

# Shape and Size Effect of Surface Plasmons on Gold Nanoparticles

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## ABSTRACT

The growth of gold nanoparticles by controlling temperature, Trisodium citrate (Agent reduction) and Chloroauric acid (Stock solution) has been examined in detail to explore the parameter space of reaction conditions. It is found that gold particles can be produced in a wide range of sizes, from (1) to (100) nm, with defined size distribution, following the earlier work of Turkevich. The reaction is initiated thermally or in comparison with UV irradiation, which results in similar final products by using UV-Spectrometer. The kinetics of the extinction spectra show the multiple steps of primary and secondary clustering leading to polycrystallites.

**Keywords:** Shape and Size Effect of Surface Plasmons, Gold Nanoparticles

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## INTRODUCTION

Gold nanoparticles (Au NPs) in the last eras, have been the focus of a massive and rapidly increasing quantity of research. As the term nanoparticle involves the small size of the element, therefore Au NPs are attractive for biomedical use in sensing [1, 2], cellular imaging [3, 4], medicine delivery [5], and cancer treatment [6]. However, many types of research exertion are also directed to chemical analysis and catalysis as seen in [7-10], electronics in [11, 12], and nonlinear optical processes in [13, 14]. This large collection of applications promoted simultaneous research on a variety of fundamental physical influences happening in Au NPs gold nanoparticles [15, 16].

Generally, three major motives were the reason for Au NPs' success in the landscape of nanoscience and nanotechnology [17-19]. Firstly, the great chemical and physical stability, involves the substantial biocompatibility of gold nanostructures (specifically for medical reasons, colloidal gold has been utilized since the Middle Ages). Secondly, the simplicity of utilizing the surface by using biological and organic molecules will help. Thirdly, the big number of optical features related to surface plasmons [19].

Definitely, Gold NPs have a huge amount of conduction electrons which can be directly polarized. This big amount is a common criterion for the special interface of electromagnetic fields with the construction of non-linear optical phenomena [4]. Essentially, extinction cross-section of Au NPs is bigger than other organic and inorganic chromophores when the size is more than 2nm and has the chance to achieve a full percentage efficiency of conversion from light to heat, large photostability and the capability to enlarge the electromagnetic area or field nano-metrically from the metal shell [4].

Since olden days, the feature of a light red color of spherical Au NPs has enticed the producers [20], and Au NPs or their nano-alloys have been discovered in decorative cups, e.g. the glitter dishes (15th-16th century) [20], the ancient Lycurgus cup (8th century B.C) [21, 22], and red ruby glasses from middle ages which are colored with the purple of Cassius [23, 24]. One of the oldest examples is the gold-plated Egyptian ivory from the 8<sup>th</sup> century (BC), where Au

NPs inadvertently produced a purple colour from a slim foil into the porous ivory basis by using gold dispersal [25]. Certainly, this sort of application has continued until the current day [26].

- Michael Faraday was the first scientist who connected Au NPs' optical characteristics to their small size. In London, he gave a lecture in the mid of 19th century about connections of Gold with the light [27]. Faraday defined the Gold colloid liquids in his research as "a beautiful ruby fluid" [27] and ascribed the effect to them (a simple change in the particles' size). Afterward, Gustav Mie in the early 1900s has accomplished the theoretical part and this work has been affected by Faraday's work, which remains valid until today [28]. The authors in the review article [29], recapped the core ideas related to surface plasmon resonance (SPR) in Au NPs, and the deeply pertinent functions, with exceptional consideration to contemporary subjects.

The article in [29] was divided into six chief parts:

1. Principles of SPR in Au NPs.
2. Features affecting the resonance of plasmon.
3. Designing the SPR of Gold NPs.
4. Roles related to SPR optical destruction.
5. Local field improvement uses.
6. Other functions and sophisticated phenomena [29].

Over the preceding 15 years, Noble element nanoparticles have been researched rigorously. The characteristics of silver or gold particles (called photonic characteristics) are attractive for use in metals and biochemical or biomedical applications [30 - 33]. Indeed, many researchers interested in gold nanoparticles as an obvious visible range optical resonance showing its sensitivity on shape and size of the particles and climate changes, also the regional field improvement of interacting the light with the resonant scheme. Accordingly, applications involve the composition of protocols that deliver well-defined forms and sizes [34, 35].

Many categories of synthesis routes are available and show many classes of synthesis techniques, which present various features of the final products. Apart from the reductant force, the stabilizer's intervention in the synthesis of the mixing stage is dangerous. Burst [36] interested in the organic phase combination and the cases

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of extensive use show it. Then Turkevich et al. [37, 38] involved in the reduction of a gold or silver salt by using citrate working on double stage, and the single stage operations. This method has been improved by Frens [39], he generates nearly sphere-shaped particles upon a variable size spectrum. Chow and Zukoski in [40], discussed the kinetics of the Turkevich process focusing on the stabilization system. The authors in [41-43] decreasing a gold salt when a complexing surfactant is available. That would enable researchers to acquire extended nanorods that are crystallographically aligned. Other reducing agents, such as Amino acids and other elimination elements, were used effectively without any additional surfactant for the manufacturing of gold particles. The shape depends precisely on the reductant [44]. UV light aided particle development was used in the situation of gold nanorods [43] or silver motes [45]. Radiation chemistry [46] affords even more direct reduction techniques, where electrons are inserted straight into the system. Pure hydrogen also was used to generate platinum or silver particles. These particles without surfactant are steady, while another acid called Ascorbic acid is usually used in the composition of nanorods [47]. A surfactant molecule (such as cetyltrimethylammonium bromide, CTAB) combines the gold ions in this operation and is not immediately lowered by ascorbic acid. Just the particle seeds of gold can grow crystallo-graphically focused rods [48]. The passivation can result in a wide range of distinct forms. Early research used the decrease of pure ascorbate to determine gold salts [49]. Goia and Matijevec have recorded very big gold particles through ascorbic acid decrease [50]. In the existence of citrate synthesized gold seeds, Jana et al. [51] used ascorbic acid reduction.

### ASSUMPTION

The orders (dipole or multiples) of different resonant types are stated with  $m = 1$  (first order, dipole),  $m=2$

(second order), and  $m=3$  (third order), when a spherical material nanoparticle with radius ( $r$ ) entrenched in a homogeneous medium is resonant at certain wavelengths. In a result, it can be supposed that the wave is a standing type produced by two SPP waves spreading clockwise and counterclockwise directions along the surface for each order when the surface plasmon resonance occurs. Consequently, the wavelength of the wave will be:

$$\lambda_m = 2\pi r / m \quad (1)$$

If

$m = 1$  (dipole resonance), the surface plasmons wavelength is equal to the sphere's edge, i.e.  $2\pi r$ .

Also, it is assumed that the plasmons of resonant surface are the same as that with the equal wavelength spreading on the interface of the silver with the air of semi-infinity (Fig. 1c). Therefore, the definition of the SPPs' wave vector on the sphere is:

$$k_m = \frac{2\pi r}{\lambda_m} = \frac{m}{r} \quad (2)$$

The relationship of propagation equation for the spherical shaped particles can be easily determined from the resonant top and wave vector.

### METHODOLOGY

The gold nanoparticles have been synthesized by using the Turkevich method (Chemical method). Three factors (Temperature – Amount of Stock Solution – Amount of reducing Agent) have been considered and implemented as variables in this experiment.

#### 1- Temperature

Firstly, we heated up the liquid at different temperatures (100 C – 90 C – 80 C – 78 C – 70 C ) and for each prepared sample the ultraviolet (UV) Spectrometer has been used to measure, choose and fix the optimum temperature. In this case, the optimal degree was (75.5 C ) and maximum lambda was (525.834 nm) and the absorption of the UV- Spectrometer for (3+) was (0.489655).

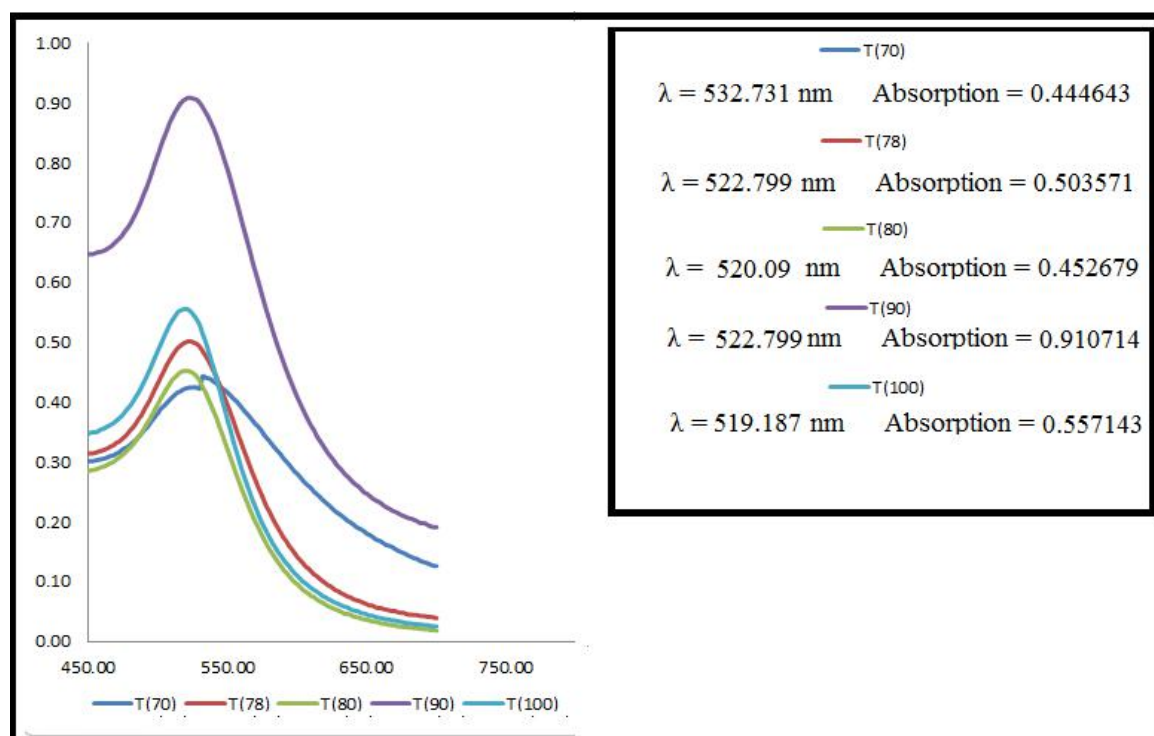


Figure 1. shows the higher values of longitudinal waves for temperature variables against the absorption intensity of

the UV-Spectrometer.

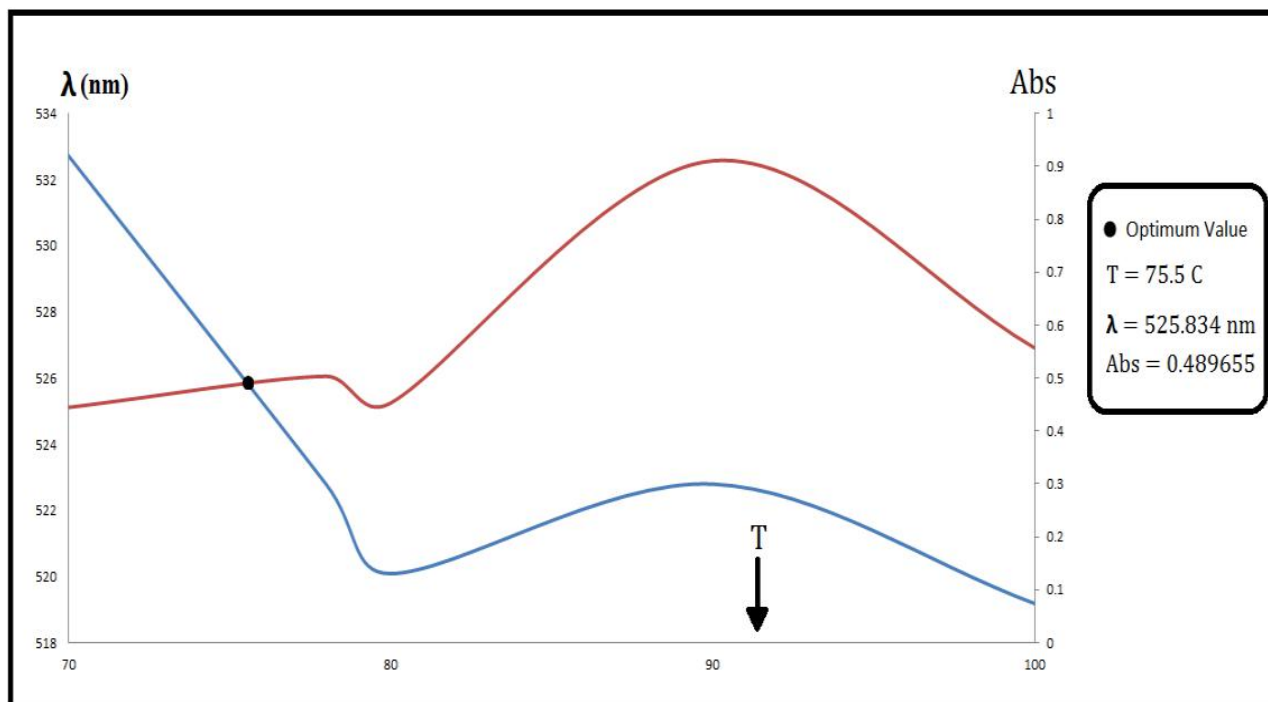


Figure 2. shows the optimum value of temperature variables. These values have been recorded by using the UV-Spectrometer.

2- Chloroauric acid (Stock solution)

Secondly, we have selected different amounts of the Stock solution of Chloroauric acid (100  $\mu$ L - 150  $\mu$ L - 200  $\mu$ L - 250  $\mu$ L - 300  $\mu$ L) and for each prepared sample, UV-Spectrometer has been used to choose the optimum amount and fix it. However, at the experiment section, we

found out three optimum amounts and they used them to prepare three other samples and used the UV-Spectrometer for each case. On the other hand, there were two optimum amounts, the best one (260  $\mu$ L) have been chosen, the maximum lambda was (526 nm) and the Absorption of the UV- Spectrometer was (0.6).

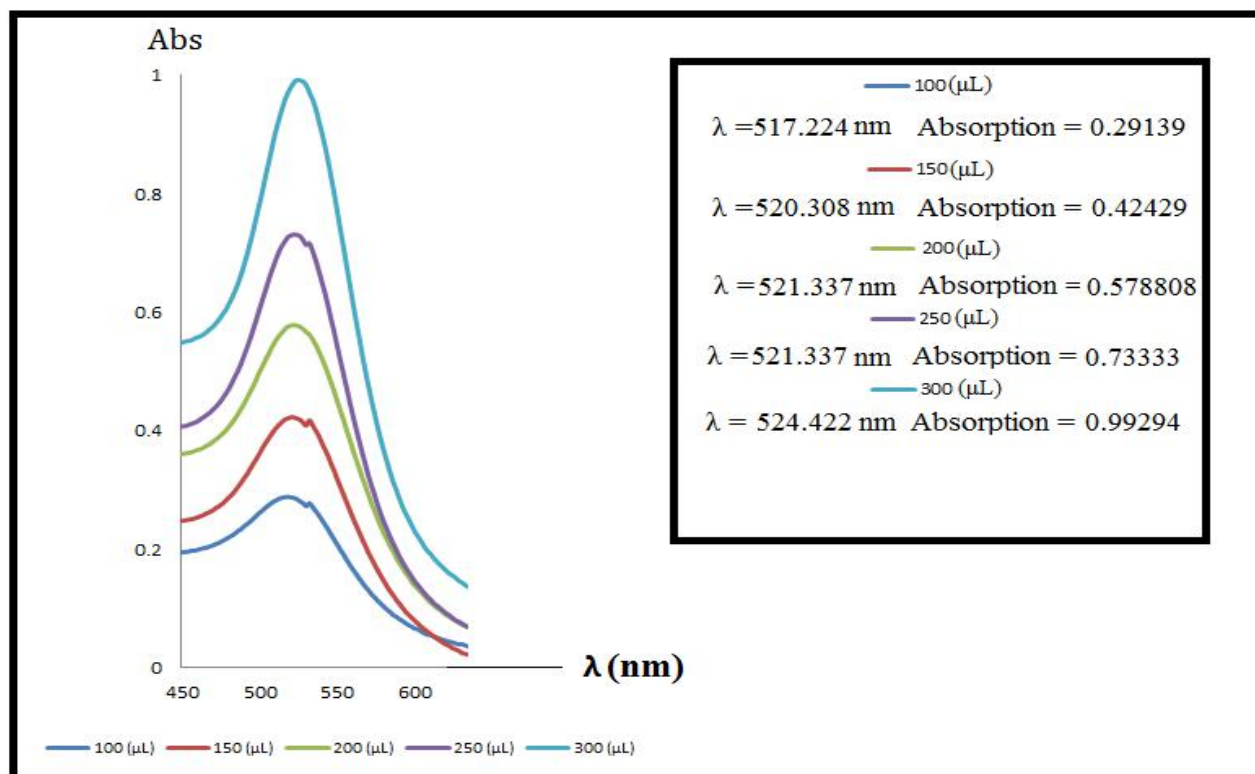


Figure 3. below show the higher values of longitudinal waves for stock solution variables against the absorption intensity of the UV-Spectrometer.

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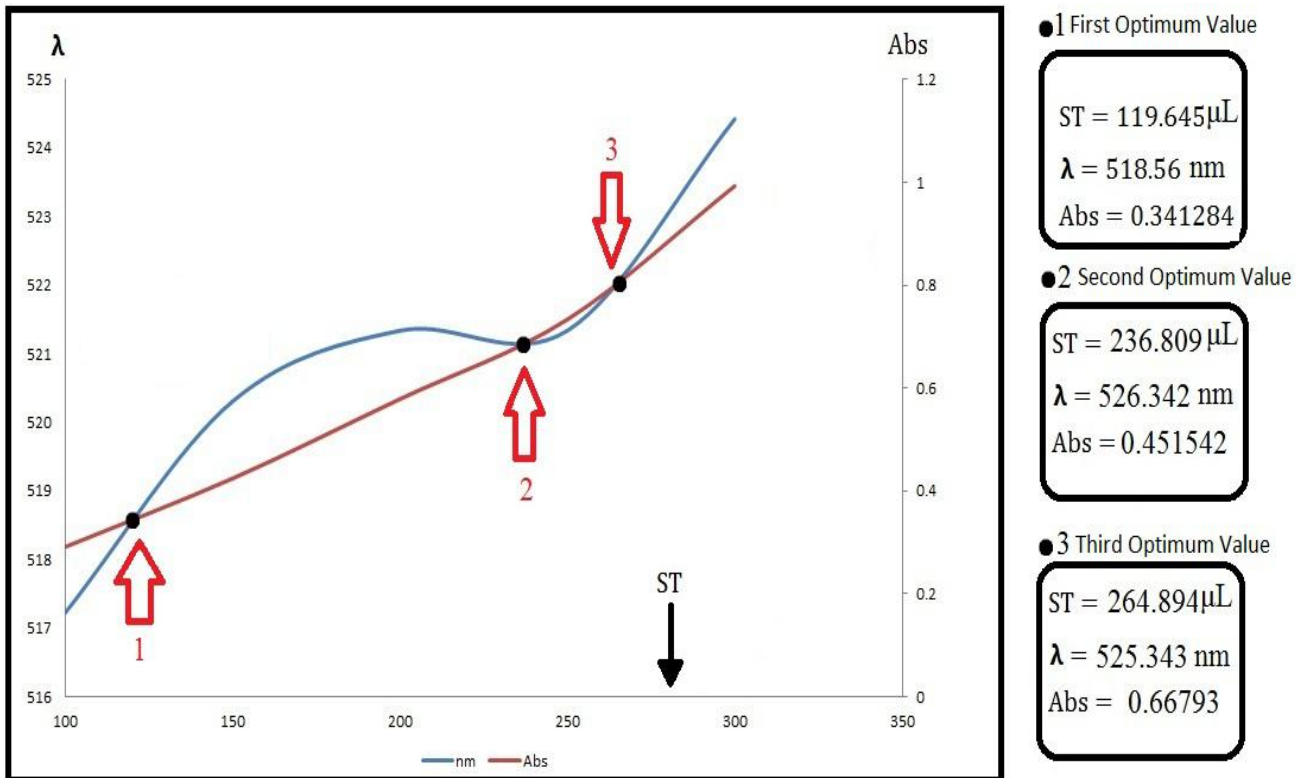


Figure 4. shows the optimum values of variable amounts for the stock solution which have been concluded by using the UV-Spectrometer against absorption intensity.

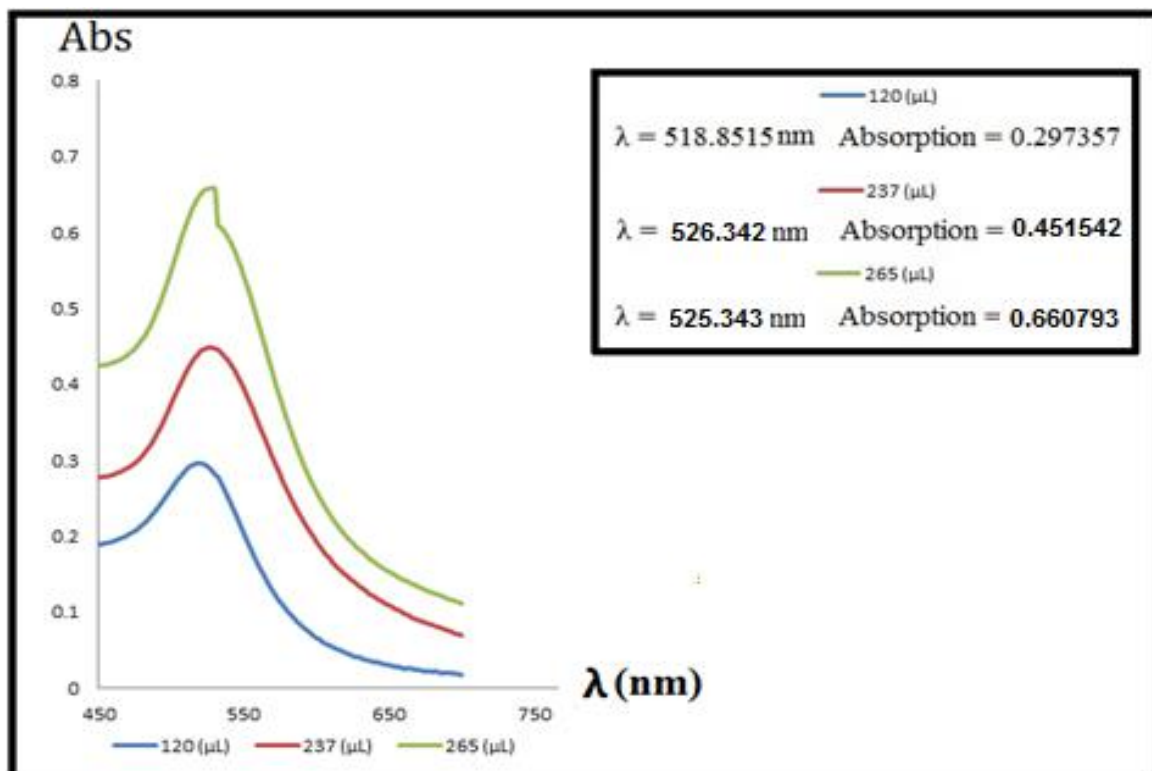


Figure 5. shows the variables of the first optimum cases against absorption intensity recorded by using the UV-Spectrometer.

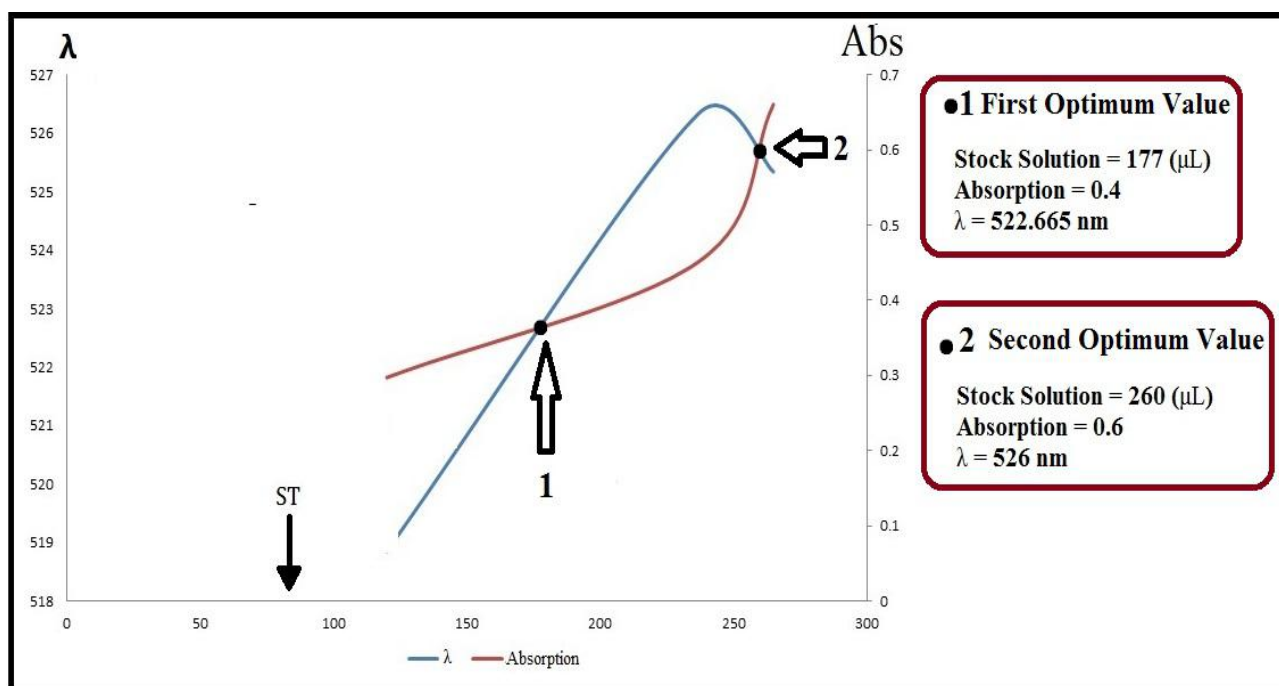


Figure 6. shows the final form of the optimum case for the stock solution against the absorption intensity of the UV-Spectrometer.

### 3- Trisodium citrate (Agent reduction)

After fixing the optimum condition and degree of the temperature and Chloroauric acid (Stock Solution), different amounts of Trisodium citrate (Reducing Agent) have been selected as following ( 400 μL - 450 μL - 500 μL - 550 μL - 600 μL ). Utilizing UV- Spectrometer and for each prepared sample the optimum amount has been chosen and maintained at (520.517 μL) and lambda maximum was (521.981 nm) and the Absorption of the UV- Spectrometer was (0.466092).

The final sample has been prepared depending on the optimum condition of each variable and then used the UV- Spectrometer for the sample. Lambda max was (524.575 nm) and the Absorption of the UV-Spectrometer was (0.618605). The tests were done by using UV-Spectrometer and Transmission electron microscopy (TEM) equipment. Figure (7) shows the higher values of longitudinal waves for the elimination factor variable against the absorption intensity of the UV - Spectrometer.

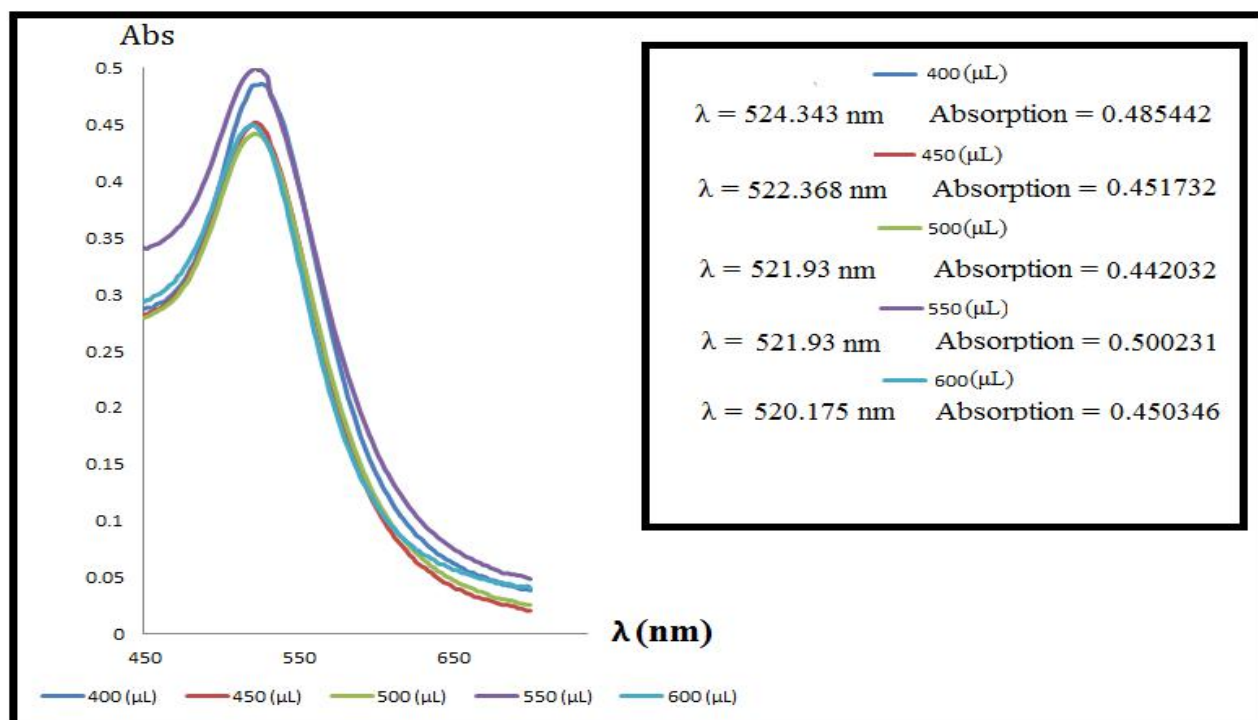


Figure 7. shows the higher values of longitudinal waves for reducing agent variables against the absorption intensity of the UV-Spectrometer.

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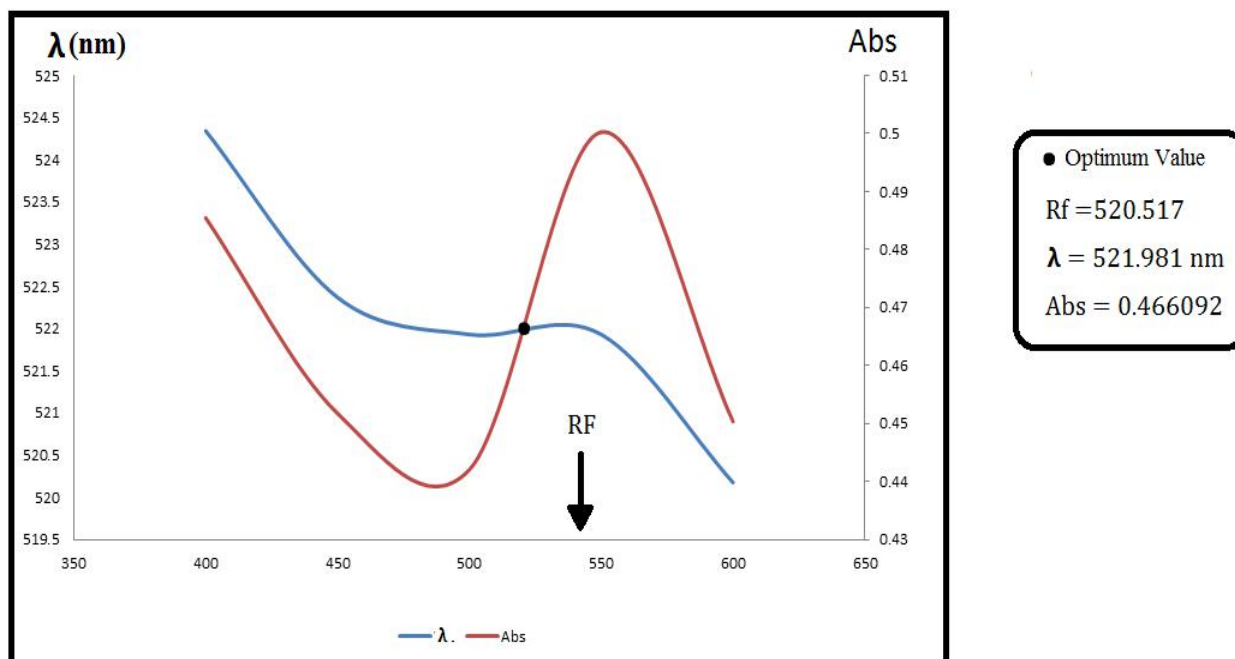


Figure 8. shows the optimum value of the elimination factor amount variable by using the UV-Spectrometer.

### CONCLUSION

The final sample has been prepared according to the optimum values of the three variables of (temperature,

stock solution amount and elimination factor amount).

The following tests applied on the sample:

- 1- **UV- Spectrometer test:** The highest peak of the longitudinal wave has been recorded (524.575 nm) at (0.618605) absorption intensity.

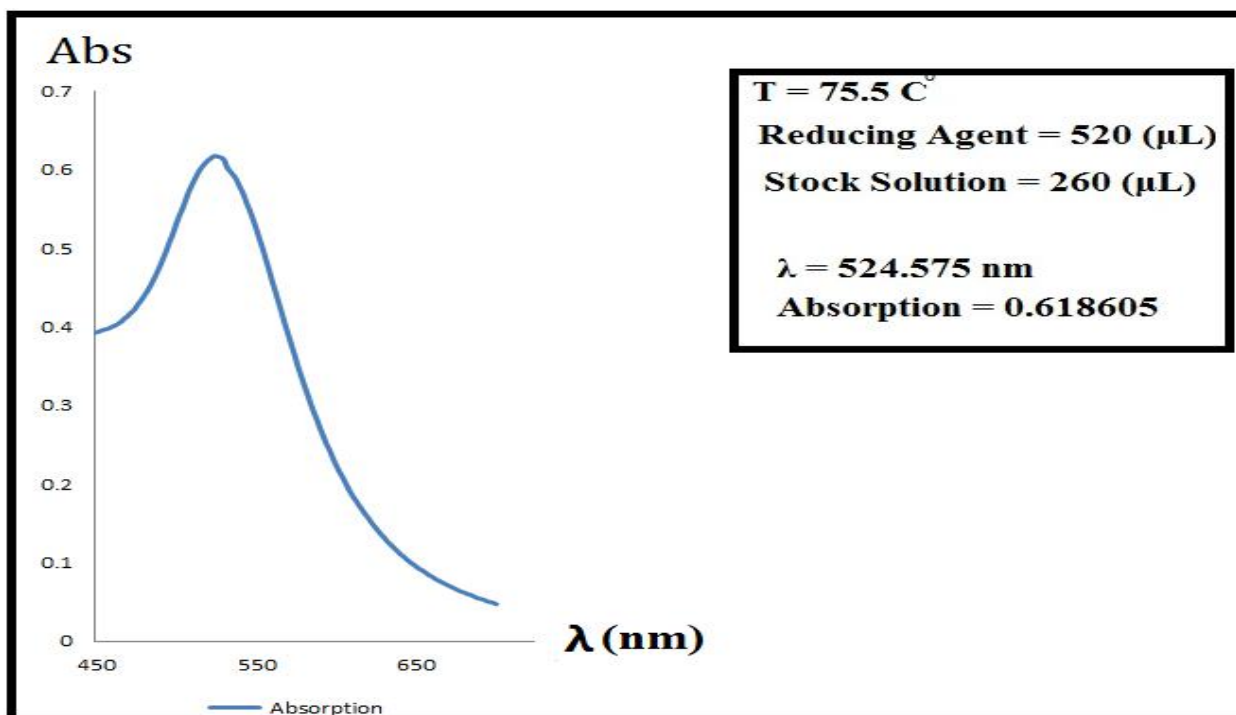


Figure 9. shows the highest value of longitudinal wave for the nano-gold sample which has been prepared by using variable methods.

- 2- **TEM test:** the circular shape of the Nanoparticles has been successfully developed in this case, which is important in producing the maximum energy. Figure (10) shows these Nanoparticles as black dots when tested by using TEM equipment.

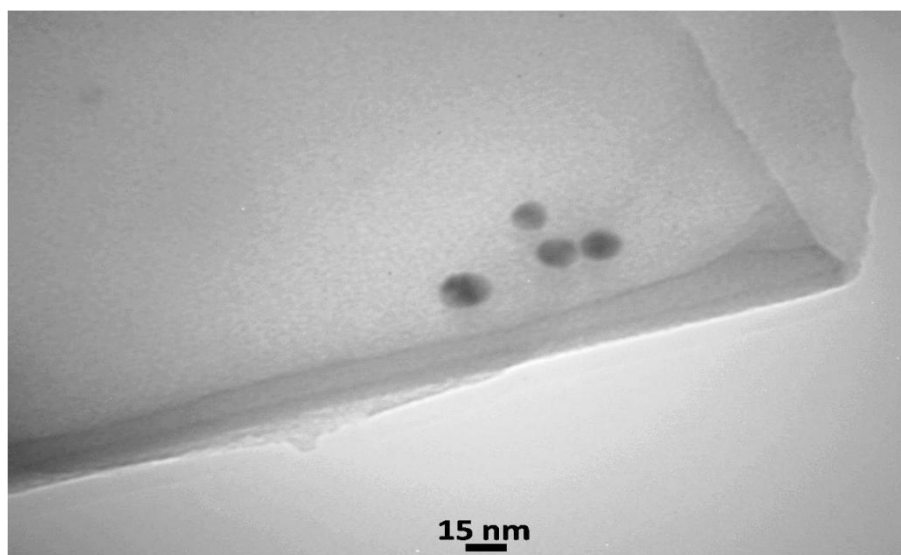


Figure 10. The prepared gold nanoparticle by TEM equipment

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