Synthesis of nano-particles: A review

Israa Abd AlHasan Hamdan[1] Alaa Abd AlHasan Hamdan [2] Eqbal A. Gatea [1]

Biology Department / Education for Pure Science College / Al-Muthanna University /Iraq[1]

[2] Pharmacy Colleges / Karbala University/ Iraq

Received (10\02\2022), **Accepted** (21\03\2022)

Abstract:

Nanotechnology is an emerging multidisciplinary technology that can be described as engineering sciences and design and characterization technology. Interest in nanotechnology has increased greatly, so there is a need to develop a deeper understanding of the nature and behavior of nano-particles, methods of preparation and identifications. In this article, discussed the most important methods of preparing these materials (chemical, physical and biological) and how they can affect their fate and behavior and the important methods for characterization.

Key words: nano- partials, chemical technique, physical technique.

الخلاصة

ان تقنية النانو تعتبر تقنية مهمة وتتطور بسرعة لاهميتها في كثير من المجالات مثل هندسية والطبية والزراعية . وزاد الاهتمام بها بشكل كبير في السنوات االقليلة الماضية لذا هناك حاجة لتطوير نظرة عميقة لفهم طبيعة وسلوك الدقائق النانوية وطرق تحضيرها وتشخيصها. في هذا المقال نناقش اهم طرق تحضير هذه المواد (الكيميائية والفيزيائية والبايلوجية) وتاثير هذا الطرق في سلوك ومسار استخدامها .كما نطرق الى اهم تقنيات التشخيص المستخدمة لاثبات تحضيرها ومعرفة حجمها وابعادها

Introduction

It is known that nanotechnologies are ways to obtain nano-materials as well as ways to work with nano-organisms [1]. Nano-materials are currently used in various fields of physics, chemistry, technology, and medicine [2-3]. The interest in nano-materials is mainly due to the fact that decreasing the particle size of a solid to less than a certain critical value can lead to a significant change in its properties. The critical particle size at which an abrupt change in properties occurs varies for most of the currently known solids (1-100 nm). Since this size is located in the nanometer region, the materials in which the effects of size on properties are observed are also called nano-materials. Nanotechnology methods for obtaining nano-materials can be divided into two fundamentally different types, (i) bottom to top, (ii) and top to bottom [4] figure (1). In the first group of nanotechnology methods, the formation of nano-particles from atoms and molecules is reduced; that is, the roughening of the elementary particles is achieved up to nanometer-sized particles. As for the second group of nanotechnology methods, nanometer sizes are achieved by crushing large particles, powders, or grains into solid materials. Nanotechnologies are divided into two groups, taking into account the main stage in which the nanostructure itself is formed. For example, typical representatives of step-by-step nanotechnologies are chemical synthesis of plasma and precipitation of liquid solutions. From top to bottom, typical representatives of nanotechnology are mechanical grinding and severe deformation of plastics. . It can be said that the first group of nanotechnology methods are largely based on the chemical approach, while the second group relies on the physical method.

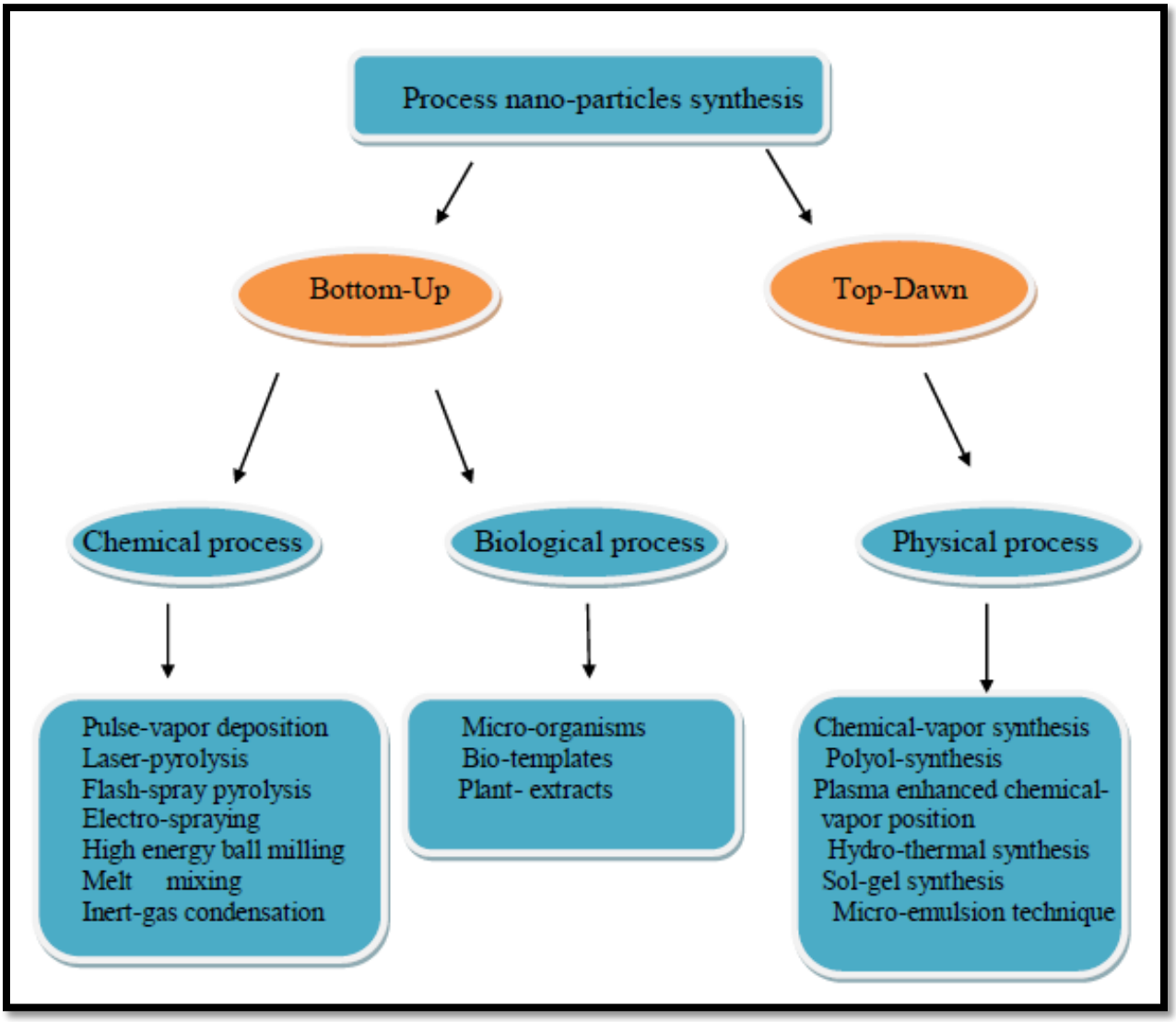

Figure (1) Diagram showing different preparation methods [4]

Nano-materials are any materials with building blocks that are 1–100 nanometers in size. The concept of nano-materials should include not only the size of the structure but also the sudden change in the properties of a substance that occurs in a nano-material [5].

Because of the small size of its constituent masses, the concept of nano-materials also differs from another concept based on a wide range of semi-crystalline matter; the properties of semi-crystalline materials as well as the properties of nano-materials differ from those of coarse-grained and coarse-grained mono-crystalline materials [6]. However, the difference in properties is related to an increase in the specific surface area, which leads to the acceleration of various processes, for example, chemical reactions, but does not lead to a decrease in the activation energy of the processes, i.e., to a decrease in the minimum temperatures at the beginning of the atomic processes. There is a fundamental difference between nano-materials and semi-crystalline materials. It is the nano-state, not the semi-crystalline state, which is the middle of the molecular and solid states. . The properties of the solid material are formed at nanometer distances, and this is also the physical reason behind the observation of a significant change in the properties of the nanometer material. The important point to remember is that the distance between the forces of the main interaction in a material varies from one to tens of nanometers. The most successful classification of nano-materials depends on the dimensions of the basic building blocks or structural elements that make up the main types of crystalline nano-materials in terms of dimensions: (i) nano-materials with zero, (ii) one-dimensional, (iii) two-dimensional, (ix) and three-dimensional dimensions [7].

Techniques for synthesis nano-particles

The creation of nano-particles can be done in three different ways. These are the techniques (i) Physical Techniques, (ii) Chemical techniques, and (iii) Biological techniques.

Physical technique

A- Plasma: Another approach for producing nano-particles is the plasma process. The starting metal is encased in a pestle, which is next encased in an evacuated chamber. High voltage coils wrapped around the evacuated chamber then heat the metal above its evaporation point.

B- Helium is the gas used in the operation, after flowing into the system; it generates a high-temperature plasma in the vicinity of the coils. The metal vapor forms nuclei on the helium gas atoms and rises to a cold collection rod, this is where nano-particles are collected and oxygen gas is used to passivity them. Plasma technologies are classified depending on the materials fed into the reactor as well as the heating source (electrodeless/ electrode containing) [8].

C- Chemical vapor-deposition: CVD technique that is a chemical reaction involved. In semiconductor production, the CVD process is commonly employed to deposit thin films of various materials. One or more volatile precursors are used in the technique. The precursors are exposed to the substrate, which breakdown and generate the desired deposit. The CVD process includes three stapes; (i) a boundary layer transport reactants over the growing surface. (ii) on the growing surface, chemical processes take place and, (iii) The gas-phase reaction's by-products must be eliminated from the surface. In the gas phase, homogeneous nucleation occurs, while heterogeneous nucleation occurs on a substrate. By using a chemical reaction in the gaseous phase, the CVD process can produce ultrafine particles with a diameter of less than 1µm. The process can be tuned to produce nano-particles ranging in size (10-100) nanometers [8].

D- Microwave-irradiation: Because of its well-known benefits over conventional synthetic pathways, is a synthesis method that has been widely employed in the synthesis of organic, inorganic, and inorganic–organic hybrid materials. Due to the increased reaction rates, higher yields, improved purity, and ease of set-up, and compared to conventional procedures, the reaction conditions are more environmentally friendly, microwave-assisted organic synthesis has become very popular [9-10].

E- Pulsed-laser method: The pulsed laser approach is most commonly utilized in the manufacture of silver nano-particles at a high rate of 3 gm/min. The machine consists of a solid disc that rotates in lockstep with the solution.

F- To develop hot spots on the disc's surface, it is exposed to pulses from a laser beam. The silver nitrate reacts with the reduction agent to produce silver particles that can be separated that used a centrifuge at hot spots. The size of the particles is determined by the laser's energy and the disc's angular velocity [11].

G- Sono-chemical reduction: Metal nano-particles have been synthesized using a sono-chemical technique. By using sono-chemical reduction of the appropriate metal ions, the production of various types of metal nano-particles has been investigated. Within loss and presence of organic additives, the sono-chemical reduction of MnO_4, Au^{3+}, Au^{+}, and Pd^{2+} were examined to the production of metal nano-particles with regulated size and form. For control the shape and size of metal nano-particles, the reduction rates were controlled. In the presence of a chemical stabilizer, citric acid, the size of the Au nano-particles made from the sono-chemical reductions of Au^{3+} was regulated [11-12].

H- Gamma-irradiation: For the synthesis of metallic nano-particles, gamma radiation is the preferred method. Because it is repeatable, it is able to control the formation of the particles, it generates monodies-pares metallic nano-particles, so it is simple and inexpensive. It uses the minimal reagents possible, It employs a reaction temperature at ambient temperature, Using as few synthetic processes as feasible (one-pot reaction) and reducing the amount of waste and by-products generated. Radiolytic reduction has been said to be an efficient method for producing mono-sized and widely dispersed metallic clusters. This method has been frequently utilized in the past to create MNP solutions, particularly gold and silver, which were then studied using UV-Visible spectroscopy to determine their plasmatic absorption band. On this subject, there is a lot of literature [13-14].

Chemical technique

A- Chemical reduction method: In 1857, Michael Faraday published the first comprehensive research of colloidal gold production and hues using the chemical reduction process. Chemical reduction of copper salts is the most straightforward, straightforward, and widely utilized method for producing copper nano-particles. It is possible to make nano-sized metal copper particles with good control over morphologies and sizes for copper salts [15].

B- micro-emulsion/colloidal: Hiral discovered in 1943 that a combination of water, oil, surfactant, and an alcohol-or amine-based co-surfactant generated clear and homogeneous solutions, which is a method for making nano-particles in which two immiscible fluids (An emulsion is a liquid that is dispersed in another liquid). Emulsions are classified as macro-emulsions, mini-emulsions, or micro-emulsions, depending on the size of the droplet. For the manufacture of inorganic nano-particles, the micro-emulsion synthesis process is commonly utilized [16-17].

C- Polyol technique: The Polyol technique is a chemical approach for nano-particle production. Non-aqueous liquid (polyol) is used here as a solvent and reducing agent .The used nano-aqueous solvents in the approach it has interest to reducing surface oxidation and agglomeration. This approach gives you more control over the size, texture, and shape of your nano-particles. The polyol approach can also be used to mass-produce nano-particles. Ethylene glycol is common liquid utilized at polyol method of manufacture of metal oxide nano-particles, because of its high boiling point, high dielectric constant, and strong reducing ability [18].

D- Thermolysis: Heat causes thermolysis, which is a chemical decomposition. Heat is used to break chemical bonds in substance being decomposed in this approach, and the process is endothermic. A positive feedback loop is produced if decomposition is sufficiently exothermic, resulting in thermal runaway [19].

E- Electrochemical methods: Chemical substances are synthesized in an electrochemical cell. Electrochemical synthesis has a number of advantages over traditional synthesis; decline the potentially wasting half reaction alternative and ability to precisely control on desired possibility in a chemical reaction. The electrochemical process consists of dissolving a metal anode in a non-protonated liquid. The particle size is determined by adjusting the current density. The influence of various electrochemical parameters on the end particle size was investigated using several types of counter electrodes [20].

Biological technique

Biological technique use microorganisms' to prepare nano-materials such as yeasts, bacteria, fungi, or plant parts (roots, leaves, bark, and flowers) after making their extracts [21]. This method of preparing nano-materials has become popular because it is low cost, non-toxic, simple and harmless to the environment. Water is used as a reducing agent in the preparation, and this is a good advantage for microorganisms [22]. It is an expensive method, but it is environmentally friendly and non-toxic, and it avoids the use of harmful chemicals. Microorganisms use the enzymes that they secrete as a reducing agent in the preparation. This method has several advantages and advantages, including the low cost of production, few accidents, and environmentally friendly, non-consuming energy, producing compounds, safe products, which do not produce quality non-recyclable waste, used in the pharmaceutical industries and for medical purposes [23-24].

Methods for identification the synthesis nano-particles

There are two ways to characterization the synthesis nano-particles (i) qualitative and (ii) quantitative methods the scheme figure (2) below summarized these methods [22-24].

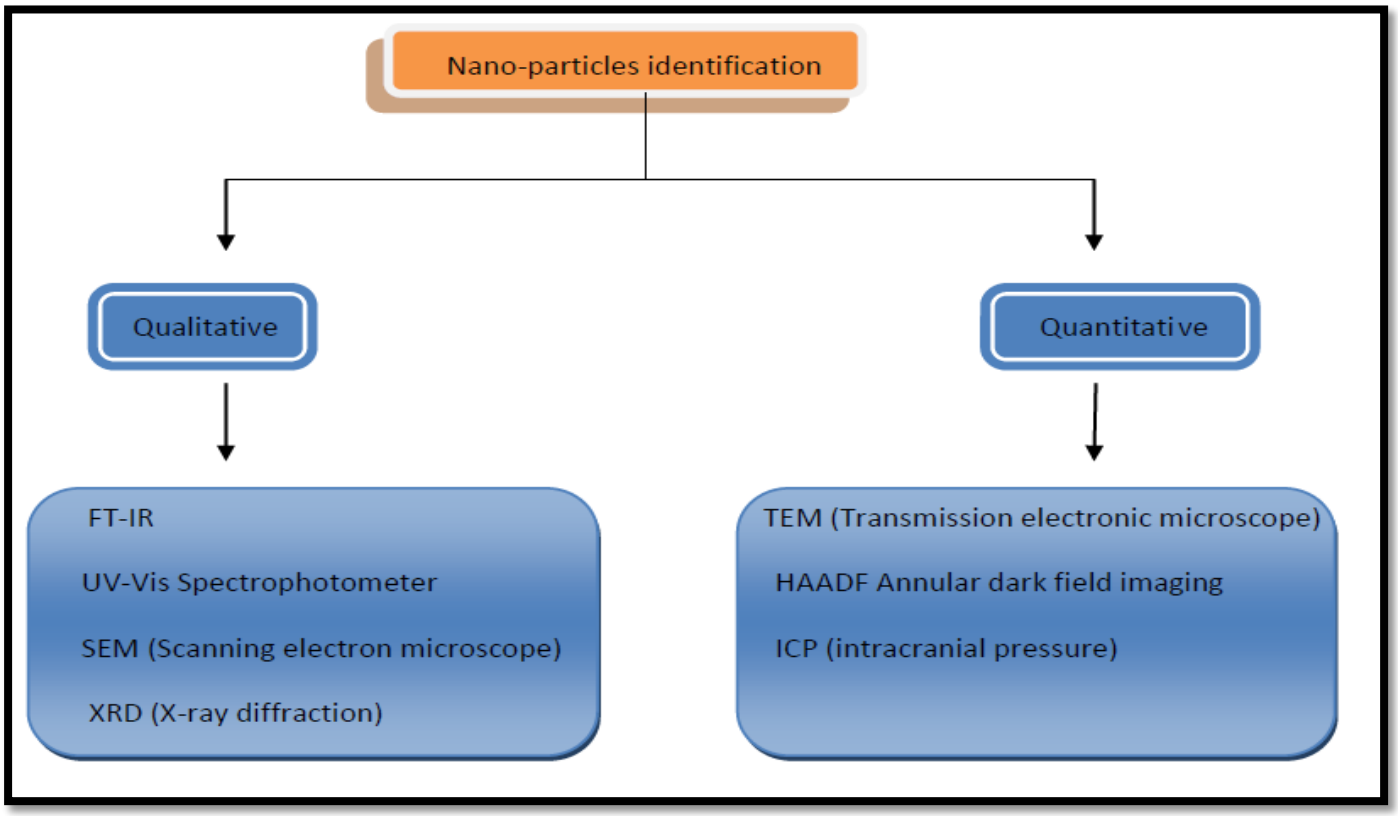

Figure (2) scheme summarized the identification techniques [22]

Qualitative analysis include FT-IR(Fourier-transform infrared-spectroscopy) which used for identify the biomaterial that used for synthesis, the stabilizer, and the reducing agent. UV-vis for determined the formation and the stability at the range (300-800nm). SEM (scanning electron microscopes) it is used to checked shape and size. X-Ray Diffraction this method used in both main analytical methods to determine of confirmation of synthesis nano- particles, crystal form, and size for them. AFM (atomic force microscope) also this technique study some properties' for the synthesis particles like size, shape, surface area.

While quantitative analysis include of some methods like TEM (transmission electron microscope)which used to study crystal structure, and the sized particles to synthesis material in nano- scale. HAADF this method used to study the interaction between nano-material and bacteria. ICP it is used to determine the concentration of metal in the original and nano- solution [24-25].

Conclusion

Nano-particles have attracted a lot of attention because of their unique chemical, biological, and physical features, which make them useful in a variety of fields. Several nano-particle preparation the approved methods which are synthesis nano-particles with different sizes and shapes. The techniques for synthesizing nano-particles were discussed, as well as their classification and identification methods. The methods for synthesis of nano-particles are chosen based on the requirements. Every approach has benefits and drawbacks, and the production method is chosen based on the available resources. Chemical procedures are favored when cost is a factor, whereas physical methods are ideal for small-scale production. Biological techniques have varying degrees of importance.

References

1- Dan Zhang, Xin-lie Ma, Yan Gu, He Huang and Guang-wie Zhang. Green Synthesis of Metallic Nanoparticles and Their Potential Application to Treat Cancer. *Frontiers in Chemistry*. 2020, 8(799). https://www.ncbi.nlm.nih.gov

2- You, H., Yang S., Ding B., and Yang H. Synthesis of colloidal metal and metal alloy nanoparticles for electrochemical energy application. *Chem. Soc. Rev.* 2013, 7 (42), p 2880-2904. DOI: 10.1030/C2CS35319A.

3- Singh, P., Kim, Y. –J, Zhang, D., and D.-C. Biological synthesis of nanoparticles from plants and microorganisms . *Trends Biotechnol*. 2016, 34, p 588-599 DOI: 10.1016/j.tibtech.2016.02.006.

4- Das, R., K., Pachapur, V.,L., Lonappan, L., Naghdi, M., Pulicharal, R., Maiti, S., et.al. Biological synthesis of metallic nanoparticles : plantes, animals and microbial aspects. *Nanotechnol. Environ Eng*. 2017, 2(8). DOI: 10.1007/s41204-017-0029-4.

5- Yongzhi Luo, Ming Yin, Lan Chen, Shengquan Yu, and Bin kang. Hot-pressed Fe^{+2}: ZnSe Ceramics with powders fabricated via grinding chemical vapor deposition ZnSe polycrystalline. *Optical Materials Express*. 2021, 11(8), p2744-2752. https://doi.org/10.1364/OME.432380

6- Hamid Reza Ghorbani. A Review of Methods for Synthesis of Al Nanoparticles. *Orient. J. Chem*. 2014, 30(4),p 1941-1949. http://dx.doi.org/10.13005/ojc/300456.

7- .Tiwiar M. . Nano Cancer Therapy Strategies. *J. Can.Res. Ther*. 2012, 8(1) p19-22. http://www.cancerjournal.net/text.asp?2012/8/1/19/95168

8- Khah V., SaraD, Djafar IR, Rahman N, Jafar IR. Aglance on the plasma synthesis methodologies of nanoparticles. Preparation of Nanoparticles. *Engineered Nanomaterials-Health and Safty*. 2020 https://doi.org/10.5772/intecjopen.90771

9- Horikoshi S, Serpone N. Introduction to Nanoparticales, Microwaves in Nanoparticales Synthesis 1st ed: Wiley- VCH Verlag GmbH & Co. KGaA: 2013 .

10- Riaz U, Ashraf SM, Madan A. Effect of microwave irradiation time and temperature on the spectroscopic and morphological properties of nanostructured poly(carbazole)synthesized within bentonite clay galleries. *New Journal of*

Chemistry.2014, 38, p 4210-4228. https://pubs.rsc.org/en/content/articlelanding/2014/nj/c3nj01597a

11- Okitsu K, Nishimura R. Sonochemical reduction method for controlled synthesis of metal annoparticles in aqueous solutions. Proceeding of 20th International Congress on Acoustics, ICA2010: p 23-27. https://www.acoustics.asn.au/conference_proceedings/ICA2010/cdrom-ICA2010/papers/p336.pdf

12- Obreja L, Foca N, Popa MI,Meling V . Alcoholic reduction platinum nanoparticles synthesis by sono-chemical method, biomaterials in biophysics. *Medical Physics and Ecology*. 2008, p 31-36.

13- Rao YN, Banerjee D, Datta A, Das SK, Guin R, Saha A. Gamma irradiation route to synthesis of highly re-dispersible natural polymer capped silver nanoparticles . *Radiation Physics and Chemistry*. 2010, 79(12), p 1240-1246. http://dx.doi.org/10.1016/j.radphyschem.2010.07.004

14- Marignier J, Belloni J, Delcourt M, Chevalier J. New micro aggregates of non noble metal and alloys prepared by irradiation induced reduction. *Nature*. 1985, 317, p 344-345. http://www.nature.com/317344aQ

15- Ghorbani H. R. A Review of Methods for Synthesis of Al Nanoparticles . *Orient. J. Chem*. 2014, 30(4). http://www.orientjchem.org/?p=6183

16- Tauer K, MPI Colloids and Interfaces, Emulsions Part 1 , Am Muhlenberg D -14476 Golm, Germmany . 2006 .

17- Yu D, Chu Y, Dong LH, Zhuo YJ. Controllable synthesis of $CaCO_3$/ micro/nanocrystals with different morphologies in micro emulation. *Chemical Research in Chinese University*. 2010, 26(5), p 678-682. http://crcu.jlu.edu.cn/EN/Y2010/V26/15/678

18- Meshesha BT, Barrabes N, Medina F, and Sueiras JE. Polyol mediated synthesis and characterization of Cu nanoparticles: Effect of hexadecylamine as stabilizing agent .*IEEE-NANO* .2009. https://www.academia.edu

19- Arshad M, Rehman S, Quresh AH, Masud K, Arif M, and Saeed A. Thermal decomposition of metal complexes of type MLX2 (M=Co(II), Cu(II), Zn(II), and Cd(II); L= DIE; X= NO3 by TG-DTA-DTG techniques in air atmosphere. *Turkish Journal of Chemistry*. 2008, 32(5), p 593-604. https://citeseerx.ist.psu.edu

20- Rodriguez-Sanchez L, Blanco MC, Lopez-Quintela MA. Electrochemical synthesis of silver nanoparticles .*The Journal of Physical Chemistry B*.2000, 104, p 9683-9688. https://pubs.acs.org

21- Shakeel Ahmed, Mudasir Ahmed, Babu Lal Swami, Saiqa Ikram. A review on plant extract mediated synthesis of silver nanoparticles for antimicrobial application: A green expertise. *Journal of Advanced Research*. 2016, 7, p 17-28. http://dx.doi.org/10.2016/j.jare.2015.02.007

22- Palaniyandi Velusamy, Govindarajan Venkat Kumar, Venkadapathi Jeyanthi, Jayabrata Das & Raman Pachaiappan. Bio-Inspired Green Nanoparticles Synthesis , Mechanism and Antibacterial Application. *Toxicol.Res.* 2016, 32(2), p 95-102. http://dx.doi.ogr/10.5487/TR.2016.32.2.095

23- Zia-ur-Rehman Mashwani, Tariq Khan, Mubarak Ali Khan, Akhtar Nadhman. Synthesis in plants and plants extracts of silver nanoparticles with potent antimicrobial properties: current status and future prospects. *Appl. Microbiol. Biotechnol*. 2015, 99(23), p 9923-9934. http://pubmed.ncbi.nlm.nih.gov

24- Hayrunnisa Nadaroglu, Azize Alayligungor, and Selvi Ince. Synthesis of Nanoparticles by Green Synthesis Method. *International Journal of Innovative Research and Reviews*. 1017, 1(1), 6-9. http:// www.injirr.com/article/view/4

25- Irfan Ijaz, Ezaz Gilani, Ammara Nazir&, Aysha Bukhari. Detail review on chemical, physical and green synthesis, classification, characterizations and applications of nanoparticles. *Green Chemistry Letters and Reviews.* 2020, 13(3), p 223-254. https://doi.org/10.1080/17518253.2020.1802517