Consider The Following Reaction: O2 2no2no2 , Rate=k[o2][no]2 Part A What Is The Overall Reaction Order?

Consider The Following Reaction: O2 2NO2 NO2, Rate=k[o2][no]2 Part A What Is The Overall Reaction Order?

Understanding reaction mechanisms and their corresponding reaction orders is fundamental in the field of chemical kinetics. In this article, we will delve into the specific reaction: $O_2 + 2NO_2 \rightarrow NO + NO_3$, with the rate law expressed as Rate = k $[O_2][NO]^2$. Our primary focus is on Part A: determining the overall reaction order. By analyzing this reaction systematically, we can better grasp how individual reactants influence the rate and how to interpret rate laws in complex chemical processes.

Understanding Reaction Order in Chemical Kinetics

What Is Reaction Order?

Reaction order describes how the rate of a chemical reaction depends on the concentration of reactants. It indicates the power to which the concentration of a reactant is raised in the rate law. The overall reaction order is the sum of the individual orders with respect to each reactant.

Types of Reaction Orders

- Zero-order: The rate is independent of the reactant concentration.
- First-order: The rate is directly proportional to the concentration of one reactant.
- Second-order: The rate is proportional to the square of one reactant's concentration or the product of the concentrations of two reactants each raised to the first power.
- Higher-order: Involving powers greater than two or more complex dependencies.

Analyzing the Given Reaction and Its Rate Law

Reaction Equation

The reaction under consideration is:

$O_2 + 2NO_2 \rightarrow NO + NO_3$

This indicates that one molecule of oxygen reacts with two molecules of nitrogen dioxide to produce nitric oxide and nitrogen trioxide.

Rate Law Provided

The rate law for this reaction is given as:

Rate = $k [O_2][NO]^2$

This expression suggests that:
- The reaction rate is directly proportional to the concentration of oxygen, $[O_2]$.
- The rate is proportional to the square of the concentration of nitrogen dioxide, [NO].

Implication of the Rate Law

The rate law directly informs us about the reaction orders:
- The order with respect to $[O_2]$ is 1.
- The order with respect to [NO] is 2.

The overall reaction order is the sum of these individual orders.

Calculating the Overall Reaction Order

Step-by-Step Determination

To find the overall reaction order, follow these steps:

1. Identify the individual orders from the rate law:
    - Order with respect to $[O_2]$ = 1
    - Order with respect to [NO] = 2
2. Sum the individual orders:

◦ Overall reaction order = 1 + 2 = 3

Therefore, the overall reaction order is 3.

Significance of the Overall Reaction Order

The overall order provides insights into how the reaction rate responds to changes in reactant concentrations:
- A third-order reaction implies that if the concentration of [O_2] and [NO] are doubled, the rate increases by a factor of $2^3 = 8$.
- Understanding this helps in designing reactors and optimizing reaction conditions for maximum efficiency.

Implications of Reaction Orders in Practical Applications

Reaction Kinetics in Industry

Knowing the overall order of a reaction aids chemical engineers in:
- Scaling up reactions from lab to industrial scale.
- Adjusting reactant concentrations to control reaction rates.
- Predicting how changes in conditions affect yield and throughput.

Predicting Reaction Behavior

Reaction orders also assist in:
- Modeling reaction progress over time.
- Estimating the time required to reach a specific conversion level.
- Understanding the reaction mechanism, especially when combined with experimental data.

How to Determine Reaction Order Experimentally

Methods Used

- Initial Rate Method: Measure initial rates at varying concentrations and analyze how rate changes with concentration.
- Integrated Rate Laws: Use concentration vs. time data to fit to different kinetic models to determine the order.

- Method of Half-Lives: For reactions where half-life depends on concentration, the order can be inferred accordingly.

Application to the Given Reaction

For the reaction with rate law Rate = k $[O_2][NO]^2$, experimental data would typically involve:
- Varying $[O_2]$ while keeping [NO] constant to confirm first-order dependence on $[O_2]$.
- Varying [NO] while keeping $[O_2]$ constant to confirm second-order dependence on [NO].

Summary and Key Takeaways

- The reaction $O_2 + 2NO_2 \rightarrow NO + NO_3$ has a rate law of Rate = k $[O_2][NO]^2$.
- The individual reaction orders are 1 for $[O_2]$ and 2 for [NO], leading to an overall order of 3.
- The overall reaction order indicates the reaction's sensitivity to concentration changes, with higher-order reactions being more sensitive.
- Understanding reaction order is crucial for reaction optimization, scaling, and mechanistic insights.
- Experimental methods such as initial rate studies help determine the reaction order in practical scenarios.

In conclusion, the overall reaction order for the given reaction is 3, making it a third-order reaction. Recognizing and calculating reaction orders are essential skills in physical chemistry, impacting how reactions are controlled, optimized, and understood at both laboratory and industrial levels.

Frequently Asked Questions

What is the overall reaction in the given chemical equation?

The overall reaction is $2\ NO_2 \rightarrow 2\ NO + O_2$.

What is the rate law for the reaction?

The rate law is rate = k $[O_2]$ $[NO]^2$.

How do you determine the overall reaction order from the rate law?

By summing the exponents of the concentration terms in the rate law, so 1 (from $[O_2]$) plus 2 (from [NO]) equals 3, making the overall order 3.

What is the overall reaction order for this reaction?

The overall reaction order is 3.

Why is understanding the overall reaction order important?

It helps in predicting how the reaction rate will change with concentration changes of reactants.

Can the reaction be considered a third-order reaction based on the rate law?

Yes, because the sum of the exponents in the rate law is 3, indicating a third-order reaction overall.

How does the reaction order affect the reaction kinetics?

The reaction order determines the dependency of the reaction rate on reactant concentrations, influencing how quickly the reaction proceeds.

Is the given rate law consistent with the stoichiometry of the reaction?

Not necessarily; the rate law is determined experimentally and may differ from the stoichiometric coefficients in the balanced equation.

Additional Resources

Consider The Following Reaction: $O_2 + 2NO_2 \rightarrow NO + NO_2$

Understanding the kinetics of chemical reactions is fundamental in fields ranging from industrial synthesis to atmospheric chemistry. The reaction between oxygen and nitrogen dioxide, represented as:

$O_2 + 2NO_2 \rightarrow NO + NO_2$

serves as a quintessential example of a multi-step reaction involving radical intermediates and complex rate law determination. In this article, we will explore the rate law, particularly focusing on the overall reaction order, and analyze the kinetic implications of the provided rate expression:

Rate = $k [O_2][NO]^2$

This detailed examination aims to clarify the reaction mechanism, interpret the rate law, and derive the overall reaction order, providing a comprehensive understanding suitable for researchers, students, and professionals alike.

Understanding the Reaction and Its Components

The reaction involves oxygen (O_2) and nitrogen dioxide (NO_2), both of which are significant in atmospheric processes and industrial applications. The reaction proceeds via radical mechanisms, often involving NO and NO_2 interconversions, and can influence phenomena such as smog formation and nitrogen oxide cycling.

Key reactants:
- Oxygen (O_2): A diatomic molecule that is relatively stable, but participates in radical chain reactions.
- Nitrogen dioxide (NO_2): A highly reactive radical involved in nitrogen oxide chemistry, capable of both propagating and terminating radical chains.

Products:
- Nitric oxide (NO): A key intermediate in nitrogen oxide chemistry.
- Nitrogen dioxide (NO_2): Reformed or regenerated in the process, often involved in catalytic cycles.

Understanding the rate law associated with this reaction helps elucidate the underlying mechanism and predict reaction behavior under various conditions.

Rate Law and Its Significance

The rate law provides a mathematical expression relating the reaction rate to the concentrations of reactants. The provided rate law is:

Rate = k $[O_2][NO]^2$

where:
- k is the rate constant, specific to temperature and other conditions.
- $[O_2]$ and [NO] are the molar concentrations of oxygen and nitric oxide, respectively.

This expression indicates that the reaction rate depends linearly on the concentration of oxygen and quadratically on the concentration of nitric oxide.

Determining the Overall Reaction Order

The overall reaction order is the sum of the individual orders with respect to each reactant. It provides insight into how the reaction rate scales with changes in reactant concentrations.

Step 1: Identify individual orders

From the rate law:

- Order with respect to O_2: 1
- Order with respect to NO: 2

Step 2: Calculate overall reaction order

Overall order = (order with respect to O_2) + (order with respect to NO)
Overall order = 1 + 2 = 3

Therefore, the overall reaction order is 3.

This implies that the reaction is third order overall, meaning that the rate is proportional to the cube of the concentration of the reacting species involved in this specific rate law under the conditions tested.

Implications of the Overall Reaction Order

Understanding that the overall order is three has several implications:

- Kinetic behavior: The reaction rate increases steeply with increases in reactant concentrations, especially NO due to its quadratic dependence.
- Reaction mechanism insights: A third-order overall reaction suggests a

multi-step process involving at least two molecules of NO in the rate-determining step or in a rapid pre-equilibrium followed by the slow step.
- Predictive modeling: Accurate kinetic models must incorporate this third-order dependence to predict concentration changes over time accurately.

Mechanistic Considerations and Rate-Determining Step

While the rate law provides the mathematical relationship, understanding the underlying mechanism requires analysis of possible elementary steps that lead to the observed kinetics.

Possible mechanistic pathways:

1. Radical chain mechanism involving NO and NO_2:

- Initiation: Formation of radicals (e.g., $NO_2\bullet$)
- Propagation: Reactions where radicals react with O_2 and NO, propagating the chain
- Termination: Radical-radical recombination

2. Rate-determining step (hypothetical):

Based on the rate law, a plausible slow step could involve the collision of one O_2 molecule with two NO molecules, such as:

$NO + NO + O_2 \rightarrow$ Products

Or a step where NO molecules react with radicals to form NO_2, which then reacts with O_2.

Possible elementary step consistent with the rate law:

- $NO + NO + O_2 \rightarrow NO_2 + NO$ (slow step)

This step would be third order overall (second order in NO plus first order in O_2), matching the overall reaction order.

Implications:

- The reaction likely proceeds via a radical chain involving $NO_2\bullet$ intermediates.
- The rate-determining step involves a bimolecular collision between two NO molecules and one O_2 molecule.

Experimental Determination and Validation

The rate law is typically determined through:

- Initial rate experiments: Measuring initial reaction rates at varying concentrations.
- Method of isolation: Holding all but one reactant concentration constant to observe changes.
- Data fitting: Plotting data to establish the dependence of rate on each reactant.

In the context of the reaction in question, experimental studies have confirmed that:

- Doubling $[O_2]$ roughly doubles the rate.
- Doubling [NO] results in approximately a fourfold increase in rate (since rate $\propto [NO]^2$).

Such experimental validation supports the proposed rate law and overall reaction order.

Broader Context and Significance

Understanding the kinetics of this reaction extends beyond academic curiosity:

- Atmospheric Chemistry: NO and NO_2 are major pollutants involved in smog formation, ozone depletion, and acid rain. Accurate kinetic models are essential for environmental regulation.
- Industrial Processes: Synthesis of nitric acid and other nitrogen-based compounds depends on controlling reaction rates and pathways.
- Catalytic Research: Insights into the reaction mechanism can inform catalyst design to optimize reaction efficiency and selectivity.

Conclusion

The reaction between oxygen and nitrogen dioxide, with the rate law Rate = $k [O_2][NO]^2$, exhibits an overall reaction order of 3. This third-order dependence indicates a complex mechanism that likely involves the collision of two NO molecules and one O_2 molecule in its rate-determining step. Recognizing this kinetic behavior is crucial for modeling atmospheric processes, optimizing industrial reactions, and understanding the fundamental radical chemistry underpinning nitrogen oxide transformations.

By thoroughly analyzing the rate law, mechanistic implications, and experimental validations, we gain a comprehensive understanding of this reaction, emphasizing the intricate interplay between reactant concentrations and reaction dynamics. Such insights are vital for advancing both scientific knowledge and practical applications in environmental and chemical engineering domains.

Consider The Following Reaction O2 2no2no2 Rate K O2 No 2 Part A What Is The Overall Reaction Order

Consider The Following Reaction O2 2no2no2 Rate K O2 No 2 Part A What Is The Overall Reaction Order

Related Articles

- Anatomy And Physiology, An Integrative Approach (latest Edition), Bundled With Connect Learning Platform
- Dana Just Finished Paying Off The $15,400 Loan She Took Out Four Years Ago. The Loan Had 6.68% Interest,
- Develop A Model To Describe How Food Is Rearranged Through Chemical Reactions Forming New Molecules That

Back to Home