28.5 G Of Calcium Carbonate (CaCOn Reacts With An Excess Of Sulfuric Acid(H SOg) To Farm Calcium Sulfate

28.5 G Of Calcium Carbonate ($CaCO_3$) Reacts With An Excess Of Sulfuric Acid (H_2SO_4) To Form Calcium Sulfate

Understanding the chemical reaction between calcium carbonate and sulfuric acid is fundamental in both academic chemistry and industrial applications. When 28.5 grams of calcium carbonate ($CaCO_3$) reacts with an excess of sulfuric acid (H_2SO_4), it produces calcium sulfate ($CaSO_4$), carbon dioxide (CO_2), and water (H_2O). This process exemplifies a typical acid-carbonate reaction, which is crucial in various sectors including manufacturing, environmental science, and chemical engineering.

In this comprehensive guide, we will explore the chemical reaction in detail, including the balanced chemical equation, molar calculations, step-by-step reaction process, and practical applications. Whether you're a chemistry student, educator, or industry professional, understanding this reaction provides valuable insights into carbonate chemistry and acid-base reactions.

Understanding the Reactants

Before delving into the reaction details, it’s essential to understand the chemical nature of the reactants involved.

Calcium Carbonate ($CaCO_3$)

- Chemical Formula: $CaCO_3$
- Common Sources: Limestone, marble, chalk, seashells
- Properties: White, insoluble in water, crystalline solid
- Uses: Building materials, antacids, industrial fillers

Sulfuric Acid (H_2SO_4)

- Chemical Formula: H_2SO_4
- Properties: Colorless, viscous, highly corrosive
- Uses: Fertilizer production, mineral processing, chemical manufacturing

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The Chemical Reaction Between Calcium Carbonate and Sulfuric Acid

Balanced Chemical Equation

The fundamental reaction between calcium carbonate and sulfuric acid can be represented as:

$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + CO_2 + H_2O$

This reaction indicates that one mole of calcium carbonate reacts with one mole of sulfuric acid to produce one mole of calcium sulfate, one mole of carbon dioxide, and one mole of water.

Reaction Type

This is a typical acid–carbonate reaction, characterized by:
- Acid reacting with carbonate to produce a salt, carbon dioxide, and water
- Gas evolution (CO_2) observable as bubbling or effervescence
- Formation of a precipitate (calcium sulfate) if conditions favor its insolubility

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Calculating the Quantity of Reactants and Products

Understanding the quantities involved requires calculating moles based on the given mass of calcium carbonate.

Step 1: Molar Mass of Calcium Carbonate

Calculate the molar mass using atomic weights:
- Calcium (Ca): 40.08 g/mol
- Carbon (C): 12.01 g/mol
- Oxygen (O): 16.00 g/mol

$$
\text{Molar mass of CaCO}_3 = 40.08 + 12.01 + (16.00 \times 3) = 100.09\, \text{g/mol}
$$

Step 2: Determine Moles of Calcium Carbonate

Given mass: 28.5 g

$$
\text{Moles of CaCO}_3 = \frac{28.5\, \text{g}}{100.09\, \text{g/mol}} \approx 0.285\, \text{mol}
$$

Step 3: Moles of Sulfuric Acid Required

From the balanced equation, 1 mol of $CaCO_3$ reacts with 1 mol of H_2SO_4.

$$
\text{Moles of H}_2\text{SO}_4 = 0.285\, \text{mol}
$$

Since the acid is in excess, more than this amount is available, ensuring complete reaction.

Step 4: Quantity of Products Formed

- Calcium sulfate ($CaSO_4$): 0.285 mol
- Carbon dioxide (CO_2): 0.285 mol
- Water (H_2O): 0.285 mol

Calculating the mass of calcium sulfate formed:

- Molar mass of $CaSO_4$:
- Ca: 40.08 g/mol
- S: 32.07 g/mol
- O: 16.00 g/mol × 4 = 64.00 g/mol

$$
\text{Molar mass of CaSO}_4 = 40.08 + 32.07 + 64.00 = 136.15\, \text{g/mol}
$$

Mass of calcium sulfate:

$$
0.285\, \text{mol} \times 136.15\, \text{g/mol} \approx 38.8\, \text{g}
$$

Practical Applications of the Reaction

The reaction between calcium carbonate and sulfuric acid has numerous practical uses across different industries.

1. Production of Gypsum (Calcium Sulfate)

- Construction Material: Gypsum is produced when calcium sulfate is processed and dried.
- Agriculture: Used as a soil conditioner to improve structure and nutrient availability.
- Medical Uses: Plaster of Paris, derived from calcium sulfate, for casts and molds.

2. Acid Neutralization and Waste Treatment

- The reaction is used to neutralize acidic waste streams in industries like mining and manufacturing.

3. Geological and Environmental Studies

- Modeling mineral formation and understanding sulfate mineral deposits.
- Studying limestone dissolution and acid rain effects.

4. Laboratory Demonstrations and Educational Purposes

- Visual demonstration of gas evolution (bubbling) during acid–carbonate reactions.
- Teaching the principles of molar calculations, stoichiometry, and reaction mechanisms.

Safety Considerations

Handling sulfuric acid requires careful safety precautions:
- Wear protective gloves, goggles, and lab coats.
- Work in a well-ventilated area.
- Add acid slowly to water or reactants to prevent splashing.
- Dispose of chemical waste according to proper protocols.

Conclusion

The reaction of 28.5 grams of calcium carbonate with excess sulfuric acid exemplifies a classic acid-base and carbonate reaction, producing calcium sulfate, carbon dioxide, and water. Precise calculations of molar quantities provide insights into the reaction's stoichiometry and yield. This reaction is not only fundamental in understanding chemical principles but also has significant industrial and environmental applications, from manufacturing building materials to waste treatment.

By mastering this reaction, students and professionals can better appreciate the practical uses of chemistry in everyday life and industry, enhancing their understanding of chemical reactions, calculations, and safety protocols.

Frequently Asked Questions

What is the chemical reaction between calcium carbonate and sulfuric acid?

Calcium carbonate reacts with sulfuric acid to produce calcium sulfate, carbon dioxide, and water: $CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + CO_2 + H_2O$.

How much calcium sulfate is formed when 28.5 g of calcium carbonate reacts with excess sulfuric acid?

Moles of $CaCO_3$: 28.5 g / 100.09 g/mol ≈ 0.285 mol. Since the reaction is 1:1, 0.285 mol of $CaSO_4$ is formed, which is approximately 47.9 g (0.285 mol × 172.17 g/mol).

Why is sulfuric acid considered in excess in this reaction?

Using excess sulfuric acid ensures complete reaction of calcium carbonate, maximizing calcium sulfate production and preventing limiting reagent issues.

What are the practical applications of producing calcium sulfate through this reaction?

Calcium sulfate, also known as plaster of Paris, is used in construction, medical casts, agriculture as a soil conditioner, and in food processing.

What safety precautions should be taken when reacting calcium carbonate with sulfuric acid?

Wear protective gloves, goggles, and lab coats; perform the reaction in a well-ventilated area or fume hood; handle sulfuric acid carefully to avoid burns and inhalation of fumes.

Additional Resources

28.5 G Of Calcium Carbonate ($CaCO_3$) Reacts With An Excess Of Sulfuric Acid (H_2SO_4) To Form Calcium Sulfate

In the realm of chemical reactions that underpin both industrial processes and everyday applications, the interaction between calcium carbonate and sulfuric acid stands out as a fundamental example of acid-base chemistry. Specifically, when 28.5 grams of calcium carbonate ($CaCO_3$) reacts with an excess of sulfuric acid (H_2SO_4), the chemical transformation yields calcium sulfate ($CaSO_4$), along with carbon dioxide (CO_2) and water (H_2O). This reaction not only exemplifies key principles of stoichiometry and chemical reactivity but also has practical implications in manufacturing, environmental science, and laboratory analysis.

This article delves into the detailed chemistry behind this reaction, exploring the molecular mechanisms, calculating the quantities involved, and discussing real-world applications and considerations.

Understanding the Reactants: Calcium Carbonate and Sulfuric Acid

Calcium Carbonate ($CaCO_3$): Nature and Properties

Calcium carbonate is a common naturally occurring mineral found in rocks such as limestone, chalk, and marble. It is characterized by its chemical formula $CaCO_3$, consisting of calcium ions (Ca^{2+}) combined with carbonate ions (CO_3^{2-}). It is insoluble in water but reacts readily with acids, making it a vital component in various industrial and biological processes.

Physical properties:
- White, powdery or crystalline solid
- Insoluble in water
- Soluble in acids, forming soluble salts and releasing carbon dioxide

Applications:
- Construction (cement, concrete)
- Agriculture (soil pH adjustment)
- Medical (antacid)
- Industrial manufacturing (calcium carbonate fillers)

Sulfuric Acid (H_2SO_4): A Strong Acid

Sulfuric acid is a highly corrosive, dense, and strong mineral acid used extensively across industries. Its chemical structure features two hydrogen atoms attached to a sulfate ion, making it a potent proton donor in reactions.

Physical properties:
- Colorless, oily liquid
- Highly hygroscopic
- Exothermic when mixed with water

Applications:
- Fertilizer production (e.g., phosphates)
- Mineral processing
- Chemical manufacturing
- Laboratory reagent

The Chemical Reaction: Formation of Calcium Sulfate

Balanced Chemical Equation

When calcium carbonate reacts with sulfuric acid, the chemical equation is:

$$CaCO_3\ (s) + H_2SO_4\ (aq) \rightarrow CaSO_4\ (s) + CO_2\ (g) + H_2O\ (l)$$

This reaction is a typical double displacement (acid-base) reaction where calcium carbonate acts as a base, neutralizing sulfuric acid, resulting in the formation of an insoluble salt—calcium sulfate—and releasing gaseous carbon dioxide along with water.

Reaction Mechanism and Process

The process involves several steps:

1. Protonation of carbonate: The hydrogen ions (H^+) from sulfuric acid protonate the carbonate ion (CO_3^{2-}), leading to the formation of carbonic acid (H_2CO_3), which is unstable and quickly decomposes into CO_2 and H_2O.

2. Precipitation of calcium sulfate: The calcium ions (Ca^{2+}) from calcium carbonate combine with sulfate ions (SO_4^{2-}) from sulfuric acid, forming calcium sulfate ($CaSO_4$), which is relatively insoluble and precipitates out of solution.

3. Gas evolution: The release of CO_2 gas manifests as bubbling or effervescence, which can be observed during the reaction.

This process exemplifies a typical acid-neutralization reaction and highlights the importance of molar relationships in predicting product quantities.

Quantitative Analysis: From Mass of Calcium Carbonate to Products

Calculating Moles of Calcium Carbonate

Given mass of calcium carbonate: 28.5 grams

The molar mass of $CaCO_3$:

- Calcium (Ca): 40.08 g/mol
- Carbon (C): 12.01 g/mol
- Oxygen (O): 16.00 g/mol × 3 = 48.00 g/mol

Total molar mass:

40.08 + 12.01 + 48.00 = 100.09 g/mol

Number of moles:

n = mass / molar mass = 28.5 g / 100.09 g/mol ≈ 0.285 mol

Stoichiometric Relationship and Product Formation

According to the balanced equation, the molar ratio of $CaCO_3$ to $CaSO_4$ is 1:1. Therefore, 0.285 mol of calcium carbonate will produce 0.285 mol of calcium sulfate.

Mass of calcium sulfate formed:

- Molar mass of $CaSO_4$:

- Calcium: 40.08 g/mol
- Sulfur: 32.07 g/mol
- Oxygen: 16.00 g/mol × 4 = 64.00 g/mol

Total: 40.08 + 32.07 + 64.00 = 136.15 g/mol

- Mass:

0.285 mol × 136.15 g/mol ≈ 38.8 grams

Gas evolved (CO_2):

- Molar mass of CO_2:

- Carbon: 12.01 g/mol
- Oxygen: 16.00 g/mol × 2 = 32.00 g/mol

Total: 12.01 + 32.00 = 44.01 g/mol

- Mass of CO_2:

0.285 mol × 44.01 g/mol ≈ 12.5 grams

This quantitative breakdown demonstrates how starting with 28.5 g of calcium carbonate leads to approximately 38.8 g of calcium sulfate and 12.5 g of carbon dioxide gas produced.

Extent of Reaction and Excess Acid

The calculation assumes complete reaction with no limiting reagent, and that sulfuric acid is in excess. In practical scenarios, the amount of sulfuric acid needed can be precisely calculated based on the moles of calcium carbonate:

- Moles of sulfuric acid required:

Since the molar ratio is 1:1,

0.285 mol H_2SO_4 needed

- Corresponding mass of sulfuric acid:

- Molar mass of H_2SO_4:

2(1.008) + 32.07 + 4(16.00) = 98.08 g/mol

- Mass:

0.285 mol × 98.08 g/mol ≈ 27.94 grams

Using excess sulfuric acid ensures complete reaction, which is typical in industrial processes.

Industrial and Practical Implications

Production of Calcium Sulfate (Gypsum)

Calcium sulfate, the product of this reaction, is widely used in manufacturing materials such as:

- Plaster of Paris: Produced by dehydrating gypsum ($CaSO_4 \cdot 2H_2O$)
- Construction materials: Drywall, cement additives
- Medical applications: Bone repair and dental products

The process of reacting calcium carbonate with sulfuric acid is a key step in manufacturing some of these materials, especially when calcium sulfate is derived from natural mineral sources or waste streams.

Environmental Considerations

The reaction releases CO_2, a greenhouse gas contributing to global warming. Managing CO_2 emissions is crucial when scaling this process industrially. Additionally, handling sulfuric acid requires safety protocols owing to its corrosive nature.

Laboratory and Educational Contexts

In educational settings, this reaction serves as a practical demonstration of acid–base reactions, gas evolution, and stoichiometry. It helps students visually grasp concepts like molar ratios and reaction yields.

Safety and Handling Precautions

- Sulfuric acid: Highly corrosive; handle with gloves, goggles, and proper ventilation
- Carbon dioxide: Gaseous byproduct; ensure adequate ventilation to prevent accumulation
- Calcium carbonate: Generally safe, but dust inhalation should be avoided

In industrial or laboratory environments, proper disposal and neutralization procedures must be followed to prevent environmental contamination.

Conclusion: Significance of the Reaction

The reaction between 28.5 grams of calcium carbonate and excess sulfuric acid exemplifies a fundamental chemical process with widespread industrial applications. It showcases how stoichiometry allows precise prediction of product amounts, highlights the importance of reaction conditions, and underscores the relevance of such reactions in manufacturing, environmental management, and scientific education.

Understanding this reaction not only deepens comprehension of acid-base chemistry but also illustrates how simple chemical principles are integral to complex real-world systems. From producing construction materials to analyzing environmental impacts, the reaction of calcium carbonate with sulfuric acid remains a cornerstone in both theoretical and applied chemistry.

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