3. 78 ML Of 2.5 M Phosphoric Acid Is Neutralized With 500 ML Of Potassium Hydroxide. What Is Theconcentration

3. 78 ML Of 2.5 M Phosphoric Acid Is Neutralized With 500 ML Of Potassium Hydroxide. What Is Theconcentration is a fundamental question in the realm of acid-base chemistry, often encountered in laboratory settings, industrial processes, and educational contexts. Understanding how to calculate the resulting concentration after a neutralization reaction is essential for chemists, students, and anyone working with chemical solutions. This article provides an in-depth exploration of the calculations involved, concepts behind acid-base neutralization, and practical applications, ensuring you gain a comprehensive understanding of this chemical process.

Understanding the Basics of Acid-Base Neutralization

Before delving into the specific problem, it's important to grasp the fundamental principles of acid-base neutralization. Neutralization is a chemical reaction where an acid reacts with a base to produce water and a salt. The general reaction can be summarized as:

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

In the context of the problem, phosphoric acid (H_3PO_4) reacts with potassium hydroxide (KOH). The balanced chemical equation for this reaction is:

$$ \text{H}_3\text{PO}_4 + 3\, \text{KOH} \rightarrow \text{K}_3\text{PO}_4 + 3\, \text{H}_2\text{O} $$

This indicates that one mole of phosphoric acid reacts with three moles of potassium hydroxide.

Calculating the Moles of Reactants

The first step in understanding the final concentration is calculating the number of moles of each reactant involved.

1. Moles of Phosphoric Acid

Given data:
- Volume of phosphoric acid, $V_{H_3PO_4} = 78\, \text{mL} = 0.078\, \text{L}$
- Concentration of phosphoric acid, $M_{H_3PO_4} = 2.5\, \text{M}$

Calculating moles:

$$
\text{moles of } H_3PO_4 = M_{H_3PO_4} \times V_{H_3PO_4} = 2.5\, \text{mol/L} \times 0.078\, \text{L} = 0.195\, \text{mol}
$$

2. Moles of Potassium Hydroxide

Given data:
- Volume of potassium hydroxide, $V_{KOH} = 500\, \text{mL} = 0.5\, \text{L}$

Since the concentration of KOH isn't specified in the problem, but the problem asks for the concentration after neutralization, we need to determine it based on the reaction.

Determining the Moles of KOH Needed

From the balanced chemical equation:

$$ \text{H}_3\text{PO}_4 + 3\, \text{KOH} \rightarrow \text{K}_3\text{PO}_4 + 3\, \text{H}_2\text{O} $$

- 1 mole of H_3PO_4 reacts with 3 moles of KOH.

Given that:

$$
\text{moles of } H_3PO_4 = 0.195\, \text{mol}
$$

The moles of KOH required for complete neutralization:

$$
\text{moles of } KOH = 3 \times 0.195\, \text{mol} = 0.585\, \text{mol}
$$

Calculating the Concentration of Potassium Hydroxide

Since 0.5 L of KOH solution contains x mol of KOH, and we know that 0.585 mol are required for complete neutralization, the concentration M_{KOH} can be calculated as:

$$
M_{KOH} = \frac{\text{moles of KOH}}{\text{volume of KOH in liters}} = \frac{0.585\, \text{mol}}{0.5\, \text{L}} = 1.17\, \text{M}
$$

This indicates that, for complete neutralization, the KOH solution should have a concentration of approximately 1.17 M.

Final Concentration of the Resulting Solution

After neutralization, the solution contains potassium phosphate (K_3PO_4), and the total volume of the solution becomes:

$$
V_{total} = V_{H_3PO_4} + V_{KOH} = 0.078\, \text{L} + 0.5\, \text{L} = 0.578\, \text{L}
$$

The moles of phosphate ions in the final solution are equal to the initial moles of phosphoric acid, assuming complete neutralization:

$$
\text{moles of } K_3PO_4 = 0.195\, \text{mol}
$$

The concentration of potassium phosphate in the final solution:

$$
M_{K_3PO_4} = \frac{\text{moles of } K_3PO_4}{V_{total}} = \frac{0.195\, \text{mol}}{0.578\, \text{L}} \approx 0.337\, \text{M}
$$

Therefore, the concentration of potassium phosphate after neutralization is approximately 0.337 M.

Practical Applications of Acid-Base Neutralization Calculations

Understanding the calculations involved in neutralization reactions is crucial across various fields:

1. Industrial Chemistry

- Designing processes for fertilizer production, where phosphoric acid and potassium hydroxide are used.
- Controlling pH levels in manufacturing to ensure product stability.

2. Laboratory Analysis

- Preparing solutions of precise concentrations for experiments.
- Titration procedures to determine unknown concentrations of acids or bases.

3. Environmental Chemistry

- Neutralizing acidic wastewater before discharge.
- Monitoring natural water bodies for acidification.

Key Points to Remember

- Balanced chemical equations are essential for accurate stoichiometric calculations.
- Moles are the bridge between volume and concentration.
- Complete neutralization occurs when the molar ratios of reactants match those in the balanced equation.
- Final concentrations depend on both the initial concentrations and the total volume after mixing.

Summary

In the specific case of neutralizing 78 mL of 2.5 M phosphoric acid with potassium hydroxide, the key steps involve calculating the moles of acid, determining the required moles of base based on the reaction stoichiometry, and then deriving the concentration of the resulting salt solution. If the potassium hydroxide solution's concentration is 1.17 M, complete neutralization occurs, leading to a final potassium phosphate concentration of approximately 0.337 M in a total volume of about 0.578 liters.

This understanding not only clarifies the calculations involved but also highlights the importance of stoichiometry in practical chemistry applications. Whether in laboratory experiments, industrial processes, or environmental management, mastering these concepts ensures precise solution preparation and effective chemical handling.

If you'd like further explanations on related topics such as titration methods, pH calculations, or buffer solutions, feel free to ask!

Frequently Asked Questions

How do you calculate the concentration of phosphoric acid after neutralization with potassium hydroxide?

You calculate the moles of phosphoric acid using its volume and molarity, then determine the moles of KOH used for neutralization, and finally find the concentration of the resulting solution based on the total volume.

What is the molarity of potassium hydroxide used to neutralize 78 mL of 2.5 M phosphoric acid?

The molarity of KOH can be determined by using the neutralization reaction's molar ratios and the given volumes, resulting in a specific concentration after calculations.

How many moles of phosphoric acid are present in 78 mL of 2.5 M

solution?

Moles of phosphoric acid = 0.078 L × 2.5 mol/L = 0.195 mol.

What is the balanced chemical equation for the neutralization of phosphoric acid with potassium hydroxide?

The balanced equation is: $H_3PO_4 + 3KOH \rightarrow K_3PO_4 + 3H_2O$.

How do you determine the concentration of the resulting solution after neutralization?

Calculate the total moles of acid and base, find the limiting reactant, and then determine the concentration based on the final volume of the solution after mixing.

What is the final concentration of the solution after 78 mL of 2.5 M phosphoric acid is neutralized with 500 mL of KOH?

First, determine the moles of acid and base, then find the total volume of the mixture. Use the remaining moles of unreacted species to calculate the final concentration. (Exact value requires further calculation based on molar ratios.)

Additional Resources

Understanding the Neutralization of Phosphoric Acid with Potassium Hydroxide: A Comprehensive Analysis

When tackling chemical reactions involving acids and bases, the process of neutralization stands as a fundamental concept in chemistry. Specifically, the reaction between phosphoric acid (H_3PO_4) and potassium hydroxide (KOH) offers rich insights into molarity, titration calculations, and solution preparation. In this detailed exploration, we'll analyze the problem: "78 mL of 2.5 M phosphoric acid is neutralized with 500 mL of potassium hydroxide. What is the concentration of the resulting solution?"

This scenario invites us to delve into stoichiometry, molarity calculations, and the principles governing acid-base reactions. Let's systematically examine each component, ensuring clarity at every step.

Background Concepts and Fundamental Principles

Before diving into calculations, it's essential to understand some core concepts that underpin the problem.

1. Molarity (M)

- Definition: Molarity is a measure of concentration, expressed as moles of solute per liter of solution.
- Formula:

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

- Significance: It allows us to quantify how much of a substance is dissolved in a given volume, critical for stoichiometric calculations.

2. The Reaction: Acid-Base Neutralization

- Phosphoric acid (H_3PO_4) is a triprotic acid, meaning it can release three hydrogen ions (H^+) per molecule.
- Potassium hydroxide (KOH) is a strong base, dissociating completely in water into K^+ and OH^- ions.
- The general neutralization reaction for phosphoric acid with KOH involves the stepwise removal of H^+ ions:

$$
\text{H}_3\text{PO}_4 + 3\text{KOH} \rightarrow \text{K}_3\text{PO}_4 + 3\text{H}_2\text{O}
$$

- This balanced reaction indicates a 1:3 molar ratio between phosphoric acid and potassium hydroxide.

3. Stoichiometry in Acid-Base Reactions

- To determine the resulting concentration after neutralization, calculating the number of moles of each reactant is vital.
- The limiting reagent concept helps identify how much of each reactant reacts.

Step-by-Step Calculation Process

Let's now proceed with precise calculations to find the concentration of the final solution after neutralization.

Step 1: Convert Given Volumes to Liters

- Phosphoric acid volume:
$$
78\, \text{mL} = \frac{78}{1000} = 0.078\, \text{L}
$$
- Potassium hydroxide volume:
$$
500\, \text{mL} = \frac{500}{1000} = 0.5\, \text{L}
$$

Step 2: Calculate Moles of Phosphoric Acid

- Given molarity of phosphoric acid: 2.5 M
- Moles of H_3PO_4:
$$
\text{moles} = \text{molarity} \times \text{volume in liters}
$$

$$
= 2.5\, \text{mol/L} \times 0.078\, \text{L} = 0.195\, \text{mol}
$$

Step 3: Determine Moles of KOH Needed for Neutralization

- The balanced reaction shows 1 mol of H_3PO_4 reacts with 3 mol of KOH.
- Moles of KOH required:
$$
0.195\, \text{mol} \times 3 = 0.585\, \text{mol}
$$

Step 4: Calculate Molarity of KOH

- Given volume of KOH: 0.5 L
- Since the amount of KOH present is essential, but the problem states that 500 mL of KOH is used for neutralization, we need to find the molarity of KOH based on its moles.

- Let's denote the molarity of KOH as M_{KOH}.

- Moles of KOH in the solution:

$$
M_{KOH} \times 0.5\, \text{L}
$$

- At this point, it's critical to clarify: the problem states that 78 mL of 2.5 M phosphoric acid is neutralized with 500 mL of potassium hydroxide, but it doesn't specify whether the KOH is in excess or exactly enough. Typically, in such problems, the KOH solution's molarity is unknown, and we are asked for the resulting concentration after neutralization.

- Assumption: The 500 mL of KOH solution contains just enough KOH to neutralize the acid (i.e., the reaction goes to completion with no excess). Therefore, the molarity of KOH can be calculated based on the moles needed for neutralization.

- Moles of KOH in 500 mL:

$$
M_{KOH} \times 0.5\, \text{L} = 0.585\, \text{mol}
$$

$$
M_{KOH} = \frac{0.585\, \text{mol}}{0.5\, \text{L}} = 1.17\, \text{M}
$$

Thus, the molarity of the KOH solution is approximately 1.17 M.

Calculating the Final Concentration of the Neutralized Solution

Having established the initial molarities and moles involved, the next step involves determining the concentration of the resultant solution after neutralization.

1. Total Volume of the Final Solution

- When two solutions are mixed, their volumes are additive (assuming ideal behavior).
- Total volume:

$$
V_{total} = 78\, \text{mL} + 500\, \text{mL} = 578\, \text{mL} = 0.578\, \text{L}
$$

2. Moles of Phosphoric Acid and Potassium Hydroxide

- Moles of phosphoric acid: 0.195 mol (as previously calculated).
- Moles of KOH used: 0.585 mol.

3. Determining the Limiting Reagent and Reaction Completion

- Given the molar ratios, KOH is in excess (since the required moles are 0.585 mol, and the initial KOH amount in 0.5 L at 1.17 M is exactly 0.585 mol).
- The reaction proceeds to neutralize all of the phosphoric acid, resulting in a solution containing potassium phosphate (K_3PO_4) and water.

4. Concentration of the Resulting Solution

- Since all phosphoric acid is neutralized, the key is to determine the concentration of the product, potassium phosphate, or the overall solution.

- Note: The question asks, "What is the concentration?" but doesn't specify whether it refers to the concentration of the residual acid, the resulting salt, or the total solution.

- In most contexts, after neutralization, the solution contains dissolved ions: K^+, PO_4^{3-}, and water, with the salt K_3PO_4 formed.

- Calculating the concentration of the salt (K_3PO_4):
- Moles of K_3PO_4 produced = moles of phosphoric acid neutralized = 0.195 mol.

- Final concentration of K_3PO_4:

$$
C_{K_3PO_4} = \frac{\text{moles}}{\text{total volume}} = \frac{0.195\, \text{mol}}{0.578\, \text{L}} \approx 0.337\, \text{M}
$$

\]

Summary and Final Insights

- Molarity of KOH solution: approximately 1.17 M.
- Total volume of the mixture after neutralization: 0.578 L.
- Moles of phosphoric acid initially present: 0.195 mol.
- Moles of KOH used for neutralization: 0.585 mol.
- Concentration of potassium phosphate (K_3PO_4) in the final mixture: approximately 0.337 M.

Additional Considerations and Practical Implications

While the above calculations provide a theoretical framework, real-world applications may involve complexities such as:

- Incomplete reactions: Usually negligible with strong acids/bases under ideal conditions.
- Volume contraction or expansion: Minor effects, generally ignored in ideal calculations.
- Solution behavior: Deviations from

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