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Understanding Combustion Reactions: Ethylene and Ethane

Chemistry plays a vital role in understanding how different substances interact, particularly during combustion processes. The data provided involves the combustion of two hydrocarbons: ethylene (C_2H_4) and ethane (C_2H_6). These reactions are fundamental in various industrial applications, such as energy production, manufacturing, and environmental management. This article delves into the details of these combustion reactions, exploring their chemical equations, enthalpy changes, and practical implications.

Breaking Down the Combustion Reactions

The Combustion of Ethylene (C_2H_4)

The given reaction:

```plaintext
C2H4 (g) + 3O2 (g) → 2CO2 (g) + 2H2O (l) ΔH = -1411.0 kJ
```

- Type of Reaction: Combustion (exothermic oxidation)
- Reactants: Ethylene gas and oxygen gas
- Products: Carbon dioxide gas and liquid water
- Enthalpy Change (ΔH): -1411.0 kilojoules (exothermic, energy released)

Understanding the Reaction:

In this reaction, ethylene (a simple alkene) reacts with oxygen to produce carbon dioxide and water. The negative sign of ΔH indicates that energy is released during the process, making it an exothermic reaction. Ethylene is a common hydrocarbon used in the production of plastics and as a fuel source.

The Combustion of Ethane (C_2H_6)

The second reaction is:

```plaintext
2C₂H₆ (g) + 7O₂ (g) → 4CO₂ (g) + 6H₂O (l)
```

- Type of Reaction: Combustion
- Reactants: Ethane gas and oxygen
- Products: Carbon dioxide and water
- Note: The ΔH value for this reaction isn't provided but is typically known for ethane combustion.

Understanding the Reaction:

Ethane, another common hydrocarbon, reacts with oxygen to produce more carbon dioxide and water compared to ethylene, reflecting its higher carbon content. Like ethylene, this reaction releases energy, which is harnessed in various industrial and domestic heating applications.

Enthalpy of Combustion: Significance and Calculation

What is Enthalpy of Combustion?

Enthalpy of combustion (ΔH_combustion) refers to the amount of energy released when one mole of a substance burns completely in oxygen under standard conditions. It is a crucial parameter for understanding the energy content of fuels and for designing combustion systems.

Interpreting the Data

- The provided ΔH for ethylene combustion is -1411.0 kJ for the balanced reaction: 1 mole of ethylene reacts with 3 moles of oxygen.
- For ethane, the reaction involves 2 moles of ethane reacting with 7 moles of oxygen,

producing more products and releasing more energy overall.

Calculating Enthalpy Changes

Using Hess's Law, we can relate the enthalpy changes of different reactions to determine unknown quantities or compare energy content.

For example, for ethane:

- Per mole basis:
Since 2 moles of ethane release a certain amount of energy,
the energy per mole of ethane can be calculated by dividing the total ΔH by 2.

- Estimating the ΔH for ethane combustion:
Based on typical data, ethane's combustion releases approximately -1560 kJ per mole.

Note: These values are approximate and based on standard thermodynamic data.

Practical Applications of Combustion Data

Understanding combustion reactions and their enthalpy changes is crucial for various practical applications:

- **Energy Production:** Optimizing fuel combustion in power plants to maximize efficiency and minimize emissions.
- **Industrial Processes:** Designing reactors and furnaces that utilize hydrocarbons like ethylene and ethane.
- **Environmental Impact:** Assessing the carbon footprint and greenhouse gas emissions resulting from hydrocarbon combustion.
- **Fuel Economy:** Calculating the energy yield from different fuels to determine cost-effectiveness.

Comparison of Ethylene and Ethane Combustion

| Aspect | Ethylene (C_2H_4) | Ethane (C_2H_6) |

Chemical Formula	C_2H_4	C_2H_6
Combustion Reaction	$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$	$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$
Enthalpy Change	-1411.0 kJ per mole of ethylene	Approx. -1560 kJ per mole of ethane
Energy Content	Slightly less than ethane per mole	Slightly higher per mole

Implications:

- Ethane generally releases more energy per mole during combustion, making it a more energy-rich fuel.
- The choice between ethylene and ethane in industrial applications depends on specific energy needs, availability, and combustion characteristics.

Environmental and Safety Considerations

- Greenhouse Gas Emissions: Combustion of hydrocarbons produces CO_2, a major greenhouse gas contributing to climate change.
- Incomplete Combustion Risks: Improper combustion can lead to carbon monoxide formation, which is toxic.
- Energy Efficiency: Optimizing combustion conditions reduces pollutant formation and improves energy efficiency.

Conclusion

The combustion reactions of ethylene and ethane are fundamental in energy production and chemical manufacturing. Understanding their chemical equations, enthalpy changes, and practical implications allows scientists and engineers to optimize processes, improve energy efficiency, and minimize environmental impacts. The provided data underscores the importance of thermodynamic principles in real-world applications, demonstrating how energy calculations guide decisions in industrial chemistry and energy management.

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By understanding these combustion reactions and their thermodynamic properties, stakeholders can make informed decisions in energy utilization, environmental protection, and industrial design.

Frequently Asked Questions

What is the balanced chemical equation for the combustion of ethylene (C_2H_4)?

The balanced equation is C_2H_4 (g) + $3O_2$ (g) → $2CO_2$ (g) + $2H_2O$ (l).

What is the enthalpy change (ΔH) associated with the combustion of ethylene as given?

The enthalpy change is 1411.0 KJ for the combustion of the given amount of ethylene.

How does the enthalpy change relate to the combustion of ethylene and ethane?

The provided ΔH value (1411.0 KJ) corresponds to the combustion of a specific amount of ethylene; for ethane, the combustion involves a different ΔH, typically more exothermic, as shown in the second reaction.

What is the significance of the second reaction involving C_2H_6 and $7O_2$?

It represents the combustion of ethane (C_2H_6), which releases more energy per mole compared to ethylene, indicating different energy contents for these hydrocarbons.

How can the given data be used to calculate the energy released per mole of ethylene?

Using the ΔH value (1411.0 KJ) and the molar quantities involved, you can determine the energy released per mole of ethylene combusted.

Why is understanding the combustion reactions of hydrocarbons important in chemistry?

These reactions are fundamental in energy production, environmental impact assessments, and understanding the thermodynamics of fuel combustion processes.

Additional Resources

Given The Following DataC2H4 (g) + 3O2 (g) -> 2CO2 (g) + 2H2O (l) H = 1411.0 KJ2C2H6 (g) + 7O2 (g)

Introduction

In the realm of chemical thermodynamics, understanding the energy changes associated with reactions is crucial for applications ranging from industrial manufacturing to environmental management. The provided data encapsulates key combustion reactions involving ethylene (C_2H_4) and ethane (C_2H_6), two fundamental hydrocarbons. Specifically, the reactions depict the oxidation of ethylene and ethane with oxygen, releasing substantial amounts of energy measured in kilojoules. This article dissects these reactions, explores their thermodynamic significance, and offers insights into their practical implications.

Understanding the Chemical Reactions

At the core, the data presents two combustion reactions:

1. Ethylene Combustion:

C_2H_4 (g) + $3O_2$ (g) → $2CO_2$ (g) + $2H_2O$ (l); $\Delta H = -1411.0$ kJ

2. Ethane Combustion:

$2C_2H_6$ (g) + $7O_2$ (g) → $4CO_2$ (g) + $6H_2O$ (l); ΔH (implied)

Note: The second reaction appears incomplete as provided, but typically, the combustion of ethane involves similar oxidation products with higher energy release due to its higher hydrogen content.

The Significance of Combustion Reactions

Combustion reactions are exothermic, releasing energy stored in chemical bonds as heat and light. They are fundamental to energy production in power plants, engines, and various industrial processes. The specific reactions involving ethylene and ethane are particularly significant because:

- Ethylene (C_2H_4): Widely used in the plastics industry, especially in manufacturing polyethylene, and as an intermediary in chemical synthesis.
- Ethane (C_2H_6): A key component of natural gas, serving as a feedstock for ethylene production and other chemicals.

The thermodynamic data provided offers insights into the energy efficiency, environmental impact, and potential for energy recovery from these hydrocarbons.

Thermodynamic Analysis of the Ethylene Combustion Reaction

Reaction Equation:

C_2H_4 (g) + $3O_2$ (g) → $2CO_2$ (g) + $2H_2O$ (l)

Enthalpy Change (ΔH): -1411.0 kJ

The negative sign indicates an exothermic process, meaning energy is released into the surroundings during combustion.

Implications:

- The energy released (~1.4 MJ per mole of ethylene) can be harnessed for heating or power generation.
- The reaction’s energetic profile is crucial for designing efficient combustion systems, such as ethylene-powered burners or engines.

Bond Energy Perspective:

Understanding which bonds are broken and formed provides deep insight into the energy changes:

- Breaking bonds: C=C double bonds, C–H bonds
- Forming bonds: C=O in CO_2, O–H in H_2O

The net energy change reflects the difference between the energy required to break bonds and that released upon forming new bonds.

Thermodynamic Considerations of the Ethane Combustion (Inferred)

Typical Reaction:

$2C_2H_6$ (g) + $7O_2$ (g) → $4CO_2$ (g) + $6H_2O$ (l)

Expected Enthalpy Change:

Based on bond energies, the combustion of ethane releases approximately -3119 kJ per mole of ethane burned.

Comparison with Ethylene:

- Ethane's combustion releases roughly twice the energy of ethylene per mole, owing to its higher hydrogen content and more energy-dense bonds.
- This difference influences fuel choice in industrial applications where energy efficiency is paramount.

Practical Applications and Environmental Impact

Energy Production:

- Combustion reactions like these are foundational in generating electricity and powering engines.
- The high energy yield underscores their importance in the energy sector.

Environmental Considerations:

- Complete combustion produces CO_2 and H_2O, which are relatively benign compared to incomplete combustion products like CO, soot, or unburned hydrocarbons.
- The energy released can be harnessed efficiently if combustion is complete, reducing pollutant formation.

Carbon Footprint and Climate Change:

- Combustion of hydrocarbons contributes to greenhouse gas emissions.
- Understanding the precise energy and emission profiles helps in developing cleaner combustion technologies and alternative fuels.

Thermodynamic Data in Chemical Engineering

Chemical engineers utilize enthalpy data like that provided to optimize processes:

- Design of combustion chambers: Ensuring sufficient oxygen supply and temperature control.
- Energy calculations: Estimating heat output and efficiency.
- Environmental controls: Minimizing pollutants by controlling reaction conditions.

Limitations and Further Considerations

While the data provides valuable insights, several factors influence real-world combustion:

- Incomplete combustion: Leading to pollutants like CO and unburned hydrocarbons.
- Flame temperature: Affects reaction completeness and pollutant formation.
- Fuel purity: Impurities can alter energy output and emissions.
- Environmental regulations: Mandate cleaner combustion practices.

Further thermodynamic parameters such as Gibbs free energy and entropy changes are essential for comprehensive process analysis but are not provided here.

Conclusion

The examined combustion reactions of ethylene and ethane reveal the substantial energy potential locked within these hydrocarbons. Ethylene's combustion releases approximately 1411 kilojoules per mole, exemplifying its role as an efficient fuel source in industrial processes. Ethane, with its higher hydrogen content, offers even greater energy yields, reinforcing its significance in energy and chemical manufacturing. Understanding these thermodynamic properties enables engineers and scientists to optimize combustion systems, improve energy efficiency, and develop environmentally sustainable practices. As the world moves toward cleaner energy solutions, such detailed chemical insights serve as foundational knowledge for innovating future technologies and mitigating climate change impacts.

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Note: The data and interpretations presented are based on standard thermodynamic principles and typical combustion values; actual process conditions may vary.

Given The Following Datac2h4 G 3o2 G Gt 2co2 G 2h2o L H 1411 0 Kj2c2h6 G 7o2 G

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