6.58 Grams Of Sulfur Trioxide And 16.4 Grams Of Water React To Form H2SO4. Identify The Limiting Reagent

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Introduction

The synthesis of sulfuric acid (H_2SO_4) from sulfur trioxide (SO_3) and water (H_2O) is a fundamental chemical process widely employed in industrial applications. Understanding the quantities involved and identifying the limiting reagent is crucial for efficient process control and optimization. This article explores the reaction between 6.58 grams of SO_3 and 16.4 grams of H_2O, focusing on calculating the amount of H_2SO_4 produced and determining which reactant limits the reaction.

Understanding the Reaction

The Chemical Equation

The reaction between sulfur trioxide and water can be represented by the balanced chemical equation:

$$
\text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4
$$

This reaction proceeds with a 1:1 molar ratio of SO_3 to H_2O to produce H_2SO_4.

Importance of the Reaction

- Industrial Significance: Production of sulfuric acid, a key chemical in manufacturing fertilizers, chemicals, and refining processes.
- Reaction Conditions: Typically carried out under controlled conditions to

optimize yield and safety.

Calculating Moles of Reactants

To analyze which reactant is limiting, first, determine the number of moles of each reactant present.

Moles of Sulfur Trioxide (SO_3)

- Given mass: 6.58 grams
- Molar mass of SO_3:

$$
\text{S} = 32.07\, g/mol, \quad \text{O} = 16.00\, g/mol
$$

$$
\text{Molar mass of SO}_3 = 32.07 + (3 \times 16.00) = 32.07 + 48.00 = 80.07\, g/mol
$$

- Calculation:

$$
\text{Moles of SO}_3 = \frac{6.58\, g}{80.07\, g/mol} \approx 0.0823\, mol
$$

Moles of Water (H_2O)

- Given mass: 16.4 grams
- Molar mass of H_2O:

$$
\text{H} = 1.008\, g/mol, \quad \text{O} = 16.00\, g/mol
$$

$$
\text{Molar mass of H}_2\text{O} = (2 \times 1.008) + 16.00 = 2.016 + 16.00 = 18.016\, g/mol
$$

- Calculation:

$$
\text{Moles of H}_2\text{O} = \frac{16.4\, g}{18.016\, g/mol} \approx 0.91\, mol
$$

Determining the Limiting Reagent

Given the balanced chemical equation:

$$
\text{SO}_3 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_4
$$

The molar ratio of SO_3 to H_2O is 1:1.

Comparison:

- Moles of SO_3: approximately 0.0823 mol
- Moles of H_2O: approximately 0.91 mol

Since the reaction requires 1 mol of each reactant per 1 mol of H_2SO_4, the limiting reagent is the reactant with fewer moles relative to its stoichiometric need.

Analysis:

- SO_3 is present at 0.0823 mol, which is significantly less than the 0.91 mol of water.
- Therefore, SO_3 is the limiting reagent because it will be consumed entirely before water is exhausted.

Calculating Theoretical Yield of H_2SO_4

Knowing the limiting reagent allows us to determine the maximum amount of sulfuric acid that can be produced.

Using the Limiting Reagent (SO_3)

- Since 1 mol SO_3 produces 1 mol H_2SO_4, the moles of H_2SO_4 formed equal the moles of SO_3 reacted:

$$
\text{Moles of H}_2\text{SO}_4 = 0.0823\, \text{mol}
$$

- Mass of H_2SO_4 produced:

$$
\text{Molar mass of H}_2\text{SO}_4 = 2(1.008) + 32.07 + 4(16.00) = 2.016 + 32.07 + 64.00 = 98.09\, \text{g/mol}
$$

$$
\text{Mass of H}_2\text{SO}_4 = 0.0823\, \text{mol} \times 98.09\, \text{g/mol} \approx 8.07\, \text{g}
$$

Result: The maximum theoretical yield of sulfuric acid is approximately 8.07 grams.

Practical Considerations and Efficiency

While the theoretical yield provides an ideal scenario, real-world reactions often encounter inefficiencies:

- Reaction Completeness: Not all reactants may react fully due to kinetic or equilibrium considerations.
- Purity of Reactants: Impurities can reduce actual yield.
- Losses During Processing: Handling and purification steps may lead to material loss.

Therefore, actual yields are typically less than the theoretical maximum. Nonetheless, knowing the limiting reagent helps in planning and optimizing the process.

Summary and Conclusion

- Reactant Quantities: 6.58 grams of SO_3 and 16.4 grams of H_2O.
- Moles Calculated:
- SO_3: approximately 0.0823 mol
- H_2O: approximately 0.91 mol
- Limiting Reagent: Sulfur trioxide (SO_3), because it has fewer moles relative to the stoichiometric requirement.

- Theoretical Yield of H_2SO_4: approximately 8.07 grams.

Understanding the limiting reagent in this reaction is essential for efficient chemical manufacturing and resource management. By calculating molar quantities, chemists can predict product yields, optimize reaction conditions, and minimize waste.

Additional Insights

- Extending the Analysis: If more water were added, the reaction would still be limited by SO_3.
- Scaling Up: In industrial settings, precise measurement of reactants ensures maximum yield and safety.
- Environmental Impact: Proper handling of SO_3 and H_2SO_4 is critical due to their corrosive nature.

Final Remarks

The analysis of the reaction between sulfur trioxide and water exemplifies fundamental principles of stoichiometry and limiting reagent determination. By thoroughly understanding these concepts, chemists and engineers can effectively control processes, reduce waste, and produce desired compounds efficiently.

Frequently Asked Questions

How do you determine the limiting reagent when 6.58 grams of sulfur trioxide react with 16.4 grams of water to form sulfuric acid?

To determine the limiting reagent, calculate the moles of each reactant, compare their mole ratios based on the balanced chemical equation, and identify which reactant is exhausted first in the reaction.

What is the balanced chemical equation for the reaction between sulfur trioxide and water to

produce sulfuric acid?

The balanced equation is: $SO_3 + H_2O \rightarrow H_2SO_4$.

How do you calculate the moles of sulfur trioxide and water used in the reaction?

Calculate moles using the molar masses: for SO_3, divide 6.58 g by 80.07 g/mol; for H_2O, divide 16.4 g by 18.02 g/mol.

Based on the molar calculations, which reactant is the limiting reagent in the formation of sulfuric acid?

By comparing the molar ratios, the reactant that is completely consumed first is the limiting reagent; calculations show whether SO_3 or H_2O limits the reaction.

Why is identifying the limiting reagent important in chemical reactions like this?

Identifying the limiting reagent helps determine the maximum amount of product that can be formed and ensures efficient use of reactants.

What are the practical applications of understanding limiting reagents in industrial sulfuric acid production?

Understanding limiting reagents allows for optimized reactant ratios, cost savings, and improved yield in large-scale sulfuric acid manufacturing processes.

If extra water is added beyond the limiting reagent, does it increase the amount of sulfuric acid produced?

No, adding excess water beyond the limiting reagent does not increase the amount of sulfuric acid formed; the limiting reagent determines the maximum yield.

Additional Resources

6.58 Grams Of Sulfur Trioxide And 16.4 Grams Of Water React To Form H2SO4. Identify The Limiting Reagent

In the realm of industrial chemistry, the synthesis of sulfuric acid (H_2SO_4) stands as one of the most vital processes due to its widespread application in manufacturing, refining, and chemical production. A typical laboratory scenario involves reacting a certain amount of sulfur trioxide (SO_3) with water (H_2O) to produce sulfuric acid. Consider a case where 6.58 grams of sulfur trioxide are combined with 16.4 grams of water. The question then arises: which of these reactants is the limiting reagent? Understanding this concept is crucial for optimizing chemical reactions, ensuring efficiency, and minimizing waste. This article explores the chemical reaction in detail, demonstrates the step-by-step process of identifying the limiting reagent, and discusses the implications of this knowledge in industrial and laboratory practices.

Understanding the Chemical Reaction: Formation of Sulfuric Acid

The synthesis of sulfuric acid via direct reaction of SO_3 with water is represented by the chemical equation:

$$SO_3 + H_2O \rightarrow H_2SO_4$$

This reaction is straightforward, involving a 1:1 molar ratio between sulfur trioxide and water. However, the practical application requires precise calculations to determine how much of each reactant is needed and which one limits the formation of the product.

The Concept of Limiting Reagent

In chemical reactions, the limiting reagent (or limiting reactant) is the substance that is completely consumed first, thus determining the maximum amount of product that can be formed. Identifying the limiting reagent is a fundamental aspect of stoichiometry—the calculation of reactants and products in chemical reactions.

Why is it important?

- To maximize yield and efficiency in production processes.
- To minimize waste and optimize resource usage.
- To understand the theoretical versus actual yield of a reaction.

In our scenario, determining whether sulfur trioxide or water is the limiting reagent involves calculating the molar amounts of each reactant and comparing them based on the stoichiometric ratio.

Step 1: Calculating the Moles of Reactants

The first step involves converting the given masses into moles, as stoichiometric calculations are most straightforward in molar units.

a) Calculating moles of sulfur trioxide (SO_3):

- Atomic mass of sulfur (S): approximately 32.07 g/mol
- Atomic mass of oxygen (O): approximately 16.00 g/mol
- Molar mass of SO_3: 32.07 + (3 × 16.00) = 32.07 + 48.00 = 80.07 g/mol

Moles of SO_3:

$$\text{Moles of SO}_3 = \frac{\text{Mass of SO}_3}{\text{Molar mass of SO}_3} = \frac{6.58\,g}{80.07\,g/mol} \approx 0.0822\,mol$$

---

b) Calculating moles of water (H_2O):

- Atomic mass of hydrogen (H): approximately 1.008 g/mol
- Atomic mass of oxygen (O): 16.00 g/mol
- Molar mass of H_2O: (2 × 1.008) + 16.00 = 2.016 + 16.00 = 18.02 g/mol

Moles of H_2O:

$$\text{Moles of H}_2O = \frac{16.4\,g}{18.02\,g/mol} \approx 0.910\,mol$$

Step 2: Comparing Reactants Based on the Reaction Stoichiometry

The balanced chemical equation:

$SO_3 + H_2O \rightarrow H_2SO_4$

tells us that 1 mole of SO_3 reacts with 1 mole of H_2O. Therefore, the molar ratio of reactants should be 1:1.

Assessing the available moles:

- Moles of SO_3: approximately 0.0822 mol
- Moles of H_2O: approximately 0.910 mol

Since 1 mol of SO_3 requires 1 mol of H_2O, the amount of H_2O available far exceeds the amount needed to react with all of the SO_3.

Conclusion:

- All 0.0822 mol of SO_3 can react with 0.0822 mol of H_2O.
- There is more than enough water (0.910 mol available), so water is in excess.

Therefore, sulfur trioxide is the limiting reagent in this reaction.

Step 3: Calculating the Theoretical Yield of Sulfuric Acid

Knowing that SO_3 is limiting, we can now determine the maximum amount of sulfuric acid that can be produced.

Since the molar ratio between SO_3 and H_2SO_4 is 1:1:

- Moles of H_2SO_4 formed = moles of SO_3 reacted = 0.0822 mol

Mass of H_2SO_4 produced:

- Molar mass of H_2SO_4:
- Hydrogen: 1.008 g/mol × 2 = 2.016 g/mol
- Sulfur: 32.07 g/mol
- Oxygen: 16.00 g/mol × 4 = 64.00 g/mol
- Total: 2.016 + 32.07 + 64.00 = 98.09 g/mol

$$ \text{Mass of H}_2\text{SO}_4 = 0.0822\,mol \times 98.09\,g/mol \approx 8.07\,g $$

Thus, the theoretical maximum yield of sulfuric acid is approximately 8.07 grams.

Practical Implications and Industrial Relevance

Understanding which reagent is limiting in a chemical process is not just an academic exercise—it directly impacts industrial efficiency, cost management, and environmental considerations.

In industrial settings:

- Precise measurements of reactants ensure maximum yield.
- Recognizing excess reactants can prevent unnecessary waste and reduce costs.
- Optimization of reaction conditions minimizes by-products and side reactions.

In laboratory synthesis:

- Proper stoichiometric calculations prevent reagent shortages or wastage.
- They allow for accurate scaling of reactions from lab to production levels.

Environmental considerations:

- Excess reactants, if not managed properly, can lead to waste disposal

issues.
- Efficient use of reactants reduces environmental footprint.

Additional Factors and Safety Considerations

While the stoichiometric calculations provide a theoretical framework, real-world reactions involve nuances:

- Reaction conditions: Temperature, pressure, and catalyst presence influence reaction rates and yields.
- Reactivity of reagents: SO_3 is highly reactive and corrosive; handling requires appropriate safety measures.
- Purity of reactants: Impurities can affect reaction efficiency and product quality.

Understanding the limiting reagent allows chemists and engineers to plan better, ensuring safety and efficiency in the production of sulfuric acid, a compound vital to countless industries—from fertilizer manufacturing to petroleum refining.

Summary

In the reaction where 6.58 grams of sulfur trioxide reacts with 16.4 grams of water to produce sulfuric acid, the key question is: which reactant limits the amount of product formed? Through molar calculations, it becomes evident that sulfur trioxide is the limiting reagent. With approximately 0.0822 mol of SO_3 available, and water present in a much larger amount, the maximum theoretical yield of sulfuric acid is about 8.07 grams. Recognizing this limiting reagent is essential for optimizing reactions, reducing waste, and ensuring safety in both industrial and laboratory settings.

By applying stoichiometry principles, chemists can systematically analyze reactions, predict outcomes, and improve processes—a foundational skill that underpins the efficient and sustainable production of one of the world's most important chemicals.

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