18 Grams Of Pentane Go Through A Burning Reaction, Where Oxygen Is Leftover. What Would Be The Volume

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Understanding the combustion of hydrocarbons like pentane is fundamental in chemistry, especially when calculating the amount of gases produced during such reactions. In this article, we will explore the combustion process of 18 grams of pentane (C_5H_{12}), analyze the reaction with oxygen, and determine the resulting volume of gases produced when excess oxygen remains. This comprehensive guide aims to clarify the stoichiometry involved, the theoretical calculations, and real-world implications.

Introduction to Combustion of Pentane

What is Combustion?

Combustion is a chemical process where a substance reacts rapidly with oxygen, producing heat and light. Hydrocarbons like pentane (C_5H_{12}) undergo combustion to produce carbon dioxide (CO_2) and water (H_2O).

Significance of Studying Pentane Combustion

- Pentane is a volatile hydrocarbon used in fuels and industrial applications.
- Understanding its combustion helps in energy production, safety measures, and environmental impact assessments.
- Calculating gas volumes aids in designing reactors and understanding emissions.

Chemical Reaction of Pentane Combustion

Balanced Chemical Equation

The combustion of pentane can be represented as:

$$C_5H_{12} + 8\ O_2 \rightarrow 5\ CO_2 + 6\ H_2O$$

This indicates:
- 1 mole of pentane reacts with 8 moles of oxygen.
- Produces 5 moles of carbon dioxide and 6 moles of water vapor.

Implications of Excess Oxygen

- When oxygen is in excess, all pentane molecules combust completely.
- The amount of oxygen initially supplied exceeds the stoichiometric requirement.
- The leftover oxygen remains unreacted after the reaction.

Calculating the Moles of Pentane

Step 1: Molar Mass of Pentane

Calculate molar mass based on atomic weights:
- Carbon (C) = 12.01 g/mol
- Hydrogen (H) = 1.008 g/mol

Molar mass of C_5H_{12}:
$(5 \times 12.01) + (12 \times 1.008) = 60.05 + 12.096 = 72.146$ g/mol

Step 2: Moles of Pentane in 18 grams

Number of moles:
n = mass / molar mass = 18 g / 72.146 g/mol ≈ 0.2494 mol

Determining the Oxygen Required for Combustion

Step 1: Moles of Oxygen Needed

From the balanced equation:
1 mol C_5H_{12} requires 8 mol O_2

Thus:
0.2494 mol C_5H_{12} × 8 mol O_2 / 1 mol C_5H_{12} ≈ 1.995 mol O_2

Approximately 2 mol O_2 are required for complete combustion of 18 g of pentane.

Step 2: Considering Excess Oxygen

Suppose the initial oxygen supplied exceeds this amount—say, 10 mol O_2—then after combustion:
- All 0.2494 mol of pentane reacts.
- Remaining oxygen:
Remaining O_2 = Initial O_2 − O_2 consumed = 10 mol − 1.995 mol ≈ 8.005 mol

This leftover oxygen is significant for calculating the total volume of gases.

Calculating Gas Volumes at Standard Conditions

Standard Conditions Assumption

- Temperature: 0°C (273.15 K)
- Pressure: 1 atm
- 1 mol of gas occupies approximately 22.4 liters (L)

Step 1: Volume of Carbon Dioxide Produced

From the reaction:
0.2494 mol pentane produce:
5 mol CO_2 per mol C_5H_{12}

Total CO_2:
0.2494 mol × 5 = 1.247 mol

Volume of CO_2:
1.247 mol × 22.4 L/mol ≈ 27.94 liters

Step 2: Volume of Water Vapor

Similarly,:
6 mol H_2O per mol C_5H_{12}

Total H_2O vapor:
0.2494 mol × 6 = 1.496 mol

Volume of H_2O vapor:
1.496 mol × 22.4 L/mol ≈ 33.54 liters

Step 3: Volume of Leftover Oxygen

Remaining oxygen:
≈8.005 mol

Volume:
8.005 mol × 22.4 L/mol ≈ 179.2 liters

Step 4: Total Gas Volume

Total gases after combustion:
- CO_2: ~27.94 L
- H_2O vapor: ~33.54 L
- Excess O_2: ~179.2 L

Total volume:
27.94 + 33.54 + 179.2 ≈ 240.68 liters

Note: The total volume depends on the initial amount of oxygen supplied. If less oxygen is supplied (equal to the stoichiometric amount), the leftover oxygen volume would be zero, and the total gases would be approximately 61.48 liters (CO_2 + H_2O).

Implications and Real-World Applications

Environmental Impact

- Complete combustion minimizes soot and unburned hydrocarbons.
- Excess oxygen ensures complete combustion but results in more oxygen consumption and larger exhaust volumes.
- Understanding gas volumes helps in designing emission control systems.

Industrial Significance

- Accurate calculations aid in designing combustion chambers and reactors.
- Ensuring proper oxygen supply optimizes fuel efficiency and reduces emissions.
- Monitoring leftover oxygen helps prevent incomplete combustion, which produces pollutants like carbon monoxide and unburned hydrocarbons.

Safety Considerations

- Excess oxygen can pose fire and explosion hazards.
- Proper ventilation and monitoring are essential when handling combustible gases.

Conclusion

In summary, burning 18 grams of pentane involves a well-defined stoichiometric process. The combustion reaction consumes approximately 2 moles of oxygen per mole of pentane, producing carbon dioxide and water vapor. When oxygen is in excess, the leftover oxygen volume can be substantial—calculations show that approximately 179 liters of leftover oxygen remain after complete combustion of 18 grams of pentane, assuming an initial supply of 10 mol O_2. The total gaseous volume produced under standard conditions is around 240 liters, composed of CO_2, H_2O vapor, and excess oxygen.

Understanding these calculations is vital for applications in energy production, environmental management, and safety protocols in industries utilizing hydrocarbons. Accurate stoichiometric analysis ensures efficient operation and compliance with environmental standards, ultimately contributing to safer and more sustainable energy practices.

References:
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Frequently Asked Questions

What is the chemical reaction when 18 grams of pentane (C5H12) combusts with excess oxygen?

The combustion reaction of pentane is: 2 C_5H_{12} + 15 O_2 → 10 CO_2 + 12 H_2O.

How do you calculate the volume of gases produced during the combustion of 18 grams of pentane?

First, determine the moles of pentane, then use stoichiometry to find moles of gases produced, and finally apply the ideal gas law at the given conditions.

What is the leftover oxygen amount after burning 18 grams of pentane?

The reaction consumes 15 moles of O_2 per 2 moles of pentane; any excess oxygen remains leftover after complete combustion, quantifiable based on initial oxygen supplied.

How can I find the total volume of gases (CO_2 and residual O_2) after combustion at standard temperature and pressure?

Calculate moles of gases produced, then multiply by 22.4 L per mole at STP to find total volume.

What assumptions are made when calculating the volume of gases in this combustion reaction?

Assumptions include ideal gas behavior, constant temperature and pressure (STP), and complete combustion of pentane without side reactions.

If oxygen is leftover, how do you determine the amount of excess oxygen after the reaction?

Subtract the moles of oxygen consumed (based on the amount of pentane burned) from the initial moles of oxygen supplied to find the leftover oxygen.

Why is understanding the volume of gases important in combustion reactions like this?

It helps in calculating gas emissions, designing combustion systems, and understanding energy release and environmental impact.

Can the volume of gases be different from the ideal gas law predictions in real scenarios?

Yes, deviations can occur due to non-ideal gas behavior, temperature and pressure variations, and impurities, but ideal calculations provide a good approximation.

Additional Resources

18 Grams Of Pentane Go Through A Burning Reaction, Where Oxygen Is Leftover. What Would Be The Volume?

Understanding the combustion of hydrocarbons like pentane is essential in both academic chemistry and practical applications such as energy production. When analyzing what happens during the combustion of 18 grams of pentane, especially in the context of leftover oxygen, it's crucial to understand the underlying chemical principles, stoichiometry, and how to calculate the resulting volumes of gases involved. This guide will take you through a comprehensive breakdown of this process, step-by-step, to determine the volume of gases produced or consumed during this reaction.

Introduction to Combustion of Pentane

Pentane (C_5H_{12}) is a hydrocarbon with five carbon atoms and twelve hydrogen atoms. It is classified as an alkane, which is generally characterized by single bonds and a formula of C_nH_{2n+2}. Combustion of hydrocarbons involves reacting the fuel with oxygen (O_2) to produce carbon dioxide (CO_2) and water (H_2O).

The general combustion reaction for pentane is:

$C_5H_{12} + O_2 \rightarrow CO_2 + H_2O$

However, to perform calculations, the actual balanced chemical equation must be established.

Step 1: Write and Balance the Combustion Equation

The combustion of pentane involves reacting with oxygen to produce carbon dioxide and water. Balancing the reaction:

- Start with unbalanced equation:

$C_5H_{12} + O_2 \rightarrow CO_2 + H_2O$

- Balance carbon atoms:

$C_5H_{12} + O_2 \rightarrow 5\ CO_2 + H_2O$

- Balance hydrogen atoms:

$C_5H_{12} + O_2 \rightarrow 5\ CO_2 + 6\ H_2O$

- Count oxygen atoms on the right:

Oxygen in products = (5 × 2) + (6 × 1) = 10 + 6 = 16 oxygen atoms

- Balance oxygen atoms on the reactant side:

Oxygen molecules provide 2 oxygen atoms each, so:

O_2 molecules needed = 16 / 2 = 8

- The balanced reaction:

$C_5H_{12} + 8\ O_2 \rightarrow 5\ CO_2 + 6\ H_2O$

Step 2: Determine Moles of Pentane

Given mass of pentane: 18 grams

- Molecular weight of pentane (C_5H_{12}):

- Carbon (C): 12.01 g/mol

- Hydrogen (H): 1.008 g/mol

Calculation:

(5 × 12.01) + (12 × 1.008) = 60.05 + 12.096 = 72.146 g/mol

- Moles of pentane:

Number of moles = mass / molar mass = 18 g / 72.146 g/mol ≈ 0.2494 mol

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Step 3: Calculate the Required Oxygen and Leftover Oxygen

From the balanced equation:

- 1 mol of pentane reacts with 8 mol of O_2

- Moles of O_2 needed for 0.2494 mol of pentane:

0.2494 mol × 8 = 1.995 mol O_2

Suppose oxygen is in excess, with leftover oxygen remaining after the reaction. To determine the volume of leftover oxygen, we need to specify how much oxygen was initially present.

Step 4: Volume Calculations Using Ideal Gas Law

The ideal gas law relates the volume of a gas to the number of moles:

PV = nRT

At standard temperature and pressure (STP; 0°C and 1 atm), 1 mol of gas occupies approximately 22.4 liters.

- Volume of oxygen needed:

Volume = moles × 22.4 L/mol

- Volume of oxygen required:

1.995 mol × 22.4 L/mol ≈ 44.7 liters

If the initial volume of oxygen supplied was greater than this, the difference would be the leftover oxygen.

Step 5: Considering Leftover Oxygen

Let's assume an initial oxygen volume of 60 liters was supplied to ensure excess oxygen is present.

- Moles of initial oxygen:

Initial moles = 60 L / 22.4 L/mol ≈ 2.6786 mol

- Moles of oxygen reacted:

0.2494 mol × 8 = 1.995 mol (as calculated)

- Moles of leftover oxygen:

Remaining moles = 2.6786 mol – 1.995 mol ≈ 0.6836 mol

- Volume of leftover oxygen:

0.6836 mol × 22.4 L/mol ≈ 15.32 liters

Thus, approximately 15.3 liters of oxygen remain unreacted after the combustion of 18 grams of pentane when starting with 60 liters of oxygen.

Summary of Key Calculations

Parameter	Value
Moles of pentane	0.249 mol
Moles of O_2 needed	1.995 mol
Initial O_2 volume	60 L
Moles of initial O_2	2.679 mol
O_2 reacted	1.995 mol
Leftover O_2	0.684 mol
Leftover O_2 volume	15.3 L

Additional Considerations

1. Temperature and Pressure Variations

The calculations above assume STP conditions. In real-world scenarios, temperature and pressure may vary, affecting gas volumes. To account for this:

- Use the ideal gas law with actual temperature and pressure.

- Convert volumes using the ratio of actual to standard conditions:

V_actual = V_STP × (P_standard / P_actual) × (T_actual / T_standard)

2. Completeness and Reaction Efficiency

Not all combustion processes are perfectly efficient. Factors such as incomplete combustion or production of by-products like carbon monoxide (CO) can alter gas volumes.

3. Safety and Practical Implications

Handling large volumes of flammable gases like pentane vapor and oxygen requires strict safety protocols. Understanding the stoichiometry helps in designing safe combustion systems and minimizing wastage or leftover gases.

Conclusion

In this detailed analysis, we've determined that the combustion of 18 grams of pentane in an excess oxygen environment will consume approximately 2 liters of oxygen per mole of pentane, totaling about 44.7 liters. If you start with 60 liters of oxygen, roughly 15.3 liters of oxygen would remain unreacted after complete combustion.

This process exemplifies how stoichiometry, gas laws, and careful calculations enable chemists and engineers to predict combustion outcomes accurately, optimize fuel efficiency, and ensure safety in industrial applications. Whether for energy generation, environmental management, or academic research, understanding these principles is fundamental in linking chemical reactions to real-world gas volume changes.

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