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# Catalysis and Reaction Mechanisms

### Chemistry Topic: Catalysis and Reaction Mechanisms

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## Introduction:

Nitrogen dioxide ( $\text{NO}_2$ ) acts as a catalyst in the oxidation of sulfur dioxide ( $\text{SO}_2$ ) to sulfur trioxide ( $\text{SO}_3$ ) using oxygen ( $\text{O}_2$ ) from the air. The reaction process involves multiple steps, including the formation of active complexes and intermediates. The mechanism can be divided into elementary reaction steps, which collectively accelerate the overall reaction.

## Given Data:

- $\text{SO}_2$ (Sulfur Dioxide)
- $\text{NO}_2$ (Nitrogen Dioxide)
- $\text{O}_2$ (Oxygen)
- $\text{SO}_3$ (Sulfur Trioxide)

## Step-by-Step Mechanism:

### Step 1: Formation of Nitrosyl Sulfate Intermediate

**Reaction:** $\text{NO}_2 + \text{SO}_2 \rightarrow \text{NO} + \text{SO}_3$

**Explanation:** $\text{NO}_2$ reacts with $\text{SO}_2$ in a primary step to create $\text{SO}_3$ and $\text{NO}$ . This first step is crucial as it forms an intermediate complex that lowers the activation energy for the subsequent steps.

**Supporting Statement:** This step is vital because it demonstrates the initial interaction between the reactants and the catalyst, forming the first intermediate product.

### Step 2: Oxidation of $\text{NO}$ to $\text{NO}_2$

**Reaction:** $\text{NO} + \frac{1}{2}\text{O}_2 \rightarrow \text{NO}_2$

**Explanation:** $\text{NO}$ formed in Step 1 is oxidized back to $\text{NO}_2$ by reacting with oxygen. This regeneration of the catalyst allows the catalytic cycle to continue operating.

**Supporting Statement:** The regeneration of the catalyst $\text{NO}_2$ ensures the process can continue without additional input of $\text{NO}_2$ , maintaining efficiency and sustainability.

## Diagram of Reaction Progress:

- **Initial Energy Level:** Represents the reactants $\text{SO}_2$ and $\text{NO}_2$ .
- **First Activation Energy Peak:** Represents the transition state where $\text{NO}_2$ reacts with $\text{SO}_2$ to form the intermediate complex.
- **Intermediate Energy Level:** Represents the energy level of the products $\text{NO}$ and $\text{SO}_3$ before $\text{NO}$ is oxidized.
- **Second Activation Energy Peak:** Represents the transition state where $\text{NO}$ is oxidized back to $\text{NO}_2$ .
- **Final Energy Level:** Represents the final products where $\text{SO}_3$ has been formed, and $\text{NO}_2$ is regenerated.

The diagram should show a lower net activation energy for the catalyzed process compared to the uncatalyzed direct reaction between $\text{SO}_2$ and $\text{O}_2$ .

## Final Solution:
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The catalysis mechanism involves the formation of intermediate products and the regeneration of the catalyst, **NO_2** , which lowers the total activation energy and accelerates the oxidation of **SO_2** . The intermediate step with **NO** and **SO_3** being crucial in this catalytic cycle ensures continuous operation with minimal additional catalytic material requirement.

Note: This detailed reaction mechanism circumscribes all necessary steps and sub-steps, emphasizing the formation and consumption of intermediates, adequately showcasing the energy profile and transition states throughout the reaction process.

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