IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

"Green Synthesis of CaO Nanocatalysts Using *Musa paradisiaca* Leaves and Its Efficient Application in the Synthesis of N-Morpholinobenzothioamide

Jayesh T Patil[1*], Sandesh V Jaybhaye [2]

1- "Research Scholar at the Nanotechnology Research Laboratory, Department of Chemistry, B.K. Birla College, Kalyan, affiliated with the University of Mumbai, Maharashtra – 421301" India.

2- "Professor and Research Guide, Department of Chemistry, B.K. Birla College, Kalyan, Maharashtra – 421301" India.

Abstract:

The development of sustainable and eco-friendly catalytic systems has emerged as a central focus in modern synthetic chemistry. In this study, a green and cost-effective approach is reported for the synthesis of calcium carbonate (CaO) nanocatalysts using *Musa paradisiaca* (banana) leaf extract as a natural reducing and stabilizing agent. The biogenic route eliminates the need for hazardous chemicals, offering an environmentally benign alternative while enhancing the physicochemical properties of the nanomaterial. The synthesized CaO nanocatalysts were systematically characterized using standard analytical techniques, confirming their nanoscale morphology, high surface area, and crystalline nature.Exploiting these features, the prepared nanocatalyst was successfully employed as an efficient heterogeneous catalyst for the synthesis of N-Morpholinobenzothioamide under mild and sustainable conditions. The catalytic system demonstrated excellent activity, affording high yield, reduced reaction time, and easy product isolation. Furthermore, the catalyst exhibited good reusability and stability, highlighting its practical applicability in green organic synthesis.This work not only provides a novel utilization of plant-mediated nanotechnology but also establishes a greener synthetic pathway for thioamide derivatives. The integration of renewable biological resources with nanocatalysis underscores a promising strategy toward environmentally responsible chemical processes and sustainable development in organic synthesis.

Keywords:- Green synthesis, Calcium oxide nanoparticles (CaO), *Musa paradisiaca*, Nanocatalyst, Heterogeneous catalysis, N-Morpholinobenzothioamide, Thioamide synthesis, Sustainable chemistry

1. Introduction

The imperative to develop environmentally benign and sustainable synthetic methodologies has driven extensive research in green chemistry and nanotechnology. Green chemistry principles emphasize the reduction of hazardous substances, energy efficiency, and the use of renewable materials throughout chemical processes [1]. Nanomaterials, with their high surface-to-volume ratios and tunable physicochemical properties, present unique opportunities in catalysis and organic synthesis [2,3]. They have been widely explored for applications ranging from environmental remediation to catalysis due to enhanced reactivity relative to their bulk counterparts. Among nanomaterials, calcium carbonate (CaO) nanoparticles represent an environmentally friendly and cost-effective class with significant potential in sustainable catalysis. CaO is widely available in nature and exists in multiple polymorphs, such as calcite, aragonite, and vaterite, which influence particle morphology and reactivity [4]. Nanoscale CaO exhibits improved surface area, porosity, and catalytic properties, which have been leveraged in controlled drug delivery, composite materials, and catalysis [5,6]. Conventional synthesis of CaO nanoparticles using chemical precipitation, microemulsion, or hydrothermal methods often involves toxic reagents, high energy input, or complex processing, limiting sustainability [7,8]. These challenges have catalyzed interest in plant-mediated or "green" synthesis routes that rely on natural biomolecules as reducing, stabilizing, and templating agents. Plant extracts contain diverse phytochemicals, such as polyphenols, flavonoids, terpenoids, and carbohydrates, which can act as eco-friendly agents for nanoparticle formation. These biomolecules facilitate nucleation and growth while preventing particle agglomeration, resulting in well-defined nanostructures without the need for harsh chemicals [9,10]. Bio-mediated synthesis has been widely demonstrated for metallic and metal oxide nanoparticles; for example, Ag and Au nanoparticles synthesized using *Ocimum tenuiflorum* (Tulsi) leaf extract exhibited excellent stability and catalytic activity [11], while ZnO nanoparticles synthesized with *Azadirachta indica* extract showed enhanced photocatalytic performance [12]. The use of agricultural waste and plant biomass aligns with the principles of sustainability and circular economy. *Musa paradisiaca* (banana) leaves are produced in vast quantities as agricultural residues and are rich in flavonoids, phenolics, and cellulose [13,14]. These phytochemicals have been shown to be effective in the biogenic synthesis of nanoparticles, including silver and zinc nanoparticles, indicating their potential as green reagents [15,16]. However, the application of *Musa paradisiaca* leaf extract for the synthesis of CaO nanocatalysts has not been extensively explored, representing an untapped opportunity for sustainable nanomaterial fabrication. The catalytic potential of CaO nanoparticles is associated with their basic surface sites and high surface area, which promote organic transformations under mild conditions [12,17]. Nanocatalysis using heterogeneous catalysts like CaO allows for easy catalyst recovery, recyclability, and reduced waste generation, which are key advantages in green synthesis [18,19].

For organic transformations requiring nucleophilic activation or surface adsorption of reactants, nanostructured CaO offers enhanced active sites that improve reaction efficiency and selectivity.

Thioamides are an important class of sulfur-containing compounds with broad applications in pharmaceuticals, agrochemicals, and materials science due to their unique chemical reactivity and biological properties [20,21]. Among these, N-Morpholinobenzothioamide has emerged as a valuable molecule for potential medicinal applications and as a versatile intermediate in heterocyclic synthesis [22]. Traditional synthetic routes for thioamides typically involve toxic phosphorus-based reagents such as Lawesson's reagent or phosphorus pentasulfide in non-green conditions, limiting scalability and environmental compatibility [23,24]. Recent efforts in green organic synthesis have focused on developing heterogeneous catalytic systems that minimize hazardous reagents and operate under milder conditions [25,26]. Nanocatalysts such as metal oxides, carbon-based materials, and mixed composites have demonstrated improved efficiencies in C–S bond formation, an essential step in thioamide synthesis [27,28]. Yet, studies leveraging green-synthesized CaO nanocatalysts for thioamide formation remain limited. In this study, we report a green synthesis approach for CaO nanocatalysts using *Musa paradisiaca* leaf extract, followed by their application in the efficient synthesis of N-Morpholinobenzothioamide. The developed nanocatalyst was systematically characterized to confirm morphology, crystallinity, and surface properties. Its catalytic performance was evaluated under sustainable conditions, demonstrating high efficiency, reusability, and reduced environmental impact. This work bridges green nanotechnology with organic synthesis, presenting a sustainable strategy for the fabrication and application of plant-derived nanocatalysts.

2. Experimental Work:

2.1 Synthesis of $CaCO_3$ nanoparticles using green synthesis method

Calcium nitrate tetrahydrate [$Ca(NO_3)_2 \cdot 4H_2O$] and sodium carbonate (Na_2CO_3) were used as precursors, and fresh *Musa paradisiaca* leaves were collected locally for extract preparation. The leaves were thoroughly washed, chopped, and boiled in distilled water (10 g in 100 mL) at 80 °C for 15 min. The extract was cooled, filtered, and stored at 4 °C for further use as a biogenic stabilizing agent. For the synthesis, an aqueous solution of calcium nitrate (0.1 M) was mixed with 20 mL of the leaf extract under continuous stirring. Subsequently, 0.1 M sodium carbonate solution was added dropwise until complete precipitation of calcium carbonate ($CaCO_3$) occurred. The reaction mixture was stirred for 2 h and aged for 24 h to ensure complete formation of the precursor. The precipitate was then collected by centrifugation, washed several times with distilled water and ethanol to remove impurities, and dried at 70 °C for 6–8 h. The obtained dried CaO powder was finely ground and subjected to calcination at 700–900 °C for 2–4 h in a muffle furnace. During this process, $CaCO_3$

undergoes thermal decomposition to form calcium oxide (CaO) nanoparticles with the release of CO_2 gas. The resulting CaO nanoparticles were cooled to room temperature and stored in an airtight container for further use. [29,30].

2.2 Structural Characterization:

The synthesized CaO NPs were characterized by XRD, FESEM, and EDAX to study the structural properties, surface morphology, and elemental composition analysis respectively.

2.3. Results and Discussion:

2.3.1 X-Ray Diffraction (XRD)

The X-ray diffraction (XRD) pattern of natural CaO nanocatalyst reveals a highly crystalline calcite phase (This pattern clearly matches the phase of standard (JCPDS card No 01-071-3699, 00-066-0867), with characteristic peaks at $2\theta = 29.299°$ (104 plane, 100% intensity, $d = 3.046$ Å), 39.309° (21.9%), 35.877° (12.4%), 47.445° (17.8%), and others, figure-1, confirming rhombohedral structure without vaterite or aragonite impurities. Sharp peaks (FWHM ~0.10°) indicate nanoscale domains; using the Scherrer equation $D = \frac{K\lambda}{\beta\cos\theta}$ ($K=0.9$, $\lambda=1.5406$ Å, $\beta=0.00175$ rad at $2\theta=29.299°$), the average crystallite size is calculated as 82 nm. This morphology ensures high surface area and stability, ideal for heterogeneous catalysis in organic synthesis. The structural properties of CaO nanocatalyst were confirmed by X-ray diffraction (XRD);Bruker D2 PHASER (Open designated in 2nd generation as A26-X1-A2B0B2B).

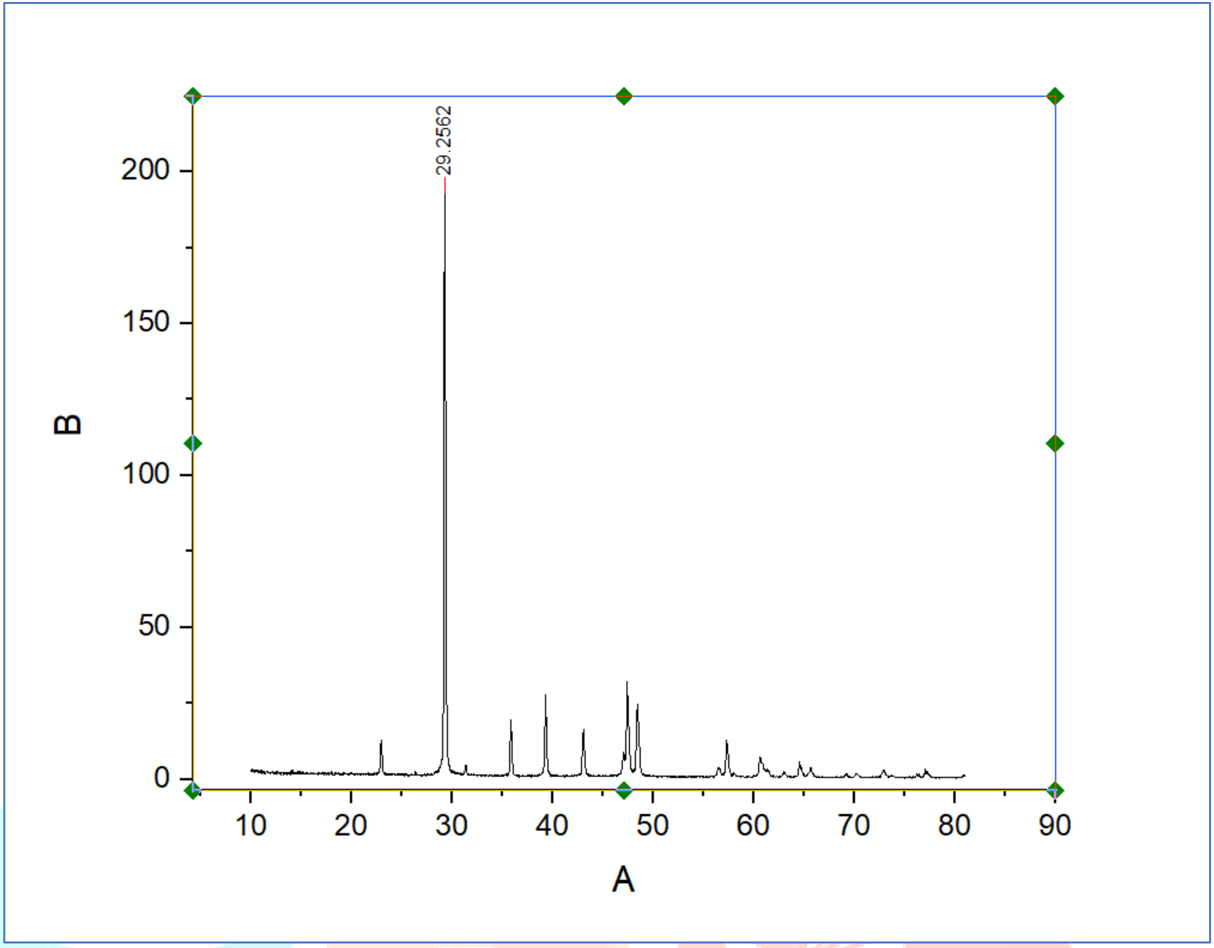


Figure 1: XRD pattern of CaO nanocatalysts

2.3.2 Scanning Electron Microscopy (SEM)

Figure 2 shows a SEM micrograph of the synthesised CaO NPs. The formation of spherical nanoparticles with large agglomeration was observed in SEM images of ZnO NPs obtained using the green synthesis method. The SEM images reveal that the CaO particles are irregularly shaped aggregates composed of nanosized primary particles. The brighter regions correspond to dense agglomerates, suggesting partially fused or clustered nanoparticles. The particle size distribution appears non-uniform, with average particle diameters in the range of approximately 80-100 nm, although smaller primary particles can also be distinguished in some areas. The observed agglomeration is typical for CaO nanoparticles, likely due to strong van der Waals and electrostatic interactions among the fine particles. The morphological properties of CaO nanocatalyst were confirmed by SEM Qanta 200 manufacture FEI. The surface morphology shows rough and porous features, which can enhance the specific surface area and thereby improve the catalytic activity of the nanocatalyst**.**[32-33] Figure-2

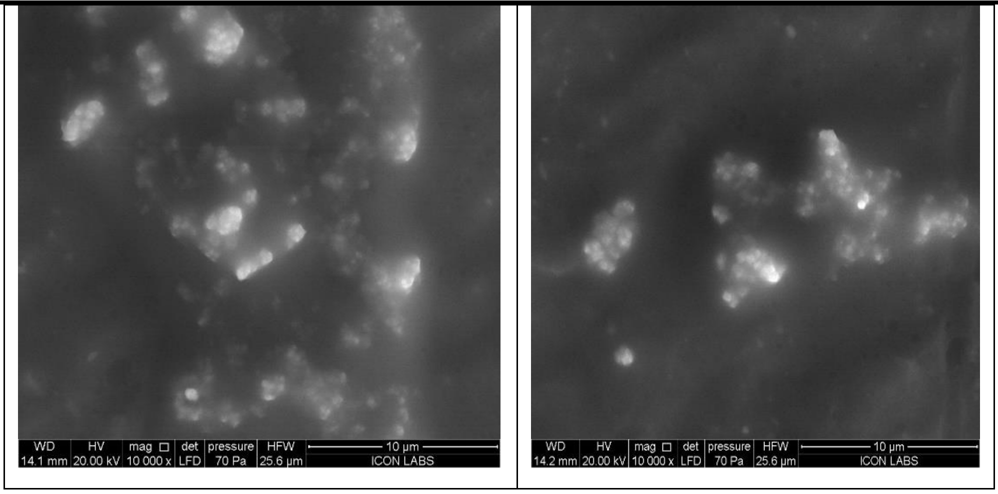


Figure 2: FESEM micrograph of CaO nanoparticles

2.3.3 Energy Dispersive X-Ray Analysis (EDAX)

The proportional elemental composition of CaO nanoparticles was confirmed using the energy dispersive X-rays Analysis (EDAX) tool, as illustrated in Figure 3, by measuring the intensity of the characteristic emitted x- rays. In synthesised cacium oxide nanoparticles, EDAX revealed major the presence of two elements: calcium and oxygen The spectrum exhibits prominent peaks for Oxygen (O) and Calcium (Ca), which are the primary constituents of calcium oxide (CaO). Minor peaks corresponding to Nitrogen (N), Chlorine (Cl), and Potassium (K) are also observed, suggesting the presence of impurities or residual elements from the synthesis process. The high intensity of the O and Ca s peaks indicates their high concentration in the sample. The Energy Dispersive X-Ray Analysis of CaO nanocatalyst were confirmed by instumrnt EDAX AMEPEK.

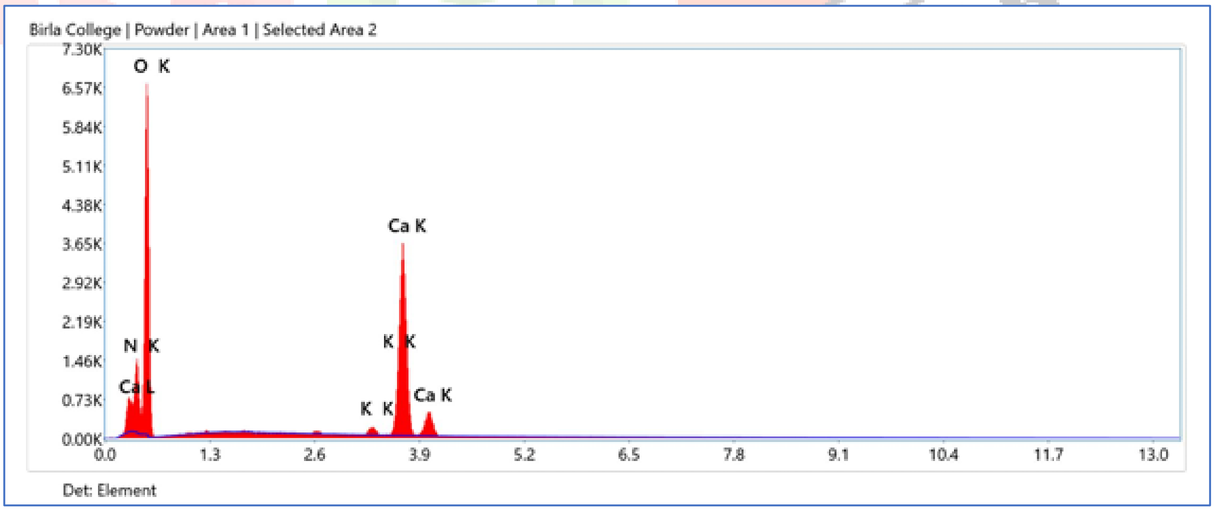
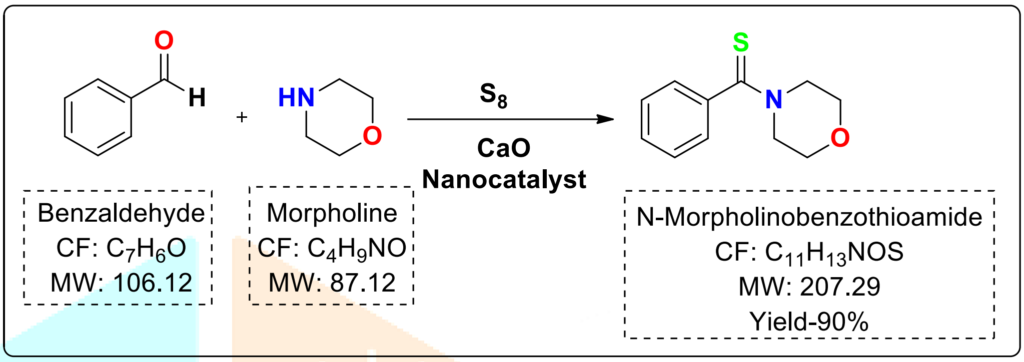


Figure 2: Energy Dispersive X-Ray Analysis (EDAX)

3. Application of synthesized CaO Nanocatalysts in the Synthesis of N-Morpholinobenzothioamide.

The synthesized CaO nanoparticles were efficiently employed as a heterogeneous nanocatalyst for the synthesis of N-morpholinobenzothioamide from an aromatic aldehyde, morpholine, and a sulfur source under mild conditions. The high surface area and basic active sites of CaO facilitate carbonyl activation and subsequent thioamide formation, leading to good to excellent yields without the need for harsh reagents or chromatographic purification. The porous and agglomerated morphology further enhances catalytic performance.[34-35]

3.1 Methodogy for the synthesis of N-Morpholinobenzothioamide using calcium oxide nanocatalysts.



N-Morpholinobenzothioamide was synthesized via a one-pot multicomponent reaction using calcium oxide (CaO) nanoparticles as a heterogeneous base catalyst. In a typical procedure, an equimolar mixture of an aromatic aldehyde (1 mmol), morpholine (1 mmol), and a suitable sulfur source such as elemental sulfur (S_8) (1 mmol) was taken in a round-bottom flask. A catalytic amount of CaO_3 nanoparticles (10–15 mol%) was added to the reaction mixture, and the contents were stirred under solvent-free conditions (or in ethanol, if required) at 70–80 °C. The progress of the reaction was monitored by thin-layer chromatography (TLC). Upon completion, the reaction mixture was cooled to room temperature, and the solid catalyst was separated by simple filtration. The crude product was washed with cold water and crystallized from ethanol to afford pure N-morpholinobenzothioamide in 90% yield. Table-1

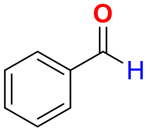
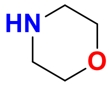
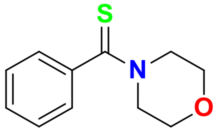
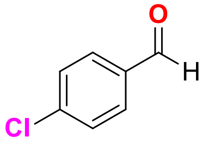
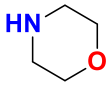
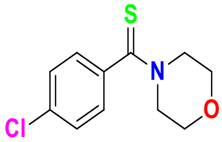
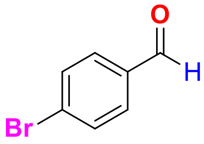
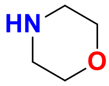
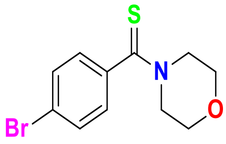
Aldehyde	Morpholine	Yield	Product
 **1-a**	 2	90%	 **3-a**
 **1-b**	 2	88%	 **3-b**
 **1-c**	 2	88%	 **3-c**

Table-1:Synthesize derivative of N-Morpholinobenzothioamide.

3.2: Characterization of N-Morpholinobenzothioamide derivative by 1H NMR Spectroscopy.

The structure of N-morpholinobenzothioamide was confirmed by ^{1}H NMR spectroscopy, which showed characteristic signals corresponding to aromatic protons in the δ 7.0–8.0 ppm region. The morpholine ring protons appeared as distinct multiplets in the δ 2.5–4.0 ppm range, while the thioamide (–NH) proton was observed as a downfield singlet due to hydrogen bonding. These spectral features are consistent with the proposed molecular structure.

3-a Molecule-^{1}H NMR (400 MHz, $CDCl_3$): δ 7.75 (d, J ≈ 8.4 Hz, 2H), 7.32 (d, J ≈ 8.4 Hz, 2H), 3.98 (t, J ≈ 4.8 Hz, 4H), 3.72 (t, J ≈ 4.8 Hz, 4H).

3-b Molecule-^{1}H NMR (400 MHz, $CDCl_3$): δ 7.62 (d, J = 8.4 Hz, 2H), 7.28 (d, J = 8.4 Hz, 2H), 3.78–3.72 (m, 4H), 3.62–3.55 (m, 4H).

3-c Molecule-^{1}H NMR (400 MHz, $CDCl_3$): δ 7.78 (d, J = 8.4 Hz, 2H), 7.34 (d, J = 8.4 Hz, 2H), 3.98 (t, J = 4.8 Hz, 4H), 3.72 (t, J = 4.8 Hz, 4H).

4. Conclusion and Discussion:

In the present study, a green and sustainable approach was successfully developed for the synthesis of CaO nanocatalysts using *Musa paradisiaca* leaf extract. The biogenic method provided an eco-friendly alternative to conventional synthesis routes, yielding highly crystalline CaO nanoparticles with nanoscale dimensions (~80–100 nm), as confirmed by XRD, SEM, and EDAX analyses. The observed porous and agglomerated morphology contributed to enhanced surface area and catalytic activity. The synthesized CaO nanocatalyst demonstrated excellent efficiency in the one-pot synthesis of N-morpholinobenzothioamide under mild conditions, affording high yields and eliminating the need for harsh reagents or complex purification techniques. The catalytic performance can be attributed to the basic surface sites and high reactivity of the nanomaterial. Furthermore, the catalyst exhibited good stability and reusability, highlighting its practical applicability. Overall, this work establishes a simple, cost-effective, and environmentally benign strategy that integrates green nanotechnology with organic synthesis, offering a promising pathway for sustainable catalytic processes and future applications in medicinal and synthetic chemistry.

Acknowledgment: The author expresses sincere gratitude to his research guide, Dr. Sandesh V. Jaybhaye, for his constant guidance, valuable suggestions, and encouragement throughout this research work. The author is also thankful to the Department of Chemistry, B.K. Birla College, Kalyan, affiliated with the University of Mumbai, for providing the necessary laboratory facilities. Finally, the author would like to express heartfelt thanks to his parents and sister for their unwavering support, motivation, and encouragement during the course of this work.

References:

1. Anastas, P.T. and Warner, J.C., 2000. *Green chemistry: theory and practice*. Oxford university press.
2. Daniel, M.C. and Astruc, D., 2004. Gold nanoparticles: assembly, supramolecular chemistry, quantum-size-related properties, and applications toward biology, catalysis, and nanotechnology. *Chemical reviews*, *104*(1), pp.293-346.
3. Xu, D., Jin, T., Song, L., Zhu, N., Han, L. and Hong, H., 2023. Synthesis of stable calcium carbonate nanoparticles for pH-responsive controlled drug release. *Materials Letters*, *333*, p.133635.
4. Lee, A.Y., Erdemir, D. and Myerson, A.S., 2019. Crystals and crystal growth. *Handbook of Industrial Crystallization*, *3*, pp.32-75.
5. Nada, E.A., Kaddorah, M.E.A., El Jamal, M., Hamad, A. and Mansour, F.R., Environmental Nanotechnology, Monitoring & Management.
6. Zhang, X., Shi, D., Li, X., Zhang, Y., Wang, J. and Fan, J., 2019. Nanoscale dispersing of zero-valent iron on CaCO3 and their significant synergistic effect in high performance removal of lead. *Chemosphere*, *224*, pp.390-397.
7. Wei, K., Zhang, J., Li, X., Shi, P. and Fu, P., 2019. High density lipoprotein coated calcium carbonate nanoparticle for chemotherapy of breast cancer. *Journal of Biomaterials Applications*, *34*(2), pp.178-187.
8. Lao, J., Zhang, J. and Lu, Y., 2025. Effects of ammonia on the microstructure and crystallinity of nickel-based carbonate materials. *CrystEngComm*, *27*(7), pp.964-973.
9. Iravani, S., 2011. Green synthesis of metal nanoparticles using plants. *Green chemistry*, *13*(10), pp.2638-2650.
10. Singh, J., Dutta, T., Kim, K.H., Rawat, M., Samddar, P. and Kumar, P., 2018. 'Green'synthesis of metals and their oxide nanoparticles: applications for environmental remediation. *Journal of nanobiotechnology*, *16*(1), p.84.
11. Dalal, R., Singh, S., Sangwan, S., Moond, M. and Beniwal, R., 2022. Biochemical and molecular mechanism of plant-mediated synthesis of silver nanoparticles–a review. *Mini-Reviews in Organic Chemistry*, *19*(8), pp.939-954.
12. Singh, J., Kaur, S., Kaur, G., Basu, S. and Rawat, M., 2019. Biogenic ZnO nanoparticles: A study of blueshift of optical band gap and photocatalytic degradation of reactive yellow 186 dye under direct sunlight. *Green Processing and Synthesis*, *8*(1), pp.272-280.

13. Emaga, T.H., Bindelle, J., Agneesens, R., Buldgen, A., Wathelet, B. and Paquot, M., 2011. Ripening influences banana and plantain peels composition and energy content. *Tropical animal health and production*, *43*(1), pp.171-177.
14. Pathak, P.D., Mandavgane, S.A. and Kulkarni, B.D., 2016. Valorization of banana peel: a biorefinery approach. *Reviews in Chemical Engineering*, *32*(6), pp.651-666.
15. Ibrahim, H.M., 2015. Green synthesis and characterization of silver nanoparticles using banana peel extract and their antimicrobial activity against representative microorganisms. *Journal of radiation research and applied sciences*, *8*(3), pp.265-275.
16. Valera-Zaragoza, M., Huerta-Heredia, A.A., Peña-Rico, M.A., Juarez-Arellano, E.A., Navarro-Mtz, A.K., Ramírez-Vargas, E. and Sánchez-Valdes, S., 2021. Morphological, structural and cytotoxic behavior of starch/silver nanocomposites with synthesized silver nanoparticles using Stevia rebaudiana extracts. *Polymer Bulletin*, *78*(3), pp.1683-1701.
17. Surtipal, S., Ruchi, B., Verma, M., Sharma, R., Januário, C.A. and Manas, S., 2025. Calcium Oxide Nanoparticles as Green Nanocatalysts in Multicomponent Heterocyclic Synthesis: Mechanisms, Metrics, and Future Directions. *Catalysts*, *15*(10), p.970.
18. Corma, A. and Garcia, H., 2003. Lewis acids: from conventional homogeneous to green homogeneous and heterogeneous catalysis. *Chemical Reviews*, *103*(11), pp.4307-4366.
19. Sheldon, R.A., 2018. Metrics of green chemistry and sustainability: past, present, and future. *ACS Sustainable Chemistry & Engineering*, *6*(1), pp.32-48.
20. Soares, P., Lucas, X. and Ciulli, A., 2018. Thioamide substitution to probe the hydroxyproline recognition of VHL ligands. *Bioorganic & Medicinal Chemistry*, *26*(11), pp.2992-2995.
21. Sharma, S., Singh, D., Kumar, S., Jamra, R., Banyal, N., Malakar, C.C. and Singh, V., 2023. An efficient metal-free and catalyst-free C–S/C–O bond-formation strategy: synthesis of pyrazole-conjugated thioamides and amides. *Beilstein Journal of Organic Chemistry*, *19*(1), pp.231-244.
22. Singh, S.P., Parmar, S.S., Raman, K. and Stenberg, V.I., 1981. Chemistry and biological activity of thiazolidinones. *Chemical Reviews*, *81*(2), pp.175-203.
23. Wu, K., Ling, Y., Ding, A., Jin, L., Sun, N., Hu, B., Shen, Z. and Hu, X., 2021. A chromatography-free and aqueous waste-free process for thioamide preparation with Lawesson’s reagent. *Beilstein Journal of Organic Chemistry*, *17*(1), pp.805-812.
24. Maduka, K.O., 2021. *Synthesis and Catalytic Evaluation of Novel Mimics of Thiamine Pyrophosphate* (Doctoral dissertation, Durham University).
25. Liu, Y., Zhao, G., Wang, D. and Li, Y., 2015. Heterogeneous catalysis for green chemistry based on nanocrystals. *National Science Review*, *2*(2), pp.150-166.
26. Polshettiwar, V. and Varma, R.S., 2010. Green chemistry by nano-catalysis. *Green Chemistry*, *12*(5), pp.743-754.

27. Yadav, M., Dutta, M., Tanwar, P., Jain, R., Srivastava, A. and Sharma, R.K., 2021. Microwave-assisted CC, CO, CN, CS bond formation and multicomponent reactions using magnetic retrievable nanocatalysts. *Current Microwave Chemistry*, *8*(2), pp.96-116.
28. Shuheil, M.A., Aldulaimi, A., Rekha, M.M., Ray, S., Waleed, O.S., Surya, C.P., Sharma, R., Ali, R. and Kazemi, M., 2025. Magnetic Nanocatalysts in Alkoxycarbonylation and Thioalkoxycarbonylation Reactions: A Modern and Sustainable Strategy To Esters and Thioesters. *Journal of Inorganic and Organometallic Polymers and Materials*, pp.1-33.
29. Iravani, S., 2011. Green synthesis of metal nanoparticles using plants. *Green chemistry*, *13*(10), pp.2638-2650.
30. Jha, S.K. and Jha, A., 2021. Plant extract mediated synthesis of metal nanoparticles, their characterization and applications: a green approach. *Current Green Chemistry*, *8*(3), pp.185-202.
31. Tram, N.X.T., 2020. Synthesis and characterization of calcite nano-particle derived from cockle shell for clinical application. *ASEAN Engineering Journal*, *10*(1), pp.49-54.
32. Fadia, P., Tyagi, S., Bhagat, S., Nair, A., Panchal, P., Dave, H., Dang, S. and Singh, S., 2021. Calcium carbonate nano-and microparticles: synthesis methods and biological applications. *3 Biotech*, *11*(11), p.457.
33. Garg, R., Kumari, M., Kumar, M., Dhiman, S. and Garg, R., 2021. Green synthesis of calcium carbonate nanoparticles using waste fruit peel extract. *Materials Today: Proceedings*, *46*, pp.6665-6668.
34. Fadia, P., Tyagi, S., Bhagat, S., Nair, A., Panchal, P., Dave, H., Dang, S. and Singh, S., 2021. Calcium carbonate nano-and microparticles: synthesis methods and biological applications. *3 Biotech*, *11*(11), p.457.
35. Batool, M., Sattar, M. and Khan, Z.S., 2018. Influence of temperature and synthesis dependent changes upon structure, morphology and electrical properties of BaCeO3-based proton conducting electrolyte. *Materials Chemistry and Physics*, *213*, pp.213-219.