Energy Transfer Efficiency of Silver Nanoparticles with Rhodamine 6G Dye

Asrar Abdulmunem Saeed[1], Mahasin F. Hadi Al-Kadhemy[2], Husam S. Al-Arab[3]

Al-Mustansiriyah University/ College of Science / Department of Physics
asrarabdulmunim@yahoo.com, drmahasinf@yahoo.com, husam.sabyh@yahoo.com

Abstract:
Absorption and Fluorescence spectra of the suspension of Ag nanoparticles with Rhodamine 6G (Rh6G) in distilled water, has been investigated for different amount of masses of Ag nanoparticles in dye solution. An absorption spectra enhancement were observed for different amount of masses, indicated that doping of Ag nanoparticles has a significant effect on the dye absorption spectra. Contrarily, all dye fluorescence emission spectra showed quenching as Ag nanoparticles amount of masses increased due to Förster resonance energy transfer (FRET).

Keywords: Ag Nanoparticles, Fluorescence Quenching, Rhodamine 6G, Absorption Spectra, Energy Transfer Efficiency.

كفاءة انتقال الطاقة لجسيمات الفضة النانوية مع صبغة الرودامين (Rh6G)

اسرار عبد المنعم سعيد ، محاسن فاضل هادي الكاظمي ، حسام صبيح العرب

الجامعة المستنصرية / كلية العلوم / قسم الفيزياء

الخلاصة

تم بحث اطياف الامتصاص والفلورة لمحلول يحتوي على جسيمات الفضة النانوية مع صبغة الرودامين نوع (Rh6G) المذابة في الماء المقطر ولكتل مختلفة من جسيمات الفضة النانوية مع محلول الصبغة، وقد تم ملاحظة تحسن اطياف الامتصاص مع زيادة الكتل، مما يكشف عن ان التطعيم بجسيمات الفضة النانوية له تاثير كبير على اطياف الامتصاص. على العكس من ذلك،

فان جميع اطياف الفلورة تم كبتها كلما ازدادت كتل جسيمات الفضة النانوية لحدوث انتقال فورستر الرنيني للطاقة (FRET).

الكلمات المفتاحية: جسيمات الفضة النانوية، كبت الفلورة، صبغة الرودامين (R6G)، اطياف الامتصاص، كفاءة انتقال الطاقة.

Introduction

Spectral study of the absorption and fluorescence emission of colloidal nanoparticles suspension (metal and non-metal) with dye solution, has been examined because of its importance in tuning luminescence intensity for biological applications [1-6] and studying optical properties of highly scattering media such as random laser dynamics. A standard random laser technique is a dye solution with nanoparticles as the scatterers in which the emission properties depend on the scatterer density, dye concentration and the pumping power. D.Q. Hoa, *et al*, investigated doping gold nanoparticles with (DCM) dye on a laser-active medium [7]. J. John, *et al*, studied the optical properties of fluorescein dye with gold nanoparticles [8] and M. Barzan and F. Hajiesmaeilbaigi [9] studied the influence of gold nanoparticles on the optical properties for Rhodamine 6G, while Brito-Silva *et al*, stated the influence of particle size and concentration on laser performance [10]. Here, the spectral characteristics of the Rhodamine 6G with Ag nanoparticles has been analyzed for different amount of masses of Ag nanoparticles with dye molecules using absorption and fluorescence spectroscopy.

Theoretical Part

When the fluorescence spectrum of a laser dye, termed the donor, overlaps with the absorption spectrum of another molecule, termed the acceptor, a Förster resonance energy transfer (FRET) process happens. The acceptor can be a fluorescent or non- fluorescent material. Energy-transferring efficiency E can be determined by [11]:

$$E = 1 - \frac{F}{F_o} \quad (1)$$

Where F and F_O are the intensities of fluorescence of dye with and without nanoparticles, respectively. To understand the kinetics of a photophysical intermolecular deactivation process (quenching), the Stern–Volmer relation can be used. In general, this method can be given by [9]:

$$\frac{F}{F_0} = 1 + K\,[Q] \qquad (2)$$

Where K is the Stern-Volmer quenching constant and $[Q]$ is the quencher amount of mass. Thus, a plot of F_0/F against [Q] must grant a straight line with a slope equivalent to K.

Experimental work

The Ag nanoparticles (with an average diameter of 50 nm, Purity: 99.99%, Nanjing Nano Technology co,ltd) dissolved in Rh6G ($C_{28}H_{31}N_2O_3Cl$, Sigma-Aldrich, 95% Pure, M_W=479.01 g/mol) with distilled water to make a solution. The concentration of Rh6G dye was (1×10^{-5} M).

The spectra of absorption and emission were measured using a UV-visible spectrophotometer (T70/T80) and spectro-fluoro-photometer (SHIMATDZU RF-5301pc), respectively. Variety of nano Ag amount of masses were investigated for dye solution ranging from 0.005 g to 0.009 g. All the samples were prepared using a hot plate magnetic stirrer until the Ag nanoparticles diffuse homogeneously through the Rh6G solution.

Results and Discussion

Figures (1) and (2) shows absorption and fluorescence spectra for Rh6G in distilled water, without Ag nanoparticles. The maximum absorption wavelength (λ_{abs}) was 525 nm, and the fluorescence wavelength (λ_f) was 554 nm.

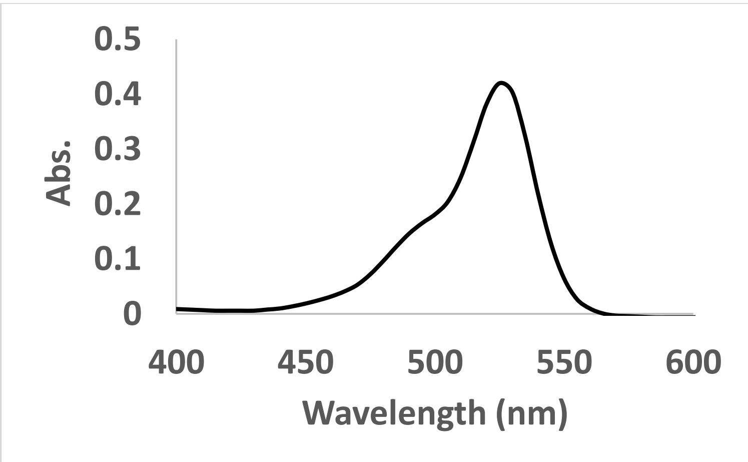

Fig. 1. Absorption spectrum of Rh6G without Ag nanoparticles.

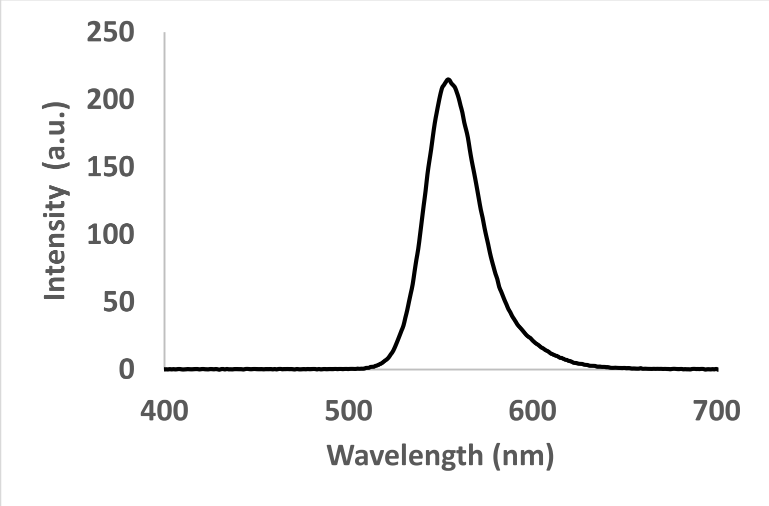

Fig. 2. Fluorescence spectrum of Rh6G without Ag nanoparticles.

Adding Ag nanoparticles led to enhancement of absorption spectral intensity, while decrease fluorescence spectral intensity with increasing Ag amount of masses as shown in figures (3) and (4), respectively.

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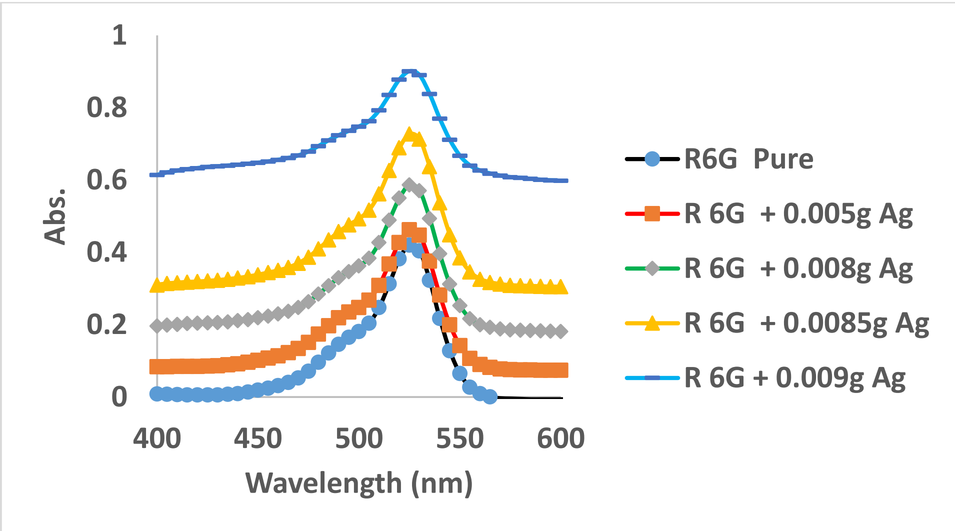
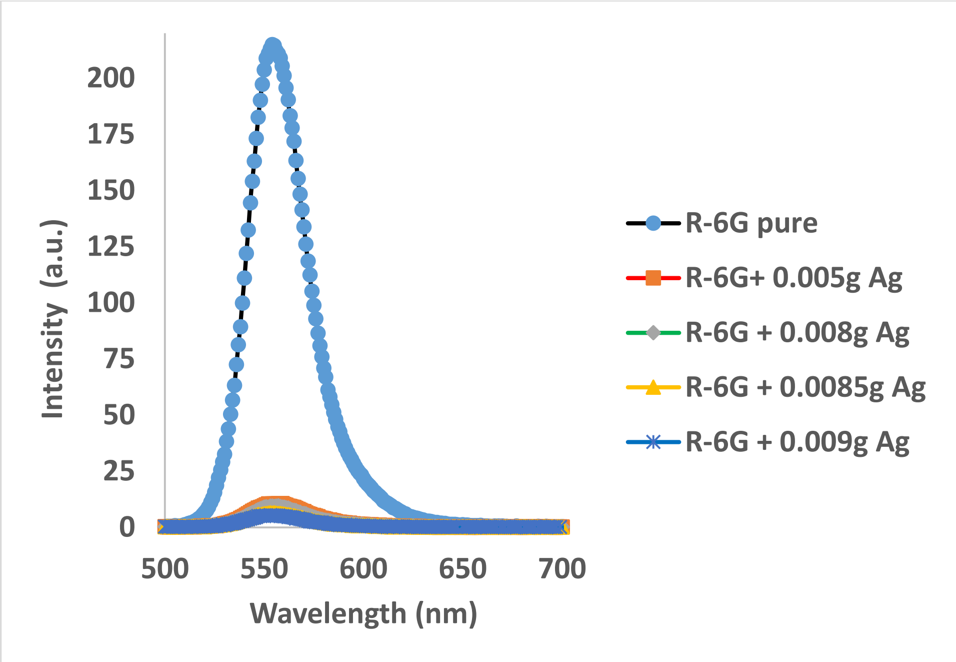
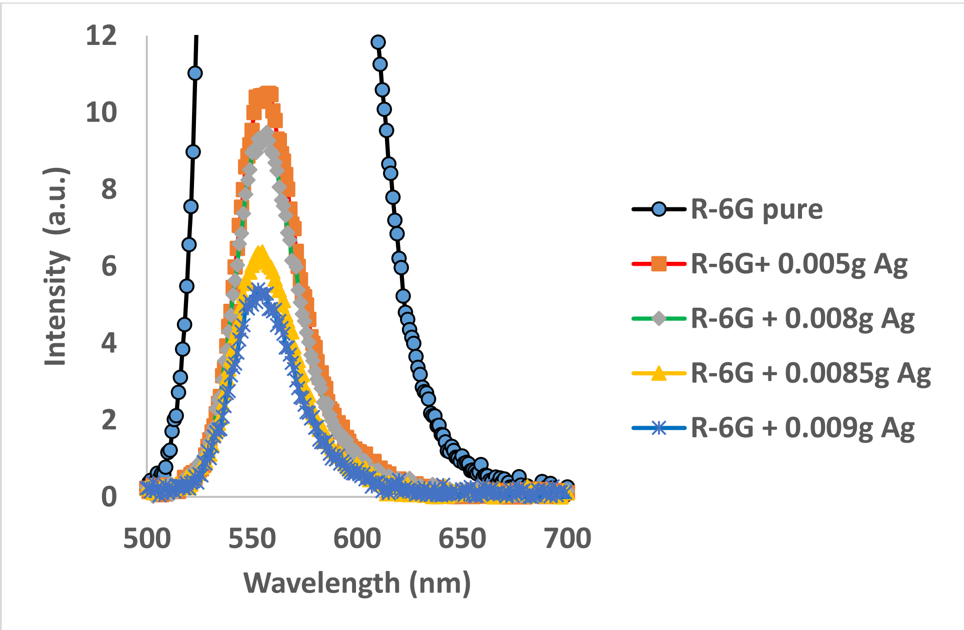


Fig. 3. Absorption spectra of Rh6G with different amount of masses of Ag nanoparticles.



(a)



(b)

Fig. 4. (a) Fluorescence Spectra of Rh6G with different amount of masses of Ag nanoparticles (b) the magnified part of the dye with different amount of masses of Ag nanoparticles.

Table (1) shows that increasing Ag amount of masses led to enhancement of absorption spectral intensity, while decrease (quenching) fluorescence spectral intensity. Also, table (1) shows very small spectral red shift, with increasing the nanoparticles amount of masses, because adding Ag nanoparticles to the dye solution provides more absorption for emitted photons so that re-absorption and re-emission lead to red shift.

Table (1) spectral information

	Ag (g)	Absorption intensity	λ_f (nm)	Fluorescence intensity
Rh6G 1×10^{-5} M	0	0.42	٥٥٤	214.84
	0.005	0.463	٥٥٥	10.44
	0.008	0.587	٥٥٤	9.31
	0.0085	0.727	٥٥٥	6.37
	0.009	0.9	٥٥٧	5.29

For increasing Ag nanoparticle amount of masses, dynamic quenching become dominant and fluorescence intensities falls down simultaneously. This behavior can be described on the basis of energy transfer between Rh6G (as donor) and silver nanoparticle (as acceptor). Energy-transferring efficiency E can be determined by eq. (1). Table (2) present the rates for energy-transfer efficiencies of the samples.

Table (2) Energy-transfer efficiencies for samples

F_O	Ag (g)	F	E
214.84	0	214.84	0
214.84	0.005	10.44	0.951
214.84	0.008	9.31	0.956
214.84	0.0085	6.37	0.970
214.84	0.009	5.29	0.975

With data from Table (2), it certain that the increasing Ag nanoparticles amount of masses will also increasing the energy-transfer (quenching) efficiencies. The addition of Ag nanoparticles led to decrease in the fluorescence intensity of Rh6G, this can be described by the equation of Stern-Volmer, eq. (2)

Figure (5), shows the F_0/F against [Q] plot. The obtained Stern-Volmer quenching constant, *K*, is 3880 M^{-1}. The effective fluorescence quenching of Rh6G by Ag nanoparticles, is due to the high value of the quenching constant.

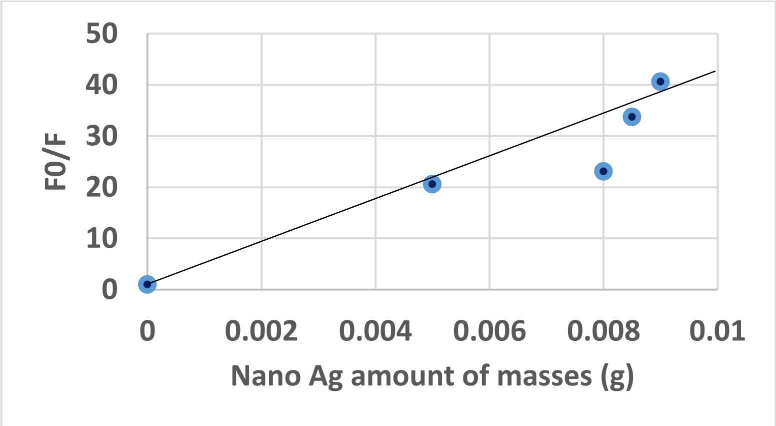


Fig. 5. Stern-Volmer plot of Rhodamine 6G with nano Ag amount of masses.

Conclusions

This study shows that changing the amount of masses of Ag nanoparticles, is a crucial controlling parameter for fluorescence quenching and absorption enhancement of Rhodamine 6G, taking fluorescence and absorption spectra. A high value of the quenching constant is acquired from the Stern-Volmer equation, which implied effictive fluorescence quenching of Rhodamine 6G by Ag nanoparticles. The concept of energy transfer between Rhodamine 6G and silver nanoparticle explained the dropping in fluorescence intensity with rising amount of Ag nanoparticles.

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