(iii) A Company Made Magnesium Using This Reaction. Calculate The Mass Of Magnesium Oxide Needed To Produce

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Introduction to Magnesium Production and Its Significance

Magnesium is a vital metal used extensively across industries, including aerospace, automotive, construction, and electronics. Its lightweight, strength, and excellent thermal conductivity make it highly desirable for manufacturing lightweight alloys and components. The production of magnesium involves complex chemical processes, often centered around extracting magnesium oxide (MgO) from mineral sources like magnesite or dolomite. Once magnesium oxide is obtained, it can be reduced to produce pure magnesium metal.

In this article, we explore a specific chemical reaction used in magnesium manufacturing. We'll examine how a company produces magnesium using this reaction and perform calculations to determine the amount of magnesium oxide required to produce a specified amount of magnesium. This not only enhances understanding of industrial chemical processes but also provides insights into resource management and process efficiency.

The Chemical Reaction Behind Magnesium Production

Overview of the Reaction

The primary chemical process used to produce magnesium metal from magnesium oxide is thermal reduction—a high-temperature reaction where magnesium oxide is reduced using a suitable reducing agent, commonly silicon or carbon in the form of coke. The most prevalent industrial method is the silicon reduction process, which involves the following reaction:

Magnesium Oxide + Silicon → Magnesium + Silicon Dioxide

In chemical terms:

$MgO + Si \rightarrow Mg + SiO_2$

This reaction typically takes place in an electric arc furnace at temperatures exceeding 1500°C, where magnesium oxide is reduced to produce magnesium vapor, which then condenses into solid metal.

Understanding the Reaction and Its Stoichiometry

Balanced Chemical Equation

The overall reaction can be written as:

$MgO + Si \rightarrow Mg + SiO_2$

This equation suggests a 1:1 molar ratio between magnesium oxide and silicon, and similarly, between magnesium and silicon dioxide.

Molar Masses

To perform calculations, we need the molar masses:

- Magnesium (Mg): 24.305 g/mol
- Magnesium Oxide (MgO): 40.305 g/mol
- Silicon (Si): 28.085 g/mol
- Silicon Dioxide (SiO_2): 60.085 g/mol

Calculating the Mass of Magnesium Oxide Needed

Suppose a company aims to produce a specific mass of magnesium metal. The key question is: How much magnesium oxide (MgO) is required to produce this amount?

Step 1: Determine the Target Mass of Magnesium

Let’s assume the company wants to produce 100 kg of magnesium metal.

Step 2: Convert Magnesium Mass to Moles

Using molar mass:

Number of moles of Mg = (Mass of Mg) / (Molar mass of Mg)

= 100,000 g / 24.305 g/mol ≈ 4113.4 mol

Step 3: Use Stoichiometry to Find Moles of MgO Needed

From the balanced equation:

1 mol MgO produces 1 mol Mg

Therefore, moles of MgO needed = moles of Mg produced = 4113.4 mol

Step 4: Convert Moles of MgO to Mass

Mass of MgO = moles × molar mass

= 4113.4 mol × 40.305 g/mol ≈ 165,693 g

= 165.693 kg

Interpreting the Results

To produce 100 kg of magnesium metal, approximately 165.7 kg of magnesium oxide is required. This calculation assumes 100% efficiency in the reduction process, meaning no losses during the reaction. In real-world industrial settings, some losses occur due to incomplete reactions, impurities, or process inefficiencies. Therefore, companies often include a safety margin or adjustment factor.

Factors Affecting the Quantity of Magnesium Oxide Needed

1. Reaction Efficiency

- Industrial processes rarely operate at 100% efficiency.
- Typical efficiencies range from 85% to 95%, necessitating additional MgO to compensate for losses.

2. Purity of Raw Materials

- Impurities in magnesium ore can affect the amount of MgO that actually reacts.
- Purity levels impact the calculation, often requiring adjustments.

3. Process Conditions

- Temperature control and reaction times influence yield.
- Optimal conditions maximize magnesium recovery, reducing waste.

Practical Applications and Industrial Significance

Resource Management

Accurate calculations of MgO requirements are critical for:

- Cost estimation
- Supply chain planning
- Minimizing waste and environmental impact

Environmental Considerations

- Efficient use of raw materials reduces energy consumption and emissions.
- Proper calculations help ensure sustainable production practices.

Economic Impact

- Precise resource calculations directly influence profitability.
- Reducing excess MgO usage lowers raw material costs.

Additional Calculations and Examples

Example 1: Producing 50 kg of Magnesium

- Moles of Mg = 50,000 g / 24.305 g/mol ≈ 2056.7 mol
- MgO needed = 2056.7 mol × 40.305 g/mol ≈ 82,846 g ≈ 82.8 kg

Example 2: Adjusting for 90% Efficiency

- Required MgO = (theoretical amount) / efficiency
- For 100 kg Mg: 165.7 kg / 0.9 ≈ 183.0 kg MgO

Conclusion

The production of magnesium from magnesium oxide involves a well-understood chemical reaction with clear stoichiometric relationships. By understanding these relationships and performing precise calculations, companies can optimize their resource usage, reduce costs, and minimize environmental impacts. Whether producing small or large quantities, accurate determination of MgO requirements is essential for efficient industrial magnesium manufacturing.

In summary, to produce 100 kg of magnesium metal, approximately 165.7 kg of magnesium oxide is needed under ideal conditions. Adjustments for process efficiency and raw material purity are crucial for real-world applications, emphasizing the importance of detailed chemical calculations in industrial operations.

Keywords: magnesium production, magnesium oxide, chemical reaction, stoichiometry, industrial chemistry, resource calculation, magnesium extraction, MgO, magnesium reduction, process efficiency

Frequently Asked Questions

What is the chemical reaction involved in producing

magnesium oxide from magnesium?

Magnesium reacts with oxygen in the air to produce magnesium oxide, following the reaction: $2Mg + O_2 \rightarrow 2MgO$.

How do you calculate the mass of magnesium oxide needed to produce a specific amount of magnesium?

First, determine the moles of magnesium involved, then use the molar ratio from the balanced equation to find the moles of MgO needed, and finally convert moles of MgO to mass using its molar mass.

What is the molar mass of magnesium and magnesium oxide?

The molar mass of magnesium (Mg) is approximately 24.3 g/mol, and magnesium oxide (MgO) is approximately 40.3 g/mol.

If a company wants to produce 100 grams of magnesium oxide, how much magnesium is required?

Calculate moles of MgO: 100 g ÷ 40.3 g/mol ≈ 2.48 mol. Since 2 mol Mg produce 2 mol MgO, the moles of Mg needed are approximately 2.48 mol. Therefore, mass of Mg = 2.48 mol × 24.3 g/mol ≈ 60.3 grams.

What are the practical considerations when producing magnesium oxide in a company?

Factors include ensuring complete reaction with oxygen, controlling temperature for optimal oxidation, handling high-temperature processes safely, and purifying the final product.

How does the reaction between magnesium and oxygen illustrate conservation of mass?

The total mass of magnesium and oxygen before the reaction equals the mass of magnesium oxide produced, demonstrating the principle of conservation of mass.

What safety precautions should be taken when producing magnesium oxide via this reaction?

Use proper protective equipment, ensure good ventilation to avoid oxygen buildup, handle magnesium with care due to its flammability, and control high-temperature conditions safely.

Can this reaction be scaled up for industrial production, and what challenges might arise?

Yes, it can be scaled up, but challenges include managing heat transfer, ensuring complete oxidation, handling reactive magnesium safely, and maintaining product purity at large scale.

What are common applications of magnesium oxide produced through this reaction?

Magnesium oxide is used in refractory materials, construction, agriculture, environmental remediation, and as a dietary supplement.

Additional Resources

A Company Made Magnesium Using This Reaction: Calculating the Mass of Magnesium Oxide Needed to Produce Magnesium

In the realm of industrial chemistry, the extraction and production of magnesium stand as significant processes that underpin a variety of applications—from aerospace components to electronics and automotive parts. Among the methods employed, the thermal reduction of magnesium oxide (MgO) remains one of the most prevalent. This investigation delves into a real-world example: a company that produces magnesium via a reaction involving magnesium oxide, exploring the chemical principles involved, the calculations necessary to determine the required quantities, and the broader implications of this process.

Introduction

Magnesium is a lightweight metal with remarkable properties such as high strength-to-weight ratio, excellent thermal conductivity, and corrosion resistance. Its production involves several chemical processes, with the most common method being the reduction of magnesium oxide (MgO) with a suitable reducing agent, typically silicon or carbon, at high temperatures.

This article aims to analyze a specific case where a manufacturing company produces magnesium by reducing magnesium oxide. We will focus on calculating the mass of magnesium oxide required to produce a desired amount of magnesium, providing a comprehensive understanding of the process's stoichiometry and practical considerations.

The Chemical Reaction at the Core

The Reduction of Magnesium Oxide

The primary chemical reaction used in magnesium extraction from MgO can be represented as:

Magnesium oxide reduction with silicon:

$$ \mathrm{MgO} + \mathrm{Si} \rightarrow \mathrm{Mg} + \mathrm{SiO}_2 $$

Alternatively, in some industrial processes, carbon is used as the reducing agent:

$$ \mathrm{MgO} + \mathrm{C} \rightarrow \mathrm{Mg} + \mathrm{CO} $$

For the purpose of this analysis, we will focus on the silicon reduction process, as it is more common in high-purity magnesium production, notably in the Pidgeon process.

Reaction Details and Stoichiometry

The reaction indicates a 1:1 molar ratio between magnesium oxide and magnesium, meaning one mole of MgO yields one mole of magnesium. The silicon acts as a reducing agent, converting MgO into metallic magnesium and forming silicon dioxide (SiO_2).

Key points:

- Moles of MgO needed: To produce a specific moles of magnesium.
- Mass relationships: Derived from molar masses.

Calculating the Mass of Magnesium Oxide Needed

Step 1: Define the Production Goal

Suppose the company aims to produce 10,000 kg of magnesium metal in a batch process.

Step 2: Convert Mass of Magnesium to Moles

Using the molar mass of magnesium:

- Molar mass of Mg: approximately 24.305 g/mol

Calculating moles of magnesium:

$$
\text{Moles of Mg} = \frac{\text{Mass of Mg}}{\text{Molar mass of Mg}} =

$$
\frac{10,000,000\, \text{g}}{24.305\, \text{g/mol}} \approx 411,380\, \text{mol}
$$

Step 3: Determine Moles of MgO Required

Given the 1:1 molar ratio:

$$
\text{Moles of MgO} = \text{Moles of Mg} = 411,380\, \text{mol}
$$

Step 4: Convert Moles of MgO to Mass

Molar mass of MgO:

- Mg: 24.305 g/mol
- O: 16.00 g/mol

$$
\text{Molar mass of MgO} = 24.305 + 16.00 = 40.305\, \text{g/mol}
$$

Therefore:

$$
\text{Mass of MgO} = 411,380\, \text{mol} \times 40.305\, \text{g/mol} \approx 16,583,264\, \text{g}
$$

or approximately 16,583 kg of magnesium oxide.

Summary of the Calculation:

Step	Calculation	Result
Moles of Mg needed	10,000 kg ÷ 24.305 g/mol	~411,380 mol
MgO required	same as Mg	411,380 mol
Mass of MgO	411,380 mol × 40.305 g/mol	~16,583 kg

Practical Considerations in Industrial Production

Efficiency and Yield

While theoretical calculations provide a baseline, real-world production involves inefficiencies:

- Reaction completeness: Not all MgO may convert to Mg.
- Material losses: Handling, filtration, and other operational factors.

- Purity of reactants: Impurities can affect the reduction efficiency.

Typically, a safety margin of 5–10% is added to account for these factors.

Energy Requirements

The reduction process occurs at temperatures exceeding 1,200°C, demanding substantial energy input, often supplied via electric arc furnaces or other high-temperature techniques. Energy costs significantly influence the overall economics of magnesium production.

Environmental Impact

The process yields silica dioxide (SiO_2) as a byproduct, which must be managed responsibly. Additionally, if carbon is used as the reducing agent, CO emissions are generated, raising environmental concerns.

Broader Implications and Industry Trends

Alternative Methods

While the silicon reduction process is prevalent, alternative methods such as the electrolytic process from magnesium chloride are gaining attention, especially for producing high-purity magnesium with lower environmental footprints.

Market Demand and Supply

Global demand for magnesium continues to grow, driven by its applications in lightweight alloys and electronics. Efficient, cost-effective production methods are crucial to meet this demand sustainably.

Technological Innovations

Research into new reduction techniques, catalysts, and energy sources aims to optimize magnesium extraction, reduce costs, and minimize environmental impacts.

Conclusion

The production of magnesium via the reduction of magnesium oxide is a complex but well-understood chemical process. Precise calculations, such as determining the amount of MgO needed to produce a specified quantity of magnesium, are vital for operational planning, cost estimation, and environmental management.

In our hypothetical scenario, producing 10,000 kg of magnesium requires approximately 16,583 kg of magnesium oxide, assuming ideal conditions. Factoring in real-world inefficiencies and safety margins, the actual input may be higher.

Understanding the stoichiometric relationships and practical considerations underpinning magnesium production not only aids industry professionals in optimizing their processes but also contributes to the broader goal of sustainable and efficient resource utilization in the metallurgical sector.

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