What Volume Of 2.0 M Hydrochloric Acid Solution Will Be Consumed When It Reacts With 5 Grams Of Magnesium

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Understanding the precise volume of hydrochloric acid (HCl) required to react completely with a given mass of magnesium (Mg) is a fundamental concept in chemistry, especially in titration processes and stoichiometry calculations. In this article, we delve into the detailed steps to determine the volume of 2.0 M hydrochloric acid solution that will be consumed when reacting with 5 grams of magnesium. This comprehensive explanation aims to clarify the underlying principles, calculations, and practical considerations involved in such a chemical reaction.

Introduction to the Reaction Between Magnesium and Hydrochloric Acid

Magnesium reacts with hydrochloric acid in a straightforward chemical process, producing magnesium chloride ($MgCl_2$) and hydrogen gas (H_2). The balanced chemical equation for this reaction is:

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

This reaction illustrates that one mole of magnesium reacts with two moles of hydrochloric acid. Understanding this molar relationship is essential for calculating the required volume of acid for a given mass of magnesium.

Understanding the Key Concepts and Definitions

Before diving into calculations, it’s important to familiarize yourself with some fundamental concepts:

1. Molarity (M)

- Molarity indicates the number of moles of solute (here, HCl) per liter of solution.
- A 2.0 M HCl solution contains 2.0 moles of HCl in 1 liter of solution.

2. Moles

- The amount of substance measured in moles (mol), representing the number of particles (atoms, molecules, ions).
- 1 mole of any substance contains Avogadro's number (~6.022×10^{23}) of particles.

3. Molar Mass

- The mass of one mole of a substance, expressed in grams per mole (g/mol).
- Magnesium's molar mass: approximately 24.305 g/mol.
- Hydrochloric acid's molar mass: approximately 36.46 g/mol.

Step-by-Step Calculation Process

The calculation involves several steps:

1. Calculate the moles of magnesium in 5 grams

$$
\text{Moles of Mg} = \frac{\text{Mass of Mg}}{\text{Molar mass of Mg}}
$$

$$
\text{Moles of Mg} = \frac{5\, \text{g}}{24.305\, \text{g/mol}} \approx 0.206\, \text{mol}
$$

2. Determine the moles of hydrochloric acid required

From the balanced chemical equation:

$$\mathrm{Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)}$$

- 1 mol of Mg reacts with 2 mol of HCl.
- Therefore, the moles of HCl needed:

$$
\text{Moles of HCl} = 2 \times \text{Moles of Mg} = 2 \times 0.206\, \text{mol} \approx 0.412\, \text{mol}
$$

3. Calculate the volume of 2.0 M HCl solution needed

Using the definition of molarity:

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

$$
\text{Volume of HCl} = \frac{0.412\, \text{mol}}{2.0\, \text{mol/L}} = 0.206\, \text{L}
$$

Convert liters to milliliters:

$$
0.206\, \text{L} \times 1000 = 206\, \text{mL}
$$

Thus, approximately 206 milliliters of 2.0 M hydrochloric acid will be consumed when reacting with 5 grams of magnesium.

Practical Considerations and Additional Insights

While calculations provide a theoretical value, real-world applications may introduce factors affecting the exact volume required.

1. Purity of Reactants

- Impurities in magnesium or acid can influence the reaction efficiency.

2. Reaction Conditions

- Temperature and agitation can affect reaction rates but not the molar ratios.

3. Measurement Accuracy

- Precise weighing and volumetric measurement are essential for accurate results.

Applications of the Calculation

Understanding how to determine the required volume of acid for a specific reaction has numerous practical applications:

- **Titration experiments:** Accurate determination of unknown concentrations.
- **Industrial processes:** Calculating reagent quantities for manufacturing or waste treatment.

- **Laboratory safety:** Proper handling and measurement of acids and reactive metals.

Summary of Key Points

- The reaction between magnesium and hydrochloric acid is a 1:2 molar ratio.
- Calculating the moles of magnesium from its mass is the first step.
- Using molarity, the volume of acid needed can be precisely determined.
- Approximately 206 mL of 2.0 M HCl is required to react with 5 grams of magnesium.

Conclusion

Accurately calculating the volume of hydrochloric acid required to react with a specific amount of magnesium involves understanding the stoichiometry of the reaction, calculating moles, and applying the definition of molarity. This detailed process highlights the importance of fundamental chemical principles in practical applications, from laboratory experiments to industrial processes. By mastering these calculations, chemists and students can ensure precise reagent usage, optimize reaction conditions, and maintain safety standards in various chemical operations.

Remember: Always handle acids and reactive metals with appropriate safety measures, including wearing protective gear and working in well-ventilated areas.

Frequently Asked Questions

How do you calculate the volume of 2.0 M hydrochloric acid required to react with 5 grams of magnesium?

First, determine the moles of magnesium using its molar mass (24.3 g/mol). Then, use the stoichiometry of the reaction $Mg + 2HCl \rightarrow MgCl_2 + H_2$ to find the moles of HCl needed (twice the moles of Mg). Finally, calculate the volume of 2.0 M HCl by dividing the moles of HCl by its molarity.

What is the molar mass of magnesium used in this calculation?

The molar mass of magnesium (Mg) is 24.3 g/mol.

How many moles of magnesium are present in 5 grams?

Number of moles = 5 g ÷ 24.3 g/mol ≈ 0.206 mol.

How many moles of hydrochloric acid are needed to react with 0.206 mol of magnesium?

Since the reaction requires 2 moles of HCl per mole of Mg, the moles of HCl needed = 2 × 0.206 mol ≈ 0.412 mol.

What is the volume of 2.0 M HCl solution required for this reaction?

Volume = moles of HCl ÷ molarity = 0.412 mol ÷ 2.0 mol/L ≈ 0.206 liters or 206 mL.

Can this calculation be used for other concentrations of hydrochloric acid?

Yes, by adjusting the molarity in the calculation, you can determine the required volume for different concentrations of HCl.

What assumptions are made in this calculation?

It assumes the reaction goes to completion, the solution is dilute enough for ideal behavior, and there are no side reactions or impurities affecting the reaction.

Additional Resources

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Introduction

Chemical reactions involving acids and metals are fundamental concepts in both educational and industrial chemistry. Among these, the reaction between magnesium and hydrochloric acid is a classic example used to demonstrate stoichiometry, molarity, and the practical applications of acid-metal reactions. Determining the volume of hydrochloric acid (HCl) needed to completely react with a given mass of magnesium (Mg) is crucial, especially in laboratory settings where precise measurements are essential for safety, efficiency, and accuracy.

This article provides an in-depth analysis of the calculation process to determine what volume of 2.0 M hydrochloric acid solution will be consumed when it reacts with 5 grams of magnesium. It explores the underlying chemical principles, detailed stoichiometric calculations, and potential implications for real-world applications.

Fundamental Chemical Principles

Before diving into calculations, it is essential to understand the fundamental principles governing the reaction between magnesium and hydrochloric acid.

The Chemical Reaction

The reaction between magnesium and hydrochloric acid is a straightforward single displacement reaction:

$$\text{Mg (s)} + 2\, \text{HCl (aq)} \rightarrow \text{MgCl}_2 \text{(aq)} + \text{H}_2 \text{(g)}$$

- Magnesium (Mg) reacts with hydrochloric acid (HCl) to produce magnesium chloride ($MgCl_2$) and hydrogen gas (H_2).
- The stoichiometry indicates that 1 mole of magnesium reacts with 2 moles of hydrochloric acid.

Molarity and Volume Relationship

Molarity (M) is defined as moles of solute per liter of solution:

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

Rearranged to find volume:

$$\text{Volume (L)} = \frac{\text{moles of solute}}{\text{molarity}}$$

In this context, the "solute" is hydrochloric acid.

Step 1: Calculating Moles of Magnesium

Given mass of magnesium:

- Mass of Mg: 5 grams
- Atomic mass of Mg: approximately 24.305 g/mol

Calculating moles:

$$\text{Moles of Mg} = \frac{\text{Mass}}{\text{Atomic mass}} = \frac{5\, \text{g}}{24.305\, \text{g/mol}} \approx 0.2057\, \text{mol}$$

This means that approximately 0.2057 moles of magnesium are available for reaction.

Step 2: Determining Moles of Hydrochloric Acid Required

From the balanced chemical equation:

$$\text{Mg (s)} + 2\, \text{HCl (aq)} \rightarrow \text{MgCl}_2 + \text{H}_2$$

- 1 mol of magnesium reacts with 2 mol of hydrochloric acid.

Therefore:

$$\text{Moles of HCl needed} = 2 \times \text{moles of Mg} = 2 \times 0.2057\, \text{mol} \approx 0.4114\, \text{mol}$$

This is the amount of hydrochloric acid required for complete reaction with 5 grams of magnesium.

Step 3: Calculating the Volume of 2.0 M HCl Solution Needed

Given the molarity of hydrochloric acid:

- Molarity (M): 2.0 mol/L

Applying the molarity-volume relationship:

$$\text{Volume in liters} = \frac{\text{moles of HCl}}{\text{molarity}} = \frac{0.4114\, \text{mol}}{2.0\, \text{mol/L}} \approx 0.2057\, \text{L}$$

Converting liters to milliliters:

$$0.2057\, \text{L} \times 1000 = 205.7\, \text{mL}$$

Final Answer:

Approximately 206 milliliters of 2.0 M hydrochloric acid solution will be consumed when it reacts with 5 grams of magnesium.

Considerations and Real-World Implications

Purity and Reaction Completeness

- Purity of Magnesium: The calculation assumes 100% pure magnesium. Impurities or oxide layers could reduce the actual reaction efficiency.
- Reaction Conditions: Temperature, agitation, and solution concentration can influence reaction completeness and kinetics.

Safety and Handling

- Hydrogen Gas Evolution: The reaction produces hydrogen gas, which is flammable. Adequate ventilation and safety precautions are necessary.

- Corrosive Nature of HCl: Proper protective equipment should be used to handle hydrochloric acid.

Industrial Applications

- Metallurgical Processes: Precise acid-metal reactions are vital in metal refining and recovery.
- Laboratory Quantification: Accurate volume calculations ensure reproducibility and safety in experimental setups.

Potential Variations and Error Margins

While the calculations are straightforward, practical applications may involve slight deviations:

- Variability in magnesium purity
- Slight errors in measuring the mass of magnesium
- Slight variations in molarity of the acid solution (e.g., due to preparation inaccuracies)
- Slight temperature fluctuations affecting reaction rates

Recognizing these factors allows for the inclusion of safety margins or adjustments in experimental design.

Conclusion

The detailed analysis reveals that approximately 206 mL of 2.0 M hydrochloric acid solution is required to fully react with 5 grams of magnesium under ideal conditions. This calculation underscores the importance of stoichiometry in chemical reactions and provides valuable insights for laboratory chemists, educators, and industrial practitioners alike.

Understanding such quantitative relationships is essential for optimizing reactions, ensuring safety, and advancing chemical knowledge. As with all chemical calculations, real-world conditions may introduce variations, but the fundamental principles remain a cornerstone of chemical science.

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