

Hydrogen Gas Combines With Nitrogen To Form Ammonia. Translate The Following Statement Into The Chemical

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Understanding the chemical transformation of hydrogen and nitrogen into ammonia is fundamental in both industrial chemistry and environmental science. This process not only underpins the production of one of the most important chemical fertilizers but also exemplifies a key example of a synthesis reaction involving diatomic gases. In this article, we will explore the chemical nature of this reaction, its industrial significance, the underlying mechanisms, and the translation of the descriptive statement into its chemical equation.

Introduction to Ammonia and Its Importance

What Is Ammonia?

Ammonia is a colorless gas with a pungent smell, composed of nitrogen and hydrogen atoms in a specific ratio. Its chemical formula is NH_3 , indicating one nitrogen atom bonded to three hydrogen atoms. It is widely used in the manufacturing of fertilizers, cleaning products, and as a precursor to various chemicals.

Significance of Ammonia Production

The industrial production of ammonia is crucial because:

- It is a primary component in nitrogen-based fertilizers that support global agriculture.
- It serves as a building block for the synthesis of other nitrogen compounds, including nitric acid and urea.
- It has applications in refrigeration, cleaning, and as a potential fuel source.

The Chemical Reaction: From Gases to Ammonia

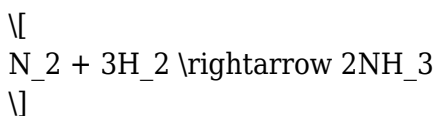
Understanding the Reactants

The reaction involves two diatomic gases:

- Hydrogen (H₂):** A colorless, flammable gas composed of two hydrogen atoms.
- Nitrogen (N₂):** A diatomic, inert gas that makes up approximately 78% of Earth's atmosphere.

The Chemical Equation

The process of combining hydrogen and nitrogen to produce ammonia is represented by the following balanced chemical equation:



This indicates that one molecule of nitrogen reacts with three molecules of hydrogen to produce two molecules of ammonia.

The Haber-Bosch Process: Industrial Synthesis of Ammonia

Historical Background

The synthesis of ammonia from nitrogen and hydrogen was industrialized in the early 20th century through the Haber-Bosch process, developed by Fritz Haber and Carl Bosch. This process revolutionized agriculture by enabling large-scale fertilizer production.

Process Overview

The Haber-Bosch process involves:

- High temperature (400-500°C)
- High pressure (150-250 atmospheres)
- Iron-based catalysts to facilitate the reaction

The reaction is reversible; thus, conditions are optimized to maximize ammonia yield.

Reaction Mechanism

The mechanism involves:

1. Adsorption of nitrogen and hydrogen molecules onto the catalyst surface.
2. Activation of molecules, breaking the triple bond in N₂.
3. Formation of NH₃ molecules, which then desorb from the catalyst surface.

Chemical Translation of the Statement

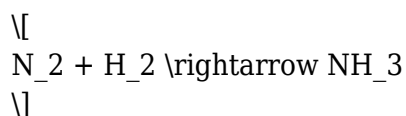
Breaking Down the Statement

The initial statement describes a chemical transformation involving hydrogen and nitrogen gases forming ammonia. To translate this into a chemical equation, identify the reactants and products, and balance the equation accordingly.

Step-by-Step Translation

- Reactants:
- Hydrogen gas (H₂)
- Nitrogen gas (N₂)
- Product:
- Ammonia (NH₃)

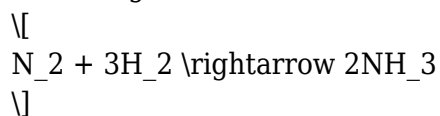
The chemical reaction is:



But to balance the equation, consider the number of atoms:

- Nitrogen: 2 atoms on left (N₂), 1 atom per NH₃ molecule
- Hydrogen: 2 atoms per H₂, 3 atoms per NH₃

Balancing:



This balanced equation accurately represents the chemical transformation described.

Additional Aspects of the Reaction

Conditions Required for the Reaction

- High temperature and pressure to overcome activation energy barrier.
- Use of catalysts (typically iron with promoters) to increase reaction rate.
- Continuous removal of ammonia from the reaction mixture to shift equilibrium toward product formation.

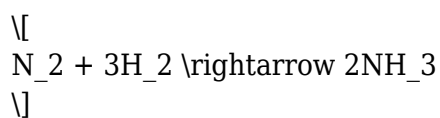
Environmental and Economic Considerations

While the Haber-Bosch process is highly efficient, it is energy-intensive and contributes significantly to global energy consumption. Efforts are ongoing to develop more sustainable methods for ammonia synthesis, such as:

- Electrochemical nitrogen reduction
- Photocatalytic processes
- Biological nitrogen fixation mimicking natural processes

Summary and Conclusion

The transformation of hydrogen gas and nitrogen gas into ammonia is a cornerstone of modern chemistry and industrial manufacturing. The process, summarized by the chemical equation:



is known as the Haber-Bosch process, which operates under specific high-temperature and high-pressure conditions with catalysts. This synthesis not only underscores the importance of gas-phase reactions but also highlights the intersection of chemistry, engineering, and environmental science. As global demand for fertilizers and sustainable chemical processes grows, understanding this reaction remains vital for scientific advancement and sustainable development.

In conclusion, translating the descriptive statement into its chemical form provides a clear and precise understanding of the reaction mechanism, conditions, and significance of ammonia synthesis from nitrogen and hydrogen gases.

Frequently Asked Questions

What is the chemical reaction involved when hydrogen gas combines with nitrogen to produce ammonia?

The chemical reaction is $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$, where nitrogen gas reacts with hydrogen gas to form ammonia.

How is ammonia synthesized from hydrogen and nitrogen gases in industrial processes?

Ammonia is synthesized via the Haber-Bosch process, where nitrogen and hydrogen gases are combined under high temperature and pressure in the presence of a catalyst to produce ammonia.

What are the chemical symbols for the elements involved in forming ammonia?

The chemical symbols are N for nitrogen and H for hydrogen, which combine to form ammonia (NH_3).

What is the significance of the reaction between hydrogen and nitrogen in the production of fertilizers?

This reaction produces ammonia, a key ingredient in fertilizers, essential for plant growth and global food production.

Translate the statement 'Hydrogen gas combines with nitrogen to form ammonia' into a balanced chemical equation.

The balanced chemical equation is $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$.

Why is the Haber-Bosch process important in chemical manufacturing?

It allows large-scale synthesis of ammonia from nitrogen and hydrogen, which is crucial for fertilizer production and supporting global agriculture.

Additional Resources

Hydrogen Gas Combines With Nitrogen To Form Ammonia. Translate The Following Statement Into The Chemical

In the world of chemistry, understanding how elements interact to form compounds is fundamental. A classic example of such a reaction is the synthesis of ammonia, a compound vital for agriculture,

industry, and environmental management. The statement "Hydrogen gas combines with nitrogen to form ammonia" succinctly describes a chemical process that underpins global food production and chemical manufacturing. To fully appreciate this transformation, it's essential to delve into the chemical equations involved, the mechanisms behind the reaction, and its significance in contemporary science and industry.

The Chemical Foundations of Ammonia Synthesis

What Is Ammonia?

Ammonia is a colorless, pungent gas with the chemical formula NH_3 . It is composed of one nitrogen atom bonded to three hydrogen atoms, forming a molecule with a trigonal pyramidal shape. Ammonia plays a crucial role not only as a building block for fertilizers but also in the production of cleaning agents, refrigerants, and pharmaceuticals.

Why Is Ammonia Important?

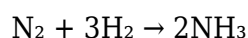
- Agriculture: Used extensively in fertilizers to promote plant growth.
- Industrial applications: Serves as a precursor for the synthesis of plastics, explosives, and textiles.
- Environmental significance: Acts as a nitrogen source in various ecological processes.

Understanding how ammonia is produced on a large scale is vital for appreciating its role in global economics and environmental management.

The Chemical Reaction: From Elements to Compound

The Direct Combination of Hydrogen and Nitrogen

The core reaction involves the direct combination of diatomic nitrogen (N_2) and diatomic hydrogen (H_2) gases to produce ammonia (NH_3). The overall chemical equation can be written as:



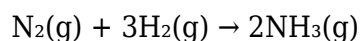
This reaction indicates that one molecule of nitrogen reacts with three molecules of hydrogen to produce two molecules of ammonia.

Translating the Statement into Chemical Terms

The statement "Hydrogen gas combines with nitrogen to form ammonia" is succinct but can be expanded into the following chemical expression:

- Reactants: N_2 (g) and H_2 (g)
- Product: NH_3 (g)

Expressed as a balanced chemical equation:



This balanced equation ensures the conservation of atoms, with the same number of each element on both sides.

The Haber-Bosch Process: Industrial Synthesis of Ammonia

Historical Context and Significance

The industrial synthesis of ammonia is primarily achieved through the Haber-Bosch process, developed in the early 20th century by Fritz Haber and Carl Bosch. This innovation revolutionized agriculture by enabling large-scale fertilizer production, greatly increasing food security worldwide.

Process Overview

The Haber-Bosch process involves several critical steps:

1. Preparation of Reactants:

- Nitrogen is obtained from the air via fractional distillation.
- Hydrogen is produced mainly through steam reforming of natural gas (methane).

2. Reaction Conditions:

- High temperature: approximately 400–500°C
- High pressure: about 150–200 atmospheres
- Catalyst: iron-based with promoters to enhance activity

3. Reaction Mechanics:

- The nitrogen and hydrogen gases are compressed and passed over the catalyst.
- The reaction reaches a dynamic equilibrium, with ammonia forming and decomposing simultaneously.

4. Ammonia Recovery:

- The gaseous mixture is cooled.
- Ammonia condenses out of the mixture, separating it from unreacted gases which are recycled.

The Role of Conditions and Catalysts

The reaction is thermodynamically favored at high pressures and moderate temperatures, balancing kinetics and equilibrium considerations. Catalysts, typically iron with potassium and aluminum oxides, accelerate the reaction without being consumed, making the process economically viable.

The Chemistry Behind Ammonia Formation

Kinetics and Thermodynamics

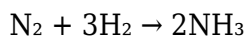
- Kinetics: The reaction between nitrogen and hydrogen has a high activation energy; thus, catalysts and elevated temperatures are essential.
- Thermodynamics: The formation of ammonia is exothermic (releases heat), which influences the optimal temperature for maximum yield.

Reaction Equilibrium

The Haber-Bosch process operates close to equilibrium. To maximize ammonia output, conditions are optimized to favor its formation, often through continuous removal of ammonia from the reaction mixture.

Balancing the Equation

The chemical equation:



- Atoms:
- Nitrogen: 2 on both sides
- Hydrogen: 6 on both sides
- States:
- Gases (g) are typical for industrial reactions involving gases.

Side Reactions and Byproducts

While the main reaction is straightforward, impurities and side reactions can occur, such as:

- Formation of hydrazine (N_2H_4) under certain conditions
- Potential formation of nitrogen oxides at high temperatures

However, the process is carefully controlled to minimize byproducts and maximize ammonia yield.

Environmental and Economic Impacts

Benefits

- Enhanced Food Production: Ammonia-based fertilizers have enabled a dramatic increase in crop yields.
- Industrial Development: Ammonia is a precursor for numerous chemicals and materials.

Challenges

- Energy Consumption: The Haber-Bosch process is energy-intensive, relying heavily on fossil fuels.
- Greenhouse Gas Emissions: The process contributes to CO_2 emissions, impacting climate change.
- Nitrogen Pollution: Excessive fertilizer use can lead to environmental issues such as eutrophication.

Future Directions

Research is ongoing to develop more sustainable ammonia synthesis methods, such as:

- Electrochemical Nitrogen Reduction: Using renewable energy to produce ammonia at ambient conditions.
- Biological Fixation: Mimicking natural nitrogen-fixing bacteria for sustainable ammonia production.

Conclusion

Understanding how hydrogen gas combines with nitrogen to form ammonia illuminates a cornerstone of modern chemistry and industry. This reaction, captured by the chemical equation $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$, underscores the importance of reaction conditions, catalysts, and process engineering in transforming simple gases into a vital compound. As the world seeks sustainable solutions for food security and environmental conservation, innovations in ammonia synthesis will continue to evolve, balancing industrial needs with ecological responsibility.

In essence, the translation of the statement into the chemical reaction underscores a fundamental chemical process that has shaped human civilization — a testament to the power of chemical reactions in transforming the elements around us into compounds that sustain life and drive industry.

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