

# Inorganic Nanoparticles Via Green Synthesis

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**Abstract-** Green synthesis of inorganic nanomaterials has emerged as an environmentally sustainable alternative to conventional chemical and physical synthesis methods. In the present study, zinc oxide (ZnO), copper oxide (CuO), and iron oxide (Fe<sub>2</sub>O<sub>3</sub>) nanoparticles were synthesized using aqueous plant extracts of Neem, Tulsi, Orange peel, and Tea leaves. These plant extracts served as natural reducing and stabilizing agents. Nanoparticle formation was confirmed through visible color change and UV-Visible spectrophotometric analysis. The characteristic absorption peaks confirmed successful nanoparticle synthesis. The influence of pH, conductivity, viscosity, and reaction time on nanoparticle formation was systematically studied using basic laboratory instrumentation including UV-Visible spectrophotometer, pH meter, conductivity meter, Redwood viscometer, hot plate, and flame photometer. Results demonstrated that near-neutral to slightly alkaline pH favored stable nanoparticle formation. Conductivity decreased during the reaction, confirming metal ion reduction. Viscosity measurements suggested interaction between biomolecules and nanoparticles, enhancing colloidal stability. The study establishes that meaningful nanoparticle synthesis and characterization can be achieved.

**Keywords –** Green synthesis, inorganic nanoparticles, ZnO nanoparticles, CuO nanoparticles, Fe<sub>2</sub>O<sub>3</sub> nanoparticles, plant extracts, UV-Visible spectroscopy, sustainable nanotechnology.

## I. INTRODUCTION

Nanomaterials are materials having at least one dimension in the range of 1–100 nm. At the nanoscale, materials exhibit unique physicochemical properties due to quantum confinement, high surface-to-volume ratio, and dominance of surface atoms.

Inorganic nanoparticles such as metal and metal oxide nanoparticles possess exceptional optical, catalytic, antimicrobial, and electronic properties. However, conventional synthesis techniques such as chemical reduction, sol-gel methods, hydrothermal synthesis, and physical vapor deposition involve toxic reagents, high energy consumption, and expensive instrumentation.

Green synthesis provides a sustainable alternative by utilizing plant-derived biomolecules as reducing and stabilizing agents. Phytochemicals such as flavonoids, polyphenols, terpenoids, alkaloids, proteins, and sugars mediate nanoparticle formation under mild conditions. This study focuses on green synthesis of

ZnO, CuO, and Fe<sub>2</sub>O<sub>3</sub> nanoparticles using locally available plant materials and characterization using only basic laboratory instruments.

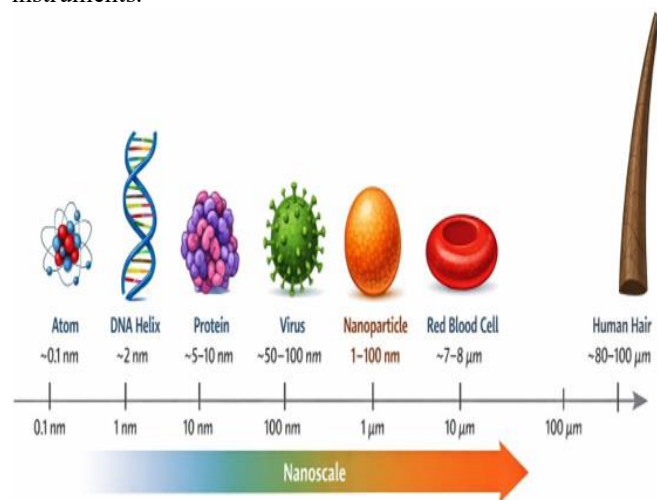


Figure 1.1 : Size Comparison of Nanoparticles

Table 1.1 : Classification of Inorganic Nanomaterials

Type	Representatives Materials	Structural Features	Key Properties	Applications
Metal Nanoparticles	Ag, Au, Cu	FCC/BCC Structures	Surface plasmon resonance, conductivity	Antimicrobial agents, sensors

<b>Metal oxide Nanoparticles</b>	ZnO, TiO <sub>2</sub> , Fe <sub>3</sub> O <sub>4</sub>	Crystalline oxide lattices	Photocatalytic, magnetic	Environmental remediation energy
<b>Ceramic Nanoparticles</b>	Al <sub>2</sub> O <sub>3</sub> , SiO	Hard, thermally stable	Mechanical strength, insulation	Structural material, coatings
<b>Semiconductor Nanoparticles</b>	CdS, ZnS	Tunable band gaps	Optical and electronic properties	LEDs, solar cells

## II. THEORETICAL AND RESEARCH BACKGROUND

Previous studies have demonstrated successful green synthesis of metal and metal oxide nanoparticles using plant extracts. Silver nanoparticles synthesized using *Azadirachta indica* and *Camellia sinensis* exhibit surface plasmon resonance (SPR) peaks around 400–420 nm. Gold nanoparticles typically show SPR peaks between 520–550 nm.

ZnO nanoparticles synthesized via green methods show characteristic UV absorption between 360–380 nm. Iron oxide nanoparticles synthesized using plant extracts demonstrate excellent adsorption properties for environmental remediation. Most reported studies rely heavily on advanced instrumentation such as SEM, TEM, XRD, and FTIR. However, preliminary confirmation of nanoparticle formation can be effectively achieved using UV–Visible spectroscopy and basic physicochemical measurements.

## III. MATERIALS AND METHODS

### Materials

- nitrate [Zn(NO<sub>3</sub>)<sub>2</sub>]
- Copper sulfate [CuSO<sub>4</sub>]
- Iron(III) chloride [FeCl<sub>3</sub>]
- leaves (*Azadirachta indica*)
- Orange peels (*Citrus sinensis*)
- Tea leaves (*Camellia sinensis*)
- Distilled water

### Preparation of Plant Extract

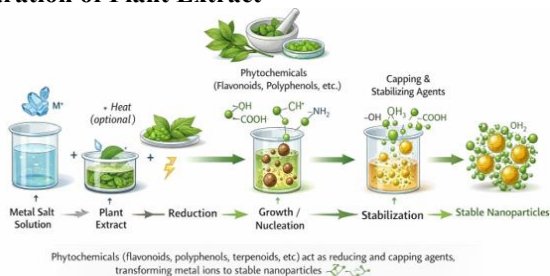


Table 5.1 : Color changes observation in the reaction

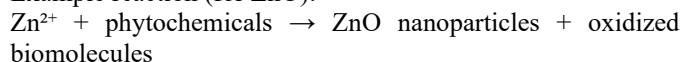
S.No.	Metal Salt	Plant Extract	Initial Color	Final color	Observation Time (min)	Remarks
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Figure 3.2.1 : Mechanism of nanoparticles Formation  
 Fresh plant materials were washed thoroughly with distilled water. The materials were shade-dried, powdered, and boiled in distilled water (10 g in 100 mL) for 15–20 minutes. The extract was filtered and stored for further use.

### Green Synthesis Procedure

Metal salt solutions (0.01 M) were prepared in distilled water. Plant extract was added dropwise under constant stirring and mild heating (60–80°C). The reaction mixture was observed for color change indicating nanoparticle formation.

Example reaction (for ZnO):



## IV. EXPERIMENTAL PROCEDURE

Plant extracts were prepared by boiling dried plant material in distilled water. The extract was mixed with metal salt solutions under heating and stirring. Nanoparticle formation was confirmed through visible color change and UV–Visible spectroscopy.

### The following basic instruments were used:

- UV–Visible spectrophotometer (200–800 nm range)
- pH meter
- Conductivity meter
- Redwood viscometer
- Flame photometer
- Hot plate

## V. RESULTS AND DISCUSSION

Characteristic absorption peaks confirmed nanoparticle formation. Conductivity decreased during the reaction due to reduction of metal ions. Near-neutral pH favored stable nanoparticle formation.

### Visual Observation

1.	Zn(NO <sub>3</sub> ) <sub>2</sub>	Neem	Colorless	Whitish suspension	15	Formation of ZnO NPs
2.	Zn(NO <sub>3</sub> ) <sub>2</sub>	Tulsi	Colorless	Off-white	20	Particle growth observed
3.	CuSO <sub>4</sub> .5H <sub>2</sub> O	Neem	Blue	Greenish-brown	25	Formation of CuO NPs
4.	FeCl <sub>3</sub>	Tulsi	Yellow-brown	Dark brown	30	Fe <sub>2</sub> O <sub>3</sub> NPs formation

### UV-Visible Analysis

Table 5.2 : Absorbance and wavelength measurements of Nanoparticles

S. No.	Nanoparticles	$\lambda_{max}(nm)$	Absorbance(a u.)	Observation Notes
1	ZnO NPs	365	0.70	UV band confirms ZnO confirm
2	CuO NPs	280	0.65	Oxide peak observed
3	Fe <sub>2</sub> O <sub>3</sub>	300	0.60	Broad absorption peak confirms iron

### Effect of pH and Conductivity Study

Table 5.3 : pH and Conductivity measurement of inorganic nanoparticles

S. No.	Nanoparticles	$\lambda_{max}(nm)$	Absorbance(a u.)	Observation Notes
1	ZnO NPs	365	0.70	UV band confirms ZnO confirm
2	CuO NPs	280	0.65	Oxide peak observed
3	Fe <sub>2</sub> O <sub>3</sub>	300	0.60	Broad absorption peak confirms iron

### Viscosity Measurement

Viscosity increased slightly after nanoparticle formation, suggesting interaction between phytochemicals and nanoparticle surfaces.

Table 5.4 : Viscosity of Inorganic Nanomatetials

S.No.	Nanoparticles	Viscosity (cP) before	Viscosity (cP) After	Observation
1	ZnO NPs	1.05	1.18	Increase due to NPs
2	CuO NPs	1.03	1.16	Stable colloidal suspension
3	Fe <sub>2</sub> O <sub>3</sub> NPs	1.04	1.17	Slight increase confirms particle formation

### Flame Photometric Analysis

Metal ion concentration reduced after synthesis, confirming conversion into nanoparticles.

Table 5.5 : Concentration and reduction percent of metal ions of inorganic nanoparticles

S.No.	Nanoparticles	Metal ion	Initial Conc. (ppm)	Final Conc. (ppm)	Reduction percent	Remarks
1	ZnO NPs	Zn <sup>2+</sup>	100	25	75%	Efficient reduction
2	CuO NPs	Cu <sup>2+</sup>	100	30	70%	Confirm CuO formation
3	Fe <sub>2</sub> O <sub>3</sub> NPs	Fe <sup>3+</sup>	100	35	65%	Iron oxide NPs formed

### Discussion

Green synthesis successfully produced inorganic nanoparticles using plant extracts as reducing and stabilizing agents. UV-

Visible spectroscopy confirmed nanoparticle formation through characteristic absorption peaks.

The decrease in conductivity and change in viscosity supported the proposed mechanism of metal ion reduction followed by stabilization. pH played a crucial role in controlling nucleation and growth.

This study proves that advanced instruments are not mandatory for meaningful nanomaterials research at the preliminary level.

## VI. CONCLUSION

The study successfully demonstrated eco-friendly synthesis of inorganic nanoparticles using basic laboratory infrastructure. Green synthesis provides a sustainable and cost-effective route for nanomaterial production.

### Key Conclusions:

- Plant extracts effectively act as reducing and capping agents.
- UV-Visible spectroscopy confirms nanoparticle formation.
- Near-neutral pH favors stable nanoparticle formation.
- Conductivity and viscosity measurements support reduction mechanism.
- Meaningful nanomaterial research can be conducted with limited infrastructure.

Green synthesis aligns with sustainable nanotechnology and is highly suitable for academic laboratories with limited resources.

## VII. FUTURE SCOPE

- Antimicrobial testing of synthesized nanoparticles
- Photocatalytic degradation studies
- Scale-up synthesis studies
- Comparative analysis with chemically synthesized nanoparticles

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