

CHAPTER I

INTRODUCTION

1.1 REVIEW OF THE EARLIER WORKS

1.1.1 Nanochemistry Review

"Nanochemistry" is the term used to describe the fusion of nanoscience and chemistry. Nanochemistry is the study of creating essential components with different surfaces, sizes, and shapes. The fields of chemistry, biology, medicine, and engineering all use nanochemistry. Substances with diameters ranging from 1 to 100 nm are the focus of this [1]. Applications of nanochemistry include supramolecular chemistry control in the biological and pharmaceutical domains, the design of crystalline catalysts, nano oxides of rare metals, nano polymers, carbon nanotubes, and nano fertilizers. These developments result in the creation of novel and enhanced biomaterials, such as artificial bones [2]. To create biosensors and nano vaccines, different nanomaterials can be bio-conjugated [3]. When combined with textiles, nanomaterials inhibit the growth of fungus and pathogens [4]. Nanomaterial conductors can be used in high-energy density batteries, cars, aerospace components, and microchips [5,6]. Compared to conventional equipment, cutting tools composed of nanomaterials are far more robust and resistant to wear. Metal-based nanoparticles (such silver, copper, zinc, platinum nanoparticles) and metal oxide-based nanoparticles (like copper oxide, zinc oxide, titanium dioxide, nickel oxide) are the two different categories of nanomaterials [7]. Another class of nanoparticles is included in doped materials [8]. Their unique optical, chemical, electrical, and physical characteristics improved their use. Metal-oxide nanoparticles are the type of nanomaterial that is most commonly used. Although nanomaterials have lately been employed in consumer goods, bulk materials have been used for a long time. Because of their photocatalytic qualities, titanium dioxide and zinc oxide nanoparticles are used extensively [9]. Common applications for them include antibacterial agents, sunscreen, cosmetics, biosensors, and bottle coatings. As a catalyst in combustion, cerium dioxide is employed in the production of gas sensors, oxygen pumps, and metallurgical glass. Among the different types of iron oxide nanoparticles, magnetite and maghemite have drawn the greatest attention due to their potential applications in colour generation, data storage, and other

fields. As a scrubber, magnesium oxide is used to eliminate airborne contaminants. In numerous oxidation processes, copper oxide nanoparticles act as catalysts [10]. Doping of nanoparticles enhances their biological, chemical, optical, and electrical characteristics. It is the incorporation of outside components into the original materials. Large-scale manufacture of semiconductors and semiconductor sensors is made possible by this technology [11,12].

1.1.2 Formation of Nanoparticles

The synthesis of nanomaterials can be done in two general ways, as top down approach and bottom up approach. The preparatory materials utilized in the two processes are the main point of difference. While bottom-up techniques start with atoms or molecules, top-down techniques start with bulk material and use physical, chemical, and mechanical processes to reduce size to nanoscale [13].

The top-down approach is used to transform bulk materials into tiny, nanoscale particles. Some disadvantages of this approach are changes in chemical and surface characteristics [14]. To create finished nanoparticles, nanosized building blocks are assembled using bottom-up techniques.

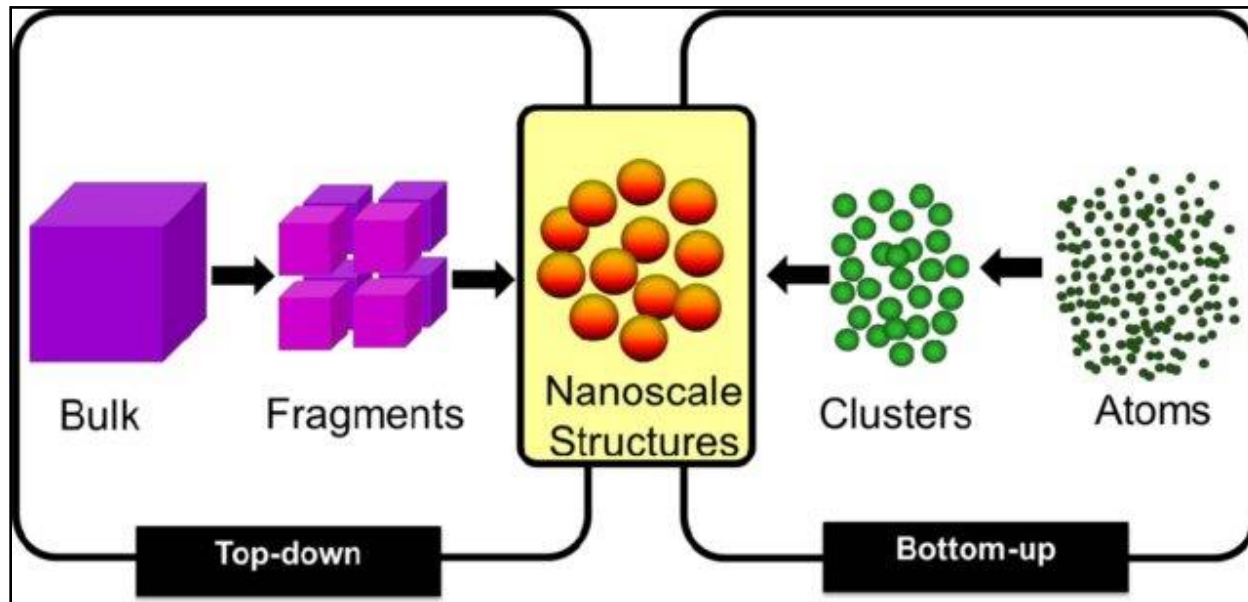


Figure 1 Illustration of two approaches of nanoparticles formation.

1.2 PURPOSE OF THE RESEARCH WORK ON NANOTECHNOLOGY

Research is a crucial pillar of development, advancing vital services and medical treatments for the benefit of both the present and the future generations. Research aims to strengthen and advance theories by methodical and careful investigation, helping to develop solid and enduring scientific truths. Researchers gather enormous volumes of data, carefully analyze it, and then interpret the results with precision by following strict protocols. Through our tenacious pursuit of knowledge, we get the understanding required for efficient problem-solving and reasoned decision-making. It enables us to take on the difficult problems that humanity faces, like eradicating diseases, dealing with environmental problems, and advancing technical advancements. Research has the power to improve people's quality of life worldwide by making new discoveries and advances, paving the way for a better future for future generations. Additionally, research is a natural part of human curiosity. People have been interested in understanding the inner workings of the world, the forces influencing nature, and the underlying mechanics of many events from ancient times to the present. Civilizations have made astounding advances in their understanding of the universe, from the tiniest subatomic particles to the grandeur of the cosmos, in an effort to solve the mysteries of our existence. The good trend of rising student interest in science and technology today portends a positive change towards a society with a higher level of scientific literacy. Younger people's increased interest in research encourages a culture of inquiry and critical thought, preparing the way for a generation of people ready to address the most serious issues facing the world. In conclusion, research illuminates the way to development and societal improvement by serving as a beacon of knowledge. Research equips us to build a world that is healthier, more sustainable, and full of technology advancements through its unwavering commitment to discovering the truth and comprehending the complexities of reality. There is little question that the results of study will play a crucial part in determining a better and more enlightened future for humanity as long as we continue to embrace the spirit of inquiry.

Researchers have recently been enthralled by the possibilities of nanotechnology since it enables them to control materials at the exceedingly minute nanoscale level. The ability to understand, alter, and manipulate matter at the atomic and molecular levels is referred to as nanotechnology, according to the National Science Foundation. There are numerous subfields of nanotechnology, including wet nanotechnology, green nanotechnology, and nanoengineering. Excitingly, nanotechnology paves the way for a wide range of uses, including improved transistors,

sophisticated water filtration systems, targeted drug delivery techniques, more advanced biological and chemical sensors, and the ability to reduce the size and power consumption of memory storage and computing components in electronic devices, including light-emitting diodes. The groundwork for molecular robots has also been laid by ground-breaking advancements in the realm of nanotechnology, where chemists have successfully integrated DNA-based rolling motors into computer functions. These cutting-edge DNA-based motors demonstrate the remarkable potential of nanotechnology in fusing computer and biological processes. They not only provide computational power but also have the capacity to use fuel in a regulated manner.

1.3 NANOPARTICLES AND THEIR TYPES

A fascinating and quickly developing field of nanotechnology research has been the creation of many kinds of nanoparticles. Small particles known as nanoparticles typically have sizes between 1 and 100 nanometers, which provides them distinct features from their bulk counterparts [15]. Nanoparticles come in a variety of forms, including:

- ❖ **Organic nanoparticles:** These are organic nanoparticles made of lipids and polymers, among other organic components. They have uses in the delivery of drugs, allowing for the encapsulation of drugs and controlled release at predetermined target locations within the body.
- ❖ **Inorganic nanoparticles:** Metals, metal oxides, metallic nanoparticles and semiconductors are examples of non-carbon-based materials that are used to make inorganic nanoparticles. These nanoparticles have unique optical, electrical, and catalytic characteristics that make them useful for sensors, imaging, electronics, catalysis and environmental cleanup.
- ❖ **Carbon based nanoparticles:** Carbon atoms are organised in certain ways in carbon nanoparticles like graphene and carbon nanotubes. They are useful in fields like nanoelectronics and reinforced materials because they have remarkable mechanical, electrical, and thermal properties.

Exciting prospects have arisen as a result of the development of these varied nanoparticles, in disciplines ranging from electronics and environmental research to medicine and energy.

Applications for nanoparticle synthesis are anticipated to grow as researchers continue to develop and improve these techniques, further revolutionizing a variety of industries and technology.

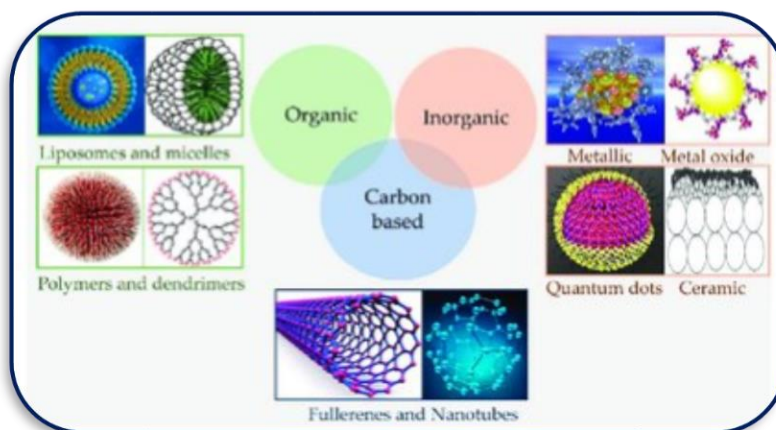


Figure 2 Different types of nanoparticles.

1.4 IRON AND ZINC METAL OXIDE NANOMATERIALS

Unique characteristics of metal oxide nanoparticles include increased reactivity, optical and magnetic capabilities, semiconductor traits, and antibacterial activities. They have numerous uses in catalysis, optoelectronics, nanoelectronics, medicine, environmental cleanup, energy storage, and other fields. These programmable and adaptable nanoparticles provide customised solutions for a range of sectors. But it's crucial to use resources responsibly and to take into account any potential negative effects on the environment and human health. Nanoscale iron oxide nanoparticles, a member of the family of metal oxide nanomaterials display special features due to their small size. Iron oxide, also known as Fe_2O_3 and Fe_3O_4 , is a typical form of iron oxide nanoparticle. Due to their magnetic characteristics, these nanoparticles are useful for MRI, magnetic data storage and other applications that require focused medication delivery [16]. Additionally studied are the catalytic properties of iron metal oxide nanoparticles in various chemical processes. Iron metal oxide nanoparticles are utilised in environmental remediation because they are effective adsorbents for removing contaminants from water and soil, in addition to their magnetic and catalytic capabilities [17]. They also have potential for energy storage, and research is currently being done to see how they might be used in lithium-ion batteries and other cutting-edge energy storage systems. In general, iron metal oxide nanoparticles have numerous uses in a variety of industries, making them a crucial aspect of nanotechnology research and

development. Their distinct qualities and wide range of possible applications continue to pique scientific curiosity and spur technical development.

In the cosmetic and medicinal industries, zinc oxide nanoparticles are used effectively [18]. These nanoparticles have also shown that they are not harmful to human health. Given that they are properly functionalized, this characteristic makes them a good contender for possible cancer treatments. They also have the ability to supply zinc, which might help with the treatment of diabetes. ZnO nanoparticles have also demonstrated promise in agriculture by raising crop output [19].

Moreover, Iron and Zinc salts are easily available, low cost and biologically chosen metals. So, here, our research is focused on iron and zinc oxide based nanomaterials.

In comparison to pure nanoparticles, nanocomposites have the following advantages: improved characteristics, reinforcement, tunability, barrier functions, lower cost, simple production, light weighting, integrated functions, thermal stability, customised conductivity, and potential for use in biomedicine. They offer adaptable solutions for a variety of industries while enhancing material performance, usability, and affordability. So, for better applicability we have synthesized the iron and zinc oxide based nanocomposites.

1.5 SYNTHETIC PROCEDURE NANOMATERIALS

There are several ways to create nanoparticles, each with benefits and drawbacks. Nanoparticle synthesis techniques that are often used include:

1. **Chemical Reduction:** In this process, metal salts are reduced to nanoparticles by utilising chemicals like sodium borohydride or hydrazine. It is a frequently used method for creating gold, silver, and platinum metal nanoparticles.
2. **Sol-Gel Method:** This method involves preparing a sol-gel precursor solution, and then hydrolysis and condensation processes produce nanoparticles. For metal oxide nanoparticles like titanium dioxide and silica, it is frequently employed.
3. **Electrochemical Synthesis:** In this process, metal ions are reduced to nanoparticles at the surface of an electrode. It is frequently applied to metal oxides and metal nanoparticles.

4. **Physical Vapour Deposition:** For the purpose of producing nanoparticles, PVD entails condensing vaporised atoms or molecules onto a substrate. This approach makes advantage of processes like sputtering and evaporation.
5. **Green Synthesis:** By using microorganisms or plant extracts as reducing agents, green synthesis uses natural sources. Producing nanoparticles with minimal environmental impact is an environmentally beneficial method.
6. **Microwave-Assisted Synthesis:** Quick heating of the reaction mixture using microwaves enables more quick and precise nanoparticle production.
7. **Hydrothermal Synthesis:** High-temperature, high-pressure aqueous environments are used to create nanoparticles, giving researchers control over their size and form.
8. **Emulsion and Microemulsion Techniques:** Emulsions or microemulsions serve as limited reaction settings that enable control over the size and structure of nanoparticles as they form.
9. **Spray Pyrolysis:** In this procedure, a precursor solution is sprayed into a hot reactor, where it quickly evaporates and condenses to produce nanoparticles.
10. **Biological Synthesis:** To create nanoparticles, reducing agents such as bacteria, fungus, or plants are employed. Recently, interest has grown in this technology because it is environmentally beneficial.

Each synthesis technique has a unique set of benefits, such as the ability to regulate size, shape, and surface qualities, as well as certain applications for which it is most appropriate. The preferred properties and intended uses of the nanoparticles determine the synthesis process to be used. Green synthesis is more environmentally beneficial because it produces biocompatible nanoparticles for a variety of applications while being energy, cost and safety efficient [20]. It offers flexible solutions in medicine, agriculture, and more because to adjustable features and easy scalability, involving communities and fostering sustainability. Here, we have synthesized pure iron oxide nanoparticles, heterostructure MnO-FeO nanocomposites, $\text{Mo}_x\text{Fe}_{1-x}\text{O}$ nanocomposites and copper-assisted iron oxide nanomaterials by green method using *Punica Granatum* peel extract as reducing agent and calcined at 700 °C. These peel extract is full of flavonoids compounds such as ellagic acid, gallic acid etc and alkaloids such as quercetin which act as reducing agent to produce nanoparticles. We have also synthesized iron zinc oxide nanocomposites by co-precipitation method and calcined at different temperatures.

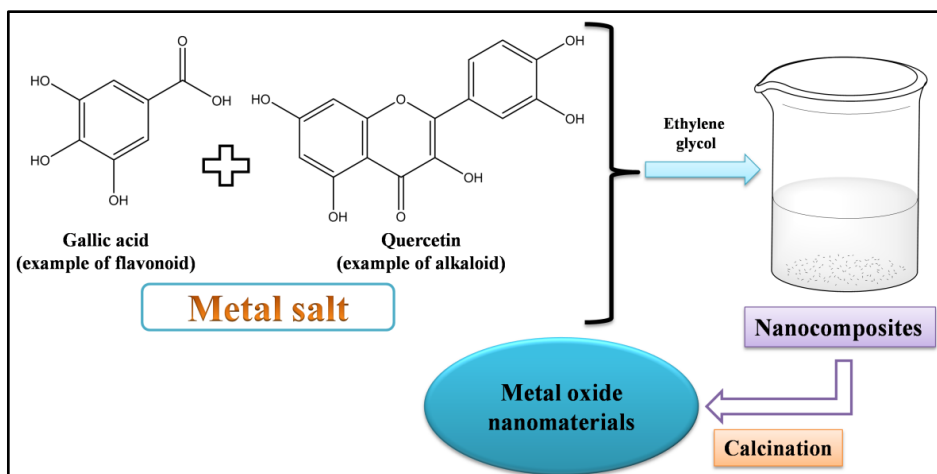


Figure 3 Nanomaterial formation mechanism by using *Punica granatum* peel extract (flavonoid and alkaloid compounds).

1.6 APPLICATIONS OF NANOMATERIALS

1.6.1 Dye removal

A variety of colours are used in the textile industry, with azo dyes - aromatic hydrocarbon derivatives of benzene, toluene, naphthalene, phenol, and aniline, being the most often used type. Due to close contact with the subjects, the solvents employed by the personnel in various sectors have a significant carcinogenic effect.

Synthetic Methylene Blue (MB) dye is widely utilised in a variety of fields, including textiles, printing and medical. Additionally, it is used in research labs as a biological stain. Despite having a wide range of uses, Methylene Blue dye is toxic and may have negative impacts on both human health and the environment. Due of its toxicity, methylene blue can harm aquatic environments and aquatic life, especially when it is unbound. Even while the dye has medical benefits, prolonged human exposure to it increases the risk of skin irritation, eye damage, and possible mutagenic effects. Because the dye lingers in the environment, it pollutes water and disturbs natural habitats. Methylene Blue removal from water is being explored using a variety of ways, including potential nanoparticle-based strategies for efficient and eco-friendly removal [21]. Through advanced oxidation processes (AOPs), some nanoparticles' catalytic characteristics can help Methylene Blue molecules break down into less dangerous compounds.

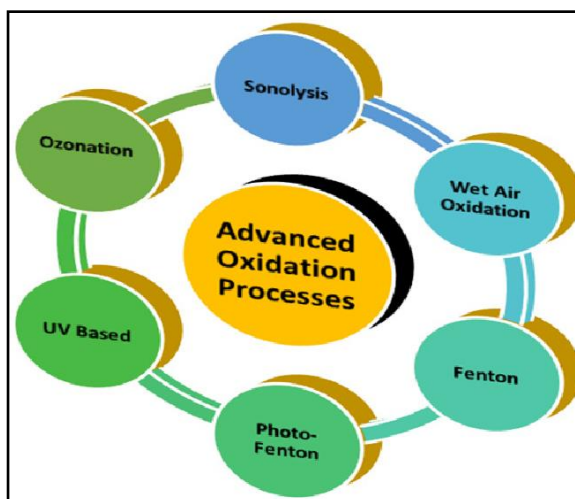


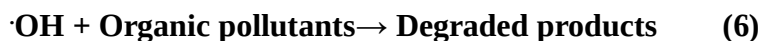
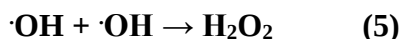
Figure 4 Different types of AOPs for the efficient removal of dye by nanoparticles.

1.6.1.1 Advanced oxidation processes (AOPs):

There are many advanced oxidation processes (AOPs) like photocatalytic, Fenton, Photo-Fenton, ozonation with nanocatalyst, peroxomonosulfate (PMS) and peroxodisulfate (PDS) based oxidation using nanomaterials. These methods provide efficient and environmentally responsible ways to remove dyes from water using nanoparticles. Under the influence of light, photocatalytic degradation uses nanoparticles to degrade dyes in water. Reactive species produced by nanoparticles oxidise dyes into less dangerous compounds. This chemical-free method is adaptable, powerful against different dyes, and uses the least amount of chemicals possible. It's crucial to remember that the efficiency of photocatalytic degradation is influenced by variables such as nanoparticle properties (size, shape), light intensity, dye concentration, and solution pH.

A powerful water treatment technique for dye removal is Fenton degradation, which is aided by iron-based nanoparticles like FeO or Fe₃O₄ [22]. This procedure combines the addition of nanoparticles with hydrogen peroxide to produce hydroxyl radicals ($\cdot\text{OH}$), which are extremely reactive. With the ultimate goal of full mineralization, these radicals efficiently transform dye contaminants into harmless chemicals. By concentrating on a variety of dye structures, Fenton degradation exhibits adaptability. The Fenton reaction is sped up by the incorporation of nanoparticles, improving its performance and cutting down on reaction time. In order to advance this technique for effective and sustainable water filtration, research is now being done to improve the properties of nanoparticles and process conditions. Fundamentally, Fenton

degradation with nanoparticles provides a potent remedy to reduce dye pollution and encourage healthier water sources. H. J. Fenton originally described the homogenous Fenton reaction in 1894. It dealt with the increased oxidative potential of hydrogen peroxide (H_2O_2) when iron (Fe) was employed as a catalyst in an acidic environment. The following chemical processes are a part of the homogeneous Fenton process:



When the Fenton reagent is exposed to UV light, an enhanced method of water treatment is called photo-Fenton degradation using nanoparticles. The nanoparticles quickly activated to produce an $\cdot\text{OH}$ radical when exposed to light.

AOPs based on homogenous Fenton reactions have been used for decades to degrade and mineralize a variety of contaminants in wastewater because to their benefits, which include short reaction times, easy instrumentation, and affordable, nontoxic catalysts. Nevertheless, there are significant disadvantages to the homogenous Fenton reaction, including the production of large amounts of iron sludges at the conclusion of the process and optimal catalytic activity at an acidic pH of 3.0. To get around these problems, the focus of study has switched to the heterogeneous Fenton reaction with iron as a solid catalyst. The hydroxyl radicals responsible for the breakdown of organic contaminants are derived from the ferrous and ferric ions that are produced on the surface of solid iron. Many kinds of heterogeneous Fenton catalysts based on iron have been created and used for the degradation of organic contaminants based on Fenton reactions throughout the last 20 years. This includes soil, clay, zero-valent iron, and iron-containing industrial ash, such as fly ash, blast furnace dust, electric furnace dust, pyrite ash, and ferrihydrite; iron oxides, such as hematite, pyrite, lepidocrocite, magnetite, and pyrite; and dye

degradation. Because of their benefits—which include greater catalytic activity over a wide pH range, reusability, and catalyst removal—iron-based heterogeneous Fenton catalysts are used. Its drawbacks include deactivation of the catalyst, leaching of metal ions from the catalyst, and a slower reaction rate than in a homogeneous Fenton reaction. Research efforts are concentrated on creating iron-free Fenton catalysts that can produce hydroxyl radicals when they combine with H_2O_2 , as both homogeneous and heterogeneous iron-based Fenton reactions have a number of drawbacks. Because catalytically-active species with a particular oxidation state can be changed from active to inactive form and vice versa by straightforward redox processes, researchers concentrated on metals, which display many oxidation states.

In order to generate insitu hydroxyl radicals for the effective degradation of dyes, researchers have investigated a variety of metals that breakdown H_2O_2 in homogeneous and heterogeneous phases even at neutral pH [23]. It has been demonstrated that several metals, including manganese, aluminium, cerium, copper, cobalt, chromium, ruthenium, and polyoxometalates, are effective non-ferrous Fenton catalysts. Fenton-like reactions are those that certain metals with many oxidation states display, similar to the Fenton reaction. These metals go through both homogeneous and heterogeneous phases when the Fenton-like reaction takes place. Both homogeneous and heterogeneous Fenton-like catalysts are names for these metals depending on their phase.

Atoms, molecules, or ions can move from a liquid phase to a solid surface through a surface phenomena called adsorption. Water contaminants are often adsorbate, which is attracted to the surface of an adsorbent through chemical or physical means. One of the most promising techniques for removing dyes from waste water is the adsorption process. Because it is quick, easy to use, affordable, has a high removal percentage, and is straightforward to build and operate, the adsorption process is highly recommended as a method for removing dissolved organic contaminants, such as colours, from industrial waste water. Diverse adsorbents composed of both natural and synthetic materials have been investigated for the purpose of eliminating dyes from industrial wastewater. Researchers have focused a lot of attention on the potential of NMs as nanoadsorbents for waste water treatment and colour removal. The synthesis of nanoadsorbents has been conducted by several means, and extensive research has been

conducted on their dye removal efficacy and mechanism. Among the different nanoadsorbents are magnetic, metallic, silica, and carbonaceous NPs.

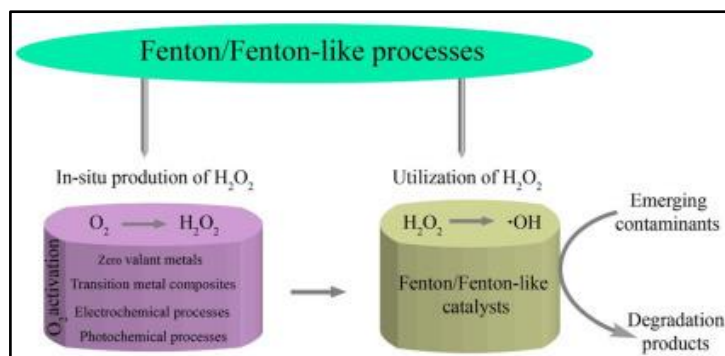


Figure 5 Scheme for fenton like degradation of dye using nanocatalyst.

Here, we have compared the photocatalytic, Fenton, photo-Fenton like degradation of methylene blue dye using pure iron oxide nanoparticles as catalyst and studied some reaction parameters for photo-Fenton process. Hence, Fenton like degradation for this dye were also studied by using Mo_xFe_{1-x}O nanocomposites and optimized the reaction conditions by varying reaction parameters.

A powerful method for dye degradation combines nanomaterials with PMS (Peroxomonosulfate) and PDS (Peroxdisulfate) activation [24]. Nanoparticles function as catalysts when added to water tainted with dye. When PMS or PDS are added, these nanoparticles activate the substances and cause the production of SO₄^{·-} sulfate radicals. These sulfate radicals attack and degrade dye molecules by oxidative processes. The process is accelerated by the presence of nanomaterials, which improves the efficiency of dye degradation. Additionally, this method often results in less non-toxic byproducts, minimizing any negative environmental effects. It is remarkably adaptable and works well with a wide range of dye kinds and molecular architectures. This approach complies with sustainable practices because it uses chemicals that are safe for the environment and nanomaterials. The goal of research is to optimise dye degradation by adjusting the process parameters and nanomaterial properties. In the end, the combination of PMS or PDS activation with nanomaterials represents a potential method for safe and effective water filtration that efficiently combats dye-induced pollution. In this instance, methylene blue dye degradation was

carried out using PDS activated Cu assisted iron oxide nanomaterials, and the reaction conditions were optimised by adjusting the reaction parameters using the most effective nanocomposites.

1.6.2 Biological Applications

Escherichia coli, *Salmonella sp.*, *Salmonella typhimurium*, *Staphylococcus aureus*, *Bacillus subtilis* etc. are a few pathogenic bacteria that have been detected in food and pose a significant risk to people. Effective antibacterial pathogen-removing agents include metal oxide nanoparticles. Metals' antibacterial properties might not exist in their salt or oxide forms, but they can exist in nano form [25]. With their strong connections to microbial DNA and protein, metal oxide nanoparticles stop microbial growth and cause cell death by disrupting the electron transport chain [26]. Therefore, in our research, we employ a precise synthesis of metal oxide nanoparticles that can be employed to prevent bacterial development. Nanoparticles do have the ability to harbour bacteria in two ways: (a) Free metal ions' toxicity and (b) reactive oxygen species production. Because of their thicker peptidoglycan coating, Gram-positive bacteria have a higher IC₅₀ value than Gram-negative bacteria. Synthesized nanocomposites satisfy the rising demand for new antimicrobials with the potential to lower healthcare expenses caused by the emergence of antibiotic resistance in bacteria. The demand for new synthetic antimicrobials has rapidly increased as a result of the usage of synthetic antimicrobials in a variety of industries, including cosmetics, medicine, textiles, and the environment.

The ability of certain chemicals, which are frequently found in foods like fruits and vegetables, to counteract the harmful effects of molecules known as free radicals within the body is referred to as having antioxidant characteristics. These free radicals have the potential to damage cells and are linked to a number of health issues. In order to prevent diseases like cancer and heart problems, antioxidants function by neutralising these dangerous chemicals. Known antioxidants include the vitamins C and E as well as minerals like selenium. Antioxidants are thought to provide health benefits, but more investigation is needed to fully understand how they work. Nitric oxide, DPPH (2,2-diphenyl-1-picrylhydrazyl), ABTS (2,2'-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid), and superoxide radical scavenging assays are some popular assays used to measure the antioxidant ability of nanoparticles. These tests assist in determining how well nanoparticles can scavenge or neutralize various free radicals, which are indicators of oxidative stress and cellular damage. Here is how each test operates:

1. **DPPH assay:** This assay is frequently used to assess the free radical scavenging ability of nanoparticles. DPPH is a stable free radical with a purple colour in its radical form. When an antioxidant interacts with DPPH, it donates an electron to the radical, causing a colour change from purple to yellow. The extent of the colour change is proportional to the scavenging activity of the antioxidant.
2. **ABTS assay:** Another stable free radical with color-changing properties is ABTS. In this test, ABTS is exposed to the antioxidants or nanoparticles, which results in a colour change from blue-green to colourless as the radicals are dissipated. The scavenging capacity of the nanoparticles is indicated by the decolorization.
3. **Nitric Oxide assay:** When produced in excess, the signalling molecule nitric oxide (NO) can become a dangerous free radical. In this test, nitric oxide radicals are produced under carefully regulated conditions. These radicals can interact with antioxidant nanoparticles and be neutralised, halting the development of hazardous chemicals. Nitric oxide concentration dropping indicates scavenging activity.
4. **Superoxide radical scavenging assay:** Oxidative stress is caused by superoxide radicals, which are produced in biological systems. In this test, the ability of nanoparticles to scavenge superoxide radicals is evaluated. Typically, a substance like NBT (nitroblue tetrazolium), which transforms colour when in contact with superoxide radicals, is utilised. The decrease in colour intensity is a sign of the nanoparticles' scavenging action.

Researchers can learn more about the ability of nanoparticles to behave as antioxidants and how well they might be able to fend off various kinds of free radicals by carrying out these assays. But Nanoparticle composition and manufacturing processes, such as calcination temperature, can affect the antioxidant capabilities of the particles. Particle size, crystal structure, surface chemistry, and oxidation state are among the things that might change during the heating process known as calcination. These modifications may affect the nanoparticles' antioxidant behavior by affecting how well they interact with and combat free radicals. Depending on the particular nanoparticles material and desired use, the ideal calcination temperature can be determined to maximize antioxidant activity. It is crucial to conduct systematic investigations to identify the temperature range that produces nanoparticles with the necessary antioxidant properties for various applications. Here how the antibacterial and antioxidant properties of the synthesized nanocomposites ($\text{ZnFe}_2\text{O}_4/\text{ZnO}$) differs with the calcination temperatures were studied.

Nanotechnology and plant biology are combined in the study of seed germination through the use of nanoparticles. Plant growth and seed germination may be impacted by the distinct physical and chemical characteristics of nanoparticles. Performing germination experiments means to keep an eye on variables like: germination rate, root and shoot length and seedling biomass. The number of seeds that sprout over time is known as the germination rate. Root and shoot length measurements are useful for evaluating growth. Weighing seedlings to measure overall growth is an aspect of seedling biomass. The influence of nanoparticles on this study also dependable on the calcinations temperature of the corresponding nanoparticles. So, we also study the effect of calcination temperatures of our synthesized nanocomposites ($\text{ZnFe}_2\text{O}_4/\text{ZnO}$) on seed germination and plant growth here.

Blood plasma contains the essential protein known as human serum albumin (HSA), which is essential for carrying molecules, preserving osmotic equilibrium, buffering pH, and promoting immunological responses. It is involved in therapeutic therapy, nutrient transport, and detoxification. Applications of HSA include drug delivery, biomarker discovery, and medical care. It is necessary for healthcare and research that it is made available through plasma donations. Particularly in nanomedicine, human serum albumin (HSA) is essential for binding with nanoparticles. The biocompatibility, stability, focused drug delivery, and controlled release are all improved by this relationship. It promotes cellular absorption, lessens toxicity, and increases circulation time. HSA-coated nanoparticles offer the promise for personalised therapy, safer and more efficient drug administration, and imaging applications. For the creation of effective nanoparticle-based therapeutics and the advancement of medical research, understanding this binding is crucial. We have studied binding interactions of pure iron oxide nanoparticles and heterostructure MnO-FeO nanocomposites and also have found binding constant for the best performing nanocomposite.

1.7 OBJECTIVES OF THE RESEARCH WORK

Thus, the objectives and uses of this research expedition are:

- ❖ The goal of green synthesis is to produce nanoparticles in a biocompatible and environmentally sustainable manner, minimising its negative effects on the environment and encouraging the responsible usage of nanomaterials.

- ❖ By simultaneously precipitating metal ions from a solution, the co-precipitation approach for nanoparticle synthesis aims to provide a scalable and regulated process that yields nanoparticles with particular characteristics for a range of applications.
- ❖ By using physiochemical techniques, this research work highlights several kinds of interactions.
- ❖ The synthesized nanomaterials can be used as nanocatalyst and also in biomedical fields like as antibacterial, antioxidant and anticancer agent.
- ❖ How variation of calcination temperatures effect structural features and applications also studied in our research work.