An Unknown Compound Contains Only C.H, And O. Combustion Of 5.60 G Of This Compound Produced 12.7 GCO2

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Understanding the composition and properties of unknown chemical compounds is a fundamental aspect of analytical chemistry. In this article, we explore the intriguing case of an unidentified compound composed solely of carbon (C), hydrogen (H), and oxygen (O). Specifically, we analyze the combustion of 5.60 grams of this compound, which results in the formation of 12.7 grams of carbon dioxide (CO_2). Through detailed calculations and chemical reasoning, we aim to determine the empirical and molecular formulas of this compound, shedding light on its molecular structure and composition.

Introduction to Combustion Analysis

Combustion analysis is a classical method used to determine the elemental composition of an organic compound. When a compound containing carbon, hydrogen, and oxygen combusts in excess oxygen, it produces carbon dioxide (CO_2) and water (H_2O). By measuring the masses of these combustion products, chemists can back-calculate the amounts of C, H, and O in the original compound.

In our case, the key data points are:

- Mass of the unknown compound: 5.60 g
- Mass of CO_2 produced: 12.7 g

The goal is to find:

- The amount of carbon in the original compound
- The amount of hydrogen
- The amount of oxygen

This information allows us to derive the empirical formula of the compound.

Step 1: Calculating the Moles of Carbon from CO_2

Since combustion produces CO_2 directly related to the carbon content, the first step is to determine how much carbon was present in the original sample.

Molar mass of CO_2:

$$
M_{CO_2} = 12.01\, \text{g/mol} + 2 \times 16.00\, \text{g/mol} = 44.01\, \text{g/mol}
$$

Number of moles of CO_2 produced:

$$
n_{CO_2} = \frac{12.7\, \text{g}}{44.01\, \text{g/mol}} \approx 0.2884\, \text{mol}
$$

Mass of carbon in CO_2:

Since each mole of CO_2 contains 1 mole of carbon:

$$
\text{Mass of C} = n_{CO_2} \times 12.01\, \text{g/mol} \approx 0.2884 \times 12.01 \approx 3.464\, \text{g}
$$

Thus, approximately 3.464 grams of carbon were present in the original 5.60 g sample.

Step 2: Calculating the Hydrogen Content

Hydrogen in the original compound is only present in the form of water produced during combustion. To find the hydrogen content, we need to determine the mass of water generated, which isn't directly provided. However, since the combustion produces only CO_2 and H_2O, the total mass of these products equals the sum of their individual masses.

Total mass of combustion products:

$$
\text{Mass of CO}_2 + \text{Mass of H}_2O = 12.7\, \text{g} + \text{(mass of H}_2O)
$$

But we don't yet know the mass of H_2O. To find it, we analyze the mass difference:

$$
\text{Mass of original compound} = 5.60\, \text{g}
$$
$$
\text{Mass of C in compound} = 3.464\, \text{g}
$$

Remaining mass:

$$
5.60\, \text{g} - 3.464\, \text{g} = 2.136\, \text{g}
$$

This remaining mass is due to hydrogen and oxygen. The combustion products account for the carbon and hydrogen, while oxygen in the original compound is part of the remaining mass not accounted for by C or H in the combustion products.

Next, we calculate the mass of hydrogen:

Mass of hydrogen:

$$
\text{Mass of H}_2O = 2 \times \text{mass of H}
$$

Let’s find the mass of hydrogen in the water produced.

Moles of H_2O produced:

- Molar mass of H_2O:

$$
M_{H_2O} = 2 \times 1.008\, \text{g/mol} + 16.00\, \text{g/mol} = 18.016\, \text{g/mol}
$$

- Moles of H_2O:

$$
n_{H_2O} = \frac{\text{Mass of H}_2O}{18.016}
$$

But we need the mass of H_2O to proceed. Alternatively, since the total mass of the original sample is known, and the carbon content is known, the remaining mass is attributable to hydrogen and oxygen.

Total mass of hydrogen:

$$
\text{Mass of H} = 2 \times \text{moles of H}_2O

\]

Alternatively, considering the combustion process:

- The mass of hydrogen in the original compound equals twice the moles of H_2O produced.

So, to find the moles of H_2O, we need to determine the mass of hydrogen in the compound.

Given that:

$$
\text{Mass of H} = \text{Mass of H}_2O \times \frac{2 \times 1.008}{18.016}
$$

Let’s denote:

$$
\text{Mass of H}_2O = m_{H_2O}
$$

Total hydrogen mass:

$$
\text{Mass of H} = m_{H_2O} \times \frac{2.016}{18.016}
$$

But since the total mass of the original compound is 5.60 g, and the mass of carbon is 3.464 g, the combined mass of hydrogen and oxygen is:

$$
5.60\, \text{g} - 3.464\, \text{g} = 2.136\, \text{g}
$$

If we can find the mass of hydrogen, then the mass of oxygen in the original compound is:

$$
\text{Mass of O} = 2.136\, \text{g} - \text{Mass of H}
$$

Using the combustion data:

The key is to relate the mass of water formed to the hydrogen in the original compound.

Because the combustion process produces water with the hydrogen from the original compound, and the total hydrogen in the compound equals the hydrogen in the water produced, we need an alternative approach.

Step 3: Determining the Moles of Hydrogen

Assumption:

- All hydrogen in the original compound ends up as water.
- The mass of water produced (which is unknown) corresponds to the amount of hydrogen.

Method:

Let's denote:

- m_{H_2O} = mass of water produced
- $n_{H_2O} = \frac{m_{H_2O}}{18.016}$ mol

Since each mole of H_2O contains 2 moles of H:

$$
\text{Moles of H} = 2 \times n_{H_2O}
$$

Mass of hydrogen in the original compound:

$$
\text{Mass of H} = \text{Moles of H} \times 1.008\, \text{g/mol} \approx 2 \times n_{H_2O} \times 1.008
$$

But we know the total mass of hydrogen in the original compound is:

$$
\text{Mass of H} = \text{Total mass} - \text{Mass of C} - \text{Mass of O}
$$

Expressed as:

$$
\text{Mass of H} = 2.136\, \text{g} - \text{Mass of O}
$$

Since oxygen is only in the original compound, and this is the only unknown, we need to find the value of m_{H_2O} that satisfies these relationships.

Step 4: Calculating the Oxygen Content

The oxygen in the original compound is not directly measured in combustion, but we can determine it by:

$$
\text{Mass of O} = \text{Mass of original compound} - (\text{Mass of C} + \text{Mass of H})
$$

From earlier:

$$
\text{Mass of C} = 3.464\, \text{g}
$$

$$
\text{Mass of H} = 2 \times n_{H_2O} \times 1.008
$$

$$
\text{Mass of O} = 5.60\, \text{g} - 3.464\, \text{g} - \text{Mass of H}
$$

But Mass of H depends on m_{H_2O}:

$$
\text{Mass of H} = 2 \times \frac{m_{H_2O}}{18.016} \times 1.008
$$

Simpl

Frequently Asked Questions

What is the main composition of the unknown compound given it contains only C, H, and O?

The compound is composed exclusively of carbon, hydrogen, and oxygen atoms.

How can the combustion of 5.60 g of the compound producing 12.7 g of CO_2 be used to determine its carbon content?

By calculating the amount of carbon in the CO_2 produced, since each mole of CO_2 contains one mole of carbon, we can find the mass of carbon in the original sample.

What is the mass of carbon in the 12.7 g of CO_2 produced during combustion?

The mass of carbon is calculated as (12.7 g CO_2) × (12.01 g C / 44.01 g CO_2) ≈ 3.45 g of carbon.

How do you determine the empirical formula of the compound based on combustion data?

Calculate the moles of C, H, and O in the original sample using the known mass of carbon, the remaining mass after subtracting carbon and hydrogen, and the total sample weight; then find the simplest ratio.

What additional data is needed to fully determine the molecular formula of the compound?

The molar mass or molecular weight of the compound is needed to relate the empirical formula to the molecular formula.

Why is it important to know the combustion products when analyzing the composition of an unknown compound?

Because combustion produces specific gaseous products like CO_2 and H_2O, which allow us to quantify the amounts of carbon and hydrogen, aiding in the determination of the compound's empirical and molecular formulas.

Additional Resources

Compound Analysis: Decoding the Composition of a Simple C-H-O Substance

Understanding the molecular makeup of unknown compounds is a fundamental pursuit in chemistry, blending analytical techniques with theoretical insights. Today, we delve into a fascinating case: an unidentified compound composed solely of carbon (C), hydrogen (H), and oxygen (O). With only 5.60 grams of this substance undergoing combustion to produce 12.7 grams of carbon dioxide (CO_2), we will explore its composition, infer its empirical formula, and evaluate its possible structure. This in-depth analysis not only highlights core principles of combustion analysis but also demonstrates how fundamental stoichiometry guides us toward understanding complex chemical identities.

Introduction to the Compound and Its Combustion Data

When faced with an unknown organic compound, especially one containing only C, H, and O, a common initial step involves combustion analysis. Combustion provides direct insight into the carbon and hydrogen content, since these elements produce predictable combustion products—carbon dioxide and water, respectively. In our scenario, the key data points are:

- Mass of the compound burned: 5.60 g
- Mass of CO_2 produced: 12.7 g

From these figures, we can determine the amount of carbon originally present. The presence of oxygen in the compound complicates the analysis but can still be deduced through systematic calculations.

Fundamental Principles of Combustion Analysis

Before diving into calculations, it is essential to understand the basic principles:

1. Complete Combustion: The compound undergoes complete oxidation, producing CO_2 and H_2O.
2. Mass Relationships:
- Carbon in the original compound forms CO_2.
- Hydrogen forms H_2O.
- Oxygen remains in the residual compound or as part of products, but in combustion analysis, it is often deduced indirectly.

3. Stoichiometry: Quantitative relationships between the initial amount of compound and the combustion products allow us to back-calculate the elemental composition.

Calculating the Carbon Content

The first step is to determine how much carbon was present in the original 5.60 g of compound.

Step 1: Find Moles of CO_2 Produced

Using molar mass of CO_2:

$$
M_{CO_2} = 44.01\, \text{g/mol}
$$

Number of moles of CO_2:

$$
n_{CO_2} = \frac{12.7\, \text{g}}{44.01\, \text{g/mol}} \approx 0.288\, \text{mol}
$$

Step 2: Determine Moles of Carbon

Since each CO_2 molecule contains one carbon atom:

$$
n_C = n_{CO_2} \approx 0.288\, \text{mol}
$$

Step 3: Calculate Mass of Carbon

Using atomic mass of carbon:

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

Mass of carbon:

$$
m_C = n_C \times M_C \approx 0.288\, \text{mol} \times 12.01\, \text{g/mol} \approx 3.46\, \text{g}
$$

Interpretation: Out of the 5.60 g of the compound burned, approximately 3.46 g was carbon.

Determining Hydrogen Content

Next, we analyze hydrogen by considering the amount of water produced during combustion.

Step 1: Establish the Mass of Water Formed

While not directly provided, the mass of H_2O produced can be inferred from the total combustion products. Total combustion products:

- CO_2: 12.7 g
- Water: To be calculated

Step 2: Use the Law of Conservation of Mass

Total mass of products (CO_2 + H_2O) should equal the mass of the original compound:

$$
m_{compound} = m_{CO_2} + m_{H_2O} + \text{Residual oxygen (if any)}
$$

Given only the total combustion products, and knowing the initial mass:

$$
5.60\, \text{g} = 12.7\, \text{g} + m_{H_2O} + \text{Residual oxygen}
$$

This suggests that the water produced contributes to the total mass of combustion products, but since the total products can't exceed the initial mass, the key is to determine the amount of hydrogen from the water produced.

Step 3: Calculate the Moles of Water

However, we need an alternative approach because the total combustion products appear to be more than the initial mass, which indicates that oxygen in the compound is being accounted for in the products, and the mass discrepancy might be due to experimental data or assumptions.

Instead, a more straightforward method is to use the known combustion reactions:

$$
\text{C}_x\text{H}_y\text{O}_z + \text{O}_2 \rightarrow x\, \text{CO}_2 + \frac{y}{2}\, \text{H}_2O
$$

From the amount of CO_2, we can find the carbon content, as done.

Step 4: Calculate Hydrogen Content

The mass of hydrogen in the compound can be found from the amount of water produced, which is related to the hydrogen content:

$$
m_{H} = \frac{y}{2} \times M_{H_2O}
$$

Given the initial total mass and known carbon mass, the hydrogen mass:

$$

$$
m_{H} = m_{initial} - m_{C} - m_{O}
$$

But since oxygen is present, and we haven't yet quantified it, we now need to find the oxygen content.

Calculating the Oxygen Content

To find the oxygen in the original compound, we use the difference between the total mass and the sum of carbon and hydrogen:

$$
m_{O} = m_{initial} - (m_{C} + m_{H})
$$

However, because we lack the direct value of m_{H}, we need to determine it through the combustion process.

Step-by-Step Determination of the Empirical Formula

Combining all the calculations, here's a structured approach:

1. Calculate Carbon:

- Carbon mass: 3.46 g

2. Estimate Hydrogen:

Suppose the compound contains y moles of hydrogen:

$$
m_{H} = y \times \frac{1\, \text{g/mol}}{2} \text{ (since 1 mol } H_2O \text{ contains 2 mol H) }
$$

But more straightforwardly, the hydrogen mass in the original compound can be calculated from the amount of water produced:

$$
m_{H} = n_{H_2O} \times M_{H} \times 2
$$

Given the total combustion data, the typical method is:

- Assume the amount of water produced is proportional to the hydrogen content:

$$
n_{H_2O} = \frac{m_{H_2O}}{18.02\, \text{g/mol}}
$$

- Hydrogen in the compound:

$$
m_{H} = n_{H_2O} \times 2 \times 1.008\, \text{g/mol}
$$

But since m_{H_2O} is unknown, an alternative is to estimate based on typical combustion ratios or experimental data.

Alternative Approach: Elemental Analysis and Empirical Formula

Given the combustion data, an effective method involves assuming a general formula $C_xH_yO_z$ and solving for x, y, z.

1. Determine the moles of carbon:

$$
n_C \approx 0.288\, \text{mol}
$$

2. Estimate moles of hydrogen:

The total mass of the compound is 5.60 g. Since 3.46 g is carbon, the remaining 2.14 g is hydrogen and oxygen.

Assuming that the oxygen content can be at most:

$$
m_O = 5.60\, \text{g} - (3.46\, \text{g} + m_H)
$$

To proceed, let's estimate the hydrogen content.

Final Steps: Deriving the Empirical Formula

Given that:

- Carbon mass: 3.46 g
- Total initial mass: 5.60 g
- Remaining mass (hydrogen + oxygen): $5.60 - 3.46 = 2.14\, \text{g}$

Suppose the hydrogen content is y mol:

$$
m_H = y \times 1.008\, \text{g/mol}
$$

Then, oxygen mass:

$$
m_O = 2.14\, \text{g} - m_H
$$

Expressed in moles:

$$
n_H = \frac{m_H}{1.008}
$$

$$
n_O = \frac{m_O}{16.00}
$$

Now, considering the molar ratios:

$$
x = n_C \approx 0.288\, \text{mol}
$$
$$
y = n_H
$$
$$
z = n_O
$$

To find the simplest whole-number

An Unknown Compound Contains Only C H And O Combustion

Of 5 60 G Of This Compound Produced 12 7 Gco2

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