A Chloride Of Silicon Contains 79. 1 Mass % Cl. What Is The Empirical Formula Of The Chloride?.

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Understanding the composition of chemical compounds is fundamental in chemistry, particularly when determining their empirical formulas. In this article, we will explore how to determine the empirical formula of a silicon chloride given that it contains 79.1% chlorine by mass. By analyzing this problem step-by-step, we will demonstrate the process of converting mass percentages into a simple, whole-number ratio of atoms, which defines the empirical formula.

What Is an Empirical Formula?

Definition and Significance

An empirical formula represents the simplest whole-number ratio of atoms of each element in a compound. Unlike the molecular formula, which specifies the actual number of atoms in a molecule, the empirical formula provides the most reduced ratio, offering insight into the compound's fundamental composition.

For example, the empirical formula for benzene (C_6H_6) is CH, since the ratio of carbon to hydrogen is 1:1, despite the molecular formula being C_6H_6.

Why Is It Important?

Determining the empirical formula is a crucial step in understanding the chemical composition of a compound, especially when experimental data such as mass percentages are available. It helps chemists:

- Identify unknown compounds
- Calculate molecular formulas if molar mass is known
- Understand the relative proportions of elements within a compound

Given Data and Objective

The problem states that a silicon chloride contains 79.1% chlorine by mass. The goal is to determine its empirical formula.

Key Data:
- Mass % of Cl: 79.1%
- Remaining mass % (assumed to be silicon): 100% - 79.1% = 20.9%

Objective:
- Find the simplest whole-number ratio of silicon (Si) to chlorine (Cl) atoms in the compound.

Step-by-Step Approach to Find the Empirical Formula

Step 1: Convert Percentages to Masses

Assuming a 100-gram sample simplifies calculations:

- Mass of silicon (Si): 20.9 grams
- Mass of chlorine (Cl): 79.1 grams

Step 2: Convert Masses to Moles

Use atomic masses:
- Silicon (Si): approximately 28.0855 g/mol
- Chlorine (Cl): approximately 35.453 g/mol

Calculate moles:

- Moles of Si:

  $$\frac{20.9\, \text{g}}{28.0855\, \text{g/mol}} \approx 0.744\, \text{mol}$$

- Moles of Cl:

  $$\frac{79.1\, \text{g}}{35.453\, \text{g/mol}} \approx 2.231\, \text{mol}$$

Step 3: Determine the Mole Ratio

Divide each by the smallest number of moles to find the simplest ratio:

- For Si: $\frac{0.744}{0.744} = 1$
- For Cl: $\frac{2.231}{0.744} \approx 3$

This yields a ratio of approximately 1:3 for Si:Cl.

Step 4: Write the Empirical Formula

Based on the mole ratio:

- Silicon: 1 atom
- Chlorine: 3 atoms

Empirical formula: $SiCl_3$

Conclusion: The Empirical Formula of the Silicon Chloride

By analyzing the mass percentages and converting them into mole ratios, we find that the empirical formula of the chloride containing 79.1% chlorine by mass is $SiCl_3$. This indicates that each silicon atom is bonded to three chlorine atoms in the simplest ratio.

Additional Insights and Applications

Understanding the empirical formula of silicon chlorides is essential in various fields, including materials science, inorganic chemistry, and industrial manufacturing.

Common Silicon Chlorides

- Silicon tetrachloride ($SiCl_4$): Used in the production of high purity silicon and in optical fibers.
- Silicon trichloride ($SiCl_3$): As determined, has an empirical formula of $SiCl_3$, often used as an intermediate in chemical synthesis.

Implications of the Empirical Formula

Knowing the empirical formula helps chemists:

- Predict physical and chemical properties
- Understand reactivity patterns
- Design synthesis routes for desired compounds

Summary

- The problem involves calculating the empirical formula of a silicon chloride with 79.1% chlorine.
- Assumptions of a 100 g sample simplify the calculations.
- Conversion of mass to moles and dividing by the smallest molar quantity reveals the mole ratio.
- The resulting empirical formula is $SiCl_3$, indicating a 1:3 ratio of silicon to chlorine atoms.

Final Thoughts

Determining the empirical formula from mass percentages is a fundamental skill in chemistry, combining concepts of molar mass, mole ratios, and simple ratios. Whether you're analyzing laboratory data or studying chemical compounds, mastering this process enables a deeper understanding of chemical compositions and molecular structures.

Remember: Always verify your calculations and consider experimental uncertainties when applicable. This systematic approach provides a reliable pathway to uncovering the basic composition of chemical substances.

Frequently Asked Questions

How do you determine the empirical formula of a compound when given the percentage composition by mass?

To find the empirical formula, convert the mass percentages to moles by dividing each by the atomic mass, then find the simplest whole number ratio of these moles. This ratio gives the subscripts in the empirical formula.

Given that a chloride of silicon contains 79.1% Cl by mass, how do you find the percentage of silicon in the compound?

Subtract the mass percentage of chlorine from 100%. So, silicon's percentage is 100% - 79.1% = 20.9%.

What are the atomic masses of silicon and chlorine used in calculating the empirical formula?

The atomic mass of silicon (Si) is approximately 28.09 g/mol, and that of chlorine (Cl) is approximately 35.45 g/mol.

How do you convert mass percentages to mole ratios for the elements in the compound?

Divide each element's mass percentage by its atomic mass to determine the number of moles. Then, divide these values by the smallest number of moles to find the simplest whole number ratio.

What is the empirical formula of a silicon chloride compound containing 79.1% Cl by mass?

The empirical formula is $SiCl_4$. This is determined by calculating the mole ratio of silicon to chlorine, which is 1:4 based on the percentage composition.

Additional Resources

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Introduction

The question of determining the empirical formula of a compound based on its elemental composition is foundational in inorganic chemistry. In the case of a chloride of silicon with a specified mass percentage of chlorine, the task involves translating this percentage into a simple, whole-number ratio of silicon to chlorine atoms. This problem not only tests fundamental concepts of stoichiometry but also highlights the critical importance of empirical formulas in understanding chemical composition, reactivity, and classification of compounds.

In this article, we undertake a comprehensive investigation into the process of deriving the empirical formula of a silicon chloride compound that contains 79.1% chlorine by mass. We explore the methodological steps, underlying principles, potential pitfalls, and broader implications of such an analysis, providing a detailed roadmap for students, educators, and researchers alike.

Background: Significance of Empirical Formulas in Chemistry

Empirical formulas serve as the simplest whole-number ratio representation of elements within a compound. Unlike molecular formulas, which specify the exact number of atoms per molecule, empirical formulas focus solely on the ratio. For inorganic compounds like silicon chlorides, empirical formulas are fundamental for:

- Classifying compounds (e.g., halides, oxides, sulfides)
- Predicting properties such as solubility, melting points, and reactivity
- Interpreting spectroscopic data
- Guiding synthesis and characterization efforts

Given the importance of empirical formulas, accurately deducing them from elemental percentages forms a core competency in chemical analysis.

Analyzing the Composition: The Given Data

The problem states:

> A chloride of silicon contains 79.1% Cl by mass.

This implies that in 100 grams of the compound:

- Chlorine (Cl) mass = 79.1 grams
- Silicon (Si) mass = 20.9 grams (since 100 - 79.1 = 20.9 grams)

The goal is to determine the empirical formula, i.e., the simplest whole-number ratio of Si to Cl

atoms consistent with this composition.

Methodology: Step-by-Step Determination

Step 1: Convert Masses to Moles

The first step involves converting the mass of each element to moles using their atomic masses:

Element	Atomic Mass (g/mol)	Mass in 100 g sample	Moles
Silicon (Si)	28.085 g/mol	20.9 g	20.9 / 28.085 ≈ 0.744 mol
Chlorine (Cl)	35.453 g/mol	79.1 g	79.1 / 35.453 ≈ 2.231 mol

Step 2: Determine the Mole Ratio

Next, divide both molar quantities by the smaller value to find the simplest ratio:

- Si: 0.744 / 0.744 = 1
- Cl: 2.231 / 0.744 ≈ 3.00

The ratios approximate to:

- Si : 1
- Cl : 3

which suggests a formula with one silicon atom for every three chlorine atoms.

Step 3: Express as Whole Numbers

Since ratios are close to whole numbers, the empirical formula is likely $SiCl_3$.

Validation: Confirming the Empirical Formula

To ensure the proposed empirical formula aligns with the mass percentage, reverse calculations are performed:

- Molar mass of $SiCl_3$:

Si: 28.085 g/mol
Cl_3: 3 × 35.453 = 106.359 g/mol

Total: 28.085 + 106.359 ≈ 134.444 g/mol

- Percentage of Cl:

(106.359 / 134.444) × 100 ≈ 79.1%

This precisely matches the given data, confirming $SiCl_3$ as the empirical formula.

Broader Context: Silicon Chlorides and Their Variants

While the empirical formula is $SiCl_3$, understanding where this compound fits in the family of silicon chlorides is essential.

Known Silicon Chlorides:

- Silicon Tetrachloride ($SiCl_4$): The most common silicon chloride, with 100% Cl by mass.
- Silicon Trichloride ($SiCl_3$): The compound deduced here, with 79.1% Cl.
- Other Variants: $SiCl_2$, SiCl, etc., are less common and typically less stable or less relevant.

The empirical formula $SiCl_3$ corresponds to silicon trichloride, a well-documented compound known for its reactivity and utility in chemical synthesis, particularly in the production of high-purity silicon and in organic synthesis as a chlorinating agent.

Implications of the Empirical Formula

Understanding that the compound's empirical formula is $SiCl_3$ has several implications:

- Chemical Reactivity: Silicon trichloride readily hydrolyzes in water to produce silicic acid and hydrochloric acid.
- Industrial Use: It serves as a precursor in the manufacture of silicon-based materials.
- Spectroscopic Features: The ratio influences IR and NMR spectral characteristics, aiding in identification.

Considerations and Limitations

While the calculation yields a clear empirical formula, several factors merit discussion:

- Purity of the Sample: Impurities could alter the percentage composition.
- Molecular vs. Empirical Formulas: The empirical formula does not specify molecular structure or size; $SiCl_3$ units could exist in complexes or polymers.
- Stability and Existence: Silicon trichloride is stable under specific conditions but can hydrolyze readily, affecting its practical handling.

Concluding Remarks

The investigation into the empirical formula of the chloride of silicon with 79.1% chlorine underscores the power of stoichiometric analysis in inorganic chemistry. By converting mass percentages to molar ratios, the simplest whole-number ratio of silicon to chlorine atoms is deduced to be 1:3, leading to the empirical formula $SiCl_3$.

This analysis not only clarifies the composition of a specific silicon chloride but also exemplifies a broader methodological approach applicable across inorganic compound analysis. As chemistry continues to evolve, foundational skills like these remain critical in understanding, designing, and utilizing chemical compounds in research and industry.

References

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Note: The detailed calculations and reasoning presented here serve as a comprehensive guide for understanding how empirical formulas are derived from elemental composition data.

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