جمهورية العراق
وزارة التعليم العالي والبحث العلمي
جامعة بابل
كلية التربية للعلوم الصرفة
قسم الفيزياء

الخواص الطيفية والبصريه لخليط صبغة – بوليمر المطعم بالجسيمات النانوية البلازمونية

رسالة مقدمة إلى
مجلس كلية التربية للعلوم الصرفة – جامعة بابل
وهي جزء من متطلبات نيل درجة الماجستير في التربية / الفيزياء

من قبل

رجاء كاظم خليف عاشور

(بكالوريوس تربية في الفيزياء2003)

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جامعة بابل / كلية التربية للعلوم الصرفة

2022 م **1444 هـ**

Republic of Iraq
Ministry of Higher Education
and Scientific Research
University of Babylon
College of Education for Pure Sciences
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Spectral and Optical Properties of Dye _ Polymer Blend Doped with Plasmonic Nanoparticles

A Thesis
Submitted to the Council of the College of Education for Pure Sciences, University of Babylon
In Partial Fulfillment of the Requirements for the Degree of Master in Education \ Physics

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2022 A.D 1444 A.H

بسم الله الرحمن الرحيم

﴿ويَسْأَلُونَكَ عَنِ الرُّوحِ قُلِ الرُّوحُ
مِنْ أَمْرِ رَبِّي وَمَا أُوتِيتُم مِّن الْعِلْمِ
إِلاَّ قَلِيلاً﴾

صدق الله العظيم

الآية 85 من سورة الاسراء

Dedication

I dedicate this simple effort...

To those who live in our hearts if they are absent...

To those under the good earth...

To those who bled their drops of blood……

To the martyrs of my wounded country who sacrificed their lives in order for us to live in dignity.

To My brother the martyr (Haider Kazem Khleaf).

Rajaa

ACKNOWLEDGEMENTS

Thanks to God, Lord of the Worlds, and my thanks to Him lacks thanks, and prayers and peace be upon the Messenger of God, Muhammad, and upon his good and pure family...

I would like to thank my supervisor (Prof. Dr. Talib Mohsen Abbas Al-Shafei) for suggesting the topic of the research and for the parental directions and constructive suggestions….

I am also pleased to extend my thanks to the Chair of the Physics Department and to all the faculty members in the College of Education for Pure Sciences / Physics Department....

Many thanks to my family, dear mother, dear father, and my brothers who supported me with all kinds of support to complete what I started.

I am pleased to thank my dear husband(Mahmood) who supported me financially and morally, and thanks go to (my children who were my best support)

Rajaa

Abstract

In the present research, the absorption and fluorescence spectra are studied and the optical and spectral properties of the organic laser dye(Nile blue) are studied using two organic solvents water and ethanol, with different concentrations (0.01, 0.03, 0.05) mM. Then (NB-PVP) blend solutions are prepared by adding a polyvinyl pyrrolidone polymer(PVP) to the Nile blue dye in a ratio of (1ml:1ml), and studying the optical and spectral properties of these blend solutions in (water ,ethanol) solvents with different concentrations of the dye solution. In addition, solutions of nanocomposites (NB-PVP/AuNps) are prepared by adding gold nanoparticles (AuNPs), which are prepared by pulsed laser ablation using an(Nd-YAG) laser beam of wavelength (1064 nm), after adding a fixed volume ratio (1ml) to the solutions. (NB-PVP) blend solutions. then studying the absorption spectra of fluorescence and the optical and spectral properties of the solutions of these nanocomposites

The results show that by increase in the concentration of the dye and for all the prepared samples the absorbance increases and the transmittance decreases according to the Beer-Lambert law and this was accompanied by an increase in the linear optical properties, by Comparing the absorbance of the dye with(water, ethanol) solvents it was found that the absorbance spectra in water solvent have two peaks of absorption spectra, while in the case of ethanol solvent there is one peak. It is also noted that the absorption spectrum of water is higher than the absorption spectrum of ethanol when the concentration of the dye is fixed. Therefore, the optical parameters of the dye dissolved in water are higher than that of the dye in the ethanol solvent. As for the fluorescence spectra, increasing the concentration of the dye leads to a decrease in the intensity of fluorescence and thus an increase in the life time of fluorescence and a decrease in the quantum yield of fluorescence For all samples of the prepared solutions.

For (NB-PVP) blend solutions a decrease in the absorbance spectrum is observed compared to dye solutions alone and for both solvents(water, ethanol), For this reason, it is observed that the increase in the intensity of fluorescence led to a decrease in the fluorescence lifetime and an increase in the quantum yield of fluorescence. The highest quantum yield of fluorescence was (0.82) in water solvent and (0.89) in ethanol solvent.

The absorption and fluorescence spectra, as well as the optical and spectral properties of the (NB-PVP/AuNps) nanocomposites solutions are studied. . It is found that the addition of gold nanoparticles (AuNPs) to (NB-PVP) blend solutions lead to a decrease in the absorbance spectrum compared to dye solutions alone and blend solutions, in addition to an increase in the intensity of fluorescence for the two solvents, it lead to a decrease in the absorbance spectrum compared to dye solutions alone and blend solutions, in addition to an increase in the intensity of fluorescence for the two solvents, this led to a decrease in the values of the fluorescence lifetime and an increase in the values of the quantum yield of fluorescence for nanocomposites solutions, it was found that the highest value of the quantum yield of fluorescence is (0.88) in the water solvent and (0.92) in the ethanol solvent. From the above and through this study, nanocomposites solutions with high quantum yield of fluorescence were obtained that can be used as active media in random lasers.

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbols	**Meaning**
A	Absorbance
I	Intensity of transmitted light
I_o	Incident intensity
C	Concentration of matter (moll/L)
ℓ	The thickness of the material
C	Velocity of light3x10^8 m/sec
ε	Molar Absorption Coefficient
λ	The Wavelength
α_o	Optical Absorption Coefficient
L	Path-length of the light
T	Transmittance
n	Refractive Index
ν	The Speed of light in medium
N	The Complex refractive index
K	Coefficient of extinction
R	The reflectivity
S_o	Ground singlet state
S_1	First excited singlet state
S_2	Second excited singlet state
T_o	Ground triplet state

T_1	First triplet state
Q_{FM}	Fluorescence Quantum Efficiency
I_C	Internal Conversion
I_{SC}	Inter System Crossing
K_{ISC}	An interfacial crossing rate
τ_{FM}	Radioactive lifetime
K_{FM}	Radioactive emission probability
K_{IC}	Internal conversion rate constant
K_{ISC}	Intersystem crossing rate constant
K_d	Rate constant for non-radioactive processes
Φ_f	Fluorescence quantum yield
τ_f	Fluorescence lifetime
T_{fRB}	The time-span of the standard compound(3.230 ns)
a_{RB}	The area under the fluorescence curve of Rhodamine B
a	The area under the curve of the compound
Φ_{FM}	The quantum yield of fluorescence
M_W	Molecular weight of molecule
V_1	The volume of the original solution
V_2	Volume after dilution
V	Solvent volume
C_1	The concentration of the original solution
C_2	Concentration after dilution
W	The total weight of dye
UV	Ultra Violet Spectrum

NB	Nile Blue
PVP	Polyvinylpyrrolidone polymer
Au NPs	Gold nanoparticles
PLAL	Pulsed Laser Ablation in Liquids

الخلاصة

في البحث الحالي درست اطياف الامتصاص والفلورة وحساب الخصائص البصرية والطيفية لصبغة عضوية ليزرية هي صبغة النيل الزرقاء باستخدام مذيبين عضويين هما الماء والايثانول وبتراكيز مختلفة (0.05,0.03,0.01) ملي مولاري. بعد ذلك حضرت محاليل خليط من (NB-PVP) وذلك بإضافة بوليمر بولي فينيل بايروليدون الى صبغة النيل الزرقاء بنسبة (1مل:1مل) ، ودراسة الخواص البصرية والطيفية لمحاليل الخليط وبمذيبين الماء والايثانول وبتراكيز مختلفة لمحلول الصبغة. اضافة الى ذلك حضرت محاليل المتراكبات النانوية (NB-PVP/AuNps) وذلك بإضافة جسيمات الذهب النانوية (AuNPs) والمحضرة بطريقة الاستئصال بالليزر النبضي باستخدام حزمة ليزر نديميوم- ياك بالطول الموجي (1064 nm) وذلك بعد اضافة نسبة حجمية ثابتة (1ml) لمحاليل خليط (NB-PVP) ومن ثم دراسة اطياف الامتصاص الفلورة والخصائص البصرية والطيفية لمحاليل هذه المتراكبات النانوية . بينت النتائج ان بزيادة تركيز الصبغة ولجميع النماذج المحضرة تزداد الامتصاصية وتقل النفاذية طبقا الى قانون بير- لامبارت ويصاحب ذلك زيادة في الخصائص البصرية الخطية . بالمقارنة مع امتصاصية الصبغة للمذيبين الماء والايثانول، وجد ان اطياف الامتصاصية بمذيب الماء تمتلك قمتين لأطياف الامتصاصية ، اما في حالة مذيب الايثانول فتوجد قمة واحدة . كذلك يلاحظ ان طيف الامتصاصية للماء اعلى من طيف الامتصاصية للإيثانول عند ثبوت تركيز الصبغة ولهذا تكون المعاملات البصرية للصبغة المذابة بالماء اعلى منها للصبغة في مذيب الايثانول .اما بالنسبة الى اطياف الفلورة فان زيادة تركيز الصبغة تؤدي الى نقصان شدة الفلورة وبالتالي زيادة زمن عمر الفلورة ونقصان المنتوج الكمي للفلورة. ولجميع نماذج المحاليل المحضرة .

بالنسبة لمحاليل الخليط (NB-PVP) ، لوحظ نقصان في طيف الامتصاصية مقارنة مع محاليل الصبغة وحدها ولكلا المذيبين ولهذا السبب لوحظ ان زيادة شدة الفلورة ادت الى نقصان زمن عمر الفلورة و زيادة المنتوج الكمي للفلورة. وكان اعلى منتوج كمي للفلورة هو (0.82) للصبغة المذابة بالماء و (0.89) للصبغة المذابة بالإيثانول.

درست اطياف الامتصاص والفلورة وكذلك الخصائص البصرية والطيفية لمحاليل المتراكبات النانوية (NB-PVP/AuNps)، وجد ان اضافة جسيمات الذهب النانوية (AuNPs) الى محاليل خليط (NB-PVP) ادى الى النقصان في طيف الامتصاصية مقارنة بمحاليل الصبغة وحدها ومحاليل الخليط، اضافة الى زيادة شدة الفلورة لكلا المذيبين وبالتالي نقصان قيم زمن عمر الفلورة وزيادة قيم المنتوج الكمي للفلورة لمحاليل المتراكبات النانوية حيث وجد اعلى قيمة للمنتوج الكمي لمحاليل المتراكبات (0.88) في مذيب الماء و (0.92) في مذيب الايثانول .مما سبق ومن خلال هذه الدراسة تم الحصول على متراكبات نانوية ذات نتاج كمي عال يمكن استخدامها كأوساط فعالة في الليزرات العشوائية .

Supervisor Certificate

I certify that this thesis entitled **"Spectral and Optical Properties of Dye-Polymer Blend Doped with Plasmonic Nanoparticles"** was prepared by the student (**Rajaa Kazem Khlief**) under our supervision at the College of Education for pure sciences, University of Babylon in partial fulfillment of the requirements for the Degree of Master in Education \ Physics

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Date: / /2022.

Head of the Department Certificate

In view of the available recommendation, I forward this thesis for debate by the examining committee.

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Examining Committee Certification

We certify that we have read this thesis entitled **"Spectral and Optical Properties of Dye-Polymer Blend Doped with Plasmonic Nanoparticles"** and as a committee examined the student in its contents and, according to our opinion, it is accepted as a thesis for the degree of Master in Education / Physics.

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Chapter One

Introduction and Literature Review

Chapter Two

Theoretical Part

Chapter Three

Experimental Part

Chapter Four

Results
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1.1 Introduction

A dye laser is a laser which uses an organic dye as the lasing medium, such as liquid solutions, gases and solid state. Organic dyes are characterized by a strong absorption band in the visible region of the electromagnetic spectrum. Such a property is found only in organic compounds which contain an extended system of conjugated bonds alternating single and double bonds. The long-wavelength absorption bond of dyes is attributed to the transition from the electronic states for this process is typically very large, thus giving rise to an absorption bond ground state S_o to the first excited singlet state S_1 .The transition moment with oscillator strength on the order of unity. The reverse process S_1 to S_o is responsible for the spontaneous emission in dye laser [1].

Dye lasers are used for applications, analytical chemistry, and other measurements, and are one of the most significant and commonly utilized applications in many areas of life. Liquid dye lasers have a very wide fluorescence optical band and are commonly used in the visible wavelength region as tunable narrow bandwidth light sources 400 nm to 700 nm. There are a variety of laser dyes available, all of which are quite efficient. One of these dyes, Nile Blue, has a wide range of uses in biology, chemistry, and physics [2]. For these many advantages, these lasers have an important role in many applied fields, which also helps their continuous development, and among the most important of these fields is the field of spectroscopy, chemistry, and photo physics, such as the use of lasers in micro chemical reactions, in the field of selective excitation, and laser communications [3] .

In recent decades, there has been a considerable deal of interest in polymer-based sensing materials; therefore, polymers have become viable for sensing technologies due to their low cost and ease of production due to the effect of external elements such as heat, deformation, chemicals, light, etc., the polymer-based sensor materials exhibit altered absorption and fluorescence characteristics. Consequently, sensors are now constrained to a broad spectrum of technologies[4] Therefore, adding the synthetic polymer host to organic laser dyes showed better compatibility[5]. It has been used in many modern photonic technology, optical amplifiers, fiber optics, and optical limiting [6].

Nanotechnology represents one of the major breakthroughs of modern science, enabling materials of distinctive size, structure and composition to be formed. For the smaller particles the percentage of surface atoms increases, leading to changes in physical and chemical properties of the materials[7]. The field of nanotechnology is one of the most popular areas for polymer science and technology. This area can generate a new material behavior [8]. Nanoparticles embedded in polymer matrix have attracted increasing interest because of the unique mechanical, optical, electrical and magnetic properties displayed by nanocomposites at low nano-filler concentrations (1-10%)[9]. This importance is due to the effect of the unique nature of the nanosized filler on the bulk properties of polymer-based nanocomposites [10].The incorporation of spherical nanoparticles into polymers allows for the alteration of physical properties as well as the implementation of new features in the polymer matrix[11].

1.2. Organic compounds:

They are hydrocarbons and their derivatives, which are used as active media in lasers dye and categorize as follows:

1.2.1. Saturated compounds

Organic compounds without double or triple bonds usually absorb at wavelength below 160nm, corresponding to a photon energy of 7.749 eV. This energy is higher than the dissociation energy of most chemical bonds. Therefore, photochemical decomposition is likely to occur, so such compounds are not very suitable as the active medium in lasers[12].

1.2.2. Unsaturated compounds

These compounds are characterized by double or triple bonds, and these compounds absorb wavelengths above (200nm). Examples of such compound are laser dyes which usually contain double bonds (conjugeated) Rhodamine - 6G dye (R6G), which belongs to the family of Xanthenes class and the Coumarin -2 dye (C2).[12].

1.3. Laser Dyes

The active medium in laser dyes consists of specific solutions of an organic dye dissolved in a liquid methyl ethyl alcohol, methyl alcohol, or water. Laser dyes have a high absorption capacity in the ultraviolet and visible regions of the spectrum depending on the chemical compositions.[13].

Dyes are classified according to the wavelength of the radiation they emit, where each group emits a specific range of the spectrum ranging between (400-1000 nm) depending on its chemical composition [14]. Laser dyes are classified according to chemical structure into the following [15]:

1. (Polymethine) dyes :It is emitted in the red or near-infrared range (700 -1000) nm .
2. Xanthene dyes (500-700) nm.
3. Coumarin dyes: It is emitted (blue-green) region i.e ،(400-500) nm.
4. (Scintillator) dyes: It is emitted in the ultraviolet region wavelength less than (400) nm.

For effective performance, laser dye molecules should have the following characteristics [1].

1. It has high photochemical stability.

2. It has a high solubility in a large number of solvents without generating molecular complexes and responds to the auxiliary factors used to overcome the formation of these complexes.
3. It should have a wide emission beam, i.e. a wide toning range.
4. The absorption spectrum of the dye must match the spectral distribution of the pumping source.
5. It has a high quantitative output during the dominance of radioactive transitions. Figure (1.1) shows The wavelength range of different dye lasers.

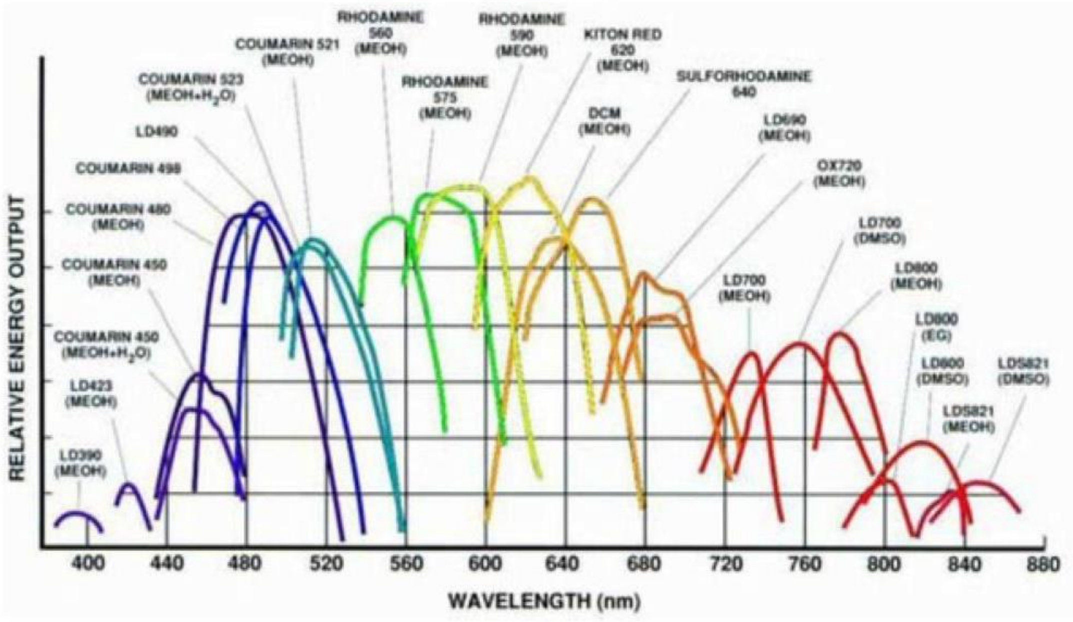

Figure (1.1): The wavelength range of different dye lasers [16]

1.4. Nile Blue Dye

The Nile Blue dye (NB) is classified as phenoxazine, which is positively charged and oxidized [17]. That of the characteristics of the dye is that it has good optical and spectral properties, with high absorption and emission, which depends on the polarity of solvents and pH [18].Figure (1.2) shows the Molecular Structure of Nile Blue dye

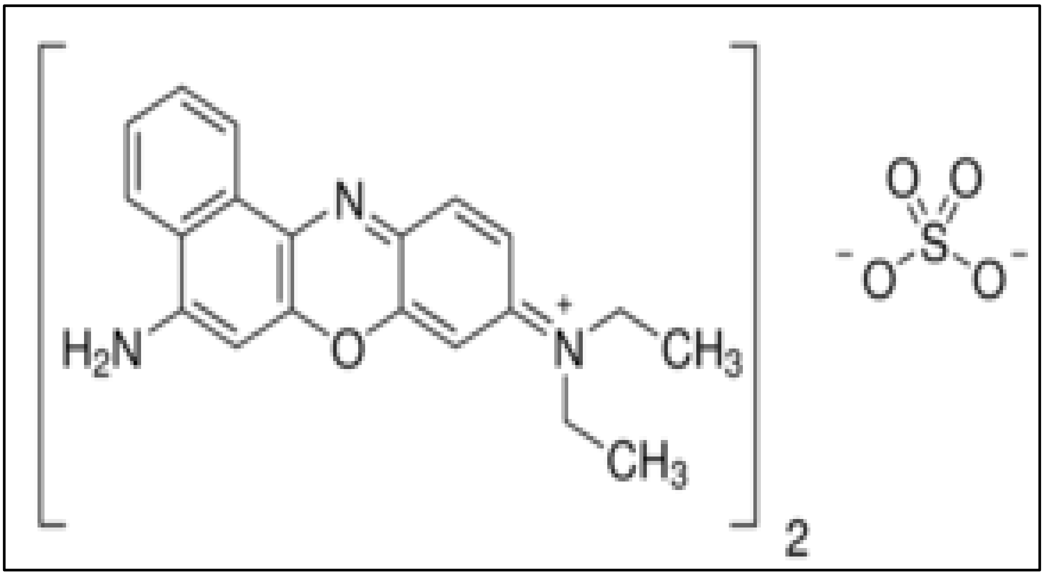

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Figure (1.2): The Molecular Structure of Nile Blue dye [18].

1.5. Polymers

Polymers are chemical compounds made up of simple building units called monomers, and they are repeated many times and are linked to each other by chemical bonds forming long molecular chains, which may take different forms linear, branched, or interlocked. The word polymer is of Latin origin consisting of two syllables (poly) which means multiple, and (mer) which means part or unit, so the word (polymer) linguistically means multi-unit[19].

Polymers may be of natural origin, taken from plants and animals, such as cellulose and fats, or they may be synthetically derived from petrochemicals and silicon. Polymers have lower density and lower strength compared to metals and alloys, have low thermal and electrical conductivity and a much lower coefficient of thermal expansion than metals, and are also characterized by their resistance to most acids, bases and some organic solutions [14].

1.6. Polyvinyl Pyrrolidone Polymer (PVP)

Polyvinyl pyrrolidone is a polymer that is non-ion-generating and is in the form of a milky white powder that dissolves in water forming colloidal solutions. Polyvinyl pyrrolidone is a poly which is a compound resulting from the substitution of an organic acid group in the place of a hydrogen atom in a molecule. Ammonia has an unusual complexity, slimy properties, and inert physiology. It is called by several names, including (Plasdon,Polyclare,Perkyal,Coleron and Albigen) [20]. As PVP binds to polar molecules exceptionally well, it is used as a binder in many pharmaceutical industrial processes for the manufacture of drugs. This binding nature leads to the application of PVP in coatings for photo-quality transparencies. PVP can be thermally cross-linked, thus ensuring good thermal stability and mechanical strength and also because the stability of PVP in water has entered in to the goods of luxuries and cosmetics [21].

The PVP polymer film has the potential capacity to store the charges responding to the dopant-dependent electrical and optical properties. It has a strong tendency for complex formation with a variety of molecules [22]. Figure (1.3) represents the molecular structure of PVP.

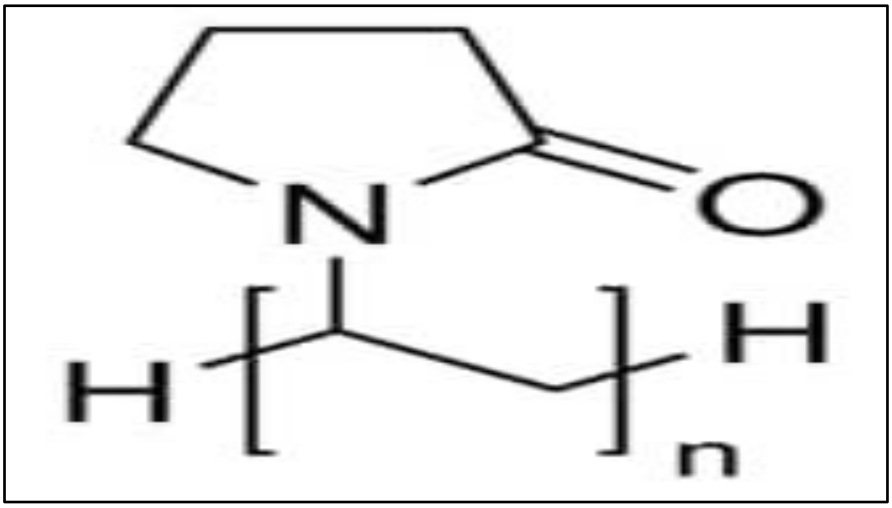

Figure (1.3): The Molecular Structure of PVP Polymer[22].

1.7. Nanoparticles

The origin of word “Nano” is derived from the Greek word (Nanos), which is the word The Greek word for dwarf means everything small, and the alone technique means: the technology of materials micro or micro microspheres. Nano science is the study of the basic principles of molecules and compounds that do not exceed100 nanometers in size and nanometer It is a unit of measurement equal to 10^{-9}meters [23].

The principle of this technique is based on capturing the infinitesimal atoms of any material and manipulating them moving them from their original positions to other positions, then merging them with atoms of other substances to form a crystal lattice to obtain highly characteristic Nano-dimensional materials[24].

The word (nanoparticles) is recently used; these particles were it is present in manufactured or natural materials since ancient times. Nanoparticles can be defined as microscopic atomic or molecular assembly ranging Their number ranges from a few atoms (molecule) to a million atoms, and they are connected in a spherical shape it has a radius of less than 100 nm[25]. the main classes of nanoscale structures can be classified by dimensions, some of which are summarized in Table(1.1)[26]

Table(1.1) Classification of Nanomaterials with Regard to Dimension[26]

Dimension	Example
0 dimension $<$100 nm	Particles , quantum dots
1 dimension $<$100 nm	Nanotubes, Nanowire ,Nanorods
2 dimension $<$100 nm	Thin films, Coatings, Multilayers
3 dimension $<$100 nm	Nanometer-sized cluster

It has recently been possible to synthesize nanoparticles from metals, insulators, semiconductors, and structures Hybrids such as (laminated nanoparticles), as well as the manufacture of models for nanoparticles of a semi-solid nature. For not amenable to hammering and, pulling, unlike regular copper particles [25].

1.8. Gold Nanoparticle (Au NPs)

Gold nanoparticles have unique optical properties because they support surface Plasmons. At specific wavelengths of light, the surface Plasmon's are driven into resonance and strongly absorb or scatter incident light [27]. This effect is so strong that it allows for individual gold nanoparticles as small as (50 nm). the Absorption and scattering of light by gold nanoparticles of sufficiently small size, that are identical to less or than the mean free path of electrons in spatially extended material should be mentioned especially [28]. In this case, it becomes necessary to account for the scattering of free electrons at the boundary of the gold nanoparticle. This is usually interpreted as a limitation of the mean free path of electrons, which leads to an additional pathway of free electron energy dissipation [29].

1.9. Pulsed Laser Ablation in Liquids (PLAL)

In the 1960s, the ruby laser has been discovered consequently, great development has been prepared in the field of laser ablation, which leads to the fact that the laser ablation techniques is applicable in various states of matter.

In1987, Patil *et. al.* was used laser irradiation by immersing iron as a goal in an aqueous solution, the manufacturing capabilities of the solid-liquid interface have since been discovered by laser irradiation. Afterward, within the 2000s, PLAL held awesome potential to produce nanostructure materials. More particularly, the preparation of noble metal nanoparticles (NPs) with controllable molecule measure in fluid arrangements of surfactants was accomplished by PLAL [30].

Pulsed laser ablation requires a high-energy laser beam to be focused on the surface of a solid target immersed in a liquid. This leads to the interaction of the laser with the target and the evaporation of the surface in the form of a plasma halo that contains different types of particles such as atoms or ions and their groups which have high kinetic energy. Particles in the plasma, halo collides and interacts with the surrounding particles. of the liquid, to produce new compounds containing atoms of the solid target and liquid [31].

The laser ablation, procedure was performed from a solid target immersed in a liquid medium inside an open vessel, where laser pulses, were fired at the target for a while to remove it. The first procedure of laser ablation is the interaction of the laser beam with the surface of the solid target, which causes , the solid target to evaporate and atomize into the liquid, forming a collide chemical reactions can occur between molecules of a solid and a solute in a liquid, and the products of the reactions are usually nanoparticles (NPs) consisting of both the target and the liquid atoms that form a suspension, in the liquid collide [32].

1.10. Plasmon phenomena

Plasmon is the field of study of photovoltaic phenomena resulting from the interaction of free electrons of noble metal nanoparticles such as gold, silver, copper, and platinum with electromagnetic waves (especially at visible optical frequencies) and collective oscillation called surface plasma. Plasmonic forms an important part of the Nano photonics field, which can confine an electromagnetic field smaller than the wavelength smaller than the diffraction limit, the near-optical field enhanced by the dimensions of the sub-wavelength based on an interaction between (electromagnetic field and conduction electrons in metal facades) [33].

When electromagnetic fields collide with a noble metal surface, they accelerate electrons to the metal and lead to polarization resulting in a recovery force that leads to the oscillation of the free electron of the noble metal. This quantized oscillation and oscillation of free electrons is a quantized of plasma oscillations called plasma [34]. Collective oscillation, called surface plasma, the specific frequency or wavelength of light falling in this phenomenon, depends heavily on the type, shape, size, and surface of noble metal nanoparticles[35] can be reached by these types of nanoparticles to strong absorption due to shifts between electronic levels[36]. The development of Nano-manufacturing techniques helps increase applications of plasma nanostructures in various fields of scientific research and photons[37].

1.11. Nanocomposite

Composite materials mean that group of engineering materials that are produced by adding certain weight or volume ratios of one or more materials (supporting materials / Materials Reinforcement) to the base material (the Matrix) of the mold material, which ensures obtaining a homogeneous compound in which the particles of the supporting materials are perfectly distributed in the selection of the base materials(Matrix), it is required that they enjoy complete neutrality so that they do not interact with each other or with the base material to retain their identity within the mold material[38].

The purpose of producing composite materials is to add certain properties to the mold material or add qualities that were not related to its performance. The nanoparticles are added during the manufacture of these materials, and as a result, it shows a significant improvement in their properties. For example, adding tubes and Carbon nanoparticles change the electrical and thermal conductivity properties of the material. The addition of types may result in other nanoparticles to improve optical properties and dielectric properties, as well as mechanical properties such as hardness and strength. the volume percentage should be The added nanoparticles are very low (0.5% to 5%) because the proportion of particles is in the range of The surface area to the volume of nanoparticles is high [39].

Due to the rapid developments in the field of technology and the need for materials that carry high specifications, this era has brought the dawn of Nano composite materials in general with a polymer basis. in particular, they have attracted the attention of many researchers and industrialists that being this is due to its high specifications, including lightweight and high mechanical resistance, in addition to being an insulating material thermal and electrical, depending on the additives, so nanocomposite materials can be defined as those polymers comes to which materials of size (9 - 10) nm are added.

1.12. Literature Survey:

H.Tajalli *et al.*, (2008), studied the absorption and fluorescence spectra of the high-fluorescent laser dye (Nile Red) and the oxazine cationic dye (Nile blue) in different solvents as a function of the polarity and type of solvent. The interaction of the dye with the anisotropic surroundings and the interaction of isotropic solvents were examined and compared using optical spectroscopy. The spectral shifts were related to the polarity of the solvent and nature. The photoelectric effect of guest-host systems in an electro-optical system was also investigated using the method of polarized spectroscopy, dichromatic ratios, degree of anisotropy, and the dichromatic ratios of these dyes were investigated in liquid crystal hosts[40].

J.Jose, *et al.*, (2009), the Preparation of four derivatives of Nile Blue dye dissolved in water through condensation reactions. These sensors were carried out under relatively mild conditions (90°C, N, N-dimethylformamide without adding acid). These fluorescent probes have more favorable fluorescence properties than two known water-soluble

Nile blue derivatives. Concentration-dependent UV absorption and fluorescent emission studies have indicated that the dyes do aggregate in an aqueous solution at lower concentrations[41].

M. Giri, *et al.* ,(2012), studied the absorption and fluorescence spectroscopy of methyl orange dye Orange Methyl in aqueous solutions and at different concentrations by analyzing of absorption and fluorescence spectra of the molecule where the absorption spectrum shows two absorption peaks at the (463-270) nm band recorded at the spectral region (220-650) nm the fluorescence spectra and showed the three peaks of (538,418, 345) nm respectively at 10^{-4} M. it is observed that the fluorescence bands at 418, 345 nm are attached to the bands the absorption is at 270nm, which gives a Stokes displacement from 75 nm to 148 nm, respectively.[42]

J. Donovalová, *et al.*, (2012), the absorption and fluorescence spectra of substituted coumarins (2-oxo-2Hchromenes) investigated in solvents and polymer matrices. The result leads to remarkable changes in the shape of the absorption spectrum and shifts the absorption to a longer wavelength, and coumarins yield more intense fluorescence in polymer matrices than when they are in solution[43].

M. Ghanipour, *et al.* ,(2013), studied the effect of silver nanoparticles doped in PVA on the optical and structural properties of composite films experimentally. Samples are PVA films of(0.14) mm thickness doped with different concentrations and sizes of silver nanoparticles. Structural properties are studied using the X-ray diffraction and FTIR spectrum. Optical properties studied using the transmittance and reflectance of samples, the influence of doped nanoparticles and their concentration on optical parameters of PVA films include absorption coefficient, optical band gap energy, and complex refractive index. (Ago) bonds are formed in the films and the band gap energy of samples is decreased. Calculations based on the WD model confirm that by doping nanoparticles, the anion strength of PVA as a dielectric medium is decreased[44].

A. F. Hassan, *et al.* ,(2014), studied the effect of concentration on spectral properties(Absorption and fluorescence) of fluorescein sodium dye in ethanol with different concentrations at the temperature of the room. An increase in the intensity of absorption is observed and a decrease in fluorescence is observed when the concentration is increased. and so Also, when the concentration was increased, the peak shift to the peak of the absorption spectrum wide take a spectral range of long wavelengths[45].

W. Z. W. Ismail *et al.*, (2015), observed improved performance with a lower lasing threshold, higher emission peak intensity, and narrower emission line width for both Rh6G and Rh640 with relatively low concentrations of gold nanoparticle scatters in comparison with dielectric scattering particles. These observations are attributed to the enhanced scattering and absorption of gold nanoparticles and increased spectral overlap between the dye fluorescence spectrum and the gold extinction spectrum, which induces localized surface Plasmon's and resonance energy transfer[46].

J. Yin et al. , (2016), the effect of the shape of Au scattering particles on the Rh6G dye-doped PMMA polymer. In particular, the effect on the centre wavelength and the threshold were considered. Rh6G dye-doped PMMA polymer disordered media containing Au nanospheres and nanorods were fabricated, using the same volume fraction of each [47]

A.F. Jaffar, *et al.* ,(2017), studied the non-linear optical properties of the thin films of Nile blue dye with the polymer polyvinyl chloride(NB/PVC) and the polymer methyl methacrylate(NB/PMMA) and their mixture(NB/PMMA 50%+PVC 50%) were studied. The nonlinear qualities are studied using the scanning technique on the third axis (z -scan) at a wavelength of 650 nm in two ways: In the first method, an opening was made in front of The detector to study the nonlinear refractive index (n_2). In the second part, the aperture was removed from the front of the detector to calculate the nonlinear absorption coefficient ($\beta 2$)[48].

Ahmed G. El-Shamya, et *al.* ,(2020), PVA/CQDs nano-composite films were made up via a solution casting approach for the methylene blue dye removal from waste water. PVA/CQDs nano-composite films were achieved by the marriage of PVA and the CQDs nano-particles, after the preparation of zero dimension CQDs nano-particles by microwave heating process[49].

B .N. Hoang *et al.* ,(2020), studied enhanced selective adsorption of cation organic dyes on polyvinyl alcohol/agar/maltodextrin water-resistance biomembrane. The synthesis of nanoparticles from plant sources has proved to be an effective and alternative method for the novel production of nanoparticles. This paper reports the bio reduction of silver nitrate into silver nanoparticles by the leaf extract of Delonix elata. The synthesized silver nanoparticles were characterized by UV–visible (UV–vis) spectroscopy, Fourier infrared spectroscopy (FT-IR), X-ray diffraction (XRD), Scanning Electron Microscopy (SEM) coupled with Energy Dispersive Spectroscopy (EDS), high-resolution transmission electron microscope (HRTEM)[50].

S. F. Haddawi et al. ,(2021), studied multi-wavelength random lasing in two dimensional flexible plexcitonic nanostructures through surface lattice plasmon amplification by using Au NPs in order to increase the energy coupling. Based on the results, the energy coupling between plasmonic Au NPs and excitons in two-dimensional nanostructure increased by enhancing the concentration of Au NPs, which smoothed the stimulated emission of multi-wavelength lasing. In addition, the efficiency of this multi-wavelength random lasing can be controlled by increasing these energy couplings [51].

1.13. Aims of the work

Aims of the present work can be summarized through the following:

1. Study the absorption and fluorescence spectra, as well as the linear optical properties (linear refractive index and linear absorption coefficient), in addition to the spectral properties (lifetime of fluorescence, quantum yield of fluorescence) for the organic Nile Blue dye (NB) dissolved in different solvents (water, ethanol) at different concentrations
2. Study the effect of gold nanoparticles (Au NPs) on absorbance and fluorescence spectra, as well as the linear optical properties (linear refractive index and linear absorption coefficient) and spectral properties (lifetime of fluorescence, quantum yield of fluorescence) for (NB-PVP/Au NPs) Nanocompsite at different concentrations for different solvents (water, ethanol).
3. The Promising application of (NB-PVP/Au NPs) Nanocomposite solution with a high quantum yield of fluorescence as active media for random lasers.

2.1. Introduction

This chapter includes the theoretical concepts of linear optical properties (absorbance, transmittance and optical parameters) for organic laser dyes, as well as photophysical processes of organic molecules (radioactive and Non-radioactive transitions) and the parameters effected by fluorescence of laser dyes. Moreover,the definition and mathematical description of the quantum efficiency of fluorescence and the lifetime of fluorescence and finally, factors effecting the fluorescence spectrum of laser dye.

2.2. Linear Optical properties:

The interaction between the nature and distribution of charges inside the material (electronic, molecular ,or ionic) and electromagnetic radiation leads to the appearance of the optical properties of materials [52].

When the electromagnetic radiation falls on the material and interacts with it, many processes occur as part of the electromagnetic radiation is absorbed by the material and the other part is called the transmitting ray because it passes through the material while another part of the electromagnetic radiation is reflected from the surface of the material called the reflected part [53].

In order to obtain information about the interference composition of the material and the nature of its bonds it is necessary to know the transmittance, absorption and reflectivity of the electromagnetic radiation falling on the material For example the energy packets and the quality of transitions within the material are identified by studying the ultraviolet spectrum but to know the field of practical applications in which materials are used the visible spectrum must be studied [54].

2.2.1 Absorbance

The mathematical quantity that relates the particle density concentration in a sample and sample thickness optical path length is the absorbance(A) or optical density [55]:

$A = Iog_{10}\left(\frac{I_\circ}{I}\right) = \varepsilon\ell C$ (2.1)

Where that:

I: is the intensity of the beam at the wavelength (λ) passing through the sample (transmitted intensity)

I_o: is the intensity of the incident beam before they enter the sample.

C: sorbent concentration (moll/L)

ε: Molar absorption coefficient and its units ($cm^{-1}M^{-1}$)

ℓ: the thickness of the material through which the incident ray is passing (cm).

The material absorption of the incident ray will cause an electronic transition if the energy value which absorbed by the material is sufficient to move of electrons to a higher energy level and according to Beer Lambert's law, the probability of the absorption of incident photons on matter increases with increasing concentration of matter [56].

Beer Lambert law is an empirical relationship linking the absorption of rays with the properties of the material that passes the beam through it. The law states that the amount of light absorbed is proportional to the number of particles that absorb it when the radiation enters a specific solution, the amount of absorbed or transmitted radiation is an exponential function of the concentration of the solution [11] and as in the following equation:

$I = I_o e^{-\alpha_\circ c L}$ (2.2)

As α_o represents the optical absorption coefficient, L: the optical path length and The equation can be written as follows:

$\mathrm{Ln}\,\frac{I_\circ}{I} = \alpha_o\, C\, L = A$ (2.3)

Beer-Lambert's law can be applied in different spectral regions such as ultraviolet visible and others provided that the radiation used is monochromatic [57].

2.2.2 Transmittance:

The transmittance to the medium (T) is the ratio of the transmitting intensity (I) to the incident intensity (I_o) after The medium absorbs part of the incident ray, so the transmitted ray is the result of an incident ray that has undergone absorption inside The material passing through it or it is the radiation flowing from the medium to the radiation falling on it i.e[8, 9]

$$\mathrm{T} = \left(\frac{I}{I_\circ}\right) \qquad (2.4)$$

According to Beer-Lambert's law, the transmittance decreases with increasing molar concentration (C) and Optical path length (ℓ) through which light passes [59].

$$T = \frac{I}{I_\circ} = 10^{-\varepsilon C \ell} \qquad (2.5)$$

Where the absorbance of the medium is related to the transmittance, the incident intensity and the penetrating intensity in the following relationship [55]

$$A = log_{10}\left(\frac{I_\circ}{I}\right) = -log_{10}(T) \qquad (2.6)$$

From this relationship noted that the transmittance (T) depends on the absorbance of the medium, the higher the absorbance corresponding the lower the average transmittance.

2.3. Optical Parameters

2.3.1. Linear Absorption Coefficient

The absorption coefficient (α_o) or the attenuation of the intensity of light passing through a substance i.e. a factor expressed as Part of the absorbed beam for a unit thickness of Article [60]According to Beer-Albert's law, the coefficient of Absorption can be found through the following relationship [61]:

$$2.303A = \alpha_{\circ}\ell \qquad (2.7)$$

$$\alpha_{\circ}(cm^{-1}) = 2.303\ \frac{A}{\ell} \qquad (2.8)$$

2.3.2. Refractive index (n):

Light travels with all its wavelengths at its maximum speed in a vacuum, which is a fixed quantity and this value decreases in any other medium, as it changes in material media with different wavelengths.

The ratio of the speed of light in a vacuum to its speed in any given medium for a given wavelength is known as the mean refractive index of that wave [62]

$$n = \frac{c}{v} \qquad (2.9)$$

The refractive index is not fixed and depends on the length of the electromagnetic wave. In addition to some materials, the refractive index varies according to the direction of progress of the electromagnetic wave in the material, and these materials are used to change the direction of polarization of those waves [63], so the Complex refractive index can be determined

$$\bar{n} = n + iK \qquad (2.10)$$

Where k is the extinction coefficient or (the imaginary part of a complex refractive index). Both (k and n) depend on the frequency of the wavelength. The absorption coefficient k can be calculated from the equation following [64].

$$K = \frac{\alpha_o \lambda}{4\pi} \qquad (2.11)$$

The refractive index shows how sensitive a material is to electromagnetic waves. When electromagnetic rays fall on a substance, it works to displace the charges in the material from their original positions, thus generating a dipole.

The energy of the incident wave will be transformed into the vibrational energy of the generated electric dipole, thus reducing the amplitude of the incident wave, and assuming that the loss in energy causes the diodes to oscillate slightly, but the delay in re-radiation will reduce the speed of light [65], Hence, it is clear that the polarization in the material due to the fall of electromagnetic rays on it is a measure of the refractive index of this material. [66], and that the refractive index can be obtained by the following equation which is the equation that I adopted in making the calculations in this research after entering it into a computer program[62]:

$$n = \left[\frac{(1+R)}{(1-R)} - (K^2+1)^{\frac{1}{2}} - \frac{(R+1)}{(R-1)}\right] \qquad (2.12)$$

Where (n) refractive index, (R) the reflectivity, and (k) the Coefficient of extinction

2.4. Photophysical Processes of organic laser dye

Many photophysical processes include radioactive and non–radioactive processes, which mean transitions between electronic states illustrated in the Figure (2.1) which are called the Jablonski diagram [67].

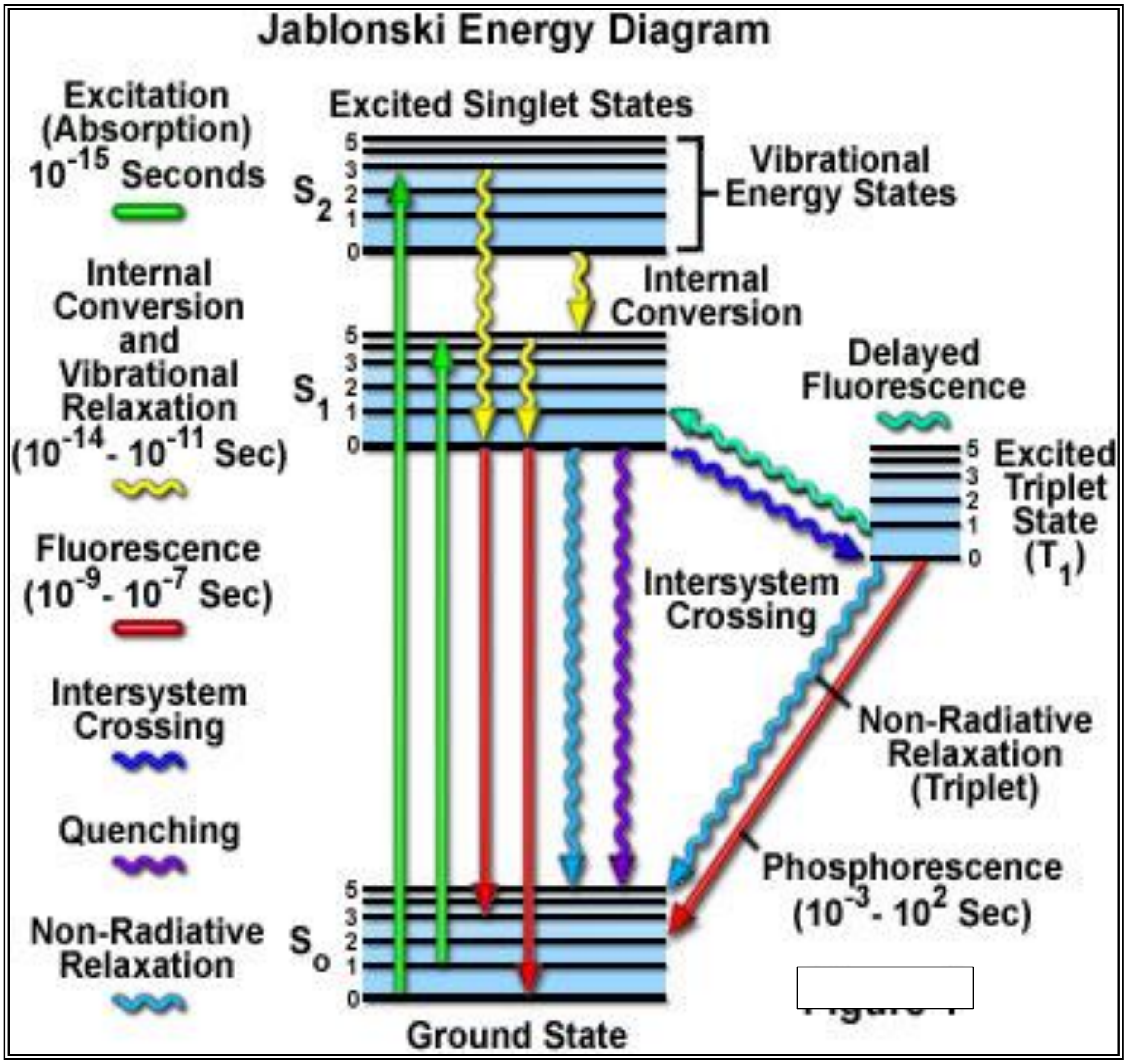

Figure (2.1) : Jablonski diagram[67]

2.4.1. Photophysical Radioactive Processes

These are the processes that are accompanied by the emission of a photon due to the transition of the excited molecule from the excited plane to one of the lower ground state levels, and they include:

2.4.1.1 Fluorescence:

It is a (direct) radioactive transfer process of the particle that takes place between levels of the same multiplicity and fluorescence occurs when moving between the vibrational level of the first excited electronic state (S_1) to any of the vibrational levels of the ground electronic state (S_o) and it is within (10^{-9}) seconds for the organic dye molecules. However, in some organic compounds, fluorescence emission occurs from the lowest level of the second excited electronic state (S_2) to any of the vibrational levels of the ground state (S_o), because the energy gap (S_1 - S_2) is large for these organic compounds, which causes a decrease in the internal transformation rate S_2 to S_1 [68].

The partial structure of organic dyes is important inefficiency. It is noted that the efficiency of fluorescence increases in molecules with a rigid structure as well as when the molecule possesses energy intervals between levels S_1 and T_1, as this leads to a decrease in the inter-system crossing rate. The spectrum of fluorescence occurs due to the absorption of the photon falling on the particle and its transmission to the higher excited electronic levels, but these molecules, by their nature, tend to be stable, so they return to the first excited level, either in the form of thermal energy or vibrational energy, and when the particles return to the initial stable levels, they emit a photon, so that the spontaneously emitted radiation energy is less than the excitation energy and the emitted wavelength is longer than the exciting wavelength [69]. the difference in wavelength or frequency units in the location of the absorption and emission (fluorescence) spectra of the same electronic transitions is known as Stokes displacement [70]. Figure (2.2) shows the Stokes displacement between the absorption and the emission spectrum.

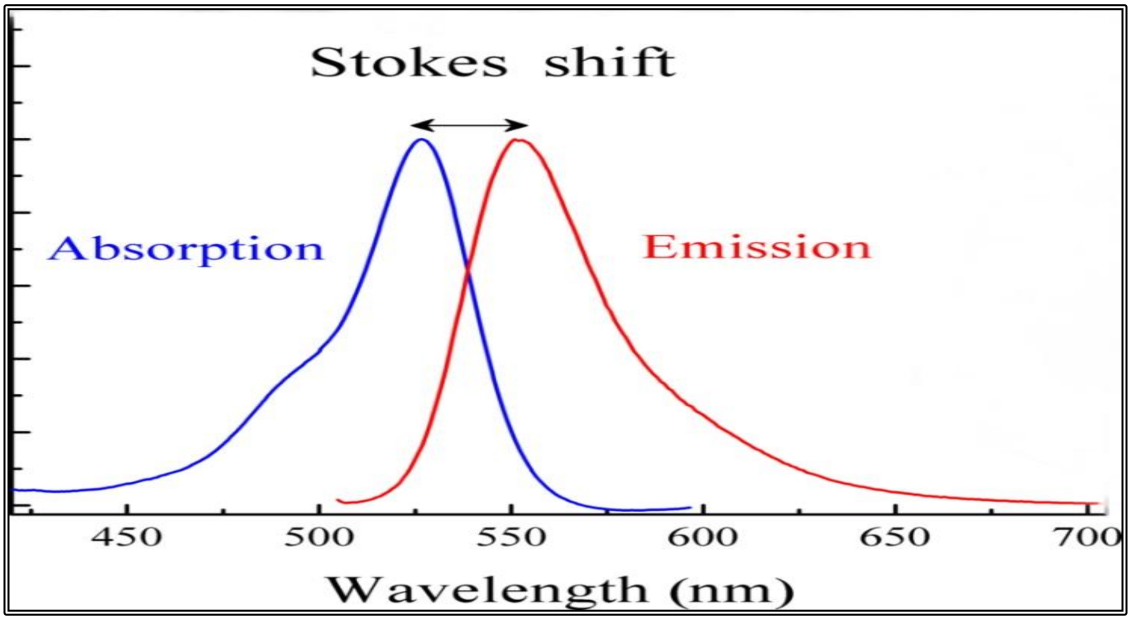

Figure (2.2): Stokes displacement between the absorption spectra and the emission spectrum [71]**.**

2.4.1.2. Phosphorescence:

According to the laws of quantum mechanics, this process is not allowed (indirect transitions) because it occurs between different multiplicity levels, as it requires a change in the magnetic spin of the electron returning to the single levels. Phosphorescence occurs when dye molecules move from the lowest vibrational level of the T_1 levels to the different vibrational levels S_o.

Since the energy of the singlet levels (S_1) is higher than that of the triple levels (T_1), therefore, the Phosphorescence spectrum is observed at wavelengths longer than the fluorescence spectrum the measured lifetime of phosphorescence is relatively long (1×10^{-4} msec). The Phosphorescence process is rapidly affected by collisions at low temperatures. One of the characteristics of Phosphorescence is that the emission continues after the source of irritation is removed due to the long lifetime of the triplet level. Therefore, the Phosphorescence process is not suitable for laser action[72].

2.4.2. Photophysical Non-Radioactive Transition

Non-radioactive transitions of dye molecules in which energy is dissipated and divided into[73]:

2.4.2.1. Intersystem crossing

It is a non-radioactive, symmetric energy transition in which the molecule relaxes in the excited state (S_1) to the lower level of the triplet excited state ($S_1 \rightarrow T_1$) at an interfacial crossing rate (K_{ISC}) of the order of ($10^{-6} – 10^{-11}$) s^{-1} and then returns to the ground state (S_o). either by a radioactive process ($T_1 \rightarrow S_o$) called phosphorescence, or by a non-radioactive process ($S_o \rightarrow T_1$) which is reverse intersystem crossing, and the rate constant for this process (K_{ISC}) is in the range of (10^{-2}-10^4) s^{-1} [74].

2.4.2.2 Internal Conversion

It is a direct transition process that occurs between the levels of one polymorphism, i.e. between the triple excited electronic levels (T_1) or between the single excited electronic levels (S_o) in a very short time of less than (10^{-11}) seconds. The excited molecule loses its energy in the form of thermal energy by collision Therefore, due to these transitions, a decrease in the value of the quantitative efficiency of fluorescence occurs in organic compounds, meaning that the internal transformation process does not prevent the occurrence of the lasing action, but it lowers the efficiency of the laser, so laser dyes with low internal transformation rates, i.e. those with high fluorescence efficiency, are preferred [75]. the process of internal transformation depends on the nature of the solvent in which the organic dye was dissolved and the properties of the solvent, as well as on the molecular structure of the organic material used [76].

2.5 Fluorescence Quantum Efficiency

The time of the radioactive transition from the lower vibrational level to the excited electronic state then to a ground vibrational level and back to its first state after this period time is called radioactive lifetime (τ_{FM}) , which is defined as the inverted rate of probability of radiation transition (K_{FM}) in unit (sec^{-1}) [77]

$$\tau_{FM} = \frac{1}{K_{FM}} \qquad (2.13)$$

Where: (K_{FM}) represents the probability of radiation transition

Because of the presence of non-radioactive processes competing with the possibility of the probability of radiation transition (K_{FM}) it will reduce the number of particles qualified for fluorescence emission, so the total probability of transition (K_F) will be the sum of the radiated and non-radioactive transition [30, 31]

$$\tau_f = \frac{1}{K_{FM} + \sum K_d} = \frac{1}{K_F} \qquad (2.14)$$

Where (ΣK_d) is the sum of constants (rate constants) for non-radioactive processes for the lowest vibratory state. The time of the fluorescence lifetime (τ_f) is the actual time of the fluorescence, which is equal to the inverted total constants of all non-radiative and radioactive processes that cause energy loss [25, 32]

$$\tau_f = \frac{1}{K_{FM} + K_{IC} + K_{ISC}} \qquad (2.15)$$

Where K_{IC} is the rate of inter conversion (sec^{-1}) and K_{ISC} is the rate of intersystem crossing (sec^{-1}). Can be the main lifetime of the excited state. There is a relation between fluorescence intensity and fluorescence lifetime (τ_f) [33, 34]

$$I = I_{\circ} \exp(-t/\tau_f) \qquad (2.16)$$

Where (I) is the fluorescence intensity at time (t), ($I_{\circ}$) represents the highest fluorescence intensity and (t) time immediately after the cessation of excitation.

The lifetime of fluorescence (τ_f) can be calculated from a standard compound known as its chronological age, as well as the area under the curve, as in the following relationship [83].

$$\tau_f = \frac{a \times \tau_{fRB}}{a_{RB}} \qquad (2.17)$$

Where (τ_{fRB}) is the lifetime of the standard compound, the Rhodamine B (3.230 ns) at the concentration (10^{-4}) M and a_{RB} is the area under the fluorescence curve of Rhodamine B and its value (117.6 cm^{-1}) , (a) is the area under the curve of the compound required in this research[83].

The quantum efficiency (Φ_f) represents the quantum yield of fluorescence, which is the ratio between the probability of radiation transition (K_{FM}) and the average of processes for the singles state ($K_{FM}+K_{IC}+K_{ISC}$).This value is a physical constant of each type of excited particle or the ratio of total energy emitted to the amount of absorbed energy. [84]

$$\phi_F = \frac{K_{FM}}{K_{FM} + K_{IC} + K_{ISC}} = \frac{K_{FM}}{K_{FM} + \sum K_d} \qquad (2.18)$$

$$\phi_F = K_{FM}\tau_F = \frac{\tau_F}{\tau_{FM}} \qquad (2.19)$$

It is also possible to calculate the quantum yield of fluorescence (Φ_{FM}) by calculating the ratio between the area of the fluorescence spectrum and the area of the absorbance spectrum, as shown in equation (2.20) [31]

$$\phi_f = \frac{\int F\,(v')\,dv\prime}{\int \varepsilon\,(v')\,dv\prime} \qquad (2.20)$$

It has been observed that the quantum yield of fluorescence for several compounds depends on the wavelength used in the excitation [64,37] and the temperature. So the quantum yield of fluorescence increases when non-radioactive processes decrease and when the temperature is reduced, the relation between them is reversed [82]The values of fluorescence production are between (0-1), therefore, the lifetime of the fluorescence is far less than the radiation lifetime due to the non-radioactive processes competing for the fluorescence process [86]Since values of the quantum efficiency are less than or equal to one, then **($\tau_{FM}>\tau_f$)** [87]

2.6. Factors affecting the characteristics of Organic Laser Dyes

Many factors effect on properties of Laser dyes are:

2.6.1. Impurities Effect

When the solution has a molar concentration of impurities, then the collision between the excited organic molecule $^1M^*$ and impurities leads to quenching of the excited molecule $^1M^*$ and an increase in the internal conversion rate or intersystem crossing rate [88]. The impurity quenching rate constant is which represents the time rate of quenching caused by the collision of impurities, therefore the fluorescence quantum efficiency decrease [89].

The other types of quenching processes are caused by impurities such as the existence of negative ions (ClO_4^-, Cl^-, Br^-, I^-) or the existence of O_2 resulting in quenching fluorescence, as a result of the charge transfer between the excited chromophore and negative ion. The quantum efficiency of dye fluorescence in the existence of the negative ion depended on the dye concentration and type of solvent [90].

2.6.2. The Concentration Effect

The absorption spectrum is normally subject to the Beer-Lambert law, meaning that the absorption cross-sections do not depend on the concentration, and the increase in the molar concentration of the dyes leads to the formation of agglomerations. - Lambert - changes occur in the properties of the absorption spectrum, and exposure of the beam with the direction towards the low-frequency region, and this leads to a decrease in the quantum output of fluorescence [91].

It has been observed that increasing the concentration of rhodamine 6G in water constitutes Steady ground state dimers, which result from the inverse encounter of two unchanged monomer molecules, are responsible for the change in the shape of the absorption spectrum of most dye solutions in high concentrations and are non-fluorescent. As for methanol, this dye has a low tendency to form this type of dimer [91].

In high concentration, the dye molecules are close to each other, and by random movement they collide with each other to form pairs of close space [92].The aggregates appear in concentrated solutions of fluorescence, as the monomer is present together with the dimer and the trimmer. These aggregates have no emission at a temperature of 20 °C. [93].

2.6.3. The Solvent effect

Solvents can also cause displacement of the absorption and fluorescence spectra, displacement of both absorption and a fluorescence spectrum implies the interaction of the solvent of both the ground state and the excited state of the molecule. On the other hand, when the fluorescence emission spectrum alone is changed, the implication is an interaction of the solvent with the excited state of the molecule but not with the ground state [94]. Since the solvent reorientation process is a director of the polarization of the excitement of the solute, it is not surprising that solvent effects on the Franck-Condon shift have been related to the dielectric constant of the solvent[95].

The PH of the solvent is also important. Many organic dyes may behave as weak acids or bases. In proton solvents, therefore partial or complete dissociation or protonation can occur in the ground state species of the solute. In effect, new species having their unique absorption and emission spectra are formed. It is also known that the acid-base properties of the excited states are often different from those of the ground state [96]

A dye may become a stronger acid or a stronger base in the excited state. This property results in dissociation and protonation, reactions in the excited state only. The reaction products are unstable in the ground state with the result that they manifest themselves by changing the fluorescence spectrum only leaving the absorption spectrum unchanged [97] The solvents also affect the fluorescence lifetime. In the case of large molecules, the spectra are shifted toward longer wavelengths but fluorescence lifetime is less affected [97].

2.7.4. The Self-Absorption Effect

self-absorption causes fluorine suppression as a result of the overlap between the fluorescence spectrum and the absorption spectrum where photons emitted by other non-irritating molecules in the dye solution are reabsorbed and this process is called self-absorption, this process changes quantitative efficiency and lifetime from their real values and the probability of self-absorption or self-absorption factors depends on the extent of molecular overlap between the absorption spectrum and the emission spectrum and the concentration as well as on the thickness of the sample passing through it is during which fluorescent photons and temperatures are reduced, their value decreases with low temperature, increases by increasing concentration, and reduces the effect of self-absorption using very diluted solutions[49, 24].

3.1 Introduction:

This chapter includes a description of the utilized chemical materials and their solvents, scheme of the work and methods of preparation the liquid solutions and their mixture (dye, polymer, nanoparticles) as well description of used devices in the measurements.

3.2. The Utilized Materials

3.2.1. Nile Blue Dye

The Nile Blue dye that is used in this research was obtained by (Sigma-Aldrich/ Germany) with high purity (99.9%).Table (3.1) shows some of the physical and chemical properties of Nile Blue.

Table (3.1): Some of the physical and chemical properties of NB[17].

Property	Description
Dye Name	**Nile Blue A(sulfate)**
Trade Name	**Nile Blue**
Supplied company	**(Sigma-Aldrich/ Germany)**
Color	**Blue Powder**
Class	**a phenoxazine**
λ_{max}	**664 nm**
Solvents	**Water,methanol,ethanol,others**
Chemical Formula	$2C_{20}H_2ON_3O.SO_4$
Molecular Weight	**732.85 g/mol**

3.2.2. Polyvinylpyrrolidone Polymer (PVP)

PVP polymer that is used in this work is obtained by Anhui Leafchem Co., Ltd, China (mainland) and has high purity (99.8%). Table (3.2) shows some of the physical and chemical properties PVP polymer.

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Table (3.2): The physical properties of Polyvinylpyrrolidone polymer[20].

Property	Description
The appearance	White powder (milky)
Solvents	water/ethanol/methanol
Abbreviation	PVP
Molecular Formula	$(C_6H_9No)_n$
Density	1.2 g/cm3
Melting Point	150c°-180c°
Molecular Weight	40.000gm/mol

2.2.3. Distilled Water Solvent

Water is the one of the most common polar solvent. Table (3.3) shows some of the chemical and physical properties of distilled water solvent.

Table (3.3): Some of the chemical and physical properties of distilled water solvent[99].

Property	Description
Chemical Formula	H_2O
Molecular Weight (gm/mole)	18.015
Refractive index	1.333
Dielectric Constant	78.540
Polarity	1.84
Viscosity(centipoises) at 20 C^o	1.008
Density(gm/cm^3)	1

3.2.4. Ethanol Solvent

It is an alcoholic organic chemical solvent and chemical formula (C_2H_5OH) and is called generally called alcohol. It is characterized by a polar compound that has the property of creating a hydrogen bond between its molecules as well as a group of hydroxyls that produce the increased cohesion of bonds and is characterized by a colorless volatile liquid that blends with polar solvents such as water and forms hydrogen ligaments with water [106]. Table (3.4) show some physical properties of water and ethanol.

Table (3.4): Some of the chemical and physical properties of ethanol solvent[87].

Property	Description
Chemical Formula	C_2H_5OH
Molecular Weight (gm/mole)	**46.07**
Refractive index	**1.3614**
Dielectric Constant	**24.195**
Polarity	**1.69**
Viscosity(centi poises) at 20 C^o	**1.943**
Density(gm/cm^3)	**0.7936**

3.3. Scheme of the Work

Figure (3.1) shows the scheme of main steps of the experimental part in this work.

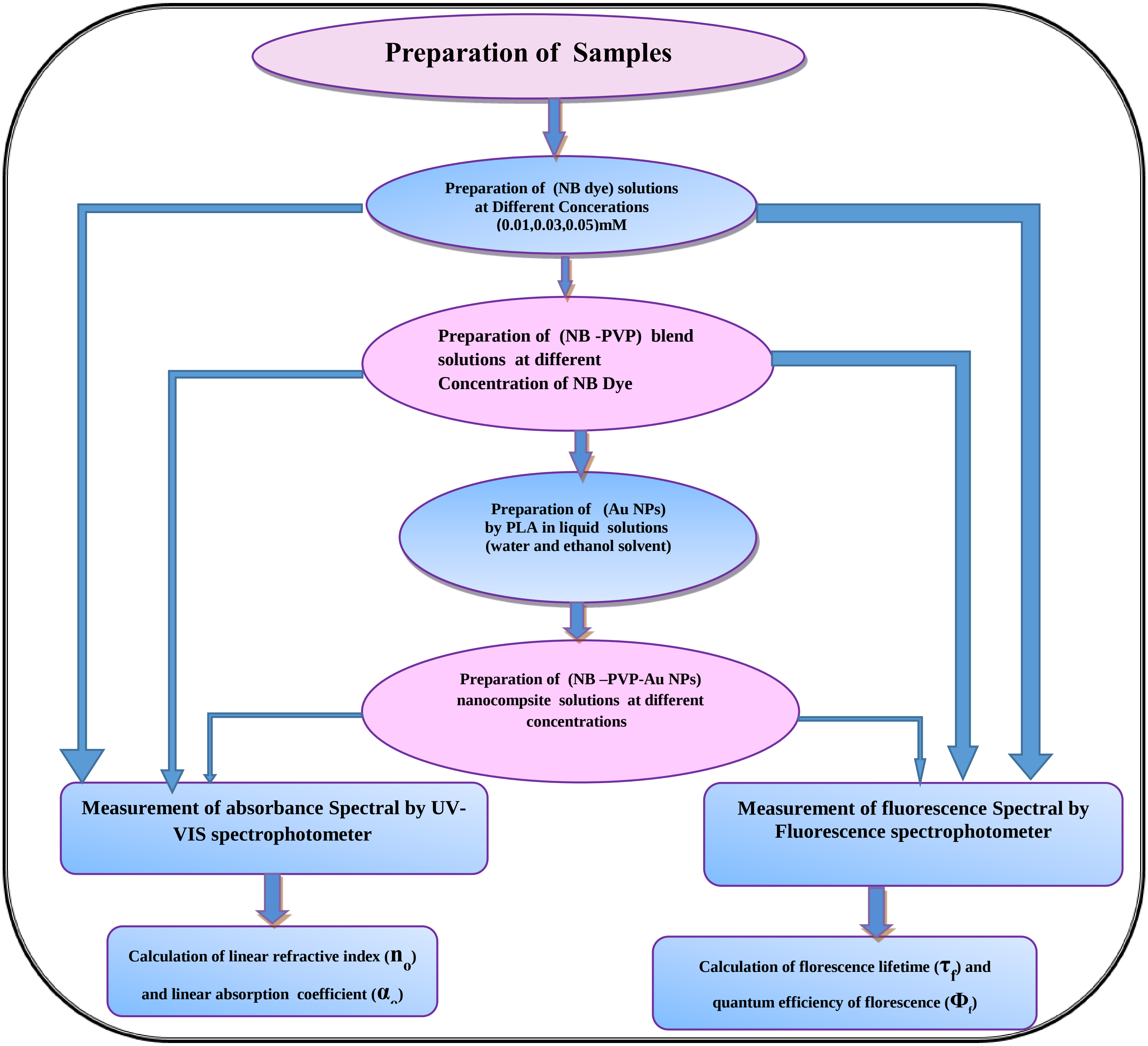


Figure (3.1): Main steps of the experimental work.

3.4. Preparation of Nile Blue dye solutions

To prepare solutions of Nile blue dye in concentration (1×10^{-3} mM), in both solvents, water and ethanol to dissolved (0.18 g) of (NB) dye powder for volume of (30 ml) of solvents used in this study and according to the relationship:

$$W = \frac{V\times C\times Mw}{1000} \quad \ldots\ldots\ldots\ldots\ldots (3.1)$$

Where

W: The weight of the dye needed to obtain the desired concentration is measured (gm)

M_W: The molecular weight of the dye used is measured (gm/ mole)

V: The volume of solvent to be added to the dye is measured (cm^3)

C: The concentration to be prepared is measured in units (M).

Also, the prepared concentration can be diluted through the use of the following relationship :

$$C_1 V_1 = C_2 V_2 \quad \ldots\ldots\ldots(3.2)$$

C_1= the concentration of the original solution.

C_2= Concentration after dilution

V_1=.= the volume of the original solution.

V_2= the final volume of the diluted solution.

The following concentrations were obtained (0.01,0.03, 0.05) mM as shown in Figure (3.2)

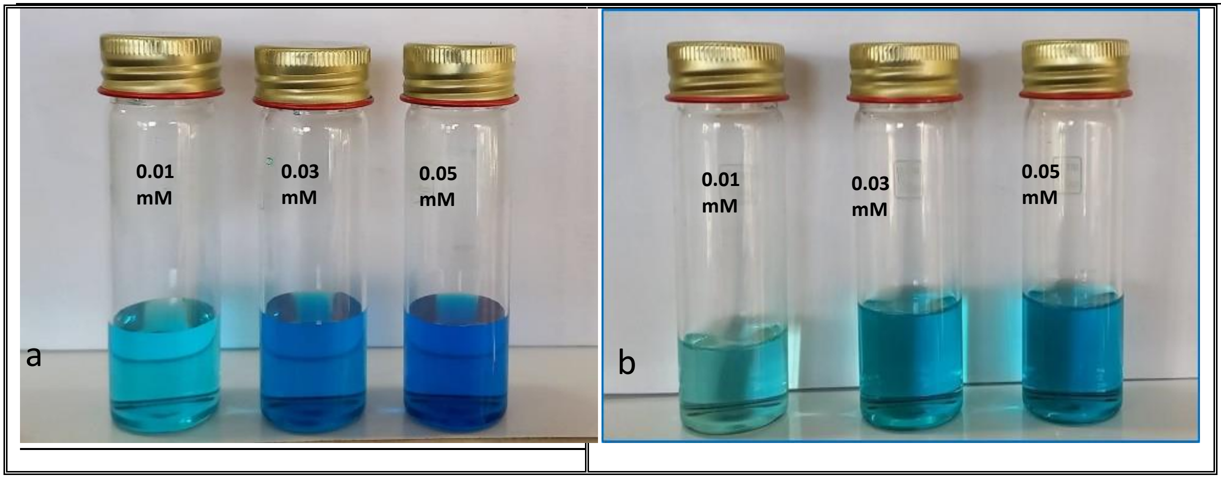


Figure (3.2): The solutions samples of NB dye at different concentrations in a.Water solvent. b. Ethanol solvent.

3.5. Preparation of the (NB - PVP) blend solutions

The blend(NB-PVP) is prepared by dissolving an amount of polymer powder(0.5) with (50ml) distilled water and ethanol solvents and stirring it by magnetic stirring for a period (5)min. Then we add equal amounts of the polymer solution to equal amounts of the used dye 1ml (NB) =1ml (PVP), then put it under magnetic stirring for 30 min, and thus we get solutions (NB-PVP) blend, as shown in the Figure (3.3).

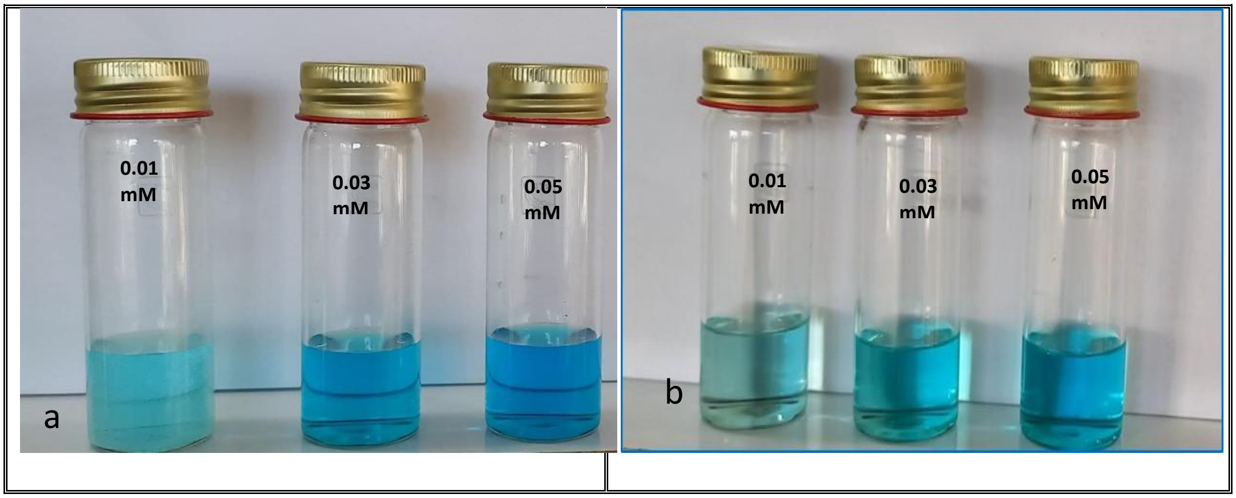


Figure (3.3): The solutions samples of (NB-PVP) blend at different concentrations in a. water solvent. b. ethanol solvent.

3.6. Preparation of the gold nanoparticles(Au NP$_S$)

A colloidal solution of gold particles was prepared with two solvents, distilled water, and ethanol using PLAL, by taking a gold strip of purity 99.9% and placing it in a glass beaker containing distilled water or ethanol after cleaning the metal with alcohol to remove impurities then a laser beam Nd: YAG(Chinese-made) of a wavelength (1064 nm) is projected onto the plate inside the case through a convex lens (10mm), the necessary force was (120 mJ/ pulse, pulse width 5 ns ,6 Hz,30 ns) to complete the process of removing the gold particles. noticed the change in the color of the liquid to a dark red, indicating the formation of the nanofluid. The concentration and size of the particles depend on the number of pulses that are fired . Figure (3.4) represents the device used for laser ablation and an experimental scheme for preparing nanoparticles.

Au NPs in Water

Au NPs in Ethanol

Figure (3.4): Scheme the preparation of (Au NPs) solution by laser ablation in liquid method.

3.7. Preparation of the (NB -PVP / AuNps) nanocomposite solutions

The nanocomposite is prepared by taking (1ml) of the colloidal solution of gold nanoparticles and adding it to the mixture (PVP-NB) and stirring it by magnetic stirring for (30 minutes), thus obtaining the (NB-PVP/Au NPs) nanocomposite . Figure (3.5) shows the solutions samples of nanocomposite in distilled water and ethanol solvents.

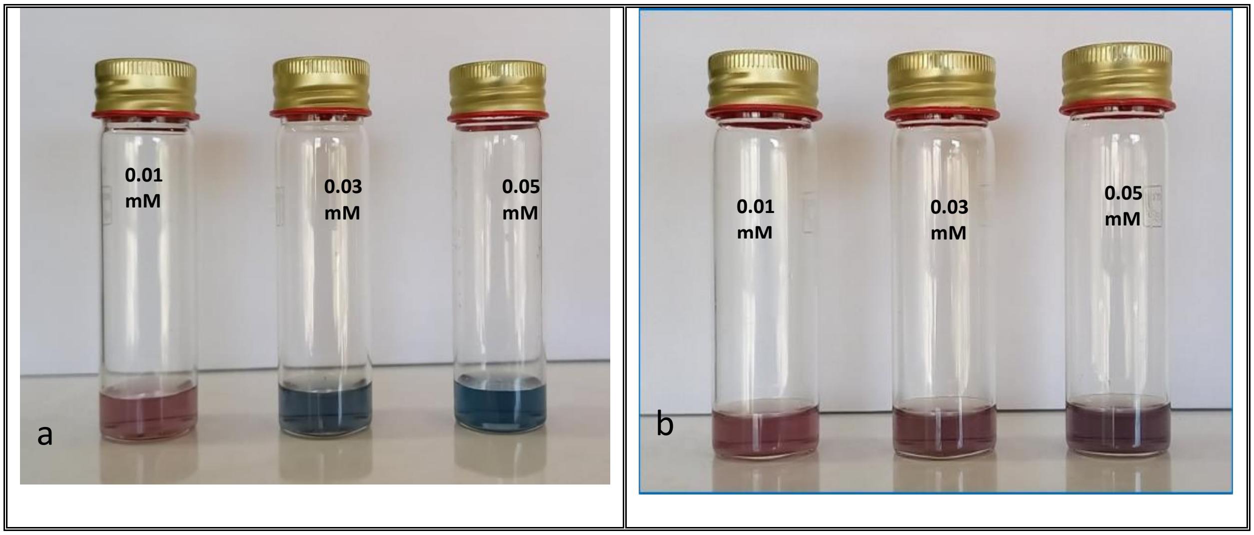


Figure (3.5): The solutions samples of (NB-PVP/Au NPs) nanocomposite at different concentrations in a. water solvent. b. ethanol solvent.

3.8. The used devices

3.8.1 Absorption Spectrophotometer

The absorption spectra for all solution samples are measured using (UV-Visible - Spectrophotometer) , type (SHIMADZU-1800).This spectrometer covers a large region of the electromagnetic spectrum, extending from the ultraviolet region to the near infrared region. Table (3.5) show specifications of used (UV-Vis Spectrophotometer), it is located in the Thin Film Laboratory, Department of Physics - College of Education for Pure Sciences as shows in the Figure (3.6).

Table (3.5) specifications of used (UV-Vis Spectrophotometer) (Shimadzu-1800).

Wavelength range	(190-1100) nm
Wavelength scan rate	Maximum 1000 nm / min
Light source	Deuterium and Tungsten Lamps
Detector	Silicon photodiode
Power requirements	(220-240) V (AC)

Figure (3.6) : UV-Visible spectrophotometer (Shimadzu-1800).

3.8.2 Fluorescence spectrophotometer

The fluorescence spectra of all prepared solutions samples were measured by a fluorescence spectrometer type (FluoroMate FS-2) of Korean origin and supplied by (SCINCO) company.Table (3.6) shows the specifications of fluorescence spectrophotometer (FluoroMate FS-2).All samples were examined in the laboratory of thin film College of Education for Pure Sciences - Department of Physics, as shown in Figure (3.7).

Table (3.6) : Specifications of fluorescence spectrophotometer (FluoroMate FS-2)

Wavelength range	(200 - 900) nm
Wavelength scan rate	200/400/600 nm / min
Light source	150 W (Xenon arc lamp)
Detector	PMT
Power requirements	(220-240) V (AC)
Resolution	0.5 nm
Wavelength Accuracy	1.0 nm

Figure (3.7) : The Fluorescence Spectrophotometer (FluoroMate FS-2) Device.

3.8.3. Scanning Electron Microscope (SEM)

Figure (3.8) shows the scanning electron microscopy device (SEM, JSM-7610F, Carl Zeiss, Germany) that operates at an accelerated voltage of 10 kV. Using SEM microscopy the information on the surface morphology of the samples and the particle size of (Au NPs) deposited on a glass substrate was determined. Figure (3.9) shows the scanning electron microscopy device(SEM, JSM-7610F, Carl Zeiss, Germany). Figure (3.11) shows the SEM image of (Au NPs) solutions in water and ethanol solvants.

Figure (3.8): Scanning Electron Microscopy device (SEM, JSM-7610F, Carl Zeiss, Germany)

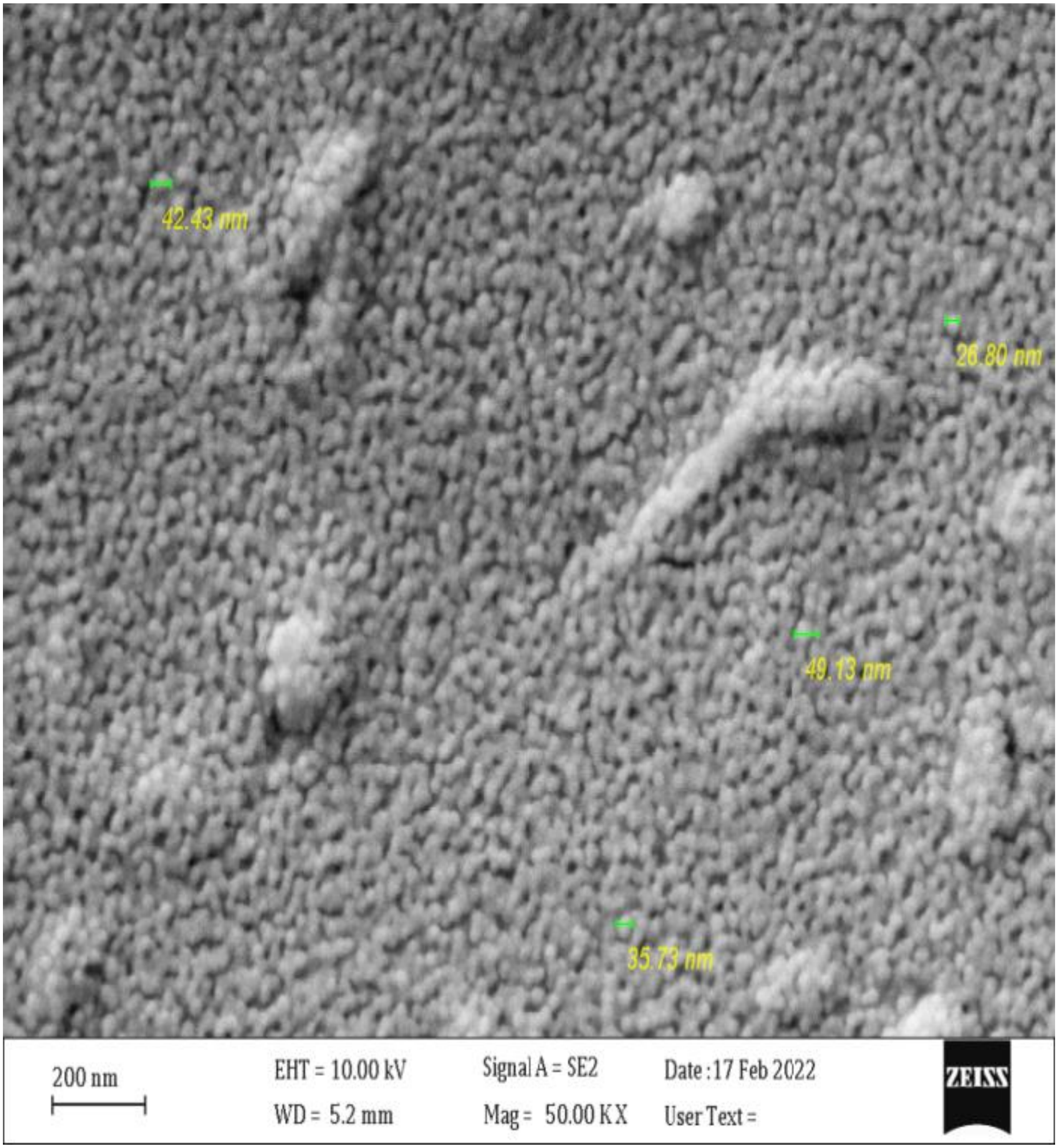


Figure (3.9) SEM image of (Au NPs) solutions in water solvent .

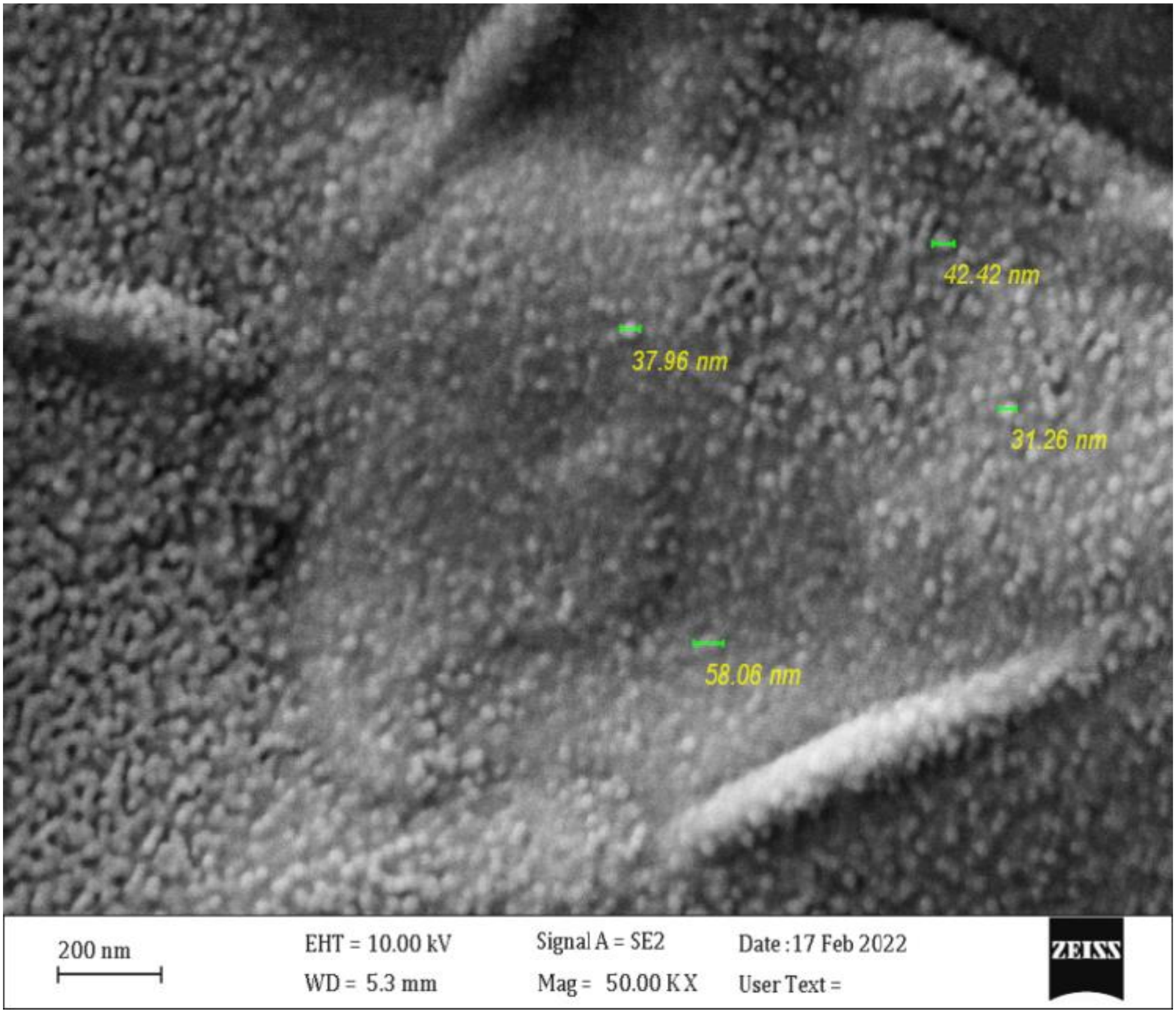


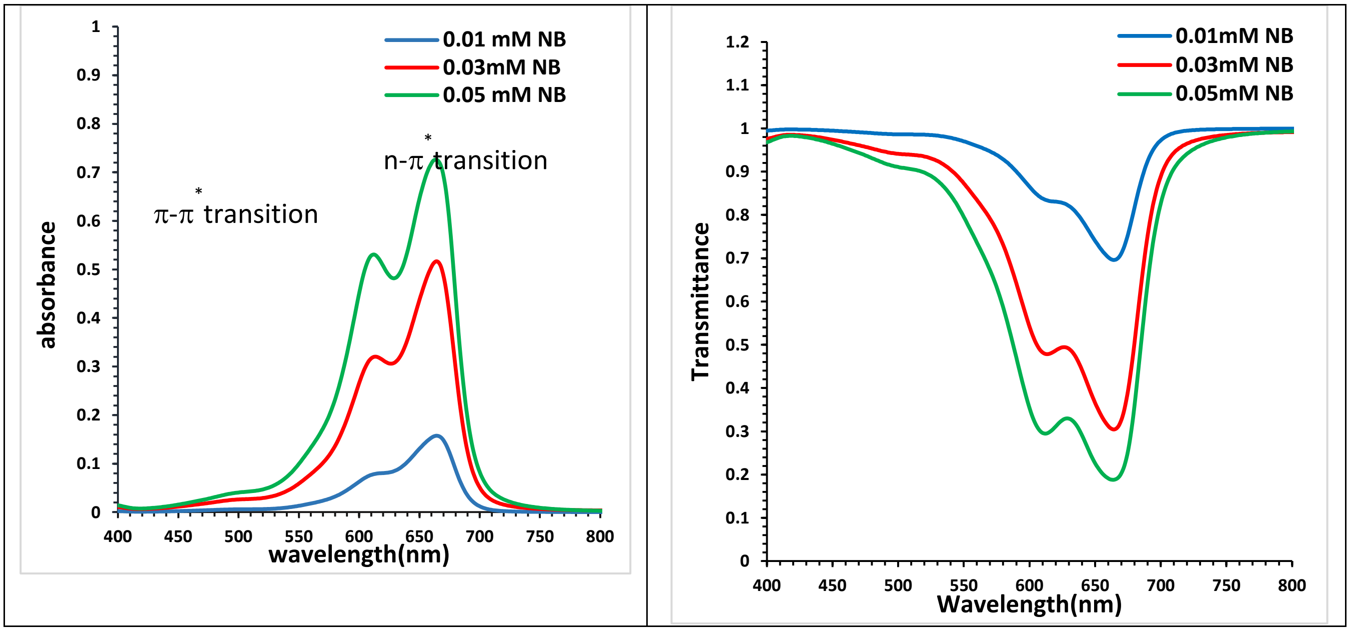
Figure (3.10) SEM image of (Au NPs) solutions in ethanol

4.1. Introduction

This chapter includes the results and discussion of the absorption spectra and linear optical properties (linear refractive index and absorption) as well as emission spectra (fluorescence) and spectral properties (the fluorescence lifetime and the quantum yield of fluorescence) of solutions (Nile blue dye, dye blend and composite) dissolved in different solvents (water, ethanol). And with different dye concentrations and with constant volume ratio additions of PVP polymer and gold nanoparticles (Au NPs). The chapter also includes the most important conclusions that have been reached and proposals for future work.

4.2. Absorbance and Transmittance spectra of Nile blue dye Solutions Dissolved in Distilled Water Solvent

Figure (4.1) shows the absorbance and transmittance spectra of NB dye solutions dissolved in water with different concentrations (0.01, 0.03, and 0.05) mM. From this figure it is observed that the absorbance and transmittance spectra consist of two peaks, and this is evidence that the exciting levels of the dye consist of two separate groups of levels, i.e. the occurrence of electronic transitions the first transition ($\pi \rightarrow \pi^*$) at short wavelengths (600-630) nm ,second transition ($n \rightarrow \pi^*$)at long wavelengths(630-670)nm[101]. The absorbance increases with increasing concentration according to Beer-Lambert's law, and the transmittance decreases because it is the opposite of absorbance. The figure shows that the width of the absorption spectrum decreases with increasing concentration.



Figrue (4.1): The Absorbance and transmittance spectra of NB dye solutions at different concentrations in distilled a water solvent.

Table (4.1) shows the values of absorbance, transmittance, linear absorption coefficient, and linear refractive index of NB dye dissolved in a water where we notice an increase in the linear absorption coefficient and the linear refractive index, and that the reason for increasing the linear refractive index depends on the density of the solution, meaning that the higher its density, the higher the refractive index.

Table (4.1) the linear optical properties of NB dye dissolved in water solvent

Material	C(mM)	λ_{abs} nm	A	T	$\alpha\ (cm)^{-1}$	n_o
NB Dye	0.01	664	0.15	0.69	0.36	1.75
	0.03	663	0.51	0.30	1.18	1.98
	0.05	662	0.72	0.18	1.67	2.39

4.3. Fluorescence Spectra of NB dye Solutions Dissolved in Distilled Water Solvent

The fluorescence spectra of samples prepared for (NB dye) solutions dissolved in water solvent at different concentrations (0.01,0.03,0.05) mM are measured using fluorescence spectrometer as shown in Figure (4.2). It is noted from the figure that the highest fluorescence intensity is (6310) and is located at the wavelength (699 nm). It is also noted that increasing the concentration leads to a decrease in the fluorescence intensity and the shift towards short wavelengths (blue shift) due to the interaction between the particles of the medium when the concentration changes. From the results of the absorbance and fluorescence spectra, the fluorescence lifetime (τ_f) and the quantum yield of fluorescence (Φ_f) were calculated. It is noted that increasing the concentration leads to an increase in the values of the lifetime of fluorescence (τ_f) and a decrease in the values of the quantum yield of fluorescence (Φ_f), and that the highest quantum yield is (0.71), as shown in Table (4.2).

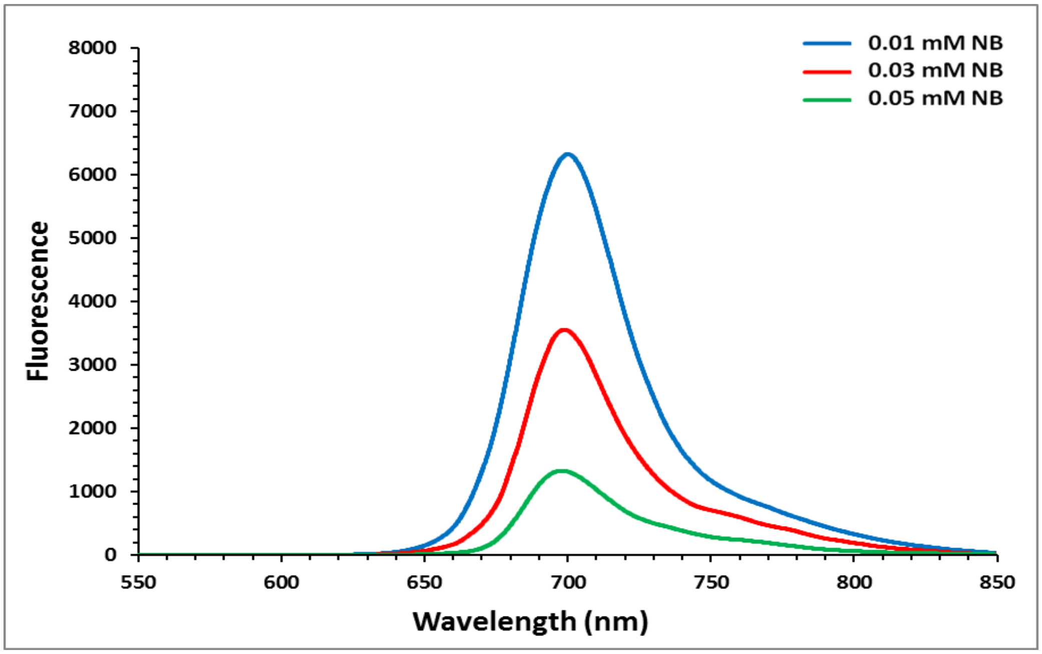


Figure (4.2) Fluorescence spectra of NB dye solutions dissolved in water solvent and at different concentrations.

Table (4.2) Spectral properties of NB dye dissolved in water solvent and at different concentrations.

Material	C(mM)	λ_{flu} nm	Intensity	τ_f	Φ_f
NB Dye	0.01	699	6310	4.23	0.71
	0.03	698	3398	5.87	0.62
	0.05	697	1392	6.56	0.53

4.4. Absorbance and transmittance Spectra of (NB-PVP) Blend Solutions Dissolved in Distilled Water Solvent

Figure (4.3) shows the absorbance and transmittance spectra of the (NB-PVP) blend solutions with different concentrations of Nile Blue dye at room temperature, upon adding NB dye to PVP polymer,blue shift in the maximum peak of monomer(n-π^*)transitions was observed with increasing doping ratio of the NB dye, which went from (664 nm), the intensity is(0.07) at low doping ratio to (662 nm), the intensity is (0.40) at the high ratio. Nevertheless, with an increasing concentration of dye for a fixed amount of polymer, the absorption intensity of NB increases as well. However, by comparison with the intensity in the previous figure for NB dye alone, it is noteworthy that this intensity was found to be reduced due to the quenching of NB by crosslinking with PVP polymer, which is the mechanism responsible for enhancing dye elimination from liquids. Furthermore, due to the overlap between molecules of PVP and the dye molecules in the molecular electronic energy levels, this leads to the split of the energy levels. As a result, the absorbance intensity decreases compared to the NB dye solution. It was found also that the discrepancy of the width of the absorption spectra of low concentrations is greater than in high concentrations[102]. Table (4.3) show the values of absorbance, transmittance, linear absorption coefficient, and linear refractive index of (NB- PVP) blend dissolved in water.

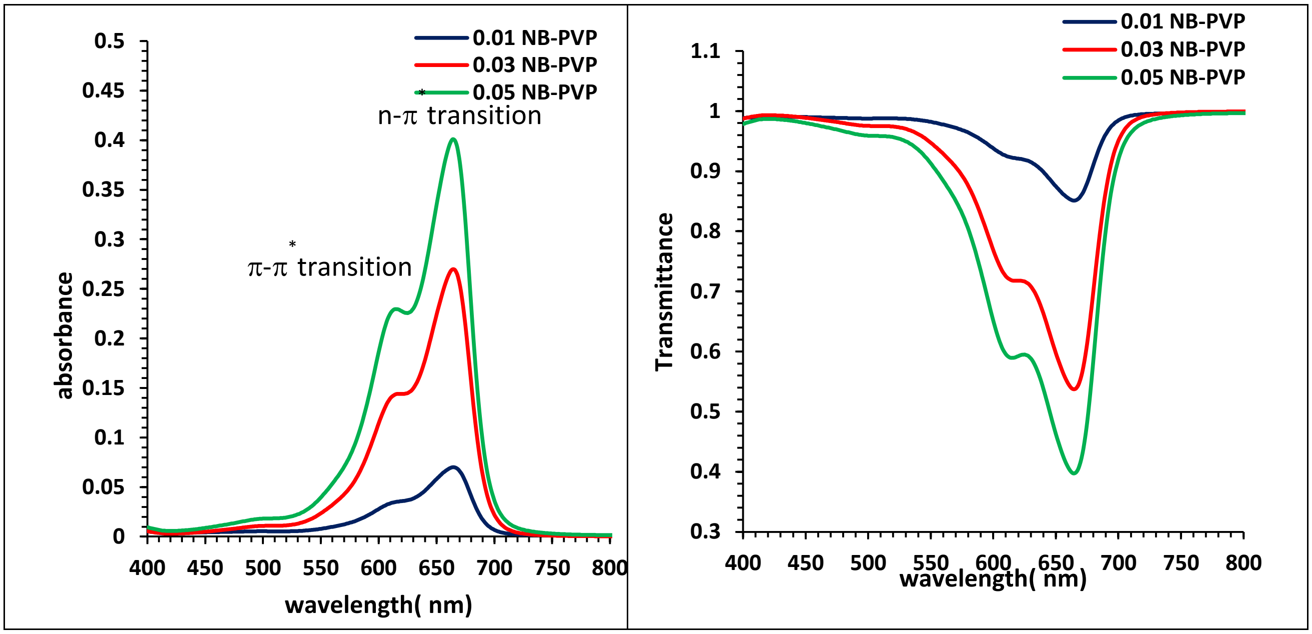


Fig (4.3) The Absorbance and transmittance spectra of (NB-PVP) blend solutions at different concentrations in distilled a water solvent.

Table (4.3) The linear optical properties of (NB -PVP) blend dissolved in a water

Material	C(mM)	λ_{abs}	A	T	α (cm)$^{-1}$	n_o
(NB - PVP) Blend	0.01	664	0.07	0.85	0.61	1.92
	0.03	663	0.2	0.53	1.62	2.07
	0.05	662	0.4	0.39	1.92	2.53

4.5. Fluorescence Spectra of (NB- PVP) Blend Solutions Dissolved in Distilled Water solvent

Figure (4.4) shows the fluorescence spectra of (NB-PVP) blend solutions dissolved in water solvent with different concentrations of NB dye (0.01,0.03,0.05) mM, and it is noted that the highest fluorescence intensity is (6350) and is located at the wavelength (697 nm).

It is also noted that the increase in concentration leads to a decrease in the fluorescence intensity and the shift towards short wavelengths (blue shift).It is also noted that the values of the quantum yield fluorescence output of (NB-PVP) Blend solutions are greater compared to (NB dye) solutions, and the reason for this is due to The decrease in the absorbance values and the increase in the fluorescence intensity values for the Blend and for all concentrations, and the highest value for the quantum yield is (0.82) as shown in Table (4.4).

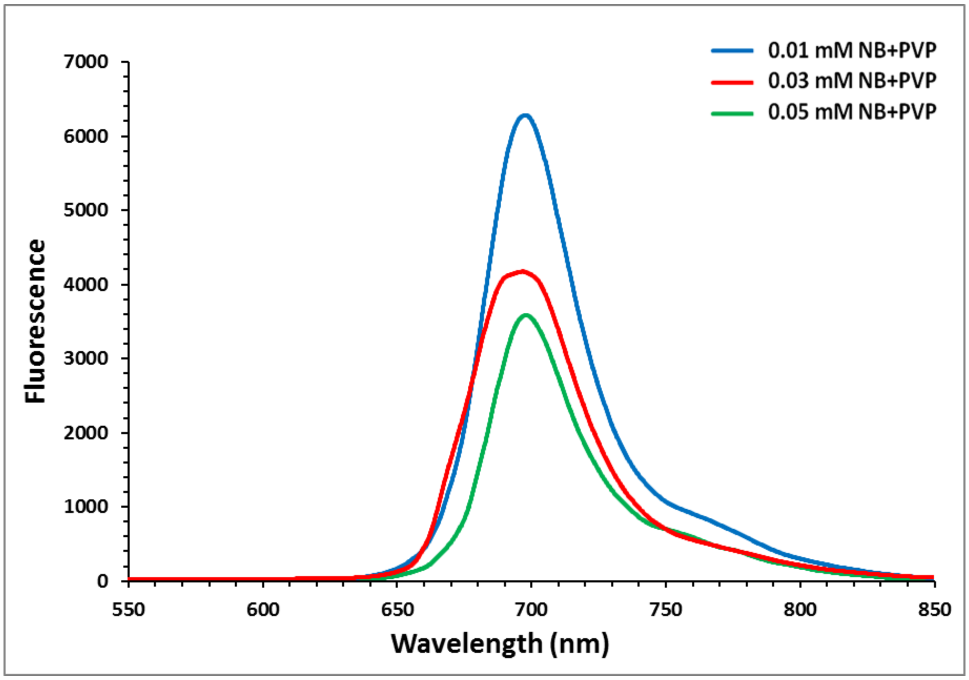


Figure (4.4): Fluorescence spectra of (NB- PVP) blend solutions dissolved in water solvent at different concentrations of NB dye.

Table (4.4): Spectral properties of solutions (NB- PVP) blend dissolved in water solvent at different concentrations of NB dye

Material	C(mM)	λ_{flu} nm	Intensity	τ_f	Φ_f
(NB - PVP) Blend	0.01	697	6350	3.15	0.82
	0.03	696	4196	4.27	0.74
	0.05	695	3605	5.48	0.63

4.6. Absorbance and Transmittane Spectra of (NB-PVP/Au Nps) Nanocomposite Solutions in distilled water

Figure (4.5) shows the absorbane and transmittance spectra of (NB-PVP/AuNps) nanocomposite solutions in distilled water when adding nanoparticles to (NB-PVP) blend at different concentrations of NB dye .The study of the effect of this addition was observed when the prepared nanoparticles were small the absorption spectra shift towards (blue shift), in addition to a decrease in the absorption intensity due to the interference between nanoparticles dye, and polymer molecules in energy levels, which leads to the division of energy levels and as a result the absorption intensity decreases. That the appearance of three peaks in the visible region, one of them represents the absorption band of (Au NPs), and the two peak represents the absorption band of (NB-PVP) blend dissolved in water[102]. Tables (4.5) show the values of absorbance, transmittance, linear absorption coefficient, and linear refractive index of (NB- PVP/ Au NPs) nanocomposite dissolved in water.

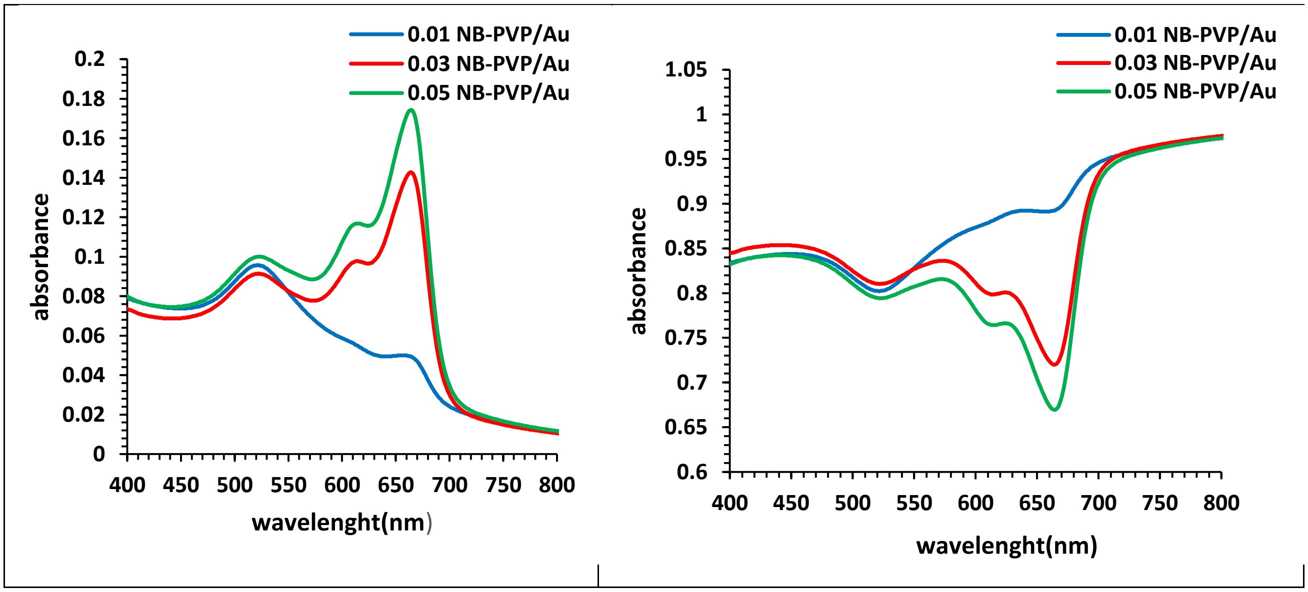


Figure (4.5): The absorbance and transmittance spectra of (NB-PVP/ AuNPs) nanocomposite solutions in water solvent at different concentrations of NB dye.

Table (4.5) the linear optical properties of (NB -PVP/Au NPs) nanocomposite dissolved in water solvent at different concentrations of NB dye.

Material	C(mM)	λ_{abs}	A	T	α (cm)$^{-1}$	n_o
(NB -PVP/Au NPs) nanocomposite	0.01	664	0.04	0.89	0.11	2.03
	0.03	663	0.14	0.71	1.32	2.68
	0.05	662	0.17	0.66	1.40	2.85

4.7. Fluorescence Spectra of (NB-PVP/AuNPs) Nanocomposite Solutions Dissolved in distilled water solvent

Figure (4.6) shows the fluorescence spectra of (NB-PVP/AuNPs) nanocomposite solutions dissolved in water solvent and with different concentrations of NB dye (0.01, 0.03, 0.05) mM. It is noted from the fluorescence spectra that the highest fluorescence intensity is (4641) and is located at The wavelength (693 nm), and it is also noted that increasing the concentration leads to a decrease in the fluorescence intensity and the shift towards short wavelengths (blue shift), also it is noted that the values of the quantum yield of fluorescence for (NB - PVP/Au NPs) nanocomposite solutions are greater compared with NB dye and (NB-PVP) solutions, due to the decrease in the nanocomposite absorbance values accompanied by an increase in the fluorescence intensity values for all concentrations, and the highest value of the quantum yield of fluorescence is (0.89) , as shown in Table (4.6).

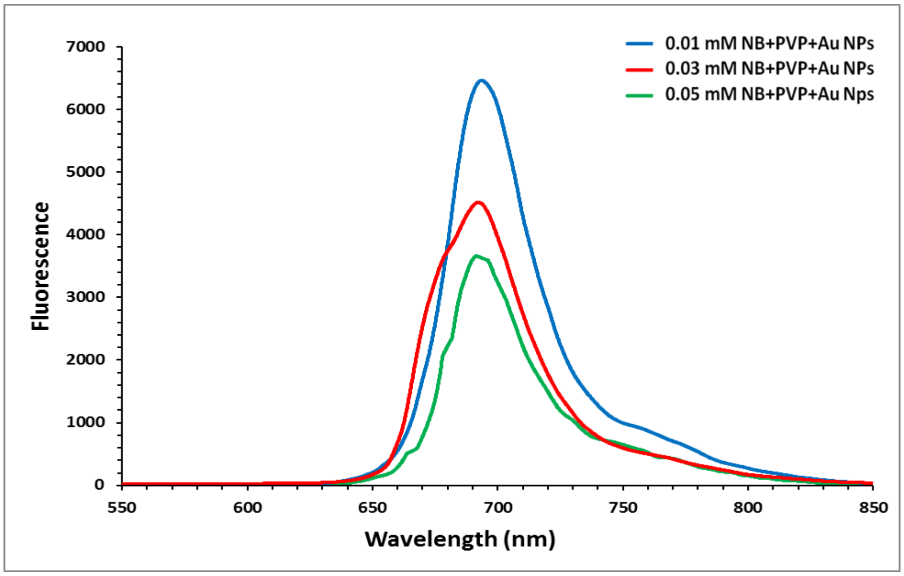


Figure (4.6) Fluorescence spectra of (NB- PVP/Au NPs) nanocomposite solutions dissolved in water solvent at different concentrations of NB dye

Table (4.6) Spectral properties of (NB- PVP/Au NPs) nanocomposite solutions dissolved in water solvent at different NB dye concentrations.

Material	C(mM)	λ_{flu} Nm	Intensity	τ_f	Φ_f
(NB -PVP/ Au NPs) Nanocomposite	0.01	693	6414	2.25	0.88
	0.03	692	4485	3.38	0.84
	0.05	691	3620	4.19	0.78

4.8. Absorbane and transmittance Spectra of Nile Blue Dissolved in Ethanol Solvent

Figure (4.7) shows the absorption and transmittance spectra of the NB dye solutions with different concentrations.It was observed that the absorbance peak shifted towards the (blue shift), When the concentration is increased, this is due to two reasons: the first reason is the increase in the number of particles, and the second reason is that the dipole moment of the ground state is less than the excited state.Concluded that increasing the concentration leads to an increase in absorbance and a decrease in transmittance according to the Beer-Lambert law. Table (4.7) shows the values of absorbance, transmittance, linear absorption coefficient, and linear refractive index of NB dissolved in ethanol.

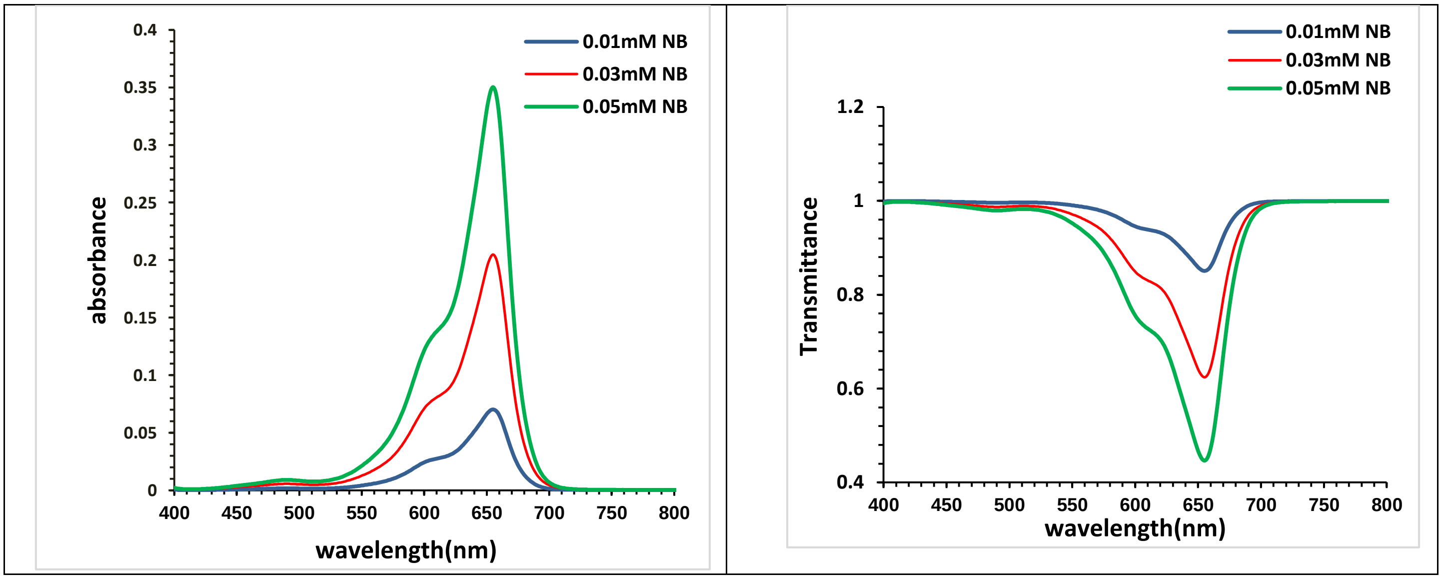


Figure (4.7): The Absorbance and transmittance spectra of NB dye solutions dissolved in ethanol solvent with different concentrations.

Table (4.7) shows the values of absorbance, transmittance, linear absorption coefficient, and linear refractive index of NB dye dissolved in an ethanol.

Table (4.7) The linear optical properties of NB dye dissolved in ethanol solvent.

Material	C(mM)	λ_{abs}	A	T	α (cm$)^{-1}$	n_o
NB Dye	0.01	655	0.07	0.85	0.16	1.66
	0.03	654	0.20	0.62	0.47	1.81
	0.05	653	0.44	0.44	0.80	2.15

To compare the two solvents and their effect on the absorbency of the dye, it was noted that the absorbance intensity of the dye in water is much greater than in ethanol. These differences can be caused by different properties of the solvent in terms of polarity and hydrogen bonding ability, as well as the ability of the dye to form dimers in water. Therefore, water is the ideal solvent for the dye.

4.9. Fluorescence Spectra of NB Dye Solutions Dissolved in Ethanol Solvent

Figure (4.8) shows the fluorescence spectra of NB dye solutions dissolved in ethanol solvent with different concentrations of NB dye (0.01,0.03,0.05) mM. It is noted from the figure that the highest fluorescence intensity is (14263) and is located at the wavelength (690 nm). It is also noted that the quantum yield of fluorescence values of NB dye solutions dissolved in the ethanol solvent are greater compared to NB dye solutions dissolved in the water solvent for all concentrations. And the highest value of the quantum yield of fluorescence is (0.77), as shown in Table (4.8).

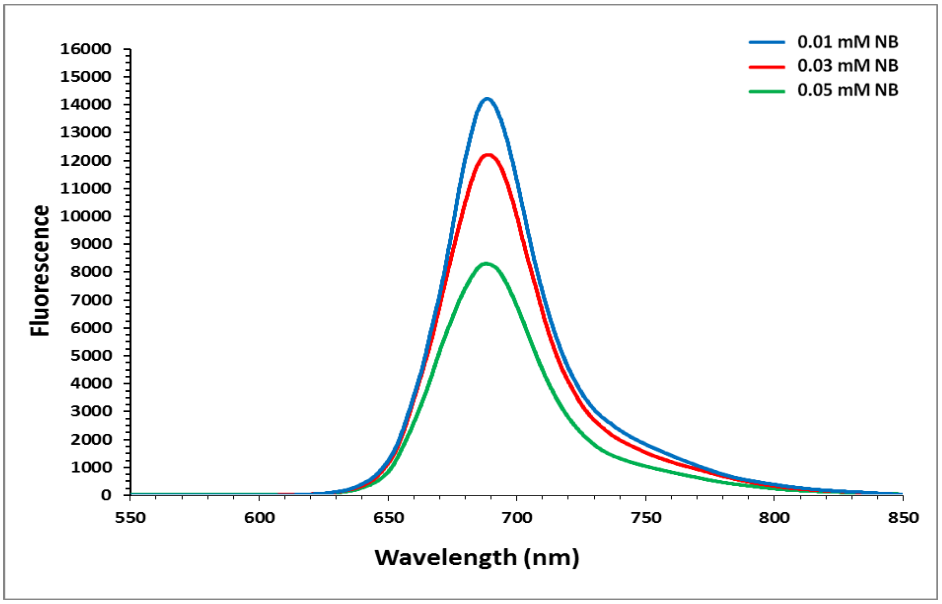


Figure (4.8) Fluorescence spectra of NB dye solutions dissolved in ethanol solvent at different concentrations.

Table (4.8) fluorescence spectra characteristics of Nile Blue dye solutions dissolved in ethanol solvent and at different concentrations.

Material	C(mM)	λ_{flu} Nm	Intensity	τ_f	Φ_f
NB Dye	0.01	690	14263	3.82	0.77
	0.03	689	12234	4.34	0.69
	0.05	688	8312	5.22	0.58

4.10. Absorbane and transmittance Spectra (NB-PVP) blend in Ethanol Solvent

Figure (4.9) shows the absorbane and transmittance spectra of a (NB) dye solutions after adding (PVP) a polymer to obtain (NB-PVP) blend solutions.

When the concentration of the polymer increases, the intensity of dye absorbance increases as well. When compared to the NB dye solutions adding comparable amounts of polymer resulted in a noticeable decrease in absorbance intensity, and when it was added, ablue shift was noted at the top of the monomer peak. It should be mentioned that the interference between dye molecules and polymer molecules at partially electronic energy levels resulted in decrease in density. As a result of the aggregate dyes being dimmer and trimmer than the pure dye solution, the intensity of absorption reduces. Transmittance reduces as concentration increases. Tables (4.9) show the values of absorbance, transmittance, linear absorption coefficient, and linear refractive index of (NB- PVP) blend solutions dissolved in ethanol.

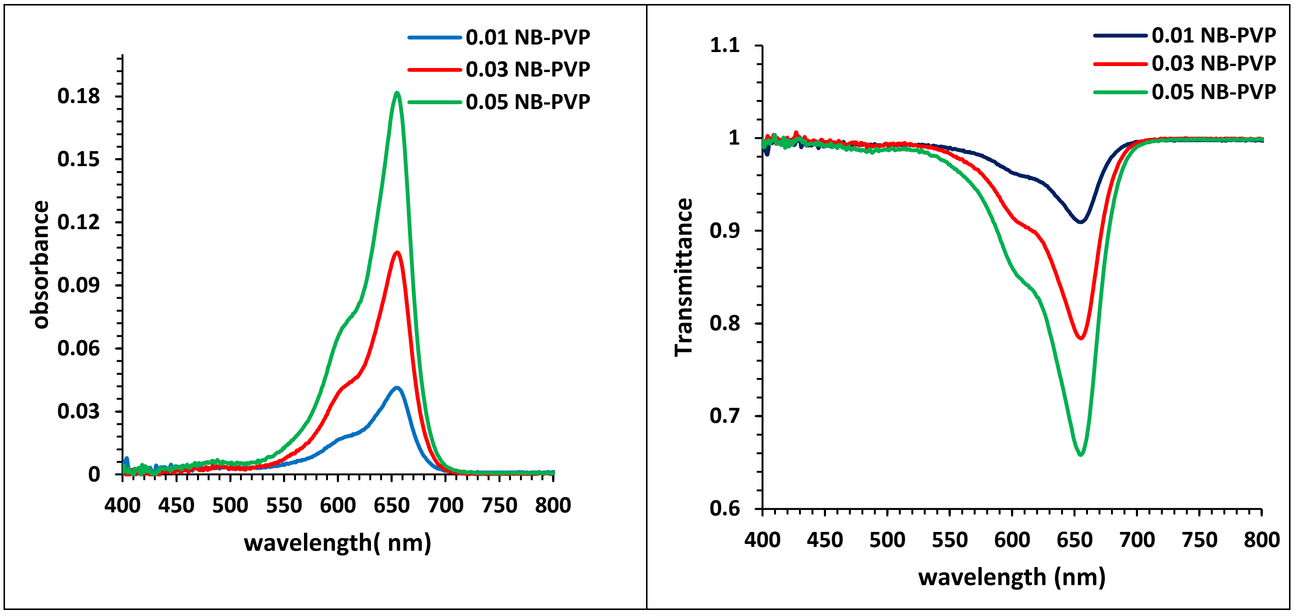


Fig (4.9) The Absorbance and transmittance spectra of(NB-PVP) blend solutions at different concentrations in ethanol solvent.

Table (4.9) The linear optical properties of (NB- PVP) blend dissolved in a ethanol.

Material	C(mM)	λ_{abs}	A	T	α (cm)$^{-1}$	n_o
(NB-PVP) Blend	0.01	655	0.04	0.90	0.12	1.83
	0.03	654	0.11	0.78	0.24	2.02
	0.05	653	0.18	0.65	0.41	2.34

4.11. Fluorescence Spectra of (PVP-NB) Blend Solutions in Ethanol Solvent

Figure (4.10) shows the fluorescence spectra of (NB – PVP) blend solutions dissolved in ethanol solvent with different concentrations of NB dye (0.01,0.03,0.05) mM.It is noted from the figure that the highest fluorescence intensity is (19115) and is located at the wavelength (687) nm. it is also noted that the values of the quantum yield of fluorescence (NB- PVP) blend solutions are greater compared to (NB dye) solutions for all concentrations, the reason for this is due to the decrease in the absorbance values of the Blend, and for the same reason it is also noted that the values of the quantum yield of fluorescence for this blend is greater compared with the same blend with water solvent, and the highest value of the quantum yield of fluorescence is (0.89), as shown in Table (4.10).

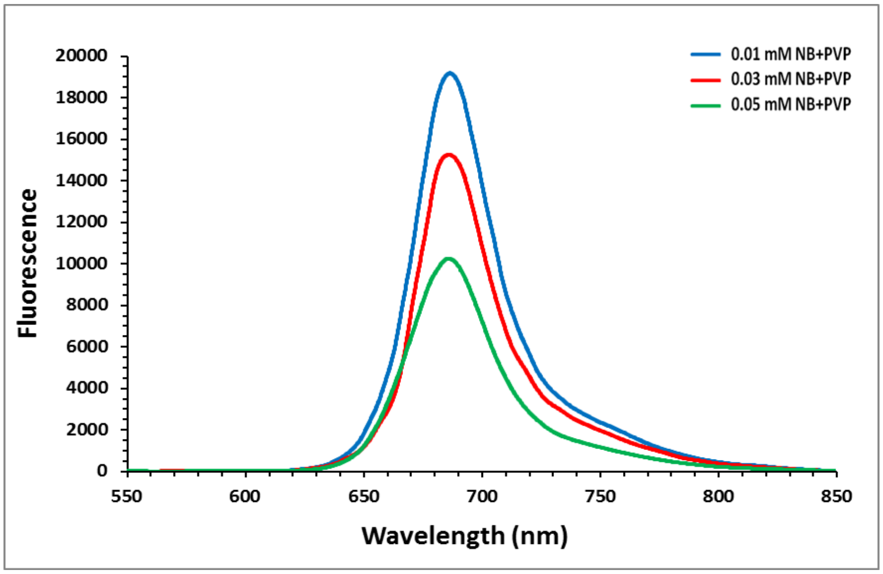


Figure (4.10): Fluorescence spectra of (NB- PVP) blend solutions dissolved in ethanol solvent with different concentrations of NB dye.

Table (4.10): Spectral properties of (NB- PVP) blend solutions with ethanol solvent with different concentrations of NB dye.

Material	C(mM)	λ_{flu} nm	Intensity	τ_f	Φ_f
NB Dye (Blend)	0.01	687	19115	2.15	0.89
	0.03	686	15253	3.01	0.87
	0.05	685	10121	4.62	0.74

4.12. Absorbane and transmittance Spectra of (NB-PVP/AuNPs) Nanocomposite in Ethanol Solvent

Fig. (4.11) shows The absorption intensity of NB/PVP/AuNps revealed two peaks, the first at wavelength (525) nm representing the nanocomposite's absorbance intensity and the second at wavelength (655) nm showing the dye absorption intensity. The influence of the method of pulsed laser ablation in liquids on the concentrations prepared from the dye was recorded, and it was noted that numerous possibilities arise in the addition process.

One of these effects is a shift in wavelengths either in the direction of (redshift) or in the direction of (blue shift) when the quantity of nanoparticles inside the liquid increases (blue shift) this is dependent on the particle size of the nanoparticles that have been created. The intensity of absorption is the other impact, in which the concentration of the chemical is linked to an increase or reduction in absorption. When the size of the produced nanoparticles is tiny and added to the dye and polymer, the intensity of absorption decreases as the dye concentration decreases.Table (4.11) show the values of absorbance, transmittance, linear absorption coefficient, and linear refractive index of (NB- PVP/AuNPs) nanocomposite solutions dissolved in ethanol solvent.

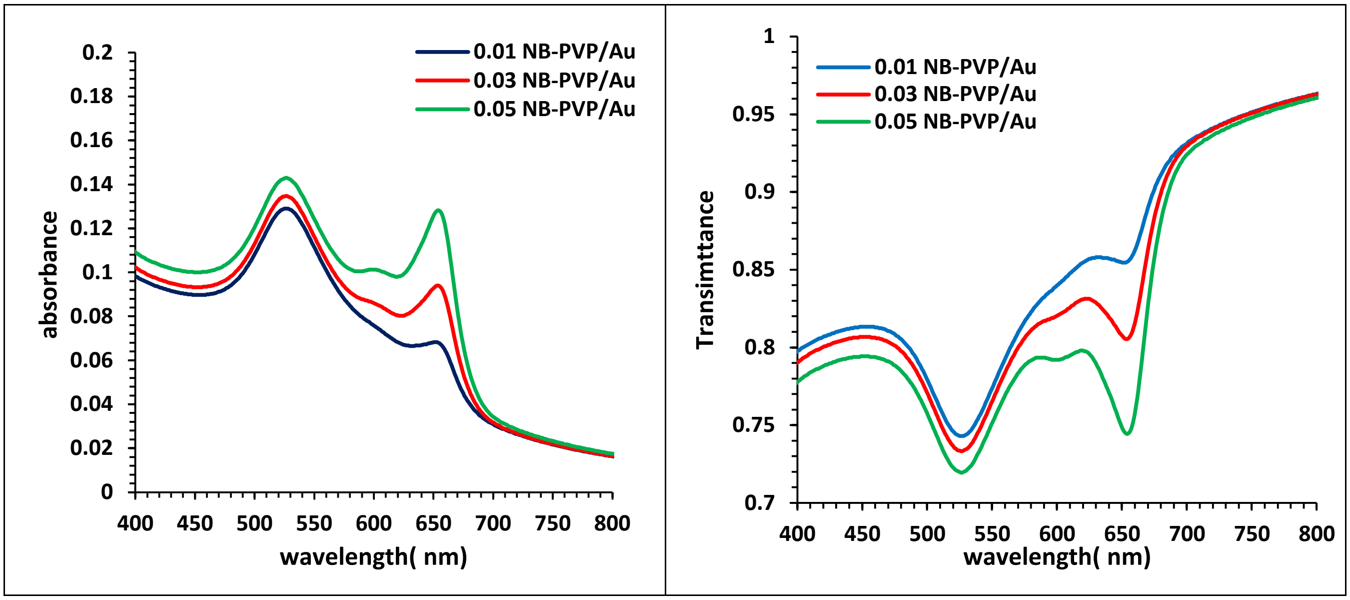


Fig (4.11) The Absorbance and transmittance spectra of (NB-PVP) blend solutions dissolved in ethanol solvent with different concentrations of NB dye.

Table (4.11) the linear optical properties of (NB – PVP/AuNPs) nanocomposite dissolved in ethanol solvent with different concentrations of NB dye.

Matreial	C(mM)	λ_{abs}	A	T	α (cm)$^{-1}$	n_o
(NB – PVP/AuNPs) Nanocomposite	0.01	655	0.06	0.85	0.15	1.94
	0.03	654	0.09	0.80	0.21	2.37
	0.05	653	0.12	0.74	0.29	2.72

4.13. Fluorescence spectra of (NB-PVP/AuNPs) Nanocomposite Solutions in Ethanol Solvent

Figure (4.12) shows the fluorescence spectra of (NB-PVP/AuNPs) nanocomposite solutions dissolved in ethanol solvent with different concentrations of NB dye (0.01,0.03,0.05) mM. It is noted from the figure that the highest fluorescence intensity is (19434) and is located at the length at the wavelength (682 nm), it is also noted that the values of the quantum yield of fluorescence for

(NB-PVP/Au NPs) nanocomposite solutions are greater compared to Blend solutions and NB dye solutions for all concentrations, due to the decrease in absorbance and increase in fluorescence intensity. For the same reason, these values are greater compared with nanocomposite solutions dissolved in water solvent, and the highest value of the quantitative product is (0.92), as shown in Table (4.12).

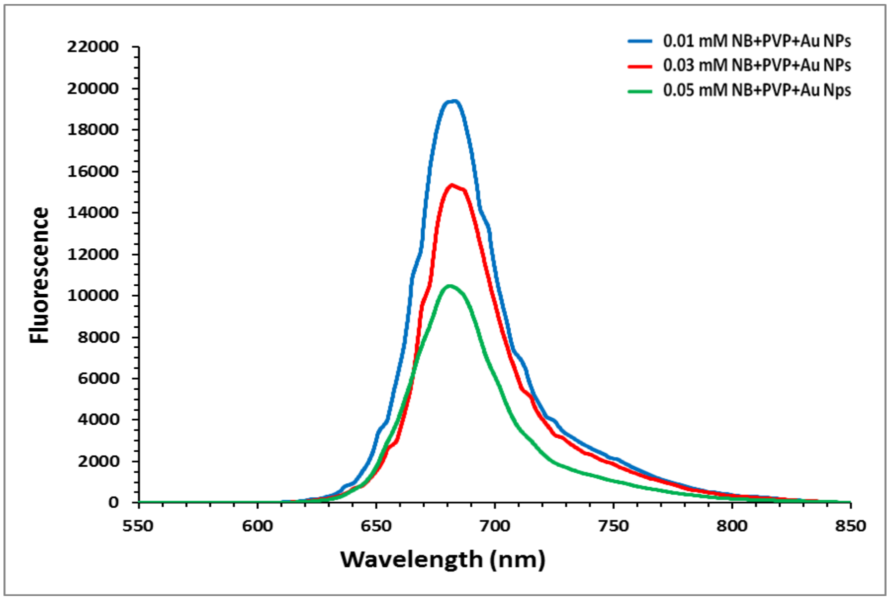


Figure (4.12) Fluorescence spectra of (NB- (PVP/Au NPs) nanocomposite solutions dissolved in ethanol with different concentrations NB dye.

Table (4.12): Spectral properties of (NB-PVP/Au NPs) nanocomposite solutions dissolved in ethanol with different concentrations NB dye.

Material	C(mM)	λ_{flu} nm	Intensity	τ_f	Φ_f
(NB -PVP/ Au NPs) Nanocomposite	0.01	682	19434	1.95	0.92
	0.03	681	15487	2.11	0.90
	0.05	680	10492	3.42	0.81

4.14. Conclusions

The study concludes they following:

1. Increasing the concentration of Nile Blue dye that dissolved in both solvents, water and ethanol, leads to an increase in intensity of absorbance spectra, for all the prepared solutions.
2. The values of linear optical properties (linear absorption coefficient and linear refractive index) increase with increasing dye concentration for all prepared solutions.
3. Increasing the concentration of dye for both solvents leads to a decrease in the intensity of fluorescence spectra, which leads to an increase in the fluorescence lifetime and a decrease in the quantum yield of fluorescence.
4. The addition of a polymer (PVP) to Nile blue dye solutions led to the formation of (NB-PVP) blend solutions that have a lower absorptive intensity compared to dye solutions alone, and this leads to a decrease in the absorbance values and an increase in transmittance values, and consequently, the values of linear optical properties.
5. The intensity of fluorescence spectra increases for (NB-PVP) blend solutions compared to dye solutions alone, and this leads to an improvement of the spectral properties, where the values of the fluorescence lifetime decrease and the values of the quantum yield of fluorescence increase compared to the values of dye solutions.
6. Solutions of (NB-PVP/AuNPs) nanocomposites are prepared by adding gold nanoparticles(AuNPs) to (NB-PVP) blend solutions so that these nanocomposites have a lower absorbance intensity compared to the solutions of the blend solutions and dye solutions alone, thus lowering the values of linear optical properties of these nanocomposites.
7. The (NB-PVP/AuNPs) nanocomposites solutions have a higher intensity of fluorescence than the dye solutions and blend solutions, and thus good

spectral properties are obtained with the lowest fluorescence life time and the highest quantum yield of fluorescence for the two solvents, water and ethanol.

4.15. Suggestions for Future Works

1. Study of the spectral and optical properties of natural and other organic dyes added to PVP/AuNPs.
2. Using other nanoparticles with (NB-PVP) polymer blend and compare their results with the current study.

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