

Gases Generated In A Chemical Reactions Are Sometimes Collected By Displacement Of Water,as Shown Above

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Understanding how gases are collected during chemical reactions is fundamental in chemistry. One common method involves the displacement of water, which allows scientists to safely and accurately gather gases produced in reactions. This technique is especially useful when dealing with gases that are insoluble or only slightly soluble in water, ensuring pure gas collection for further analysis. In this article, we will explore the principles behind the displacement of water method, its applications, procedures, advantages, limitations, and examples to enhance your understanding of this essential laboratory technique.

Principle Behind Collection of Gases by Displacement of Water

The displacement of water method relies on the fact that many gases are insoluble or only sparingly soluble in water, allowing them to be collected without dissolving significantly. When a gas is generated in a reaction vessel, it can be channeled into an inverted water-filled container (usually a trough or a jar), which is submerged in water. Since water is nearly incompressible and the gas is less dense than water, the gas displaces the water in the container, allowing for its collection and measurement.

Key Principles:

- Insolubility of the Gas: The gas must not dissolve significantly in water to avoid contamination.
- Density of the Gas: Gases lighter than air (like hydrogen and helium) can be collected by displacement of water.
- Non-reactivity: The gas should not react with water or the container material.
- Sealed System: To prevent gas escape, the system must be airtight once the gas displaces the water.

Applications of Displacement of Water Method

This technique is widely used in various laboratory and industrial processes,

including:

1. Hydrogen Gas Collection

Hydrogen gas is often generated via reactions like the zinc and hydrochloric acid reaction. Its collection through water displacement is standard due to its insolubility and lightness.

2. Oxygen Gas Collection

Oxygen produced from decomposition of potassium chlorate or other reactions can be collected similarly, provided it does not react with water.

3. Carbon Dioxide Collection

Although carbon dioxide is more soluble in water, it can sometimes be collected by displacement of water if proper precautions are taken, especially when pure samples are needed.

4. Gases in Industrial Processes

Industries often use water displacement to collect gases like ammonia or inert gases, provided they are compatible with water.

Procedure for Collecting Gases by Displacement of Water

The collection process involves several carefully executed steps to ensure safety and accuracy:

Materials Needed:

- Gas generation apparatus (e.g., test tube, flask)
- Delivery tube or delivery pipe
- Water trough or basin
- Collection jar or container (preferably an inverted glass jar or bottle)
- Clamp stand
- Water
- Gas-tight seal or rubber stoppers

Step-by-Step Process:

1. Set Up the Apparatus:

- Fill the water trough with clean water.
- Fill the collection jar completely with water and invert it carefully without trapping air.
- Place the inverted jar into the water trough, ensuring it is submerged and water-tight.

2. Connect the Gas Source:

- Attach the delivery tube to the reaction vessel generating the gas.
- Connect the other end of the delivery tube to the mouth of the inverted jar, ensuring a secure seal with rubber stoppers if necessary.

3. Initiate the Reaction:

- Carry out the chemical reaction carefully, observing safety precautions.
- As the gas is produced, it travels through the delivery tube and displaces the water in the inverted jar.

4. Collect the Gas:

- The gas fills the jar, pushing out the water.
- Once the jar is filled with the gas, stop the reaction or seal the jar to prevent gas escape.

5. Measurement and Analysis:

- The volume of gas can be measured by noting the level of water displaced or by using graduated collection jars.
- Proceed with further tests or experiments as required.

Advantages of Collecting Gases by Displacement of Water

This method offers several benefits, making it a popular choice in laboratory settings:

- **Simplicity:** The setup is straightforward and easy to assemble.
- **Safety:** It minimizes exposure to hazardous gases when properly handled.
- **Purity of Gas:** The method allows collection of relatively pure gases free from contamination.
- **Cost-Effective:** Requires minimal expensive equipment.

Limitations and Precautions

Despite its advantages, the displacement of water method has certain limitations:

Limitations:

- Solubility Issues: Gases like carbon dioxide and ammonia dissolve in water, which can lead to underestimation of volume.
- Reactivity: Gases reactive with water (e.g., chlorine, sulfur dioxide) cannot be collected using this method.
- Density Considerations: Heavier gases (like carbon dioxide) may dissolve more readily, affecting collection efficiency.
- Leakage: Ensuring airtight seals is crucial; leaks can lead to loss of gas and inaccurate results.

Precautions:

- Use appropriate safety gear, including gloves and goggles.
- Ensure the apparatus is airtight to prevent gas escape.
- Use water that is free of impurities.
- Be cautious with reactive gases; conduct reactions in well-ventilated areas or under fume hoods.

Examples of Gases Collected by Displacement of Water

Understanding practical examples helps reinforce the concept:

Example 1: Collection of Hydrogen Gas

- Reaction: $\text{Zinc} + \text{Hydrochloric acid} \rightarrow \text{Zinc chloride} + \text{Hydrogen}$
- Process: Hydrogen gas generated in a test tube is directed into an inverted jar filled with water, displacing the water and collecting hydrogen.

Example 2: Collection of Oxygen Gas

- Reaction: Decomposition of potassium chlorate using heat
- Process: Oxygen released is collected by displacement of water in a similar setup.

Example 3: Collection of Carbon Dioxide

- Reaction: Reaction of calcium carbonate with hydrochloric acid
- Process: Carbon dioxide produced is collected by displacement of water, provided measures are taken to minimize its solubility issues.

Alternative Methods of Gas Collection

While displacement of water is common, other techniques include:

- Displacement of Air: Suitable for gases insoluble or reactive with water.
- Using Gas Syringes: For small quantities and gases that are soluble or reactive.
- Direct Collection: In some industrial settings, gases are directly transported through pipelines.

Conclusion

The displacement of water remains an essential and versatile technique for collecting gases generated during chemical reactions. Its simplicity, safety, and effectiveness make it a preferred method in educational laboratories and research settings. Understanding the principles, proper setup, and limitations of this technique ensures accurate data collection and safe handling of gases. Whether collecting hydrogen, oxygen, or other gases, mastering this method is fundamental for chemistry students and professionals alike.

Summary:

- Gases are collected by displacing water when they are insoluble and less dense than water.
- Proper setup and safety precautions are crucial.
- The method is widely applicable but has limitations with soluble and reactive gases.
- Alternative methods exist for specific gases or conditions.
- Practical applications include hydrogen, oxygen, and carbon dioxide collection.

By mastering the displacement of water technique, chemists can confidently analyze gaseous products of reactions, contributing to advancements in research, industry, and education.

Frequently Asked Questions

Why are gases generated in some chemical reactions collected by displacement of water?

Gases are collected by displacement of water because they are insoluble in water and do not react with it, allowing their collection over water without contamination.

Which gases are suitable for collection by displacement of water?

Gases such as hydrogen, oxygen, carbon dioxide, and chlorine are suitable because they are insoluble or only slightly soluble in water and do not react with it.

What precautions should be taken while collecting gases by water displacement?

Ensure the gas does not react with water, avoid leaks, use a proper water trough, and prevent the gas from dissolving in water to get an accurate collection.

How can you confirm that the collected gas is pure using water displacement?

You can perform tests such as burning a glowing splint for hydrogen or relighting a splint for oxygen to confirm the gas's identity and purity.

Why is water displacement used instead of other methods for gas collection?

Water displacement is simple, inexpensive, and suitable for gases that are insoluble and unreactive with water, making it an effective method for collection.

Can all gases be collected by displacement of water?

No, gases that are soluble in water or react with water cannot be collected by this method; they require other collection techniques like dry collection or collection over air.

What is the role of a delivery tube in collecting gases by water displacement?

The delivery tube directs the gas from the reaction vessel into the water-filled container, allowing the gas to displace water and be collected.

How does temperature affect the collection of gases by water displacement?

Higher temperatures increase the solubility of gases in water and may cause bubbling or loss of gas, so experiments are usually conducted at room temperature for accuracy.

What are the limitations of collecting gases by displacement of water?

Limitations include the solubility of gases in water, potential reactions with water, and the inability to collect highly soluble or reactive gases using this method.

How can the volume of gas collected by water displacement be measured accurately?

Using a gas jar or eudiometer and measuring the displacement of water allows for accurate determination of the gas's volume during collection.

Additional Resources

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Introduction

Chemical reactions are fundamental to understanding the behavior of matter, and gases play a pivotal role in many of these reactions. The ability to effectively collect and analyze gases generated during chemical processes is crucial in both academic research and industrial applications. One widely used technique for collecting gases is displacement of water, a method that leverages the physical property of water to facilitate gas collection without contamination or significant loss. This article explores the principles, procedures, advantages, limitations, and applications of collecting gases through water displacement, providing a comprehensive review suitable for researchers, educators, and professionals in the field of chemistry.

Historical Context and Significance

The method of collecting gases by water displacement dates back to the early days of chemistry in the 18th and 19th centuries. Chemists like Joseph Priestley and Antoine Lavoisier employed water displacement techniques to study gases such as oxygen, hydrogen, and carbon dioxide. These foundational experiments laid the groundwork for modern gas collection methods, emphasizing safety, purity, and efficiency.

The significance of water displacement arises from its simplicity and effectiveness, especially for gases that are insoluble or only slightly soluble in water. It allows for the collection of gases in a relatively pure form, which can then be analyzed for composition, volume, and other

properties.

Principles of Gas Collection by Displacement of Water

The core principle behind collecting gases via water displacement hinges on the physical dissimilarity between water and the gas being collected.

Specifically:

- Insolubility or Low Solubility: The collected gas must be insoluble or only sparingly soluble in water to prevent contamination or loss.
- Non-reactivity with Water: The gas should not react chemically with water under the conditions of collection.
- Density Considerations: The gas's density influences whether it will naturally rise and be collectable over water.

The process involves generating the gas in a reaction vessel, then connecting this vessel to an inverted container (often a graduated cylinder or gas jar) filled with water and submerged in a water trough. As the gas is produced, it displaces the water in the inverted container, allowing for measurement and collection.

Methodology: Step-by-Step Procedure

The process of collecting gases by displacement of water involves several precise steps to ensure safety and accuracy:

1. Preparation of Equipment:

- Clean and rinse the collection vessel (e.g., a gas jar or test tube).
- Fill the vessel completely with water, then invert it in a water trough, ensuring no air bubbles are trapped inside.
- Connect the reaction vessel (e.g., a test tube, flask) to the inverted water-filled container via a delivery tube.

2. Generation of Gas:

- Carry out the chemical reaction that produces the gas in the reaction vessel.
- Ensure the reaction produces enough pressure to push the gas into the collection vessel but not so much as to cause spillage or breakage.

3. Collection of Gas:

- As the gas is generated, it travels through the delivery tube and displaces the water in the inverted container.
- Continue the reaction until the desired volume of gas is collected.

4. Measurement and Analysis:

- Once the collection is complete, record the volume of gas displaced, often read directly from the graduated cylinder.

- The collected gas can then be subjected to further analysis, such as chemical composition testing.

Types of Gases Suitable for Water Displacement Collection

Not all gases are suitable for collection via water displacement. Gases that generally qualify include:

- Hydrogen (H_2): Light, insoluble, and non-reactive with water.
- Oxygen (O_2): Slightly soluble but still effectively collected.
- Carbon Dioxide (CO_2): More soluble, but still feasible with proper adjustments.
- Ammonia (NH_3): Soluble in water, thus requiring precautions.
- Chlorine (Cl_2): Slightly soluble, requiring careful handling.

Gases unsuitable for water displacement include:

- Hydrogen chloride (HCl): Reacts with water, producing hydrochloric acid.
- Sulfur dioxide (SO_2): Soluble and reactive.
- Nitrogen oxides (NO , NO_2): Reactive and soluble, requiring alternative methods.

This classification underscores the importance of understanding gas properties before selecting a collection method.

Advantages of Displacement of Water Method

The water displacement technique offers numerous benefits:

- Simplicity and Accessibility: Requires minimal specialized equipment.
- Cost-Effectiveness: Utilizes common laboratory materials.
- Safety: When handling non-reactive gases, reduces risk of explosion or inhalation.
- Purity of Collected Gas: Minimizes contamination when the gas is insoluble and non-reactive with water.
- Ease of Measurement: Gas volume can be directly read from graduated collection devices.

Limitations and Challenges

Despite its advantages, the water displacement method has notable limitations:

- Solubility Issues: Gases that dissolve appreciably in water cannot be collected effectively.

- Reactivity: Gases reactive with water may produce unwanted byproducts, complicating analysis.
- Pressure Constraints: Excessive pressure can cause the water to be pushed out or damage equipment.
- Leakage Risks: Imperfect seals or connections can lead to gas loss.
- Temperature Dependence: Gas solubility and volume are temperature-sensitive, requiring controlled conditions.

Researchers must carefully consider these factors when designing experiments.

Practical Applications in Industry and Research

Gas collection by water displacement finds extensive use across various fields:

- Educational Laboratories: Demonstrations of gas laws, such as hydrogen and oxygen production.
- Chemical Manufacturing: Production and collection of gases during synthesis processes.
- Environmental Monitoring: Collection of gases like CO₂ for analysis.
- Analytical Chemistry: Purification and quantification of gases for spectroscopic or chromatographic analysis.
- Energy Research: Collection of hydrogen for fuel cell studies.

Each application demands specific considerations regarding gas properties and safety protocols.

Safety Considerations

Handling gases and performing water displacement experiments require adherence to safety guidelines:

- Ventilation: Conduct experiments in well-ventilated areas or under fume hoods.
- Protective Equipment: Use goggles, gloves, and lab coats.
- Gas Specific Hazards:
 - Hydrogen: Flammable; avoid sparks.
 - Chlorine: Toxic; prevent inhalation.
 - Ammonia: Corrosive; handle with care.
- Equipment Integrity: Regularly inspect apparatus for leaks or damage.
- Proper Disposal: Dispose of residual gases and reaction byproducts according to environmental regulations.

Innovations and Future Directions

Advancements aim to address current limitations:

- Alternative Collection Methods: Use of gas syringes or sealed containers for highly soluble or reactive gases.
- Automated Systems: Integration of sensors and automation for precise control and measurement.
- Material Improvements: Development of corrosion-resistant and flexible materials for safer handling.
- Miniaturization: Microfluidic devices for small-scale, precise gas collection.

Research continues to refine the technique, making it safer, more efficient, and adaptable to a broader range of gases.

Conclusion

The collection of gases generated in chemical reactions through displacement of water remains a cornerstone technique in experimental chemistry. Its simplicity, cost-effectiveness, and versatility make it indispensable for both educational and industrial applications. However, understanding the properties of the gases involved, alongside careful experimental design and safety measures, is essential to maximize its effectiveness and mitigate potential hazards.

As scientific understanding deepens and technological innovations emerge, the water displacement method will undoubtedly evolve, maintaining its relevance in the ever-advancing field of chemical research. Recognizing its principles, applications, and limitations fosters safer and more accurate scientific investigations, ultimately contributing to the broader understanding of chemical phenomena.

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