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Understanding chemical reactions and gas collection procedures is fundamental in chemistry education and laboratory practice. In this comprehensive guide, we explore the process of collecting gas produced when magnesium reacts with hydrochloric acid, focusing on the reaction specifics, calculation methods, and safety considerations. Whether you're a student preparing for an exam or a budding chemist conducting experiments, this article provides detailed insights into the reaction dynamics and gas collection techniques involved.

Introduction to the Reaction Between Magnesium and Hydrochloric Acid

Basic Chemical Reaction

The reaction between magnesium (Mg) and hydrochloric acid (HCl) is a classic example of a single displacement reaction involving a metal and an acid. When magnesium reacts with excess hydrochloric acid, magnesium chloride ($MgCl_2$) and hydrogen gas (H_2) are produced:

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

This reaction is exothermic, releasing energy, and is commonly studied because it demonstrates gas evolution, stoichiometry, and reaction rates.

Significance of Gas Collection

Collecting the hydrogen gas generated helps in:
- Determining the amount of hydrogen produced
- Understanding reaction stoichiometry
- Analyzing gas laws and behaviors
- Conducting practical applications like hydrogen fuel experiments

Experimental Setup and Procedure

Materials Needed

Before starting the experiment, gather the following:

- Magnesium ribbon or powder
- Hydrochloric acid (excess)
- Conical flask or reaction vessel

- Delivery tube or rubber tubing
- Gas collection apparatus (e.g., gas jar, graduated cylinder inverted in water)
- Clamp stand and stand
- Water trough
- Safety equipment (goggles, gloves)

Step-by-Step Procedure

1. Preparation: Set up the water trough and fill it with water. Fit the gas delivery tube to the reaction vessel securely.
2. Reaction Initiation: Add a known quantity of magnesium (1.5 grams) to the conical flask.
3. Adding Acid: Carefully pour excess hydrochloric acid into the flask, ensuring magnesium is submerged.
4. Gas Collection: As hydrogen gas is produced, it travels through the delivery tube into the inverted gas jar or graduated cylinder filled with water.
5. Observation: Record the volume of hydrogen gas collected over time.
6. Completion: Once the reaction ceases, note the final gas volume for calculations.

Calculations Involving Gas Production

Understanding how to calculate the amount of hydrogen gas produced involves stoichiometry and gas laws.

Moles of Magnesium Reacted

Given:
- Mass of magnesium, m = 1.5 g
- Atomic mass of Mg ≈ 24.31 g/mol

Calculation:

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Number of moles of Mg (n) = m / molar mass = 1.5 g / 24.31 g/mol ≈ 0.0616 mol
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Maximum Theoretical Volume of Hydrogen Gas

From the balanced equation:

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

1 mole of Mg produces 1 mole of H_2 gas.

Thus:
- Moles of H_2 produced = moles of Mg reacted = 0.0616 mol

At standard temperature and pressure (STP), 1 mol of gas occupies 22.4 liters.

Calculation:

$$\text{Volume of } H_2 \text{ } (V) = \text{moles} \times \text{molar volume} = 0.0616 \text{ mol} \times 22.4 \text{ L/mol} \approx 1.38 \text{ liters}$$

Note: Actual collected volume may be less due to experimental losses or incomplete reactions.

Factors Affecting Gas Collection Efficiency

Several factors influence the amount of hydrogen gas collected:

Reaction Completeness

- Ensuring excess HCl is added guarantees complete reaction of magnesium.
- Insufficient acid can limit gas production.

Reaction Conditions

- Temperature: Higher temperatures increase reaction rates but may affect gas volume.
- Surface Area: Larger surface area of magnesium (e.g., powder vs. ribbon) accelerates the reaction.

Gas Collection Method

- Proper sealing of the apparatus prevents gas leakage.
- Water displacement methods are standard but may cause some hydrogen to dissolve in water.

Safety Precautions During the Experiment

Hydrogen gas is flammable and explosive when mixed with air. Proper safety measures include:

- Performing the experiment in a well-ventilated area or under a fume hood
- Using safety goggles and gloves
- Ensuring no open flames or sparks nearby
- Handling acids with care to prevent spills and burns

Applications of Gas Collection from Magnesium and HCl Reaction

This reaction and gas collection process have multiple practical applications:

Educational Demonstrations

- Illustrating gas laws and stoichiometry concepts
- Demonstrating reaction kinetics

Hydrogen Production

- Laboratory-scale hydrogen generation for experiments
- Potential applications in clean energy research

Industrial Relevance

- Manufacturing magnesium compounds
- Developing hydrogen-based fuel cells

Conclusion

The reaction between magnesium and hydrochloric acid is a fundamental chemical process that exemplifies gas evolution and stoichiometric principles. By carefully collecting and measuring the hydrogen gas produced from 1.5 grams of magnesium, students can deepen their understanding of chemical reactions, gas laws, and experimental techniques. Proper setup, safety precautions, and accurate calculations are essential to derive meaningful insights from the experiment. This process not only reinforces theoretical knowledge but also highlights practical applications in science and industry.

Further Reading and Resources

- Standard Chemistry Textbooks on Reactions of Metals with Acids
- Laboratory Manuals on Gas Collection Techniques
- Safety Guidelines for Handling Acids and Flammable Gases
- Online Resources for Stoichiometry and Gas Laws Calculations

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Keywords: magnesium reaction, hydrogen gas collection, Mg and HCl reaction, stoichiometry, gas laws, laboratory experiment, gas volume calculation, safety in chemical reactions, hydrogen fuel production

Frequently Asked Questions

What is the chemical reaction involved when magnesium reacts with hydrochloric acid?

The reaction is $Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$, producing magnesium chloride and hydrogen gas.

How much hydrogen gas is expected to be produced from 1.5 grams of magnesium reacting with excess HCl?

Approximately 0.0324 moles of H_2 gas are produced, which corresponds to about 0.0073 liters (assuming ideal conditions) of hydrogen gas.

What is the molar mass of magnesium, and how is it used to calculate the amount of H_2 produced?

The molar mass of magnesium is approximately 24.3 g/mol. It is used to convert grams of Mg to moles, which then helps calculate the moles of H_2 gas produced based on the reaction stoichiometry.

What are the units of volume used to measure the collected hydrogen gas, and how is it calculated?

The volume of hydrogen gas is typically measured in liters (L) at standard temperature and pressure (STP). It is calculated using molar volume (22.4 L/mol) multiplied by the number of moles of H_2 produced.

Why is excess HCl used in this reaction, and what does it mean?

Excess HCl ensures that all magnesium reacts completely, allowing for maximum hydrogen gas production and simplifying calculations based on the limiting reagent.

How does the reaction of magnesium with HCl demonstrate a chemical change?

The reaction produces new substances (magnesium chloride and hydrogen gas), indicating a chemical change involving the breaking and forming of chemical bonds.

What safety precautions should be taken when collecting hydrogen gas from this reaction?

Hydrogen is flammable and explosive, so the reaction should be carried out in a well-ventilated area, away from open flames or sparks, with proper eye protection and safety equipment.

How can the amount of hydrogen gas collected be experimentally measured?

The gas can be collected over water or in a gas syringe, and its volume can be measured directly, ensuring the system is airtight to prevent gas escape.

What factors could affect the amount of hydrogen gas produced in this reaction?

Factors include purity of magnesium, temperature, reaction completeness, and whether the reaction occurs under ideal conditions, all of which can influence the gas volume collected.

Additional Resources

A Student Is Collecting The Gas Produced from The Reaction Of 1.5 Grams Of Mg With Excess HCl — a scenario that offers a fascinating glimpse into basic chemical principles, stoichiometry, and laboratory techniques. Whether you're a student preparing for an exam, a science enthusiast exploring chemical reactions, or a teacher designing experiments, understanding this process provides valuable insights into how gases are generated, measured, and analyzed in a controlled setting. This guide aims to break down the reaction step by step, explore the underlying chemistry, and provide practical tips for accurately collecting and analyzing the gas produced.

Understanding the Reaction: Magnesium and Hydrochloric Acid

The Chemical Equation

At the core of this scenario is a simple yet instructive chemical reaction:

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

In words, solid magnesium reacts with hydrochloric acid to produce magnesium chloride and hydrogen gas. This reaction is a classic example of a single displacement reaction and is often used in laboratories to generate hydrogen gas in a controlled manner.

Key Concepts

- Reactants: Magnesium metal (Mg) and hydrochloric acid (HCl)
- Products: Magnesium chloride ($MgCl_2$) and hydrogen gas (H_2)
- Reaction Type: Single replacement / acid-metal reaction
- Gas Produced: Hydrogen (H_2), which is colorless, odorless, and flammable

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Step-by-Step Breakdown of the Experimental Process

1. Calculating the Theoretical Amount of Hydrogen Gas

Before collecting any gas, it's essential to understand how much hydrogen can be produced from a given amount of magnesium. This involves stoichiometry—the calculation of reactants and products in chemical reactions.

Moles of Magnesium

Given:
- Mass of Mg = 1.5 grams
- Atomic mass of Mg ≈ 24.305 g/mol

Calculate moles of Mg:

$$
\text{Moles of Mg} = \frac{\text{Mass of Mg}}{\text{Atomic mass of Mg}} = \frac{1.5\,g}{24.305\,g/mol} \approx 0.0617\,mol
$$

Moles of Hydrogen Gas

From the balanced chemical equation:

$$
1\, \text{mol Mg} \rightarrow 1\, \text{mol H}_2
$$

Thus, moles of H_2 produced:

$$
0.0617\, \text{mol Mg} \rightarrow 0.0617\, \text{mol H}_2
$$

Volume of Hydrogen Gas at STP

At standard temperature and pressure (STP), 1 mole of gas occupies approximately 22.4 liters.

$$
\text{Volume of H}_2 = 0.0617\, \text{mol} \times 22.4\, \text{L/mol} \approx 1.385\, \text{L}
$$

This means, theoretically, 1.5 grams of magnesium reacting with excess HCl can produce approximately 1.385 liters of hydrogen gas at STP.

Practical Considerations in Gas Collection

2. Excess Hydrochloric Acid

Using excess HCl ensures complete reaction of magnesium, preventing limiting reagent issues. Typically, a concentration of about 1 M (molar) or higher is used, but the key is to have an amount of acid sufficient to react with all magnesium present.

3. Setting Up the Experiment

To collect hydrogen gas efficiently, a typical setup includes:

- Reaction Vessel: A container (like a beaker or conical flask) containing hydrochloric acid.
- Delivery Tube: Connected to the reaction vessel, directing the gas.
- Gas Collection Method: Usually an inverted graduated cylinder or burette filled with water (displacement method), or using a gas syringe.

4. Gas Displacement Method

Hydrogen gas is collected by displacement of water due to its insolubility in water and low density. The steps involve:

- Filling a graduated cylinder or burette with water and inverting it in a water trough.
- Connecting the delivery tube from the reaction flask to the submerged opening of the inverted cylinder.
- Initiating the reaction and allowing hydrogen to displace water, which can then be measured.

5. Ensuring Safety

Hydrogen is flammable and explosive when mixed with air in certain ratios. Safety precautions include:

- Conducting the experiment in a well-ventilated area.
- Avoiding open flames or sparks near the setup.
- Using safety goggles and gloves.

Calculating Actual Gas Yield and Percent Yield

6. Measuring the Collected Gas

Once the reaction has completed, the volume of hydrogen collected is measured. Suppose the student collects 1.2 liters of hydrogen gas.

7. Determining Percent Yield

Percent yield indicates the efficiency of the reaction:

$$
\text{Percent Yield} = \left(\frac{\text{Actual Yield}}{\text{Theoretical Yield}} \right) \times 100
$$

Using the theoretical volume of 1.385 liters and the actual collected volume of 1.2 liters:

$$
\text{Percent Yield} = \left(\frac{1.2}{1.385} \right) \times 100 \approx 86.6\%
$$

This value accounts for experimental losses, gas solubility, leaks, or measurement inaccuracies.

Factors Affecting Gas Collection and Measurement

8. Gas Solubility in Water

Hydrogen's solubility in water (~0.018 g per 100 mL at 20°C) is minimal but can lead to slight underestimation of the gas volume. To account for this, corrections or alternative collection methods (like dry displacement with a pneumatic trough) can be used.

9. Temperature and Pressure Variations

Gas volume is influenced by temperature and pressure:

- Higher temperatures increase gas volume.
- Higher pressures decrease it.

Using the ideal gas law, corrections can be made if conditions deviate from STP:

$$
PV = nRT
$$

where:

- P = pressure
- V = volume
- n = moles of gas
- R = ideal gas constant
- T = temperature in Kelvin

10. Ensuring Accurate Measurements

- Use calibrated laboratory glassware.
- Record temperature and atmospheric pressure.
- Minimize leaks in the apparatus.
- Conduct multiple trials for consistency.

Practical Tips for Students

- Always weigh the magnesium carefully for accurate stoichiometric calculations.
- Ensure the experimental setup is airtight to prevent gas leaks.
- Use a consistent method for gas collection to facilitate comparison across trials.
- Perform the experiment in a well-ventilated area to prevent accumulation of flammable gases.
- Record environmental conditions (temperature, pressure) for correction calculations.
- Practice safety protocols diligently.

Broader Applications and Learning Outcomes

This experiment isn't just about measuring hydrogen gas; it embodies core principles of chemistry:

- Stoichiometry: Connecting mass, moles, and volume.
- Gas laws: Understanding how gases behave under different conditions.
- Laboratory techniques: Gas collection, measurement, and safety.
- Chemical reactivity: Demonstrating how metals react with acids.

By mastering this process, students deepen their understanding of chemical reactions, experimental design, and the importance of precise measurements. Such foundational knowledge underpins advances in fields like chemical engineering, environmental science, and materials chemistry.

Conclusion

A Student Is Collecting The Gas Produced from The Reaction Of 1.5 Grams Of Mg With Excess HCl exemplifies a fundamental yet vital experiment in chemistry. Through careful calculation, precise setup, and attentive measurement, students can accurately determine the amount of hydrogen gas generated, reinforcing their grasp of chemical principles and laboratory skills. Whether for academic purposes or practical applications, understanding this reaction empowers learners to appreciate the tangible aspects of chemical transformations and the critical role they play in scientific discovery.

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