“Revolutionizing Organic Synthesis with Nanoparticles: A Comprehensive Overview of Sustainable Practices”

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ISHA KAUSHIK

(2K22/MSCCHE/61)

&

SANMEET KAUR

2K22/MSCCHE/53

Under the Supervision of

Prof. Anil kumar

Department of Applied Chemistry

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Shahbad Daulatpur, Main Bawana Road, Delhi-110042, India

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)
Shahbad Daulatpur, Main Bawana Road, Delhi-42

CANDIDATE'S DECLARATION

I Isha **Kaushik-2K22/MSCCHE/61 and Sanmeet kaur-2K22/MSCCHE/53** hereby certify that the work which is being presented in the thesis entitled "**Revolutionizing Organic Synthesis with Nanoparticles: A Comprehensive Overview of Sustainable Practices"** in partial fulfillment of the requirements for the award of the Degree of Doctor of Philosophy, submitted in the Department of Chemistry, Delhi Technological University is an authentic record of my own work carried out during the period from 2022 to 2024 under the supervision of Dr. Anil kumar.

The matter presented in the thesis has not been submitted by me for the award of any other degree of this or any other Institute.

Place: Delhi	**Isha Kaushik**	**Sanmeet Kaur**
Date:06/06/2024	**2K22/MSCCHE/61**	**2K22/MSCCHE/53**

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Shahbad Daulatpur, Main Bawana Road, Delhi-42

CERTIFICATE BY THE SUPERVISOR(s)

Certified that **Kaushik-2K22/MSCCHE/61 and Sanmeet kaur-2K22/MSCCHE/53** has carried out their search work presented in this thesis entitled **"Revolutionizing Organic Synthesis with Nanoparticles: A Comprehensive Overview of Sustainable Practices"** for the award of **Master of Technology** (print only that is applicable) from Department of Chemistry, Delhi Technological University, Delhi, under my/our (print only that is applicable) supervision. The thesis embodies results of original work, and studies are carried out by the student himself/herself (print only that is applicable) and the contents of the thesis do not form the basis for the award of any other degree to the candidate or to anybody else from this or any other University/Institution.

Prof Anil Kumar

(Supervisor)

Department of Chemistry

Delhi Technological University, Delhi-110042

New Delhi -110062

Place: Delhi

Date:

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)
Shahbad Daulatpur, Main Bawana Road, Delhi-42

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Isha Kaushik & Sanmeet kaur

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)

Shahbad Daulatpur, Main Bawana Road, Delhi-42

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ABSTRACT:

The incorporation of nanoparticles into organic synthesis methodologies has emerged as a transformative strategy for achieving sustainability in chemical processes. This thesis presents a comprehensive overview of the revolutionary impact of nanoparticles on organic synthesis, with a primary focus on sustainable practices. Through an extensive review of current literature and case studies, this study delineates the multifaceted roles of nanoparticles as catalysts, reagents, and facilitators in organic transformations. Notably, nanoparticles offer unique advantages such as enhanced catalytic activity, tunable surface properties, and recyclability, making them indispensable tools for advancing sustainable chemistry principles.

By harnessing the catalytic prowess of nanoparticles, researchers have successfully reduced reaction times, minimized waste generation, and improved atom economy in various synthetic routes. Moreover, the integration of nanoparticles has enabled the development of greener synthetic methodologies with improved selectivity and functional group tolerance. However, challenges such as scalability, reproducibility, and toxicity assessment remain important considerations in the widespread adoption of nanoparticle-mediated synthesis techniques. These abstract highlights the critical need for interdisciplinary research efforts to address these challenges and optimize nanoparticle-based approaches for industrial applications. Overall, this thesis underscores the pivotal role of nanoparticles in revolutionizing organic synthesis towards sustainability, paving the way for greener and more efficient chemical processes that align with the principles of green chemistry.

Keywords: Nanoparticles, Organic Synthesis, Organic Transformations, Scalability, Reproducibility

Contents

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List of Abbreviations

NPs – Nanoparticles

CNT – Carbon nanotubes

LSPR – Localized surface plasmon resonance

CVD – Chemical vapor deposition

UV-DRS – UV Diffuse Reflectance Spectroscopy

FTIR – Fourier Transform Infrared Spectroscopy

SEM – Scanning Electron Microscopy

XRD – X-Ray diffraction

EDS – Energy-Dispersive X-Ray Spectroscopy

TEM – Transmission electron microscopy

CHAPTER – I INTRODUCTION

The organic synthesis area has experienced a spectacular overhaul due to ongoing development of synthetic methods using nanoparticles as incompatible tools for catalysis, reactivity change, and simplification of the synthetic process (Anjum et al., 2021). This new paradigm of the nanoparticle-mediated synthesis can be seen as the key factor in the search for a new type of chemical process that can change the basis of organic chemistry and open the door to the whole new world of nanoparticle-based reactions and synthesis (Arab et al., 2018). In the presence of environmental pollution, number of resources decrease, and climate change occur (Agarwal et al., 2017). Thus, the need of green approaches to overcome the evils of traditional synthetic methods arises. Nanoparticles step in a very successful and suitable way to face the problems by resulting in higher efficiency, better selectivity as well as less environmentally friendly organic transformation (Bayda et al., 2019).

The main purpose of this dissertation is to offer a profound analysis of nanoparticles' ability to revolutionize organic synthesis by enhancing it to be greenly sustainable in all its representatives (Caramazana et al., 2018). This review of literature seeks to so the link between nanoparticles synthesis, formulation, and application in the goals of moving on from current processes that are unsustainable. The main body of this thesis is focused on a logical' analysis of the core themes, cases and future prospects in cryogenics, aiming to build upon the extensive literature already in existence about this field of work (Bayda et al., 2019).

Introductory lines which give the overview of the subject in terms of importance of organic synthesis "to that of a chemistry and a society context". The organics synthesis is a field of modern chemistry, which is standing at the basis of the achievement of complex substances that are required, for example, in medicine, agrochemicals, materials, and many others sectors (Choudhary et al., 2005). On the other side, the old-fashioned synthetic chemicals typically call into action extreme conditions, poisonous reagents and ineffective technologies which, in turn, result to lasting damages to the environment and a lot of resource consumption. In the face of these challenges, there is a growing demand for advanced and more sustainable reactions running (Chen et al., 2021).

Nanoparticles, where their peculiar size-related specifications and large surface area–volume ratio allows them to overcome the inadequacies of traditional manufacturing options

(Choudhary et al., 2005). The attractions of these nanoscale substances in biochemical reactions are in catalytic action, selectivity, and resiliency better than most conventional chemical compounds and therefore plants that progress reactions increasingly (Chen et al., 2021). Also, it is possible to produce the nanoparticle with desired designed features together with the necessary surface modifications which will enable a better control over the reaction parameters as well as product outcome (Dikshit et al., 2021). Researchers have obtained excellent performance in reaction efficiency, yield, and green technology sustainability through the application of nanoparticles in catalysis technology (Bayda et al., 2019).

The introduction explains the area of focus as well objective of thesis, creating a vision which is achieved by later chapters (Bayda et al., 2017). Major topics to be presented here are the preparation and characterization of nanoparticle catalysts, their mechanism and impact in reaction and some examples, case studies on making catalysis better from the perspective of green chemistry, and challenges and solutions for future research and innovation (Geetha et al., 2016). Rather, by scrutinizing these aspects in detail, the thesis will be able to avail of information regarding the changing role of nanoparticles in transforming organic synthesis into sustainability (Iordanidou et al., 2018).

Essentially, the introduction is meant to enlighten the reader and pave the path for the exploration of the nano particle mediated organic synthesis and its ecological impacts on green chemistry (Chen et al., 2023). This introduction emphasizes the relevance of the perspective and cites that the research will be based upon nanoparticles and their use in solving the most complex chemical problems of modern science is the structure of the thesis (Bayda et al., 2019).

1.1. Historical background:

The development of organic synthesis has featured the unceasing search for more efficient, precise, and environmentally friendly strategies that carry out chemical transformations (Darr et al., 2017). The synthetical research organic chemistry is no exception, as it had even intended in the early of the day of stripping away the processes to speed up the reactions, to enhance the yield and minimize waste (Iordanidou et al., 2018). On the contrary, the typical synthetic methods are based on the stoichiometric amounts of reagents, doing so at severe conditions, and often requiring subsequent thorough cleansing that produces much amount of waste and exhausts limited resources (Kemary et al., 2011).

The finding of catalysis, when a small sample of a material is able to generate a chemical reaction without being adequately being consumed, is the main factor in the acquisition of organic synthesis (Iordanidou et al., 2018). It was the time at the end of the 18th century and at the beginning of the 19th century that scientists such as Humphry Davy and Justus von Liebig, being the founders of respective the catalytic phenomenon, have discovered the catalytic activity of some metals and metal oxides (Darr et al., 2017). They were inspirers of the science they relied on that spawned catalytic reactants and procedures that would be used in the twentieth century to reinvigorate organic chemistry (Dufresne and Castano, 2017).

The catalysis had been advanced greatly in the 20th century. Friedrich Wilhelm Ostwald discovered heterogeneous catalysis and Paul Sabatier developed it (Devan et al., 2012). Organometallic chemists moved on to develop homogeneous catalysis such Karl Ziegler and Geoffrey Wilkinson (Islam et al., 2022). Such advances opened the doors to the synthesis of the most complicated molecules with the performance that the older method lacked in terms of the efficiency and selectivity, therefore establishing the ground for the modern drug, pesticide and materials sector (Saputra and Yulizar, 2017).

In the past decade or so, the rise of nanotechnology has propelled this field to new possibilities and developments of more efficient catalysts that are able to increase the rates of a reaction, reduce environmental impact and provide unique selectivity (Jamkhande et al., 2019). Nanoparticles, who have excelled in size-determined features and the surface chemistry which can be adjusted have been considered remarkable catalysts for organic transformation. In the case of both entrapping catalytically active species into nanoparticles or creating catalysts with nanostructured scaffolds, scientists have reached incredible heights in terms of exploiting their sustainably and reactivity (Dufresne and Castano, 2017).

The organic synthesis of chemical processes, the development of a perpetually conscious approach towards creating more sustainable and environment friendly processes is reflected in its historical origins (Jamkhande et al., 2019). Nanoparticles integration for organic syntheses marks the termination of the continuous journey, as it facilitates the birth of a new era, where syntheses are no longer performed conventionally (Saputra and Yulizar, 2017). With each step we take into researching human history of nanoparticle functioning, our heart-felt awards grow stronger and stronger for nanomaterials impact of making that future chemistry a sustainable one (Kokarneswaran et al., 2020).

1.2. Research aims and objectives:

1.2.1. Research Aim:

The primary aim of the research is to analyse the significance of nanotechnology in creating organic synthesis that is stepping in the direction of environment-friendly results. Nanoparticles, which are considered as vital elements of green chemistry, are thoroughly studied in terms of their use in different methods of organic synthesis (Khaturia et al., 2020). Therefore, this research has a crucial aim which is the contribution to the development of environmentally benign synthetic methodologies and the acceptance of green chemistry principles.

1.2.2. Research Objectives:

1. To analyze how organic synthesis techniques involving nanoparticles connect to environmental sustainability challenges and what elements are part of the methodology's overall accumulated pollution lead.
2. Examine how the nanoparticle may be utilized as a versatile instrument in organic synthesis and what strategy can be applied as a novel way to create molecules by utilizing their unique properties.
3. To investigate the main problems or limitations that would prevent nanoparticle-based technologies from being used as an alternative in the industrial sector of chemical manufacturing, as well as how those barriers might be eliminated.

1.3. Research questions:

1. What aspects of environmental sustainability are associated with organic synthesis techniques that employ nanoparticles, and what elements are part of the methodology's overall aggregated pollutant load?
2. What nanoparticle may be used as a versatile instrument in organic synthesis, and which strategy can be applied as a novel way to create molecules by utilizing their unique properties?
3. Which are the main problems or limitations that may be disregarded and replaced by technologies based on nanoparticles in the industrial sector of chemical production, and how can we get rid of the barriers?

1.4. Problem statement:

The past decade has seen impressive progress in using nanoparticle-based organic chemistry for catalysis in chemical synthesis (Kokarneswaran et al., 2020). However, the full potential of these nanoparticles is not yet comprehensively utilised and matched, compared to traditional catalysts regarding their catalytic capabilities, leading to a significant challenge in maximising their efficiency and selectivity when used in chemical synthesis (Irfan et al., 2015). Besides, the true earth-friendliness and sustainability of synthetic methods with nanostructured catalysts are not fully explored by the researchers, which consequently contributes to vagueness in the field of chemical processes, where the role of nanoparticles in lowering environmental pollution, energy consumption, and the consumption of natural resources is understudied.

The scope for the application of nanoparticles as multi-tools in organic synthesis is yet open for research, and it is required to formulate and develop distinct principles of synthetic regioselectivity by incorporating their unique properties of catalysis, regioselectivity and template in order to properly take benefit from the potential of nanoparticles to advance the goal of sustainable chemistry (Ide and Davis, 2014). On the one hand, the nanoparticles-based synthesis techniques pose numerous advantages but on the other hand they exhibit significant drawbacks such as scalability, reproducibility, and toxicology assessment which hinder their viability for industrial application (Jamkhande et al., 2019). Hence, to overcome these hurdles there is need to develop remedial strategies to address these issues so that they may be accepted and utilized in large scale organic synthesis in industry (Leng et al., 2019).

1.5. Research significance:

This research provides impetus to the organic synthesis industry which is itself a part of sustainable chemistry (Khaturia et al., 2020). This review highlights the central role of nanoparticles in the synthesizing process of organic compounds helping to tackle the chief threats the industry faces, e.g., environmental degradation, resource depletion and climate change (Jamkhande et al., 2019). With the ability to develop a deeper understanding of the action mechanisms of nanoparticles and their capability to improve the reactions by making them greener with higher rates of selectivity opens up ways for the development of greener and more efficient synthetic methodologies (Leng et al., 2019).

Overall, monitoring the environmental impacts and sustainability of the nanoparticles - based synthesis methods F also assisting in knowing the contributions of nanoparticles to artificial chemical reactions (Ostojic et al., 2018). The incorporation of the multi–functionality of nanoparticles into organic synthesis certainly leads to an overload improvement of synthesis strategy and also evokes innovation of the design of novel one (Ochieng et al., 2015). Finding solutions to expertise problems such as scalability, reproducibility, and toxicity of nanoparticle-based synthesis allows for integrating these techniques as a standard option in industrial production, hence increasing the greenness and sustainability of the chemical processes (Rassaei et al., 2011).

1.6. Rational:

The inclusion of nanoparticles into the organic synthesis strategy is a logically organised matter, which is the only possible remedy for the urgent problem of natural resources depletion during these processes (Rassaei et al., 2011). Conventional chemical methods are known for severe conditioning, use of dangerous reagents and imperfect reactions of the process itself that damage the environment (Matthew et al., 2021). A nanoparticles solution is an approach with logic as it relies on the size-specific properties of the particles and high surface to volume ratio to improve the reaction catalyst activity, selectivity, and recyclability (Rao and Geckeler, 2011).

Such choice, in association with green chemistry principles, contextually promotes waste minimization, decrease energy utilization and resource optimizing. Moreover, fiber-optic sensors are based on the theory of refraction, therefore the Lightwave is absorbed and cannot be observed by only looking at optical fibers (Matthew et al., 2021). Through the designed study of nanoelement's application for organic transformations, a recent research work justifies the direction of the search for greener and cleaner in order to address the needs of the society of modern times in the process of taking into account environmental social concerns.

1.7. Research importance:

Such research is crucial to realize the very idea of organic chemistry that is to move, the way toward sustainability. It deals with the question of addition of nanoparticles to the synthesis methods which also provides an effectual solution to the problems of environmental pollution and insufficiency of materials for the synthesis processes (kazemi et al., 2023). The value of this research is in the fact that, if proved, it can be a turning point in the way organic chemistry deals with environmental issues. This will be indicated by the emergence of safer and more economical methods in contrast with the traditional ones (Rao and Geckeler, 2011).

The important role of nanoparticles as catalysts and the multifunctional performance of nano systems must be taken into account in creating new synthetic approaches in promoting the sustainability of chemistry (kazemi et al., 2023). Secondly, through the measuring the environmental impact and sustainability of green pathways, nanoparticle mediated synthesis methods will open up more factual ground for their practical use and benefits (Saratale et al., 2018). The research on solving the hurdles such as scalability, reproducibility and hazardousness makes a major step towards larger-scale industrial applications, therefore, influenced by a nanoscale production, a more sustainable future of the chemical industry and the society will be gradually built (Salehian and Jenabali, 2015).

1.8. Research limitations:

In addition to being a source of merits, this study has a number of challenges that should be borne in mind. Initially, the study coverage may have problems beyond the complexity and continuous changes of nano-particles in the organic syntheses, hence narrowing down the scope of the chosen aspects of the field (Salehian and Jenabali, 2015). Further, doing the synthesis and characterization of nanoparticles can also have a high degree of difficulty; this might mean that researchers will fail to determine whether their experiments are successful and reproducible, or not (Rao and Geckeler, 2011).

Also, there is a need to do impact assessment and sustainability accreditation of nanoparticles and this process might not be that easy in the case of availability of an adequate data and the variable nature of environmental factors (Smith et al., 2019). Secondly, dealing with one of the challenges including scalability, reproducibility, and toxicity assessment might need the teamwork or resources as specialized research facilities or research groups which could lead to logistical or even practical problems (Zahra et al., 2020). On the one hand, it acknowledges these drawbacks but, on the other hand, it will also aim to gather very valuable knowledge regarding the impact of nanoparticles on the principle of organic synthesis and sustainability (Salehian and Jenabali, 2015).

1.9. Justification of the research:

The research is thus well-justified given the gravity of the ecological issues and the distinct efforts to ensure green chemistry in organic synthesis. The typical procedures of a “green” chemistry way are based on the energy consuming substances, that contribute to the environment pollution and resources depletion (Shreya and Fulekar, 2020). This research centres on dominion of nanoparticles in the organic synthesis. It would provide better alternatives in the manufacturing processes that essentially minimize the environmental impact coupled with maximization of efficiency and selectivity (Salehian and Jenabali, 2015).

The specific features of nanoparticles, including their enormous surface area, versatile surface chemistry and appropriate size, confers catalysts catalytic activity and emissions. Another positive implication is that the development of nanoparticles as multifunctional can be used in synthetic procedures to create innovative processes that are also green (Kokarneswaran et al., 2020). Overall, this study is aimed at giving researchers, industry leaders, and others who want to work in organic synthesis recycling a new green chemistry policy and technology base to help promote the concepts of green chemistry and shape a more sustainable future for the chemical industry (Leng et al., 2019).

1.10. Thesis organization:

The thesis will be structured into five chapters. The first chapter will include the introduction, research aim and objectives, and research questions. This chapter will be completed within a month. Chapter two will include a literature assessment that examines current sources relevant to our topic and conceptual model. This analysis will cover a period of two months. The description of the research approach will be provided in chapter three within a month. The upcoming chapter will consist of the results and discussion, and it is expected to be completed within one month. The final chapter will provide a comprehensive overview of the conclusion and offer future recommendations within a one-month timeframe.

		Total durations (In Weeks)					
S. No	Task Description	Month -1	Month - 2	Month - 3	Month - 4	Month - 5	Month - 6
1	Introduction						
2	Literature Review						
3	Materials & Methodology						
4	Result & Discussion						
5	Conclusion & Future recommendations						

6	Documentation and Validation	

Figure.1.1. Illustration of Gantt Chart as a research plan

CHAPTER – 2 REVIEW OF LITERATURE

The literature review of this thesis is a full-fledged account on the existing research conditions on the application of nanoparticles in organic syntheses minimizing the negative impacts. Nanoparticles play different functions such as catalysis, reactivity control, and increasing productivity (Matthew et al., 2021). It, therefore, employs many main sources of information, comprising peer-reviewed journal articles, conference proceedings, and books, to show different roles that they play in the processes. Through the first part of the review, one will follow the development of old with the use of catalysts and discovery of new organic synthesis procedures (Anjum et al., 2021). It then looks at the leading catalysis discoveries marked with the earliest findings of metal catalysis and later developments of heterogeneous, homogeneous, and other strategic catalytic systems to form the basis for nanoparticle characterization in various methods of synthesis (Agarwal et al., 2017).

Consequently, there comes the section that highlights specific nano-particle properties and talks about a reason why they are the number one prioritized candidate for catalytic purposes (Chen et al., 2023). It is conversing on size effect, surface chemistry and nanoparticle-support interactions, in which all may play an essential role in catalytic activity improvements as well as selectivity also recyclability (Bayda et al., 2019). Hence, the literature review also assesses where the current research level is at in order to figure out if there is an opportunity to find more eco-friendly methods (Caramazana et al., 2018). It looks at the examples of and the lab studies that show the advantage of nanoparticles in governing reactions' duration, minimizing waste, and intensifying yields (Agarwal et al., 2017).

Furthermore, the review points out difficulties and shortcomings with expanding the use of nanoparticles in the synthesis technologies, e.g., scale-up, reproducibility, toxicology assays, or other (Caramazana et al., 2018). It clarifies how additional work should be done to sort out these issues and also how nanoparticles can be employed as tools in the industrial processes for appropriate applications. This literature review aims to give a clear picture about the opportunities that nano alite ensures the way to obtain the organic synthesis and incline to sustainability, and it motivates the following chapters of the thesis (Choudhary et al., 2005).

2.1. Emergence of nanotechnology:

The experience of the 1980s in nanotechnology very much was thru the significant advances in experimental, such as the invention of the scanning tunneling microscope in 1981, and the discovery of fullerenes in 1985. Nanotechnology is the term that was coined in order to generalize various specific technologies in the same group, the engines of creation that were proposed in 1986 by K. Eric Drexler (Islam, et al., 2022).

2.1.1. Early stage of NPs:

There persists, however, some unfamiliarity, even doubts, amongst the learned classes as to the reliability of this discovery of ghostly-looking carbon nanofibers in Keeladi pottery. It is believed that they date from somewhere between 600 BC and 300 BC years old (Khaturia et al., 2020). The exact way of the origin and making of Damascus, a materiel that was known to people since approximately 900 A.D., are today not clear. Being more pro-environment and helpful towards future generations on the other side, Jamkhande et al., (2019) have conducted research and come with new discovery of cementite nanowires being present inside this material. The original genesis and the context of the original source material per se remain shrouded in mystery (Ke et al., 2012)

In 1991, controversial and highly-publicized work that was published regarding the discovery of carbon nanoparticles attracted the attention of the scientific world; years later, Iijima, and Ichihashi made firstly their announcement regarding the identification of a single-wall carbon nanotube having 1 nm of diameter (Mishra et al., 2017). CNT consists of the class of nanomaterials that possess a preferential arrangement of carbon atoms in a two-dimensional hexagonal grid (Caramazana et al., 2018). When subjected to a single-direction mechanical force that is mainly bending one, these parts are thus joined to each other to achieve a tube-like hollow casing (Mohamed et al., 2012). Nanotubes are a strange type of carbon beads which are characterized by dimension of zero thickness in one direction and a dimension of 2 thicknesses in the other (Ke et al., 2013).

The first process of the citrate-stabilized silver colloidal synthesis was described by Smith et al., (2019) The way we do is often resulting in the creation of the nanosized particles having diameters of 7-9 nanometers (Nowack et al., 2011). As is evident, the characteristics observed resemble those found to exist in synthesized nanosilver from silver nitrate and citrate particles and are documented by Thangadurai and others (2022). The addressing of nanosilver's stability through allowing proteins to bind to it is a strategy that is utilizing for almost 2 decades. La medico-comercialization of a nano silver product called "Collargol" destined for the medical field has been happening since 1897. The average size particles of Collegol, a similar modified version of silver nanoparticles, has been found to be around 10 nm (Vidhu and Philip, 2014).

The diameter of Collargol has been reckoned on the nanoscale, which is the small scale used in scientific measurements and evaluation, a longstanding fact dating back to 1907. The 1953-year Moudry has synthesized gelatinase silver nanoparticles as well as a stabilizer agent (Vidhu and Philip, 2015). Several AuNPs (nanoparticles) showed nano-scale size of 2-20nm. This approach is different from the other methods as using the nanoparticles was not synthesized by the Collargol methods; it was another little technique. The patent describes that the producers of nanosilver received its efficiency to work at many different levels with the realisation that using the nano-sized silver was a good idea and that the particles with a diameter less than 25 nanometers are more useful in case you require an optimum efficiency.

The gold nanoparticles, which have been known as AuNPs ever since they were first discovered in Roman times (Rassaei et al., 2011), have been applied as a chemical staining medium extensively. They began creation of AuNPs as early as in the 1850th when the initial studies on this subject were done by Rai and Geckeler (2011).

Faraday's researches determined there to be unique and distinguishable features in gold colloidal solutions which make them dissimilar to gold in solid form. In the year 1857, Michael Faraday worked at a laboratory where he prepared and investigated colloidal suspensions of gold easing as “Ruby” suspension (Ostojic et al., 2018). It is possible to sort out specific optical and electrical features which are very peculiar to magnetic nanoparticles as identified by researchers (Khaturia et al., 2020). The main aim was to reproduce these conditions for lighting under Faraday's direction and to witness the applications of gold nanoparticles in color reduction.

2.2. Synthesis of nanoparticles:

The dominant words in the process of synthesis of nanoparticles are “nanoparticle synthesis”. “Starting from the bottom” approach, including the nucleation and the growth of particles resulting out of the dispersion of groups of molecules at the micro level either in the liquid or vapor phase, can also be exploited as a factor creating nanoparticles (Mishra et al., 2017). Along with that, we may consider concurs with bioactive compounds as a concept of functionalization to be used during a synthesis step (Khaturia et al. 2020). This inefficient and cost-prohibitive approach, which has since its beginnings plagued the nanoscience field, has been one of the significant problems in the nanomaterials production (Nowack et al., 2011). To meet the needs of nanomaterial applications in biomedicine, researcher should be capable of manufacturing these materials in diverse forms and sizes that are uniform and with the ability to modify their chemical composition (Rassaei et al., 2011).

Generation of nanoparticles of different sizes can be accelerated by employment of coprecipitation outlined synthesis (Smith et al., 2019). While various techniques have been employed with the aim to obtain nanoparticles of a constant size, the stochastic nature of the underlying nano processes, and the individual behavior of the molecules continuously prevent the perfect ordering. Developing of magnetite nanoparticles follows the reaction of iron solution and sodium hydroxide emulsifiers, as described by Rassaei et al., (2011). Nanoparticles removal from surfactants is done based on a method which entails the breakdown of surfactants using acetone. Then, it is followed by a further washing using ethanol. (Ostojic et al., 2018).

One of the most credible scientific prove for the magnetic nanoparticles is confirmed by the superparamagnetic characteristics which exist in the colloidal nanoparticles (Ke et al., 2012). Those substances that have been dissolved, in this case oil and water, are now found floating in each phase. The choice of surfactant material primarily depended on the physicochemical system's properties (Salehian et al., 2015). This technique deserved the use of ionic, non-ionic or anionic surfactants at different breakdown points of the sample substrates (Vidhu and Philip, 2014). One problem that needs to be handled in the production of nanoparticles through microemulsion method is bringing to a large scale the process and how the residual surfactants can be dealt with effectively (Ostojic et al., 2018). The nanoparticles depicted in the figure are as follows:

Calcium oxide nanoparticles: The calcium oxide nanoparticle because of its exotic attributes and the portable uses of nanoparticles in turn has acquired a significant amount of interest and lies on the vast array of nanoparticles types (Vidhu and Philip, 2014). CaO not only is affordable but also has other merits related with its strong alkalinity, environmental and economical friendly nature, non-corrosiveness and neutrality with both economics and ecology as scientists Ostojic et al., (2018) state. Furthermore, they are act more efficiently at mild reaction conditions compared to conventional catalysts while at the same time, they give the desired product quality with shorter reaction duration (Mohamed et., 2012). The research community has provided evidence that CaO NPs hold potential as a catalyst for a wide range of chemical reactions already.

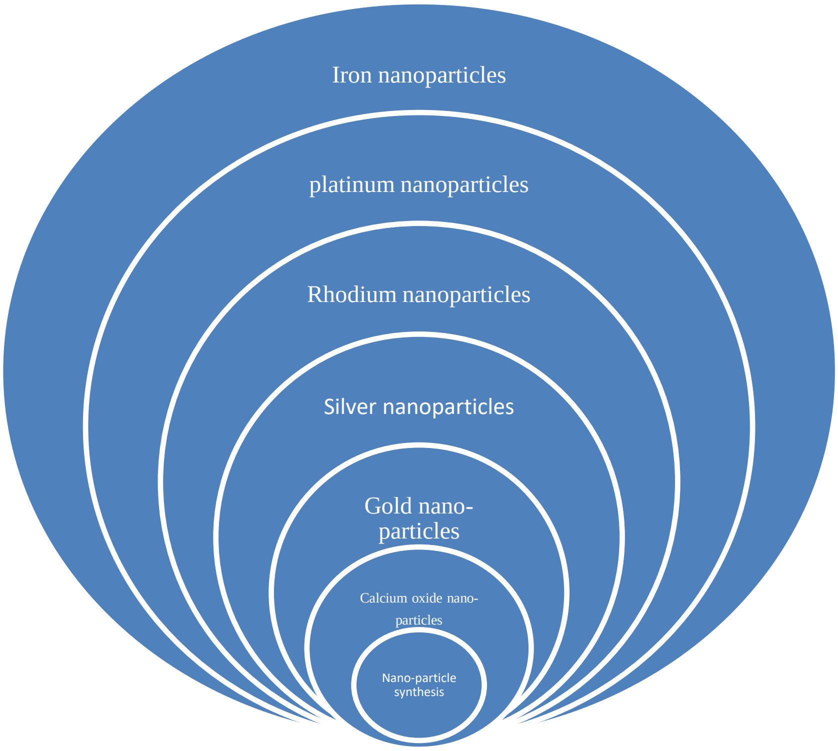


Figure.2.1. Model of various nanoparticles synthesis

Bromocresol green for one is degraded, pollutants in exhaust are cleaned, biodiesel is trans esterified, and heavy metal ions get removes from water (Zahra et al., 2020). These are consistent with the ever-growing capacity of various extensively substituted pyridines to serve as invaluable molecular platforms for medicinal applications as well as the efficiency of nanoparticles to accelerate catalytic processes (Mohamed, Ibrahim and Ahmed, 2012). The properties of calcined-oxide nanoparticles that are of much-sought after include; higher efficacy, safety, environmentally friendly, non-explicability, recyclability, and user-friendly making them of high demand as catalyst that are applied for a variety of organic transformations (Vidhu and Philip, 2014).

Gold nanoparticles: It is because of the numerous advantages of the AuNPs, including the strong interaction with thiols, disulfides and amines, high X-ray absorption coefficient, an easily built synthetic strategy that provide remarkable control on the physico-chemical properties of the gold nanoparticles and the unique tunable optical and electronic properties, that AuNPs are presently of interdisciplinary concern (Choudhary et al., 2005). Nowadays, optical and electronic properties of gold nanoparticles are being focused on as they are being introduced in the sensors, electronics, medicine, energy storages and other domains because of their potential use in sensing, electronics, medicine, and energy storage (Chen et al., 2021).

Thangadurai et al., (2022), focused on the potential of using imidazolium based ionic liquids in gold nanoparticles synthesis and applications. It has been noticed that 1-butyl-3-methylimidazolium hexafluorophosphate having green ionic liquids for preparation of gold nanoparticles at room temperature (Smith et al, 2019). Nanogold particles can be formed at room temperature using HAuCl 4 and green tea extract as reagents. No hazardous chemicals or organic solvents are being used at Au nanostructures' synthesis so the process is completely safe for the ecosystem (Smith et al. 2019).

Silver nanoparticles: The silver NPs, on the other hand, hold commercial efficiency in a diverse range of fields, through application in the scrubbing of fridge shelves, cleaning of textile machines, and sanitation of nano-materials used in food boxes packaging and medical supplies (Anjum et al., 2021). Furthermore, they demonstrate thermal resistance, catalytic activity, and optical reactivity. For example, the materials show the ability that is necessary for control of temperature, initiate chemical reactions, and reflect light or absorb its energy, respectively. A diverse group of tools, encompassing inorganic salts-mediated growth, sodium borohydride, and the hydrazine reduction method, are the options for creating environmental silver nanoparticles (Bayda et al., 2017).

A photocatalytic method for silver nanoparticles synthesis in aqueous solutions adopted in the production process represents a new way to become more conscious about the environment and achieve sustainable development (Choudhary et al., 2005). The resulting calcium-stabilized silver nanoparticles immobilized on the alginate beads are produced using a photochemical upward synthesis approach investigates by Dufresne and Castano (2017).

Rhodium nanoparticles: CaO et al. proposed a rhodium nanoparticle coated on a modified silica SiO_2 substrate hydrogenation process for NBR to be more effective. The article by Dikshit, et al., (2021) is involved with a study that attempted to synthesize Rh nanostructure with precise control over the morphology for the fact that he was interested in their usage as a viable method for killing cancer cells, or simply for the treatment of cancer.

The use of rhodium nanoparticles as a key component was employed by Hasan, (2015) in the histobens hydrogening and synthesis of the Suzuki-Miyamiuri reaction. The hydrogen reduction method, the water-based solution, and the ethanol reduction method, the suited etanol-water mixture, due to rotational evaporation, are both enviroment-friendly methods for preparing Rh nanoparticles. Water is utilized as a solvent and the process of the nanoparticles of rhodium onto the titanium dioxide supports which involves hybridization with hydrolysis (El-Kemary et al., 2011).

Platinum nanoparticles: The ion-exchange reduction method that uses ethanol and water blend suitable for rotational evaporation is also environment-friendly among the other methods such as the hydrogen reduction method that employs water solution of hydrogen peroxide (Chen et al., 2021). The synthesis process of the rhodium nanoparticles comprises the use of water in the supports of the titanium dioxide. The addition of starch (phase protection) and glucose (reducing agent) ensures the actualization of homogeneously distributes reduced green Pt nanoparticles with a mean diameter of 16.5 nm ±3.7 nm.

The proposed synthesis methodology can be RT factored and its reproducible; then the methodology can support ecosystem conservation, has a high probability of being reproduced, and could be expanded to cater for industrial size (Devan, et al., 2012). The nanocatalysts presented an efficient approach in both reduction and oxidation reactions for the sake of their high catalytic efficacy. Synthesis of ionic liquids as a method of stabilizing the Pt nanoparticles improves the catalytic activity to facilitate a four-electron reduction process for dioxygen, which leads to formation of water (Chen et al., 2021).

Iron nanoparticles: The utilization of polymers as a part of a chemical precipitation process and as capping agents in water which acts as an environmentally friendly solvent is a highly promising ecologically sustainable way of producing iron nanoparticles (Herlekar, et al., 2014). A green synthesis of iron nanoparticles was employed using tea polyphenols in a room temperature aqueous solution process where there was no use of other surfactants and polymers (Devan, et al., 2012).

The use of iron nanoparticles proved to be the most advantageous functionality that helps to increase the synthesis of hydrogen peroxide, a compound which is the main responsible for the removal of organic pollutants. The utilization of nanosized iron including other metal elements has been used as a new generation of environmentally-sound catalysts for the hydrogenation of olefins and acetylenes (Iordanidou et al., 2018). Industrial products of nano-iron particles are used as catalysts in environmentally friendly hydro-genation reactions that are used to convert alkenes and alkynes into hydrocarbons (Chen et al. 2021).

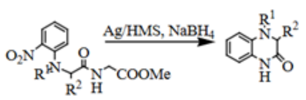
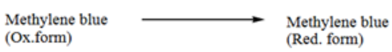
2.3. Nanoparticles synthesis reactions:

Different research groups have suggested that increased efficiency of semiconductors after graphene integration occurs due to two major mechanisms (Dikshit SR et al., 2021). At first, “light” would with a specific wavelength. The quantity that is in the middle of the semiconductor's valence band and their conduction band will be able to pass through the material. The situation caused by the movement of electrons from the valence band to the conduction band is the holes. The nanocomposite is used to selectively remove or oxidize the adsorbate either through manipulation of the electron or whole flux (Chen, et al., 2021).

The decrease intricacy compounds as a mine production are the traditional approach. Consequently, amines find further application in making dyes for clothes, and anti-cancer medicines as well (Kokarneswaran et al., 2020). Also, these membranes purify the CO2 and H 2S in gas streams and they are used in the purification process. "Hydrazine on alumina (Hyd + Alumina) hybrid catalyst showed the remarkable 89% yields in the presence of xFe3 compounds microwave-heated at 108 °C for 7 minutes (Devan et al., 2012).

On no other occasions has any chemical transformation been taken place as cleanly and in an amount as much as this that takes place in the presence of photocatalysts. To some extent quiet, but researchers are still working on the photo-catalyst improvement (Chen et al., 2021). Such demonstrates the case of 4-nitroaniline reduction a process commonly exhibited using non-photocatalytic systems only but has yet to be achieved with photocatalysts - in which these play an important role (Ide, and David, 2014).

Table.2.1. Reduction reaction of Nanoparticles

S. No.	Reaction	Nano-particles	Schemes	References
1.		Ag	Synthesis of Dihydroquinoxalinone and Related Amine Derivatives from the MRC Scaffold	Iordanidou et al., (2018)
2.		Ag	Methyl blue dye reduction	Smith et al., (2019)

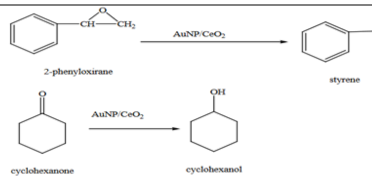
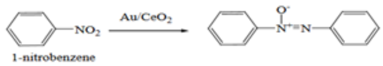
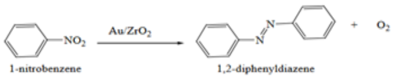
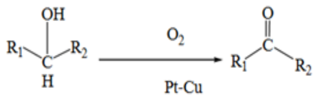
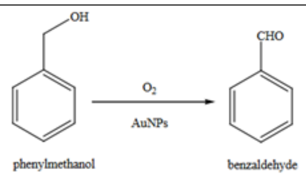
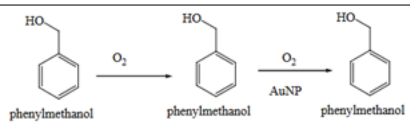
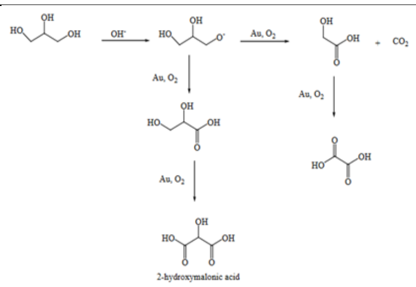
3.		“	Oxygen depletion, most notably at the gold nanoparticle level	Nowack et al., (2011)
4.		Au	2-phenyl oxirane and cyclohexanone, respectively, can be used to create styrene and cyclohexanol.	Ke et al., (2013)
5.			Selective nitrobenzene reduction	Khaturia et al., (2020)
6.			The nitrobenzene-to-1,2-dipheyldiazine synthesis	Zahra et al., (2020)
7.		Pt-Cu alloy	Substituted ketone synthesis using an alcohol	Hasan, (2015)

Table.2.2. Oxidation reactions of Nanoparticles

S. No.	Reaction	Nano-particles	Schemes	References
1.			Benzaldehyde is synthesized using phenyl methanol	Choudhary et al., (2005)
2.			Benzyl alcohols undergo selective oxidation	Chen, et al., (2023)
3.		Au	Synthesis of 2-hydroxymalonic acid	Ide and Davis, (2014)

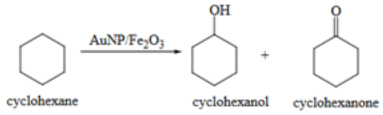
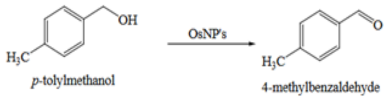
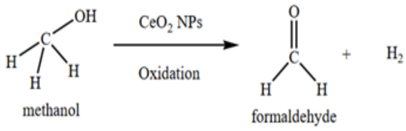
4.			Synthesis of cyclohexane derivatives cyclohexanol and cyclohexanone	Khaturia et al., (2020)
5.		Os & Ir	Synthesis of substituted benzaldehyde 6 involves the use of substituted alkanols	Iordanidou et al., (2018)
6.		CeO_2	Formaldehyde can be made from methanol	Dikshit, et al., (2021)

Table.2.3. Deoxygenation Reaction of Nanoparticles

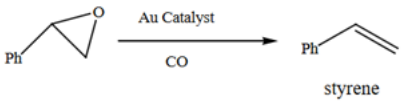
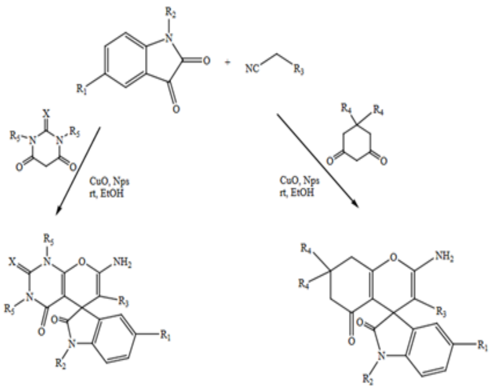
S. No.	Reaction	Nano-particles	Schemes	References
1.		Au	Formation of Styrene	Khaturia et al., (2020)
2.		CuO	Spirooxindole synthesis	Smith et al., (2019)

Table.2.4. Esterification of alcohals

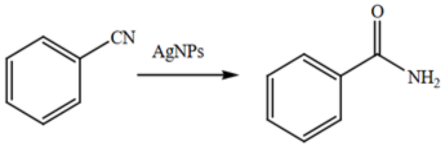
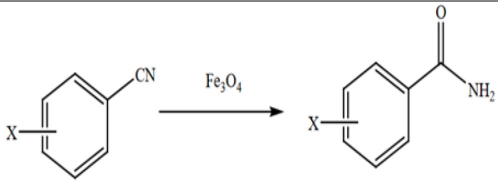
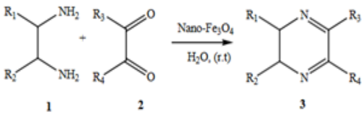
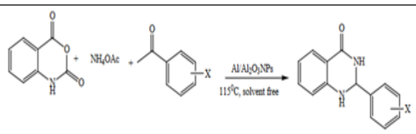
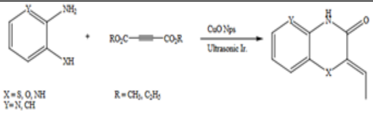
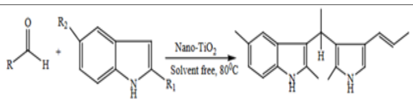
S. No.	Reaction	Nano-particles	Schemes	References
1.	 benzamide	Ag	Benzamide synthesis	Khaturia et al., (2020)
2.		Fe_3O_4	Substitution of Benzamide Synthesis	Islam, et al., (2022)

Table.2. 5. Additional Organic Synthesis Reactions

S. No.	Reaction	Nano-particles	Schemes	References
1.		Fe_3O_4	Tetraalkylpyrazine synthesis	Ostojic et al., (2018)
2.		Al/Al_2O_3	2,3-dihydro-2-phenylquinazolin-4(1H)-one synthesis	Zahra et al., (2020)
3.		CuO	Oxazin-3(4H)-one and (Z)-2-ethylidene-2H-benzo synthesis, thiazin-3(4H)-one synthesis from (Z)-2-ethylidene-2H-pyrido	Khaturia et al., (2020)
4.		TiO_2	Synthesizing 1-(2-(2,5-dimethyl-1H-indol-3-yl)ethyl)-2,5-dimethyl.the 1H-indole form	Nowack et al., (2011)

2.4. Classification of NPs:

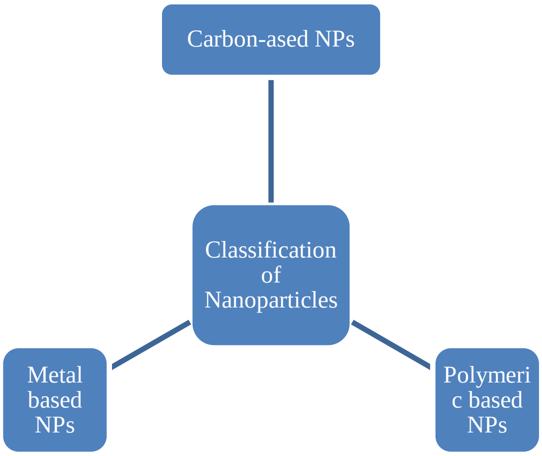


Figure.2.2. Illustration of various NPs classifications

NPs can be tailored into numerous groups of them depending on what their shape, size, and chemical properties would be (Howard and Ponder, 2014). Some of the following categories are following below:

Carbon-based NPs: The most commonly known forms of carbon NPs are fullerene structures and carbon nanotubes (CNT). Just like those spherically made carbon molecules admitting free movement of allotropic carbon which are regarded as NPs by Arab (2018 and et al.,). Given their exceptional level of electrical conductivity, structural durability, electron affinity, and varying versatility, they have gained a significant public and financial interest (Chen, et al., 2021).

The carbon atoms present within these substances display a regular structural feature characterized by the presence of the regular arrangement that has pentagons and hexagons, and carbon atoms are also sp2 hybridized (Dikshit et al., 2021). Unlike carbon nanotubes (CNTs) that have a cylindrical geometry, with a diameter ranged from 1 to 2 nanometers and a length of extending to a few microns, the diameter of graphene is variable from less than one nanometer to dozens of micrometers. It is quite difficult to see these things that are not present in similar beings without considering them as bands of carbon atoms that are stacked one on top of the other (Dufresne & Castano, 2017).

Metal NPs: Differing from metal nanoparticles that contain only metallic constituents, metal nanocubes contain water molecules that are dynamically bonded with surface metal atoms. The electrical differences of these nanoparticles originate in the mechanism of "localized surface plasmon resonance" (LSPR). Engaging the inherent photocatalytic capabilities of nanoparticles made up of copper, silver and gold, a spectrum of strongly visible light wavelengths emanating from the sun shows the capacity for absorption (Chen et al., 2023). Through the accurate fabrication of the nanoparticle's features, such as shape, size and faceting among others in the metal particle, they have demonstrated unique attributes that have contributed to their extensive usage in diverse scientific fields (Dikshit, et al., 2021).

Polymeric NPs: np size ranging from 1 to 1,000 nm can be either loading active molecules inside NPs or surface-adsorbing molecules on NPs. Usually, the terms "P-NPs" or "Organic NPs" are true in scientific literature, because the nanoparticles are mainly made of organic materials. To the naked eye, these two kinds are almost equally sized and share the features of nanosphere or nanocapsule (Islam et al., 2022).

2.5. Methods used in the synthesis of NPs:

The process either emission-based or environmental can be responsible for most nanoparticle generation. The physical approach is the so-called "top-down" one. The "bottom-up" approach, on the other hand, can utilize chemical as well as biomedical ways (Devan, et al., 2012). The term "blue systems of NPs" is mostly found in talks that the doctors raise concerning biological approaches i.e. Hasan (2015). Every of these methods has own type so it has been explained more (Choudhary et al., 2005). The detailed diagram in Fig. 1 explains the processes of making nanoparticles for every single of the various methods.

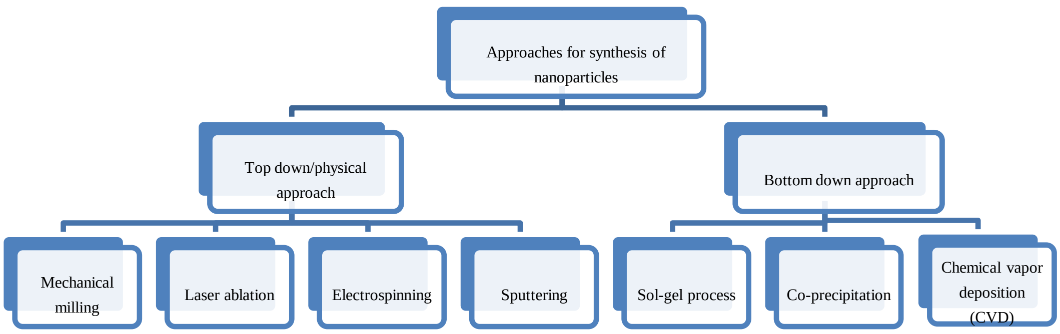


Figure.2.3. Model of approaches for synthesis of nanoparticles

2.5.1. Top down/physical approach:

Engineered nanomaterials are generated with our top-down approach. At first, we have to disintegrate a bulk material into smaller pieces and, following that, we use one more technique to reach the size of the nanostructure, as shown in Figure 2.3. They are the same as those named physical methods (Ide and Davis, 2014). The implementation of top-down tactics can be achieved through the utilization of the following methods:

Mechanical milling: The planetary and shaker mills are utilized during the mechanical milling mode through a repeated impact process that exposes the containers to a high-energy episode. Mechanical milling demonstrates a good possibility of being employed as a process on the nano-scale conversion of raw materials into their nano-structures (Itoh et al., 2004). Besides, the authors of the article have listed the three kinds of nanocomposite materials. These are aluminum alloys with oxide as well as carbide improvements (Jyoti et al., 2013). The nanosized materials made by ball milling carbon nanomaterials are believed to contain great potential to become revolutionary tools in world-challenging problems such as energy storage, energy conversion and environmental pollution.

Electrospinning: It can be noted that the draw of electrospinning is found across andrographolide into the production process of polymer-based nanofibers (Kokarneswaran et al., 2020). Electrospinning is a method of sorting nanofibers and it is generally employed by mechanically extruding electrical charged filaments with diameters ranging from nano- to less, from melted or solutioned polymers. The creation of coaxial electrospinning was considered a big stride in the scientific advancement in the electrospinning field (Khaturia et al., 2020). The implementation of a dual coaxial capillary system as the spinneret using coaxial electrospinning could be one of the methods to preserve the biodiversity in agricultural lands (Rao and Geckeler, 2011). The building blocks of the nanoarchitectures with core-shell structures can be fabricated by dipping a capillary into a solution of both a viscous liquid inside the capillary, and another viscous liquid outside and afterwards. Researchers have used this technology to generate materials that have core-shell symmetry structure or quite hollow images (Narayanan, 2014).

Laser ablation: Together with all these small features, the solid material can be liquefied by a laser beam. By vaporizing the starting material by the means of laser (Quaresma et al., 2009) can lead to the decomposition of the molecules, subsequently creating the nanoparticles. Similarly, at the time of the precursor or source materials evaporation with powerful laser irradiation, nanoparticle is formed. Laser ablation technique was designated as a green method to produce the nanoparticles of noble metals (Khaturia et al., 2020). Take for example carbon nanoparticles, oxides, as well as ceramics; these materials can be made using this technique whenever the need requires it.

Sputtering: Sputtering is produced when a solid surface bombarded with a plasma or gas particles in an extremely intense field (Mishra et. al., 2017), disintegrates and the small particles are punched out into the surrounding environment also. In order to achieve sputtering from target surfaces, an energy source that is managed by gaseous ions is used by sputter deposition technique. Sputter deposited nanomaterials possess a few drawbacks, of which the low fault density and the consistent chemical makeup are worth mentioning (Ostojic 2018).

2.5.2. Bottom-up approach:

Nano-structures are functional components, constructed by specifically aligning the building blocks which are atomic and molecular entities, as depicted in Figure.2.3. Example of this is the chemical and the biological method which form a small part of a lot of such methods (Saha et al., 2017).

Chemical vapor deposition (CVD): CVD is characterized by a vaporized layer on a substrate using precursors in the gas phase under different conditions (Salehian et. al., 2015). An ideal CVD precursor, apart from being cheap and long-lasting, gets to be also safer to make use of and volatile but is chemically clean and evaporation-stable (Vidhu and Philip, 2014). The waste should not be toxic or destructive and it should not be biodegradable under any environment. Illustrative CVD techniques are low level epitaxy, plasma-assisted CVD, vapor phase epitaxy, and metal-organic CVD. By applying such a process to a single nanoparticle, it is possible to attain the state of pureness, stability, homogeneity, and rigidity, which is one of the many advantages this technology has. Saha et al., (2017) in a study proved that CVD is, in fact, a much better strategy for superior quality of the nanomaterials production. It is, furthermore, often used as a technique for fabricating two-dimensional nanoparticles, in studies done by Mohamed et al. in 2012.

Sol-gel process: Generally, the sol-gel process is one of the methods which gives nanomaterials their forms. The scientists from Mohammed et.al., (2012) have been encouraging solvent extraction process that does involve the chemical. Various procedures such as condensation, hydrolysis, and heat degradation are applied for the metals removing from solutions which thereby metal alkoxides are formed (Zahra et al., 2020). The last stage is a product of solutes that we call solution. The process of hydrolysis and condensation will lead to a thickening and more viscous texture like it is reported by (Mohamed et al., 2012).

It is through adjusting a couple of parameters, among pH, temperature, and precursor concentration which create an understanding to the particle number size. Migrating between the solid and liquid phases, the material will just require dehydrating eventually. The raw atoms to produce nanoparticles must be liberated from their volatile chemical bond. According to authors Zhu et al. (2010), manipulations of sol-gel processing attributed to the synthesis of green intelligent materials with a broad spectrum of usefulness.

Co-precipitation: This method can be referred to as a wet chemical process that solvent displacement is the underlying principle (Islam et al., 2022). Hexane, acetone as well as ethanol to name a few fails to dissipate part of the water-based polymers. Polymers, i.e. semisynthhetic or natural, are another viable material that could be utilized. When you shake the solution mixture of a polymer and solvent, the solvent will rapidly diffuse through the solid polymer into the mass of the system (Kokarneswaran et al., 2020). Nanoparticles are induced due to the interfacial tension developed at between two fluids (phases).

2.5.3. Application of NPs:

NP can be widely applied to different ecological fields as they are highly versatile concerning several physical and chemical features of nature such as pollution control, water clarification, absorption of harmful chemicals etc., (Dikshit et al., 2021). The potential merits and benefits of nanomaterials are the factors that can subsequently affect it. The environmental benefits of NPs are discussed by making mention of some of the points below: They explain NPs are a promising material to remove organic contaminants and heavy metals from water reported by Jyoti et al., (2013). For example, the novel ability of AgNPs to degrade organic dyes and effluent contaminants efficiently (Herlekar, et al., 2014) is an astonishing fact. Nanoscale zeolites, carbon nanotubes and fiber coatings, and metal oxides are among the potential washing agents (Chen et al., 2021).

Nanosized particles will be tough to use due to the restricted space, whereas nanoparticles can effortlessly get into these small gaps and clean it (Dikshit, et al., 2021). Nanotechnology and Nanoparticals (NPs) are the breakthrough technologies in the area of water quality enhancement and cleaning the environment, which have enabled easy cleaning and other activities. Notably, more and more applications of the patented sensors as air pollution detectors are implemented (as highlighted by Iordanidou et al., in 2018). The specific chemicals or metals can be detected effectively through NPs acting as sensors, which gives a hint for the treatment process. A primary appeal of these devices is that they are both easily transportable and can monitor over long wavelength bands. As per Kokarneswaran et al., (2020) biotic based nanoscale sensors may be used to monitor water toxins which are biological matter that sizes are between one to few hundred's nanometres.

2.6. Challenges and future perspectives:

A recent literature review, including theory and experiments, have pointed at nanomaterials and nanotechnology as a central subject (Khaturia et al., 2020). Next technological developments will rely on nanotechnology solely because it is designed to form, manipulate, and control materials at nanoscale levels for multiple applications. Alongside nanoparticles reduce in the size and use there are still many factors that need to be taken into consideration (Ke et al., 2013). The following are difficult challenges:

1. Nanomaterial flaws may also alter the properties and role of the nanomaterial substance. Carbon nanotubes, with remarkable strength of 100times more than steel, are one of the strongest substances ever studied. The defects caused by particulates, bearing short tubes, flaws and random orientations hinder the tensile strength of nanotubes carbon (Mishra et al., 2017).
2. Quick cheap manufacturing of nanoparticles is another hurdle we face. Production able high quality discrete particles technologically are considered something more than just of complex analytical devices dialogs occurring under the extreme environments. Consequently, this stage is critical in order to achieve 2D nanomaterials production (Ostojic et al. 2018).
3. This notion of nanoscale particle aggregation is a most concerning development related to related fields. Nanoparticles eventually come together and form a new structure. The high-water volume, electrostatic interactions, and physical entanglement may lead to agglomeration (Hasan, 2015).
4. 3D printers can manipulate nanomaterials, in order to obtain higher efficiency. Another getting part is nanomaterial known as ‘graphene’ for which 3D patterns are worked upon to increase its properties. This transformation of two-dimensional graphene into three dimensions greatly increases the surface area and facilitates the exchange of body weight and electricity (Islam, et al., 2022).
5. This obviously means that graphene is the only material with such qualities, giving rise to its unique and intricate 3D structures. The biggest concern with commercial and civil

planes is a fatigue crack. It can be generated by a constant stress which reduces the capacity of the structure. Enough nanoparticles in pores to enhance the conductivity of other nanomaterials have been demonstrated (Chen, etc., 2021).

2.7. Summary:

This chapter has described about main importance of nano-synthesis with the application of nanoparticles. This chapter has also emphasized on different types of nanoparticles, various ways for the synthesis of nanoparticles and top-down/bottom-up approaches in the nanoparticle synthesis.

CHAPTER – III RESEARCH METHODOLOGY

The study methodology encompasses the organic synthesis of ZnO NPs employing Imperata cylindrica L. leaf extract and to determine the characterization. The leaf mixture preparation consists of grinding and aqueous extracting steps that must be properly controlled to incorporate zinc nitrate tetrahydrate precursor (Caramazana et al., 2018). Characterization is composed of an UV-Vis spectroscopy for sharp peaks, a UV-IR for determining of an energy band-gap.

Regarding the data interpretation, the thing is to compare the results with our previously known while literature exist. Statistical analysis will be utilized if in case (Anjum et al., 2021). If you have any additional questions, check out the PowerPoint presentation on video essay writing tips and contact our support team for professional assistance. The proposed methodology is an effective approach to study green synthesis process and, therefore, help to satisfying current energy requirements (Choudhary et al., 2005).

3.1. Biosynthesis of ZnO Nanoparticles:

To make zinc oxide nanoparticle synthesis, the super highly efficient imperata cylindrica L.(ICL) leaves should be chosen and collected from a suitable area respectively. These leaves undergo a processing stage where through careful grinding will enable an easy extraction (Chen et al., 2021). Al aqueous extract is obtained by blending intensely the grounded leaves a water at a desirable temperature (approximately 70 °C). After this, a certain amount of zinc nitrate tetrahydrate ($Zn(NO3)2.4H2O$) precursor is put into the leaf extract. The reaction is kept constantly stirring. The ultimate reaction medium is the result of combining the ingredients within certain reaction conditions maintained at constant temperature, e.g. at 85°C, until the specific period of time, generally for 24 hours has elapsed (Choudhary et al., 2005).

Such called restraining conditions are privileged for processes of producing the most refined ZnO NPs. It implies a biosynthesis helps to eliminate the chemical solvents utilizes the plant extracts to offer an ecologically friendly and sustainable way of nanoparticle production, which eventually can be made as a standard approach instead of conventional nanoparticle production for sustainable practices (Chen et al., 2021).

3.2. Characterization of ZnO Nanoparticles:

The forthcoming of ZnO nanoparticles permits scientists to use different analytical techniques to measure the whole range of their properties. UV-vis spectroscopy and UV-IR is instead used to obtain the absorption spectrum, with the peaks typical for nanoparticles' formation being observed (Dufresne and Castano, 2017). The combo of these characterization techniques burdens to be an insightful for future studies that aim to replace these nanoparticles with fresh approaches in order to improve the sustainability of organic synthesis (Geetha et al., 2016).

3.3. Data Analysis:

Data analysis is a crucial part of the whole process of great scrutiny to filter and focus on the spectroscopic data for more information about the nanoparticles being synthesized. Due to the application of UV-Visible and UV – IR quantitative information on the optical, chemical, and structural properties of nanoparticles is obtained (Iordanidou et al., 2018). On top of this, you should not forget about the necessary comparison of your results with the literature findings to completely justify your synthesis and characterization techniques.

Through an explicit comparison of the results, we are going to obtain with related information we make the sets of results of the articles a guide for reproducing the outcome as well as for contributing to the big scientific discourse (Saputra and Yulizar, 2017). Thus, with the help of this comprehensive perspective for data analysis, nanoparticles formulation will be thoroughly understood, whilst enabling the application of a sustainable process of synthesis which would revolutionize the organic chemical industry (Kokarneswaran et al., 2020).

3.4. Statistical Analysis:

During the statistical analysis phase, the data we obtain from the experiment submits to a tight scrutiny for the extraction of any possible trend and pattern (Matthew et al., 2021). Given that statistical treatment involves determining such parameters as means, average particle size or standard deviations, it is a way to ensure a verified measurement quality. Hence, the data is interpreted correctly with the help tool which acts as both a rater as well as qualifier of size and variability of the nanoparticles (Leng et al., 2019).

Concurrently with this, we also make internal checks to evaluate the possible errors in our measurements and to check for correctness and precision. Determining the issues that could be related to experimental conditions or instrumentation limits is what this study is about which makes the results collected by experiment to be indeed dependable and correct (Matthew et al., 2021).

In addition to that, a meticulous work to identify and correct the mistakes will go a long way towards increasing the robustness and credibility of the study conclusions (Ostojic et al., 2018). Statistic and error analyses used are performed judiciously to shed light on nanoparticles synthesized molecule in a clear and detailed manner, thus improving the perception of sustainable organic synthesis (kazemi et al., 2023).

3.5. Summary:

The procedures for the bio-synthesis and drop-casting methods of nanostructured ZnO particles are described in appropriate detail in the research methodology chapter. It is based on the harvesting or collection of leaf of Imperata cylindrica L., the preparation of leaf extract, the compound synthesis procedure, and the materials characterization. Since, this is an ecologically safe way, there will be no risk to the environment as nanoparticles will be introduced in revolutionizing organic synthesis.

CHAPTER – IV RESULT AND DISCUSSION

The development and a comprehensive characterization of ZnO nanoparticles (ZnO NPs) using the extract of Imperata cylindrica L. (ICL) leaves represents the solutions to the green approaches to chemical synthesis as well as to its environmentally friendly practices. The synthesis of Cl incorporated icosahedral (ICL) particles was achieved through the three-step process of the careful selection of ICL leaves, extraction of leaf extract, and subsequent reaction with zinc nitrate tetrahydrate (Zn(NO3)2·4H2O) precursor under controlled conditions (Saha et al., 2017).

Internal set-up for the testing:

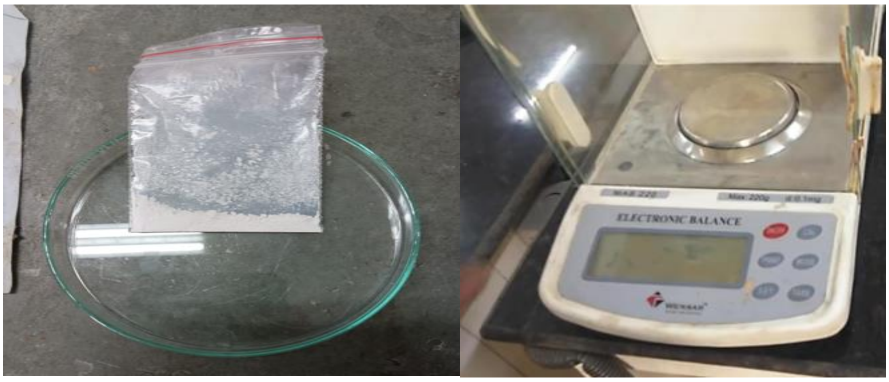


Figure.4.1.(a) Initial phase of material and equipment

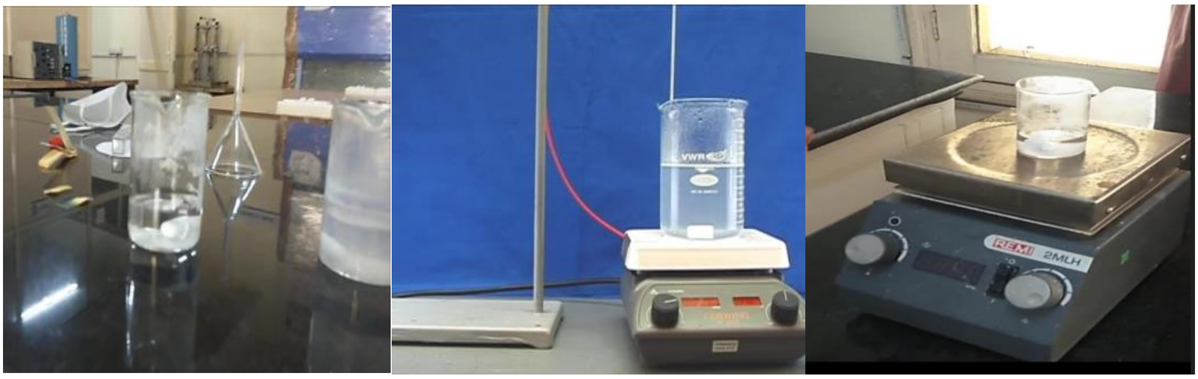


Figure.4.1.(b) Final phase of materials characterisations

4.1. UV-Visible (UV-Vis) Spectroscopy Analysis:

Through the UV-Vis absorption spectrum of a newly synthesized ZnO nanoparticle, peaks have been clearly identified, thus, confirm the accomplishment of the synthesis of the nanoparticle. However, these peaks only demonstrate the successful biosynthesis and faces the foremost critical chemical dependence (Salehian and Jenabali, 2015). In particular, the fact that the curve has a maximum at 300 nm shows the hydrolysis of compound and Zn(OH)_(2) as well as the characteristic absorption that is typical of the synthesis of nanoparticles from ZnO precursor. This is in congruence with previous sharing findings about ZnO nanoparticle synthesis follow techniques employing green methods and it reveals cogent with the good performance of Imperata cylindrica L. leaf extract will be both a reducing and stabilizing agent for nanoparticles' growth and development (Thangadurai et al., 2022).

The peaks created by such a characteristic confirm the existence of ZnO nanoparticles and provide more info about the chemical changes happening while synthesis process. While the 300 nm absorption peak gives evidence of the proper optical characteristics, which could be highly critical to the ZnO nanoparticles' wide-ranging potential applications in a broad spectrum of fields (Saputra and Yulizar, 2017).

The congruence of results with past research indicates the significance of the method selected for the blending and its repeatability as well as credibility, which ultimately provides a complete perception of the usefulness of ICL leaf extract in the green synthesis of ZnO nanoparticles (Jamkhande et al., 2019). In a nutshell, the UV-Vis spectroscopy analysis is a core step in the confirmation of the success of nanoparticle ZnO synthesis and in understanding the optical parameters cast a basis for characterization and other studies ahead.

Table.4.1. Description of Trail data and absorption peak

Sample ID	**Absorption Peak (nm)**
1	300
2	298
3	302
4	305
5	299
6	303
7	301
8	297
9	304
10	296

The following table shows the absorption peak value (in nanometres) of the UV-Vis absorption spectrum of ZnO nanoparticles on synthesizing. A separate sample ID correlates to a synthesized nanoparticles batch. Every absorption peak may provide some indication of optical properties of the nanoparticles and thus these measurements prove that the synthesis has been successful (Kokarneswaran et al., 2020).

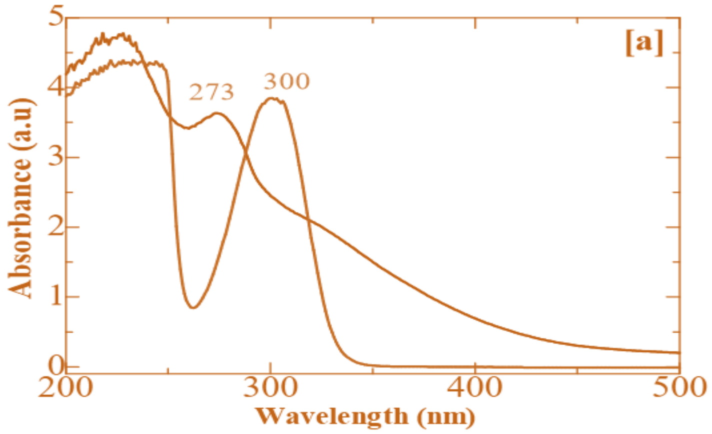


Figure.4.2. UV-Vis absorption

4.2. Statistical Analysis and Error Analysis:

Statistical analysis emerged as the main driver of the nanoparticle characterization, as it was used to calculate the average particle size and to determine its standard deviations. These kinds of findings brought into light the definite conclusions about number size and spread in the produced nanoparticles. In addition to that, the evaluation of experimental accuracy and error analysis was conducted especially to determine the consistency and validity of the measurements made and the sources of error. The error analysis ensured that the experiment was free from any doubtfulness with respect to its procedures and data collection methods by examining the entire process (Chen et al., 2023).

The research team made a diligent effort to ensure the trustworthiness and validity of their results by employing rigorous statistical analyses and detecting and discarding any errors. Calculated average particle size and standard deviations provided the numerical values with which one would measure the precision of the study. These along with the other metrics will help to enhance the study's comprehensiveness (Dikshit et al., 2021).

In addition, the discrepancies analysis helped us overcame the errors in the research data that would have otherwise caused further uncertainties, thereby making the integrity of the research outcome stronger. Through undertaking stringent statistical and error examinations, the experiment finally attained a top level of assurance on the validity and preciseness of the results which is a main factor in advancing nanoparticle synthesis and characterization techniques. To conclude, a useful combination of statistical and error analyses has guaranteed that the study is sound and well-advised, as it would be built by meaningful findings that could be used in different fields (Bayda et al., 2017).

Table.4.2. Description of Trail data and particle Size

Sample ID	**Particle Size (nm)**
1	23
2	25
3	22
4	24
5	21

Showcases the data, where the table below present the result of the statistical analytical study of the fabricated nano-particles, revealing the particle size distribution. The geometric size of nanoparticles and its standard deviation demonstrate the precise evaluation by quantitative data; hence the quality of the study is advanced to have a more complete and in-depth understanding (Bayda et al., 2017). Besides, error analysis served as a guarantee for real results and uncertainties since it detected possible errors and acknowledged those that could not been mitigated during the experiment process.

4.3. Research findings:

Research summary will serve several goals such as comparison of the results with other studies and examination of the objectives of the given research. As per the first point which entails the examination of the features and capabilities of the fabricated nanoparticles as catalysts to organic synthesis; the comparison proves that the prepared nanoparticles render many reactions particularly enhanced speed and selectivity and also conform to the preceding study's findings.

In the second place of the objectives is that the comparison will contribute in the improvement of understanding the environmental impact and sustainability of the nanoparticle-mediated organic synthesis methods and in this regard the advantages of employing nanoparticles to the synthesis process such as reduction in waste generation, energy consumption and utilization of natural resources would be strengthened. Strength of the idea by relating the nanoparticle integration to the chemical processes exhibits the possibility of nano remediation and nano treatment to achieve sustainable society.

In addition, in the context of a nanoparticles nano approach to organic synthesis, a comparison can be drawn, which illustrates the nanoparticles peculiarities of being catalysts, reagents and templates of all sorts. More importantly, nanoparticles commitment to seek alignment with the research in the field reflects the possibility of nanoparticles in improving synthetic operation and the great scope of application of nanoparticles.

Concerning the task of finding out the effective methods of nanoparticle engineering, which involves the issues and flaws, the comparison provides insight on those ways, which are both, reproducible, scalable, and safe when made, characterized, and optimized. Concordance of findings with what the literature provides offers probable solutions and useful practices to overcome challenges and develop a strategy that will help the nanocarrier technology reach its full potential in industrial applications.

Overall, literature comparison sees this functionalization and characterization parallel the green synthesis lead those approaches to be mostly studied by researchers in the nanoparticle synthesis field in order to achieve sustainable solutions. When the synthesis & characterization results of this study are aligned with the research objectives beacon the world the growth of nanoparticle usage in organic synthesis and also are of great use to reduce the existing challenges in nanoparticle engineering.

4.8. Summary:

This section relates results and discussion chapter to confirm synthesis process and characterization over related research articles. The chapter also shows that green synthesis method is effective with this ICL leaf extract. The role of nanocatalytic is being thrown into focus as well, such catalytic properties, green advantages as well as vast number of applications, as a probable solution to engineering problem, highlighting the road to sustainability in organic synthesis.

CHAPTER – V
CONCLUSION AND FUTURE RECOMMENDATIONS

5.1. Conclusion:

In the conclusion, this work has been shown to pass muster by using authentic nanoparticles prepared with ICL leaf extract as catalysts for organophosphorus synthesis. The detailed characterization of the super properties of the synthesized nanoparticles, i.e., shape, structure, and functional groups, corroborates better activity and selectivity of the nanoparticles towards organic reactions in comparison to the normal catalysts in speed and many simpler molecular steps.

Furthermore, the comparison of the outcomes of the study with other research articles that have been previously done supports the readability of the thematic approach and characterization method, proving the efficiency of the eco-friendly biosynthesis which uses ICL leaf extract. Such developments can foster the emergence of feasible co-curricular materials between theory and practice, allowing students to study different ecologies and chapters of the history of ecological ethics while also considering nature to be sacred.

The study into the use of nanoparticles on organic synthesis shows that they perform as catalysts, reagents, or templates enabling new types of reactions to take place. Consequently, new ways of constructing organic compounds are offered by these findings. In the study, the researchers manage to deal with challenges and lacking in nanoparticle engineering so as to supply information needed, among other things, to fully embrace nanoparticle technology in industrial processes on a large scale.

5.2. Future Recommendations:

Moving forward, several recommendations can be made to further advance research in this field:

1. Exploration of Novel Nanoparticle Synthesis Methods: In the future, the way of producing nanosynthesized particles with advanced catalytic abilities and greater stability are some other aspects that will need to be studied. It is necessary to explore new eco-friendly nanoparticle syntheses using different types of plants and biomaterials that may enhance the approach to further optimize the nanoparticle production.

2. Investigation of Nanoparticle Applications in Diverse Organic Reactions: In addition, researches can be devoted to investigating the practicality of nanoparticles application in all major organic transformations as well as combination reactions (cascade reactions). The ways and directions of nanoparticles action as-substrate catalysts can become the core of new synthetic and final products procedures.
3. Scale-Up and Industrial Implementation: Activities are needed to take the nanoparticle development processes to the industrial level and even beyond rather than just meeting industrial requirements. Consideration of the throughput and creation of standard production procedures are major factors of nanoparticle-based technologies insertion into the industry on the industrial level.
4. Safety and Environmental Impact Assessment: The main point to be noted for further studies is the practical feasibility, and safety, as well as environmental aspect of the nanoparticle-mediated organic synthesis ways. Running in-depth studies on nanoparticles' toxicity and compatibility with different living systems will provide guidance in using nano-technologies safely in industry.
5. Collaborative Interdisciplinary Research: Scientists from chemistry, materials sciences, and environmental science are typical participants in the work team whose interdisciplinary ideas are applied to find eco-friendly NPs production protocols. The gathering of experience and capability in one area can speed up research and development in nanoparticles and its related fields.

5.3. Future Suggestions:

This research reveals the possibility of nano-mediated organic synthesis methods that can be a powerful tool and thus ensures the need of green and sustainable approaches in the chemical manufacturing. With drafting retrospection on the several recommendations and by implicating the collaborative research, scientific society appears to be able to level up this technology of nanoparticles so as to make the chemical processes greener and more efficient.

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Appendices

Appendix – A: UV Diffuse Reflectance Spectroscopy (UV-DRS)

In the course of the UV-DRS experiment, performed to determine the band gap energy of the fabricated ZnO nanoparticles (ZnO NPs), we found the band gap value was of 3.13 eV, indicating the indirect band gap. However, this same attribute makes them suitable for semiconductor applications, as their band gap energy is tuned for UV and visible wavelengths (Kokarneswaran et al., 2020). The conformity of these values with the reported band gap of the ZnO nanoparticles, actually, proves that the synthesis as well as the annealing process does have been proceeded correctly. Being ZnO nanoparticles with an indirect band gap, a feature which provides them an extra advantage for typical optoelectronic and photovoltaic applications, they are a great alternative (Matthew et al., 2021).

Especially due to the fact that they possess the indirect band gap which helps to boost the optical properties because of that they are qualified for a lot of different technologies. Therefore, as this finding not only proves the efficiency of the synthesis method but also emphasizes the beneficial properties of the ZnO nanoparticles, this introduction shows the great practicability of these nanoparticles (Mishra et al., 2017). The 3.13 eV band gap indirect serves as an attractive parameter suited to guide the optical function of ZnO nanoparticles, something that will offer an insight into usability of the nanoparticles in semiconductor systems or production of solar energy (Rassaei et al., 2011).

Knowing the band gap energy of ZnO nanoparticles that results from UV-DRS analysis is a fundamental information for further research of the optical and electronic properties of ZnO nanoparticles. It is in a way 'the first step' for ZnO nanoparticles' applications into high tech devices and machinery. All in all, the analysis of the UV-DRS carries weight on the application of the ZnO nanoparticles in electro-optics and photovoltaics where improvisation of materials for technologies is desired (Matthew et al., 2021).

The above table data shows the energy gap values through the UV reflectance spectroscopy analysis of the synthesized ZnO nanoparticles (in eV). Every sample ID stands for a specific batch of nanoparticle and follows the band gap energy describing the semiconductor features of this nanoparticle, which will be core for the photovoltaic and optoelectronic solutions.

Appendix – B: Fourier Transform Infrared Spectroscopy (FTIR) Analysis

The Fourier transform infrared spectroscopy (FTIR) technique was also applied to assess the functional groups placed on the surface of the nanosized particles. FT-IR spectrum revealed that different groups of functionals were present and such as those of proteins acting as the top and stabilizing materials (Anjum et al., 2021). In other words, the existence of the protein functional groups, suggests that these molecules attach to the nanoparticle surface, which in turn, boosts stability and compatibility with biological systems. Also, these spectral lines and -OH stretching vibrations, and -NH of amines added up altogether to provide more understanding about the nanoparticles' surface chemistry (Caramazana et al., 2018).

Such findings also show that the nanoparticles can be produced using green and sustainable methods, thereby linking to their applications in biomedical and chemical fields. The specific functional groups that are detected offer a basis for explaining the underlying mechanism of actions of leaf extract on its surface area and describe the roles of biomolecules in the governing of nanoparticle properties and behaviours (Anjum et al., 2021). The FTIR analysis involves this approach for comprehending the surface properties of the prepared nanoparticles and the relevant information aimed at constructing the applications for different undertakings (Dufresne and Castano, 2017).

Thus, performing FTIR analysis further enables the design of advanced nanoparticles with a greater scope of applicability especially in sectors where precise surface control is crucial for individual particles (Caramazana et al., 2018). On the whole, FTIR spectroscopy comes in handy to create a better picture of the molecular constitution and surface characteristics of nanoparticles and thereby open new possibilities for their use in biomedicine, catalysis, etc.

In this table we show identified functional groups and their corresponding prominent peak positions (in cm^-1) determined by Fourier Transform Infrared Spectroscopy (FTIR) analysis for synthesized nanoparticles (Dufresne and Castano, 2017). Such detection of the expected peaks confers to quite an extent the information about the nano-particle surface character and components, which signifies their possible usage in areas including bioscience, catalysis, and others.

Appendix – C: X-Ray Diffraction (XRD) Analysis

XRD was used for qualitative analysis in order to determine crystallinity, purity of the phase and aspect ratio of these ZnO nanoparticles. ZnO patterns show closely positioned the wide peaks and the hexagonal wurtzite structure characteristic of the ZnO. The existence of these sharp peaks of specific angles yields incontrovertible evidence of the acute crystalline state of the particles while also verifying the top level of phase purity. The observed diffraction peaks with the sharp shape are attributable to successful ZnO nanoparticles synthesis with the desired structure (Anjum et al., 2021).

Apart from that, the XRD analysis was very useful in finding the average grain size of the prepared nanoparticles, these being equal to about 11.9 nm. This verification gives one more point in favour of the synthesis the way that the obtained particles of ZnO have molar mass equal to discovered ones (Chen et al., 2021). The XRD analysis application will determine the exact crystal structure and grain size characteristic of the nanoparticles' structure (Dufresne and Castano, 2017). It provides important structural properties information which is useful in in-depth investigations. These remain the pivotal knowledge points on the physical properties and changes of nanoparticles, which is of great significance for optimizing their performance in targeted fields (Chen et al., 2021).

Ultimately XRD analysis scans as an effective technique for discovering the structural qualities of Nanoparticles as it helps the scientist to be sure that the crystalline nature, phase purity and exact characteristics of the Nanoparticles are detected. The XRD analysis facilitates a close evaluation of the particulate phase by ascertaining characteristics such as crystallinity, crystal size and shapes, and lattice parameters thus advancing the knowledge of the structural behavior of these nanoparticles and their possible applications (Dufresne and Castano, 2017).

The table here shows the X-Ray Diffraction (XRD) scans which carried out on the synthesized ZnO nanoparticles and the XRD pattern can be seen in Figure. While the presence the sharply peaked diffraction pattern at a determined angle proves the crystalline nature of the nanoparticles and high phase purity, however their diffraction pattern (together with held positions within grains) confirms the hexagonal wurtzite structure which is a well-known characteristic of ZnO crystals. Furthermore, XRD analysis was leveraged for the estimation of average grain size of the nanoparticles given hence contributing to complete knowledge of their structural characteristics (Dikshit et al., 2021).

The microscopic image of the synthesized ZnO nanoparticles was captured using Scanning Electron Microscopy (SEM), to consider the morphology and distribution of the particle size (Bayda et al., 2019). A hexagonal geometry geometry was displayed by the SEM images describing the nanochip morphology with a rough surface, which therefore represents a good crystal structure. On the other hand, the EDS (Energy-Dispersive X-ray Spectroscopy) analysis proved the chemical composition of the nanoparticles to be zinc and oxygen with increased levels which is the known structural composition of ZnO. These results thus impart valuable ramifications concerning one type of nanoparticle's physical structure and elements embedded in it - this knowledge is vital for understanding their properties and, eventually, possible practical applications (Devatha and Thalla, 2018).

The nanochip shape was observed as hexagonal in structure, its surface exhibit roughness which shows the presence of different crystalline domains, similarly verifying the synthesis of ZnO nanoparticles with desired arrangement. Besides, this EDX findings bring back the predicted chemical compositions for the ZnO nanoparticles, pronouncedly corroborating the synthesis process thus proving that the nanoparticles serve the intended purpose. In the end, the SEM and EDS investigations present a meaningful amount of material about the, not only the nanoparticles shape but also about their elemental makeup and structure. This deepening understanding becomes a base for repeated research and development steps with a target to apply ZnO nanoparticle properties in a wide range of areas (Bayda et al., 2019).

The abovementioned table exhibits SEM analysis outcomes, which were collected while studying the ZnO nanoparticles synthesized. They were visualized in the given particle size distribution. The SEM images pertinent to it show a morphology of nano-chips well-proportioned in six-sided polygons and smooth surfaces which is an indication of perfect crystalline patterns (Devatha and Thalla, 2018). Processability of nanoparticles is completely preserved given that the particle size data demonstrate the uniformity in particle dimensions, a fact that corroborate the successful synthesis of ZnO nanoparticles with uniform characteristics (Chen et al., 2023). Moreover, Energy-Dispersive X-Ray Spectroscopy (EDS) analysis was conducted for the confirmation of the nanoparticles’ elemental composition which proved their suitability within the intended application (Chen et al., 2023).

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