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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

(قَالُوا سُبْحَانَكَ لَا عِلْمَ لَنَا إِلَّا  
مَا عَلَّمْتَنَا إِنَّكَ أَنْتَ الْعَلِيمُ  
الْحَكِيمُ )

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# **DEDICATION**

Dedicate Our Project to Our Supervisor  
***Doctor. Rafal Ahmed***

***Our Father, Our Mother, Our Brothers & Our Sisters***

*Who always encouraged and supported me, and without  
them this work would not have been possible.*

***Mahdy Kaseem Abd***

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## **Chapter One: Introduction**

## **Introduction 11.**

Gold considered as the 3rd element from periodic table at Group 11 classification, situated beneath Cu and Ag. Gold takes shape in the face-centred cubic (F.C.C) structure (is liable for its flexibility), its radius as metallic being silver tantamount. The single-bond covalent radius in particles is littler for Au than for Ag [1]. Gold has various unique characters that have fascinated and attracted mankind since discovery. Gold is unreactive where at atmosphere will not tarnish; hence, its colour forever is attractive and was utilized in shaping jewellery for such reason [2]. Gold has a special blend of chemical and physical characters in states as microscopic and macroscopic: On scale as macroscopic, it is recognized for its yellow unique colour, potential of high redox and chemically stable. Its electronic structure outcome and comprehension that starts with science of quantum along with Einstein's relativity hypothesis [3]. As far nano scale, conductivity, the electronic structure, reactivity, temperature of melting and mechanical characters have been noticed to change if particles turn into smaller than size being critical. Major factors are there which of responsibility for such variations:

Ratio of high surface/volume, therefore, several physical nanoparticles characters i.e., stability and solubility are taking control through nanoparticle surface nature and that is why nanoparticles of this metal utilized as catalyst [4, 5], its applications being widely spread in nano-particulate and macroscopic states [6].

**1.2 Gold Nanoparticles GNPs:** 'Michael Faraday in 1857, conveyed the Royal Society Bakerian Lecture in London with the title of "Test Relations of Gold (and different metals) to light". Michael was the 1st to sense that shading was due to the gold particles moment size [7]. Although some scientists see the experiment of Faraday as a landmark in nanotechnology and nano-science history [8], the gold chemical inertness being a bulk metal appeared to provide very few chances to open up chemistries being exciting and new. The new nanotechnology field render it possible to find the matter unique properties if sub-classified to nano scale [2]. At the point when the size of a gold molecule is dynamically diminished underneath about 10nm, such particles, frequently named nanoparticles [3]. Gold nanoparticles (Au NPs) are especially intriguing a direct result of its simple readiness and high strength. Au Nano-spheres: The diameter of Au Nano-sphere could range from (1

to 100) nm, and might be produced via reducing solution as aqueous  $\text{HAuCl}_4$  under specific parameters and conditions with the addition of various reducing agents. Citrate is reducing agent mostly used commonly was that made Au Nano-spheres as mono disperse [11, 12]. Turkevich et al.[13] had briefly investigated the many factors influence i.e., gold/citrate proportion,temperature, and the request for reagents expansion control the gold Nano-spheres size dispersion being created. Reducing the citrate amount would produce greater Nano-spheres amount. Gold Nano-spheres usually display a single absorption peak between (510 and 550) nm in the visible spectrum [14]. Au Nano-rods: The Au Nano-rod diameter of could be established of template membrane holes. Au Nano-rod length might be measured through dropped Au quantity inside the membrane hole [15, 16]. In 1997, the basic Au NRs were blended through electro-chemical strategy. Platinum and gold as cathode and anode, respectively were immersed in an electrolytic organization having cosurfactant, cationic surfactant, and hexadecyl tri-methyl ammonium bromide (CTAB).Au NPs were shaped via rotating the bulk metal of gold being structure of anode into nanoparticles [17, 18]. The “seed mediated synthesis” will be the most popular form of gold Nano-rods synthesis and had been conducted between 1999 and 2004 [19, 20]. Quickly, by including the round 'seed' nanoparticles ( $\sim 4$  nm) to a development arrangement, for example, ascorbic corrosive, salt of gold, nitrate of silver, and cetyl tri-methyl ammonium bromide (CTAB), the particles as rod like are shaped [21].Au Nano-shells: Nano-shell denoted as spherical nanoparticle type with core being dielectric that was enclosed via a thin shell being metallic (Au usually) [22]. The synthetic of gold Nano-shells presented of small Nano-spheres of Au to the silica core with (2-4nm) diameter. The silica core diameter control Au Nano-shell diameter. Thickness of shell might be measured via dropped Au quantity on surface of core [23].Au Nano-cages: Were produced via galvanic aqueous  $\text{HAuCl}_4$  and truncated silver Nano-cubes replacement reaction. Ethylene glycol reduced  $\text{AgNO}_3$  to create atoms of silver where reduction being extra produced Nano-crystals [24]. Au Nano-cage could offer main compensations: their peaks as surface plasmon resonance changed via proportion between  $\text{HAuCl}_4$  and Ag Nano-cubes, Au Nano-cage could show peaks of resonance in region of NIR with about ( $<50\text{nm}$ ) size and the surface changes could be utilized in different applications as biomedical [25].

### **1.3 Au NPs Synthesis:**

Various methods are there for Au NPs synthesis, containing procedures of bottomup and top-down. Process of bottom up is commonly effective and in Nano-science it considered as popular protocol with very attractive advantages potentially [26]. They include simplicity of experiment down to the size of atomic scale, 3dimensional assembly possibility and the inexpensive mass fabrication potential [27]. Techniques of top down is suffering from the removal need for large material amounts, whereas techniques of bottom up is suffering from poor mono-disparity because of the arrest growth need at all nanoparticles same point [28,29]. The workers [30] synthesize Au NPs with 20 nm as average diameter at distribution of very narrow size and reproducibility being good. It is thus commonly utilized for preparing Au NPs in solution that used widely as agents of labelling in samples being biologically utilizing TEM. The mostly simplest and commonly utilized production of nanoparticles of gold (Au NPs) is the aqueous HAuCl<sub>4</sub> reduction via citrate of sodium at reflux [31]. Despite citrate of sodium is mostly agent of reducing, NPs of metal can be produced via borohydride use and other agents of reducing [11].

#### **Pulsed Laser Ablation**

Among the many different techniques for the synthesis of Au NPs , the laser ablation technique is believed to be the most efficient, reliable, and cost-effective, as well as the best in the terms of the size distribution of the nanoparticles. A Quanta-Ray PRO- Series 350-10 nanosecond 532 nm Nd:YAG laser source with a 10 Hz repetition rate and a pulse duration of 10 ns from Spectra-Physics was used for the synthesis of the Au NPs.

The Au NP colloids were created by exposing a square piece of bulk Au with a purity of about 99% to the laser beam while the sample was immersed in a glass beaker that was filled with 22 mL of distilled water. The laser beam was guided by three mirrors and then focused onto the bulk Au sample using a 10 cm convex lens, for which a glass cap with a hole with a diameter that was close to the diameter of the laser beam was used to avoid the occurrence of water splashing as this could affect the quality of the laser ablation output. The LATs of 5 and 10 min were

enough to obtain Au NP colloids without agglomeration and with good solubility using magnetic stirrers.

## **Chemical method**

Generally, the preparation of AuNPs by the chemical reduction method includes two main parts: (1) reduction by agents, for instance borohydrides, aminoboranes, formaldehyde, hydrazine, hydroxylamine, polyols, citric and oxalic acids, sugars, hydrogen peroxide, carbon monoxide, sulfites, hydrogen, acetylene, and other electronic reducing agents including electron-rich transition-metal sandwich complexes; (2) stabilization using agents, for instance trisodium citrate dihydrate, sulfur ligands (in particular thiolates), phosphorus ligands, oxygen-based ligands, nitrogen-based ligands (including heterocyclic compounds), dendrimers, polymers and surfactants (in particular, cetyltrimethylammonium bromide (CTAB)). To avoid the aggregation of the particles, some kind of stabilizing agent is usually added (

Citation

Zhao et al. 2013).

Turkevich method

One of the most well-known techniques for the synthesis of AuNPs is based on the reduction of  $\text{HAuCl}_4$  by citrate in water, which was first designed by Turkevich in 1951. In this method, the  $\text{HAuCl}_4$  solution is boiled, and the trisodium citrate dihydrate is then rapidly added into the boiling solution under vigorous stirring. After a few minutes, the color of the solution changes from light yellow to wine red. This method results in AuNPs measuring about 20 nm in diameter. In this technique, citrate ions play a double role, as both stabilizing and reducing agents



The Turkevich method was modified by Frens, in 1973, to obtain AuNPs with diameters ranging from 15 to 150 nm, by controlling the ratio of reducing agent/stabilizing agent (trisodium citrate/gold). The Turkevich-Frens method has been further modified by several research groups (

Citation

Frens 1973).

Kimling et al. demonstrated that a high citrate concentration more quickly stabilizes AuNPs of smaller sizes, while a small concentration of citrate will lead to the aggregation of the small particles into larger particles (

Citation

Zhao et al. 2013,

Citation

Kimling et al. 2006).

Recently, the important role of sodium citrate on the pH of the solution, and its role in controlling the size of the nanoparticle, were indicated based on a theoretical model and experimental results (

Citation

Li et al. 2011,

Citation

Ji et al. 2007,

Citation

Yang et al. 2007,

Citation

Kumar et al. 2007).

Puntes et al. have reported that the addition of reagents in the inverse sequence (addition of  $\text{HAuCl}_4$  into a boiling sodium citrate solution) leads to the production of AuNPs with small size and a narrow size distribution

### **The Brust-Schiffrin method**

The Brust-Schiffrin method was discovered by Brust and Schiffrin in 1994. This method allowed an easy approach to the synthesis of thermally stable and air-stable AuNPs of controlled size and low dispersity. In this technique,  $\text{AuCl}_4^-$  was transferred to a toluene phase from an aqueous solution using tetraoctylammonium bromide (TOAB) as the phase-transfer agent, and reduced by  $\text{NaBH}_4$ , in the presence of dodecanethiol. Addition of the reducing agent causes a color change of the organic phase, from orange to deep brown. This clearly indicates the formation of AuNPs

### **Seeding growth method**

Another method that has also been reported for the synthesis of gold nanoparticles is the seeding growth method. According to the seeding growth process, gold nanoparticles of diameters 5–40 nm and a narrow size distribution were synthesized. Particle size can be controlled by the changeable ratio of seed to metal salt, and therefore every size in the range 5–40 nm can be prepared (

Citation

Jana et al. 2001). This method has the advantage of being a simple, quick, and low cost process; while trisodium citrate was used as a source of  $\text{OH}^-$  ions in the seeding step, sodium borohydrate ( $\text{NaBH}_4$ ) was used as a reducing agent

Although chemical methods are the most common approach for the synthesis of metallic nanoparticles, the use of expensive and toxic reagents as reducing and

stabilizing agents limits their applications. In addition, these nanoparticles may have harmful effects in biomedical applications (

Citation

Noruzi et al. 2011,

Citation

Shankar et al. 2004). Hence, there is a growing need to develop eco-friendly and cost-effective procedures for the synthesis of nanoparticles that do not use any toxic chemicals. Biological synthesis of nanoparticles has been at the center of attention as a green and eco-friendly method in current years. In biological methods, nanoparticles are synthesized by microorganisms, enzymes, and plants or plant extracts (

Recently, the use of plants for the synthesis of nanoparticles is gaining importance, because of their availability, low cost, eco-friendliness and non-toxic nature. In recent years, the biosynthesis of AuNPs using plants such as *Azadirachta indica* (

Kumar et al. 2011).

Umesh Kumar et al. reported the green synthesis of gold nanoparticles using onion (*Allium cepa*) extract as the reducing agent. The reduction of AuNPs occurs due to the activity of vitamin C in onion extract

#### **1.4 Au NPs Properties:**

#### **Plasmon's:**

Plasmon is surface-charge oscillation quantum; oscillation is begun as a result of an external field of electric forcing the surface particle charges to amass at one end. Material plasmonics only seem on the nano-scale; due to larger scales of surface charge realignment to an external field is so quick for oscillation surface-charge to happen [32]. Plasmons occur within metals bulk and their presence was utilized to elucidate losses of energy correlated with electrons emitted into metals as bulk [34]. Metals which best display such free-electron plasma performance including alkali metals, Al, Mg, and noble metals such as Ag, Au and Cu [35]. Surface plasmons (SPs) are plasmon type correlated with the metals surfaces. When the metal

absorbs a resonant wavelength of light, it causes the electronic cloud to vibrate and disperse the energy on material surface that is named the surface plasmon resonance (SPR). For such phenomenon to happen in metallic NPs, the size of particle ( $2R$ ) should be much lesser than the incident light  $\lambda$  ( $2R < \lambda$ ) (assuming shape is spherical in) which cause Raman-scattered light intensity enhancement via a factor of 1011. Such influence is altered strongly via molecule binding to particle surface and can be utilized for measuring the singular molecules presence [36]. The incident light electric field can prompt an electric dipole in the metal particle via moving several delocalized electrons in one path away from the rest of the particle of metal and therefore creating on one side a net negative charge. As long as the rest of the metal particle is successfully a cationic nuclei lattice of and localizing core electrons, the side reverse the negative charge has a net charge being positive. This means that there are certain wavelengths that the photons do not reflect on the metal, but that they are absorbed and converted into a surface plasmon resonance, that is, the electronic vibration of cloud [37]. Photons combination and SPs yield excitations being electromagnetic at extended surfaces recognized as surface plasmons propagating (PSPs) [35, 38]. To answer the question regarding nanoparticles interaction with light, the answer deceits in the localized plasmon resonance surface understanding (LSPR) phenomena that are affected deeply via environment and the shape of Nano-metal. LSPs are the united electron vacillations in small volumes.

### **A) Factors affecting the surface plasmon resonance:**

Band intensity of SPR and  $\lambda$  rely on factors affect the density of electron charge on the surface of particle i.e., the type of metal, size of particle, composition, structure, shape, and the surrounding medium dielectric constant, as described by Mie theory theoretically [39]. a) NPs Size and Shape: Different shapes particles have various plasmon characters i.e., in Nano-rods of old, the resonance of plasmon then splitting into 2 modes: mode being longitudinal along the long rod axis and mode being transverse perpendicular to the 1st [35, 40]. Also, metal particles being hollow head for having frequencies of plasmon

resonant lower than particles of solid metal [41]. Edwards [8] first recognized the surface Plasmon oscillation and explained. As NPs shape or size changes, the noticed colour changes also. Spheres of gold have a red colour characteristic, whereas spheres of silver are yellow. Treatments more recently have illustrated that the colour is because of collective electrons oscillation in band of conduction defined as the surface oscillation of Plasmon. Frequency of oscillation is typically in region of visible for silver and gold causing strong surface absorption of Plasmon resonance [4]. If NPs of metal are increase, their optical character change slightly only as noticed for Nano- spheres of gold various samples.

**1.4.2 Non radiative properties** Au NPs able to change the light absorbed into heat through nonradioactive processes series that studied extensively via El-Sayed et al., utilizing dynamics of ultrafast. Principally, process of transformation energy begins through collisions of electron–electron foremost hot electrons with high temperatures of 1000 K. After that, electrons pass energy to phonon via interactions of electron–phonon on 0.5–1 ps order, results in a lattice being hot with temperature elevates on the order of a few degrees tens. The process of electron–phonon relaxation is shape and size independent and independent also for the longitudinal or transverse surface rods of plasmon [40].

Heating of lattice via cooling and electrons via medium surrounding is process being competitive. When rate of heating is so faster than the rate of cooling, heat being massive iscollected within the lattice enough to cause changes in particle structural i.e., melting of NPs or in Nano-seconds cause fragmentation [39].

## **Chapter Two: Applications of Au NPs**

### **2 Applications of Au NPs:**

The unique chemical and physical characters of Au NPs offer different applications:

#### **2.1 Electronics:**

The reduction of the sizes in microelectronics in call for the use of Nanolithographic technology that induces exponential cost increases in the design of the manufacturing facility. To have Nano-structures in large amounts, molecules can be synthesized in a precisely regulated way, using molecules as electronic components in the Nanoelectronic circuitry can be a promising alternative to producing high-density chips at more affordable prices [53]. For research on potential developments such as Nanoelectronics or biomedical applications, ligandstabilized (Au NPs) are of high importance. This interest derives from the unusual size-dependent properties such as SPR or charging effects of Coulomb [54]. the particles instantly heat up, destroying tumour cells. The important features of AuNPs that have been used in photodynamic therapy are efficient fluorescence quenching and surface plasmon resonance (SPR) absorption [9]. A. Amendoeira et al [58] have shown that PDT strategies are based on the combinatory use of three key components capable of generating ROS at the site of oxidative stress that destroys cancer cells: I) The photosensitive (PS), a light-activated chemical compound. II) The irradiation of light at a sufficient wavelength. III) Tissue molecular oxy-gen to induce ROS and cell death by oxide-tive damage.

## **2.2 Therapeutic Agent Delivery:**

The considerable features of AuNPs such as unique optical, physicochemical properties, biocompatibility, functional flexibility, tunable monolayers, controlled disparity, high surface area for loading the density of drugs, stability and nontoxicity make them an efficient nanocarrier in drug delivery systems (DDSs) [59, 60]. These effective nanocarriers are capable of transferring various drugs. Besides the spherical nanoparticles, recent researchers have proposed stable colloidal gold nanorods as an appropriate agent for drug delivery. D. Matteis et al [61] have studied Au NPs are also used on deeper sections of the eye such as the retina. The study was carried out to investigate how Au NPs can be used to deliver drug and bio macromolecules to the eye and how they can be used as active therapeutic tools. A cellmembrane coating strategy opened new opportunities for multifunctional drug delivery platforms. Sokolov et al. [62] employed Au NPs for imaging of cancer utilizing microscopy laser as confocal, imaging technique of

dark-field was illustrated via El-Sayed et al. [63] for having high potential for cancer molecular-specific detection. **2.3 Sensing:**

Au NPs have been used as efficient sensors for the detection of different analytes such as metal ions, anions, and molecules like, saccharides, nucleotides, proteins and toxins [9]. According to the sensing strategy, the AuNPs sensors can be colorimetric, fluorescence- based, electrical and electrochemical, surface plasmon resonance, surface enhanced Raman scattering (SERS)-based, quartz crystal microbalance-based and Bio-Barcode assay sensors [64]. Different types of nanobiosensors have employed special features of AuNPs. - Electrochemical sensors depend on the electrical properties of bio-functionalized electrodes in the presence of a sample analyte. Electrochemical sensors can be divided into amperometric, impedimetric, potentiometric, and conductometric. -Optical sensors depend on changes in colour or in surface plasmon resonance. Optical sensors can be divided into colorimetric, surface plasmon resonance, fluorescence quenching, and biobarcode sensors [65].'

#### **2.4 Probes:**

Gold nanoparticles also scatter light and can produce an array of interesting colours under dark-field microscopy. The scattered colours of gold nanoparticles are currently used for biological imaging applications. Also, gold nanoparticles are relatively dense, making them useful as probes for transmission electron microscopy [66].

#### **Conclusions:**

In summary, we have collected some recent papers of research on physical properties and applications of AuNPs, the surface plasmon resonance (SPR) phenomenon happen in metallic NPs, the NPs Size and Shape, Dielectric environment and interparticle interactions are factors affecting the surface plasmon resonance. The changing size property of AuNPs effect on colour of this particles play an important role for different biological and physical applications, Au NPs will have a red colour in solution. When particles aggregate, the solution will appear blue/purple with progression to a clear one along precipitates being black

Polarization being large optically correlated with the SPR results in a large enhancement of local electric field at the surface of NPs as well as powerfully enhanced scattering and absorption of light through NPs at frequency of SPR

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