensure proper reagent use and reaction completion.

Final Remarks

Mastering such calculations enhances one's ability to perform titrations efficiently and accurately. It also reinforces the fundamental principles of chemical reactions, emphasizing the importance of balanced equations, concentration units, and careful measurement. Whether in a classroom, research lab, or industrial setting, these skills are vital for precise chemical manipulation and analysis.

In essence, about 16.07 mL of 0.610 M NaOH solution is required to neutralize 20.0 mL of 0.245 M H_2SO_4, based on stoichiometric principles and molarity calculations.

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