Show The Calculation That Leads To Your Answer.A Compound Is Composed Of Hydrogen And Carbon. It Is 89.94%

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Understanding the composition of chemical compounds is fundamental in chemistry, especially when analyzing organic molecules that are primarily composed of hydrogen and carbon. When a compound's percentage composition is given—as in this case, 89.94%—the key to uncovering its molecular formula involves systematic calculations. This article guides you through the detailed steps of deriving the empirical formula and molecular formula of such a compound, based on its percentage composition. By following this methodology, you will see how the calculation leads to a clear understanding of the compound's structure.

Interpreting the Percentage Composition

Before diving into calculations, it's important to interpret what the percentage composition signifies. The statement indicates that, by mass, the compound consists of 89.94% hydrogen and the remaining percentage (100% - 89.94% = 10.06%) of carbon. This mass-based data allows us to determine the ratio of moles of each element in the compound, which is essential for establishing the empirical formula.

Step 1: Assigning Sample Masses

To perform the calculation, assume a convenient total mass for the sample, typically 100 grams. This simplifies the process because the percentages directly translate into grams:

- Mass of hydrogen = 89.94 grams
- Mass of carbon = 10.06 grams

This assumption does not affect the ratio of elements, as the calculation is based on proportions rather than absolute quantities.

Step 2: Calculating Moles of Each Element

Next, convert the mass of each element to moles using their molar masses:

- Hydrogen (H): Molar mass ≈ 1.008 g/mol
- Carbon (C): Molar mass ≈ 12.01 g/mol

Calculations:

1. **Moles of hydrogen:**
   $$
   \frac{89.94\, \text{g}}{1.008\, \text{g/mol}} \approx 89.33\, \text{mol}
   $$

2. **Moles of carbon:**
   $$
   \frac{10.06\, \text{g}}{12.01\, \text{g/mol}} \approx 0.837\, \text{mol}
   $$

Note: These values represent the molar quantities of each element in the assumed 100 g sample.

Step 3: Determining the Simplest Whole Number Ratio

To find the empirical formula, express the molar amounts as ratios by dividing each by the smallest number of moles:

- The smallest value among 89.33 mol (H) and 0.837 mol (C) is 0.837 mol.

Calculations:

1. **Hydrogen:**
   $$
   \frac{89.33}{0.837} \approx 106.72
   $$

2. **Carbon:**
   $$
   \frac{0.837}{0.837} = 1
   $$

This ratio suggests approximately 106.72 hydrogen atoms for every carbon atom.

Note: Since these numbers are not whole numbers, we need to scale them to the nearest whole numbers for an empirical formula.

Step 4: Scaling to Whole Numbers

To convert ratios to whole numbers, identify an appropriate factor. Here, 106.72 is very close to 107, so we round to the nearest whole number:

- Hydrogen: 107
- Carbon: 1

Thus, the empirical formula is approximately C_1H_{107}.

Important: Empirical formulas are typically simplified to the smallest whole number ratio. Since 1 and 107 are already in the lowest terms, this formula indicates a very high hydrogen content relative to carbon.

Step 5: Confirming the Empirical Formula

The empirical formula derived from the ratio is:

C_1H_{107}

Given this, the molecular formula can be determined if additional data, such as molar mass, is provided. Without that, the empirical formula remains the best representation based on the percentage composition.

Additional Considerations: Calculating the Molecular Formula

If the molar mass of the compound is known, the molecular formula can be found by:

1. Calculating the molar mass of the empirical formula.
2. Dividing the molar mass of the compound by the empirical formula mass to find the multiplication factor.
3. Multiplying the empirical formula subscripts by this factor.

Example:

Suppose the molar mass of the compound is known to be approximately 1,200 g/mol:

$$
\text{Factor} = \frac{1200\, \text{g/mol}}{\text{Empirical formula mass}}
$$

Calculating the empirical formula mass:

\[

$$
(1 \times 12.01\, \text{g/mol}) + (107 \times 1.008\, \text{g/mol}) \approx 12.01 + 107.86 \approx 119.87\, \text{g/mol}
$$

Then,

$$
\text{Factor} \approx \frac{1200}{119.87} \approx 10
$$

Finally, multiply the subscripts of the empirical formula by 10:

Molecular formula:

$$
\mathrm{C}_{10} \mathrm{H}_{1070}
$$

This illustrates how the molecular formula relates to the empirical formula once the molar mass is known.

Conclusion: The Significance of Calculation in Chemical Analysis

This detailed calculation demonstrates how chemists determine the composition of compounds based on percentage data. The process involves converting percentages to masses, then moles, and finally establishing the simplest whole number ratio. The methodology not only helps in identifying the empirical formula but also provides insight into the molecular structure when molar mass data are available. Understanding these calculations is crucial in fields such as organic chemistry, pharmaceuticals, and material science, where precise molecular information guides research and development.

By mastering the step-by-step approach outlined here, you can confidently analyze other compounds with known percentage compositions, enhancing your skills in chemical analysis and compound characterization.

Frequently Asked Questions

What is the empirical formula of a compound that is 89.94% carbon and the remainder hydrogen?

To find the empirical formula, assume a 100 g sample: 89.94 g C and 10.06 g H. Moles of C = 89.94 / 12.01 ≈ 7.49 mol; moles of H = 10.06 / 1.008 ≈ 9.97 mol. Divide by the smallest number (7.49): C = 1, H ≈ 1.33. Multiply both by 3 to get whole numbers: C = 3, H ≈ 4. C_3H_4 is the empirical formula.

How do you determine the molecular formula from the empirical formula in this case?

First, find the molar mass of the empirical formula C_3H_4: (3×12.01) + (4×1.008) ≈ 36.03 + 4.032 ≈ 40.06 g/mol. Given the compound is 89.94% C, the molar mass of the compound is approximately 40.06 / 0.8994 ≈ 44.52 g/mol. Since the molecular mass is close to 44.52 g/mol, the ratio of molecular to empirical formula mass is about 44.52 / 40.06 ≈ 1.11, approximately 1. So, the molecular formula is the same as the empirical formula, C_3H_4.

What is the significance of the percentage composition in determining the empirical formula?

The percentage composition helps determine the ratio of elements in the compound by converting percentages to moles, which then reveal the simplest whole-number ratio of atoms—forming the empirical formula.

Can the compound be a hydrocarbon based on its composition?

Yes, since the compound contains only hydrogen and carbon, and the percentages suggest a typical hydrocarbon composition, it is likely a hydrocarbon.

How accurate is the assumption that the compound is 100 g for calculations?

Assuming a 100 g sample simplifies calculations because the percentages directly translate to grams, making it straightforward to find moles and ratios without affecting the empirical formula.

Why do we multiply the mole ratios by 3 in this calculation?

Because the initial ratio of H to C was approximately 1.33:1, multiplying both by 3 converts 1.33 to 4 and C to 3, giving whole-number subscripts for the empirical formula C_3H_4.

What is the overall process to find the empirical and molecular formulas from percentage data?

First, assume a sample size (commonly 100 g), convert percentage to grams, then to moles for each element. Find the simplest whole-number ratio to get the empirical formula. Calculate the empirical formula mass and compare it to the molar mass of the compound (if known) to find the molecular formula.

Additional Resources

Understanding the Composition of a Compound Made of Hydrogen and Carbon: A Step-by-Step Calculation

When examining chemical compounds, especially organic compounds composed predominantly of hydrogen and carbon, understanding their percentage composition is fundamental. In this detailed analysis, we explore how to determine the percentage of each element within a compound when given specific data—namely, that the compound is 89.94% composed of one of the elements (typically carbon or hydrogen). This process involves a systematic approach, grounded in chemical principles, molar mass calculations, and stoichiometry.

Introduction to Organic Compounds and Their Composition

Organic compounds primarily consist of carbon and hydrogen atoms, although they may also include other elements such as oxygen, nitrogen, sulfur, etc. For simplicity, in this discussion, we focus solely on compounds made of hydrogen (H) and carbon (C).

Key concepts:

- Percentage composition: The mass percentage of each element in a compound indicates how much of the total mass is contributed by that element.
- Empirical formula: The simplest whole-number ratio of atoms of each element in a compound.
- Molecular formula: The actual number of atoms of each element in a molecule, which is a multiple of the empirical formula.

Given Data and Objective

Suppose we are told:

- The compound is composed of hydrogen and carbon.
- The percentage of one element (say, carbon) is 89.94%.

Objective:
Determine the empirical formula of the compound, the molecular formula if molar mass is provided, or other relevant properties based on this percentage.

Step 1: Understanding the Percentage Composition

The first step is to interpret the given percentage correctly.

- If the compound is 89.94% carbon by mass, then the remaining percentage (100% - 89.94% =

10.06%) is hydrogen.
- Conversely, if the 89.94% pertains to hydrogen, then the remaining percentage is carbon.

For this analysis, we'll assume the compound is 89.94% carbon.
(If the problem states otherwise, simply swap the roles of hydrogen and carbon in the calculations.)

Step 2: Assigning Variables and Using Molar Masses

Let’s denote:

- The total mass of the compound as 100 grams (for simplicity).
- Mass of carbon in the compound: 89.94 grams.
- Mass of hydrogen in the compound: 10.06 grams.

Atomic masses:

- Carbon (C): approximately 12.01 g/mol.
- Hydrogen (H): approximately 1.008 g/mol.

Step 3: Calculating Moles of Elements

Calculate the number of moles of each element:

- Moles of carbon:

$$
\text{Moles of C} = \frac{\text{Mass of C}}{\text{Atomic mass of C}} = \frac{89.94}{12.01} \approx 7.49\, \text{mol}
$$

- Moles of hydrogen:

$$
\text{Moles of H} = \frac{\text{Mass of H}}{\text{Atomic mass of H}} = \frac{10.06}{1.008} \approx 9.98\, \text{mol}
$$

Step 4: Determining the Empirical Formula

To find the simplest whole-number ratio:

- Divide both mole quantities by the smaller of the two:

$$
\frac{7.49}{7.49} = 1
$$

$$
\frac{9.98}{7.49} \approx 1.33
$$

- The ratio of C:H atoms is approximately 1 : 1.33.

Since 1.33 is not a whole number, multiply both ratios by 3 to clear the fraction:

$$
\text{C} : 1 \times 3 = 3
$$
$$
\text{H} : 1.33 \times 3 \approx 4
$$

Empirical formula:

$$
\boxed{\text{C}_3\text{H}_4}
$$

This indicates the empirical formula of the compound is C_3H_4.

Step 5: Verifying and Interpreting the Empirical Formula

The empirical formula C_3H_4 suggests the compound's molecular structure could be a hydrocarbon with three carbons and four hydrogens. Examples include:

- Allene (C_3H_4): A known organic compound with a linear structure.
- Proposed structure: The empirical formula aligns with certain hydrocarbons or derivatives.

Step 6: Calculating the Molar Mass of the Empirical Formula

Determine the molar mass:

$$
\text{Molar mass of } \text{C}_3\text{H}_4 = (3 \times 12.01) + (4 \times 1.008) = 36.03 + 4.032 = 40.062\, \text{g/mol}
$$

Step 7: Confirming the Percentage Composition

To verify the percentage of carbon in the empirical formula:

$$
\%\, \text{C} = \frac{\text{Mass of C in formula}}{\text{Molar mass of formula}} \times 100 = \frac{36.03}{40.062} \times 100 \approx 89.9\%
$$

This matches closely with the given 89.94%, confirming the validity of the empirical formula.

Similarly, percentage of hydrogen:

$$
\%\, \text{H} = \frac{4.032}{40.062} \times 100 \approx 10.06\%
$$

which aligns with the earlier calculation, confirming our assumptions.

Step 8: Determining the Molecular Formula (If Molar Mass Is Known)

If, additionally, the molar mass of the actual compound is provided, the molecular formula can be determined by:

1. Calculating the ratio:

$$
n = \frac{\text{Molar mass of compound}}{\text{Molar mass of empirical formula}}
$$

2. Multiplying the empirical formula subscripts by n to find the molecular formula.

For example:
If molar mass of the compound is 80.12 g/mol,

$$
n = \frac{80.12}{40.062} \approx 2
$$

Thus, the molecular formula:

$$
\boxed{\text{C}_6\text{H}_8}
$$

which is twice the empirical formula.

Additional Considerations and Common Misconceptions

- Assumption on Percentages:
The calculation hinges on the assumption that 89.94% refers to carbon. If the percentage pertains to hydrogen (i.e., 89.94%), the process is similar but with roles of hydrogen and carbon reversed.

- Purity and Experimental Error:
Real-world data may involve impurities or measurement errors. The calculated empirical formula provides the most probable ratio, but experimental validation is necessary.

- Structural Implications:
The empirical and molecular formulas give insight into possible structural configurations, which influence physical and chemical properties.

- Multiple Compounds with Same Percentages:
Different compounds can share similar percentage compositions but differ in structure and properties, emphasizing the importance of structural analysis.

Summary of the Calculation Process

Step	Description	Result
1. Assign percentage composition	Assume 89.94% carbon, 10.06% hydrogen	Carbon and hydrogen masses known
2. Calculate moles of each element	Using atomic masses	C ≈ 7.49 mol, H ≈ 9.98 mol

3. Find mole ratio	Divide by smallest mole value	C: 1, H: 1.33
4. Convert to whole numbers	Multiply ratio by 3	C: 3, H: 4
5. Deduce empirical formula	C_3H_4	Confirmed by percentage match
6. Calculate molar mass	40.06 g/mol	Validates empirical formula
7. Determine molecular formula (if molar mass given)	Multiply empirical formula by a whole number	For molar mass 80.12 g/mol: C_6H_8

Conclusion

Through methodical calculation, we have demonstrated how to determine the empirical formula of a compound composed of hydrogen and carbon when the percentage composition is known. The key takeaways include understanding molar mass calculations, ratio determination, and how to verify the empirical formula against percentage data.

This process is fundamental in analytical chemistry, organic synthesis, and material science, enabling chemists to deduce molecular structures from elemental analysis data. Mastery of these calculations aids in the identification of unknown compounds and the design of new molecules with desired properties.

Final Note:
Always verify assumptions with actual data and context. If the initial percentage refers to hydrogen instead of carbon, reverse the calculations accordingly to find the correct empirical formula.

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