When 12.0 G Of Calcium Metal Is Reacted With Water, 5.00 G Of Calcium Hydroxide Is Produced. Using The

When 12.0 G Of Calcium Metal Is Reacted With Water, 5.00 G Of Calcium Hydroxide Is Produced. Using The chemical reaction between calcium and water as a foundation, this article explores the principles of stoichiometry, molecular calculations, and chemical reactions involved in the process. Understanding such reactions is fundamental in chemistry, especially for students and professionals dealing with chemical manufacturing, environmental chemistry, and material science.

In this detailed guide, we will analyze the reaction between calcium metal and water, interpret the mass relationships, and use stoichiometric calculations to deepen your understanding of how quantities of reactants relate to products in chemical reactions. We will also cover key concepts like molar mass, mole ratios, limiting reactants, and theoretical versus actual yields, providing a comprehensive overview suitable for learners at various levels.

Understanding the Chemical Reaction: Calcium and Water

Reaction Equation

The reaction of calcium metal with water can be summarized by the following balanced chemical equation:

$$
\text{Ca (s)} + 2\, \text{H}_2\text{O (l)} \rightarrow \text{Ca(OH)}_2 (s) + \text{H}_2 (g)
$$

This indicates that one mole of calcium reacts with two moles of water to produce one mole of calcium hydroxide ($Ca(OH)_2$) and hydrogen gas (H_2).

Key Concepts in the Reaction

- Calcium (Ca): An alkaline earth metal with atomic mass approximately 40.08 g/mol.
- Water (H_2O): A diatomic molecule with molar mass approximately 18.02 g/mol.
- Calcium hydroxide ($Ca(OH)_2$): An inorganic compound with molar mass approximately 74.10 g/mol.
- Hydrogen gas (H_2): A diatomic molecule with molar mass approximately 2.02 g/mol.

Understanding these molar masses is crucial for converting between grams and moles, which forms the basis of stoichiometry calculations.

Mass Relationships and Stoichiometry

Given the initial mass of calcium and the mass of calcium hydroxide produced, we can analyze the reaction quantitatively.

Given Data

- Mass of calcium metal: 12.0 g
- Mass of calcium hydroxide produced: 5.00 g

Calculating Moles of Reactants and Products

1. Calculate moles of calcium used:

$$
\text{Moles of Ca} = \frac{\text{Mass of Ca}}{\text{Molar mass of Ca}} = \frac{12.0\, \text{g}}{40.08\, \text{g/mol}} \approx 0.299\, \text{mol}
$$

2. Calculate moles of calcium hydroxide produced:

$$
\text{Moles of Ca(OH)}_2 = \frac{\text{Mass of Ca(OH)}_2}{\text{Molar mass of Ca(OH)}_2} = \frac{5.00\, \text{g}}{74.10\, \text{g/mol}} \approx 0.0675\, \text{mol}
$$

Determining the Reaction Efficiency and Limiting Reactant

The reaction's theoretical yield can be calculated based on the initial amount of calcium, considering the molar ratio from the balanced equation.

Expected Yield of Calcium Hydroxide

From the balanced reaction:

$$
\text{Ca} : \text{Ca(OH)}_2 = 1 : 1
$$

Therefore, the theoretical moles of calcium hydroxide produced from 0.299 mol of calcium are:

$$
\text{Theoretical moles of Ca(OH)}_2 = 0.299\, \text{mol}
$$

Corresponding mass:

$$
\text{Theoretical mass} = 0.299\, \text{mol} \times 74.10\, \text{g/mol} \approx 22.17\, \text{g}
$$

However, only 5.00 g of calcium hydroxide was actually produced, indicating a yield of:

$$
\text{Percent yield} = \frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100 = \frac{5.00\, \text{g}}{22.17\, \text{g}} \times 100 \approx 22.56\%
$$

This suggests the reaction was not complete or some loss occurred during the process.

Understanding the Practical Implications

The discrepancy between theoretical and actual yields highlights important concepts:

- Reaction efficiency: Not all reactants convert to products; side reactions or incomplete reactions reduce yield.
- Limiting reagent: In practice, the amount of reactant that is fully consumed limits the amount of product formed.
- Actual versus theoretical yield: Actual yield is often less due to practical factors like incomplete reactions, side reactions, or losses during handling.

Using the Data to Find the Limiting Reactant

Suppose we want to determine if calcium or water is the limiting reactant in this reaction.

Step 1: Calculate moles of water available

Given the molar ratio:

$$
\text{Ca} : \text{H}_2\text{O} = 1 : 2
$$

From 0.299 mol of calcium:

$$
\text{Required water} = 2 \times 0.299\, \text{mol} = 0.598\, \text{mol}
$$

Mass of water needed:

$$
0.598\, \text{mol} \times 18.02\, \text{g/mol} \approx 10.77\, \text{g}
$$

If only 12.0 g of calcium is reacted, and assuming excess water is present, then calcium is the limiting reagent if less than 10.77 g of water is available. Conversely, if less water is present, water becomes limiting.

Step 2: Conclusion

In practical situations, knowing the initial amounts of all reactants helps determine which is limiting and how much product can be formed.

Environmental and Industrial Applications

Understanding reactions like calcium with water has real-world significance:

- In construction: Calcium hydroxide (lime) is used in mortar and plaster.
- In environmental chemistry: Calcium compounds help neutralize acidic soils and waters.
- In hydrogen production: Reactions releasing hydrogen gas can be harnessed for energy.

Summary and Key Takeaways

- The reaction of calcium with water produces calcium hydroxide and hydrogen gas, following the molar ratio 1:2.
- The actual yield of calcium hydroxide (5.00 g) is significantly less than the theoretical yield (~22.17

g), indicating lower efficiency.
- Calculations involve converting grams to moles using molar masses and using stoichiometry to relate reactants to products.
- Understanding limiting reactants helps optimize chemical processes and maximize yields.
- Practical applications of calcium hydroxide are widespread in industry and environmental management.

Conclusion

Analyzing the reaction between calcium metal and water not only reinforces fundamental concepts in stoichiometry but also showcases the importance of precise measurements and calculations in chemistry. Recognizing the differences between theoretical and actual yields enables chemists to improve reaction conditions and optimize processes. Whether in industrial production or environmental remediation, mastering these principles ensures efficient and sustainable chemical practices.

Keywords: calcium metal, calcium hydroxide, chemical reaction, stoichiometry, molar mass, limiting reactant, theoretical yield, actual yield, environmental chemistry, industrial applications

Frequently Asked Questions

What is the balanced chemical equation for the reaction between calcium metal and water?

The balanced equation is: Ca (s) + 2 H_2O (l) → $Ca(OH)_2$ (aq) + H_2 (g).

How much calcium hydroxide is expected to be produced from 12.0 g of calcium metal?

Based on the reaction, 12.0 g of calcium produces approximately 5.00 g of $Ca(OH)_2$, as given in the problem.

What is the molar mass of calcium used in these calculations?

The molar mass of calcium (Ca) is approximately 40.08 g/mol.

How do you determine the theoretical yield of calcium hydroxide from the given amount of calcium?

Convert the mass of calcium to moles, then use the molar ratio from the balanced equation to find moles of $Ca(OH)_2$, and convert back to grams.

Why is only 5.00 g of calcium hydroxide produced from 12.0 g of calcium, despite the larger amount of calcium?

The given amount reflects the actual yield or perhaps the limiting reagent's amount; the calculation shows the theoretical yield based on molar ratios.

What is the significance of the molar ratio in this reaction?

The molar ratio (1:2) between calcium and water determines how much calcium hydroxide can be produced per mole of calcium reacted.

How can this reaction be used to determine the purity of calcium metal?

By comparing the actual yield of calcium hydroxide to the theoretical yield calculated from pure calcium, purity can be assessed.

What safety precautions should be taken when reacting calcium with water?

Calcium reacts vigorously with water, releasing hydrogen gas, which is flammable. Conduct the reaction in a well-ventilated area and wear protective gear.

How does temperature affect the reaction of calcium with water?

Higher temperatures can increase the reaction rate, potentially making the reaction more vigorous and releasing hydrogen gas more rapidly.

Additional Resources

When 12.0 G Of Calcium Metal Is Reacted With Water, 5.00 G Of Calcium Hydroxide Is Produced. Using The Principles of Stoichiometry, This Reaction Demonstrates Key Concepts in Chemical Quantities and Reactions.

Understanding the reaction between calcium metal and water is fundamental in chemistry, especially when exploring stoichiometry—the quantitative study of reactants and products in chemical reactions. In this article, we will analyze the process step-by-step, examining how 12.0 grams of calcium metal reacts with water and results in the formation of 5.00 grams of calcium hydroxide. This detailed breakdown will provide insights into the underlying chemical principles, calculations, and implications for real-world applications.

Introduction to the Reaction: Calcium and Water

Calcium (Ca) is an alkaline earth metal known for its reactivity, especially with water. When calcium reacts with water, it forms calcium hydroxide ($Ca(OH)_2$) and hydrogen gas (H_2). The general reaction can be written as:

\[Ca (s) + 2H_2O (l) \rightarrow Ca(OH)_2 (aq) + H_2 (g) \]

This reaction is an example of a single replacement process where calcium displaces hydrogen from water.

The Significance of Quantitative Analysis in Chemical Reactions

Before delving into calculations, it's essential to understand why quantifying reactants and products matters:

- Predicting product amounts: Stoichiometry allows us to determine how much product is formed from given reactants.
- Limiting reactants: Identifying which reactant limits the reaction helps optimize yields.
- Reaction efficiency: Comparing theoretical yields to actual yields assesses the reaction's completeness.

The scenario provided—reacting 12.0 g of calcium with water to produce 5.00 g of calcium hydroxide—serves as a practical case study for these concepts.

Step-by-Step Breakdown of the Reaction

1. Write and Balance the Chemical Equation

The unbalanced reaction:

\[Ca (s) + 2H_2O (l) \rightarrow Ca(OH)_2 (aq) + H_2 (g) \]

This equation is already balanced, with 1 calcium atom, 2 hydrogens from water, and 2 oxygens in calcium hydroxide.

2. Calculate the Molar Masses

Substance	Formula	Molar Mass (g/mol)
Calcium	Ca	40.08
Water	H_2O	18.02
Calcium Hydroxide	$Ca(OH)_2$	74.10
Hydrogen Gas	H_2	2.02

3. Determine Moles of Reactants

a. Moles of calcium:

$$ \text{Moles of Ca} = \frac{\text{Mass of Ca}}{\text{Molar mass of Ca}} = \frac{12.0\,g}{40.08\,g/mol} \approx 0.299\,mol $$

---

4. Calculate Theoretical Yield of Calcium Hydroxide

Based on the balanced equation, 1 mol of calcium produces 1 mol of calcium hydroxide.

$$ \text{Moles of Ca(OH)}_2 = \text{Moles of Ca} \approx 0.299\,mol $$

Mass of calcium hydroxide produced:

$$ \text{Mass} = \text{moles} \times \text{molar mass} = 0.299\,mol \times 74.10\,g/mol \approx 22.16\,g $$

Theoretical maximum yield: approximately 22.16 g of calcium hydroxide.

---

5. Comparing to Actual Yield

The problem states that 5.00 g of calcium hydroxide is produced.

Actual yield: 5.00 g

This discrepancy suggests the reaction did not proceed to completion or some reactant was lost. To understand this better, we analyze the limiting reagent and reaction efficiency.

Determining the Limiting Reagent and Reaction Efficiency

1. Calculate the Moles of Calcium Hydroxide actually formed:

$$ \text{Moles of Ca(OH)}_2 = \frac{5.00\,g}{74.10\,g/mol} \approx 0.0675\,mol $$

2. Find the moles of calcium required for this amount:

Since 1 mol calcium produces 1 mol calcium hydroxide,

$$ \text{Calcium needed} = 0.0675\,mol $$

Comparing this to the initial moles of calcium (0.299 mol), calcium is in excess, and water is likely the limiting reagent.

Analyzing Water as the Limiting Reactant

1. Moles of water reacted:

From the balanced reaction:

$$ 2\,H_2O : 1\,Ca $$

Thus, for 0.0675 mol calcium, amount of water needed:

$$ 2 \times 0.0675\,mol = 0.135\,mol $$

2. Mass of water needed:

$$ 0.135\,mol \times 18.02\,g/mol \approx 2.43\,g $$

3. Is there enough water?

The question doesn’t specify the amount of water initially present, but assuming excess water, the limiting reagent is calcium. If water were limiting, the maximum calcium hydroxide produced would be based on the water amount.

Calculating Reaction Yield and Efficiency

1. Theoretical maximum calcium hydroxide:

Based on initial calcium:

$$ 0.299\,mol \rightarrow 22.16\,g $$

2. Actual yield:

$$ 5.00\,g $$

3. Percent yield:

$$ \frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100 = \frac{5.00}{22.16} \times 100 \approx 22.56\% $$

This indicates the reaction was only about 22.5% efficient under the given conditions.

Practical Implications and Applications

Understanding this reaction's stoichiometry has various real-world applications:

- Material synthesis: Producing calcium hydroxide is vital in construction (e.g., lime mortar), water treatment, and chemical manufacturing.
- Reactant management: Knowing the theoretical yields helps optimize reactant quantities, reducing waste and costs.

- Reaction control: Recognizing limiting reagents ensures reactions are carried out efficiently, maximizing product formation.

Factors Affecting Reaction Yield

Several factors could influence the actual yield in laboratory or industrial settings:

- Purity of reactants: Impurities can slow or inhibit reaction.
- Reaction conditions: Temperature, pressure, and agitation affect reaction rates.
- Incomplete reactions: Kinetic barriers or insufficient reaction time lead to lower yields.
- Loss of product: During separation and purification, some product may be lost.

Summary and Key Takeaways

- Reacting 12.0 g of calcium metal with excess water theoretically produces around 22.16 g of calcium hydroxide.
- The actual production of 5.00 g indicates a reaction efficiency of approximately 22.5%.
- The reaction involves a simple stoichiometric relationship, allowing calculation of reactant and product quantities.
- Understanding limiting reagents and reaction yields is crucial in laboratory and industrial chemistry.

Final Thoughts

This analysis of the reaction between calcium metal and water exemplifies how stoichiometry guides chemists in predicting and controlling product yields. Recognizing the factors that limit reaction efficiency enables better process design, cost savings, and improved material utilization. Whether in research, manufacturing, or education, mastering these principles is fundamental to advancing chemical science and its applications.

Remember: Always verify the initial quantities, reaction conditions, and purity of reactants to accurately interpret yields and optimize chemical processes.

When 12 0 G Of Calcium Metal Is Reacted With Water 5 00 G Of Calcium Hydroxide Is Produced Using The

When 12 0 G Of Calcium Metal Is Reacted With Water 5 00 G Of Calcium Hydroxide Is Produced Using The

Related Articles

- 1) Find The Number Of Units X That Produces A Maximum Revenue R In The Given Equation.R = 66x2/3 4xx=2)
- 7. The Dxy, Dxz, And Dyz Orbitals Are Lower In Energy Than The Dz2 And Dx2 Y2 Orbitals In An Octahedral
- 2. Ang Layunin Ng Isang Travel Brochure AyA Makahikayat B Makapagbigay C. MakahimokD. Makasigurepasagot

Back to Home