How Many Grams Of Copper Were Consumed If 0.134 Mol Of NO2 Gas Was Produced?

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Understanding the relationship between chemical reactions and the quantities of reactants and products involved is fundamental in chemistry. When a specific amount of a gas like nitrogen dioxide (NO_2) is produced, it's often essential to determine how much of the reactant, such as copper, was consumed during the process. In this article, we will explore how to calculate the grams of copper used when 0.134 mol of NO_2 gas is generated, examining the underlying chemical principles, the relevant reactions, and step-by-step calculation methods. This knowledge is crucial for students, chemists, and industry professionals involved in processes like metal oxidation, manufacturing, and environmental chemistry.

Understanding the Chemical Reaction: Copper and Nitrogen Dioxide

1. The Role of Copper in Producing NO_2

Copper (Cu) can react with nitric acid or nitrogen oxides to produce nitrogen dioxide (NO_2). In many industrial or laboratory reactions, copper acts as a reducing or oxidizing agent depending on the reaction conditions. The most common scenario involves copper reacting with nitric acid (HNO_3), leading to the formation of copper nitrate and NO_2 gas.

2. Typical Reaction Equations Involving Copper and NO_2

One of the primary reactions involving copper and nitric acid is:

$$ 3Cu + 8HNO_3 \rightarrow 3Cu(NO_3)_2 + 2NO_2 + 4H_2O $$

This reaction indicates that three moles of copper produce two moles of NO_2 gas. It's crucial to note this stoichiometric ratio to determine how much copper is needed to produce a given amount of NO_2.

Stoichiometry: The Key to Calculating Copper Consumption

1. Understanding Molar Ratios

The molar ratio between copper and NO_2 in the reaction above is:

$$ \frac{3\, \text{mol Cu}}{2\, \text{mol NO}_2} $$

This ratio means that for every 2 moles of NO_2 produced, 3 moles of copper are consumed.

2. Step-by-Step Calculation Process

To determine the grams of copper used:

- Step 1: Identify the amount of NO_2 produced (given as 0.134 mol).
- Step 2: Use the molar ratio to find the moles of copper consumed.
- Step 3: Convert moles of copper to grams using its molar mass.

Calculating Moles of Copper Consumed

1. Applying the Molar Ratio

Using the molar ratio from the balanced reaction:

$$
\text{Moles of Cu} = \text{Moles of NO}_2 \times \frac{3\, \text{mol Cu}}{2\, \text{mol NO}_2}
$$

Plugging in the numbers:

$$
\text{Moles of Cu} = 0.134\, \text{mol} \times \frac{3}{2} = 0.134 \times 1.5 = 0.201\, \text{mol}
$$

This means approximately 0.201 mol of copper was consumed to produce 0.134 mol of NO_2.

Converting Moles of Copper to Grams

1. Molar Mass of Copper

Copper has a molar mass of approximately:

$$ 63.55\, \text{g/mol} $$

2. Final Calculation

Multiply the moles of copper by its molar mass:

$$
\text{Mass of Cu} = 0.201\, \text{mol} \times 63.55\, \text{g/mol} \approx 12.78\, \text{g}
$$

Therefore, about 12.78 grams of copper were consumed to produce 0.134 mol of NO_2 gas.

Additional Factors to Consider

1. Reaction Conditions

- Temperature and pressure can influence the reaction efficiency.
- The purity of copper and reactants impacts the actual amount consumed.
- Side reactions may occur, affecting the exact quantity of copper used.

2. Variations in Reactions

While the reaction provided is typical, other reactions involving copper and nitrogen oxides can have different stoichiometric ratios. Always verify the specific reaction equation relevant to your context.

Practical Applications and Importance

1. Industrial Manufacturing

- Calculating reactant quantities ensures cost efficiency and process optimization.
- Managing copper consumption helps in environmental impact assessments.

2. Laboratory Experiments

- Precise calculations are vital for accurate experimental results.
- Understanding molar relationships enhances conceptual grasp of chemical reactions.

3. Environmental Chemistry

- Tracking copper usage aids in evaluating environmental emissions.
- Proper waste management depends on understanding the quantities of reactants and products.

Summary of Key Points

- The reaction between copper and nitric acid produces NO_2 gas, with a known molar ratio.
- To find the grams of copper consumed, first determine moles based on the molar ratio.
- Convert moles to grams using the molar mass of copper.
- For 0.134 mol of NO_2 produced, approximately 12.78 grams of copper were consumed, based on the reaction's stoichiometry.

Final Thoughts

Understanding how to calculate the grams of copper consumed for a given amount of NO_2 production is essential in both academic and industrial chemistry. Mastering stoichiometry, molar ratios, and conversion techniques allows chemists to optimize reactions, reduce costs, and minimize environmental impact. Whether you are designing a chemical process or conducting an experiment, these calculations form the backbone of quantitative chemistry.

Remember: Always verify the specific reaction conditions and equations relevant to your scenario, as variations can significantly affect the calculations. Accurate measurements and careful stoichiometric analysis are

key to successful chemical calculations and practical applications.

Frequently Asked Questions

How do you determine the amount of copper consumed when 0.134 mol of NO_2 gas is produced?

You need to use the balanced chemical equation to find the molar ratio between copper and NO_2, then convert moles of NO_2 to grams of copper based on this ratio.

What is the balanced chemical equation involved in the production of NO_2 from copper?

One common reaction is $3Cu + 4NO_2 \rightarrow 3CuO + 2NO$; however, the specific reaction depends on the process, so ensure the correct reaction is used for calculations.

How many moles of copper are needed to produce 0.134 mol of NO_2?

If the balanced equation shows a molar ratio of $4NO_2$ to 3Cu, then moles of Cu = (3/4) × 0.134 mol = 0.1005 mol.

What is the molar mass of copper used in the calculation?

The molar mass of copper (Cu) is approximately 63.55 g/mol.

How many grams of copper were consumed to produce 0.134 mol of NO_2?

Using the molar amount of copper (0.1005 mol) and its molar mass, grams of Cu = 0.1005 mol × 63.55 g/mol ≈ 6.39 grams.

Does the calculation depend on the purity of copper used in the reaction?

Yes, the actual weight may vary if the copper is not pure; calculations assume pure copper for theoretical purposes.

What assumptions are made in calculating the grams

of copper from NO_2 produced?

Assumptions include complete reaction, 100% yield, and that the molar ratio from the balanced equation accurately reflects the reaction occurring.

Can this calculation be applied to other similar reactions producing NO_2?

Yes, but you must use the specific balanced chemical equation for each reaction to determine the molar ratios.

If the yield of the reaction is less than 100%, how does that affect the grams of copper consumed?

The actual grams of copper would be higher than the calculated amount for the theoretical yield, accounting for the reaction’s efficiency.

What practical applications involve calculating grams of copper based on NO_2 production?

Such calculations are relevant in industrial processes like copper ore refining, pollution control, and chemical manufacturing where precise material accounting is essential.

Additional Resources

How Many Grams Of Copper Were Consumed If 0.134 Mol Of NO2 Gas Was Produced?

Understanding the relationship between chemical reactions and the quantities of reactants and products involved is fundamental in chemistry, especially in fields such as industrial processes, environmental science, and materials engineering. A common question posed in such contexts is: "Given a certain amount of a product, how much of the reactant was consumed?" This query involves stoichiometric calculations, which serve as the backbone for quantifying chemical processes. In this article, we delve into the specific scenario of determining the grams of copper that were consumed when 0.134 mol of nitrogen dioxide (NO_2) gas is produced, providing a comprehensive overview of the principles, calculations, and implications involved.

Understanding the Chemical Context and Reaction Involved

The Role of Copper in Chemical Reactions

Copper (Cu) is a versatile transition metal widely used in electrical wiring, plumbing, and industrial catalysis. In chemistry, copper often acts as a reducing agent or a catalyst. Its role becomes particularly interesting when it participates in reactions that produce nitrogen oxides, such as NO or NO_2 gases, which are significant in environmental chemistry due to their role in air pollution and smog formation.

Common Reactions Producing NO_2 and Copper's Involvement

One typical industrial or laboratory process involves the oxidation of copper in the presence of nitrogen-containing compounds, leading to the formation of copper oxides and nitrogen oxides. For example, when copper reacts with nitric acid or nitrogen oxides, various reactions can occur:

- Reaction with Nitric Acid:

$$
3\, \text{Cu} + 8\, \text{HNO}_3 \rightarrow 3\, \text{Cu(NO}_3)_2 + 4\, \text{H}_2\text{O}
$$

This process generally produces nitrogen dioxide as a byproduct under certain conditions, especially when concentrated nitric acid is involved.

- Reaction with Nitrogen Oxides:

Copper can catalyze or participate in reactions that generate NO_2, especially in combustion or high-temperature processes.

To simplify the calculation, we will assume a typical reaction where copper reacts with nitric acid, producing copper nitrate and nitrogen dioxide gas, which aligns with the common industrial processes and lab scenarios.

The Balanced Chemical Equation and Stoichiometry

Formulating the Relevant Reaction

To determine how much copper was consumed, we first need the balanced chemical equation relating copper to NO_2 production. A representative reaction involving copper and nitric acid that produces NO_2 is:

$$
\text{Cu} + 4\, \text{HNO}_3 \rightarrow \text{Cu(NO}_3)_2 + 2\, \text{NO}_2 + 2\, \text{H}_2\text{O}
$$

Note: This is a simplified representation; actual reactions may vary depending on conditions. Here, one mole of copper reacts to produce 2 moles of NO_2 gas.

Key point: For our calculation, the critical relationship is:

$$
\text{Cu} : \text{NO}_2 \quad \text{molar ratio} = 1 : 2
$$

This ratio indicates that 1 mole of copper produces 2 moles of NO_2.

Implication of the Molar Ratio

Given the molar ratio:

$$
\text{Moles of Cu} = \frac{1}{2} \times \text{Moles of NO}_2
$$

Therefore, if 0.134 mol of NO_2 are produced, the moles of copper consumed are:

$$
\text{Moles of Cu} = \frac{1}{2} \times 0.134\, \text{mol} = 0.067\, \text{mol}
$$

This fundamental ratio allows us to directly connect the amount of nitrogen dioxide gas formed to the amount of copper used in the process.

Calculating the Grams of Copper Consumed

Atomic Mass of Copper

To translate moles into grams, the atomic mass of copper must be considered. Copper's molar mass is approximately:

$$
\text{Atomic mass of Cu} \approx 63.55\, \text{g/mol}
$$

This value is essential for converting between moles and grams, as the molar mass acts as a conversion factor.

Final Calculation

Using the number of moles of copper and its molar mass:

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

Substituting the known values:

$$
\text{Mass of Cu} = 0.067\, \text{mol} \times 63.55\, \text{g/mol}
$$

$$
\text{Mass of Cu} \approx 4.263\, \text{g}
$$

Result: Approximately 4.26 grams of copper were consumed to produce 0.134 mol of NO_2 gas.

Additional Considerations and Real-World Implications

Reaction Efficiency and Yield

The calculations provided assume a perfect, 100% efficiency and complete reaction—conditions rarely met in real-world scenarios. Industrial processes often have yields less than 100%, meaning more copper might be required to produce the same amount of NO_2. Conversely, side reactions could consume

additional copper or produce other nitrogen oxides.

Implication: Actual copper consumption could be higher than calculated, depending on process efficiency.

Environmental and Industrial Significance

Understanding the amount of copper involved in nitrogen dioxide production has environmental implications. NO_2 is a primary air pollutant linked to respiratory issues, smog formation, and acid rain. Industries that manage or produce NO_2 must control copper usage to minimize environmental impact and optimize resource utilization.

Resource Management: Accurate calculations of reactant consumption help industries plan material procurement, cost analysis, and waste management.

Relevance in Laboratory and Educational Settings

In academic contexts, such calculations reinforce understanding of stoichiometry, gas laws, and chemical reaction mechanisms. They serve as practical exercises for students to connect theoretical concepts with real-world applications.

Potential Variations and Additional Factors

Alternative Reactions and Conditions

Different reactions involving copper could produce NO_2 under varying conditions. For example:

- Reaction with nitric acid at different concentrations.
- Reactions involving copper oxides or nitrates in thermal processes.
- Catalytic reactions in combustion engines or industrial furnaces.

Each reaction pathway has its own molar ratios, influencing the amount of copper consumed per mole of NO_2 produced.

Impact of Reaction Conditions

Temperature, pressure, and presence of catalysts can alter the efficiency and pathways of copper reactions, potentially changing the molar ratios and yield.

Summary and Conclusions

The question of "How many grams of copper were consumed if 0.134 mol of NO_2 gas was produced" hinges on understanding the stoichiometric relationships within the relevant chemical reactions. Based on typical reaction pathways involving copper and nitric acid, we established that:

- The molar ratio of copper to NO_2 is 1:2.
- Moles of copper consumed are half the moles of NO_2 produced, i.e., 0.067 mol.
- The grams of copper consumed are approximately 4.26 grams.

This calculation underscores the importance of stoichiometry in quantifying reactant consumption and product formation. It also highlights the relevance of such calculations in industrial chemistry, environmental science, and educational contexts. Accurate knowledge of reactant quantities allows for better resource management, process optimization, and environmental impact assessment.

In conclusion, producing 0.134 mol of NO_2 gas from copper involves the consumption of roughly 4.26 grams of copper under ideal conditions. This insight not only clarifies the quantitative relationship between reactants and products but also emphasizes the critical role of stoichiometric analysis in understanding and managing chemical processes effectively.

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