How Many Molecules Of CO2 Will Be Produced If 27. 3 G Of C8H18 Are Combusted

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Understanding the combustion process of hydrocarbons like octane (C8H18) is fundamental in chemistry, especially in contexts related to energy production, environmental science, and chemical engineering. This article provides a comprehensive explanation of how to determine the number of carbon dioxide (CO2) molecules produced when a specific mass of octane undergoes complete combustion. We will cover the principles of combustion reactions, the steps for calculating the number of molecules, and relevant concepts to deepen your understanding.

Introduction to Combustion of Hydrocarbons

Combustion is a chemical reaction where a substance reacts with oxygen, releasing energy in the form of heat and light. Hydrocarbons, such as octane (C8H18), are common fuels that combust in the presence of oxygen:

$$ \text{Hydrocarbon} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} $$

In the case of octane, the complete combustion reaction can be written as:

$$ \text{C}_8\text{H}_{18} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} $$

However, to determine the exact amount of CO2 produced, we need to balance this chemical equation.

Balancing the Combustion Equation for Octane

Step 1: Write the unbalanced equation

$$
\text{C}_8\text{H}_{18} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}
$$

Step 2: Balance carbons and hydrogens

- Carbon atoms: 8 in C8H18, so produce 8 CO2 molecules.

- Hydrogen atoms: 18 in C8H18, so produce 9 H2O molecules (since each water has 2 H).

$$
\text{C}_8\text{H}_{18} + \text{O}_2 \rightarrow 8 \text{CO}_2 + 9 \text{H}_2O
$$

Step 3: Balance oxygen atoms

- Total oxygen atoms on the right:

$$
8 \times 2 (\text{from CO}_2) + 9 \times 1 (\text{from H}_2O) = 16 + 9 = 25
$$

- Since each O2 molecule provides 2 oxygen atoms, the number of O2 molecules needed:

$$
\frac{25}{2} = 12.5
$$

- To avoid fractional coefficients, multiply entire equation by 2:

$$
2 \text{C}_8\text{H}_{18} + 25 \text{O}_2 \rightarrow 16 \text{CO}_2 + 18 \text{H}_2O
$$

This is the balanced combustion equation for octane.

Calculating Moles of C8H18 in 27.3 g

To determine the number of molecules of CO2 produced, first, calculate how many moles of octane are present in 27.3 grams.

Step 1: Find the molar mass of C8H18

- Carbon (C): 12.01 g/mol

- Hydrogen (H): 1.008 g/mol

$$
\text{Molar mass of C}_8\text{H}_{18} = (8 \times 12.01) + (18 \times 1.008) = 96.08 + 18.144 = 114.224\, \text{g/mol}
$$

Step 2: Calculate moles of octane

$$
\text{Moles of C}_8\text{H}_{18} = \frac{\text{Mass}}{\text{Molar mass}} = \frac{27.3\, \text{g}}{114.224\, \text{g/mol}} \approx 0.239\, \text{mol}
$$

Determining Moles of CO2 Produced

Using the balanced equation, the molar ratio of octane to CO2 is 2:16, or simplified as 1:8.

- For every 1 mol of C8H18 combusted, 8 mol of CO2 are produced.

- Therefore, the moles of CO2 generated from 0.239 mol of octane:

$$
\text{Moles of CO}_2 = 0.239\, \text{mol} \times 8 = 1.912\, \text{mol}
$$

Calculating the Number of CO2 Molecules

To find the actual number of CO2 molecules, we use Avogadro's number, which states that:

$$ 1\, \text{mol} = 6.022 \times 10^{23} \text{ molecules} $$

Step 1: Multiply moles of CO2 by Avogadro's number

$$
\text{Number of CO}_2 \text{ molecules} = 1.912\, \text{mol} \times 6.022 \times 10^{23} \text{ molecules/mol}
$$

$$
= 1.912 \times 6.022 \times 10^{23} \approx 1.15 \times 10^{24} \text{ molecules}
$$

Summary of Calculation

Step	Description	Result
1	Molar mass of C8H18	114.224 g/mol
2	Moles of C8H18 in 27.3 g	≈ 0.239 mol

| 3 | Moles of CO_2 produced | ≈ 1.912 mol |
| 4 | Number of CO_2 molecules | ≈ 1.15 × 10^24 molecules |

Additional Considerations

Complete vs. Incomplete Combustion

This calculation assumes complete combustion, where all carbon is converted into CO_2. In real-world scenarios, incomplete combustion can occur due to insufficient oxygen, leading to the production of carbon monoxide (CO) or soot (carbon). The amount of CO_2 produced in such cases would be less than the theoretical maximum.

Environmental Impact of CO_2 Production

Understanding the quantity of CO_2 generated from fuel combustion is critical in environmental science, as CO_2 is a greenhouse gas contributing to climate change. Quantitative assessments like this help in calculating carbon footprints and designing cleaner combustion technologies.

Applications in Engineering and Industry

Engineers use these calculations to design engines, optimize fuel efficiency, and reduce emissions. Accurate mole-to-molecule conversions enable precise modeling of combustion processes and environmental impact assessments.

Conclusion

To summarize, when 27.3 grams of octane (C_8H_{18}) undergo complete combustion, approximately 1.15 × 10^24 molecules of carbon dioxide are produced. This calculation involves understanding the chemical reaction, balancing the combustion equation, converting mass to moles, and then translating moles into molecules using Avogadro's number. Mastery of these concepts is essential for students and professionals working in chemistry, environmental science, and engineering disciplines.

By following these systematic steps, you can analyze similar combustion reactions involving different hydrocarbons and determine the number of molecules produced, which is crucial for scientific accuracy and environmental considerations.

Frequently Asked Questions

How many molecules of CO_2 are produced when 27.3 g of C_8H_{18} combusts?

Approximately 4.91×10^{23} molecules of CO_2 are produced.

What is the balanced chemical equation for the combustion of C_8H_{18}?

$C_8H_{18} + 12.5\ O_2 \rightarrow 8\ CO_2 + 9\ H_2O$.

How do you calculate the number of CO_2 molecules from a given mass of C_8H_{18}?

First, determine moles of C_8H_{18}, then use the molar ratio from the balanced equation to find moles of CO_2, and finally multiply by Avogadro's number to get molecules.

What is the molar mass of C_8H_{18}?

The molar mass of C_8H_{18} is approximately 114.23 g/mol.

How many moles of C_8H_{18} are in 27.3 g?

About 0.239 moles of C_8H_{18} (27.3 g ÷ 114.23 g/mol).

How many moles of CO_2 are produced from 0.239 moles of C_8H_{18}?

Approximately 1.91 moles of CO_2 are produced, based on the molar ratio 8:1.

What is the significance of Avogadro's number in this calculation?

Avogadro's number (6.022×10^{23}) allows conversion from moles to molecules, enabling calculation of the exact number of CO_2 molecules produced.

Additional Resources

How Many Molecules Of CO2 Will Be Produced If 27.3 G Of C8H18 Are Combusted: An In-Depth Investigation

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Introduction

Combustion reactions are fundamental processes in chemistry, playing a critical role in energy production, environmental impacts, and industrial applications. Among various hydrocarbons, alkanes

like octane (C_8H_{18}) are prominent due to their widespread use as fuels in internal combustion engines. A key concern associated with hydrocarbon combustion is the release of carbon dioxide (CO_2), a greenhouse gas contributing to climate change.

This article provides a comprehensive analysis of how many molecules of CO_2 are produced when 27.3 grams of octane are combusted completely. We delve into the stoichiometry of the reaction, the conversion steps from grams to molecules, and explore the broader implications of such calculations in environmental and industrial contexts.

Understanding the Combustion of Octane (C_8H_{18})

The Combustion Reaction

The complete combustion of octane involves reacting it with oxygen (O_2) to produce carbon dioxide (CO_2) and water (H_2O):

$$\text{C}_8\text{H}_{18} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O}$$

Balancing this chemical equation is essential for accurate stoichiometric calculations.

Balancing the Equation

Let's balance the combustion of octane:

1. Carbon atoms: 8 in octane → 8 CO_2 molecules
2. Hydrogen atoms: 18 in octane → 9 H_2O molecules
3. Oxygen atoms:

- On the right side: $8 \times 2 + 9 \times 1 = 16 + 9 = 25$

- On the left side: O_2 molecules. Since each O_2 provides 2 oxygen atoms, total oxygen molecules needed:

$$\frac{25}{2} = 12.5 \text{ O}_2$$

To eliminate fractions, multiply the entire equation by 2:

$$2\, \text{C}_8\text{H}_{18} + 25\, \text{O}_2 \rightarrow 16\, \text{CO}_2 + 18\, \text{H}_2\text{O}$$

This balanced equation indicates that:

- 2 moles of octane produce 16 moles of CO_2
- 25 moles of O_2 are consumed

Calculating the Moles of Octane in 27.3 Grams

Step 1: Determine the molar mass of C8H18

Calculate the molar mass:

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

$$\text{Molar mass of C8H18} = (8 \times 12.01) + (18 \times 1.008)$$

$$= 96.08 + 18.144 = 114.224\, \text{g/mol}$$

Step 2: Convert grams to moles

Using the molar mass:

$$\text{Moles of C8H18} = \frac{27.3\, \text{g}}{114.224\, \text{g/mol}} \approx 0.239\, \text{mol}$$

Determining Moles of CO2 Produced

Step 1: Use the stoichiometric ratio

From the balanced equation:

- 2 mol of C8H18 produce 16 mol of CO2

Thus, 1 mol of C8H18 produces:

$$\frac{16\, \text{mol CO}_2}{2\, \text{mol C}_8\text{H}_{18}} = 8\, \text{mol CO}_2$$

Step 2: Calculate the moles of CO2 from the given amount of octane

Given 0.239 mol of octane:

$$\text{Moles of CO}_2 = 0.239\, \text{mol C}_8\text{H}_{18} \times 8\, \text{mol CO}_2 / \text{mol C}_8\text{H}_{18} \approx 1.912\, \text{mol CO}_2$$

Converting Moles of CO2 to Molecules

Avogadro’s number states that 1 mole contains approximately 6.022×10^{23} molecules.

$$\text{Number of CO}_2 \text{ molecules} = 1.912\, \text{mol} \times 6.022 \times 10^{23}\, \text{molecules/mol}$$

$$\approx 1.15 \times 10^{24}\, \text{molecules}$$

Thus, approximately 1.15×10^{24} molecules of CO2 are produced when 27.3 grams of

octane are combusted completely.

Broader Implications of Combustion Calculations

Environmental Impact

Understanding the quantity of CO_2 produced per unit of fuel burned is crucial in assessing the environmental footprint of hydrocarbon combustion. With the calculated number of molecules, environmental scientists can estimate the total greenhouse gases emitted by vehicles or power plants over specific fuel consumption rates.

Industrial and Engineering Significance

Engineers utilize these calculations to optimize combustion efficiency, design cleaner engines, and develop alternative fuels. Accurate stoichiometric data helps in reducing excess oxygen, minimizing pollutant formation, and improving energy output.

Carbon Footprint Estimation

By translating the number of molecules to mass and then to broader scales, industries and governments can estimate the carbon footprint associated with fuel consumption and formulate policies to mitigate climate change.

Additional Considerations

Complete vs. Incomplete Combustion

The calculations assume complete combustion, which is idealized. In real-world conditions, incomplete combustion can produce CO, unburned hydrocarbons, and other pollutants, altering the actual CO_2 emissions.

Variability in Fuel Composition

Real fuels often contain additives or variations in composition, which can affect the stoichiometry and emission profiles.

The Role of Catalysts and Emission Controls

Technologies like catalytic converters and scrubbers are employed to reduce harmful emissions, but the fundamental molecular calculations remain essential for baseline estimations.

Conclusion

The combustion of 27.3 grams of octane (C_8H_{18}) results in approximately 1.15×10^{24} molecules of carbon dioxide. This calculation highlights the vast number of molecules involved in

everyday combustion processes and underscores the importance of stoichiometric understanding in addressing environmental challenges. As society seeks sustainable solutions, such fundamental chemical insights are indispensable for developing cleaner energy technologies and mitigating climate change impacts.

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