200 G Of 90% Pure CaCO3 Is Completely Reacted With Excess HCI To Produce CaCl2, H2O And CO2. A. Which

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Understanding chemical reactions involving calcium carbonate ($CaCO_3$) and hydrochloric acid (HCl) is fundamental in both industrial applications and laboratory procedures. When 200 grams of 90% pure calcium carbonate reacts with excess hydrochloric acid, it produces calcium chloride ($CaCl_2$), water (H_2O), and carbon dioxide (CO_2). This article offers an in-depth exploration of this reaction, covering the stoichiometry involved, the chemical principles, and practical applications. Whether you're a student preparing for exams or a professional in chemical industries, understanding this reaction is essential for grasping core concepts in acid-base chemistry and reaction mechanisms.

Understanding the Components Involved

Before delving into the reaction specifics, it's important to understand the nature of the reactants and products.

Calcium Carbonate ($CaCO_3$)

- Chemical Formula: $CaCO_3$
- Properties: A common white solid found in limestone, marble, and chalk.
- Purity: The problem specifies 90% purity, meaning 90% of the mass is pure $CaCO_3$, with impurities making up the remaining 10%.

Hydrochloric Acid (HCl)

- Chemical Formula: HCl
- Properties: A strong acid that readily reacts with carbonate compounds.
- Excess HCl: The reaction involves excess HCl, ensuring complete reaction of $CaCO_3$.

Products of the Reaction

- Calcium Chloride ($CaCl_2$): An ionic compound used in various industrial applications.
- Water (H_2O): A common byproduct.
- Carbon Dioxide (CO_2): A gas released during the reaction.

Step-by-Step Analysis of the Reaction

The core reaction can be summarized as:

$$ \text{CaCO}_3 + 2 \text{HCl} \rightarrow \text{CaCl}_2 + \text{H}_2\text{O} + \text{CO}_2 $$

This reaction is a typical acid-carbonate reaction, characterized by the release of CO_2 gas.

Key Aspects of the Reaction

- Stoichiometry: The molar ratio of reactants and products.
- Complete Reaction: Ensured by using excess HCl.
- Reaction Conditions: Usually occurs at room temperature, but can be accelerated with heat.

Calculating the Moles of $CaCO_3$ in 200 g of 90% Pure Sample

The first step involves determining how many moles of $CaCO_3$ are present in the given sample, accounting for purity.

Step 1: Adjust for purity

- Mass of pure $CaCO_3$:

$$
\text{Mass of pure CaCO}_3 = \text{Total mass} \times \text{Purity}
$$

$$
= 200\, \text{g} \times 0.90 = 180\, \text{g}
$$

Step 2: Calculate moles of $CaCO_3$

- Molar mass of $CaCO_3$:

\[

$$
\text{Ca} = 40.08\, \text{g/mol}
$$

$$
\text{C} = 12.01\, \text{g/mol}
$$

$$
\text{O}_3 = 3 \times 16.00\, \text{g/mol} = 48.00\, \text{g/mol}
$$

$$
\text{Total} = 40.08 + 12.01 + 48.00 = 100.09\, \text{g/mol}
$$

- Number of moles:

$$
n_{CaCO_3} = \frac{180\, \text{g}}{100.09\, \text{g/mol}} \approx 1.798\, \text{mol}
$$

Determining the Amount of HCl Required

The reaction shows that 1 mole of $CaCO_3$ reacts with 2 moles of HCl.

Step 1: Moles of HCl needed for complete reaction

$$
n_{HCl} = 2 \times n_{CaCO_3} = 2 \times 1.798 \approx 3.596\, \text{mol}
$$

Step 2: Volume of HCl solution (if concentration is known)

- If hydrochloric acid concentration is given (say 1 M), then:

$$
V_{HCl} = \frac{n_{HCl}}{C_{HCl}} = \frac{3.596\, \text{mol}}{1\, \text{mol/L}} = 3.596\, \text{L}
$$

- Since the problem states excess HCl, the actual volume used would be higher, but the molar amount needed remains 3.596 mol.

Products Formation and Yield Calculation

Having established the amount of $CaCO_3$ involved, it’s important to analyze the production of products.

Calcium Chloride ($CaCl_2$)

- Moles produced: Equal to the moles of $CaCO_3$ reacted, which is approximately 1.798 mol.
- Mass of $CaCl_2$ produced:

$$
\text{Molar mass of CaCl}_2 = 40.08 + 2 \times 35.45 = 110.98\, \text{g/mol}
$$

$$
\text{Mass} = 1.798\, \text{mol} \times 110.98\, \text{g/mol} \approx 199.5\, \text{g}
$$

Water (H_2O)

- Moles: Same as $CaCl_2$, 1.798 mol.
- Mass:

$$
\text{Molar mass of H}_2\text{O} = 18.02\, \text{g/mol}
$$

$$
\text{Mass} = 1.798\, \text{mol} \times 18.02\, \text{g/mol} \approx 32.4\, \text{g}
$$

Carbon Dioxide (CO_2)

- Moles: Same as $CaCO_3$, 1.798 mol.
- Mass:

$$
\text{Molar mass of CO}_2 = 44.01\, \text{g/mol}
$$

$$
\text{Mass} = 1.798\, \text{mol} \times 44.01\, \text{g/mol} \approx 79.1\, \text{g}
$$

- Volume of CO_2 (at standard conditions):

Using the molar volume of gas at STP (~22.4 L/mol):

$$
V_{CO_2} = 1.798\, \text{mol} \times 22.4\, \text{L/mol} \approx 40.3\, \text{L}
$$

Practical Applications of the Reaction

This reaction has multiple industrial and environmental applications, including:

- **Production of Calcium Chloride:** Used in de-icing, dust control, and as a food additive.
- **Carbon Dioxide Generation:** CO_2 is used in carbonated beverages, fire extinguishers, and as a refrigerant.
- **Extraction and Purification Processes:** Understanding this reaction aids in mineral processing and waste treatment.

Environmental Considerations and Safety

While the reaction is straightforward, safety precautions are necessary:

- Handling acids: Hydrochloric acid is corrosive; proper PPE and ventilation are essential.
- Gas Venting: CO_2 is non-toxic but can displace oxygen; proper ventilation prevents suffocation risks.
- Waste Management: Disposal of calcium chloride solutions must follow environmental regulations.

Summary and Key Takeaways

In this detailed exploration, we analyzed the complete reaction of 200 grams of 90% pure calcium carbonate with excess hydrochloric acid. The critical points include:

- Mass and molar calculations based on purity.
- Stoichiometric ratios guiding the amount of reactants and products.
- Quantitative yields of CaCl2, H2O, and CO2.
- Industrial relevance of the reaction products.
- Environmental and safety considerations when performing such reactions.

Understanding these principles is fundamental for chemists working in mineral processing, manufacturing, and environmental science. The reaction not only exemplifies classic acid-base chemistry but also highlights the importance of stoichiometry in practical applications.

By mastering the calculations and concepts discussed here, you will be well-equipped to handle similar reactions involving calcium

Frequently Asked Questions

What is the balanced chemical equation for the reaction between calcium carbonate ($CaCO_3$) and hydrochloric acid (HCl)?

The balanced chemical equation is $CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$.

How do you determine the amount of calcium carbonate ($CaCO_3$) in grams when given 200 g of 90% pure $CaCO_3$?

You multiply the total weight by the purity percentage: 200 g × 0.90 = 180 g of pure $CaCO_3$.

What is the molar mass of calcium carbonate ($CaCO_3$)?

The molar mass of $CaCO_3$ is approximately 100.09 g/mol.

How many moles of $CaCO_3$ are present in 180 g of pure $CaCO_3$?

Number of moles = mass / molar mass = 180 g / 100.09 g/mol ≈ 1.80 mol.

How much HCl is required to completely react with 1.80 mol of $CaCO_3$?

From the balanced equation, 1 mol of $CaCO_3$ reacts with 2 mol of HCl, so HCl needed = 1.80 mol × 2 = 3.60 mol. Since molar mass of HCl is about 36.46 g/mol, HCl required = 3.60 mol × 36.46 g/mol ≈ 131.26 g.

What are the products formed when $CaCO_3$ reacts with excess HCl?

The products are calcium chloride ($CaCl_2$), water (H_2O), and carbon dioxide (CO_2).

How can the amount of calcium chloride ($CaCl_2$) produced be calculated from the initial amount of $CaCO_3$?

Since the molar ratio of $CaCO_3$ to $CaCl_2$ is 1:1, 1.80 mol of $CaCO_3$ produces 1.80 mol of $CaCl_2$. The mass of $CaCl_2$ = moles × molar mass (110.98 g/mol) ≈ 1.80 mol × 110.98 g/mol ≈ 199.76 g.

Additional Resources

200 G Of 90% Pure CaCO3 Is Completely Reacted With Excess HCl To Produce CaCl2, H2O And CO2. A. Which

Introduction

Calcium carbonate ($CaCO_3$) is a widely encountered compound in natural and industrial contexts, primarily occurring as limestone, marble, and chalk. Its chemical reactivity with acids makes it an essential component in various manufacturing processes, environmental applications, and laboratory experiments. When calcium carbonate reacts with hydrochloric acid (HCl), it produces calcium chloride ($CaCl_2$), water (H_2O), and carbon dioxide (CO_2). This reaction exemplifies a classic acid-base reaction involving a carbonate salt and an acid, leading to gaseous and aqueous products.

In this article, we analyze a specific scenario: 200 grams of 90% pure calcium carbonate reacts completely with excess HCl. The goal is to understand the stoichiometry, the amount of products formed, and the implications of purity on the reaction. The discussion will cover the chemical principles involved, detailed calculations, and practical considerations, providing a comprehensive overview suitable for students, educators, and professionals alike.

Understanding the Reaction: Chemical Equation and Principles

1. The Core Reaction

The fundamental chemical reaction between calcium carbonate and hydrochloric acid is represented as:

$CaCO_3$ (s) + 2 HCl (aq) → $CaCl_2$ (aq) + H_2O (l) + CO_2 (g)

This balanced equation indicates that one mole of calcium carbonate reacts with two moles of hydrochloric acid to produce one mole each of calcium chloride and carbon dioxide, along with water.

2. Stoichiometry and Molar Ratios

The molar ratio from the balanced equation is:

- $CaCO_3$: HCl = 1 : 2
- $CaCO_3$: $CaCl_2$ = 1 : 1
- $CaCO_3$: CO_2 = 1 : 1

This ratio is crucial for calculating the amount of reactants needed and the quantities of products formed.

3. Purity Considerations

Given that the starting calcium carbonate is 90% pure, only 90% of the 200 grams is actual $CaCO_3$:

Pure $CaCO_3$ mass = 200 g × 0.90 = 180 g

The remaining 20 g is impurities, which do not participate in the reaction but impact calculations and yield assessments.

Calculations: Quantitative Analysis

1. Moles of Calcium Carbonate

- Molecular weight of $CaCO_3$:
Ca (40.08 g/mol) + C (12.01 g/mol) + 3×O (3×16.00 g/mol) = 100.09 g/mol

- Moles of $CaCO_3$:
Moles = mass / molar mass = 180 g / 100.09 g/mol ≈ 1.799 mol

This is the amount of calcium carbonate available for reaction.

2. Moles of Hydrochloric Acid Needed

- From the stoichiometry:
1 mol $CaCO_3$ reacts with 2 mol HCl

- Total moles of HCl required:
1.799 mol × 2 = 3.598 mol

Since HCl is in excess, the actual amount used will be more than this, ensuring complete reaction.

3. Mass of HCl Required

- Molecular weight of HCl:
H (1.008 g/mol) + Cl (35.45 g/mol) = 36.458 g/mol

- Mass of HCl needed:
3.598 mol × 36.458 g/mol ≈ 131.2 g

In practical applications, an excess—say 10-20%—is used to ensure complete reaction. For example, using 150 g of HCl would be sufficient.

4. Products Formed

- Calcium chloride ($CaCl_2$):

- Molar mass of $CaCl_2$:
Ca (40.08 g/mol) + 2×Cl (2×35.45 g/mol) = 110.98 g/mol

- Moles of $CaCl_2$ produced:
1.799 mol (from stoichiometry)

- Mass of $CaCl_2$:
1.799 mol × 110.98 g/mol ≈ 199.8 g

- Carbon dioxide (CO_2):

- Molar mass of CO_2:
C (12.01 g/mol) + 2×O (2×16.00 g/mol) = 44.01 g/mol

- Moles of CO_2 released:
1.799 mol

- Mass of CO_2:
1.799 mol × 44.01 g/mol ≈ 79.1 g

- Water (H_2O):

- Molar mass of H_2O:
$2 \times H (2 \times 1.008 g/mol) + O (16.00 g/mol) = 18.016 g/mol$

- Moles of H_2O:
1.799 mol

- Mass of H_2O:
$1.799 mol \times 18.016 g/mol \approx 32.4 g$

These calculations assume complete reaction and no side reactions or losses.

Impact of Purity and Practical Considerations

1. Effect of Impurities

The 10% impurities in the initial $CaCO_3$ mean that not all the mass is reactive. This affects yield calculations and process efficiency. Impurities may include other carbonates, silicates, or inert materials, which do not react with HCl and can influence the physical handling of the reactants.

Practically, the actual amount of $CaCO_3$ reacting is 180 g, as calculated, but the remaining 20 g of impurities do not contribute to the reaction, potentially diluting the product and complicating purification.

2. Reaction Conditions and Efficiency

- Excess HCl: Using an excess ensures complete reaction but requires proper handling and disposal considerations due to acid excess and gaseous byproducts.

- Reaction Environment: Temperature, agitation, and concentration influence reaction rate and completeness.

- Gas Evolution: CO_2 release can cause pressure buildup; appropriate venting or containment is necessary.

3. Purification and Yield

Post-reaction, calcium chloride can be separated via filtration, evaporation, or crystallization. The theoretical yield is approximately 199.8 g of $CaCl_2$, but actual yields may vary due to losses, incomplete reactions, or impurities.

Environmental and Industrial Significance

1. Industrial Applications

The reaction of $CaCO_3$ with HCl is fundamental in producing calcium chloride, used in de-icing, dust control, and as a food additive. It also plays a role in the manufacturing of other calcium compounds.

2. Environmental Impacts

- Carbon Capture: The release of CO_2 adds to greenhouse gases, but understanding this reaction helps in designing processes to minimize emissions.

- Waste Management: Handling of residual impurities and byproducts is vital to prevent environmental contamination.

Conclusion

The complete reaction of 200 grams of 90% pure calcium carbonate with excess hydrochloric acid exemplifies fundamental principles of chemical stoichiometry, purity considerations, and practical applications. Calculations reveal that approximately 1.799 moles of $CaCO_3$ are involved, leading to the formation of roughly 199.8 grams of calcium chloride, 79.1 grams of carbon dioxide, and 32.4 grams of water, assuming ideal conditions.

Understanding the precise quantities, the effects of impurity, and the reaction conditions is crucial for optimizing industrial processes, ensuring safety, and minimizing environmental impact. This scenario highlights the importance of chemical calculations in real-world applications and the need for careful planning and management in chemical manufacturing and environmental stewardship.

References

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- House, J. E. (2007). Fundamentals of Chemical Engineering Thermodynamics. Prentice Hall.

- Laboratory manuals and safety guidelines for handling acids and gases.

Note: All calculations are based on ideal scenarios. Actual laboratory or industrial conditions may require adjustments for efficiency, safety, and environmental compliance.

200 G Of 90 Pure Caco3 Is Completely Reacted With Excess Hci To Produce Cacl2 H2o And Co2 A Which

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