How Many Grams Of Steam Are Produced When 675 Grams Of Oxygen Gas Combust?2c8h18 (l) + 2502 (g) -->

How Many Grams Of Steam Are Produced When 675 Grams Of Oxygen Gas Combust? C8H18 (l) + 2502 (g) -->

Understanding the amount of steam produced during the combustion of hydrocarbons like octane (C8H18) is essential in various fields, including chemical engineering, energy production, and environmental science. This article provides a comprehensive analysis of how to determine the grams of steam generated when 675 grams of oxygen gas are consumed during the combustion of octane, presenting the process step-by-step, grounded in stoichiometry principles.

Introduction to Combustion of Octane (C8H18)

The combustion of hydrocarbons such as octane (C8H18) is a fundamental chemical reaction, often studied in thermodynamics and chemical engineering. It involves the reaction of octane with oxygen (O_2) to produce carbon dioxide (CO_2) and water vapor (H_2O). The general combustion reaction for octane is:

$$\mathrm{C_8H_{18} + O_2 \rightarrow CO_2 + H_2O}$$

However, the complete balanced chemical equation for octane combustion is more detailed and specific, including coefficients that satisfy the conservation of atoms.

Balanced Chemical Equation for Octane Combustion

To accurately compute the amount of steam produced, the first step is to write and balance the chemical equation.

Unbalanced Equation:

$$\mathrm{C_8H_{18} + O_2 \rightarrow CO_2 + H_2O}$$

Balancing the Equation:

1. Balance carbon atoms:

$$\mathrm{C_8H_{18} + O_2 \rightarrow 8\,CO_2 + H_2O}$$

2. Balance hydrogen atoms:

$$\mathrm{C_8H_{18} + O_2 \rightarrow 8\,CO_2 + 9\,H_2O}$$

3. Balance oxygen atoms:

- On the right side, total oxygen atoms:

$$ (8 \times 2) + (9 \times 1) = 16 + 9 = 25 $$

- On the left side, oxygen appears as O_2 molecules; each O_2 provides 2 oxygen atoms, so:

$$ \mathrm{O_2} \text{ molecules} = \frac{25}{2} = 12.5 $$

- To eliminate fractional coefficients, multiply the entire equation by 2:

$$ 2\,C_8H_{18} + 25\,O_2 \rightarrow 16\,CO_2 + 18\,H_2O $$

Final Balanced Equation:

$$ \boxed{2\,C_8H_{18} + 25\,O_2 \rightarrow 16\,CO_2 + 18\,H_2O} $$

This balanced equation indicates that 25 moles of oxygen are required to completely combust 2 moles of octane, producing 16 moles of CO_2 and 18 moles of H_2O.

Calculating the Moles of Oxygen Consumed

Given that 675 grams of oxygen gas (O_2) are involved, the first step is to determine how many moles of oxygen this mass corresponds to.

Molar mass of O_2:

$$ \mathrm{O_2} = 16 \times 2 = 32\, \mathrm{g/mol} $$

Number of moles of oxygen:

$$ \text{Moles of } O_2 = \frac{\text{Mass of } O_2}{\text{Molar mass of } O_2} = \frac{675\,g}{32\,g/mol} \approx 21.09\, \text{mol} $$

Determining the Moles of Octane Combusted

The balanced chemical equation shows that:

- 25 mol of O_2 correspond to 2 mol of C_8H_{18}.

Therefore, the molar ratio is:

$$ \frac{2\, \text{mol C}_8\text{H}_{18}}{25\, \text{mol O}_2} $$

Using this ratio, the moles of octane combusted when 21.09 mol of oxygen are used:

$$ \text{Moles of } C_8H_{18} = \left(\frac{2}{25} \right) \times 21.09 \approx 1.69\, \text{mol} $$

Calculating the Moles of Water (Steam) Produced

From the balanced equation, 2 mol of octane produce 18 mol of water vapor (H_2O). Thus, the molar ratio of octane to water is:

$$\frac{18\, \text{mol } H_2O}{2\, \text{mol } C_8H_{18}} = 9$$

Therefore, the moles of water produced when 1.69 mol of octane are combusted:

$$\text{Moles of } H_2O = 1.69 \times 9 \approx 15.21\, \text{mol}$$

Converting Moles of Water to Grams

The molar mass of water:

$$\mathrm{H_2O} = (2 \times 1) + 16 = 18\, \mathrm{g/mol}$$

Total grams of steam produced:

$$\text{Mass of } H_2O = 15.21\, \text{mol} \times 18\, \mathrm{g/mol} \approx 273.78\, \text{g}$$

Final Result: How Many Grams of Steam Are Produced?

Answer:

When 675 grams of oxygen gas are combusted with octane according to the balanced chemical equation, approximately 273.78 grams of steam (water vapor) are produced.

Additional Considerations and Real-World Applications

Understanding the theoretical yield of steam during hydrocarbon combustion is crucial for:

- Energy efficiency calculations: Estimating how much water vapor is produced in fuel combustion processes.
- Environmental impact assessments: Recognizing water vapor emissions from combustion engines or power plants.
- Design of combustion systems: Ensuring proper handling of exhaust gases and vapor recovery.

Factors affecting actual steam production:

- Incomplete combustion leading to less water formation.
- Variations in reaction conditions and impurities.
- Practical losses during industrial processes.

Summary of Key Steps for Calculations

To determine the grams of steam produced during hydrocarbon combustion, follow this structured approach:

1. Write and balance the chemical combustion equation.
2. Convert given mass of reactant (oxygen) to moles.
3. Use mole ratios from the balanced equation to find moles of hydrocarbon combusted.
4. Determine moles of water produced based on the molar ratio.
5. Convert moles of water to grams using molar mass.
6. Interpret the results in the context of the specific reaction.

Conclusion

Calculating the amount of steam produced during the combustion of octane provides valuable insights into the chemical process's efficiency and by-products. Based on the stoichiometric calculations, approximately 273.78 grams of water vapor are generated when 675 grams of oxygen are consumed during the complete combustion of octane. Such calculations are fundamental in chemical engineering, fuel efficiency analysis, and environmental management.

FAQs

Q1: Can the actual steam produced be more or less than the calculated value?
Yes, actual conditions such as incomplete combustion, impurities, and system inefficiencies can lead to variations.

Q2: How is the amount of oxygen supplied in real-world combustion systems controlled?
Through precise fuel-to-air ratio control in burners and engines.

Q3: Why is understanding water vapor production important?
Because water vapor impacts exhaust composition, environmental emissions, and energy efficiency.

Q4: Is the calculated water vapor in the gaseous form?
Yes, under typical combustion conditions, water is produced as vapor.

Q5: How does this calculation apply to other hydrocarbons?
The same principles apply; just the balanced chemical equation and molar ratios change accordingly.

By mastering these calculations, engineers and scientists can optimize combustion processes, reduce environmental impact, and improve energy utilization.

Frequently Asked Questions

How do you calculate the amount of steam produced when 675 grams of oxygen gas combusts with 2C8H18?

To determine the amount of steam produced, first write the balanced combustion equation, find the molar ratios, calculate moles of oxygen combusted, and then use the stoichiometric ratios to find the moles of water produced, converting that to grams.

What is the balanced chemical equation for the combustion of octane (C8H18) with oxygen?

The balanced equation is 2 C8H18 + 25 O2 ? 16 CO2 + 18 H2O.

How many grams of water (steam) are produced when 675 grams of oxygen gas combusts according to the equation?

Using the molar ratios, 675 grams of O2 corresponds to approximately 129.6 grams of H2O produced during combustion.

What is the molar mass of oxygen gas (O2) and water (H2O), and how are they used in calculations?

Oxygen (O2) has a molar mass of 32 g/mol, and water (H2O) has a molar mass of 18 g/mol. These are used to convert between mass and moles for stoichiometric calculations.

Can you explain how to determine the limiting reagent in this combustion reaction?

Since the problem states a specific amount of oxygen, if the amount of octane is sufficient, oxygen is the limiting reagent. Calculations compare the molar amounts to identify which reactant is limiting.

What is the significance of converting grams to moles in combustion calculations?

Converting grams to moles allows us to use the molar ratios from the balanced equation to accurately determine the amount of products formed, such as water (steam).

Are there any assumptions made when calculating the amount of steam produced in this reaction?

Yes, assumptions include complete combustion with no side reactions, ideal gas behavior, and that all oxygen reacts fully to produce water, without losses or impurities.

Additional Resources

How Many Grams Of Steam Are Produced When 675 Grams Of Oxygen Gas Combust?

Understanding the precise amount of steam produced during combustion reactions is fundamental in fields ranging from chemical engineering and environmental science to energy production and industrial processes. This detailed investigation explores the combustion of 2c8h18 (octane) with oxygen, focusing on calculating the grams of steam generated when 675 grams of oxygen gas are involved. The process involves a thorough examination of the reaction stoichiometry, molar relationships, and practical considerations for real-world

applications.

Introduction to Combustion of Octane and Its Significance

Combustion reactions are exothermic processes where a hydrocarbon reacts with oxygen to produce carbon dioxide, water (as vapor or liquid), and energy. Octane (C_8H_{18}) is a primary component of gasoline and a common hydrocarbon used in combustion studies due to its well-characterized chemical properties.

The general combustion reaction for octane is:

$C_8H_{18} + O_2 \rightarrow CO_2 + H_2O + \text{energy}$

In a complete combustion scenario, octane reacts with oxygen to produce carbon dioxide and water vapor. The amount of water (steam) produced is directly related to the amount of octane burned and the oxygen supplied.

Understanding the Reaction: Combustion of C_8H_{18}

Balanced Chemical Equation

To determine the grams of steam produced, we first need the balanced chemical equation for the combustion of octane:

$C_8H_{18} + \frac{25}{2} O_2 \rightarrow 8 CO_2 + 9 H_2O$

Multiplying through by 2 to clear fractions:

$2 C_8H_{18} + 25 O_2 \rightarrow 16 CO_2 + 18 H_2O$

Key Points:

- 2 moles of octane react with 25 moles of oxygen.
- The reaction produces 18 moles of water vapor.

This stoichiometry will serve as the foundation for our calculations.

Calculating Molar Quantities: From Grams to Moles

Step 1: Determine the molar mass of octane (C_8H_{18})

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

Molar mass of C8H18:

= (8 × 12.01) + (18 × 1.008)
= 96.08 + 18.144
= 114.224 g/mol

Step 2: Determine the molar amount of oxygen supplied (675 grams)

- Molar mass of O2:

Oxygen (O): 16.00 g/mol
Oxygen molecule (O2): 32.00 g/mol

Number of moles of O2:

= 675 g / 32.00 g/mol
≈ 21.09 mol

Using Stoichiometry to Find Water Produced

Step 3: Establish molar relationships

From the balanced reaction:

2 C8H18 + 25 O2 → 18 H2O

- 2 mol C8H18 produces 18 mol H2O
- Therefore, 1 mol C8H18 produces 9 mol H2O

Since oxygen is the limiting reagent, we need to determine how much octane corresponds to the available oxygen.

Step 4: Find the amount of octane that reacts with 21.09 mol of O2

Molar ratio:

25 mol O2 : 2 mol C8H18

Thus,

Number of moles of octane reacting:

= (21.09 mol O2) × (2 mol C8H18 / 25 mol O2)
= 21.09 × 0.08
≈ 1.687 mol C8H18

Step 5: Calculate moles of water produced

Using the molar ratio:

1 mol C8H18 → 9 mol H2O

So,

Moles of H2O produced:

= 1.687 mol C8H18 × 9 mol H2O / 1 mol C8H18
≈ 15.183 mol H2O

Converting Moles of Water to Grams of Steam

Step 6: Molar mass of water (H2O)

- Hydrogen: 1.008 g/mol
- Oxygen: 16.00 g/mol

Molar mass of H2O:

= (2 × 1.008) + 16.00
= 2.016 + 16.00
= 18.016 g/mol

Step 7: Total grams of steam (water vapor)

Mass of water:

= 15.183 mol × 18.016 g/mol
≈ 273.4 grams

Summary of Findings

Based on the stoichiometric calculations:

- When 675 grams of oxygen are combusted with octane (C8H18), approximately 273.4 grams of steam (water vapor) are produced.

This calculation assumes complete combustion, ideal conditions, and no side reactions or losses.

Additional Considerations and Practical Implications

1. Reaction Efficiency and Real-World Conditions

In practical combustion systems, factors such as incomplete combustion, impurities, and heat losses can influence the actual amount of water produced. Typically, the theoretical yield provides an upper limit, with real yields often somewhat lower.

2. Role of Excess Oxygen

The calculation assumes oxygen is the limiting reagent. In real engines or industrial burners, excess oxygen might be present, leading to increased production of water, but not proportional to the oxygen supplied.

3. State of Water: Vapor or Liquid?

The calculation assumes water remains as vapor (steam). Under certain conditions, water may condense into liquid, affecting measurement and utilization.

4. Environmental and Energy Considerations

The production of water vapor during combustion is a critical factor in environmental emissions. Understanding the quantities involved aids in designing cleaner and more efficient combustion systems.

Conclusion

Through a detailed analysis rooted in stoichiometry and chemical principles, we have determined that burning 675 grams of oxygen with octane produces approximately 273 grams of steam. This insight is valuable for engineers, chemists, and environmental scientists seeking to quantify water vapor emissions, optimize combustion processes, or develop energy-efficient systems.

The methodology demonstrated here underscores the importance of balanced chemical equations, molar conversions, and reaction ratios in practical calculations involving real-world chemical reactions. Accurately predicting the amount of steam generated not only aids in process control but also enhances our understanding of combustion's environmental impact and efficiency.

References

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Note: All calculations are theoretical and assume ideal conditions. Real-world results may vary due to system inefficiencies and environmental factors.

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