Chapter

Introductory Chapter: Gold Nanoparticles – Scientific Background and Potential Horizons

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1. Introduction

Gold was discovered quite early and has been studied and used for at least a few thousand years. Gold follows copper and silver in importance on the periodic table, placing it in Group 11. Because of its flexible face-centered cubic (F.C.C.) structure, gold has a metallic radius comparable to that of silver [1]. Particles of Au have a lower single-bond covalent radius compared to Ag. Gold's combination of chemical and physical properties is unique, and this is true in both its microscopic and macroscopic phases. Its macroscopic chemical stability, strong redox potential, and bright yellow color make it easily recognizable. Its electrical structure can be comprehended by applying concepts from quantum mechanics and Einstein's theory of relativity. It has been observed that the conductivity, electrical structure, reactivity, melting temperature, and mechanical properties of particles will change at the nanoscale if the particles are reduced in size to a point smaller than the minimum permissible size [2]. Nanomaterial particles (nm) are considered important because of their physical and chemical properties, and they are being studied for applications in various fields. It has the potential to revolutionize many different fields in order to increase productivity [3]. Organic photovoltaics, sensory probes, therapeutic agents, drug administration in biological and medical applications, electronic conductors, and catalysis are a few of the cutting-edge uses that have been investigated and implemented in recent years. Recently, a new class of materials known as nanomaterials has evolved. Nanomaterials are those whose fundamental unit, roughly corresponding to the size of 10–100 atoms, is closely packed within a three-dimensional region with a dimension on the nanometer scale (0.1–100 nm) [4]). Nanomaterials, such as nanoparticles, have been under development the longest and are the most advanced technology. Various fields, including medicine, biology, physics, chemistry, and the senses, use nanoparticles and nanotechnology extensively because of their unique features [5]. Nanoparticles made of noble metals, including copper, mercury, silver, platinum, and gold, have recently received more attention from scientists. Gold nanoparticles' optical and electrical properties can be tuned by adjusting their size, shape, surface chemistry, or aggregation state [6]. As a result, gold nanoparticles have become a popular choice for use in various applications. Their exceptional physical qualities account for this. Surface plasmon oscillations, for instance, may be used for sensing, imaging, and labeling. As a result, gold nanoparticles are often employed in medicinal applications rather than potentially harmful metals like platinum. Making nanoparticles of gold makes it possible to utilize previously inaccessible places, opening up exciting new avenues of research and development.

2. Gold nanoparticle properties and their various applications and activities

Gold nanoparticles are a versatile material that can be used in a wide range of applications. This is because their electronic and physical properties are well understood, thanks to well-developed ways to make them. Their surface chemistry is also easy to change. Because of these qualities, gold nanoparticles are one of the most commonly used nanomaterials in academic research and are a key part of many medical devices and industrial products around the world. Gold nanoparticle utilization has several practical benefits, in this case, gold nanoparticles' diameter of 5 nm or less are ideal for use as catalysts [7]. Toxic air pollutants may be converted into far safer molecules. In addition, this gold nanoparticle can potentially be employed in treating tumors and cancer [8]. It's also applicable to other molecules, including those used in medicine. Moreover, gold nanoparticles have the fantastic and practical capacity to transform specific wavelengths of light into heat [9]. Gold nanoparticles, in particular, have shown great promise in improving the performance of solar cells, which absorb sunlight and convert it into electricity [10]. Gold nanoparticles have recently been discovered to be useful in various scientific disciplines. Optical coding in many colors for biological experiments is one example of how glasses may be coated to alter their characteristics. These gold nanoparticles have also been employed to improve organic light-emitting diodes' quantum and electroluminescence efficiency. Detecting minute concentrations of analytes is now possible with novel sensors made possible by nanoparticle materials—for instance, a few parts per million (ppm) of chemical vapors. In addition, these gold nanoparticles have traditionally been used in the textile dyeing process. Another fascinating use for these nanoparticles is in high-density data storage and the provision of sustainable energy through solar cells [11]. For a better industrial clean processes, less pollution, and purified water are just a few of the many critical environmental issues that may be addressed using technologies based on gold nanoparticles [12]. Similarly resistant to oxidation, gold is, in reality, one of the most stable metals. In addition to catalyzing the electrochemical redox oxidation and reduction of CO and CH3OH, the hydrogenation of unsaturated substrates, and CO oxidation, functional thiolate-stabilized gold nanoparticles may also catalyze the hydrogenation of unsaturated substrates [13]. As part of nanotechnology, gold nanoparticles may regulate and detect mercury. In theory, gold nanoparticles may be very effective as mercury oxidation catalysts. One of the best applications of gold nanoparticles is improving environmental quality. Carbon monoxide is a poisonous gas with no taste or smell, yet it may kill a person within minutes [14]. The solution can be found simply in gold nanoparticles. Gold nanoparticles transform carbon monoxide (CO) into carbon dioxide (CO_2), a far safer chemical [15]. In recent years, noble metal nanoparticles have become more popular for water purification and contaminant detection. Gold nanoparticles have also been shown to be efficient adsorbents for filtering out high levels of mercury in the water supply. Contrarily, AuNPs possess a variety of features that make them excellent bionanotechnology instruments. These systems are useful for imaging because of the large variety of surface functions and bioconjugates that may be attached to AuNPs and their exceptional physical characteristics. And by modifying the monolayer on

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the surface of the analyte, a highly sensitive and selective diagnostic system may be developed. Therapeutic potential has also been seen for AuNP-based delivery vectors, owing to their high surface loading of medication and genes and their tuneable release of the payloads. Collectively, AuNPs are very adaptable materials for future biological and bioengineering uses.

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