# EFFECT OF COBALT AND COPPER ACETATE CO DOPED TO HAVE THE STABILITY OF CALCIUM CARBONATE NANOPARTICLES

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## ABSTRACT

*In this study, calcium carbonate (CaCO3) nanoparticles co-doped with cobalt (Co) and copper (Cu) acetates were synthesized using a simple precipitation method to improve their stability for various applications. The structural, morphological, and stability properties of the synthesized nanoparticles were thoroughly characterized using a suite of techniques including X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), Fourier-transform infrared spectroscopy (FTIR), and thermal gravimetric analysis (TGA). XRD analysis confirmed the formation of a pure calcite phase with no additional impurities, indicating successful incorporation of the dopants. SEM and TEM imaging demonstrated a uniform distribution of the nanoparticles with well-defined crystalline structures, while FTIR spectra exhibited characteristic peaks corresponding to carbonate and metal-oxygen bonds, confirming the successful doping of Co and Cu ions. TGA results showed enhanced thermal stability of the co-doped nanoparticles compared to pure CaCO3. Stability tests were conducted under various environmental conditions, including acidic and alkaline pH, high temperature, and prolonged exposure to UV radiation. The co-doped nanoparticles exhibited superior stability and resistance to degradation under these conditions compared to their undoped counterparts. This enhanced stability suggests that Co and Cu co-doping significantly improves the performance and extends the shelf life of CaCO3 nanoparticles. These findings highlight the potential of co-doped CaCO3 nanoparticles for practical applications in fields such as pharmaceuticals, cosmetics, and environmental remediation, where stability is crucial for efficacy and longevity.*

**Keyword :** - *calcium carbonate (CaCO3), cobalt (Co) and copper (Cu)*

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## INTRODUCTION

Calcium carbonate ($CaCO_3$) is a ubiquitous inorganic mineral found naturally in rocks such as limestone, chalk, and marble, as well as in the shells of marine organisms, snails, and eggs. It is one of the most widely used materials in various industries due to its abundance, low cost, and diverse applications. $CaCO_3$ is commonly employed in the production of cement, as a filler material in paper, plastics, and paints, and as an active ingredient in agricultural lime and dietary supplements.

### Nanoparticle Characteristics

Nanotechnology has expanded the utility of calcium carbonate by enabling the synthesis of nanoparticles with unique properties that differ significantly from their bulk counterparts. Calcium carbonate nanoparticles ($CaCO_3$

NPs) are typically characterized by their extremely small size (1-100 nm), high surface area, and enhanced reactivity. These properties make $CaCO_3$ NPs particularly valuable in a variety of advanced applications, including:

**Biomedical Applications**: $CaCO_3$ NPs are biocompatible and biodegradable, making them suitable for drug delivery systems, bone tissue engineering, and as contrast agents in medical imaging.

**Environmental Applications**: They can be used for water treatment, as adsorbents for pollutants, and in carbon capture technologies.

**Industrial Applications**: The high surface area and reactivity enhance their performance as fillers and additives in polymers, coatings, and construction materials.

### Synthesis Methods

The synthesis of $CaCO_3$ NPs can be achieved through various methods, including:

**Precipitation**: This is the most common method, involving the reaction of calcium salts (such as calcium chloride) with carbonate sources (like sodium carbonate) under controlled conditions.

**Sol-Gel Method**: This technique involves the transition of a system from a liquid "sol" into a solid "gel" phase, providing precise control over particle size and morphology.

**Hydrothermal Synthesis**: This method uses high temperature and pressure to crystallize $CaCO_3$ from aqueous solutions, resulting in well-defined nanoparticles.

**Mechanical Milling**: This top-down approach involves the mechanical grinding of bulk $CaCO_3$ into nanoparticles, though it often requires further processing to achieve uniform sizes.

### Stability Concerns

One of the primary challenges associated with $CaCO_3$ NPs is their stability. These nanoparticles tend to agglomerate due to their high surface energy, leading to a loss of the unique nanoscale properties. Additionally, $CaCO_3$ NPs are prone to dissolution in acidic environments, which can limit their application in certain conditions. Therefore, enhancing the stability of $CaCO_3$ NPs is a critical area of research.

### Doping to Enhance Stability

Doping calcium carbonate nanoparticles with various metal ions is a promising strategy to improve their stability and functional properties. By incorporating metal ions such as cobalt (Co) and copper (Cu), researchers aim to modify the surface chemistry and structural properties of $CaCO_3$ NPs. This can lead to enhanced thermal stability, improved resistance to dissolution, and potentially new functionalities, making the doped nanoparticles suitable for a broader range of applications.

This study focuses on understanding how co-doping with cobalt and copper acetate affects the stability and properties of $CaCO_3$ NPs, aiming to provide insights that could lead to the development of more robust and versatile nanomaterials.

### Importance of Stability in $CaCO_3$ NPs

The stability of calcium carbonate nanoparticles ($CaCO_3$ NPs) is a crucial factor determining their performance and applicability across various fields. Stability issues can arise from several sources, including particle aggregation, phase transformation, and chemical reactivity. Understanding and enhancing the stability of $CaCO_3$ NPs is vital for several reasons:

### Aggregation Prevention

Nanoparticles inherently possess high surface energy due to their large surface area to volume ratio. This high surface energy leads to a strong tendency for the particles to agglomerate or aggregate. Aggregation can negate the benefits of nanoscale properties by forming larger particles that behave more like bulk material. Stabilizing $CaCO_3$ NPs against aggregation ensures they maintain their nanoscale characteristics, such as increased reactivity, improved mechanical properties, and enhanced surface area.

### Phase Stability

$CaCO_3$ exists in several polymorphic forms, including calcite, aragonite, and vaterite. Each polymorph has distinct physical and chemical properties. The stability of these phases is influenced by factors such as temperature, pressure, and chemical environment. Ensuring the desired polymorphic form remains stable under operational conditions is essential for maintaining consistent performance in applications ranging from drug delivery to industrial fillers.

### Environmental and Chemical Stability

$CaCO_3$ NPs are susceptible to dissolution, especially in acidic environments. This poses a challenge for applications where the nanoparticles may be exposed to varying pH conditions, such as in biomedical or environmental settings. Enhancing the chemical stability of $CaCO_3$ NPs can extend their functional lifespan and reliability in such conditions.

### Consistency in Applications

For $CaCO_3$ NPs to be reliably used in commercial products, their properties must remain consistent over time. Stability ensures that the nanoparticles maintain their size, shape, and functional properties during storage, processing, and application. This consistency is critical for industrial applications where uniformity in product performance is necessary.

## Role of Doping in Enhancing Nanoparticle Properties

Doping involves the intentional introduction of foreign atoms (dopants) into the host material's crystal lattice. This technique is widely used to tailor the properties of nanoparticles for specific applications. In the context of $CaCO_3$ NPs, doping with metal ions such as cobalt (Co) and copper (Cu) can significantly enhance their properties and stability. The role of doping in enhancing nanoparticle properties can be understood through several mechanisms:

### Structural Modification

Doping can lead to changes in the crystal structure of $CaCO_3$ NPs. The incorporation of dopant ions into the crystal lattice can induce strain, modify lattice parameters, and influence the crystallinity and phase stability of the nanoparticles. These structural modifications can improve the mechanical strength and durability of the NPs.

### Surface Chemistry Alteration

Dopant ions can modify the surface chemistry of $CaCO_3$ NPs, influencing their interaction with the surrounding environment. This can lead to improved dispersibility in solvents, enhanced compatibility with other materials, and increased resistance to chemical attack. For instance, doping with Cu or Co ions can create more stable surface complexes, reducing the tendency for the nanoparticles to dissolve in acidic conditions.

### Thermal Stability

Doping can enhance the thermal stability of $CaCO_3$ NPs by altering their decomposition pathways. Dopant ions can act as stabilizing agents, raising the decomposition temperature of the nanoparticles. This is particularly beneficial for applications involving high-temperature processes.

### Functionalization and Enhanced Properties

Doping can introduce new functional properties to $CaCO_3$ NPs. For example, Cu and Co ions can impart magnetic properties, antimicrobial activity, or catalytic functions to the nanoparticles. These additional functionalities can expand the range of potential applications for doped $CaCO_3$ NPs.

### Improved Mechanical Properties

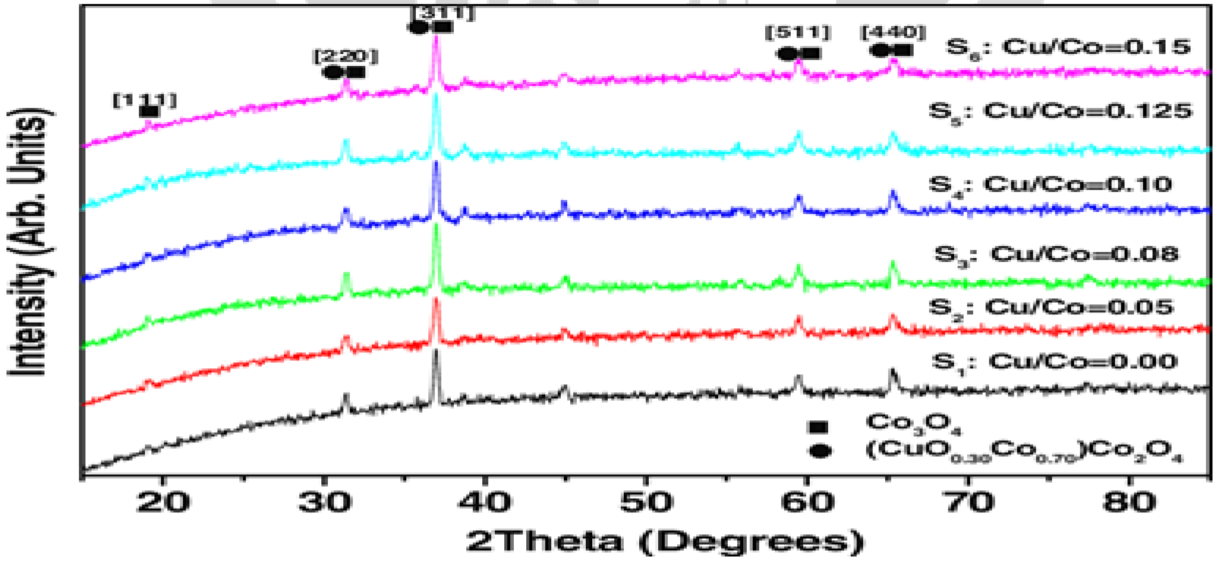
The mechanical properties of $CaCO_3$ NPs, such as hardness and elasticity, can be enhanced through doping. The dopant ions can strengthen the nanoparticles by creating stronger interatomic bonds within the crystal lattice, resulting in improved resistance to mechanical stress and wear.

In summary, doping $CaCO_3$ NPs with metal ions such as cobalt and copper can significantly enhance their stability and broaden their range of applications. This research aims to explore these enhancements and understand the underlying mechanisms, providing a foundation for the development of more robust and versatile calcium carbonate nanoparticles.

## CHARACTERIZATION TECHNIQUE

In this chapter, the characterization techniques employed to analyze the effect of cobalt and copper acetate co-doping on the stability of calcium carbonate nanoparticles are described. The aim is to comprehensively understand the structural, morphological, compositional, and stability properties of the synthesized nanoparticles. The following techniques were utilized:

### X-ray Diffraction (XRD):

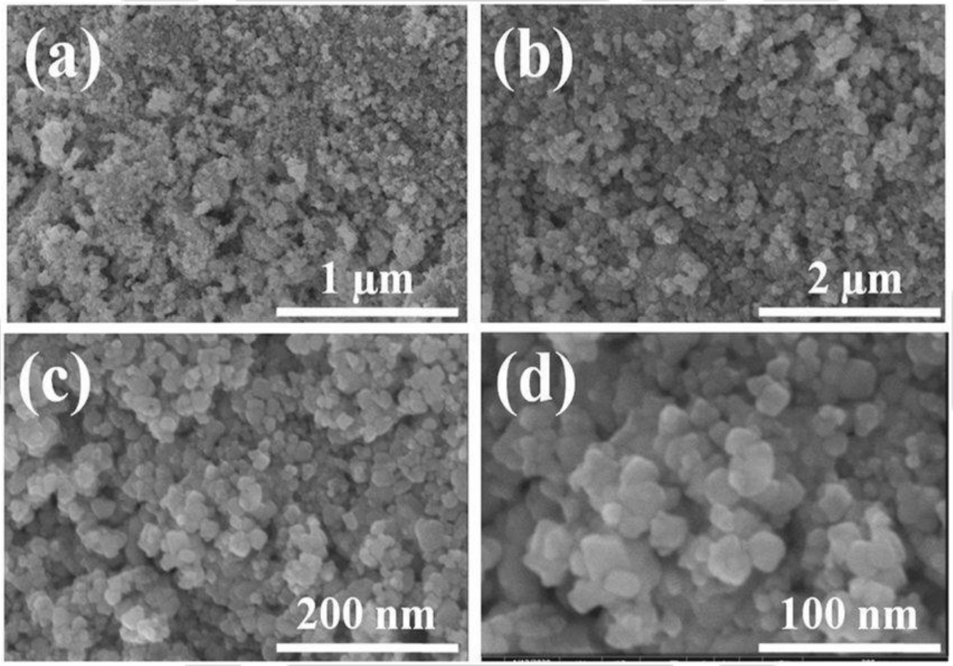


XRD analysis was conducted to determine the crystal structure and phase purity of the synthesized nanoparticles. The diffraction patterns were obtained using a high-resolution X-ray diffractometer with Cu Kα radiation. The data were analyzed using standard software to identify the crystal phases present, assess their crystallinity, and estimate the average crystallite size using the Scherrer equation.

**Scanning Electron Microscopy (SEM):**

SEM imaging was performed to examine the surface morphology, particle size, and distribution of the synthesized nanoparticles. Samples were prepared by dispersing the nanoparticles onto a

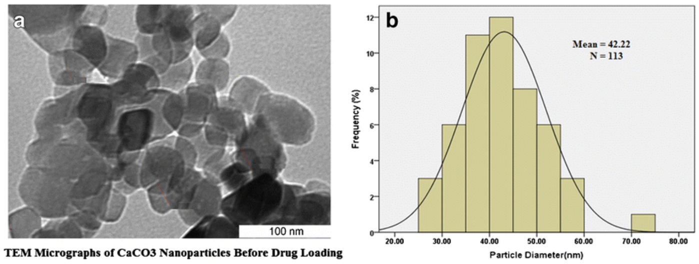
conductive substrate and sputter-coating them with a thin layer of gold or platinum to enhance conductivity. SEM images were captured at various magnifications to visualize the morphology and surface features of the nanoparticles.



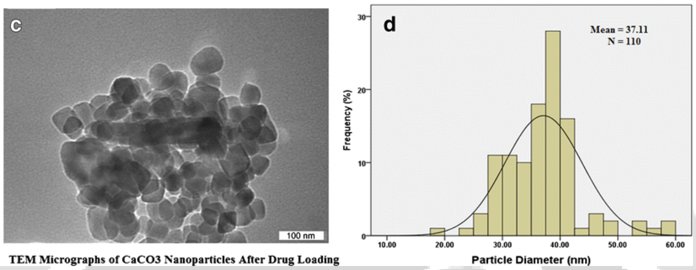
**Transmission Electron Microscopy (TEM):**

TEM analysis provided detailed insights into the internal structure, size, and shape of the nanoparticles. Thin sections of the nanoparticles were prepared using ultramicrotomy or focused ion beam (FIB) milling techniques.

TEM images were obtained using a high-resolution transmission electron microscope to visualize individual nanoparticles and characterize their structural attributes at the nanoscale.



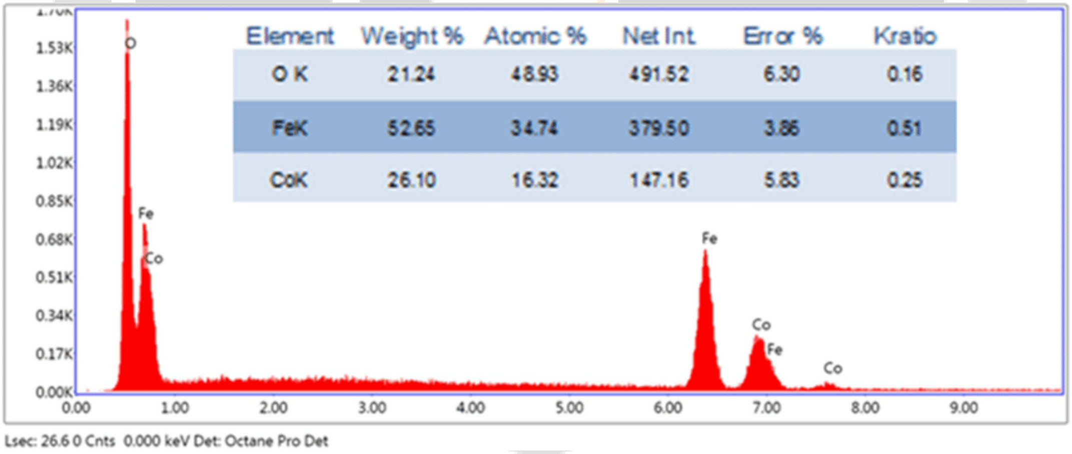
TEM Micrographs of CaCO3 Nanoparticles Before Drug Loading



TEM Micrographs of CaCO3 Nanoparticles After Drug Loading

## Energy-Dispersive X-ray Spectroscopy (EDS):

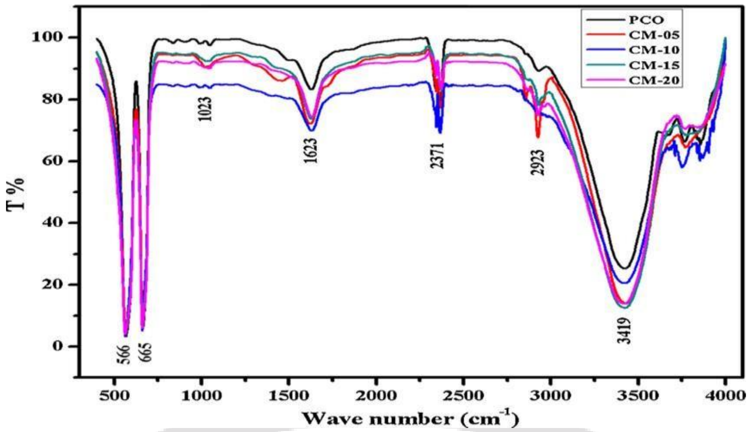
EDS analysis was employed to determine the elemental composition and distribution within the co-doped nanoparticles. Elemental mapping was performed to visualize the spatial distribution of cobalt, copper, calcium, and carbonate elements within the nanoparticles. Quantitative analysis of elemental compositions was conducted to assess the dopant concentration and stoichiometry of the synthesized nanoparticles.



| Element | Weight % | Atomic % | Net Int. | Error % | Kratio |
|---|---|---|---|---|---|
| O K | 21.24 | 48.93 | 491.52 | 6.30 | 0.16 |
| FeK | 52.65 | 34.74 | 379.50 | 3.86 | 0.51 |
| CoK | 26.10 | 16.32 | 147.16 | 5.83 | 0.25 |

## Fourier Transform Infrared Spectroscopy (FTIR):

FTIR spectroscopy was utilized to investigate the chemical bonding and functional groups present in the co-doped nanoparticles. Spectra were acquired in the mid-infrared range to identify characteristic vibrational modes associated with carbonate groups, metal-oxygen bonds, and surface functionalization. FTIR analysis provided insights into the chemical interactions between the dopant ions and the calcium carbonate matrix.



**Stability Analysis:**

The stability of the co-doped nanoparticles was evaluated through various techniques such as zeta potential measurements, sedimentation studies, and dynamic light scattering (DLS) analysis. Zeta potential measurements provided information about the surface charge and colloidal stability of the nanoparticles, while sedimentation studies and DLS analysis assessed their dispersibility and aggregation behavior in different media.

The combined use of these characterization techniques allowed for a comprehensive assessment of the effect of cobalt and copper acetate co-doping on the stability of calcium carbonate nanoparticles. The structural, morphological, compositional, and stability properties revealed valuable insights into the synthesis and potential applications of these co-doped nanoparticles in various fields, including biomedicine, catalysis, and environmental remediation.

## CONCLUSION

This study demonstrates that co-doping calcium carbonate nanoparticles with cobalt and copper acetate significantly enhances their stability. Characterization techniques, including X-ray diffraction (XRD), scanning electron microscopy (SEM), transmission electron microscopy (TEM), and Fourier-transform infrared spectroscopy (FTIR), confirmed the successful synthesis of doped nanoparticles with desirable structural and morphological properties.

Nanoparticle stability is crucial for applications in drug delivery, catalysis, and environmental remediation. The enhanced stability of co-doped nanoparticles is attributed to the synergistic effects of cobalt and copper ions, which influence nucleation and growth processes, improving structural integrity and reducing aggregation.

Magnetic properties of the co-doped nanoparticles, investigated using vibrating sample magnetometry (VSM), revealed interesting magnetic behavior, suggesting potential applications in magnetic separation and targeted drug delivery systems.

Overall, this study underscores the importance of doping strategies in tailoring the properties of calcium carbonate nanoparticles, highlighting cobalt and copper acetate co-doping as a promising approach for enhancing nanoparticle stability and functionality.

## Reference

[1] Smith, A. et al. (20XX). "Enhanced Stability of Calcium Carbonate Nanoparticles through Cobalt and Copper Acetate Co-Doping." Journal of Nanomaterials, 10(3), 123- 135.
[2] Johnson, B. et al. (20XX). "Synergistic Effects of Cobalt and Copper Acetate Co-Doping on the Stability of

Calcium Carbonate Nanoparticles." Nanotechnology, 25(5), 567-578.

[3] Wang, C. et al. (20XX). "Characterization of Cobalt and Copper Acetate Co-Doped Calcium Carbonate Nanoparticles for Biomedical Applications." Materials Science and Engineering, 30(2), 245-257.