For The Reaction 4 A + 5 B 2 C + 3 D, What Is The Magnitude Of The Rate Of Change For [B] When [A] Is

For The Reaction 4 A + 5 B 2 C + 3 D, What Is The Magnitude Of The Rate Of Change For [B] When [A] Is a fundamental question in chemical kinetics that involves understanding how concentrations of reactants and products change over time during a chemical reaction. This article provides a comprehensive explanation of how to determine the rate of change of [B] in the context of the given reaction, emphasizing the importance of rate laws, stoichiometry, and reaction kinetics principles. Whether you're a student, researcher, or enthusiast, this guide aims to clarify these concepts with detailed explanations and practical examples.

Understanding the Reaction and Its Components

The Reaction Equation

The reaction under consideration is:

4 A + 5 B → 2 C + 3 D

This indicates that four molecules of reactant A react with five molecules of reactant B to produce two molecules of product C and three molecules of product D. The reaction is typically studied in terms of the concentrations of these species over time.

Key Concepts in Reaction Kinetics

- Rate of Reaction: The speed at which reactants are consumed and products are formed.
- Rate Law: An expression that relates the rate of reaction to the concentrations of reactants, often in the form:

$$
\text{Rate} = k [A]^m [B]^n
$$

where:
- k is the rate constant,
- m and n are the orders of the reaction with respect to A and B, respectively.

- Stoichiometry: The quantitative relationship between reactants and products, reflected in the coefficients of the balanced chemical equation.

Determining the Rate of Change of [B]

Relationship Between Reaction Rate and Concentration Changes

The rate of a reaction can be expressed in terms of the change in concentration of any reactant or product over time. For a general reaction:

$$
aA + bB \rightarrow cC + dD
$$

the rate of reaction can be defined as:

$$
\text{Rate} = -\frac{1}{a} \frac{d[A]}{dt} = -\frac{1}{b} \frac{d[B]}{dt} = \frac{1}{c} \frac{d[C]}{dt} = \frac{1}{d} \frac{d[D]}{dt}
$$

Note the negative signs for reactants, since their concentrations decrease over time.

Applying to Our Reaction

For the specific reaction:

$$ 4A + 5B \rightarrow 2C + 3D $$

the rate of change of [B] relates to the overall reaction rate as:

$$
\frac{d[B]}{dt} = - \frac{5}{\text{reaction rate}}
$$

Similarly, the rate of reaction can be expressed in terms of the change in [A]:

$$
\text{Rate} = - \frac{1}{4} \frac{d[A]}{dt}
$$

and for [B]:

$$
\frac{d[B]}{dt} = - 5 \times \text{Rate}

\]

This proportionality indicates that the rate of change of [B] is directly related to the overall reaction rate, scaled by the stoichiometric coefficient.

Calculating the Magnitude of the Rate of Change of [B]

Step 1: Find the Reaction Rate

To determine \(\frac{d[B]}{dt}\), you first need to know the reaction rate, which can be obtained from experimental data or rate laws.

Suppose, at a certain instant, the concentration of A is known, and the reaction rate has been measured or calculated. For this example, assume:

- The reaction rate, \(r \), is known to be \(0.02\, \text{mol L}^{-1} \text{s}^{-1} \).

This value might come from experimental kinetic data or a rate law expression.

Step 2: Use Stoichiometry to Find \(\frac{d[B]}{dt}\)

Given the relation:

\[
\frac{d[B]}{dt} = - 5 \times \text{Rate}
\]

we substitute the known rate:

\[
\frac{d[B]}{dt} = - 5 \times 0.02 = - 0.10\, \text{mol L}^{-1} \text{s}^{-1}
\]

The negative sign indicates that [B] is decreasing over time. The magnitude of the rate of change is therefore:

\[
|\frac{d[B]}{dt}| = 0.10\, \text{mol L}^{-1} \text{s}^{-1}
\]

This value indicates that the concentration of B decreases at a rate of 0.10

mol per liter per second under the given conditions.

Factors Affecting the Rate of Change of [B]

1. Concentration of Reactants

The rate of reaction is highly dependent on the concentrations of reactants A and B. According to the rate law:

$$
\text{Rate} = k [A]^m [B]^n
$$

any change in [A] or [B] will influence the overall rate, and consequently, the rate of change of [B].

2. Temperature

Increasing temperature generally increases the rate constant k, which accelerates the reaction, and thereby increases the magnitude of $\frac{d[B]}{dt}$.

3. Catalysts and Inhibitors

The presence of catalysts can lower activation energy, increasing reaction rate, whereas inhibitors can slow it down, decreasing the rate of concentration change.

4. Reaction Conditions

Pressure, solvent, and other environmental factors also influence reaction kinetics.

Practical Example and Calculation

Suppose:

- At a given instant, [A] = 0.5 M,
- The rate constant k = 0.1 L mol^{-1} s^{-1},
- The reaction is first order with respect to both A and B (i.e., $m = n = 1$).

Calculate the reaction rate:

$$
r = k [A][B]
$$

Assuming [B] = 0.3 M,

$$
r = 0.1 \times 0.5 \times 0.3 = 0.015\, \text{mol L}^{-1} \text{s}^{-1}
$$

Determine the rate of change of [B]:

$$
\frac{d[B]}{dt} = -5 \times r = -5 \times 0.015 = -0.075\, \text{mol L}^{-1} \text{s}^{-1}
$$

The magnitude:

$$
|\frac{d[B]}{dt}| = 0.075\, \text{mol L}^{-1} \text{s}^{-1}
$$

indicates that under these conditions, [B] decreases at a rate of 0.075 mol per liter per second.

Summary and Key Takeaways

- The rate of change of [B] can be directly calculated from the overall reaction rate and the stoichiometric coefficients.
- Understanding the rate law is crucial for accurate calculations; reaction orders significantly influence the rate.
- Reaction conditions such as concentration, temperature, and catalysts can alter the rate and the magnitude of concentration changes.
- Practical calculations involve substituting known or measured reaction rates into stoichiometric relationships to find the specific rate of change of [B].

Conclusion

Determining the magnitude of the rate of change for [B] in the reaction \(4A + 5B \rightarrow 2C + 3D\) requires understanding the relationship between the overall reaction rate and the stoichiometric coefficients. By applying principles of reaction kinetics, rate laws, and stoichiometry, one can accurately calculate how rapidly [B] decreases over time under specific conditions. This knowledge is essential for controlling reaction processes in industrial chemistry, optimizing reaction conditions, and understanding reaction mechanisms.

If you want to analyze a particular scenario with specific concentrations or rate data, always start with the reaction's rate law and stoichiometry to perform precise calculations.

Frequently Asked Questions

In the reaction 4 A + 5 B → 2 C + 3 D, how do you express the rate of change of [B] in terms of the reaction rate?

The rate of change of [B] is related to the reaction rate by the formula: Rate = -(1/5) d[B]/dt. Therefore, d[B]/dt = -5 Rate.

Given the reaction 4 A + 5 B → 2 C + 3 D, how does the concentration of B change with respect to A when [A] varies?

Since the stoichiometric coefficients are fixed, the rate of change of [B] is directly proportional to the rate of the reaction, scaled by the ratio 5/4, meaning as [A] changes, [B] changes accordingly to maintain the reaction rate.

How do you calculate the magnitude of the rate of change of [B] when [A] is known in the reaction 4 A + 5 B → 2 C + 3 D?

You first determine the reaction rate at the given [A], then multiply by 5 to find the magnitude of d[B]/dt, using the relation d[B]/dt = -5 Rate.

If the rate of the reaction is known at a certain concentration of A, how can I find the rate of

change of [B] at that point?

Use the relation d[B]/dt = -5 Rate. Plug in the known reaction rate to find the magnitude of the rate of change of [B].

When [A] is changing during the reaction, how does that affect the rate of change of [B] in the reaction 4 A + 5 B → 2 C + 3 D?

As [A] changes, the reaction rate generally changes as well (assuming a rate law), which in turn affects the magnitude of d[B]/dt proportionally, scaled by the coefficient 5.

What is the relationship between the rate of change of [A] and [B] in the reaction 4 A + 5 B → 2 C + 3 D?

The rate of change of [A] and [B] are linked through the reaction rate: d[A]/dt = -(1/4) Rate, and d[B]/dt = -(1/5) Rate. Therefore, their rates of change are related by a ratio of 4/5.

How can I determine the rate of change of [B] if the rate of the reaction is given at a specific [A] concentration?

Calculate the reaction rate at that [A], then multiply by -5 to get the magnitude of d[B]/dt, since d[B]/dt = -5 Rate.

In the context of the reaction 4 A + 5 B → 2 C + 3 D, what does the negative sign in the rate of change of [B] indicate?

The negative sign indicates that [B] decreases over time as the reaction proceeds.

How does changing [A] influence the magnitude of the rate of change of [B] in the reaction?

Changing [A] affects the reaction rate depending on the rate law; as the rate increases or decreases with [A], the magnitude of d[B]/dt (which equals 5 times the reaction rate) will correspondingly increase or decrease.

Can you provide a formula to compute the magnitude

of the rate of change of [B] when [A] is known?

Yes. If the reaction rate at a given [A] is known, then |d[B]/dt| = 5 Rate at [A].

Additional Resources

For The Reaction 4 A + 5 B → 2 C + 3 D, What Is The Magnitude Of The Rate Of Change For [B] When [A] Is

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Introduction: Understanding Reaction Rates and Their Significance

In the realm of chemical kinetics, one of the fundamental pursuits is understanding how the concentrations of reactants and products change over time during a chemical reaction. These changes are quantified through what is known as reaction rates. Grasping the concept of reaction rates is crucial not only for academic purposes but also for practical applications across industries such as pharmaceuticals, environmental science, and chemical manufacturing.

The question at hand involves a specific reaction:

4 A + 5 B → 2 C + 3 D

and seeks to determine the magnitude of the rate of change of the concentration of reactant B, denoted as \([B]\), under certain conditions, particularly when the concentration of A, \([A]\), is known or specified.

This exploration will delve deeply into the principles of reaction kinetics, stoichiometry, and rate laws to elucidate the connection between the concentration changes of different species involved in the reaction. The goal is to provide a comprehensive, analytical overview that enables a clear understanding of how the rate of change of \([B]\) can be determined in this context.

Fundamentals of Reaction Kinetics

What Is Reaction Rate?

Reaction rate is defined as the change in concentration of a reactant or product per unit time. Mathematically, it is expressed as:

$$
\text{Rate} = -\frac{1}{\text{coeff. of reactant}} \times \frac{d[\text{reactant}]}{dt} = \frac{1}{\text{coeff. of product}} \times \frac{d[\text{product}]}{dt}
$$

The negative sign indicates that the concentration of reactants decreases over time, whereas for products, it increases. The rate of a reaction is often represented as the rate of change of a particular species' concentration divided by its stoichiometric coefficient.

Reaction Rate Law

The rate law expresses the dependence of the reaction rate on the concentrations of reactants:

$$
\text{Rate} = k [A]^m [B]^n
$$

where:

- k is the rate constant, specific to a particular reaction at a given temperature.
- m and n are the reaction orders with respect to reactants A and B, respectively.

Determining the exponents m and n is fundamental to understanding how the concentration of each reactant influences the overall reaction rate. These are typically obtained through experimental data.

Analyzing the Given Reaction: Stoichiometry and Rate Relationships

Reaction Equation and Stoichiometric Coefficients

The reaction provided is:

4 A + 5 B → 2 C + 3 D

This indicates that:

- 4 moles of A are consumed for every reaction event.
- 5 moles of B are consumed per reaction.
- 2 moles of C are formed.
- 3 moles of D are formed.

The stoichiometric coefficients are crucial because they establish the relationship between the rates of change of different species’ concentrations.

Relating Rates of Change of Reactants and Products

The rate of the reaction, often called the reaction rate, can be expressed in terms of the change in concentration of any species:

$$
\text{Rate} = -\frac{1}{4} \frac{d[A]}{dt} = -\frac{1}{5} \frac{d[B]}{dt} = \frac{1}{2} \frac{d[C]}{dt} = \frac{1}{3} \frac{d[D]}{dt}
$$

This set of relationships ensures consistency across the reaction's stoichiometry. The negative signs for reactants indicate their decreasing concentrations, while products increase.

Therefore, the rate of change of $[B]$ is related to the overall reaction rate by:

$$
\frac{d[B]}{dt} = -5 \times \text{Rate}
$$

and similarly,

$$
\frac{d[A]}{dt} = -4 \times \text{Rate}
$$

Determining the Rate of Change of [B]

Step 1: Establish the Rate Law

To find the rate of change of $[B]$, we need the reaction rate law:

$$
\text{Rate} = k [A]^m [B]^n
$$

The exponents m and n are typically determined experimentally. In many cases, reaction mechanisms suggest certain orders, but without specific experimental data, assumptions must be made or the question posed as an exercise in understanding the relationships.

For the purpose of this discussion, let’s assume that the reaction is elementary (a single-step process), and its molecularity is consistent with the stoichiometry. Although this is often an oversimplification, it provides a basis for understanding the proportionality.

In an elementary reaction, the reaction order matches the sum of the stoichiometric coefficients involved in the rate-determining step. If we assume that the reaction is elementary and that the orders correspond to the coefficients:

$$
m = 1, \quad n = 1
$$

This simplifies the rate law to:

$$
\text{Rate} = k [A][B]
$$

Alternatively, if the reaction order differs, the logic remains similar—only the exponents change accordingly.

Step 2: Express $\frac{d[B]}{dt}$ in Terms of Rate

From the stoichiometry:

$$
\frac{d[B]}{dt} = -5 \times \text{Rate}
$$

Substituting the rate law:

$$
\frac{d[B]}{dt} = -5 \times k [A]^m [B]^n
$$

\]

This equation tells us that the magnitude of the rate of change of \([B]\) depends on the current concentrations of A and B, the rate constant \(k\), and the reaction orders.

Calculating the Magnitude When \([A]\) Is Known

Understanding the Variables

Suppose the concentration of A at the moment of interest is known, say \([A] = A_0\), and similarly, \([B] = B_0\). The goal is to determine the magnitude of \(\frac{d[B]}{dt}\), which is the absolute value of the rate of change.

The expression simplifies to:

\[
\left| \frac{d[B]}{dt} \right| = 5 \times k \times [A]^m \times [B]^n
\]

Given:

- \([A] = A_0\)
- \([B] = B_0\)
- \(k\), \(m\), and \(n\) are known or assumed.

Note: If the rate constant \(k\) and reaction orders are not specified, the calculation remains symbolic, emphasizing the proportional relationship.

Step 1: Input Known Values

For illustration, suppose:

- \([A] = 0.1\, \text{M}\)
- \([B] = 0.05\, \text{M}\)
- \(k = 1\, \text{L/(mol·s)}\) (for simplicity)
- \(m = 1\)
- \(n = 1\)

then,

\[
\left| \frac{d[B]}{dt} \right| = 5 \times 1 \times (0.1)^{1} \times

(0.05)^{1} = 5 \times 0.1 \times 0.05
\]

Calculating:

\[
\left| \frac{d[B]}{dt} \right| = 5 \times 0.005 = 0.025\, \text{M/s}
\]

This result indicates that \([B]\) decreases at a rate of 0.025 mol per liter per second at that particular moment.

Note: The actual magnitude heavily depends on the specific values of \([A]\), \([B]\), \(k\), and the reaction orders. Without experimental data, this example serves to illustrate the calculation process.

Impact of Varying \([A]\) on \(\frac{d[B]}{dt}\)

Influence of \([A]\) Concentration

Since the rate is proportional to \([A]^m\), a change in \([A]\) significantly impacts the rate of change of \([B]\). For instance:

- If \([A]\) doubles, and \(m=1\), the rate doubles.
- If \([A]\) triples, the rate triples.

This emphasizes the importance of reactant concentration in controlling reaction kinetics.

Effect of Reaction Orders

Reaction orders determine how sensitively the rate responds to concentration changes:

- First-order (\(m=1\) or \(n=1\

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