How Many Moles Of Methane Are Produced When 85.1 Moles Of Carbon Dioxide Gas React With Excess Hydrogen

How Many Moles Of Methane Are Produced When 85.1 Moles Of Carbon Dioxide Gas React With Excess Hydrogen

Understanding the amount of methane produced during a chemical reaction requires a clear grasp of the underlying chemical principles, including stoichiometry, chemical equations, and molar ratios. In this comprehensive guide, we will explore how to determine the moles of methane generated when 85.1 moles of carbon dioxide react with excess hydrogen. We will examine the relevant chemical reactions, perform detailed stoichiometric calculations, and discuss important concepts to deepen your understanding of this process.

Introduction to the Reaction Between Carbon Dioxide and Hydrogen

Chemical reactions involving carbon dioxide (CO_2) and hydrogen (H_2) are fundamental in various industrial processes, including the synthesis of hydrocarbons like methane (CH_4). The primary reaction of interest here is the Sabatier reaction, which involves the catalytic reduction of carbon dioxide with hydrogen to produce methane and water.

Understanding the Chemical Equation

Before calculating the amount of methane produced, it is essential to understand the balanced chemical equation for the reaction:

The Sabatier Reaction

$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

This equation indicates that:
- 1 mole of carbon dioxide reacts with 4 moles of hydrogen.
- The reaction produces 1 mole of methane (CH_4) and 2 moles of water.

Implications for Stoichiometry

From the balanced equation, the molar ratios are:
- $CO_2 : H_2 : CH_4 = 1 : 4 : 1$

This ratio is crucial for calculating how much methane is produced based on the amount of carbon dioxide and the availability of hydrogen.

Calculating Moles of Methane Produced

Given:
- Moles of CO_2 = 85.1 mol
- Excess H_2 (more than enough to react with all CO_2)

Since hydrogen is in excess, the limiting reagent is carbon dioxide. Therefore, the amount of methane produced depends directly on the amount of CO_2 available.

Step-by-Step Calculation

1. **Identify the limiting reagent:** In this scenario, CO_2 is limiting because we have 85.1 mol, and hydrogen is in excess.

2. **Use molar ratios from the balanced equation:** For every 1 mol of CO_2, 1 mol of CH_4 is produced.

3. **Calculate the moles of methane:** Since the molar ratio is 1:1, the moles of methane produced are equal to the moles of CO_2 reacted.

Calculation:

Moles of CH_4 = Moles of CO_2 × (Moles of CH_4 / Moles of CO_2) = 85.1 mol × (1 mol / 1 mol) = 85.1 mol

Final Answer:

85.1 moles of methane (CH_4) are produced when 85.1 moles of carbon dioxide react with excess hydrogen.

Additional Considerations

While the core calculation is straightforward, several factors influence the reaction's efficiency and the actual yield of methane.

Reaction Conditions

- Temperature and pressure significantly affect the reaction rate and yield.
- Catalysts such as nickel are often used to facilitate the Sabatier reaction.

Purity of Reactants

- Impurities in gases can lead to side reactions, reducing the yield of methane.
- Ensuring high purity of CO_2 and H_2 enhances the efficiency.

Reaction Completeness

- Excess hydrogen ensures complete conversion of CO_2.
- The reaction's equilibrium position can be shifted by adjusting conditions to maximize methane production.

Real-World Applications of Methane Production from CO_2 and H_2

Understanding the stoichiometry of this reaction has practical implications in various fields.

Renewable Energy and Carbon Capture

- Converting captured CO_2 into useful fuels like methane provides a sustainable energy pathway.
- Renewable hydrogen (produced via electrolysis using renewable energy) makes this process environmentally friendly.

Synthetic Natural Gas (SNG) Production

- The methane produced can be used as a substitute for natural gas.
- It allows for storage and transportation of renewable energy.

Industrial Synthesis of Hydrocarbons

- The Sabatier process is employed in chemical industries to synthesize methane efficiently.

Summary of Key Points

- The balanced chemical equation for methane synthesis from CO_2 and H_2 is $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$.
- Given 85.1 mol of CO_2 and excess H_2, 85.1 mol of methane are produced.
- The reaction is highly dependent on conditions such as temperature, pressure, and catalyst presence.
- This process plays a vital role in sustainable energy and carbon recycling initiatives.

Frequently Asked Questions (FAQs)

1. What happens if hydrogen is not in excess?

If hydrogen is limited, it becomes the limiting reagent. The amount of methane produced would then depend on the moles of hydrogen available, following the molar ratio of 4:1 (H_2:CO_2).

2. Can this reaction be performed at room temperature?

Typically, the Sabatier reaction requires elevated temperatures (around 300-400°C) and a catalyst to proceed efficiently. Performing it at room temperature would result in very low conversion rates.

3. Is the reaction reversible?

Yes, the Sabatier reaction is reversible. Adjusting conditions like temperature and pressure can shift the equilibrium, affecting methane yield.

4. How does this reaction contribute to environmental sustainability?

By converting CO_2, a greenhouse gas, into methane, this process can help reduce atmospheric CO_2 levels, especially when powered by renewable energy sources for hydrogen production.

Conclusion

In summary, when 85.1 moles of carbon dioxide react with excess hydrogen, the reaction produces an equivalent amount of methane, 85.1 moles. This straightforward stoichiometric calculation hinges on understanding the balanced chemical equation and molar ratios. The Sabatier process not only exemplifies fundamental chemical principles but also demonstrates practical applications in renewable energy, carbon recycling, and synthetic fuel production. Mastery of these concepts is essential for students, chemists, and engineers involved in sustainable chemical processes and environmental science.

References
- Smith, J. M., & Van Ness, H. C. (2012). Introduction to Chemical Engineering Thermodynamics. McGraw-Hill Education.
- Atkins, P., & de Paula, J. (2010). Physical Chemistry. Oxford University Press.
- U.S. Department of Energy. (2021). Hydrogen Production and Storage.

Frequently Asked Questions

What is the balanced chemical equation for the production of methane from carbon dioxide and hydrogen?

The balanced chemical equation is: $CO_2 + 4\ H_2 \rightarrow CH_4 + 2\ H_2O$.

How many moles of methane are produced when 85.1 moles of CO_2 react with excess hydrogen?

According to the balanced equation, 1 mole of CO_2 produces 1 mole of CH_4. Therefore, 85.1 moles of CO_2 produce 85.1 moles of methane.

Does the amount of hydrogen affect the amount of methane produced in this reaction?

Yes, but only if there is enough hydrogen to react with all the CO_2. Since hydrogen is in excess, it does not limit the reaction, and the amount of methane depends solely on the CO_2 amount.

What is the significance of excess hydrogen in this reaction?

Excess hydrogen ensures that all CO_2 reacts completely, so the amount of methane produced depends solely on the amount of CO_2 available.

How can I calculate the amount of methane produced in grams from 85.1 moles of CO_2?

First, determine the molar mass of methane (16.04 g/mol). Since 85.1 moles of CO_2 produce 85.1 moles of CH_4, multiply 85.1 mol by 16.04 g/mol to get approximately 1,364 grams of methane.

Is the production of methane from CO_2 and hydrogen an example of a reduction reaction?

Yes, because CO_2 is being reduced to form methane (CH_4), gaining hydrogen atoms and electrons in the process.

Additional Resources

How Many Moles Of Methane Are Produced When 85.1 Moles Of Carbon Dioxide Gas React With Excess Hydrogen

Understanding the quantitative aspects of chemical reactions is fundamental in chemistry, especially when dealing with gases and their molar relationships. In this guide, we will explore how many moles of methane are produced when 85.1 moles of carbon dioxide gas react with excess hydrogen. This problem exemplifies the practical application of stoichiometry, the branch of chemistry concerned with the quantitative relationships between reactants and products in chemical reactions.

Introduction to the Reaction

To address the question, it’s important to first understand the chemical reaction involved. The specific reaction where carbon dioxide reacts with hydrogen to produce methane is known as the Sabatier reaction or methanation process. This process is significant in fields like renewable energy, where excess hydrogen—often produced via electrolysis—is used to convert carbon dioxide into methane, a storable and transportable fuel.

The chemical equation for the methanation reaction is:

$CO_2 + 4\ H_2 \rightarrow CH_4 + 2\ H_2O$

This balanced equation indicates that:

- 1 mole of carbon dioxide reacts with 4 moles of hydrogen.
- The products are 1 mole of methane (CH_4) and 2 moles of water.

Step-by-Step Breakdown of the Problem

To determine how many moles of methane are produced from a given amount of carbon dioxide, follow these steps:

1. Identify the known quantities:
- Moles of CO_2: 85.1 mol
- Excess hydrogen: present in a large amount, so it's not limiting.

2. Write the balanced chemical equation:

$CO_2 + 4\ H_2 \rightarrow CH_4 + 2\ H_2O$

3. Determine the mole ratio:

- From the balanced equation, 1 mol of CO_2 produces 1 mol of CH_4.
- Therefore, the mole ratio of CO_2 to CH_4 is 1:1.

4. Calculate moles of methane produced:

- Since the ratio is 1:1, the moles of methane produced are equal to the moles of carbon dioxide reacted, assuming hydrogen is in excess.

Calculating the Moles of Methane

Given the mole ratio and initial quantity, the calculation is straightforward:

- Moles of CH_4 = Moles of CO_2 reacted

Thus,

Moles of methane produced = 85.1 mol

Additional Considerations and Practical Implications

While the calculation appears simple, several factors can influence the actual yield and the process's efficiency:

1. Reaction Completeness

- The calculation assumes complete reaction—meaning all 85.1 mol of CO_2 react fully with excess hydrogen.
- In real-world scenarios, reaction conditions, catalysts, and temperature can impact the reaction completeness.

2. Excess Hydrogen Assurance

- The problem states hydrogen is in excess, ensuring that hydrogen availability does not limit methane production.
- If hydrogen were limiting, the amount of methane would be based on the limiting reagent, requiring additional calculations.

3. Yield and Efficiency

- Laboratory or industrial processes often have less-than-100% yields.
- Actual methane produced might be slightly less, depending on reaction conditions and purification steps.

4. Environmental and Industrial Relevance

- This reaction is pivotal in renewable energy sectors, especially when converting surplus renewable energy into storable fuels.
- It also plays a role in carbon capture and utilization (CCU) strategies, transforming greenhouse gases into valuable fuels.

Summary of Key Points

- The balanced chemical equation shows a 1:1 molar relationship between

carbon dioxide and methane.
- Given 85.1 moles of CO_2 and excess hydrogen, 85.1 moles of methane will be produced.
- Stoichiometry allows straightforward calculation based on mole ratios from the balanced equation.
- Real-world factors such as reaction efficiency, catalysts, and conditions can influence actual yields but are not considered in this ideal calculation.

Final Thoughts

Understanding the molar relationships in chemical reactions not only aids in solving theoretical problems but also informs practical applications in industry and environmental management. The ability to predict product quantities from given reactants is essential for designing chemical processes, optimizing reactors, and assessing resource requirements.

In this specific case, reacting 85.1 moles of carbon dioxide with excess hydrogen results in an equal amount of 85.1 moles of methane, assuming ideal conditions and complete reaction. This highlights the elegance of stoichiometry—where balanced equations serve as precise tools to quantify the unseen world of molecules and atoms.

In conclusion, the process of calculating how many moles of methane are produced when 85.1 moles of carbon dioxide react with excess hydrogen demonstrates the practical power of chemical equations and molar ratios, bridging theoretical chemistry with real-world applications.

How Many Moles Of Methane Are Produced When 85 1 Moles Of Carbon Dioxide Gas React With Excess Hydrogen

How Many Moles Of Methane Are Produced When 85 1 Moles Of Carbon Dioxide Gas React With Excess Hydrogen

Related Articles

- How Do You Think The Basic Concepts Of Economics Will Impact Your Life (in Fashion, Your Future Career,
- Cysco Corp Has A Budget Of $1,200,000 In 2017 For Prevention Costs. If It Decides To Automate A Portion
- How Important Do You Think Employee Understanding Of Localmarkets Is In Terms Of Operating A Successful

Back to Home