How Many Moles Of Co2 And H2o Will Be Produced By Combustion Analysis Of 0.010 Mol Of Styrene?

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Understanding the combustion of organic compounds like styrene is fundamental in chemistry, especially when quantifying the amounts of carbon dioxide (CO_2) and water (H_2O) produced during combustion. This article explores the process of determining the moles of CO_2 and H_2O generated from burning 0.010 mol of styrene, providing a comprehensive overview suitable for students, educators, and chemistry enthusiasts alike.

Introduction to Styrene and Its Combustion

Styrene, also known as vinylbenzene, is an aromatic hydrocarbon with the chemical formula C_8H_8. It is widely used in the production of plastics, resins, and rubber. Its combustion is a classic example used in organic chemistry to illustrate how hydrocarbons react with oxygen, producing carbon dioxide and water.

Chemical Formula of Styrene: C_8H_8

Molecular Structure: Styrene consists of a benzene ring attached to an ethenyl group (–$CH=CH_2$). Its aromatic nature influences its combustion behavior and the formation of combustion products.

General Combustion Reaction of Styrene

When styrene undergoes complete combustion in excess oxygen, it produces carbon dioxide and water:

\[\text{C}_8\text{H}_8 + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} \]

However, to determine the exact amounts of CO_2 and H_2O produced, the balanced chemical equation must be established.

Balancing the Combustion Equation

Let's write the unbalanced combustion reaction:

\[\text{C}_8\text{H}_8 + O_2 \rightarrow CO_2 + H_2O \]

Balance carbon atoms:

$$ \text{C}_8\text{H}_8 + O_2 \rightarrow 8\, \text{CO}_2 + H_2O $$

Balance hydrogen atoms:

$$ \text{C}_8\text{H}_8 + O_2 \rightarrow 8\, \text{CO}_2 + 4\, H_2O $$

Now, balance oxygen atoms:

On the right side, oxygen atoms are:

$$ 8 \times 2 = 16 \text{ (from CO}_2) + 4 \times 1 = 4 \text{ (from H}_2\text{O}) = 20 $$

Thus, total oxygen atoms needed:

$$ 20 $$

On the left side, oxygen molecules (O_2) contribute 2 oxygen atoms each:

$$ \text{Number of O}_2 \text{ molecules} = \frac{20}{2} = 10 $$

The balanced combustion reaction:

$$ \text{C}_8\text{H}_8 + 10\, O_2 \rightarrow 8\, CO_2 + 4\, H_2O $$

Calculating Moles of CO_2 and H_2O Produced

Given 0.010 mol of styrene, the goal is to find the moles of CO_2 and H_2O generated.

Step 1: Determine the molar ratios

From the balanced equation:

- 1 mol of styrene produces 8 mol of CO_2
- 1 mol of styrene produces 4 mol of H_2O

This ratio remains constant regardless of the amount of styrene burned.

Step 2: Apply the molar ratios to the given amount

For 0.010 mol of styrene:

- Moles of CO_2 produced:

$$
0.010\, \text{mol} \times \frac{8\, \text{mol CO}_2}{1\, \text{mol styrene}} = 0.080\, \text{mol CO}_2
$$

- Moles of H_2O produced:

$$
0.010\, \text{mol} \times \frac{4\, \text{mol H}_2\text{O}}{1\, \text{mol styrene}} = 0.040\, \text{mol H}_2\text{O}
$$

Summary:

Product	Moles Produced
CO_2	0.080 mol
H_2O	0.040 mol

Implications and Applications of These Calculations

Understanding the quantities of gases produced during combustion has practical significance in various fields:

- Environmental Chemistry: Quantifying CO_2 emissions helps assess carbon footprints and environmental impact.
- Industrial Processes: In manufacturing, knowing combustion efficiencies aids in optimizing fuel use and reducing waste.
- Analytical Chemistry: Combustion analysis serves as a method to determine the composition of unknown organic compounds.

Additional Factors to Consider

While the theoretical calculations provide ideal results, real-world combustion may involve incomplete reactions or side products due to impurities, temperature variations, or incomplete oxygen supply. Therefore, actual experimental values might slightly differ from theoretical predictions.

Complete vs. Incomplete Combustion

- Complete Combustion: Produces only CO_2 and H_2O, as detailed above.
- Incomplete Combustion: May generate CO, soot, or other hydrocarbons, leading to less predictable product quantities.

Practical Example: Calculating Gas Volumes at Standard Conditions

Suppose you want to know the volume of CO_2 and H_2O vapor produced at standard temperature and pressure (STP). Using the molar volume of gases at STP (~22.4 L/mol):

- Volume of CO_2:

$$
0.080\, \text{mol} \times 22.4\, \text{L/mol} = 1.792\, \text{L}
$$

- Volume of H_2O vapor:

$$
0.040\, \text{mol} \times 22.4\, \text{L/mol} = 0.896\, \text{L}
$$

These calculations are useful in laboratory settings where gas collection and measurement are involved.

Conclusion

In summary, when combusting 0.010 mol of styrene, approximately 0.080 mol of carbon dioxide and 0.040 mol of water vapor are produced under ideal, complete combustion conditions. This precise quantification is essential for environmental assessments, industrial applications, and analytical chemistry. Understanding the stoichiometry involved in combustion reactions enables chemists to predict product yields, optimize processes, and interpret experimental data accurately.

Key Takeaways

- The balanced combustion equation for styrene is: $\text{C}_8\text{H}_8 + 10\, O_2 \rightarrow 8\, CO_2 + 4\, H_2O$.
- 0.010 mol of styrene produces 0.080 mol of CO_2 and 0.040 mol of H_2O.
- Gas volumes at STP can be calculated using molar volume, aiding practical laboratory measurements.
- Real-world factors can influence actual yields, so theoretical calculations serve as ideal benchmarks.

By mastering these calculations, students and professionals can better analyze combustion processes, interpret data, and make informed decisions in research and industry.

Frequently Asked Questions

What is the balanced combustion reaction for styrene (C_8H_8)?

The balanced combustion reaction is: $C_8H_8 + 10O_2 \rightarrow 8CO_2 + 4H_2O$.

How many moles of CO_2 are produced from 0.010 mol of styrene?

Since 1 mol of styrene produces 8 mol of CO_2, 0.010 mol of styrene produces 0.080 mol of CO_2.

How many moles of H_2O are produced from 0.010 mol of styrene?

Since 1 mol of styrene produces 4 mol of H_2O, 0.010 mol of styrene produces 0.040 mol of H_2O.

Why is it important to know the mole ratios in combustion analysis?

Mole ratios allow us to determine the amounts of products formed from a given amount of reactant, enabling quantitative analysis of combustion products.

What assumptions are made during the combustion analysis of styrene?

It is assumed that the combustion is complete, all carbon converts to CO_2, and all hydrogen converts to H_2O, with no side reactions.

If the combustion is incomplete, how does this affect the amount of CO_2 and H_2O produced?

Incomplete combustion can lead to less CO_2 and H_2O formation and the formation of carbon monoxide or other products, thus skewing calculations.

Can the molar masses of CO_2 and H_2O be used to convert moles to grams in this analysis?

Yes, molar masses (CO_2 = 44.01 g/mol and H_2O = 18.02 g/mol) allow conversion of the moles produced into grams for further analysis.

How does the initial amount of styrene influence the total CO2 and H2O produced during combustion?

The initial amount of styrene directly determines the total moles of CO2 and H2O produced, following the stoichiometric ratios in the balanced reaction.

Additional Resources

How Many Moles Of CO_2 And H_2O Will Be Produced By Combustion Analysis Of 0.010 Mol Of Styrene?

Understanding the combustion process of organic compounds like styrene is fundamental in analytical chemistry, especially when quantifying the elements within a substance. When styrene undergoes complete combustion, it reacts with oxygen to produce carbon dioxide (CO_2) and water (H_2O). By analyzing the amounts of these combustion products, chemists can determine the original composition of the compound. In this article, we delve into the precise calculation of how many moles of CO_2 and H_2O are produced from the combustion of 0.010 mol of styrene, providing a clear, step-by-step breakdown suitable for students, professionals, or enthusiasts eager to deepen their understanding of combustion analysis.

Understanding the Chemical Structure of Styrene

Before jumping into the calculations, it's essential to comprehend the molecular structure of styrene and its chemical formula. Styrene, also known as phenylethene, is an aromatic hydrocarbon with the molecular formula C_8H_8.

Structural Representation:
- A benzene ring (C_6H_6) attached to a vinyl group ($CH=CH_2$).

Molecular formula: C_8H_8

This structure indicates that each molecule contains:
- 8 carbon atoms
- 8 hydrogen atoms

Understanding this composition is crucial because combustion reactions involve oxidation of these elements to form CO_2 and H_2O.

The Combustion Reaction of Styrene: A Chemical Perspective

Complete combustion of an organic hydrocarbon generally involves reacting with excess oxygen (O_2) to produce carbon dioxide (CO_2) and water (H_2O).

General combustion reaction of C_xH_y:

$C_xH_y + (x + y/4)\ O_2 \rightarrow x\ CO_2 + (y/2)\ H_2O$

This formula accounts for the stoichiometric coefficients needed for complete combustion, ensuring all carbon and hydrogen are fully oxidized.

Applying this to styrene (C_8H_8):

$C_8H_8 + (8 + 8/4)\ O_2 \rightarrow 8\ CO_2 + 4\ H_2O$

Simplify the oxygen coefficient:

$8 + 2 = 10$

Thus, the balanced combustion reaction is:

$C_8H_8 + 10\ O_2 \rightarrow 8\ CO_2 + 4\ H_2O$

This balanced equation indicates that:

- 1 mole of styrene produces 8 moles of CO_2
- 1 mole of styrene produces 4 moles of H_2O

Calculating the Moles of Products from 0.010 Moles of Styrene

Given the balanced combustion reaction, the next step is to determine the amounts of CO_2 and H_2O produced from a specific quantity of styrene.

Initial amount:

- Styrene: 0.010 mol

Using stoichiometry:

- Moles of CO_2 produced = (Coefficient of CO_2 / Coefficient of styrene) × moles of styrene
- Moles of H_2O produced = (Coefficient of H_2O / Coefficient of styrene) × moles of styrene

Calculations:

- CO_2:

$(8 / 1) \times 0.010 \text{ mol} = 0.080 \text{ mol}$

- H_2O:

$(4 / 1) \times 0.010 \text{ mol} = 0.040 \text{ mol}$

Result:

- 0.010 mol of styrene produces 0.080 mol of CO_2

- 0.010 mol of styrene produces 0.040 mol of H_2O

Significance of These Calculations

The ability to accurately predict the quantities of combustion products has numerous practical applications:

- Elemental analysis: Determines the purity and composition of the original compound.
- Environmental monitoring: Quantifies emissions from combustion of various hydrocarbons.
- Industrial processes: Ensures complete combustion reducing waste and maximizing energy efficiency.
- Research and development: Facilitates the design of new compounds with predictable combustion profiles.

In laboratory settings, these calculations serve as fundamental tools for chemists to validate experimental results and ensure the consistency of their analytical procedures.

Factors Influencing Combustion Efficiency and Measurement

While theoretical calculations provide idealized values, real-world combustion processes can be influenced by various factors:

- Incomplete combustion: Not all carbon may convert to CO_2, leading to CO or other byproducts.
- Hydrocarbon impurities: Contaminants can alter the expected ratios of products.
- Measurement errors: Analytical techniques like gas chromatography or infrared spectroscopy can introduce inaccuracies.
- Environmental conditions: Temperature, pressure, and oxygen availability affect combustion completeness.

Understanding these factors helps in designing experiments and interpreting data accurately.

Practical Considerations in Combustion Analysis

When performing combustion analysis in a laboratory, several practical steps are typically followed:

1. Sample Preparation: Precisely weigh a known amount of styrene.
2. Complete Combustion: Use a combustion bomb or sealed environment to ensure all hydrocarbons are oxidized.
3. Collection of Products: Capture CO_2 and H_2O in suitable traps or analyze gases directly.
4. Quantitative Analysis: Use instrumentation to measure the amounts of CO_2 and H_2O produced.
5. Calculation of Moles: Convert measured quantities into moles and compare with

theoretical predictions.

This systematic approach allows chemists to reliably determine the composition of unknown samples or verify purity.

Broader Implications and Applications

Calculating the exact amounts of CO_2 and H_2O produced from styrene combustion extends beyond academic exercises:

- Environmental Impact: Understanding emissions from styrene-based products, like plastics, helps assess their ecological footprint.
- Industrial Optimization: Manufacturers can optimize combustion processes to reduce waste and improve energy use.
- Material Development: Designing new polymers with tailored combustion profiles for safety and environmental considerations.
- Educational Value: Reinforces fundamental principles of stoichiometry and chemical reactions for students.

Conclusion

The combustion analysis of styrene, with its well-defined molecular structure, offers a straightforward yet profound illustration of stoichiometry in action. From a starting point of 0.010 mol of styrene, we can confidently state that combustion will produce approximately 0.080 mol of CO_2 and 0.040 mol of H_2O, assuming complete combustion. These calculations are vital for analytical chemists, environmental scientists, and industrial practitioners alike, providing insights into the elemental composition of hydrocarbons and their combustion behavior.

In essence, such detailed quantitative understanding underscores the power of chemistry to decode and predict the behavior of complex molecules, ensuring safety, efficiency, and environmental responsibility across various sectors.

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