What Volume (mL) Of 7.48 X 10-2 M Perchloric Acid Can 115 ML Of 0.244 M Sodium Hydroxide? A) 125 B) 8.60

What Volume (mL) Of 7.48 X 10-2 M Perchloric Acid Can 115 ML Of 0.244 M Sodium Hydroxide? A) 125 B) 8.60

Understanding the precise volume of perchloric acid needed to neutralize a given volume of sodium hydroxide is a fundamental concept in acid-base chemistry. This calculation involves stoichiometry, molarity, and volume relationships, which are essential in laboratory titrations and various industrial processes. In this article, we will explore the detailed steps to determine whether 125 mL or 8.60 mL of 7.48×10^{-2} M perchloric acid ($HClO_4$) is required to neutralize 115 mL of 0.244 M sodium hydroxide (NaOH). By following a systematic approach, you will gain a clear understanding of how to solve similar titration problems efficiently.

Understanding the Chemistry: Acid-Base Neutralization

What is Perchloric Acid?

Perchloric acid ($HClO_4$) is a strong mineral acid known for its high acidity and complete dissociation in aqueous solutions. Its strength makes it an excellent titrant for neutralization reactions.

What is Sodium Hydroxide?

Sodium hydroxide (NaOH) is a strong base, also fully dissociating in water, making it reactive and suitable for titration with strong acids.

Neutralization Reaction

The core reaction between perchloric acid and sodium hydroxide is:

$$\mathrm{HClO_4 + NaOH \rightarrow NaClO_4 + H_2O}$$

Since both are strong acid and base, they react in a 1:1 molar ratio.

Step-by-Step Calculation for the Required Volume of Perchloric Acid

Step 1: Write the Known Data

- Concentration of NaOH: $C_{NaOH} = 0.244\, \text{M}$
- Volume of NaOH: $V_{NaOH} = 115\, \text{mL}$
- Concentration of $HClO_4$: $C_{HClO_4} = 7.48 \times 10^{-2}\, \text{M}$

Step 2: Calculate the Moles of NaOH

Using the formula:

$$\text{Moles} = \text{Concentration} \times \text{Volume (in liters)}$$

Convert volume to liters:

$$V_{NaOH} = 115\, \text{mL} = 0.115\, \text{L}$$

Calculate:

$$n_{NaOH} = 0.244\, \text{mol/L} \times 0.115\, \text{L} = 0.02806\, \text{mol}$$

Step 3: Determine Moles of $HClO_4$ Needed

Because the reaction is 1:1:

$$n_{HClO_4} = n_{NaOH} = 0.02806\, \text{mol}$$

Step 4: Calculate the Volume of $HClO_4$ Required

Using molarity:

$$V_{HClO_4} = \frac{n_{HClO_4}}{C_{HClO_4}}$$

$$V_{HClO_4} = \frac{0.02806\, \text{mol}}{7.48 \times 10^{-2}\, \text{mol/L}}$$

$$V_{HClO_4} \approx 0.375\, \text{L}$$

Convert to milliliters:

$$V_{HClO_4} \approx 375\, \text{mL}$$

Analyzing the Results: Which Option is Correct?

Given the options:
- A) 125 mL
- B) 8.60 mL

Our calculation indicates that approximately 375 mL of 7.48×10^{-2} M perchloric acid is required to neutralize 115 mL of 0.244 M NaOH. Neither of the options matches this volume, suggesting a need to re-express or double-check the calculations.

Re-evaluating the Problem: Is There a Misinterpretation?

The initial calculation assumes complete neutralization with a 1:1 molar ratio, which is correct for strong acid-strong base reactions. However, the options provided hint at potential alternative interpretations or perhaps a different question context.

Possible Clarifications and Considerations

1. Are the options referring to the volume of acid needed for a different concentration?

If the options are limited to 125 mL or 8.60 mL, perhaps the question is asking about the volume of concentrated perchloric acid, or perhaps a typo exists.

2. Is there a different stoichiometry or dilution factor involved?

Given the data, the calculations are straightforward for a 1:1 reaction.

3. Could the options be referencing the volume of acid needed for a different amount of base?

No, the problem clearly states 115 mL of 0.244 M NaOH.

Conclusion: Which Option Is Correct Based on Proper Calculation?

Based on standard stoichiometry:

- Volume of perchloric acid needed ≈ 375 mL (for complete neutralization)
- Neither 125 mL nor 8.60 mL matches this volume, indicating potential issues with the options provided or the context.

However, if the question is asking for the volume required to neutralize a different amount of NaOH, or if the options are approximate, then:

- 125 mL is closer to a proportional volume (but still significantly different).
- 8.60 mL is much smaller and unlikely given the calculations.

Summary and Final Thoughts

- Theoretical calculation shows approximately 375 mL of 7.48×10^{-2} M perchloric acid is required to neutralize 115 mL of 0.244 M NaOH.
- Neither of the provided options perfectly matches this value.
- In practical scenarios, always double-check the data, units, and reaction ratios.

Additional Tips for Acid-Base Titration Calculations

- Always convert all volumes to liters when calculating moles.

- Remember the reaction ratio; for strong acid and base, it is typically 1:1.
- Be attentive to the molarity and volume units to avoid calculation errors.
- Use precise calculations and consider significant figures for accuracy.

Conclusion

Accurate determination of the volume of perchloric acid necessary to neutralize a specific amount of sodium hydroxide involves understanding the molarity-volume relationship and the mole ratio from the balanced chemical equation. In this case, the calculations indicate that approximately 375 mL of 7.48×10^{-2} M perchloric acid are needed, which does not align with the options of 125 mL or 8.60 mL. For precise laboratory work or exam settings, always perform detailed step-by-step calculations and verify all data points.

Frequently Asked Questions

What volume (mL) of 7.48 x 10^-2 M perchloric acid is needed to neutralize 115 mL of 0.244 M sodium hydroxide?

8.60 mL

How is the volume of perchloric acid calculated when titrating with sodium hydroxide?

Using the titration formula: M1V1 = M2V2, where M1 and V1 are concentration and volume of acid, and M2 and V2 are those of the base.

What is the molarity of sodium hydroxide in the titration problem?

0.244 M

What is the concentration of perchloric acid in the problem?

7.48 x 10^-2 M

Which option is correct for the volume of perchloric acid needed: 125 mL or 8.60 mL?

8.60 mL

Why is perchloric acid considered a strong acid in titration calculations?

Because it dissociates completely in water, allowing for straightforward molarity calculations during titration.

What is the significance of the molarity values in titration calculations?

They allow for calculating the exact volume of titrant needed to neutralize a given amount of analyte based on molar ratios.

Additional Resources

Perchloric Acid: Unlocking Precise Acid-Base Neutralization Calculations

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Introduction

In the realm of chemical reactions, particularly titrations, understanding the interplay between acids and bases is fundamental. When dealing with solutions of different molarities and volumes, accurate calculations are essential to determine how much of one reagent is needed to neutralize another. Here, we explore a classic acid-base problem: determining the volume (in mL) of a specific concentration of perchloric acid ($HClO_4$) required to neutralize a given volume of sodium hydroxide (NaOH) solution.

This problem not only underscores core principles of molarity and stoichiometry but also illustrates practical application in laboratory settings, industrial processes, and quality control. Let's examine the problem in detail, dissect the chemistry involved, and derive the solution with clarity and precision.

Background: Understanding the Reactants

Perchloric Acid ($HClO_4$)

Perchloric acid is a strong, monoprotic acid—meaning each molecule releases one proton (H^+) during dissociation. Its high reactivity and complete dissociation in aqueous solutions make it an ideal titrant in analytical chemistry. The given concentration of perchloric acid is:

- Concentration: 7.48×10^{-2} M (or 0.0748 mol/L)

Sodium Hydroxide (NaOH)

Sodium hydroxide is a strong base, also dissociating completely in water:

- Concentration: 0.244 M
- Volume: 115 mL

The primary goal is to find out what volume (in mL) of perchloric acid solution at 7.48×10^{-2} M is necessary to neutralize that 115 mL of 0.244 M NaOH.

The Core Concept: Acid-Base Neutralization and Stoichiometry

At the heart of this problem lies the concept of stoichiometry—the quantitative relationship between reactants and products in a chemical reaction.

The Reaction: Acid and Base

Perchloric acid reacts with sodium hydroxide as follows:

$$
\mathrm{HClO_4} + \mathrm{NaOH} \rightarrow \mathrm{NaClO_4} + \mathrm{H_2O}
$$

Since both are strong electrolytes and monoprotic, the reaction ratio is 1:1: one mole of $HClO_4$ reacts with one mole of NaOH.

Step-by-Step Calculation

Step 1: Calculate Moles of NaOH

First, determine how many moles of NaOH are present in 115 mL of 0.244 M solution:

$$
\text{Moles of NaOH} = \text{Concentration} \times \text{Volume (L)}
$$

Convert volume to liters:

$$
115\, \text{mL} = 0.115\, \text{L}
$$

Calculate:

$$
\text{Moles of NaOH} = 0.244\, \text{mol/L} \times 0.115\, \text{L} = 0.02806\, \text{mol}
$$

Step 2: Determine Moles of $HClO_4$ Needed

From the 1:1 reaction ratio, the moles of perchloric acid required are equal to the moles of NaOH:

$$
\text{Moles of HClO}_4 = 0.02806\, \text{mol}
$$

Step 3: Calculate Volume of $HClO_4$ Solution

Using the molarity of perchloric acid, find the volume needed:

$$
\text{Volume of HClO}_4 = \frac{\text{Moles of HClO}_4}{\text{Concentration of HClO}_4}
$$

$$
V = \frac{0.02806\, \text{mol}}{0.0748\, \text{mol/L}} \approx 0.375\, \text{L}
$$

Convert to milliliters:

$$
0.375\, \text{L} = 375\, \text{mL}
$$

Analyzing the Provided Options

With the calculation indicating that approximately 375 mL of the perchloric acid solution is necessary to neutralize the 115 mL of 0.244 M NaOH, neither of the options (A) 125 mL nor (B) 8.60 mL directly matches this result. This discrepancy warrants further discussion.

Possible reasons:

- Unit misinterpretation: Are the options referring to a different scenario?
- Typographical error in the options: Maybe options are misprinted.
- Question context: Could there be a different interpretation of the concentration units or reaction conditions?

Clarification and Reconsideration

Given the initial calculation's straightforward approach, it's clear that 375 mL of perchloric acid is needed for complete neutralization under the specified conditions.

However, the problem explicitly offers two options:

- A) 125 mL
- B) 8.60 mL

This suggests that perhaps the question is asking for the volume of perchloric acid solution required to neutralize only a part of the initial NaOH solution or under different conditions—or perhaps the units or concentrations have been misinterpreted.

Revisiting the problem statement

"What volume (mL) of 7.48×10^{-2} M perchloric acid can 115 mL of 0.244 M sodium hydroxide neutralize?"

- The initial calculation is solid; it indicates about 375 mL of perchloric acid is needed.

- Since the options are significantly lower, it's possible that the question is a multiple-choice based on a different interpretation, such as "What volume of perchloric acid is needed to neutralize a different amount of NaOH".

Alternative Scenario: Calculating for the Given Options

Suppose the question was asking for the volume of perchloric acid that can neutralize a specific amount of NaOH corresponding to the options provided:

For Option A) 125 mL

Calculate moles of NaOH that can be neutralized:

$$
\text{NaOH moles} = 0.244\, \text{mol/L} \times 0.125\, \text{L} = 0.0305\, \text{mol}
$$

Number of moles of $HClO_4$ needed:

$$
0.0305\, \text{mol}
$$

Corresponding volume of perchloric acid:

$$
V = \frac{0.0305\, \text{mol}}{0.0748\, \text{mol/L}} \approx 0.407\, \text{L} = 407\, \text{mL}
$$

Again, not matching options.

For Option B) 8.60 mL

Calculate moles of NaOH:

$$
0.244\, \text{mol/L} \times 0.0086\, \text{L} \approx 0.0021\, \text{mol}
$$

Moles of $HClO_4$ needed:

$$
0.0021\, \text{mol}
$$

Corresponding volume of perchloric acid:

$$
V = \frac{0.0021\, \text{mol}}{0.0748\, \text{mol/L}} \approx 0.028\, \text{L} = 28\, \text{mL}
$$

Again, does not match options.

Final Insights and Practical Implications

Given the calculations, the volume of perchloric acid needed to neutralize 115 mL of 0.244 M NaOH is approximately 375 mL.

However, the options—125 mL and 8.60 mL—are significantly lower. This discrepancy suggests that perhaps the original problem contains a typo or is a simplified question designed to test conceptual understanding rather than exact calculations.

Possible interpretation:

- If the question intended to ask: "What volume of a more concentrated perchloric acid solution (say, 7.48×10^{-1} M, i.e., 0.748 M) is needed?"

Let's test this:

$$
V = \frac{0.02806\, \text{mol}}{0.748\, \text{mol/L}} \approx 0.0375\, \text{L} = 37.5\, \text{mL}
$$

No match, either.

Conclusion: Practical Takeaways

1. Fundamental Principles: For strong acid-strong base reactions, molarity and volume are directly proportional when the reaction ratio is 1:1.

2. Calculations Are Straightforward: Moles of base determine moles of acid needed, which then determine the volume given the acid's molarity.

3. Context Matters: Discrepancies between calculation and options highlight the importance of carefully interpreting problem statements, units, and potential typographical errors.

4. Expert Tip: When faced with conflicting options, double-check the initial data, units, and reaction ratios. Always clarify whether the question pertains to neutralizing the entire base volume or a part of it.

Final Remarks

In laboratory practice,

What Volume Ml Of 7 48 X 10 2 M Perchloric Acid Can 115 Ml Of 0 244 M Sodium Hydroxide A 125 B 8 60

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