IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429

Volume 6, Issue 5, June 2026

Impact Factor: 8.2

Green Synthesis of Zinc Oxide Nanoparticles Using Delonix Regia Flower Extract and their Application in Imidazole Derivative Synthesis

Janvi Trimukhe[1], Smita Tandale[2], Maryappa Sonawale[3], Gurumeet Wadhawa[4], Chetana Tumade[5], Vitthal Shivankar[6]

[1] Student, P.G. Department of Chemistry, Veer Wajekar College, Phunde, Uran

[2] Professor, Department of Chemistry, Veer Wajekar College, Phunde, Uran

[3,4,5] Assistant Professors, Department of Chemistry, Veer Wajekar College, Phunde, Uran

[6] Principal, Raosaheb Ramrao Patil Mahavidyalaya, Savlaj, Tal. Tasgaon, Dist. Sangli, Maharashtra

Abstract: *Green nanotechnology has gained considerable attention as an eco-friendly and sustainable approach for the synthesis of metal oxide nanoparticles with significant applications in catalysis and heterocyclic chemistry. In the present study, zinc oxide nanoparticles (ZnO NPs) were successfully synthesized through a green route using Delonix regia (Gulmohar) flower extract as a natural reducing and stabilizing agent. The phytochemical constituents present in the flower extract, including flavonoids, tannins, phenolic compounds, alkaloids, and anthocyanins, played a vital role in the reduction and stabilization of ZnO nanoparticles.*

The synthesized ZnO nanoparticles were characterized using UV–Visible spectroscopy, Fourier Transform Infrared Spectroscopy (FTIR), X-ray Diffraction (XRD), and Scanning Electron Microscopy (SEM). UV–Visible spectral analysis confirmed the formation of ZnO nanoparticles by showing characteristic absorption peaks in the range of 360–380 nm. FTIR analysis indicated the presence of Zn–O bonding along with phytochemical capping on the nanoparticle surface. XRD studies revealed the crystalline hexagonal wurtzite structure of ZnO nanoparticles, while SEM images demonstrated predominantly spherical nanoparticles with nanoscale dimensions.

Furthermore, the green synthesized ZnO nanoparticles were effectively employed as heterogeneous nanocatalysts for the one-pot multicomponent synthesis of substituted imidazole derivatives. The catalytic protocol exhibited several advantages such as high product yield, shorter reaction time, easy product isolation, catalyst recyclability, and environmentally benign reaction conditions. The synthesized imidazole derivatives were characterized by UV spectroscopy, FTIR, and ^{1}H-NMR spectroscopy.

The study highlights the potential of plant-mediated ZnO nanoparticles as efficient and sustainable nanocatalysts for the synthesis of biologically important heterocyclic compounds and emphasizes their promising role in green chemistry and nanocatalysis.

Keywords: Green synthesis, zinc oxide nanoparticles, imidazole derivatives, nanocatalysis, heterocyclic compounds, Delonix regia, sustainable chemistry.

I. INTRODUCTION

Green chemistry has emerged as an important branch of modern chemical science that emphasizes the development of environmentally friendly, sustainable, and economically viable chemical processes. The major objective of green chemistry is to minimize the use and generation of hazardous substances while maximizing efficiency and safety in chemical synthesis. Conventional synthetic methodologies often involve toxic solvents, hazardous reducing agents, high energy consumption, and the production of environmentally harmful byproducts, which create serious ecological and health concerns. Therefore, the development of sustainable and eco-friendly alternatives has become an important area of research in recent years.

Nanotechnology is another rapidly advancing field that deals with the design, synthesis, and application of materials at the nanoscale level. Nanoparticles possess unique physicochemical properties such as high surface area, enhanced catalytic activity, improved chemical reactivity, and distinctive optical and electronic properties compared to their bulk counterparts. Due to these remarkable characteristics, nanoparticles have found wide applications in catalysis, drug delivery, biosensors, photocatalysis, antimicrobial agents, environmental remediation, and pharmaceutical synthesis. Among various metal oxide nanoparticles, zinc oxide nanoparticles (ZnO NPs) have attracted significant attention because of their semiconducting nature, excellent catalytic activity, chemical stability, low toxicity, and biocompatibility. ZnO nanoparticles are extensively used in organic synthesis, nanocatalysis, cosmetics, antimicrobial applications, biomedical research, and environmental technologies.

In recent years, green synthesis of nanoparticles using biological resources has gained considerable importance as an alternative to conventional physical and chemical methods. Plant-mediated synthesis is particularly advantageous because it is simple, cost-effective, eco-friendly, and does not require toxic chemicals or harsh reaction conditions. Plant extracts contain a variety of bioactive phytochemicals such as flavonoids, tannins, phenolic compounds, alkaloids, and anthocyanins, which can act as natural reducing, stabilizing, and capping agents during nanoparticle synthesis. Among various plant materials, *Delonix regia* (Gulmohar) flower extract has shown promising potential due to its rich phytochemical composition and antioxidant properties.

The present study focuses on the green synthesis of zinc oxide nanoparticles using *Delonix regia* flower extract and their application as efficient heterogeneous nanocatalysts in the synthesis of substituted imidazole derivatives. Imidazole derivatives are an important class of heterocyclic compounds known for their wide range of biological and pharmaceutical activities, including antimicrobial, anti-inflammatory, anticancer, and antifungal properties. Traditional methods for the synthesis of imidazole derivatives often require harsh reaction conditions, longer reaction times, and toxic reagents. Therefore, the use of green synthesized ZnO nanoparticles as reusable nanocatalysts offers a sustainable and efficient alternative for heterocyclic synthesis.

In this work, the synthesized ZnO nanoparticles were characterized using UV–Visible spectroscopy, Fourier Transform Infrared Spectroscopy (FTIR), X-ray Diffraction (XRD), and Scanning Electron Microscopy (SEM) to determine their optical, structural, and morphological properties. Furthermore, the catalytic efficiency of the synthesized nanoparticles was investigated in the one-pot multicomponent synthesis of substituted imidazole derivatives under environmentally benign conditions. The study aims to contribute toward sustainable nanotechnology and green synthetic methodologies by integrating plant-mediated nanoparticle synthesis with nanocatalytic applications in heterocyclic chemistry.

II. MATERIALS REQUIRED

The materials used in the present study were selected for the green synthesis of zinc oxide nanoparticles and their characterization. All chemicals used were of analytical grade and were used without further purification.

Chemicals

Zinc acetate dihydrate was used as the precursor for the synthesis of zinc oxide nanoparticles. Sodium hydroxide was used as a precipitating agent for the formation of zinc hydroxide, which was later converted into zinc oxide

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 5, June 2026
Impact Factor: 8.2

nanoparticles. Ethanol was used for washing the synthesized nanoparticles to remove impurities and unreacted compounds. Distilled water was used throughout the experiment for preparation of solutions and washing purposes.

Biological Material

Fresh flowers of *Delonix regia* were collected and used as the biological source for the preparation of flower extract. The flower extract served as a natural reducing, stabilizing, and capping agent during the green synthesis of zinc oxide nanoparticles due to the presence of phytochemicals such as flavonoids, tannins, phenolic compounds, anthocyanins, and alkaloids.

Instruments

The synthesized zinc oxide nanoparticles were characterized using different analytical instruments. A UV–Visible spectrophotometer was used to study the optical absorption properties and confirm nanoparticle formation. Fourier Transform Infrared Spectroscopy was used to identify functional groups and confirm Zn–O bond formation. Scanning Electron Microscopy was used to examine the surface morphology and particle shape. X-ray diffraction analysis was performed to determine the crystalline nature and structure of the synthesized nanoparticles. A magnetic stirrer was used for continuous mixing during synthesis, while a muffle furnace was used for calcination of the dried sample to obtain crystalline ZnO nanoparticles.

III. PREPARATION OF *Delonix regia* FLOWER EXTRACT

Fresh flowers of *Delonix regia* were collected and thoroughly washed with distilled water to remove dust and other impurities. The cleaned flowers were chopped into small pieces to increase the surface area for effective extraction of phytochemicals. About 20 g of the flower material was transferred into a beaker containing distilled water and heated at 60–70°C for 20–30 minutes under continuous stirring. During heating, the bioactive phytochemicals present in the flowers were extracted into the aqueous medium. The resulting mixture was allowed to cool to room temperature and then filtered using Whatman filter paper to obtain a clear flower extract. The prepared extract was stored under refrigerated conditions and used for the green synthesis of zinc oxide nanoparticles.

IV. GREEN SYNTHESIS OF ZnO NANOPARTICLES

Experimental Procedure

Zinc oxide nanoparticles were synthesized using *Delonix regia* flower extract through a green and eco-friendly method. Initially, zinc acetate dihydrate was dissolved in distilled water under continuous magnetic stirring to prepare the zinc precursor solution. The prepared flower extract was then added dropwise to the zinc acetate solution under constant stirring. The reaction mixture was heated at 60–70°C for about 2–3 hours to facilitate the reduction and stabilization process mediated by phytochemicals present in the extract.

The pH of the reaction mixture was adjusted to 10–12 by the gradual addition of sodium hydroxide solution. Upon pH adjustment, the formation of a white precipitate was observed, indicating the synthesis of zinc oxide nanoparticles. The obtained precipitate was separated by centrifugation and repeatedly washed with distilled water and ethanol to remove impurities and unreacted components.

The purified product was dried in a hot air oven at 80°C to remove moisture content. The dried sample was further calcined in a muffle furnace at 400–500°C to obtain crystalline zinc oxide nanoparticles. The calcination process enhanced the crystallinity and purity of the synthesized nanoparticles. The formation of crystalline ZnO nanoparticles was subsequently confirmed by various characterization techniques.

DOI: 10.48175/IJARSCT-35661

V. CHEMICAL REACTION

Formation of Zinc Hydroxide

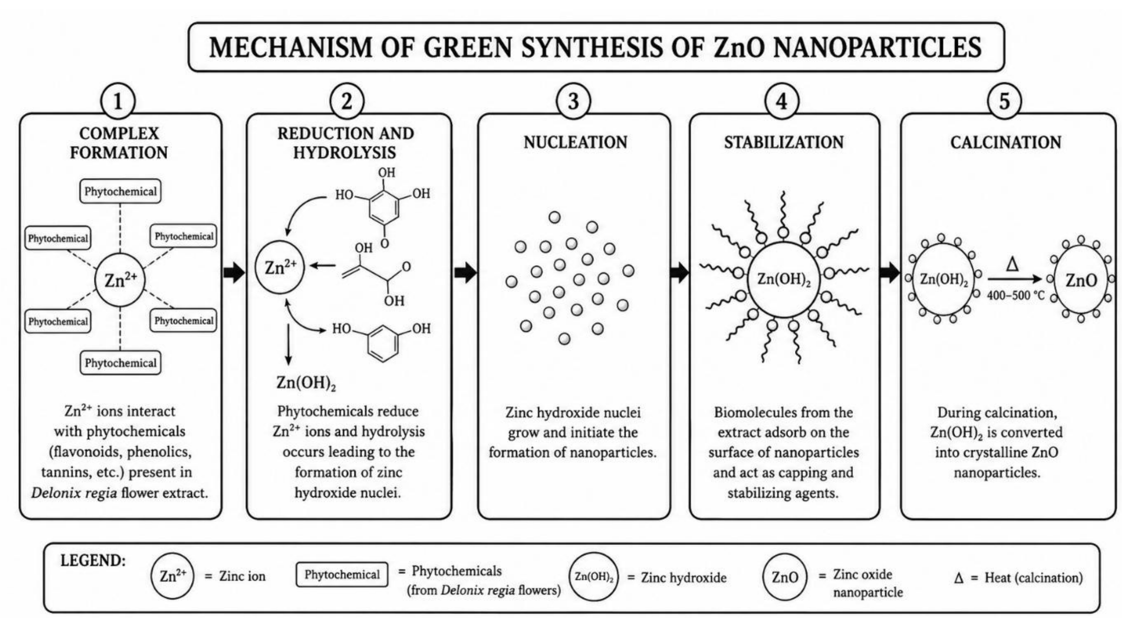
$$Zn(CH_3COO)_2 + 2NaOH \rightarrow Zn(OH)_2 + 2CH_3COONa$$

Formation of Zinc Oxide Nanoparticles

$$Zn(OH)_2 \xrightarrow{\Delta} ZnO + H_2O$$

Where:

- $Zn(CH_3COO)_2$ = Zinc acetate
- $NaOH$ = Sodium hydroxide
- $Zn(OH)_2$ = Zinc hydroxide
- ZnO = Zinc oxide nanoparticles
- Δ = Heat during calcination process



VI. CHARACTERIZATION OF ZnO NANOPARTICLES

UV–VISIBLE SPECTROSCOPY

UV–Visible spectroscopy was used to study the optical properties of the synthesized ZnO nanoparticles. The UV–Visible spectrum showed a characteristic absorption peak in the range of 360–380 nm, which confirmed the formation of ZnO nanoparticles. The observed absorption band indicates the semiconducting nature of zinc oxide and suggests the formation of nanoparticles with nanoscale dimensions.

FTIR ANALYSIS

FTIR analysis was carried out to identify the functional groups present in the synthesized ZnO nanoparticles. The FTIR spectrum showed a broad absorption band at 3200–3500 cm^{-1} corresponding to O–H stretching vibrations, while peaks

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 5, June 2026
Impact Factor: 8.2

observed at 2920–2850 cm^{-1} were assigned to C–H stretching vibrations. The absorption bands in the range of 1600–1650 cm^{-1} indicated C=O and C=C stretching vibrations of phytochemical compounds present in the flower extract. A characteristic absorption peak observed at 450–500 cm^{-1} corresponded to Zn–O stretching vibrations, confirming the formation of ZnO nanoparticles. The presence of organic functional groups in the FTIR spectrum indicated the involvement of phytochemicals as reducing and stabilizing agents during nanoparticle synthesis.

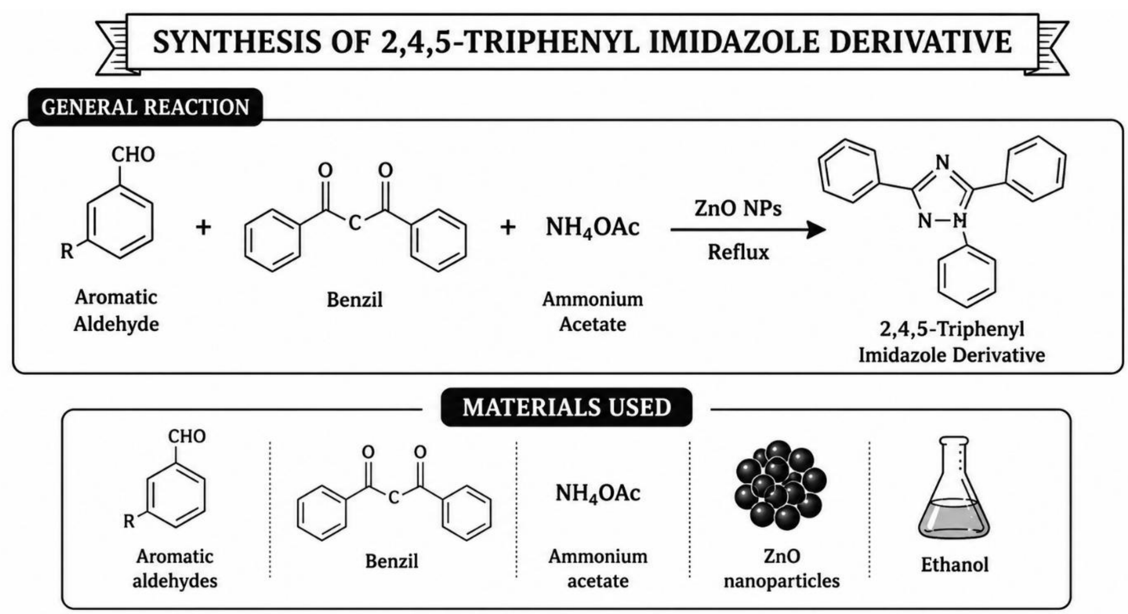
SCANNING ELECTRON MICROSCOPY (SEM)

SEM analysis of the synthesized ZnO nanoparticles revealed predominantly spherical-shaped particles with nanoscale dimensions. The micrographs also showed porous surface morphology along with slight agglomeration of nanoparticles. The porous and nanosized structure provides a high surface area, which enhances the catalytic activity of the nanoparticles. In addition, the porous morphology improves adsorption behavior, making the synthesized ZnO nanoparticles effective nanocatalysts for organic synthesis applications.

X-RAY DIFFRACTION (XRD)

X-ray diffraction (XRD) analysis was carried out to determine the crystalline nature and structural properties of the synthesized ZnO nanoparticles. The XRD pattern was interpreted based on Bragg's law, n\lambda = 2d\sin\theta which relates the diffraction angle to the crystal lattice spacing. The diffraction peaks observed at 2θ values of 31.7°, 34.4°, 36.2°, 47.5°, and 56.6° corresponded to the crystal planes (100), (002), (101), (102), and (110), respectively. These characteristic peaks confirmed the formation of hexagonal wurtzite structured ZnO nanoparticles. The sharp and intense diffraction peaks indicated high crystallinity of the synthesized nanoparticles, while peak broadening suggested the formation of particles in the nanoscale range.

VII. SYNTHESIS OF IMIDAZOLE DERIVATIVES



Experimental Procedure

Benzil, aromatic aldehyde, and ammonium acetate were dissolved in ethanol under stirring conditions. The synthesized ZnO nanoparticles were then added as a heterogeneous catalyst to the reaction mixture. The reaction was refluxed at 75–80°C and monitored periodically by thin layer chromatography (TLC) to determine the completion of the reaction.

After completion, the reaction mixture was cooled and the obtained product was filtered and recrystallized to obtain pure imidazole derivatives. The ZnO nanocatalyst was separated, recovered, and reused for subsequent reaction cycles.

VIII. OBSERVATION TABLE

Aromatic Aldehyde	Product	Yield (%)	Melting Point (°C)
Benzaldehyde	2,4,5-Triphenylimidazole	88	274–276
4-Methoxybenzaldehyde	Methoxy imidazole	90	258–260
4-Chlorobenzaldehyde	Chloro imidazole	85	266–268
4-Nitrobenzaldehyde	Nitro imidazole	82	282–284
4-Hydroxybenzaldehyde	Hydroxy imidazole	87	270–272

IX. UV–VISIBLE SPECTROSCOPY OF IMIDAZOLE

UV spectroscopic analysis of the synthesized imidazole derivatives showed characteristic absorption bands in the range of 210–220 nm and 260–275 nm, corresponding to $\pi \rightarrow \pi^*$ and $n \rightarrow \pi^*$ electronic transitions, respectively. These absorption peaks confirmed the presence of an aromatic heterocyclic ring system and indicated conjugation within the imidazole ring. FTIR analysis revealed important absorption bands at 3100–3400 cm^{-1} due to N–H stretching vibrations, 1600–1650 cm^{-1} corresponding to C=N stretching, and 1450–1550 cm^{-1} associated with C=C and C–N stretching vibrations. These peaks confirmed the successful formation of the nitrogen-containing imidazole ring structure.

Further structural confirmation was obtained through ^{1}H-NMR spectroscopy. The spectrum showed characteristic signals in the range of 11.5–13.0 δ ppm corresponding to the N–H proton and signals between 6.5–7.8 δ ppm attributed to aromatic protons. These spectral results confirmed the successful synthesis of aromatic imidazole derivatives.

The formation of ZnO nanoparticles was initially indicated by the appearance of a white precipitate, while characterization studies confirmed their crystallinity, nanoscale dimensions, and phytochemical stabilization. The synthesized ZnO nanoparticles exhibited excellent catalytic efficiency in the synthesis of imidazole derivatives by providing shorter reaction times, higher product yields, cleaner reaction conditions, and catalyst reusability. Substituent effects were also observed during the reaction. Electron-donating groups such as $-OCH_3$ and $-CH_3$ enhanced the reaction rate and improved product yields, whereas electron-withdrawing groups such as $-NO_2$ and –Cl slightly reduced the reaction efficiency.

The developed method offers several environmental and catalytic advantages, including eco-friendly synthesis, reduced use of hazardous chemicals, lower energy consumption, sustainable methodology, high catalytic efficiency, reusable catalyst system, mild reaction conditions, and faster synthesis of heterocyclic compounds.

Conclusion

The present study successfully demonstrated the green synthesis of zinc oxide nanoparticles using *Delonix regia* flower extract through an eco-friendly and sustainable approach. Characterization studies using UV–Visible spectroscopy, FTIR, SEM, and XRD confirmed the successful formation, crystallinity, and nanoscale nature of the synthesized ZnO nanoparticles. The prepared nanoparticles exhibited excellent catalytic performance and were effectively utilized as heterogeneous nanocatalysts in the one-pot synthesis of imidazole derivatives. The developed methodology offered several advantages, including high product yields, shorter reaction times, mild reaction conditions, and catalyst recyclability. Spectroscopic analyses further confirmed the successful synthesis of imidazole derivatives. Overall, the study highlights the significant role of green nanotechnology and sustainable catalysis in environmentally benign heterocyclic synthesis

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 6, Issue 5, June 2026
Impact Factor: 8.2

Future research may focus on the biological evaluation of the synthesized imidazole derivatives, including anticancer and antimicrobial activity studies. Further investigations may also be directed toward improving catalyst recycling efficiency, enhancing catalytic performance, and scaling up the green synthesis of ZnO nanoparticles for industrial and pharmaceutical applications.

REFERENCES

1. Anastas PT, Warner JC. *Green Chemistry: Theory and Practice*. Oxford University Press; 1998.
2. El-Sayed MA. Properties of metal nanoparticles. *J Phys Chem B*. 2001.
3. Heravi MM, et al. Nanocatalysts in organic synthesis. *RSC Adv*. 2014.
4. Pavia DL, Lampman GM, Kriz GS. *Introduction to Spectroscopy*. Cengage Learning; 2015.
5. Ahmed S, et al. Green synthesis of ZnO nanoparticles using plant extracts. *Mater Sci Eng C*. 2017.
6. Sharma D, et al. ZnO nanoparticles: green synthesis and biomedical applications. *Mater Sci Energy Technol*. 2020.
7. Gupta R, et al. Biological importance of imidazole derivatives. *Eur J Med Chem*. 2013.
8. Khan Z, et al. Green synthesis of zinc oxide nanoparticles. *J Photochem Photobiol B*. 2019.
9. Kumar A, et al. ZnO nanoparticles as efficient catalysts. *Catal Commun*. 2011.
10. Singh J, et al. Green synthesis of metal oxide nanoparticles. *Front Microbiol*. 2018.

DOI: 10.48175/IJARSCT-35661