How Many Moles Of C Are Needed To React With 1.25 Grams Of Tio2

How Many Moles Of C Are Needed To React With 1.25 Grams Of Tio2 is a common question in stoichiometry, especially when exploring reduction reactions involving titanium dioxide (TiO_2) and carbon (C). Understanding how to determine the amount of reactants needed in a chemical reaction is fundamental in chemistry, whether for academic purposes, industrial processes, or research. This article elucidates the step-by-step process to calculate the number of moles of carbon required to completely react with a given mass of titanium dioxide, incorporating essential concepts such as molar mass, balanced chemical equations, and mole ratios.

Understanding the Reaction Between TiO_2 and Carbon

The Chemical Equation

The reaction between titanium dioxide (TiO_2) and carbon (C) typically involves the reduction of TiO_2 to metallic titanium, with carbon serving as the reducing agent. The balanced chemical equation for this process can be written as:

$$TiO_2 + 2C \rightarrow Ti + 2CO$$

This equation indicates that one mole of TiO_2 reacts with two moles of carbon to produce titanium metal and carbon monoxide gas.

Significance of the Reaction

This reduction process is vital in materials science and metallurgy, where titanium is extracted from its ore. Understanding the stoichiometry allows engineers to optimize reaction conditions, minimize waste, and control costs.

Step-by-Step Calculation

Step 1: Determine the Molar Masses

Calculating molar masses is the first step, as it provides the link between mass and moles.

- **Molar mass of TiO_2:**

- Titanium (Ti): approximately 47.87 g/mol
- Oxygen (O): approximately 16.00 g/mol
- Therefore, molar mass of TiO_2 = 47.87 + (2 × 16.00) = 47.87 + 32.00 = 79.87 g/mol

- **Molar mass of C:**

  - Carbon (C): approximately 12.01 g/mol

Step 2: Convert the Given Mass of TiO_2 to Moles

Given mass of TiO_2 = 1.25 grams.

Number of moles of TiO_2:
$$
\text{Moles of } TiO_2 = \frac{\text{Mass of } TiO_2}{\text{Molar mass of } TiO_2} = \frac{1.25}{79.87} \approx 0.01565 \text{ mol}
$$

Step 3: Use the Mole Ratio from the Balanced Equation

From the balanced reaction:
- 1 mol TiO_2 reacts with 2 mol C.

Therefore, the moles of C needed:
$$
\text{Moles of C} = 2 \times \text{Moles of } TiO_2 = 2 \times 0.01565 \approx 0.0313 \text{ mol}
$$

Step 4: Final Result

Approximately 0.0313 moles of carbon are required to react completely with 1.25 grams of TiO_2.

Additional Considerations

1. Purity of Reactants

In practical scenarios, reactants might not be pure. Adjustments should be made based on the purity levels to ensure accurate calculations.

2. Reaction Conditions

Factors like temperature, pressure, and presence of catalysts can influence the reaction's efficiency but do not alter the stoichiometric ratios.

3. Excess Reactant

In industrial processes, an excess of carbon is often used to ensure complete reduction of TiO_2, which means the actual amount used may be higher than the stoichiometric requirement.

Applications of This Calculation

1. Industrial Titanium Production

Manufacturers need precise calculations to optimize the amount of carbon used in the reduction process, reducing costs and improving yield.

2. Academic Laboratory Experiments

Students and educators utilize such calculations to understand reaction stoichiometry and develop practical skills.

3. Environmental Impact Assessments

Accurate reactant calculations help predict emissions and waste products, aiding in environmental management.

Summary

To summarize, calculating how many moles of carbon are needed to react with a specific mass of TiO_2 involves understanding the chemical reaction, determining molar masses, converting mass to moles, and applying the mole ratio from the balanced equation. For 1.25 grams of TiO_2, approximately 0.0313 moles of carbon are required for complete reaction. Mastery of these calculations is essential for chemists, engineers, and students working with reduction reactions or involved in material synthesis processes.

Key Takeaways

- The balanced chemical equation for TiO_2 reduction with carbon is $TiO_2 + 2C \rightarrow Ti + 2CO$.
- Molar masses are crucial for converting between mass and moles.
- The mole ratio guides the amount of reactant needed.
- Practical applications include industrial manufacturing and academic demonstrations.
- Always consider real-world factors like purity and excess reactants.

By mastering the stoichiometric principles outlined here, practitioners can efficiently plan and execute reactions involving titanium dioxide and carbon, ensuring optimal resource utilization and process efficiency.

Frequently Asked Questions

How do I calculate the number of moles of carbon needed to react with 1.25 grams of TiO_2?

First, determine the molar mass of TiO_2 (about 79.87 g/mol). Then, find the moles of TiO_2: 1.25 g ÷ 79.87 g/mol ≈ 0.01565 mol. The reaction between TiO_2 and carbon typically involves reduction; assuming a 1:1 molar ratio, you need approximately 0.01565 mol of C.

What is the balanced chemical equation for the reaction between TiO_2 and carbon?

A common reduction reaction is: $TiO_2 + 2C \rightarrow Ti + 2CO$. This shows 2 moles of carbon react with 1 mole of TiO_2.

Based on the balanced equation, how many moles of C are needed for 1.25 grams of TiO_2?

Since the molar ratio is 2 C to 1 TiO_2, and you have approximately 0.01565 mol of TiO_2, you need 2 × 0.01565 mol ≈ 0.0313 mol of C.

What is the mass of carbon required to react with 1.25 grams of TiO_2?

Using the moles of C needed (0.0313 mol) and the molar mass of carbon (12.01 g/mol), the mass required is 0.0313 mol × 12.01 g/mol ≈ 0.376 g.

If I only have 0.3 grams of carbon, will it be enough to react with 1.25 grams of TiO_2?

No, since approximately 0.376 grams of carbon are needed, 0.3 grams would be insufficient for complete reaction.

How do I adjust calculations if the reaction ratio between TiO_2 and C is different?

You would modify the molar ratio in the calculation based on the balanced chemical equation. For example, if the ratio is not 2:1, use the actual coefficients to determine the required moles of C.

Why is understanding the mole ratio important in this reaction?

The mole ratio from the balanced equation ensures you use the correct amount of reactants for complete and efficient reaction without excess or deficiency.

Additional Resources

How Many Moles Of Carbon (C) Are Needed To React With 1.25 Grams Of Titanium Dioxide (TiO_2)

Understanding the precise amount of reactants required in a chemical reaction is fundamental in stoichiometry, which allows chemists to predict product yields, optimize reactions, and understand reaction mechanisms. In this detailed exploration, we will analyze how to determine the number of moles of carbon needed to react completely with 1.25 grams of titanium dioxide (TiO_2). This involves a thorough understanding of the chemical reaction involved, molar mass calculations, mole ratios, and potential reaction pathways.

Fundamental Concepts in Stoichiometry

Before diving into the specifics, it's essential to review some core concepts:

- Moles: A measure of the amount of substance, defined as the number of particles (atoms, molecules, ions) divided by Avogadro's number ($\sim 6.022 \times 10^{23}$).

- Molar Mass: The mass of one mole of a substance, expressed in grams per mole (g/mol).

- Stoichiometry: The calculation of reactants and products in chemical reactions based on balanced chemical equations.

Understanding the Reactants: TiO_2 and C

Properties of Titanium Dioxide (TiO_2)

- Chemical formula: TiO_2
- Molar mass calculation:

- Titanium (Ti): approximately 47.87 g/mol
- Oxygen (O): approximately 16.00 g/mol

Therefore,
$$
\text{Molar mass of TiO}_2 = 47.87 + 2 \times 16.00 = 47.87 + 32.00 = 79.87 \text{ g/mol}
$$

Properties of Carbon (C)

- Elemental carbon, atomic number 6
- Molar mass: approximately 12.01 g/mol

Identifying the Reaction: TiO_2 and Carbon

The key to solving this problem is understanding what reaction occurs between titanium dioxide and carbon. Titanium dioxide is a stable oxide, but under certain conditions—such as high temperature in a reducing environment—carbon can reduce TiO_2 to metallic titanium.

Common Reduction Reaction

The typical reduction of TiO_2 by carbon can be represented as:

$$
\text{TiO}_2 + \text{C} \rightarrow \text{Ti} + \text{CO}_2
$$

This reaction occurs at elevated temperatures (often in a furnace), where carbon acts as a reducing agent, removing oxygen from TiO_2 to produce titanium metal and carbon dioxide gas.

Balanced Chemical Equation

Let's verify the balanced equation:

$$
\text{TiO}_2 + \text{C} \rightarrow \text{Ti} + 2\,\text{CO}
$$

Alternatively, it can be written as:

$$
\text{TiO}_2 + \text{C} \rightarrow \text{Ti} + \text{CO}_2
$$

However, in industrial processes, the reduction often produces CO (carbon monoxide) instead of CO_2, depending on conditions.

For simplicity and typical reduction process, the balanced equation is:

$$
\text{TiO}_2 + \text{C} \rightarrow \text{Ti} + \text{CO}_2
$$

This indicates a 1:1 molar ratio between TiO_2 and C.

Calculating the Moles of TiO_2 in 1.25 grams

To determine how many moles of C are needed, we first calculate the moles of TiO_2:

$$
\text{Moles of TiO}_2 = \frac{\text{Mass of TiO}_2}{\text{Molar mass of TiO}_2}
$$

Substitute the known values:

$$
\text{Moles of TiO}_2 = \frac{1.25\, \text{g}}{79.87\, \text{g/mol}} \approx 0.01565\, \text{mol}
$$

This is the amount of TiO_2 present in 1.25 grams.

Determining the Moles of Carbon Required

From the balanced chemical equation:

$$
\text{TiO}_2 + \text{C} \rightarrow \text{Ti} + \text{CO}_2
$$

the molar ratio of TiO_2 to C is 1:1. Therefore, the moles of carbon required to react with all the TiO_2 are equal to the moles of TiO_2 present.

$$
\text{Moles of C} = \text{Moles of TiO}_2 \approx 0.01565\, \text{mol}
$$

Final answer:

Approximately 0.01565 moles of carbon are needed to react completely with 1.25 grams of TiO_2.

Implications and Practical Considerations

While the stoichiometric calculation provides a theoretical value, real-world reactions often require an excess of reactants to drive the reaction to completion. Factors influencing this include:

- Reaction Conditions: Temperature, pressure, and presence of catalysts can affect the efficiency of reduction.
- Purity of Reactants: Impurities may alter the amount of carbon needed.
- Kinetics: Reaction rate may necessitate using more carbon to achieve complete reduction within a desired timeframe.

In industrial settings, it is common to add a slight excess (e.g., 5-10%) of carbon to ensure complete reduction.

Example: Adjusting for Excess Carbon

Suppose an engineer wants to add 10% excess carbon:

$$
\text{Adjusted moles of C} = 0.01565 \times 1.10 \approx 0.0172\, \text{mol}
$$

This ensures complete reaction even if some carbon does not react due to kinetic limitations.

Calculating the Mass of Carbon Needed

To find the mass of carbon corresponding to 0.01565 mol:

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

$$
\text{Mass of C} = 0.01565\, \text{mol} \times 12.01\, \text{g/mol} \approx 0.188\, \text{g}
$$

If considering an excess:

$$
0.0172\, \text{mol} \times 12.01\, \text{g/mol} \approx 0.206\, \text{g}
$$

Thus, approximately 0.188 grams of carbon are theoretically required, with a recommended excess amount of about 0.018 grams to ensure complete reduction.

Additional Factors and Advanced Considerations

While the basic calculation hinges on the balanced chemical equation, several advanced considerations can influence the actual amount of carbon needed:

- Reaction Pathways: Alternative reduction pathways may involve different stoichiometries, especially under varying conditions.
- Thermodynamics: The Gibbs free energy change determines whether the reduction is thermodynamically favorable at specific temperatures.
- Kinetic Barriers: Activation energies may require higher temperatures or catalysts, impacting the amount of reactant needed.
- Environmental Conditions: Presence of other gases, such as oxygen, can affect the reduction process.

Understanding these factors is crucial for designing industrial processes, laboratory experiments, or even estimating resource requirements.

Summary of Key Steps

1. Identify the chemical reaction: $TiO_2 + C \rightarrow Ti + CO_2$ (or CO).
2. Calculate molar mass of TiO_2: 79.87 g/mol.
3. Determine moles of TiO_2 in given mass:

$$
\text{Moles of TiO}_2 = \frac{1.25\, \text{g}}{79.87\, \text{g/mol}} \approx 0.01565\, \text{mol}
$$

4. Use the molar ratio from the balanced equation: 1 mol TiO_2 reacts with 1 mol C.
5. Determine moles of C needed: approximately 0.01565 mol.
6. Convert to mass of carbon: about 0.188 grams.

Conclusion

In summary, to react completely with 1.25 grams of titanium dioxide (TiO_2), approximately 0.01565 moles of carbon (C) are required under ideal, stoichiometric conditions. Practical applications often involve using a slight excess of carbon to ensure complete reaction, accounting for kinetic and thermodynamic factors. This calculation exemplifies how fundamental stoichiometry principles enable precise resource planning in chemical synthesis, materials processing, and industrial manufacturing.

By understanding the underlying chemistry, molar relationships, and real-world considerations, chemists and engineers can optimize processes, reduce waste, and improve efficiency in the production of titanium metal and related materials.

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