If 95.0 G CuS And 55.7 G O2 Are Available, Which Reactant Is The Limiting Reactant?

Introduction

If 95.0 G CuS And 55.7 G O2 Are Available, Which Reactant Is The Limiting Reactant? This question is fundamental in stoichiometry, the branch of chemistry that deals with the quantitative relationships between reactants and products in chemical reactions. Identifying the limiting reactant is crucial because it determines the maximum amount of product that can be formed in a reaction. In this article, we will analyze the given quantities of copper sulfide (CuS) and oxygen (O_2) to determine which reactant limits the reaction, thereby establishing the theoretical yield of the products formed.

Understanding the Reaction

Writing the Balanced Chemical Equation

To analyze which reactant is limiting, the first step is to understand the chemical reaction involved. Copper sulfide reacts with oxygen to form copper (II) oxide and sulfur dioxide. The balanced chemical equation is:

$2\ CuS + 3\ O_2 \rightarrow 2\ CuO + 2\ SO_2$

This equation indicates that 2 moles of CuS react with 3 moles of O_2 to produce copper(II) oxide and sulfur dioxide. The molar ratios are vital for converting the given masses into moles and comparing the amounts of reactants involved.

Calculating Moles of Reactants

Moles of CuS

Given the mass of copper sulfide is 95.0 grams, we calculate the moles by dividing by its molar mass.

- **Molar mass of CuS:** Cu (63.55 g/mol) + S (32.07 g/mol) = 95.62 g/mol
- **Moles of CuS:**

$$
\frac{95.0\, \text{g}}{95.62\, \text{g/mol}} \approx 0.993\, \text{mol}
$$

Moles of O_2

The mass of oxygen provided is 55.7 grams. The molar mass of O_2 is:

- **Molar mass of O_2:** 2 × 16.00 g/mol = 32.00 g/mol
- **Moles of O_2:**
  $$
  \frac{55.7\, \text{g}}{32.00\, \text{g/mol}} \approx 1.74\, \text{mol}
  $$

Determining the Limiting Reactant

Using Stoichiometry to Compare Reactant Ratios

Next, we compare the available moles of reactants based on the stoichiometric coefficients in the balanced equation:

- From the balanced equation: 2 CuS : 3 O_2
- Calculate the amount of O_2 required for 0.993 mol of CuS:

Required O_2 = (3/2) × Moles of CuS = 1.5 × 0.993 mol ≈ 1.49 mol

Since only approximately 1.74 mol of O_2 are available, and 1.49 mol are required to react completely with the available CuS, there is more than enough oxygen to react with all of the CuS.

Comparing the Reactants

- **CuS:** 0.993 mol available
- **O_2:** 1.74 mol available, but only 1.49 mol needed for complete reaction with CuS

Because oxygen is in excess, the limiting reactant must be copper sulfide

(CuS). Copper sulfide will be consumed first, limiting the amount of product formed in the reaction.

Quantitative Confirmation of the Limiting Reactant

Calculating Theoretical Product Yield

Knowing that CuS is limiting, we can calculate the maximum amount of products formed, specifically copper(II) oxide (CuO) and sulfur dioxide (SO_2).

- From the balanced equation, 2 mol CuS produce 2 mol CuO and 2 mol SO_2.
- Therefore, 0.993 mol CuS will produce:

Moles of CuO = (2/2) × 0.993 mol = 0.993 mol
Moles of SO_2 = (2/2) × 0.993 mol = 0.993 mol

Next, convert these moles into grams:

- **Mass of CuO:**
$$
0.993\, \text{mol} \times (63.55 + 16.00) \text{g/mol} = 0.993\, \text{mol} \times 79.55\, \text{g/mol} \approx 79.05\, \text{g}
$$
- **Mass of SO_2:**
$$
0.993\, \text{mol} \times (32.00 + 16.00) \text{g/mol} = 0.993\, \text{mol} \times 48.00\, \text{g/mol} \approx 47.76\, \text{g}
$$

Implication of the Results

These calculations confirm that all the CuS will be consumed to produce approximately 79.05 grams of CuO and 47.76 grams of SO_2, with excess O_2 remaining unreacted. This validates that CuS is the limiting reactant, not oxygen.

Summary of Findings

- Initial moles of CuS: approximately 0.993 mol

- Initial moles of O_2: approximately 1.74 mol
- O_2 is in excess because only about 1.49 mol are needed to react with all CuS
- CuS is the limiting reactant
- Maximum products formed: approximately 79.05 g CuO and 47.76 g SO_2

Conclusion

Based on the stoichiometric calculations, copper sulfide (CuS) is the limiting reactant when 95.0 grams of CuS and 55.7 grams of O_2 are available. The excess oxygen ensures that all the CuS will be consumed first, limiting the amount of products formed. This example highlights the importance of stoichiometry in predicting reaction outcomes and optimizing reactant use in chemical processes.

Practical Significance

Understanding limiting reactants is crucial in industrial chemistry for maximizing efficiency, minimizing waste, and controlling product yields. In real-world applications, such calculations inform decisions in manufacturing processes, environmental management, and resource allocation.

Final Remarks

Mastering the process of identifying limiting reactants involves writing balanced equations, converting masses to moles, and comparing the molar ratios. This foundational skill in chemistry enables scientists and engineers to design better reactions, predict product quantities, and improve overall process economics.

Frequently Asked Questions

How do I determine the limiting reactant when given 95.0 g of CuS and 55.7 g of O_2?

First, convert both quantities to moles, then compare the mole ratios needed for the reaction to identify which reactant runs out first, making it the limiting reactant.

What is the balanced chemical equation for the reaction between CuS and O_2?

The balanced equation is 2 CuS + 3 O_2 → 2 $CuSO_4$, which helps in calculating the molar ratios needed to identify the limiting reactant.

How do I convert grams of CuS and O_2 to moles for this problem?

Divide the mass of each reactant by its molar mass: CuS (96.6 g/mol) and O_2 (32.0 g/mol), to find the number of moles available.

Which reactant is the limiting reactant if I have 95.0 g of CuS and 55.7 g of O_2?

By calculating moles, CuS (0.983 mol) and O_2 (1.74 mol), and comparing the molar ratios needed, CuS is the limiting reactant because it will be consumed first.

Why is it important to identify the limiting reactant in a chemical reaction?

Because it determines the maximum amount of product that can be formed and helps in optimizing the reactant quantities for efficient reactions.

Can I use the mole ratio from the balanced equation to find the limiting reactant?

Yes, by comparing the actual mole ratio of reactants to the stoichiometric ratio from the balanced equation, you can identify the limiting reactant.

What steps should I follow to solve for the limiting reactant in this problem?

Convert grams to moles, compare the available mole ratios to the stoichiometric ratios from the balanced equation, and identify which reactant is exhausted first.

Additional Resources

Understanding Limiting Reactants: Analyzing the Reaction Between Copper Sulfide (CuS) and Oxygen (O_2)

In the realm of chemical reactions, the concept of a limiting reactant is fundamental to understanding how reactions proceed and how much product can be formed. When two reactants are involved, the one that gets completely consumed first—thus limiting the amount of product formed—is known as the limiting reactant. Determining which reactant is limiting is crucial in both laboratory and industrial chemistry for optimizing yields and ensuring cost-effectiveness.

This article provides a comprehensive analysis of a specific scenario: Given 95.0 grams of copper sulfide (CuS) and 55.7 grams of oxygen (O_2), which reactant is the limiting reactant? We will explore this question in depth, covering the chemical reaction involved, calculations to determine the limiting reactant, and the broader implications of such analyses.

Fundamentals of Limiting Reactant Concept

What Is a Limiting Reactant?

In any chemical reaction, reactants are combined according to stoichiometric ratios specified by the balanced chemical equation. The limiting reactant is the substance that runs out first, thereby determining the maximum amount of product that can be produced. Once this reactant is exhausted, the reaction stops, regardless of the amount of other reactants remaining.

Understanding which reactant is limiting helps chemists:
- Calculate theoretical yields.
- Minimize waste by optimizing reactant ratios.
- Understand reaction efficiency and kinetics.

Excess Reactant

The reactant that remains after the limiting reactant is consumed is called the excess reactant. Knowing the excess amount is important for calculating leftover materials and for planning subsequent reactions.

The Reaction Between Copper Sulfide (CuS) and Oxygen (O_2)

Balanced Chemical Equation

The specific reaction under consideration involves copper sulfide reacting with oxygen to form copper oxide (CuO) and sulfur dioxide (SO_2). The balanced chemical equation is:

$$ 2\, \mathrm{CuS} + 3\, \mathrm{O}_2 \rightarrow 2\, \mathrm{CuO} + 2\, \mathrm{SO}_2 $$

This balanced equation indicates:
- 2 moles of CuS react with 3 moles of O_2.
- The reaction produces 2 moles of copper(II) oxide and 2 moles of sulfur dioxide.

Reaction Context and Significance

This reaction is significant in metallurgy and environmental chemistry, where copper sulfide ores are processed. Understanding the limiting reactant allows for optimal control over the chemical processing, reducing waste and improving yield.

Calculating the Moles of Each Reactant

Moles of Copper Sulfide (CuS)

Given the mass of CuS:
- Mass of CuS = 95.0 g

Molar mass of CuS:
- Copper (Cu): approximately 63.55 g/mol
- Sulfur (S): approximately 32.07 g/mol

$$ \text{Molar mass of CuS} = 63.55 + 32.07 = 95.62\, \text{g/mol} $$

Calculating moles:
$$ \text{Moles of CuS} = \frac{95.0\, \text{g}}{95.62\, \text{g/mol}} \approx 0.993\, \text{mol} $$

Moles of Oxygen (O_2)

Given the mass of O_2:
- Mass of O_2 = 55.7 g

Molar mass of O_2:
- Oxygen molecule (O_2): approximately 32.00 g/mol

Calculating moles:

$$ \text{Moles of O}_2 = \frac{55.7\, \text{g}}{32.00\, \text{g/mol}} \approx 1.742\, \text{mol} $$

Determining the Limiting Reactant Through Stoichiometry

Using the Balanced Equation

From the balanced equation:

$$ 2\, \mathrm{CuS} + 3\, \mathrm{O}_2 \rightarrow \text{Products} $$

- 2 mol CuS react with 3 mol O_2.
- Therefore, the molar ratio is:

$$ \frac{\text{mol CuS}}{\text{mol O}_2} = \frac{2}{3} \approx 0.6667 $$

Comparing Available Moles to Theoretical Ratios

Step 1: Calculate how much O_2 is required to react with the available CuS:

$$ \text{O}_2 \text{ needed} = \left(\frac{3}{2} \right) \times \text{moles of CuS} $$
$$ = 1.5 \times 0.993 \approx 1.490\, \text{mol} $$

Step 2: Check whether the available O_2 exceeds this requirement:

- Available O_2: 1.742 mol
- Required O_2: 1.490 mol

Since 1.742 mol > 1.490 mol, there is more oxygen than needed to react with all the CuS.

Step 3: Determine how much CuS can be reacted with the available O_2:

$$ \text{CuS that can react} = \left(\frac{2}{3} \right) \times \text{moles of O}_2 $$
$$ = \frac{2}{3} \times 1.742 \approx 1.161\, \text{mol} $$

Compare this to the actual moles of CuS:

- Available CuS: 0.993 mol
- Max CuS that can react with available O_2: 1.161 mol

Since 0.993 mol < 1.161 mol, all the CuS can fully react with the available oxygen.

Conclusion: The oxygen is in excess because there is more oxygen than required to react with all the CuS present. Therefore, CuS is the limiting reactant.

Implications and Broader Context

Yield Calculation and Industrial Relevance

Knowing the limiting reactant enables precise calculation of theoretical yields. For instance, from the amount of CuS (0.993 mol), the maximum amount of sulfur dioxide and copper oxide produced can be calculated:

- For every 2 mol CuS, 2 mol SO_2 is produced:

$$\text{Moles of SO}_2 = \frac{2}{2} \times 0.993 = 0.993\, \text{mol}$$

- Mass of SO_2:

$$\text{Mass} = 0.993\, \text{mol} \times 64.07\, \text{g/mol} \approx 63.7\, \text{g}$$

Similarly, copper oxide production can be calculated, which is critical for process design and economic considerations.

Environmental Considerations

This reaction plays a role in the removal of sulfur compounds from industrial emissions, reducing sulfur dioxide release into the atmosphere, which contributes to acid rain. Efficiently determining limiting reactants ensures optimal operation, minimizing waste and environmental impact.

Educational and Laboratory Significance

This analysis exemplifies core principles of stoichiometry, emphasizing the importance of molar ratios, unit conversions, and the use of balanced equations in practical contexts.

Summary and Final Remarks

In conclusion, based on the available quantities—95.0 grams of CuS and 55.7 grams of O_2—the limiting reactant in the reaction to produce copper oxide and sulfur dioxide is copper sulfide (CuS). The calculations demonstrate that all of the CuS can be consumed with the oxygen present, leaving some oxygen unreacted. This insight is vital for optimizing industrial processes, conducting accurate yield predictions, and understanding the stoichiometric relationships fundamental to chemistry.

By carefully analyzing the molar ratios and applying stoichiometry principles, chemists can ensure efficient resource utilization, minimize waste, and advance environmental and industrial objectives. This scenario underscores the importance of limiting reactant determination as a cornerstone of chemical analysis and process optimization.

References:
- Zumdahl, S. S., & Zumdahl, S. A. (2014). Chemistry: An Atoms First Approach. Cengage Learning.
- Atkins, P., & de Paula, J. (2014). Physical Chemistry. Oxford University Press.
- Lide, D. R. (Ed.). (2004). Handbook of Chemistry and Physics. CRC Press.

If 95 0 G Cus And 55 7 G O2 Are Available Which Reactant Is The Limiting Reactant

If 95 0 G Cus And 55 7 G O2 Are Available Which Reactant Is The Limiting Reactant

Related Articles

- Athens Is Thought To Have Emerged From The Dark Ages As A Leading Polis Because It
- What Does It Mean To "secure The Blessings Of Liberty To Ourselves And Our Posterity"
- What Is The Mass Of An Object That Accelerates At 5 M/s2 When Pushed With 100 N?

Back to Home