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Review Article

A New Perspective on the Design, Synthesis, and Applications of $Co(NO_3)_2 \cdot 6H_2O$ in Enhancing Catalyst Performance

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ABSTRACT

Cobalt(II) nitrate hexahydrate ($Co(NO_3)_2 \cdot 6H_2O$) serves as a key precursor in the synthesis of catalysts and various coordination compounds, significantly improving catalytic performance. With its unique chemical and physical properties, this compound enables the design and production of more efficient catalysts. The presence of Co^{2+} ions in $Co(NO_3)_2 \cdot 6H_2O$ facilitates the formation of diverse coordination structures, which are highly active in catalytic reactions. These ions can combine with different ligands to create effective active sites, enhancing reaction speed and selectivity. Using $Co(NO_3)_2 \cdot 6H_2O$ as a precursor simplifies and reduces the cost of synthesizing cobalt-based catalysts. By enabling the formation of cobalt nanoparticles or other cobalt-containing compounds, it contributes to the production of catalysts with high activity and stability. Additionally, catalysts synthesized using $Co(NO_3)_2 \cdot 6H_2O$ exhibit improved thermal and chemical stability, extending their lifespan, reducing replacement frequency, and lowering operational costs in industrial processes. Overall, $Co(NO_3)_2 \cdot 6H_2O$ plays a vital role in designing advanced cobalt-based catalysts, paving the way for more efficient, durable, and cost-effective catalytic systems in both industrial and research applications.

Keywords: Design, Synthesis, Performance, Catalysts

1. Importance of research:

In recent decades, the development of efficient and stable catalysts has been a primary focus in industrial chemistry and academic research. Metal salts, particularly those with well-defined structures, have played a crucial role in enhancing catalytic performance. Cobalt(II) nitrate hexahydrate [$Co(NO_3)_2 \cdot 6H_2O$], with its unique properties, has emerged as a significant precursor for catalyst synthesis. This compound provides a stable and accessible source of Co^{2+} ions, essential for catalytic processes. The six water molecules in its structure enhance solubility in polar solvents like water, ensuring uniform distribution of cobalt ions within the catalytic matrix. Furthermore, $Co(NO_3)_2·6H_2O$ serves as a precursor for synthesizing cobalt nanoparticles or other cobalt-based compounds, which exhibit high catalytic activity due to their large surface-to-volume ratio. Selecting the right precursor is critical in modern catalyst design, $Co(NO_3)_2·6H_2O$ allows precise control over growth processes and phase formation, resulting in catalysts with optimized surface properties and enhanced activity. This review highlights the role of Co(NO3)2•6H2O in advancing catalyst technology and its potential for future innovations. .[5]

(NO3)2•6H2O, or six-water cobalt nitrate, as a key precursor in the synthesis of catalysts and various coordination compounds, plays a significant role in improving the performance of catalysts. Combining with its special chemical and physical characteristics, it allows the design and production of more efficient catalysts. [12]

1.1. Mate $Co(NO_3)_2·6H_2O$ in improving the performance of catalysts:

Rich source of Co^{2+} ions: The presence of Co^{2+} ions in the structure of $Co(NO_3)_2·6H_2O$ allows the formation of various coordination structures that are active in catalytic reactions. These or can combine with different ligands to create effective active sites that lead to improved rate and selectivity of reactions. [1]

Tel in the synthesis of cobalt catalysts: The use of $Co(NO_3)_2·6H_2O$ as a precursor makes the synthesis process of cobalt-based catalysts simpler and more cost-effective. This combination helps to produce catalysts with high activity and suitable stability by allowing suitable conditions for the formation of cobalt nanoparticles or other cobalt-containing compounds. [6]

Enhancement and useful life of catalysts: The use of $Co(NO_3)_2·6H_2O$ in the synthesis of catalysts can lead to the improvement of their thermal and chemical stability. This feature increases the life of the catalyst and reduces the need to replace them frequently, which ultimately leads to a reduction in operating costs and an increase in the productivity of industrial processes. [5]

Conclusion: (NO3)2•6H2O with its unique features, as an effective precursor in the design and synthesis of cobalt-based catalysts, plays a significant role in improving the performance of catalysts.

The use of this combination of industrial and research processes can lead to the development of more efficient, sustainable and economical catalysts. [3]

2. Theoretical foundations

1. An introduction to catalysts and their importance

Talysers are substances that increase the speed of chemical reactions without being consumed in the process. By reducing the activation energy of reactions, they provide new reaction pathways that lead to increased efficiency and reduced reaction time. Chemical barrier, catalysts play a vital role in improving the efficiency of processes, reducing energy consumption and reducing the production of unwanted by-products.

2. The role of transition metals in catalysis

Veta metals, especially cobalt (Co), are employed in homogeneous and heterogeneous catalysts due to their semi-filled d-orbitals and ability to change oxidation states. This feature allows them to interact with reactive species and facilitate various reactive pathways.

3.Cobalt nitrate six abe [$Co(NO_3)_2 \cdot 6H_2O$]: structure and characteristics

Abe cobalt nitrate is a compound composed of one divalent cobalt ion (Co^{2+}), two nitrate ions (NO_3^-), and six water molecules. This compound contains red crystals and dissolves well in polar solvents such as water. The presence of six molecules in its structure provides high solubility, which is important for catalytic applications.

4. Tradition of preparation $Co(NO_3)_2 \cdot 6H_2O$

Six-water cobalt nitrate is usually prepared by the reaction between cobalt oxide (CoO) or cobalt hydroxide [$Co(OH)_2$] with nitric acid (HNO_3). In this reaction, cobalt hydroxide oxide is dissolved in nitric acid and after evaporation of the solution, $Co(NO_3)_2 \cdot 6H_2O$ crystals are obtained.. [12]

5. Applicationso (NO_3)2•6H_2O in improving the performance of catalysts

(a) Pre-material for the preparation of cobalt catalysts:

Co(NO3)2•6H2O is used as an important precursor for the synthesis of cobalt-based catalysts. In catalytic preparation processes, this compound can be easily converted into cobalt oxide (Co_3O_4) or metal cobalt nanoparticles, both of which are used in various catalytic reactions.

b) Catalyst in the oxidation reaction:

Cobalt-based catalysts, especially those prepared from $Co(NO_3)_2·6H_2O$, are used in oxidation reactions such as the oxidation of hydrocarbons and alcohols. By providing the cobalt active site, these catalysts facilitate electron transfer and increase reaction efficiency.. [11]

c) Catalyst in hydrogenation reactions:Cobalt nanoparticles prepared from $Co(NO_3)_2·6H_2O$ act as catalysts in hydrogenation reactions, such as hydrogenation of alkenes and alkynes. These nanoparticles, having a special surface, provide the effective absorption of reactive molecules.6. Advantages of using $Co(NO_3)_2·6H_2O$ in the design of catalysts

• High solubility: The compound readily dissolves in water and polar solvents, which allows the preparation of uniform solutions for catalyst synthesis processes.

• Chemical stability: $Co(NO_3)_2·6H_2O$ is environmentally stable and can be used as a reliable source for Co^{2+} ions in the synthesis of catalysts.

• Ease of preparation: This compound is easily prepared by continuous chemical reactions and its production cost is relatively low.

7. Research challenges and opportunities

With the mentioned advantages, the use of $Co(NO_3)_2·6H_2O$ catalysts may face challenges such as controlling the size and distribution of cobalt nanoparticles, catalyst stability under reaction conditions and its recovery.

3. Background

Lee et al. (2018): In this study, cobalt oxide nanoparticles (Co_3O_4) were synthesized using $Co(NO_3)_2·6H_2O$ as a precursor and hydrothermal method. These nanoparticles were used as catalysts in the carbon monoxide oxidation reaction. The results showed that Co_3O_4 nanoparticles have high catalytic activity and can fully oxidize carbon monoxide at low temperatures. This performance was attributed to the porous structure and high specific surface area of the nanoparticles, which provides easier access of reactants to the active sites of the catalyst. [13]

Chen et al. (2019): They used $Co(NO_3)_2 \cdot 6H_2O$ to synthesize cobalt-based metal-organic frameworks (MOFs). These MOFs were employed as precursors for the preparation of cobalt/nitrogen-doped carbon (Co/NC) catalysts. The resulting catalysts were evaluated in the oxygen reduction reaction (ORR) in fuel cells and showed to have high electrocatalytic activity comparable to platinum catalysts. This function was attributed to the presence of cobalt-nitrogen active sites and a porous carbon structure that facilitates mass and electron transfer. [11]

Zhang et al. (2020): In this research, cobalt oxide nanosheets were synthesized using $Co(NO_3)_2 \cdot 6H_2O$ and chemical deposition method. These nanofluids were used as catalysts in the oxidation reaction of benzyl alcohol to benzaldehyde. The results showed that Co_3O_4 nanosheets have high catalytic activity and good selectivity. This performance was attributed to the two-dimensional structure and high active surface area of the nanovores, which provides easier access of the reactants to the active sites.

Liu et al. (2021): They used $Co(NO_3)_2 \cdot 6H_2O$ to synthesize phosphorus-doped cobalt (CoP) nanoparticles. These nanoparticles were evaluated as catalysts in the hydrogenation reaction of nitrobenzene to aniline. The results showed that CoP nanoparticles have high catalytic activity and good stability. Phosphorus doping resulted in increased electron density in cobalt and improved hydrogen absorption on the catalyst surface, which contributes to increased catalytic activity. [1]

Wang et al. (2017): In this study, cobalt oxide nanoparticles were synthesized using $Co(NO_3)_2 \cdot 6H_2O$ and sol-gel method. These nanoparticles were used as catalysts in the oxidation reaction of hydrocarbons. The results showed that Co_3O_4 nanoparticles have high catalytic activity in the oxidation of cyclohexane to cyclohexanone and cyclohexanol. This performance was attributed to the size of the nanoparticles and their uniform distribution, which increases access to active sites. [9]

Yang et al. (2016): They used $Co(NO_3)_2 \cdot 6H_2O$ to synthesize nitrogen-doped cobalt (Co-N) nanoparticles. These nanoparticles were evaluated as catalysts in the oxidation reaction of alcohols. The results showed that Co-N nanoparticles have high catalytic activity and good selectivity. Nitrogen doping resulted in increased thermal and chemical stability of the catalyst, which helps to improve its performance..[22]

Zhou et al. (2015): In this research, cobalt oxide nanoparticles were synthesized using $Co(NO_3)_2 \cdot 6H_2O$ and microwave-hydrothermal method. These nanoparticles were used as catalysts in the hydrogen oxidation reaction. The results showed that Co_3O_4 nanoparticles have high catalytic activity in hydrogen oxidation. This performance was attributed to the porous structure and size of the nanoparticles, which provide a high active surface area.. [23]

They $Co(NO_3)_2 \cdot 6H_2O$ to synthesize sulfur-doped cobalt (CoS) nanoparticles. These nanoparticles were evaluated as catalysts in the hydrogenation reaction of phenol to cyclohexanone. The results showed that CoS nanoparticles have higher catalytic activity than pure cobalt nanoparticles. The reason for this was the increased electron density at the cobalt surface due to sulfur doping, which helped improve electrochemical performance. In addition, the high stability of CoS nanoparticles under harsh operating conditions made them a suitable option for industrial applications.

Kim et al. (2022):

In this study, cobalt-based metal-organic frameworks (MOF) were synthesized using $Co(NO_3)_2 \cdot 6H_2O$ These materials were used as precursors for the preparation of cobalt-nitrogen (Co-N-C) carbon catalysts in the oxygen reduction reaction (ORR) in fuel cells. The results showed that these catalysts have a performance close to platinum catalysts, but their production cost is much lower. The high activity of the catalyst was attributed to the creation of active Co-N sites and optimization of the distribution of cobalt particles within the carbonaceous porous structure, leading to improved electrical conductivity and accelerated electron transfer.

They synthesized Co_3O_4 nanostructured fibers using $Co(NO_3)_2 \cdot 6H_2O$ and electrospinning method. These fibers were investigated as catalysts in the photocatalytic decomposition of organic pollutants. The results showed that this catalyst is able to completely degrade methylene blue dye in a short period of time. This high performance was attributed to the large specific surface area, porous structure, and increased ultraviolet light absorption in nanostructured fibers. Also, the catalyst had a high reusability and after five cycles of use, no significant drop in its activity was observed.

A study on $Cu/ZnO/Al_2O_3$ catalysts for hydrogenation of CO_2 to methanol $Cu/ZnO/Al_2O_3$ catalysts were prepared using co-precipitation method and their performance in hydrogenation of CO_2 to methanol was investigated. Netashan gave that adding small amounts of zirconium (Zr), zinc (Zn), and cerium (Ce) to the catalyst structure improved its stability, selectivity, and yield. This fog emphasizes the importance of choosing suitable precursors such as $Co(NO_3)_2 \cdot 6H_2O$ in the synthesis of efficient catalysts. (ammonurea.ir)

Effect of pH on catalyst properties/$ZnO/Al_2O_3/ZrO_2$

In a study, Xiao et al investigated the effect of pH on the catalytic properties of Cu/ $ZnO/Al_2O_3/ZrO_2$The results showed that increasing the pH above the neutral value leads to an increase in CO_2 conversion and methanol selectivity. These findings emphasize the importance of synthesis conditions and selection of suitable precursors such as $Co(NO_3)_2{\cdot}6H_2O$ in the performance of catalysts.

Synthesis of Cu/ $ZnO/Al_2O_3/ZrO_2$catalysts using co-precipitation method

In this research, $Cu/ZnO/Al_2O_3/Z$ catalysts were prepared using co-precipitation method and their performance in hydrogenation of CO_2 to methanol was investigated. It did not give results that adding small amounts of zirconium (Zr) to the catalyst structure improves its stability and efficiency. This layer emphasizes the importance of choosing suitable precursors such as $Co(NO_3)_2{\cdot}6H_2O$ in the synthesis of efficient calizores.

Investigating the effect of temperature and pH on the performance of Cu/ZnO// $ZnO/Al_2O_3/ZrO_2$catalysts

In this study, the effect of pH on the performance of Cu/ $ZnO/Al_2O_3/ZrO_2$catalysts in the hydrogenation of CO_2 to methanol was investigated. The results showed that increasing the temperature and pH above the neutral value leads to an increase in CO_2 conversion and methanol selectivity. These findings emphasize the importance of Schreintz and the selection of suitable precursors such $Co(NO_3)_2{\cdot}6H_2O$ in improving the performance of calyzores.

Synthesis of Cu/ZnO /Al_2O_3/ZrO_2catalysts using sol-gel method

In this research, Cu/ $ZnO/Al_2O_3/ZrO_2$catalysts were prepared using sol-gel method and their performance in hydrogenation of CO_2 to methanol was investigated. The results showed that adding small amounts of zirconium (Zr) to the catalyst structure improves its stability and efficiency. This study emphasizes the importance of suitable precursors such as $Co(NO_3)_2{\cdot}6H_2O$ in the synthesis of efficient catalysts.

Summing up

These studies show that $Co(NO_3)_2 \cdot 6H_2O$ can be used as an effective precursor in the synthesis of cobalt nanostructures to improve the performance of catalysts. The results of various researches have shown that optimization of porous structure, doping with other elements and advanced synthesis methods can have a significant effect on increasing the efficiency of catalysts.

4. Optimal synthesis conditions:

To achieve high purity and yield of Mena in the preparation of $Co(NO_3)_2 \cdot 6H_2O$, it is necessary to pay attention to the following points:

• Molar ratio of reactants: Steph of the appropriate molar ratio between Cobbett nitrate and water or nitric acid to prevent the formation of by-products.

• Reaction temperature: performing the reaction at a temperature or a mild temperature to prevent the decomposition of the final compound.

• Solubility: Using our appropriate solvents, water, to dissolve reactants and facilitate the reaction.

• Reaction time: control the reaction time to prevent the formation of Jai products and increase the purity of the final product.

By observing these conditions, high-quality cobalt nitrate with six waters and suitable yield can be prepared, which is used in the synthesis of catalysts and other chemical applications.

Catalytic applications $Co(NO_3)_2 \cdot 6H_2O$

(NO3)2•6H2O , or six-water cobalt nitrate, is used as an important precursor in the synthesis of various catalysts and coordination compounds. Due to its special chemical and physical characteristics, the compound plays a significant role in improving the performance of catalysts.

• Progenitor for the synthesis of cobalt catalysts:

$Co(NO_2 \cdot 6H_2 O)$ is used as a rich source of Co^{2+} ions in the synthesis of cobalt-based catalysts. These or can combine with different ligands to form diverse chorodinacy structures that are active in catalytic reactions.

4.1. Kurds in hydrogenation reactions:

Cobalt-based catalysis, especially those prepared from $Co(NO_3)_2{\cdot}6H_2O$

, are employed in hydrogenation reactions such as hydrogenation of alkenes and alkynes. By providing active cobalt sites, these catallias facilitate electron transfer and increase reaction efficiency.

4.2. Use of oxidation reactions:

$Co(NO_3)_2{\cdot}6H_2O$ desynthesis of oxidation catalysts is also used. These catalysts can act as catalysts in the oxidation reactions of hydrocarbons and alcohols and increase the reaction rate by reducing the activation energy.

4.3. Combinatorial synthesis:

$Co(NO_3)_2{\cdot}6H_2O$ is used as a precursor to prepare chorodinionic compounds such as cobaloximes and carbonateotetraminocobalt(III). These compounds are of interest in catalytic reaction and as enzymatic models in chemical research.

4.4. Application in productions and inks:

$Co(NO_3)_2{\cdot}6H_2O$ is used in the dyeing industry and the production of inks as a source of cobalt. This combination helps to produce cobalt dyes and is used in blue and green colors.

4.5. Use in the pharmaceutical industry

In the pharmaceutical industry, cobalt nitrate is used as an antibacterial and antiseptic agent in some medicinal products. It is also used in medical and biological research as a coloring agent to identify and examine cell structures.

Due to the wide applications of $Co(6H_2O)$ in the synthesis of catalysts and various industries, more research is necessary in the field of optimizing the synthesis conditions and developing new applications of this compound.

4.6 Catalytic mechanisms associated with $Co(NO_3)_2{\cdot}6H_2O$

$(NO_3)2$•$6H_2O$, or six-water cobalt nitrate, is used as an important precursor in the synthesis of various catalysts and coordination compounds. Due to its special chemical and physical characteristics, the compound plays a significant role in improving the performance of catalysts.

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Challenges and limitations of using $Co(NO_3)_2{\cdot}6H_2O$ in catalysts

The use of $Co(NO_3)_2{\cdot}6H_2O$ in the synthesis of various catalysts and coordination compounds, despite its many advantages, is also associated with challenges and limitations, which are discussed below:

1.Thermal and chemical stability:

$Co(NO_3)_2{\cdot}6H_2O$ at high temperatures and corrosive environments may decompose and produce toxic compounds such as NO_2. Inye can adversely affect the stability of catalysts based on this compound.

$Co(NO_3)_2{\cdot}6H_2O$ is the reason for the presence of water molecules in its structure, when exposed to air humidity, it may hydrate and its physical and chemical properties may change. These changes affect the performance of catalysts based on this compound.

4. Tule cost

$Co(NO_3)_2{\cdot}6H_2O$ production processes may be expensive and require special equipment, which can affect the final cost of production catalysts.

5. Toxicity and environmental hazards:

Nickel and cobalt compounds, including nickel nitrate, can be harmful to the environment and human health. Inhalation of jasmine dust with these compounds can cause respiratory and skin problems. Therefore, proper van management of these materials is essential.

6. Need for reaction conditions p:

Some catalytic reactions based $Co(NO_3)_2{\cdot}6H_2O$ may require special reaction conditions such as high temperature, high pressure or special environments, which can increase the complexity and cost of the process.

7. Resilience to abrasion:

$Co(NO_3)_2{\cdot}6H_2O$ -based catalysts may experience wear and erosion over time, which can lead to reduced catalytic activity and the need for frequent catalyst replacement.

8. Limitations on the choice of a ligand

In the synthesis of chorodination compounds using $Co(NO_3)_2{\cdot}6H_2O$, the selection of suitable ligands to form stable and active structures may be limited, which can affect catalyst design and performance.

Due to these challenges and limitations, more constraints are necessary to improve stability, reduce costs and increase the efficiency of $Co(NO_3)_2{\cdot}6H_2O$ -based catalysts and properly manage the environmental and health risks associated with them.

Summarizing the contents and emphasizing the importance of $Co(NO_3)_2{\cdot}6H_2O$ in improving the performance of catalysts.

$(NO_3)2{\bullet}6H_2O$, or six-water cobalt nitrate, as a key precursor in the synthesis of catalysts and various coordination compounds, plays a significant role in improving the performance of catalysts. Combining with its special chemical and physical characteristics, it allows the design and production of more efficient catalysts.

5. Mate $Co(NO_3)_2{\cdot}6H_2O$ in improving the performance of catalysts:

1.Rich source of Co^{2+} ions: The presence of Co^{2+} ions in the structure of $Co(NO_3)_2{\cdot}6H_2O$ allows the formation of various coordination structures that are active in catalytic reactions. These or can combine with different ligands to create effective active sites that lead to improved rate and selectivity of reactions.

2.Tel in the synthesis of cobalt catalysts: The use of $o(NO_3)2{\bullet}6H_2O$ as a precursor makes the synthesis process of cobalt-based catalysts simpler and more cost-effective. This combination helps to produce catalysts with high activity and suitable stability by allowing suitable conditions for the formation of cobalt nanoparticles or other cobalt-containing compounds.

3.Enhancement and useful life of catalysts: The use of $Co(NO_3)_2{\cdot}6H_2O$ in the synthesis of catalysts can lead to the improvement of their thermal and chemical stability. This feature increases the life of the catalyst and reduces the need to replace them frequently, which ultimately leads to a reduction in operating costs and an increase in the productivity of industrial processes.

Conclusion$(NO_3)2{\bullet}6H_2O$ with its unique features, as an effective precursor in the design and synthesis of cobalt-based catalysts, plays a significant role in improving the performance of catalysts. The use of this combination of industrial and research processes can lead to the development of more efficient, sustainable and economical catalysts.

6. Suggestions

1 Study on the synthesis and surface modification of catalysts: the effect of adding different ligands to the structure of $Co(NO_3)_2{\cdot}6H_2O$ and its effect on the activity and selectivity of

catalysts. Precision demord postsynthetic modification methods to improve the stability and efficiency of catalysts.

2.Bi-mechanisms of catalytic reactions:

o Study on the mechanisms of catalytic reactions improved using $Co(NO_3)_2·6H_2O$.

o Use of spectroscopic techniques and computational simulations for a better understanding of catalytic processes.

3.Evaluation of the availability and useful life of catalysts:

o Research in thermal and chemical hair removal of catalysts based on $Co(NO_3)_2·6H_2O$ in different operating conditions.

o Investigating the mechanism of fermentation and methods of improving the useful life of catalysts.

4.Development of applications for catalysts:

o Investigating the use of $Co(NO_3)_2·6H_2O$ -based caliso in new or less noticed reactions.

O Study on the biomedical and environmental application of catalysts.

5.Study on scalability and industrial application:

O Research on the methods of acceptability of catalysts for use on an industrial scale.

o Investigating economic and biological issues during the wet with the production and use of catalysts based on $Co(NO_3)_2·6H_2O$.

Limitations:

: Thermal and chemical stability: $Co(NO_3)_2·6H_2O$ at high temperatures and corrosive environments may decompose and produce toxic compounds such as NO_2 This can negatively affect the stability of catalysts based on this compound.

2.Yell by-products:

In the future of synthesis, by-products such as precipitated carbon may be formed which adversely affect catalytic activity. As in hydrogenation reactions, coke formation can lead to a decrease in the efficiency and useful life of the catalyst.

3.Moisture sensitivity:

o $Co(NO_3)_2{\cdot}6H_2O$ Due to the presence of water molecules in its structure, exposed to air humidity may hydrate and its physical and chemical properties may change. These changes can affect the performance of catalysts based on this compound.

4. Production cost: - Production processes $o(NO_3)2{\bullet}6H_2O$ may be expensive and require special equipment, which can affect the final cost of production catalysts.

5.Toxicity and environmental hazards:

Nickel and cobal compounds such as nickel nitrate can be harmful to the environment and human health. Inhalation of dust or contact of these compounds can cause respiratory and skin problems. Therefore, proper and safe material management is essential.

6. Need for specific reaction conditions: - Some $Co(NO_3)_2{\cdot}6H_2O$ catalyst-based reactions may require specific reaction conditions such as high temperature, high pressure or specific environments, which can increase the complexity and cost of the process.

7.Wear and wear stability

o Catalysts based on $Co(NO_3)_2{\cdot}6H_2O$ mem have wear and erosion over time, which can lead to reduced catalytic activity and the need to replace the catalyst frequently.

8.Limitation in the selection of ligands: In the synthesis of chorodination compounds based on $Co(NO_3)_2{\cdot}6H_2O$, the selection of suitable ligands to form stable and active structures may be limited, which can affect the design and performance of the catalyst.

Due to these limitations, researchers should consider the development and use of $Co(NO_3)_2{\cdot}6H_2O$ in catalysts, optimization of reaction conditions, selection of low-risk materials and development of cost-effective production methods.

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