

Ammonia Chemically Reacts With Oxygen Gas To Produce Nitric Oxide And Water . What Mass Of Oxygen Gas

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Introduction

Ammonia chemically reacts with oxygen gas in a significant oxidation reaction that has both industrial and environmental implications. This reaction is a fundamental process in various manufacturing industries, particularly in the production of nitric acid, which is crucial for fertilizers, explosives, and other chemicals. Understanding the precise quantities involved in this chemical reaction is essential for efficient industrial processes, resource management, and environmental safety.

In this article, we explore the chemical equation involved when ammonia reacts with oxygen, analyze the stoichiometry of the reaction, and determine the mass of oxygen gas required to react completely with a given amount of ammonia. Whether you are a student studying chemistry, an engineer involved in chemical manufacturing, or an enthusiast keen on understanding chemical reactions, this comprehensive guide provides detailed insights into this important reaction.

The Chemical Reaction Between Ammonia and Oxygen

The Basic Chemical Equation

The reaction between ammonia (NH_3) and oxygen (O_2) produces nitric oxide (NO) and water (H_2O). The balanced chemical equation for this process is:



This reaction is an example of a combustion or oxidation process where ammonia acts as a reducing agent, and oxygen is the oxidizing agent.

Understanding the Reaction Components

- Ammonia (NH_3): A colorless gas with a pungent smell, commonly used as a fertilizer.
- Oxygen (O_2): A diatomic gas essential for combustion and respiration.
- Nitric Oxide (NO): A colorless gas that plays a role in atmospheric chemistry and industrial processes.
- Water (H_2O): The common product of oxidation reactions involving nitrogen compounds.

Stoichiometry of the Reaction

Interpreting the Balanced Equation

The balanced chemical equation indicates that:

- 4 moles of ammonia react with 5 moles of oxygen.
- The reaction produces 4 moles of nitric oxide and 6 moles of water.

This molar ratio is crucial for calculating the amount of oxygen needed to react with a given amount of ammonia.

Calculating the Moles of Oxygen Gas Needed

Suppose you have a specific mass of ammonia and want to determine how much oxygen gas is required for complete reaction. The steps involve:

1. Convert the mass of ammonia to moles.
2. Use the molar ratio from the balanced equation to find the moles of oxygen.
3. Convert the moles of oxygen to mass.

Calculating the Mass of Oxygen Gas Required

Step 1: Determine the Moles of Ammonia

The molar mass of ammonia (NH_3):

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\[
\mathrm{N} = 14.01\, \mathrm{g/mol}
\]
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$$\mathrm{H} = 1.008, \mathrm{g/mol}$$

\]

\[

$$\mathrm{Molar\, mass\, of\, NH_3} = 14.01 + (3 \times 1.008) = 17.034, \mathrm{g/mol}$$

\]

If you have a mass $(m_{\mathrm{NH_3}})$ of ammonia, the number of moles is:

\[

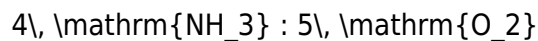
$$n_{\mathrm{NH_3}} = \frac{m_{\mathrm{NH_3}}}{17.034}$$

\]

Step 2: Use the Molar Ratio to Find Moles of Oxygen

From the balanced equation:

\[



\]

The molar ratio:

\[

$$n_{\mathrm{O_2}} = \frac{5}{4} \times n_{\mathrm{NH_3}}$$

\]

Step 3: Convert Moles of Oxygen to Mass

The molar mass of oxygen gas ($\mathrm{O_2}$):

\[

$$\mathrm{O_2} = 2 \times 16.00 = 32.00, \mathrm{g/mol}$$

\]

Thus, the mass of oxygen gas needed:

\[

$$m_{\mathrm{O_2}} = n_{\mathrm{O_2}} \times 32.00 = \left(\frac{5}{4} \times n_{\mathrm{NH_3}} \right) \times 32.00$$

\]

Substituting $(n_{\mathrm{NH_3}})$:

\[

$$m_{\text{O}_2} = \left(\frac{5}{4} \times \frac{m_{\text{NH}_3}}{17.034} \right) \times 32.00$$

Simplify:

$$m_{\text{O}_2} = \frac{5 \times 32.00}{4 \times 17.034} \times m_{\text{NH}_3}$$

$$m_{\text{O}_2} \approx \frac{160}{68.136} \times m_{\text{NH}_3} \approx 2.347 \times m_{\text{NH}_3}$$

Practical Example: Calculating Oxygen Mass for 10 grams of Ammonia

Suppose you want to find the mass of oxygen gas required to completely react with 10 grams of ammonia:

$$m_{\text{O}_2} \approx 2.347 \times 10, \text{ g} = 23.47, \text{ g}$$

Therefore, approximately 23.47 grams of oxygen gas are needed to fully react with 10 grams of ammonia.

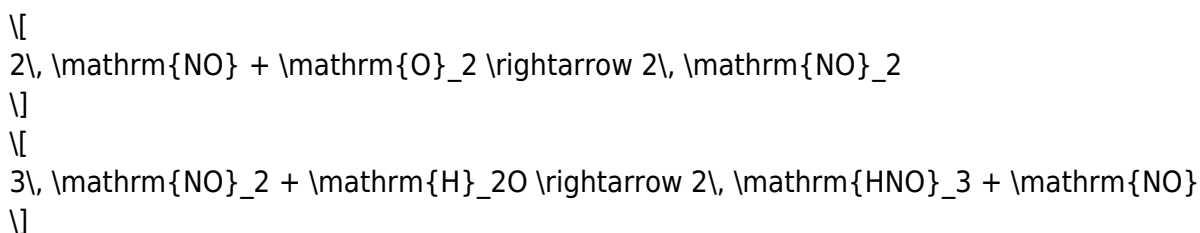
Environmental Significance of the Reaction

This reaction plays a pivotal role in atmospheric chemistry and pollution control. Nitric oxide (NO), produced during the reaction, can further react to form nitrogen dioxide (NO₂), contributing to smog formation and acid rain. Controlling the amount of oxygen and ammonia in industrial processes helps minimize undesirable emissions.

Industrial Applications of Ammonia and Oxygen Reactions

Production of Nitric Acid

The nitric oxide produced in this reaction is often oxidized further to nitrogen dioxide (NO₂), which is then absorbed in water to produce nitric acid:



This process, known as the Ostwald process, is vital for manufacturing fertilizers.

Environmental Control and Emission Reduction

Industries must carefully monitor oxygen and ammonia levels to prevent the formation of nitrogen oxides, which contribute to air pollution. Catalytic converters and emission control systems are designed based on stoichiometric calculations similar to those discussed here.

Factors Affecting the Reaction Efficiency

- Temperature: Elevated temperatures favor the formation of nitric oxide.
- Pressure: Increased pressure can influence reaction rates.
- Catalysts: Certain catalysts can improve reaction efficiency and selectivity.
- Purity of Reactants: Impurities can hinder the reaction or produce unwanted byproducts.

Conclusion

Understanding the chemical reaction between ammonia and oxygen gas is essential for various industrial applications, environmental management, and chemical education. By analyzing the stoichiometry, we can accurately determine the amount of oxygen required to react with a given quantity of ammonia. This knowledge not only helps in optimizing industrial processes but also in minimizing environmental impact by controlling emissions.

In practical terms, for every 17 grams of ammonia, approximately 32 grams of oxygen are needed for complete reaction, highlighting the importance of precise calculations in chemical manufacturing. Whether producing nitric acid or managing pollution, mastery of these stoichiometric principles is fundamental to advancing chemical science and industry.

Keywords: Ammonia, Oxygen Gas, Nitric Oxide, Water, Chemical Reaction, Stoichiometry, Molar Mass, Industrial Chemistry, Environmental Impact, Nitric Acid Production

Frequently Asked Questions

What is the chemical reaction between ammonia and oxygen gas?

Ammonia chemically reacts with oxygen gas to produce nitric oxide (NO) and water (H₂O), represented by the equation: $4 \text{NH}_3 + 5 \text{O}_2 \rightarrow 4 \text{NO} + 6 \text{H}_2\text{O}$.

How do you calculate the mass of oxygen gas needed to react completely with a given amount of ammonia?

First, determine the molar amount of ammonia, then use the stoichiometric ratio from the balanced equation (5 mol O₂ per 4 mol NH₃) to find moles of oxygen required. Finally, multiply by oxygen's molar mass (32 g/mol) to find the mass needed.

What factors influence the amount of oxygen gas required in the reaction with ammonia?

The amount of ammonia present, reaction conditions such as temperature and pressure, and ensuring complete reaction without excess oxygen all influence the amount of oxygen gas needed.

Why is the reaction between ammonia and oxygen important industrially?

This reaction is crucial in the production of nitric oxide, which is a key intermediate in manufacturing nitric acid, fertilizers, and other chemicals.

If 10 grams of ammonia react completely, how much oxygen gas is needed?

Calculate moles of ammonia: $10 \text{ g} / 17 \text{ g/mol} \approx 0.588 \text{ mol}$. Using the ratio 4 mol NH₃ : 5 mol O₂, oxygen needed = $(0.588 \text{ mol NH}_3) \times (5/4) \approx 0.735 \text{ mol O}_2$. Mass of oxygen = $0.735 \text{ mol} \times 32 \text{ g/mol} \approx 23.52 \text{ grams}$.

Additional Resources

Ammonia and Oxygen Reaction: An In-Depth Analysis of Nitric Oxide and Water Formation

Introduction: The Significance of Ammonia's Reactivity with Oxygen

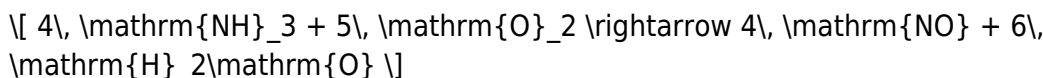
Ammonia (NH₃) is a fundamental chemical compound with vast industrial applications, from fertilizers to cleaning products. Its reactivity with oxygen (O₂) is particularly crucial, especially in the context of nitric oxide (NO) production, which is a key precursor in manufacturing nitric acid—a vital chemical in various industries including agriculture, explosives, and electronics.

Understanding the reaction between ammonia and oxygen not only provides insights into chemical processes but also enables precise calculations of reactant quantities needed for desired outputs. This article explores the chemical reaction where ammonia reacts with oxygen to produce nitric oxide and water, focusing especially on how to determine the mass of oxygen required for a given amount of ammonia.

The Chemical Reaction: Breaking Down the Process

The Balanced Chemical Equation

The core reaction under discussion is:



This reaction is a typical oxidation process where ammonia acts as the reducing agent, and oxygen is the oxidizing agent.

Key points:

- Reactants: Ammonia (NH₃) and oxygen (O₂)
- Products: Nitric oxide (NO) and water (H₂O)
- Stoichiometry: The molar ratio of NH₃ to O₂ is 4:5

Understanding the Reaction Dynamics

This reaction is exothermic, releasing heat, and is often used in industrial processes such as the Ostwald process for nitric acid production. It involves:

- Oxidation of ammonia: NH₃ loses electrons, forming NO.
- Formation of water: Hydrogen atoms combine with oxygen to produce H₂O.

Calculating the Required Mass of Oxygen Gas

Suppose an industrial process or laboratory experiment involves a specific amount of ammonia. The question arises: "What mass of oxygen gas is needed to react completely with a given amount of ammonia?"

This calculation hinges on stoichiometry—the quantitative relationship between reactants and products.

Step 1: Determine the Moles of Ammonia

Suppose you have n grams of ammonia. First, convert this mass to moles:

$$\text{Moles of NH}_3 = \frac{\text{Mass of NH}_3}{\text{Molar mass of NH}_3}$$

- Molar mass of NH_3 : approximately 17.03 g/mol

Example:

If you have 34.06 grams of NH_3 :

$$\text{Moles of NH}_3 = \frac{34.06 \text{ g}}{17.03 \text{ g/mol}} = 2 \text{ mol}$$

Step 2: Use Stoichiometry to Find Moles of O_2 Needed

From the balanced equation:



The molar ratio:

$$4 \text{ mol NH}_3 : 5 \text{ mol O}_2$$

Thus, to find the moles of oxygen needed for 2 mol of ammonia:

$$\text{Moles of O}_2 = \frac{5}{4} \times \text{Moles of NH}_3 = \frac{5}{4} \times 2 = 2.5 \text{ mol}$$

Step 3: Convert Moles of O₂ to Mass

- Molar mass of O₂: approximately 32.00 g/mol

Mass of oxygen required:

$$\text{Mass} = \text{Moles} \times \text{Molar mass}$$

$$\text{Mass of O}_2 = 2.5 \text{ mol} \times 32.00 \text{ g/mol} = 80 \text{ g}$$

Summary:

- To react completely with 34.06 g of ammonia, 80 g of oxygen gas is required.

Implications and Practical Applications

Industrial Significance

Understanding the precise amount of oxygen needed is critical in large-scale manufacturing, ensuring efficient use of raw materials and minimizing waste. For example, in the Ostwald process, controlling the oxygen input optimizes nitric oxide yield, which subsequently leads to high-purity nitric acid.

Environmental and Safety Considerations

The reaction's exothermic nature necessitates careful control to prevent runaway reactions, especially in confined spaces. Accurate calculations of reactant quantities contribute to safer operation and reduced environmental impact.

Additional Factors Affecting the Reaction

While stoichiometry provides the ideal theoretical values, real-world reactions may deviate due to:

- Incomplete reactions: Factors like temperature, pressure, and purity influence completeness.
- Side reactions: Formation of nitrogen gases (N₂), nitrogen dioxide (NO₂), or other nitrogen oxides can occur.
- Reaction kinetics: The rate at which the reaction proceeds depends on catalysts, temperature, and reactant concentrations.

Understanding these factors is vital for optimizing industrial processes.

Conclusion: Mastering the Ammonia-Oxygen Reaction

The reaction between ammonia and oxygen gas to produce nitric oxide and water is a cornerstone in industrial chemistry, underpinning the production of essential chemicals like nitric acid. Precise stoichiometric calculations enable engineers and chemists to determine the exact mass of oxygen needed for a given amount of ammonia, ensuring efficient, safe, and sustainable operation.

By applying the balanced chemical equation and molar relationships, one can seamlessly transition from theoretical understanding to practical application, whether in laboratory experiments or large-scale manufacturing. As chemistry continues to evolve, mastery of such fundamental reactions remains crucial for innovation and environmental stewardship.

In essence, knowing the amount of oxygen gas required to react fully with a specific quantity of ammonia empowers professionals to optimize processes, reduce waste, and uphold safety standards—highlighting the enduring importance of chemical stoichiometry in modern industry.

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