

Calculate The SO₂ Concentration In Flue Gas When 100 Moles Of C₇H₁₃ Containing 5% Sulphur Is Burnt In

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Understanding how to calculate sulfur dioxide (SO₂) concentration in flue gases is essential for environmental engineers, combustion specialists, and pollution control professionals. When hydrocarbons containing sulfur are burned, sulfur compounds are converted into SO₂, which can contribute to acid rain and atmospheric pollution. This article provides a comprehensive guide to calculating the SO₂ concentration in flue gases resulting from the combustion of 100 moles of C₇H₁₃ containing 5% sulfur. Through step-by-step analysis, relevant chemical reactions, and calculation methods, readers will gain a thorough understanding of the process involved.

Introduction to Sulfur in Hydrocarbon Combustion

Sulfur is a common impurity found in various fuels and hydrocarbons. When these fuels are burned, sulfur oxidizes to form sulfur oxides, primarily SO₂ and SO₃, with SO₂ being the predominant form under typical combustion conditions. The concentration of SO₂ in flue gases depends on:

- The amount of sulfur present in the fuel.
- The combustion process conditions.
- The extent of oxidation during combustion.

Recognizing these factors helps in designing emission control systems and complying with environmental standards.

Understanding the Composition of the Fuel (C₇H₁₃) Containing Sulfur

Before calculating SO₂ emissions, it is crucial to understand the composition of the hydrocarbon fuel:

Details of the Fuel

- The hydrocarbon is C₇H₁₃.
- It contains 5% sulfur by weight.

Key points:

- The sulfur is present as an impurity within the hydrocarbon.
- The total moles of hydrocarbon burned are 100 moles.

Calculating the Amount of Sulfur in the Fuel

To determine the sulfur content:

1. Find the molar mass of C₇H₁₃.
2. Calculate the total weight of 100 moles of C₇H₁₃.
3. Use the 5% sulfur content to find the mass of sulfur.

Step-by-step Calculation:

- Molar mass of C₇H₁₃:
- Carbon (C): 12.01 g/mol
- Hydrogen (H): 1.008 g/mol

$$M_{\text{C}_7\text{H}_{13}} = (7 \times 12.01) + (13 \times 1.008) = 84.07 + 13.104 = 97.174, \text{ g/mol}$$

- Total mass of 100 moles:

$$100 \times 97.174 = 9717.4, \text{ g}$$

- Mass of sulfur in the fuel:
- Since sulfur is 5% by weight:

$$\text{Mass of sulfur} = 0.05 \times 9717.4 = 485.87, \text{ g}$$

- Convert sulfur mass to moles:

- Atomic mass of sulfur (S): 32.06 g/mol

$$\text{Moles of S} = \frac{485.87}{32.06} \approx 15.17, \text{ moles}$$

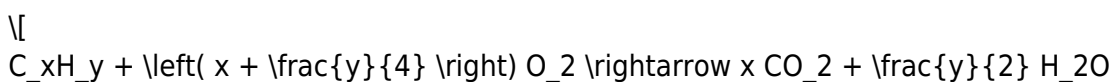
Thus, the total sulfur present in the 100 moles of fuel is approximately 15.17 moles.

Combustion Reaction of C₇H₁₃ with Sulfur

The combustion process of hydrocarbons involves reacting with oxygen, producing CO₂ and H₂O. The sulfur impurity combusts to form SO₂.

General Combustion Reactions:

- Hydrocarbon:



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- Sulfur:

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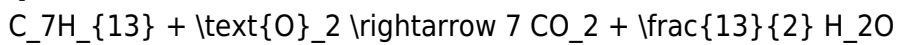
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Note: Under complete combustion conditions, all sulfur converts to SO_2 .

Specific Reaction for C_7H_{13} with Sulfur

- Combustion of hydrocarbon:

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- Combustion of sulfur:

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Since the sulfur content is known, the total amount of sulfur combusted is approximately 15.17 moles, producing an equal number of moles of SO_2 .

Calculating the Total Moles of Flue Gas Produced

To determine the SO_2 concentration, we need to find the total moles of gases emitted during combustion.

Step 1: Moles of Hydrocarbon Consumed

- Given: 100 moles of C_7H_{13} .

- Since each mole of hydrocarbon burns completely, the total moles of gases produced from hydrocarbon combustion are:

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$$\text{CO}_2: 7 \times 100 = 700, \text{ moles}$$

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$$\text{H}_2\text{O}: \frac{13}{2} \times 100 = 650, \text{ moles}$$

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Note: In flue gases, water vapor may condense depending on temperature, but for this calculation, we assume all gases remain in the vapor phase.

Step 2: Moles of SO₂ Produced

- Since 15.17 moles of sulfur are burned:

$$\text{SO}_2: 15.17, \text{ moles}$$

Step 3: Total Moles of Flue Gas

- Total moles:

$$\text{Total} = 700, (\text{CO}_2) + 650, (\text{H}_2\text{O}) + 15.17, (\text{SO}_2) = 1365.17, \text{ moles}$$

Additional gases: Depending on excess air and combustion efficiency, nitrogen and excess oxygen may also be present, but in this simplified calculation, we focus on the primary combustion products.

Calculating SO₂ Concentration in Flue Gas

The concentration of SO₂ in the flue gas is typically expressed in parts per million (ppm) by volume or as a percentage.

Method 1: Part per Million (ppm)

- The molar concentration of SO₂:

$$\text{SO}_2, \text{ ppm} = \frac{\text{Moles of SO}_2}{\text{Total moles of gases}} \times 10^6$$

- Substituting the values:

$$\text{SO}_2, \text{ ppm} = \frac{15.17}{1365.17} \times 10^6 \approx 11,100, \text{ ppm}$$

Interpretation: The SO₂ concentration is approximately 11,100 ppm by volume.

Method 2: Percentage Concentration

- Percentage by volume:

$$\text{SO}_2, \% = \frac{\text{Moles of SO}_2}{\text{Total moles of gases}} \times 100$$

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- Calculation:

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$$\text{SO}_2, \% = \frac{15.17}{1365.17} \times 100 \approx 1.11\%$$

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Conclusion: The SO₂ concentration in the flue gas is approximately 1.11% by volume.

Additional Factors Influencing SO₂ Concentration

While the above calculation provides a baseline estimate, real-world scenarios involve several additional factors:

1. Excess Air and Combustion Efficiency

- Excess air can dilute SO₂ concentrations.
- Incomplete combustion may alter the amount of SO₂ produced.

2. Temperature and Flue Gas Composition

- Temperature affects water vapor condensation.
- Flue gases may contain other nitrogen oxides, CO, unburned hydrocarbons, etc.

3. Pollution Control Devices

- Scrubbers and catalytic converters can reduce SO₂ emissions before release.

Environmental Implications and Compliance

Knowing the SO₂ concentration in flue gases is vital for environmental compliance:

- Regulatory agencies set limits on SO₂ emissions (e.g., EPA standards).
- Proper calculation helps in designing emission control systems.
- Monitoring SO₂ levels prevents environmental damage such as acid rain and respiratory issues.

Summary and Key Takeaways

- Burning 100 moles of C₇H₁₃ with 5% sulfur results in approximately 15.17 moles of sulfur.
- Complete combustion converts sulfur to SO₂, totaling around 15.17 moles of SO₂.
- Total moles of flue gases are roughly 1365.17.
- The SO₂ concentration in flue gas is estimated at about 1.11% by volume or 11,100 ppm.

Final Remarks

Calculating SO

Frequently Asked Questions

How do you determine the SO₂ concentration in flue gas when burning C₇H₁₃ containing sulfur?

First, calculate the amount of sulfur in the fuel, then determine the amount of SO₂ formed during combustion, and finally, express the SO₂ amount as a concentration in the flue gas, typically in parts per million (ppm).

What is the process to find the amount of sulfur in 100 moles of C₇H₁₃ with 5% sulfur content?

Multiply the total moles of fuel (100 mol) by the sulfur percentage (5%), resulting in 5 moles of sulfur present in the fuel.

How is the amount of SO₂ produced related to the sulfur content in the fuel?

Since each mole of sulfur forms one mole of SO₂ upon combustion, 5 moles of sulfur produce 5 moles of SO₂ gas.

What is the total moles of flue gas produced during combustion of 100 moles of C₇H₁₃?

This depends on the complete combustion reaction, but typically, combustion produces CO₂ and H₂O; the total moles can be calculated based on stoichiometry, adding the moles of gases produced.

How do you calculate SO₂ concentration in ppm in the flue gas?

Use the formula: (moles of SO₂ / total moles of flue gases) × 10⁶ to get the concentration in ppm.

If 5 moles of SO₂ are produced in the combustion process, how do you find its concentration in the flue gases?

Divide 5 moles of SO₂ by the total moles of flue gases produced, then multiply by 10⁶ to convert to ppm.

What assumptions are typically made in calculating SO₂ concentration for such combustion processes?

Assumptions include complete combustion, no formation of other sulfur compounds, and that all sulfur in the fuel converts to SO₂ without losses or side reactions.

Why is understanding SO₂ concentration in flue gases important?

Monitoring SO₂ levels is crucial for environmental protection, regulatory compliance, and designing pollution control systems like scrubbers to reduce sulfur emissions.

Additional Resources

Calculate The SO₂ Concentration In Flue Gas When 100 Moles Of C₇H₁₃ Containing 5% Sulphur Is Burnt In

Introduction

Understanding the formation and concentration of sulfur dioxide (SO₂) in flue gases is crucial for environmental monitoring and pollution control. When hydrocarbons containing sulfur are combusted, sulfur is oxidized to form SO₂, a significant pollutant responsible for acid rain and respiratory issues. This article provides a comprehensive analysis of calculating the SO₂ concentration in the flue gases produced from burning a specific hydrocarbon—C₇H₁₃—with a known sulfur content. The focus is on the step-by-step calculation process, including chemical reactions, molar considerations, and implications for environmental standards.

Fundamental Concepts and Background

Understanding Hydrocarbon Composition and Sulfur Content

The hydrocarbon in question, C₇H₁₃, is a heptane derivative with an empirical formula indicating a mixture of alkanes or branched hydrocarbons. The critical detail here is that the compound contains 5% sulfur by weight. This percentage directly influences the amount of sulfur available during combustion and consequently the amount of SO₂ produced.

Combustion Process Overview

Combustion of hydrocarbons is a chemical oxidation process where the hydrocarbon reacts with oxygen (O₂) to produce carbon dioxide (CO₂) and water (H₂O). When sulfur is present, it is oxidized to sulfur oxides, primarily SO₂, under typical combustion conditions. The general combustion reactions involve:

- Hydrocarbon oxidation: $C_nH_m + O_2 \rightarrow CO_2 + H_2O$
- Sulfur oxidation: $S + O_2 \rightarrow SO_2$

The combustion temperature, oxygen availability, and other operational parameters influence the extent of sulfur oxidation and the formation of SO₂.

Calculating the Total Sulfur Content in the Hydrocarbon Mixture

Step 1: Determine the Mass of Sulfur in 100 Moles of C₇H₁₃

Given:

- Total moles of hydrocarbon = 100 mol
- Sulfur content = 5% by weight

Calculating molar masses:

- Molar mass of C₇H₁₃:

$$\begin{aligned} & \backslash [\\ & (7 \times 12.01) + (13 \times 1.008) = 84.07 + 13.104 = 97.174, \text{ g/mol} \\ & \backslash] \end{aligned}$$

- Total mass of 100 mol of C₇H₁₃:

$$\begin{aligned} & \backslash [\\ & 100 \times 97.174 = 9717.4, \text{ g} \\ & \backslash] \end{aligned}$$

Determining sulfur mass:

Since sulfur constitutes 5% by weight:

$$\begin{aligned} & \backslash [\\ & \text{Mass of sulfur} = 0.05 \times 9717.4 = 485.87, \text{ g} \end{aligned}$$

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Number of moles of sulfur:

- Atomic mass of sulfur (S) ≈ 32.06 g/mol

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$$\text{Moles of sulfur} = \frac{485.87}{32.06} \approx 15.16, \text{ mol}$$

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Conclusion:

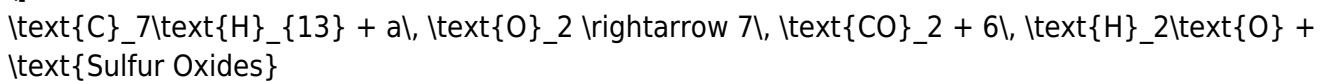
- Total sulfur present in the hydrocarbon mixture = approximately 15.16 mol

Stoichiometry of Combustion and SO₂ Formation

Step 2: Establishing the Combustion Reaction

The combustion of C₇H₁₃ with sulfur content, assuming complete oxidation, can be represented as:

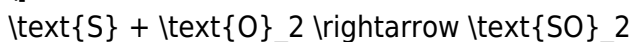
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The exact amount of oxygen required depends on the hydrocarbon's composition, but for sulfur, the oxidation is straightforward:

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Given complete oxidation, all sulfur is converted to SO₂.

Note: The combustion process may produce some SO₃, but under typical conditions, SO₂ is the primary sulfur oxide formed.

Step 3: Moles of SO₂ Produced

Since 15.16 mol of sulfur are present, and each mol of sulfur yields one mol of SO₂:

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$$\text{Moles of SO}_2 = 15.16, \text{ mol}$$

\]

This is the theoretical maximum amount of SO₂ generated assuming complete oxidation.

Calculating Flue Gas Composition and SO₂ Concentration

Step 4: Estimating the Total Moles of Flue Gas

The total moles of flue gases depend on the combustion process, specifically:

- The amount of oxygen supplied
- The amount of excess air (if any)
- Combustion of hydrocarbons producing CO₂ and H₂O
- The oxidation of sulfur producing SO₂

Assumption: Complete combustion with excess oxygen is typical for safety and efficiency. For calculation simplicity, assume a theoretical stoichiometric combustion with no excess air, and consider the oxygen supplied as part of the combustion.

Molar calculations:

- Moles of hydrocarbon burned = 100 mol
- Moles of sulfur burned = 15.16 mol
- Oxygen required for hydrocarbon oxidation (for C₇H₁₃):

The combustion of C₇H₁₃:



(Derived from balancing: 7 carbons require 14 O, 13 hydrogens require 6.5 O, total 20.5 O atoms, or 10.25 mol O₂ per mol hydrocarbon. For simplicity, approximate as 10.5 mol O₂ per mol C₇H₁₃.)

- Moles of oxygen required for 100 mol hydrocarbon:

$$100 \times 10.5 = 1050 \text{ mol}$$

- Moles of oxygen for sulfur oxidation:

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$15.16 \text{ mol S} \rightarrow 15.16 \text{ mol SO}_2$

Each mol SO₂ formation consumes 1 mol O₂:

15.16 mol O_2

- Total oxygen consumption:

$1050 + 15.16 \approx 1065.16 \text{ mol}$

- Total moles of gases produced:

- From hydrocarbon:

- 100 mol C₇H₁₃ produces:

- 7 mol CO₂ per mol hydrocarbon: $(100 \times 7 = 700 \text{ mol})$

- 6.5 mol H₂O per mol hydrocarbon: $(100 \times 6.5 = 650 \text{ mol})$

- From sulfur oxidation:

- 15.16 mol SO₂

- Remaining oxygen in flue gas:

- Moles of excess O₂:

$\text{Oxygen supplied} - \text{Oxygen consumed} = 1065.16 - (1050 + 15.16) = 0 \text{ mol}$

Assuming stoichiometric combustion, all oxygen is consumed.

Total moles of flue gases:

$700 \text{ mol CO}_2 + 650 \text{ mol H}_2\text{O} + 15.16 \text{ mol SO}_2 = 1365.16 \text{ mol}$

Step 5: Calculating SO₂ Concentration in the Flue Gas

The concentration of SO₂ in the flue gas can be expressed as a volume percentage or molar fraction.

Molar fraction of SO₂:

$\text{Molar fraction of SO}_2 = \frac{15.16}{1365.16}$

$$\text{Mole fraction of SO}_2 = \frac{15.16}{1365.16} \approx 0.0111$$

Volume percentage of SO₂:

Assuming ideal gas behavior at standard conditions, molar fractions translate directly to volume percentages:

$$\text{SO}_2 \text{ concentration} \approx 1.11\%$$

This indicates that under idealized conditions, approximately 1.11% of the flue gas volume is SO₂.

Environmental and Practical Implications

Pollution Control and Emission Standards

The calculated SO₂ concentration highlights the importance of emission controls in combustion processes involving sulfur-containing fuels. Regulatory standards often limit SO₂ emissions to prevent acid rain and protect air quality. The typical permissible SO₂ concentration in flue gases varies by jurisdiction but often ranges below 0.5% by volume,

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