A Combination If 32.5 G Of Nh3 React With An Excess Of Oxygen In The Reaction Below, How Many Grams Of

A Combination If 32.5 G Of Nh3 React With An Excess Of Oxygen In The Reaction Below, How Many Grams Of ammonia (NH_3) will be produced or consumed in the chemical reaction, and what are the implications of this process in industrial and environmental contexts? Understanding the stoichiometry of ammonia's combustion or oxidation reactions is fundamental in chemistry, especially in fields such as chemical manufacturing, environmental science, and energy production. This article provides a comprehensive analysis of the reaction involving ammonia and excess oxygen, including detailed calculations, reaction mechanisms, and real-world applications.

Understanding the Reaction Between Ammonia and Oxygen

Overview of Ammonia (NH_3)

Ammonia is a colorless, pungent gas with the chemical formula NH_3. It is widely used in fertilizers, cleaning products, and as an industrial precursor for the synthesis of various chemicals. Its chemical properties make it highly reactive, especially with oxidizing agents such as oxygen.

Common Reactions of Ammonia with Oxygen

When ammonia reacts with oxygen, it undergoes oxidation, which can be summarized by the simplified reaction:

$$4 \, \text{NH}_3 + 3 \, \text{O}_2 \rightarrow 2 \, \text{N}_2 + 6 \, \text{H}_2O$$

This reaction is exothermic and is a key part of combustion processes involving ammonia. It produces nitrogen gas and water vapor, which are environmentally benign, making it a cleaner alternative to hydrocarbon combustion.

Calculating the Reactant and Product Masses in the NH_3–O_2 Reaction

Given Data and Objective

- Mass of ammonia (NH_3): 32.5 grams
- Oxygen: Excess (meaning enough oxygen is present to ensure complete reaction)
- Goal: Determine how many grams of nitrogen gas (N_2) and water vapor (H_2O) are produced, or how much NH_3 reacts.

Step-by-Step Calculation Process

1. **Calculate the molar mass of NH_3:**
    - Nitrogen (N): 14.01 g/mol

    - Hydrogen (H): 1.008 g/mol

$$
\text{Molar mass of NH}_3 = 14.01 + (3 \times 1.008) = 17.034\, \text{g/mol}
$$

2. **Determine the number of moles of NH_3:**
$$
\text{Moles of NH}_3 = \frac{32.5\, \text{g}}{17.034\, \text{g/mol}} \approx 1.909\, \text{mol}
$$

3. **Use the balanced chemical equation to find the mole ratio:**
$$
4\, \text{NH}_3 : 3\, \text{O}_2 : 2\, \text{N}_2 : 6\, \text{H}_2O
$$
Since oxygen is in excess, focus on NH_3 consumption and product formation.

4. **Calculate the moles of N_2 produced:**
$$
\text{Moles of N}_2 = \frac{1}{2} \times \text{moles of NH}_3 = \frac{1}{2} \times 1.909 \approx 0.9545\, \text{mol}
$$

5. **Calculate the mass of N_2 produced:**
$$
\text{Molar mass of N}_2 = 2 \times 14.01 = 28.02\, \text{g/mol}
$$
$$
\text{Mass of N}_2 = 0.9545 \times 28.02 \approx 26.75\, \text{g}
$$

6. **Calculate the moles of H_2O produced:**
$$
\text{Moles of H}_2O = \frac{6}{4} \times \text{moles of NH}_3 = 1.5 \times 1.909 \approx 2.864\, \text{mol}
$$

7. **Calculate the mass of H_2O produced:**
$$
\text{Molar mass of H}_2O = 2 \times 1.008 + 16.00 = 18.016\, \text{g/mol}
$$
$$
\text{Mass of H}_2O = 2.864 \times 18.016 \approx 51.55\, \text{g}
$$

Summary of Results

- Ammonia reacted: approximately 32.5 grams
- Nitrogen gas produced: approximately 26.75 grams
- Water vapor produced: approximately 51.55 grams

Since oxygen is in excess, all the ammonia reacts completely, and these calculations reflect the maximum possible products.

Implications of Ammonia Combustion and Oxidation

Industrial Significance

Ammonia's reaction with oxygen is fundamental in various industrial processes:

- **Ammonia Combustion Engines:** Using ammonia as a fuel source, especially due to its high energy density and cleaner emissions.
- **Waste Treatment:** Oxidation of ammonia in wastewater treatment plants to remove excess nitrogen compounds.
- **Production of Nitrogen and Water:** Key steps in chemical manufacturing, including nitric acid production.

Environmental Impact

The reaction's products, nitrogen and water, are environmentally benign, making ammonia a potential clean fuel alternative. However, incomplete combustion or improper handling can lead to emissions of nitrogen oxides (NO_x), which are pollutants.

Applications and Safety Considerations

Industrial Applications

- Ammonia-based energy systems
- Fertilizer production
- Chemical synthesis

Safety Precautions

- Handling ammonia requires protective gear due to its toxicity and corrosiveness.
- Proper ventilation to prevent buildup of ammonia vapors.
- Controlled combustion environments to minimize NO_x emissions.

Environmental Benefits of Using Ammonia as a Fuel

Using ammonia as an energy carrier offers several environmental advantages:

- Zero carbon dioxide emissions during combustion.
- Produces nitrogen and water, which are harmless.
- Potential to reduce reliance on fossil fuels.

However, managing NO_x emissions remains a challenge, necessitating advanced catalytic treatment systems.

Conclusion

In summary, reacting 32.5 grams of ammonia (NH_3) with excess oxygen results in the production of approximately 26.75 grams of nitrogen gas (N_2) and 51.55 grams of water vapor (H_2O). Understanding the stoichiometry of this reaction is crucial for optimizing industrial processes, reducing environmental impact, and advancing clean energy technologies. As research continues to improve ammonia-based energy systems, the knowledge of such fundamental calculations will remain vital for engineers, chemists, and environmental scientists aiming to develop sustainable solutions for the future.

Key Takeaways

- The molar mass of NH_3 is 17.034 g/mol.
- Complete reaction of 32.5 g of NH_3 yields approximately 26.75 g of N_2 and 51.55 g of H_2O.
- Excess oxygen ensures full conversion of ammonia, maximizing product yields.
- The reaction is environmentally cleaner compared to hydrocarbon combustion but requires emission controls.

By mastering the stoichiometry and reaction mechanisms of ammonia oxidation, professionals can better design processes that are efficient, safe, and environmentally sustainable.

Frequently Asked Questions

What is the chemical reaction when 32.5 g of NH3 reacts with excess oxygen?

The reaction is 4 NH3 + 3 O2 → 2 N2 + 6 H2O.

How do you calculate the amount of nitrogen gas produced from 32.5 g of NH3 reacting with oxygen?

First, convert 32.5 g NH3 to moles, then use the molar ratio from the balanced equation to find moles of N2 formed, and finally convert back to grams.

What is the molar mass of NH3 and how is it used in calculations?

The molar mass of NH3 is approximately 17.03 g/mol. It is used to convert grams of NH3 to moles for stoichiometric calculations.

How many grams of N2 are produced from 32.5 g of NH3?

Approximately 22.8 grams of N2 are produced, based on stoichiometric calculations from the balanced equation.

Does excess oxygen affect the amount of NH3 reacted in the reaction?

No, excess oxygen ensures all NH3 reacts completely, so the limiting reactant is NH3 itself.

What are the key steps to solve this type of problem involving gases and stoichiometry?

Convert given mass to moles, use the balanced chemical equation to find the mole ratio, then convert the desired product's moles back to grams.

What is the significance of the molar ratio in the reaction between NH3 and O2?

The molar ratio (4:3 for NH3:O2) helps determine the amount of products formed from a given amount of reactant.

How does temperature and pressure affect the calculations in this reaction?

For mass-based calculations, temperature and pressure don't affect the stoichiometry; they are more relevant when dealing with gas volumes.

What safety considerations are important when reacting ammonia with oxygen?

Reactions can produce harmful gases and heat; proper ventilation, protective equipment, and handling procedures are essential.

Additional Resources

A Combination If 32.5 G Of NH_3 React With An Excess Of Oxygen: How Many Grams Of Product Are Formed?

In the realm of chemical reactions, understanding the quantitative aspects of reactants and products is fundamental for both theoretical insights and practical applications. The reaction between ammonia (NH_3) and oxygen (O_2) stands out as a classic example often examined in combustion chemistry, environmental science, and industrial processes such as nitric acid production. This investigation delves into a specific scenario: what happens when 32.5 grams of ammonia (NH_3) react with an excess of oxygen? The central question is: how many grams of product are formed?

This comprehensive analysis aims to demystify the chemical principles involved, explore the reaction mechanism, perform detailed stoichiometric calculations, and interpret the results in context. Such an exploration not only enhances understanding of this particular reaction but also exemplifies the broader methodology of quantitative chemical analysis.

Understanding the Reactants and the Reaction Mechanism

The Reactants: Ammonia (NH_3) and Oxygen (O_2)

- Ammonia (NH_3): A colorless, pungent gas widely used in fertilizers, cleaning agents, and as a precursor in chemical synthesis. Its molar mass is approximately 17.03 g/mol.
- Oxygen (O_2): An abundant diatomic gas essential for combustion and respiration, with a molar mass of about 32.00 g/mol.

In combustion reactions, ammonia reacts with oxygen to produce nitrogen (N_2), water (H_2O), and sometimes nitrogen oxides (NO□), depending on conditions. For simplicity, and aligned with typical combustion scenarios, the primary reaction considered is the complete oxidation of ammonia:

Reaction (Complete Combustion of NH_3):

$$ 4\, \mathrm{NH}_3 + 3\, \mathrm{O}_2 \rightarrow 2\, \mathrm{N}_2 + 6\, \mathrm{H}_2O $$

This balanced equation indicates that four moles of ammonia react with three moles of oxygen to produce nitrogen and water.

Quantitative Analysis: Calculating the Product Mass

Step 1: Determine Moles of NH_3 Reacting

Given mass of NH_3:

$$ \text{Mass of NH}_3 = 32.5\, \mathrm{g} $$

Calculate the number of moles:

$$ \text{Moles of NH}_3 = \frac{\text{Mass}}{\text{Molar mass}} = \frac{32.5\, \mathrm{g}}{17.03\, \mathrm{g/mol}} \approx 1.909\, \text{mol} $$

Step 2: Use Stoichiometry to Find Moles of Products

From the balanced equation:

$$ 4\, \mathrm{mol\, NH}_3 \rightarrow 2\, \mathrm{mol\, N}_2 $$
$$ 4\, \mathrm{mol\, NH}_3 \rightarrow 6\, \mathrm{mol\, H}_2O $$

Calculate the moles of nitrogen and water produced:

- Nitrogen (N_2):

$$ \text{Moles of N}_2 = \frac{2}{4} \times 1.909 \approx 0.9545\, \text{mol} $$

- Water (H_2O):

$$ \text{Moles of H}_2O = \frac{6}{4} \times 1.909 \approx 2.863\, \text{mol} $$

Since oxygen is in excess, it does not limit the reaction; thus, the amount of products depends solely on the amount of ammonia.

Step 3: Convert Moles of Products to Masses

- Mass of N_2:

$$ \text{Mass} = \text{moles} \times \text{molar mass} = 0.9545\, \text{mol} \times 28.02\, $$

$$\mathrm{g/mol} \approx 26.74\, \mathrm{g}$$

- Mass of H_2O:

$$\text{Mass} = 2.863\, \text{mol} \times 18.02\, \mathrm{g/mol} \approx 51.52\, \mathrm{g}$$

Implications and Considerations

Product Yield and Reaction Efficiency

In an ideal scenario with complete combustion and no side reactions, the total product mass sums to:

$$\text{Total mass} = 26.74\, \mathrm{g} + 51.52\, \mathrm{g} = 78.26\, \mathrm{g}$$

This aligns with the law of conservation of mass. Practically, reactions may not reach 100% efficiency due to side reactions, incomplete combustion, or energy constraints, but this calculation provides a theoretical maximum.

Environmental and Industrial Significance

The oxidation of ammonia is foundational in processes like:

- Nitric Acid Production: Ammonia oxidation to nitrogen oxides, which are then converted to nitric acid.
- Waste Management: Combustion of ammonia in waste treatment to eliminate hazardous gases.
- Energy Generation: Potential use in fuel cells or combustion engines with controlled emissions.

Understanding the stoichiometry and yields informs process optimization, environmental impact assessments, and safety protocols.

Additional Analytical Perspectives

Effect of Excess Oxygen

The phrase "with an excess of oxygen" implies that oxygen is not the limiting reactant. This ensures complete oxidation of ammonia, maximizing product formation. However, in real systems, excess oxygen can influence reaction rates, heat management, and emissions.

Potential Side Reactions and Byproducts

While the idealized reaction produces nitrogen and water, real combustion may produce nitrogen oxides (NO, NO_2), especially at high temperatures, which are environmentally regulated pollutants. The formation of NO? involves complex mechanisms and depends on temperature and oxygen availability.

Safety Considerations

Ammonia and oxygen reactions are highly exothermic. Precise stoichiometric calculations are vital for designing safe industrial reactors, preventing explosions, and managing heat dissipation.

Conclusion: Quantitative Summary

Starting with 32.5 grams of ammonia, reacting with excess oxygen, the theoretical maximum yields are approximately:

- 26.74 grams of nitrogen gas (N_2)
- 51.52 grams of water vapor (H_2O)

Totaling about 78.26 grams of products, illustrating the straightforward relationship governed by stoichiometry. This detailed analysis exemplifies how fundamental chemical principles underpin practical applications and environmental strategies, emphasizing the importance of precise calculations in chemical engineering and research.

In closing, understanding the mass relationships in ammonia combustion not only satisfies academic curiosity but also enhances the capacity for responsible industrial practice, environmental protection, and innovation in chemical processes.

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