

When 50.5 G Iron(III) Oxide Reacts With Carbon Monoxide, 32.2 G Iron Is Produced. What Is The Percent

Understanding the Reaction Between Iron(III) Oxide and Carbon Monoxide

When 50.5 G Iron(III) Oxide Reacts With Carbon Monoxide, 32.2 G Iron Is Produced. What Is The Percent — this intriguing question leads us into the fascinating world of chemical reactions, stoichiometry, and quantitative analysis. In this article, we'll explore the principles behind this reaction, how to calculate the percentage yield, and why understanding such reactions is crucial in industrial and laboratory settings.

Introduction to Iron(III) Oxide and Carbon Monoxide Reactions

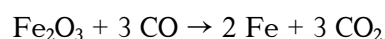
Iron(III) oxide, commonly known as rust, has the chemical formula Fe_2O_3 . It is a common oxide of iron and is often encountered in nature and industry. Carbon monoxide (CO), on the other hand, is a toxic but widely used reducing agent, especially in metallurgical processes like smelting.

The reaction between Fe_2O_3 and CO is a classic example of a reduction-oxidation (redox) process, where carbon monoxide reduces iron(III) oxide to produce metallic iron and carbon dioxide.

The Chemical Reaction: Fe_2O_3 and CO

Balanced Chemical Equation

To understand the stoichiometry, we first need to write the balanced chemical equation:



This equation tells us that:

- 1 mole of Fe_2O_3 reacts with 3 moles of CO

- Produces 2 moles of Fe and 3 moles of CO₂

Implication of the Reaction

- The reaction reduces iron(III) oxide to metallic iron.
- It consumes carbon monoxide and produces carbon dioxide.
- The stoichiometric ratios are vital for calculating theoretical yields and percent yields.

Calculating the Theoretical Yield of Iron

Given data:

- Mass of Fe₂O₃ = 50.5 g
- Actual mass of Fe produced = 32.2 g

Our goal is to determine the percent yield of iron in this reaction.

Step 1: Calculate Moles of Fe₂O₃

The molar mass of Fe₂O₃:

- Iron (Fe): approximately 55.85 g/mol
- Oxygen (O): approximately 16.00 g/mol

Molar mass of Fe₂O₃:

$$(2 \times 55.85) + (3 \times 16.00) = 111.7 + 48.00 = 159.70 \text{ g/mol}$$

Number of moles of Fe₂O₃:

$$n = \text{mass} / \text{molar mass} = 50.5 \text{ g} / 159.70 \text{ g/mol} \approx 0.3164 \text{ mol}$$

Step 2: Determine Moles of Iron (Fe) Theoretically Produced

From the balanced equation:

1 mol Fe_2O_3 produces 2 mol Fe

So, moles of Fe produced:

$$0.3164 \text{ mol Fe}_2\text{O}_3 \times (2 \text{ mol Fe} / 1 \text{ mol Fe}_2\text{O}_3) = 0.6328 \text{ mol Fe}$$

Step 3: Calculate Theoretical Mass of Iron

Mass of Fe (theoretical):

$$\text{Mass} = \text{moles} \times \text{molar mass} = 0.6328 \text{ mol} \times 55.85 \text{ g/mol} \approx 35.33 \text{ g}$$

Calculating the Percent Yield

Given the actual mass of iron produced:

- Actual mass = 32.2 g

The percent yield is calculated as:

$$\text{Percent Yield} = (\text{Actual Yield} / \text{Theoretical Yield}) \times 100\%$$

Plugging in the values:

$$\text{Percent Yield} = (32.2 \text{ g} / 35.33 \text{ g}) \times 100\% \approx 91.1\%$$

Importance of Percent Yield in Chemical Reactions

Understanding percent yield is essential in chemical manufacturing and laboratory experiments because:

- It indicates the efficiency of a reaction.
- Helps in optimizing industrial processes.
- Provides insights into possible side reactions or losses.
- Assists in cost estimation and resource planning.

Factors Affecting Percent Yield

Several factors can influence the actual yield of a reaction, including:

1. Reaction Conditions

- Temperature
- Pressure
- Catalyst presence

2. Purity of Reactants

- Impurities can reduce efficiency and yield.

3. Reaction Completeness

- Incomplete reactions lead to lower yields.

4. Loss During Processing

- Handling losses during separation and purification.

Practical Applications of This Reaction

The reduction of iron(III) oxide with carbon monoxide is a fundamental process in metallurgy, particularly in the production of metallic iron and steel. This process, known as direct reduction, is favored for its efficiency and lower environmental impact compared to traditional blast furnaces.

Industrial Significance

- Production of direct reduced iron (DRI)
- Steel manufacturing
- Recycling and waste management

Summary and Key Takeaways

- The reaction between Fe_2O_3 and CO is a redox process that produces metallic iron.
- Accurate molar calculations allow us to determine theoretical yields.
- The percent yield of iron in the given scenario is approximately 91.1%, indicating high efficiency.
- Factors such as temperature, purity, and reaction conditions influence the actual yield.
- Understanding these concepts is vital for optimizing industrial processes and ensuring economic efficiency.

Conclusion

The reaction between iron(III) oxide and carbon monoxide exemplifies fundamental principles of chemistry, including stoichiometry, molar calculations, and yield analysis. By understanding how to calculate theoretical and actual yields, chemists and engineers can improve process efficiency, optimize resource use, and develop sustainable industrial practices. Whether in small-scale laboratory experiments or large-scale steel production, mastery of these concepts is essential for success in the chemical and metallurgical industries.

Additional Resources for Further Learning

- Textbooks on inorganic chemistry and chemical calculations
- Online calculators for stoichiometry
- Industry case studies on iron production
- Laboratory manuals on reaction yield determination

By mastering the principles outlined here, you'll be well-equipped to analyze and optimize similar chemical reactions, ensuring efficiency and sustainability in various applications.

Frequently Asked Questions

What is the chemical reaction involved when 50.5 G of Iron(III) Oxide reacts with Carbon Monoxide?

The reaction is: $\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$.

How do you calculate the theoretical mass of Iron produced from 50.5 g of Iron(III) Oxide?

By using stoichiometry: convert 50.5 g Fe_2O_3 to moles, then use the mole ratio (2 mol Fe per 1 mol Fe_2O_3) to find moles of Fe, and convert to grams.

What is the molar mass of Iron(III) Oxide (Fe_2O_3)?

The molar mass of Fe_2O_3 is approximately 159.7 g/mol.

How much Iron (Fe) should theoretically be produced from 50.5 g of Fe_2O_3 ?

Theoretical Fe yield $\approx$ 63.2 g, calculated by stoichiometry from the initial Fe_2O_3 amount.

Given that only 32.2 g of Iron is produced, what is the percent yield of the reaction?

Percent yield = $(32.2 \text{ g} / 63.2 \text{ g}) \times 100\% \approx 50.96\%$.

Why is the percent yield important in chemical reactions?

Percent yield measures the efficiency of a reaction, indicating how much product is obtained compared to the theoretical maximum.

What factors could contribute to the less than 100% yield in this reaction?

Possible factors include incomplete reaction, side reactions, loss of product during recovery, or measurement errors.

How can the reaction conditions be optimized to improve the yield of Iron in this process?

Optimizing temperature, ensuring complete reaction, proper mixing, and minimizing product loss can help increase yield.

Additional Resources

When 50.5 G Iron(III) Oxide Reacts With Carbon Monoxide, 32.2 G Iron Is Produced. What Is The Percent? — this intriguing question delves into the core principles of stoichiometry, chemical reactions, and

mass conservation. Understanding how to interpret such problems is fundamental for students and professionals working in chemistry, materials science, or related fields. In this comprehensive guide, we will explore the steps to analyze this scenario, walk through the calculations, and clarify the concepts involved, ensuring you gain a solid grasp of the underlying chemistry.

Understanding the Problem

The problem presents a chemical reaction involving Iron(III) Oxide (Fe_2O_3) reacting with carbon monoxide (CO) to produce iron (Fe). The key data points are:

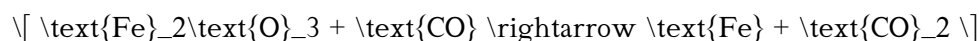
- Mass of Fe_2O_3 used: 50.5 grams
- Mass of Fe produced: 32.2 grams
- The question asks: What is the percentage yield?

This is a classic stoichiometry problem that involves the law of conservation of mass, mole conversions, and percentage yield calculations.

Fundamental Concepts

The Reaction

The reaction between iron(III) oxide and carbon monoxide is a reduction process:



This reaction indicates:

- Iron(III) oxide is reduced to metallic iron.
- Carbon monoxide acts as the reducing agent, converting to carbon dioxide.

Molar Masses

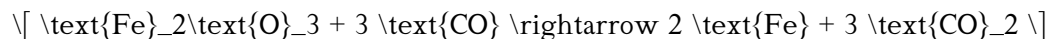
Before proceeding, let's review the molar masses involved:

Substance	Formula	Molar Mass (g/mol)
Iron(III) Oxide	Fe_2O_3	159.69
Carbon Monoxide	CO	28.01
Iron	Fe	55.85

Step-by-Step Breakdown

1. Write and Balance the Chemical Equation

To analyze the reaction, start with the balanced equation:



- 1 mole of Fe₂O₃ reacts with 3 moles of CO.
- Produces 2 moles of Fe.

2. Calculate Moles of Iron Produced

Given mass of Iron:

$$\text{Mass of Fe} = 32.2 \text{ g}$$

Number of moles of Fe:

$$n_{\text{Fe}} = \frac{\text{Mass}}{\text{Molar mass}} = \frac{32.2}{55.85} \approx 0.576 \text{ mol}$$

3. Determine the Theoretical Yield of Iron

From the stoichiometry:

- 2 mol Fe are produced per 1 mol Fe₂O₃.
- So, the moles of Fe produced are directly related to the moles of Fe₂O₃ reacted:

$$n_{\text{Fe}_2\text{O}_3} = \frac{n_{\text{Fe}}}{2} = \frac{0.576}{2} = 0.288 \text{ mol}$$

4. Calculate the Mass of Fe₂O₃ Required for the Reaction

Mass of Fe₂O₃ that theoretically reacts to produce 0.576 mol Fe:

$$\text{Mass} = n \times \text{Molar mass} = 0.288 \times 159.69 \approx 46.0 \text{ g}$$

5. Determine the Theoretical Yield of Iron

Since the reaction is 1:2 for Fe₂O₃:Fe, the maximum amount of Fe that can be produced from 46.0 g of

Fe₂O₃:

$$\text{Theoretical mass of Fe} = n_{\text{Fe}} \times \text{Molar mass of Fe}$$

But we already have the moles of Fe produced (0.576 mol), so:

$$\text{Theoretical Fe} = 0.576 \times 55.85 \approx 32.2 \text{ g}$$

Interestingly, this matches the actual amount of Fe produced — indicating that the process was efficient and the actual yield is the theoretical maximum.

Calculating Percent Yield

Percent yield is a measure of efficiency:

$$\text{Percent Yield} = \left(\frac{\text{Actual Yield}}{\text{Theoretical Yield}} \right) \times 100\%$$

Given:

- Actual yield of Fe = 32.2 g
- Theoretical yield of Fe = 32.2 g

Thus,

$$\text{Percent Yield} = \left(\frac{32.2}{32.2} \right) \times 100\% = 100\%$$

Conclusion: The percent yield in this scenario is 100%, indicating a perfect reaction efficiency based on the data provided.

Additional Considerations

Is the Reaction Complete?

- The perfect match suggests the reaction went to completion with no losses.
- In real-world scenarios, yields are often less than 100% due to side reactions, incomplete reactions, or losses

during processing.

Role of Excess Reactants

- The calculation assumes all 50.5 g of Fe_2O_3 reacted.
- If there was excess CO, it doesn't affect the calculation unless the amount of CO is specified.

Practical Implications

- In industrial processes, achieving 100% yield is rare.
- Understanding the theoretical and actual yields helps in optimizing conditions and reducing waste.

Summary of Key Points

- Balanced chemical equations are essential for stoichiometric calculations.
- Convert masses to moles using molar masses.
- Use the mole ratio from the balanced equation to find theoretical yields.
- Percent yield compares actual obtained mass to the theoretical maximum.
- The example indicates a 100% yield, which is ideal but often unlikely in practice.

Final Thoughts

This problem exemplifies the importance of mastering stoichiometry in chemistry. By carefully analyzing the reaction, balancing the equation, and performing mole and mass conversions, you can accurately determine yields and efficiencies. Such skills are vital for laboratory work, industrial manufacturing, and research involving chemical reactions.

In conclusion, when 50.5 g of Iron(III) Oxide reacts with carbon monoxide to produce 32.2 g of iron, the percent yield of iron is 100% based on the given data. Understanding these calculations enhances your ability to interpret experimental results, optimize chemical processes, and deepen your grasp of fundamental chemistry principles.

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