Determine The Molarity Of Phosphoric Acid If 20ml Acid Titrated With 15.9 Ml Of 0.200 M Sodium Hyhdroxide

Determine The Molarity Of Phosphoric Acid If 20ml Acid Titrated With 15.9 Ml Of 0.200 M Sodium Hyhdroxide is a common problem in analytical chemistry, especially in acid-base titration experiments. This type of calculation helps chemists understand the concentration of unknown solutions by using a titrant of known concentration. In this case, we are asked to find the molarity of phosphoric acid (H_3PO_4) based on titration data involving sodium hydroxide (NaOH). To solve this problem accurately, it's essential to understand the principles of titration, the chemical reactions involved, and the stoichiometry of the reaction between phosphoric acid and sodium hydroxide.

Understanding the Titration Process

What is Titration?

Titration is a laboratory technique used to determine the concentration of an unknown solution by reacting it with a solution of known concentration. The process involves gradually adding the titrant (here, sodium hydroxide) to the analyte (phosphoric acid) until the reaction reaches its equivalence point, which is often indicated by a color change in an appropriate indicator.

Significance of the Data Provided

In this problem, the key data points are:
- Volume of phosphoric acid used: 20 mL
- Volume of sodium hydroxide used: 15.9 mL
- Concentration of sodium hydroxide: 0.200 M

Using these, we can determine the molarity of phosphoric acid by applying stoichiometry principles.

Chemical Reactions Involved

Reaction Between Phosphoric Acid and Sodium Hydroxide

Phosphoric acid (H_3PO_4) is a triprotic acid, meaning it can release three protons (H^+) per molecule. The balanced neutralization reactions with NaOH, which is a strong base, are:

1. First proton:
$H_3PO_4 + NaOH \rightarrow NaH_2PO_4 + H_2O$

2. Second proton:
$NaH_2PO_4 + NaOH \rightarrow Na_2HPO_4 + H_2O$

3. Third proton:
$Na_2HPO_4 + NaOH \rightarrow Na_3PO_4 + H_2O$

In total, one mole of H_3PO_4 reacts with three moles of NaOH. Therefore, for complete neutralization, the molar ratio is 1:3.

Calculating the Molarity of Phosphoric Acid

Step 1: Calculate Moles of Sodium Hydroxide Used

Given:
- Volume of NaOH = 15.9 mL = 0.0159 L
- Concentration of NaOH = 0.200 M

Number of moles of NaOH:
$$
\text{moles NaOH} = \text{Concentration} \times \text{Volume} = 0.200\, \text{mol/L} \times 0.0159\, \text{L} = 0.00318\, \text{mol}
$$

Step 2: Determine Moles of Phosphoric Acid Neutralized

Since each mole of H_3PO_4 reacts with three moles of NaOH, the moles of phosphoric acid in the 20 mL sample are:
$$
\text{moles } H_3PO_4 = \frac{\text{moles NaOH}}{3} = \frac{0.00318}{3} = 0.00106\, \text{mol}
$$

Step 3: Calculate Molarity of Phosphoric Acid

The molarity (M) of the phosphoric acid solution is:
$$
\text{Molarity of } H_3PO_4 = \frac{\text{moles of } H_3PO_4}{\text{volume of solution in liters}} = \frac{0.00106\, \text{mol}}{0.020\, \text{L}} = 0.053\, \text{M}
$$

Thus, the molarity of the phosphoric acid solution is approximately 0.053 M.

Important Considerations and Assumptions

Assumption of Complete Neutralization

The calculation assumes that the titration reached the equivalence point where all the acid has been neutralized by the base. Accurate titration techniques and indicators ensure this point is correctly identified.

Indicator Choice

Choosing the correct indicator is essential. For phosphoric acid titrations, phenolphthalein is commonly used because it changes color around the pH at the equivalence point for such acid-base reactions.

Purity of the Reagents

It is presumed that both the phosphoric acid solution and sodium hydroxide are pure and free from contamination, which is critical for precise calculations.

Additional Insights and Applications

Significance of Molarity Determination

Determining the molarity of acids like phosphoric acid is crucial in many fields including pharmaceuticals, food industry, and chemical manufacturing. It ensures proper formulation, safety, and compliance with standards.

Extension to Other Titration Calculations

The approach used here—applying stoichiometry, molarity, and volume data—is applicable to various other titration problems involving different acids, bases, and even redox reactions.

Summary of the Calculation Steps

1. Calculate moles of NaOH used in titration.
2. Determine the moles of phosphoric acid based on the stoichiometry (1:3 ratio).
3. Calculate the molarity of phosphoric acid from the moles and volume.

Final Answer: The molarity of the phosphoric acid solution is approximately 0.053 M.

Conclusion

In conclusion, by carefully analyzing the titration data and applying stoichiometric principles, we have determined that the molarity of the phosphoric acid solution is approximately 0.053 M. This calculation underscores the importance of understanding chemical reactions, molarity, and titration techniques in analytical chemistry. Accurate measurement and proper interpretation of titration data allow chemists to ascertain the concentration of unknown solutions, ensuring quality control and scientific precision in various applications.

References and Further Reading

- "Quantitative Chemical Analysis" by Daniel C. Harris
- "Principles of Modern Chemistry" by David W. Oxtoby, H. Pat Gillis, and Laurie J. Butler
- Online resources on titration and acid-base chemistry from reputable educational websites such as Khan Academy and ChemGuide.

Frequently Asked Questions

How do you calculate the molarity of phosphoric acid from the titration data provided?

To calculate the molarity of phosphoric acid, use the titration formula: $M_1V_1 = M_2V_2$, where M_1 and V_1 are the molarity and volume of the acid, and M_2 and V_2 are those of the base. Rearranged, $M_1 = (M_2 \times V_2) / V_1$. Substitute the given values to find the molarity of the acid.

What is the balanced chemical equation for the titration of phosphoric acid with sodium hydroxide?

The balanced equation is: $H_3PO_4 + 3\ NaOH \rightarrow Na_3PO_4 + 3\ H_2O$. This indicates that one mole of phosphoric acid reacts with three moles of sodium hydroxide.

How does the stoichiometry of the reaction affect the calculation of phosphoric acid molarity?

Since phosphoric acid reacts with sodium hydroxide in a 1:3 molar ratio, you must account for this in calculations. The amount of NaOH used corresponds to three times the amount of phosphoric acid present, influencing the molarity calculation accordingly.

Calculate the molarity of phosphoric acid given 20 mL acid titrated with 15.9 mL of 0.200 M NaOH.

Using the formula: $M_1 = (M_2 \times V_2) / (3 \times V_1)$. Plugging in the values: $M_1 = (0.200\ mol/L \times 15.9\ mL) / (3 \times 20$

mL) = (0.200 × 15.9) / 60 = 3.18 / 60 = 0.053 mol/L. Therefore, the molarity of phosphoric acid is approximately 0.053 M.

Why is it important to consider the molar ratio when determining the molarity of the acid?

Because the reaction between phosphoric acid and sodium hydroxide involves a 1:3 molar ratio, accounting for this ensures accurate calculation of the acid's molarity from titration data. Ignoring this ratio would lead to incorrect results.

What are common sources of error in titration experiments like this, and how can they be minimized?

Common errors include inaccurate measurement of volumes, incomplete reactions, or impurities. These can be minimized by careful calibration of equipment, performing multiple trials, and ensuring proper technique during titration.

Additional Resources

Determine The Molarity Of Phosphoric Acid If 20ml Acid Titrated With 15.9 Ml Of 0.200 M Sodium Hydroxide

Understanding how to determine the molarity of an unknown acid through titration is a fundamental skill in chemistry. Today, we will explore a practical example involving phosphoric acid and sodium hydroxide: Determine the molarity of phosphoric acid if 20 ml acid is titrated with 15.9 ml of 0.200 M sodium hydroxide. This process not only reinforces principles of molarity, mole ratios, and titration techniques but also provides a step-by-step methodological guide to solving similar problems in laboratory and academic settings.

Introduction: The Significance of Titration in Acid-Base Analysis

Titration is an essential quantitative analysis technique used to determine the concentration of an unknown solution. In acid-base titrations, an acid reacts with a base in a well-defined chemical reaction. By adding a titrant of known concentration until the reaction reaches its equivalence point, the amount of acid or base in the sample can be calculated.

In our specific case, phosphoric acid (H_3PO_4) — a triprotic acid — is titrated with sodium hydroxide (NaOH), a strong base. The goal is to find the molarity of phosphoric acid based on the titration data provided.

Understanding the Chemistry: The Reaction Between Phosphoric Acid and Sodium Hydroxide

The Balanced Chemical Equation

Phosphoric acid is a triprotic acid, meaning it can release up to three protons (H^+) per molecule. Its reactions with sodium hydroxide can be represented as:

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

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

Step-by-Step Approach to Calculate the Molarity of Phosphoric Acid

1. Gather All Known Data

- Volume of phosphoric acid (unknown molarity): 20 mL (or 0.020 L)
- Volume of sodium hydroxide used: 15.9 mL (or 0.0159 L)
- Molarity of sodium hydroxide: 0.200 M

2. Convert Volumes to Liters

- Acid volume: 20 mL = 0.020 L
- Base volume: 15.9 mL = 0.0159 L

3. Calculate Moles of Sodium Hydroxide Used

Using the molarity formula:

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

$$\text{Moles of NaOH} = 0.200\, \text{mol/L} \times 0.0159\, \text{L}$$

$$\text{Moles of NaOH} = 0.00318\, \text{mol}$$

4. Determine Moles of Phosphoric Acid

From the balanced chemical equation, the molar ratio of phosphoric acid to sodium hydroxide is:

$$\text{H}_3\text{PO}_4 : \text{NaOH} = 1 : 3$$

Therefore, the moles of phosphoric acid are:

$$\text{Moles of H}_3\text{PO}_4 = \frac{\text{Moles of NaOH}}{3}$$

$$\text{Moles of H}_3\text{PO}_4 = \frac{0.00318}{3} = 0.00106\, \text{mol}$$

5. Calculate Molarity of Phosphoric Acid

Finally, molarity is moles of solute divided by liters of solution:

$$\text{Molarity of H}_3\text{PO}_4 = \frac{\text{Moles of H}_3\text{PO}_4}{\text{Volume of acid in liters}}$$

$$\text{Molarity of H}_3\text{PO}_4 = \frac{0.00106}{0.020} = 0.053\, \text{M}$$

Thus, the molarity of phosphoric acid is approximately 0.053 M.

Detailed Explanation of Each Step

Why Convert Volumes to Liters?

Since molarity is expressed in mol/L, all volume measurements should be converted to liters to maintain consistent units during calculations. This step is critical to avoid errors.

The Importance of Mole Ratios

The key to this calculation lies in the mole ratio from the balanced equation. Recognizing that phosphoric acid is triprotic and reacts with three equivalents of NaOH per molecule is vital. This ratio directly impacts the calculation of the acid's molarity.

Ensuring Accuracy and Precision

- Use calibrated burettes and pipettes for volume measurements.
- Record data meticulously.
- Be mindful of significant figures; in this case, three significant figures are appropriate for the final answer.

Additional Considerations and Practical Tips

Choosing Indicators

While not explicitly mentioned in this problem, selecting an appropriate indicator (like phenolphthalein) ensures an accurate detection of the titration endpoint.

Endpoint Detection

The endpoint is when the indicator changes color, signaling the reaction is complete. Proper technique involves slow addition near the endpoint to avoid overshooting, which can lead to inaccuracies.

Repeating for Consistency

Perform multiple titrations to ensure reproducibility. Calculating an average molarity from several trials increases reliability.

Common Mistakes to Avoid

- Forgetting the mole ratio when dealing with polyprotic acids like phosphoric acid.
- Mixing units or failing to convert volumes to liters.
- Using the wrong molarity or volume data.
- Not performing multiple trials to confirm results.

Summary and Final Remarks

Determine the molarity of phosphoric acid if 20 ml acid is titrated with 15.9 ml of 0.200 M sodium hydroxide involves understanding the stoichiometry of the reaction, precise measurement, and careful calculation. The key steps include calculating the moles of the titrant, adjusting for the mole ratio from the balanced chemical equation, and then computing the molarity of the unknown acid.

This process exemplifies fundamental titration principles—an essential technique in analytical chemistry, environmental testing, and quality control. Mastery of such calculations enhances one's ability to analyze unknown solutions accurately and supports broader applications in scientific research and industry.

Final Thought

While the numbers may seem straightforward, the underlying concepts of molarity, mole ratios, and titration techniques are foundational to understanding chemical reactions quantitatively. Practice with various acids and bases, and always pay close attention to units and ratios, will equip you with the skills necessary for precise chemical analysis.

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