

A 25.0 mL Solution Of HNO₃ Is Neutralized With 42.5 mL Of 0.250 M Ba(OH)₂. What Is The Concentration Of

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Understanding acid-base reactions is fundamental in chemistry, especially when determining unknown concentrations of solutions through titration. In this article, we explore how to calculate the concentration of a nitric acid (HNO₃) solution when it is neutralized with a known volume and concentration of barium hydroxide (Ba(OH)₂). This example illustrates key principles of molarity, stoichiometry, and titration calculations, providing a comprehensive guide for students and enthusiasts alike.

Understanding the Problem

The problem states:

- A 25.0 mL solution of nitric acid (HNO₃) is neutralized.
- The titrant used is 42.5 mL of 0.250 M barium hydroxide (Ba(OH)₂).
- The goal is to find the concentration of the nitric acid solution.

This scenario involves a typical acid-base titration where a strong acid reacts with a strong base. To approach this, we need to understand the chemical reaction involved, write the balanced chemical equation, and then apply stoichiometry to determine the unknown molarity.

The Chemical Reaction Between HNO_3 and Ba(OH)_2

1. The Reaction Equation

The neutralization between nitric acid and barium hydroxide can be represented as:



Key points:

- Barium hydroxide is a strong base, dissociating completely in solution:



- Nitric acid is a strong acid, dissociating completely into H^+ and NO_3^- ions:



- The balanced chemical equation shows that 2 mol of HNO_3 react with 1 mol of Ba(OH)_2 .

2. Molar Ratios

From the balanced equation:

- 2 mol HNO_3 : 1 mol Ba(OH)_2

This molar ratio is critical for calculating the unknown concentration of nitric acid.

Calculating the Moles of Ba(OH)_2

Given:

- Volume of Ba(OH)_2 solution = 42.5 mL = 0.0425 L

- Concentration of Ba(OH)_2 = 0.250 M

The number of moles of Ba(OH)_2 used in the titration:

$$\text{Moles of Ba(OH)}_2 = \text{Concentration} \times \text{Volume}$$

$$= 0.250 \, \text{mol/L} \times 0.0425 \, \text{L}$$

$$= 0.010625 \, \text{mol}$$

This is the amount of base that reacted with the acid.

Determining the Moles of HNO_3

Using the molar ratio from the balanced equation:

$$\text{Moles of HNO}_3 = 2 \times \text{Moles of Ba(OH)}_2$$

$$= 2 \times 0.010625$$

$$= 0.02125 \, \text{mol}$$

So, 0.02125 moles of nitric acid were present in the original 25.0 mL solution.

Calculating the Concentration of HNO_3

Given:

- Volume of HNO_3 solution = 25.0 mL = 0.0250 L

Concentration (molarity) of HNO_3 :

$$\text{Molarity} = \frac{\text{Moles of solute}}{\text{Volume of solution in liters}}$$

$$M = \frac{0.02125 \text{ mol}}{0.0250 \text{ L}}$$

$$M = 0.85 \text{ M}$$

Final answer:

The concentration of the nitric acid solution is 0.85 M.

Summary of the Calculation Steps

1. Identify the balanced chemical equation for the neutralization reaction.
2. Calculate the moles of Ba(OH)_2 used based on its concentration and volume.
3. Use the molar ratio from the balanced equation to find the moles of HNO_3 .
4. Divide the moles of HNO_3 by the initial volume of the acid solution to find its molarity.

Additional Considerations

1. Importance of Accurate Measurements

Accurate measurement of volumes and concentrations is crucial for reliable titration results. Slight errors can significantly affect the calculated molarity.

2. Titration Technique

Using proper titration techniques, such as slow addition near the endpoint and consistent swirling, ensures precise determination of the equivalence point.

3. Safety Precautions

Handling strong acids and bases requires appropriate safety measures, including gloves and eye protection.

Applications of Acid-Base Titration

Understanding how to determine unknown concentrations through titration is essential in various fields:

- Pharmaceuticals: determining active ingredient concentrations
- Environmental science: analyzing pollutant levels in water
- Food industry: assessing acidity in products
- Research laboratories: conducting chemical analyses

Conclusion

By carefully analyzing the reaction between nitric acid and barium hydroxide, and applying stoichiometric principles, we found that the concentration of the nitric acid solution is approximately 0.85 M. This method exemplifies the power of titration in analytical chemistry, enabling precise

determination of unknown solution concentrations through systematic calculations. Whether in academic settings or industrial applications, mastering these concepts is fundamental for accurate chemical analysis and quality control.

Remember: Always ensure your measurements are precise, and understand the underlying chemical reactions to confidently solve titration problems like this one.

Frequently Asked Questions

What is the concentration of HNO_3 in the solution after neutralization with $\text{Ba}(\text{OH})_2$?

First, calculate moles of $\text{Ba}(\text{OH})_2$: $0.250 \text{ M} \times 0.0425 \text{ L} = 0.010625 \text{ mol}$. Since $\text{Ba}(\text{OH})_2$ provides 2 OH^- ions per formula unit, moles of $\text{OH}^- = 2 \times 0.010625 = 0.02125 \text{ mol}$. The neutralization reaction is $\text{HNO}_3 + \text{Ba}(\text{OH})_2 \rightarrow \text{Ba}(\text{NO}_3)_2 + 2 \text{H}_2\text{O}$, so moles of $\text{HNO}_3 = \text{moles of OH}^- = 0.02125 \text{ mol}$. The initial volume of HNO_3 solution is $25.0 \text{ mL} = 0.025 \text{ L}$. Therefore, the concentration of $\text{HNO}_3 = 0.02125 \text{ mol} / 0.025 \text{ L} = 0.85 \text{ M}$.

How do you determine the molarity of HNO_3 from the titration data with $\text{Ba}(\text{OH})_2$?

You calculate the moles of $\text{Ba}(\text{OH})_2$ used: $0.250 \text{ M} \times 0.0425 \text{ L} = 0.010625 \text{ mol}$. Since each $\text{Ba}(\text{OH})_2$ reacts with 2 HNO_3 molecules, the moles of $\text{HNO}_3 = 2 \times 0.010625 \text{ mol} = 0.02125 \text{ mol}$. Dividing this by the initial volume of HNO_3 solution (0.025 L) gives its molarity: 0.85 M.

What is the balanced chemical equation for the neutralization of HNO_3 with $\text{Ba}(\text{OH})_2$?

The balanced equation is: $2 \text{HNO}_3 + \text{Ba}(\text{OH})_2 \rightarrow \text{Ba}(\text{NO}_3)_2 + 2 \text{H}_2\text{O}$. This indicates that 2 moles of HNO_3 react with 1 mole of $\text{Ba}(\text{OH})_2$.

Why is it necessary to consider the mole ratio in calculating the concentration of HNO_3 ?

Because the titration involves a stoichiometric reaction where the molar ratio between HNO_3 and Ba(OH)_2 is 2:1, ensuring accurate calculation of the acid's concentration based on the base volume and molarity.

If the volume of Ba(OH)_2 used was doubled, how would that affect the calculated concentration of HNO_3 ?

Doubling the volume of Ba(OH)_2 would double the moles of base reacted, thus doubling the moles of HNO_3 neutralized. Consequently, the calculated concentration of HNO_3 would also double, assuming the initial volume remains the same.

Additional Resources

Understanding Acid-Base Neutralization: A Deep Dive into the HNO_3 and Ba(OH)_2 Reaction

In the realm of chemistry, understanding neutralization reactions is fundamental for both academic pursuits and practical applications—ranging from industrial processes to laboratory experiments. Today, we explore a classic acid-base reaction involving nitric acid (HNO_3) and barium hydroxide (Ba(OH)_2), focusing on how to determine the concentration of the unknown solution after neutralization. This analysis not only highlights the core principles of molarity and molar ratios but also underscores the importance of precise calculations in chemical reactions.

Background: The Chemistry of HNO_3 and $\text{Ba}(\text{OH})_2$

Before diving into calculations, it's essential to understand the chemical nature of the reactants involved: nitric acid (HNO_3) and barium hydroxide ($\text{Ba}(\text{OH})_2$).

Properties of Nitric Acid (HNO_3)

- Type: Strong acid
- Behavior in water: Completely dissociates into hydrogen ions (H^+) and nitrate ions (NO_3^-)
- Relevance: Commonly used in laboratories and industrial processes, with applications ranging from fertilizer production to chemical synthesis

Properties of Barium Hydroxide ($\text{Ba}(\text{OH})_2$)

- Type: Strong base
- Behavior in water: Fully dissociates into barium ions (Ba^{2+}) and hydroxide ions (OH^-)
- Relevance: Utilized in titrations, analytical chemistry, and as a precursor in manufacturing barium compounds

Understanding the Neutralization Reaction

Reaction Equation:



This balanced equation indicates:

- Two moles of nitric acid react with one mole of barium hydroxide.
- The products are barium nitrate ($\text{Ba}(\text{NO}_3)_2$) and water.

Implication: For every 2 moles of HNO_3 , only 1 mole of $\text{Ba}(\text{OH})_2$ is needed for complete neutralization.

Experimental Data and Objective

Suppose you have:

- A 25.0 mL solution of HNO_3 (unknown concentration, molarity = ?)
- 42.5 mL of 0.250 M $\text{Ba}(\text{OH})_2$ used to titrate the acid

Objective: Determine the molarity of the nitric acid solution.

Step-by-Step Calculation Process

1. Calculate Moles of $\text{Ba}(\text{OH})_2$ Used

The first step involves calculating the number of moles of $\text{Ba}(\text{OH})_2$ in the titrant:

$$\text{Moles of Ba(OH)}_2 = \text{Molarity} \times \text{Volume (in liters)}$$

Convert volume from milliliters to liters:

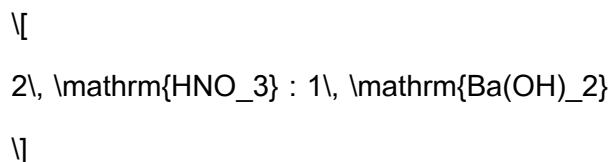
$$\begin{aligned} & \left[\right. \\ & 42.5 \text{ mL} = 0.0425 \text{ L} \\ & \left. \right] \end{aligned}$$

Calculate:

$$\begin{aligned} & \left[\right. \\ & \text{Moles of Ba(OH)}_2 = 0.250 \text{ mol/L} \times 0.0425 \text{ L} = 0.010625 \text{ mol} \\ & \left. \right] \end{aligned}$$

2. Use Stoichiometry to Find Moles of HNO₃

From the balanced equation:



$$\text{Moles of HNO}_3 = 2 \times \text{moles of Ba(OH)}_2$$

$$\begin{aligned} & \left[\right. \\ & \text{Moles of HNO}_3 = 2 \times 0.010625 \text{ mol} = 0.02125 \text{ mol} \\ & \left. \right] \end{aligned}$$

3. Determine Molarity of HNO₃

Given the volume of the HNO₃ solution:

$$V_{\text{HNO}_3} = 25.0\text{ mL} = 0.0250\text{ L}$$

Calculate molarity:

$$\text{Molarity of HNO}_3 = \frac{\text{Moles of HNO}_3}{\text{Volume in liters}} = \frac{0.02125\text{ mol}}{0.0250\text{ L}} = 0.85\text{ M}$$

Implications of the Calculation

Result:

$$\boxed{\text{Concentration of HNO}_3 = \mathbf{0.85\text{ M}}}$$

This value indicates that the nitric acid solution has a molarity of approximately 0.85 mol/L, which is a typical concentration for laboratory acids used in titrations.

Additional Perspectives and Considerations

Why is this calculation important?

- Precision in chemical reactions: Knowing the concentration of an acid or base is vital for process control, safety, and efficacy in both industrial and laboratory settings.
- Titration technique mastery: Mastering the stoichiometric principles ensures accuracy in quantitative analysis.

Common pitfalls to avoid:

- Incorrect unit conversions: Always convert mL to L to maintain consistency.
- Misreading molar ratios: Remember the coefficients from the balanced chemical equation.
- Neglecting complete dissociation: Both HNO_3 and Ba(OH)_2 are strong electrolytes, implying full dissociation.

Variations and extensions:

- Different concentrations: Adjusting the titrant concentration alters the calculation but follows the same principles.
- Using indicators: In practical titrations, indicators signal the endpoint, correlating volume measurements with reaction completion.
- Calculating pH: Post-neutralization, the pH can be calculated based on the remaining species in solution.

Conclusion: The Significance of Accurate Quantitative Analysis

This exploration into the neutralization of nitric acid with barium hydroxide underscores the importance of fundamental chemical principles—stoichiometry, molarity, and balanced equations—in real-world applications. By methodically analyzing the titration data, we deduced that the original HNO_3 solution has a concentration of approximately 0.85 M, a critical piece of information for anyone working with these chemicals.

Such detailed calculations not only reinforce theoretical knowledge but also enhance practical skills in precise laboratory analysis, essential for scientific research, industrial manufacturing, and educational purposes. Mastery of these concepts empowers chemists and students alike to conduct accurate experiments, optimize processes, and ensure safety in handling reactive chemicals.

In essence, understanding acid-base neutralization through calculations like these exemplifies the core of analytical chemistry—transforming data into actionable scientific insights.

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