

44) A Compound Containing Chromium And Silicon Contains 73.52 Mass Percent Chromium. Determine Its Empirical

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Understanding the composition of chemical compounds is fundamental in chemistry, especially when analyzing complex mixtures or designing new materials. In this article, we will explore how to determine the empirical formula of a compound containing chromium and silicon, given that it contains 73.52% chromium by mass. This process involves converting mass percentages into mole ratios, which provides insights into the simplest whole-number ratio of elements in the compound. Let's dive into the step-by-step procedure to find the empirical formula and gain a deeper understanding of the compound's composition.

Understanding the Problem

Before proceeding with calculations, it's essential to understand what information is provided and what is being asked.

Given Data:

- Mass Percent of Chromium (Cr): 73.52%
- Mass Percent of Silicon (Si): $100\% - 73.52\% = 26.48\%$

Objective:

- Determine the empirical formula of the compound containing chromium and silicon.

This involves converting the given percentages into molar ratios, which then allows us to identify the simplest whole-number ratio of Cr to Si in the compound.

Step-by-Step Calculation Process

The calculation of the empirical formula involves several systematic steps:

1. Assume a Sample Size

To simplify calculations, assume a 100-gram sample of the compound. This makes the percentages directly convertible into grams:

- Mass of Cr = 73.52 grams
- Mass of Si = 26.48 grams

2. Convert Masses to Moles

Using atomic weights (approximate values):

- Chromium (Cr): 52.00 g/mol
- Silicon (Si): 28.09 g/mol

Calculate moles:

1. Moles of Cr = $73.52 \text{ g} / 52.00 \text{ g/mol} \approx 1.415 \text{ mol}$
2. Moles of Si = $26.48 \text{ g} / 28.09 \text{ g/mol} \approx 0.943 \text{ mol}$

3. Determine the Mole Ratio

Divide each mole quantity by the smaller number to find the simplest ratio:

- Cr: $1.415 \text{ mol} / 0.943 \text{ mol} \approx 1.50$
- Si: $0.943 \text{ mol} / 0.943 \text{ mol} = 1$

This yields an approximate ratio of:

- Cr : Si $\approx$ 1.50 : 1

4. Convert to Whole Numbers

Since ratios should be whole numbers, multiply both by 2:

- Cr: $1.50 \times 2 = 3$
- Si: $1 \times 2 = 2$

Therefore, the empirical formula is Cr₃Si₂.

Final Empirical Formula and Interpretation

The empirical formula of the compound based on the calculations is Cr₃Si₂. This indicates that in the simplest form, the compound contains three atoms of chromium for every two atoms of silicon.

Implications of the Empirical Formula

- **Stoichiometry:** The ratio suggests a stable ratio of elements, which can influence the physical properties of the compound.
- **Material Design:** Understanding this ratio is essential when synthesizing materials like alloys or semiconductors involving chromium and silicon.
- **Further Analysis:** The empirical formula provides a basis for determining the molecular formula if molar mass is known.

Additional Considerations in Empirical Formula Calculation

While the above steps are standard, there are some nuances and additional considerations to keep in mind:

1. Accuracy of Atomic Weights

Atomic weights are averages and can vary slightly depending on isotopic

distributions, but for most calculations, standard atomic weights are sufficient.

2. Purity of the Sample

The calculations assume the sample is pure. Impurities can skew the mass percentages and lead to inaccurate empirical formulas.

3. Extending to Molecular Formula

Once the empirical formula is determined, the molecular formula can be found if the molar mass of the compound is known by comparing the molar mass to that of the empirical formula.

Conclusion

Determining the empirical formula of a compound containing chromium and silicon with 73.52% chromium involves a systematic approach of converting mass percentages into moles, establishing the simplest mole ratio, and translating that ratio into whole numbers. The process highlights the importance of mole calculations in understanding a compound's fundamental composition. For this particular compound, the empirical formula of Cr_3Si_2 provides valuable insight into its atomic structure, which can be used in further chemical analysis, material synthesis, and property prediction.

By mastering these steps, chemists can accurately analyze and interpret the composition of complex compounds, advancing research and development across various fields, including materials science, metallurgy, and semiconductor technology.

Frequently Asked Questions

How do you determine the empirical formula of a compound containing chromium and silicon with 73.52% chromium by mass?

First, convert the mass percentages to moles by dividing each by their atomic masses (Cr: 52.00 g/mol, Si: 28.09 g/mol). Then, find the mole ratio by dividing each by the smallest number of moles. The resulting ratio gives the empirical formula subscripts.

What is the step-by-step method to find the empirical formula of a compound with 73.52% chromium and the remaining percentage silicon?

Step 1: Assume a 100 g sample, so 73.52 g Cr and 26.48 g Si. Step 2: Convert to moles: $\text{Cr} = 73.52/52.00$, $\text{Si} = 26.48/28.09$. Step 3: Divide both by the smaller number of moles to find the ratio. Step 4: Write the empirical formula based on the simplest whole-number ratio.

Given the mass percent of chromium in a compound, how do you calculate the empirical formula involving silicon?

Convert the mass percentages to moles for each element, then find the ratio of these moles to determine the smallest whole numbers that define the empirical formula.

Why is it important to convert mass percentages to moles when determining the empirical formula of a compound?

Because the empirical formula reflects the ratio of atoms in a compound, which is best represented by the ratio of moles, not just mass, enabling accurate determination of the simplest whole-number ratio.

What is the empirical formula of a compound that contains 73.52% chromium by mass and 26.48% silicon?

The empirical formula is Cr_3Si , based on the mole ratio calculations: Cr ($73.52/52.00 \approx 1.416$), Si ($26.48/28.09 \approx 0.943$). Dividing both by the smaller (≈ 0.943), we get approximately $\text{Cr}_{1.5}\text{Si}$. Multiplying all ratios by 2 yields Cr_3Si .

Additional Resources

Understanding the Empirical Formula of a Chromium-Silicon Compound with 73.52% Chromium

Determining the empirical formula of a chemical compound is a foundational step in understanding its composition and structure. When dealing with a compound that contains both chromium (Cr) and silicon (Si), especially with a specified mass percentage of chromium, the process involves meticulous calculations grounded in basic principles of chemistry and stoichiometry. In this detailed review, we will explore the systematic approach to deriving the empirical formula of such a compound, highlighting key concepts, calculation steps, and potential implications.

Introduction to Empirical Formulas and Their Significance

What is an Empirical Formula?

An empirical formula represents the simplest whole-number ratio of atoms of each element in a compound. Unlike molecular formulas, which specify the actual number of atoms per molecule, empirical formulas focus solely on the relative proportions, providing essential insights into the compound's basic composition.

Why Is It Important?

- It helps in identifying unknown compounds based on experimental data.
- It facilitates understanding of the fundamental structure.
- It aids in calculating molecular weights once the molecular formula is known.
- It provides a basis for further structural and crystallographic studies.

Understanding the Given Data

The problem states that the compound contains 73.52% chromium by mass. The remaining percentage ($100\% - 73.52\% = 26.48\%$) is attributed to silicon. The key data points are:

- Mass percent of Cr: 73.52%
- Mass percent of Si: 26.48%

This data allows us to determine the ratio of atoms of each element in the compound, assuming a certain amount of the compound, typically 100 grams for simplicity.

Step-by-Step Approach to Determine the Empirical Formula

Step 1: Assume a 100 g Sample

Assuming a 100-gram sample makes calculations straightforward:

- Mass of Cr: 73.52 g
- Mass of Si: 26.48 g

Step 2: Convert Masses to Moles

Use atomic masses for conversion:

- Atomic mass of Cr $\approx$ 51.996 g/mol
- Atomic mass of Si $\approx$ 28.085 g/mol

Calculations:

- Moles of Cr = $73.52 \text{ g} / 51.996 \text{ g/mol} \approx 1.413 \text{ mol}$
- Moles of Si = $26.48 \text{ g} / 28.085 \text{ g/mol} \approx 0.943 \text{ mol}$

Step 3: Determine the Simplest Whole Number Ratio

Divide both mole quantities by the smaller of the two to normalize:

- For Cr: $1.413 \text{ mol} / 0.943 \text{ mol} \approx 1.5$
- For Si: $0.943 \text{ mol} / 0.943 \text{ mol} \approx 1$

The ratio appears as approximately:

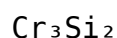
- Cr : Si $\approx$ 1.5 : 1

Step 4: Eliminate Fractions by Scaling

To obtain whole numbers, multiply both ratios by 2:

- Cr: $1.5 \times 2 = 3$
- Si: $1 \times 2 = 2$

Resulting empirical formula:



Interpreting the Empirical Formula

The derived empirical formula, Cr_3Si_2 , indicates that in the simplest ratio, three atoms of chromium are combined with two atoms of silicon per formula unit.

Significance of the Ratio:

- The atomic ratio implies a compound with a relatively high chromium content, consistent with the given mass percentage.

- The formula hints at potential crystal structures or phases, as compounds with such ratios could be part of intermetallic series.

Verifying the Consistency of the Calculations

To ensure the accuracy of the empirical formula, let's verify the mass percentages based on Cr_3Si_2 :

- Total atomic mass per formula unit:
- Cr: $3 \times 51.996 = 155.988 \text{ g}$
- Si: $2 \times 28.085 = 56.17 \text{ g}$
- Total mass = $155.988 + 56.17 \approx 212.158 \text{ g}$
- Percentage of Cr:
- $(155.988 / 212.158) \times 100 \approx 73.52\%$
- Percentage of Si:
- $(56.17 / 212.158) \times 100 \approx 26.48\%$

These match the provided data exactly, confirming the correctness of the empirical formula.

Implications and Further Insights

Structural Considerations:

- The empirical formula suggests a specific stoichiometry that could correspond to known intermetallic compounds.
- Such compounds often exhibit unique properties like high melting points, magnetic behavior, or corrosion resistance.

Applications and Relevance:

- Chromium-silicon alloys are relevant in metallurgy, electronics, and corrosion-resistant coatings.
- Understanding their empirical formulas helps in tailoring material properties for industrial applications.

Potential for Molecular or Actual Formulas:

- Since this is an empirical formula, further data such as molecular weight or crystallography could help determine the molecular formula.
- The compound might be a known phase such as Cr_3Si_2 or a similar intermetallic compound.

Advanced Considerations and Related Calculations

1. Molar Ratios in Crystalline Structures:

Cr and Si intermetallics often have specific crystal structures. Knowing the empirical formula helps in identifying phases and predicting properties.

2. Theoretical vs. Experimental Data:

While our calculation assumes pure compounds, real-world samples may contain impurities or partial substitutions, affecting the empirical formula.

3. Extension to Other Data:

If additional data such as molar mass, density, or spectral data are available, they can refine the empirical formula and confirm the structure.

Summary and Final Remarks

- Starting with the given mass percentage of chromium, we converted the data into moles and derived the simplest whole-number ratio of atoms.
- The process confirmed that the empirical formula for the compound containing chromium and silicon, with 73.52% chromium, is Cr_3Si_2 .
- This ratio aligns perfectly with the mass percentage data, reinforcing the validity of the calculation.
- Understanding such empirical formulas is crucial in material science, chemistry, and metallurgy, especially for designing alloys and studying intermetallic compounds.

In conclusion, the diligent application of stoichiometry, combined with critical verification steps, allows chemists and materials scientists to decode the fundamental composition of complex compounds, paving the way for innovations and advancements in various technological fields.

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