If 6.00 Ml Of 0.4 M Phosphoric Acid (H3PO4) Reacted With 18 ML Of 0.5 M Sodium Hydroxide (NaOH). Calculate

If 6.00 mL Of 0.4 M Phosphoric Acid (H_3PO_4) Reacted With 18 mL Of 0.5 M Sodium Hydroxide (NaOH). Calculate

Understanding the chemical reactions between acids and bases is fundamental in chemistry. When dealing with specific volumes and molarities, calculating the amount of reactants involved, the extent of the reaction, or the leftover reactants requires precise stoichiometric analysis. In this article, we will explore how to determine the reaction outcome when 6.00 mL of 0.4 M phosphoric acid reacts with 18 mL of 0.5 M sodium hydroxide, including detailed calculations and explanations.

Overview of the Reaction Between Phosphoric Acid and Sodium Hydroxide

1. Chemical Equation and Stoichiometry

The reaction between phosphoric acid (H_3PO_4) and sodium hydroxide (NaOH) is a typical acid-base neutralization:

$H_3PO_4 + 3\ NaOH \rightarrow Na_3PO_4 + 3\ H_2O$

- Phosphoric acid is a triprotic acid, meaning it can donate three protons (H^+).
- Sodium hydroxide is a strong base that can accept protons.

The balanced chemical equation indicates that one mole of H_3PO_4 reacts with three moles of NaOH.

2. Calculating Moles of Reactants

Before proceeding, it is essential to calculate the number of moles of each reactant based on their given volumes and molarities.

a. Moles of Phosphoric Acid (H_3PO_4):

- Volume of H_3PO_4 = 6.00 mL = 0.00600 L
- Molarity of H_3PO_4 = 0.4 M

Moles of H_3PO_4 = Molarity × Volume = 0.4 mol/L × 0.00600 L = 0.00240 mol

b. Moles of Sodium Hydroxide (NaOH):

- Volume of NaOH = 18 mL = 0.01800 L
- Molarity of NaOH = 0.5 M

Moles of NaOH = 0.5 mol/L × 0.01800 L = 0.00900 mol

Stoichiometric Analysis of the Reaction

1. Determining the Limiting Reactant

Based on the balanced chemical equation, the molar ratio is:

H_3PO_4 : NaOH = 1 : 3

- Moles of NaOH required to completely react with 0.00240 mol of H_3PO_4:

NaOH needed = 0.00240 mol × 3 = 0.00720 mol

- Available moles of NaOH = 0.00900 mol

Since 0.00900 mol > 0.00720 mol, there is more NaOH than needed, meaning NaOH is in excess.

- Therefore, phosphoric acid is the limiting reactant.

2. Determining the Extent of the Reaction

Since the limiting reactant (H_3PO_4) is 0.00240 mol and the molar ratio is 1:3, the amount of NaOH that reacts is:

NaOH reacted = 0.00240 mol × 3 = 0.00720 mol

Remaining NaOH:

Remaining NaOH = 0.00900 mol − 0.00720 mol = 0.00180 mol

Calculations of Final Concentrations and

Remaining Reactants

1. Moles of NaOH Remaining

- Remaining NaOH = 0.00180 mol

2. Volume of the mixture:

- Total volume = 6.00 mL + 18.00 mL = 24.00 mL = 0.02400 L

3. Concentration of leftover NaOH:

Concentration = Moles / Volume = 0.00180 mol / 0.02400 L = 0.075 M

4. Moles of Unreacted Phosphoric Acid

Since all 0.00240 mol of H_3PO_4 reacted, there is no phosphoric acid remaining.

Summary of Results

- Reacted phosphoric acid: 0.00240 mol
- Remaining sodium hydroxide: 0.00180 mol
- Final concentration of remaining NaOH: 0.075 M
- Phosphoric acid remaining: None (completely reacted)

Additional Considerations and Applications

1. pH Calculation of the Final Solution

To determine the pH of the solution after the reaction, considering the excess NaOH:

$pOH = -\log [OH^-] = -\log 0.075 \approx 1.12$

$pH = 14 - pOH \approx 12.88$

This indicates a basic solution due to excess NaOH.

2. Implications in Industrial and Laboratory Settings

Understanding the stoichiometry of acid-base reactions like this is crucial in various settings:

- Titration procedures: Accurate determination of reactant concentrations.
- Chemical manufacturing: Ensuring complete reactions and proper waste management.
- Pharmaceuticals: Precise formulation of compounds requiring pH adjustments.

Conclusion

By analyzing the reaction between 6.00 mL of 0.4 M phosphoric acid and 18 mL of 0.5 M sodium hydroxide, we've demonstrated essential stoichiometric calculations. The limiting reactant was phosphoric acid, which fully reacted, leaving excess NaOH in solution. The remaining sodium hydroxide has a concentration of approximately 0.075 M, resulting in a solution with a pH around 12.88. Such calculations are fundamental in chemistry for controlling reactions, preparing solutions, and understanding reaction dynamics. Mastery of these principles enables chemists to predict reaction outcomes accurately and optimize processes across scientific and industrial applications.

Frequently Asked Questions

What is the balanced chemical equation for the reaction between phosphoric acid (H_3PO_4) and sodium hydroxide (NaOH)?

The balanced equation is $H_3PO_4 + 3NaOH \rightarrow Na_3PO_4 + 3H_2O$.

How do you determine the moles of phosphoric acid used in the reaction?

Calculate moles by multiplying volume in liters by molarity: 6.00 mL = 0.006 L; moles = 0.006 L × 0.4 mol/L = 0.0024 mol of H_3PO_4.

How do you find the moles of sodium hydroxide involved in the reaction?

Convert volume to liters: 18 mL = 0.018 L; then multiply by molarity: 0.018 L × 0.5 mol/L = 0.009 mol of NaOH.

What is the limiting reagent in the reaction between phosphoric acid and sodium hydroxide?

Phosphoric acid is the limiting reagent because it has fewer moles (0.0024 mol) compared to NaOH (0.009 mol).

How much NaOH is required to completely neutralize 6.00 mL of 0.4 M H_3PO_4?

Since 1 mol of H_3PO_4 reacts with 3 mol of NaOH, the required NaOH is 0.0024 mol × 3 = 0.0072 mol, which is about 0.0144 L or 14.4 mL of 0.5 M NaOH.

What is the pH of the solution after the reaction if excess NaOH is present?

If excess NaOH remains, the solution will be basic, and pH can be calculated using the remaining moles of NaOH divided by total volume to find the concentration, then applying pH = 14 - pOH.

How do you calculate the amount of salt (Na_3PO_4) produced in this reaction?

Since 1 mol of H_3PO_4 yields 1 mol of Na_3PO_4, the moles produced are 0.0024 mol, which can be converted to mass using molar mass: 164 g/mol for Na_3PO_4.

If all phosphoric acid is reacted, what is the volume of NaOH left unreacted?

Given the initial NaOH moles (0.009 mol) and the moles needed for complete neutralization (0.0072 mol), the excess NaOH is 0.009 - 0.0072 = 0.0018 mol. Convert to volume: 0.0018 mol / 0.5 mol/L = 0.0036 L or 3.6 mL of NaOH remaining.

What is the significance of molarity in calculating the reaction outcome between H_3PO_4 and NaOH?

Molarity allows for determining the precise number of moles of reactants involved, enabling calculation of limiting reagents, products formed, and leftover reactants in the reaction.

Additional Resources

If 6.00 mL of 0.4 M phosphoric acid (H_3PO_4) reacted with 18 mL of 0.5 M sodium hydroxide (NaOH). Calculate the amount of acid neutralized, determine the limiting reagent, and explore the resulting chemical implications. This scenario offers an excellent opportunity to delve into acid-base titrations, stoichiometry, and the principles governing chemical reactions, serving as a practical illustration of fundamental chemistry concepts.

Understanding the Reactants and Their Properties

Before embarking on the calculation, it's essential to comprehend the nature of the reactants involved.

Phosphoric Acid (H_3PO_4)

- Chemical Structure & Properties: Phosphoric acid is a triprotic acid, meaning it can donate three protons (H^+) per molecule. Its molecular weight is approximately 98.00 g/mol.
- Concentration & Volume: Given as 0.4 M (moles per liter) and a volume of 6.00 mL (or 0.00600 L).

Sodium Hydroxide (NaOH)

- Chemical Properties: NaOH is a strong base that dissociates completely in water, providing hydroxide ions (OH^-).
- Concentration & Volume: 0.5 M with a volume of 18 mL (or 0.018 L).

Understanding these properties sets the stage for calculating the moles of each reactant involved and analyzing their reaction.

Calculating the Moles of Reactants

The first step is determining the number of moles of phosphoric acid and sodium hydroxide present in the given volumes.

Moles of Phosphoric Acid (H_3PO_4)

Using the molarity formula:

\[\text{Moles} = \text{Molarity} \times \text{Volume} \]

\[
\text{Moles of } H_3PO_4 = 0.4\, \text{mol/L} \times 0.00600\, \text{L} =

0.0024\, \text{mol}
\]

Moles of Sodium Hydroxide (NaOH)

Similarly,

\[
\text{Moles of } NaOH = 0.5\, \text{mol/L} \times 0.018\, \text{L} = 0.009\, \text{mol}
\]

Understanding the Reaction and Stoichiometry

Chemical reactions are governed by stoichiometry—the quantitative relationship between reactants and products.

The Acid-Base Reaction of Phosphoric Acid and Sodium Hydroxide

Phosphoric acid (H_3PO_4) is triprotic, capable of donating three protons:

\[
\text{H}_3\text{PO}_4 \rightarrow 3 \text{H}^+ + \text{PO}_4^{3-}
\]

Each proton can react with one hydroxide ion:

\[
\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}
\]

Thus, the complete neutralization involves three moles of H^+ per mole of H_3PO_4:

\[
\text{H}_3\text{PO}_4 + 3\, \text{NaOH} \rightarrow \text{Na}_3\text{PO}_4 + 3\, \text{H}_2\text{O}
\]

The balanced chemical equation:

\[
\text{H}_3\text{PO}_4 + 3\, \text{NaOH} \rightarrow \text{Na}_3\text{PO}_4 + 3\, \text{H}_2\text{O}

\]

Determining the Limiting Reactant

Knowing the mole ratio (1:3) is crucial to identifying which reactant is limiting.

- Moles of H_3PO_4: 0.0024 mol
- Moles of NaOH: 0.009 mol

Calculate the amount of NaOH required to fully react with the available phosphoric acid:

$$
\text{NaOH required} = 3 \times \text{moles of } H_3PO_4 = 3 \times 0.0024 = 0.0072\, \text{mol}
$$

Since 0.009 mol of NaOH is available, which is greater than 0.0072 mol, NaOH is in excess.

Therefore, the limiting reagent is phosphoric acid (H_3PO_4). The amount of acid determines how much base can be neutralized.

Calculating the Extent of Reaction and Remaining Reactants

Given that all 0.0024 mol of H_3PO_4 will react (since it's limiting), the amount of NaOH that reacts:

$$
\text{NaOH used} = 3 \times 0.0024\, \text{mol} = 0.0072\, \text{mol}
$$

Remaining NaOH:

$$
\text{NaOH remaining} = 0.009\, \text{mol} - 0.0072\, \text{mol} = 0.0018\, \text{mol}
$$

Calculating pH and Final Solution Composition

The reaction produces sodium phosphate (Na_3PO_4) and water. Since excess NaOH remains, the solution will be basic.

Concentrations After Reaction

- Total volume: Sum of reactant volumes: 6.00 mL + 18.00 mL = 24.00 mL (or 0.024 L)
- Remaining NaOH concentration:

$$
\text{Concentration of remaining NaOH} = \frac{0.0018\, \text{mol}}{0.024\, \text{L}} \approx 0.075\, \text{M}
$$

- Sodium phosphate produced:

$$
\text{Moles of } Na_3PO_4 = \text{moles of } H_3PO_4 \text{ reacted} = 0.0024\, \text{mol}
$$

- Concentration of sodium phosphate:

$$
\frac{0.0024\, \text{mol}}{0.024\, \text{L}} = 0.10\, \text{M}
$$

Implication: The solution contains a significant amount of sodium phosphate, which is the salt resulting from complete neutralization of phosphoric acid's first and second protons, with some remaining hydroxide ions.

Determining pH

- Since excess NaOH remains, the pH will be basic.
- Estimate pOH:

$$
\text{pOH} = -\log [\text{OH}^-] = -\log 0.075 \approx 1.12
$$

- Calculate pH:

$$
\text{pH} = 14 - \text{pOH} \approx 14 - 1.12 = 12.88
$$

This high pH indicates a strongly basic solution, characteristic of excess NaOH.

Summary and Practical Applications

This calculation illustrates key principles in acid-base titrations:

- Mole Ratio and Stoichiometry: Understanding the balanced chemical equations allows precise calculation of reactants and products.
- Limiting Reagent Identification: Recognizing which reactant is exhausted first influences the amount of products formed.
- Residual Reactants and pH: Excess base or acid determines the final solution's pH, crucial in titration analysis.

In practical laboratory settings, such calculations are fundamental for:

- Preparing buffered solutions
- Determining the concentration of unknown solutions
- Designing titration experiments to analyze acid or base strengths

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Final Remarks

The scenario of reacting 6.00 mL of 0.4 M phosphoric acid with 18 mL of 0.5 M sodium hydroxide exemplifies core chemistry concepts. It demonstrates how to systematically approach reaction calculations, interpret the stoichiometry, identify limiting reagents, and predict the solution's pH after the reaction. Such analyses are invaluable in both academic research and industrial applications, ensuring precise control and understanding of chemical processes.

Note: Always remember to consider solution volumes, molarities, and reaction stoichiometry carefully. Small variations in measurements can significantly influence the outcomes in real laboratory scenarios.

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