Effect concentration on spectral properties of Rhodamin 6G dye

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ABSTRACT

The spectral properties (absorption and fluorescence) of R6G dye dissolved in acetone were studied for different concentrations ($5x10^{-6}$, $1x10^{-5}$, $5x10^{-5}$, $1x10^{-4}$, and $5x10^{-4}$) mol/l. The results showed that, increase in the absorption intensity with the increased concentration which are found in agreement with Beer – Lambert law. And, shift the absorption and fluorescence spectrum with increase the concentration of the sample. The quantum efficiency of the R6G dye solution were (98.53%, 97.55%, 71.7%, 51.24, and 33.27%) for all concentration respectively, and also, the overlap between the absorption spectrum and the fluorescence decreases with increasing concentration, which, can be due to increase of stokes shift, with increases concentration of the dye solution and this case reduce self-absorption process.

الملخص

تم دراسة الخصائص الطيفية (الفلورة والامتصاصية) لصبغة الرودامين 6G المذابة في مذيب الاسيتون ولتراكيز مختلفة ($5x10^{-6}$, $1x10^{-5}$, $5x10^{-5}$, $1x10^{-4}$, $5x10^{-4}$) مول/لتر، واشارت النتائج الى زيادة شدة الامتصاص بزيادة التركيز وهذا يفق مع قانون بير–لامبرت. وكذلك، ازاحة كل من طيف الامتصاصية والفلورة مع زيادة التركيز. وكانت الكفاءة الكمية للمحلول (٩٨.٥٣% ، ٩٧.٥٥% ، ٧١.٧% ، ٥١.٢٤% و ٣٣.٢٧%) للتراكيز على التوالي، وكذالك لوحظ نقصان في التداخل بين طيف الامتصاص والفلورة بسبب زيادة ازاحة ستوكس بزيادة التركيز وهذا يقلل من عملية الامتصاص الذاتي.

Keywords: Xanthene dyes, Laser dye, Rhodamine 6G, quantum efficiency.

Introduction:

Rhodamine dyes are fluorophores that belong to the family of xanthenes along with fluorescein and eosin dyes, as shown in the figure (1) [1]. Rhodamine 6G dye is commonly used as an active medium in tunable lasers due to its high fluorescence quantum yield [2], and also they have broad reaching applications due to their photostability, high absorption coefficients and excellent fluorescence quantum yields [3].

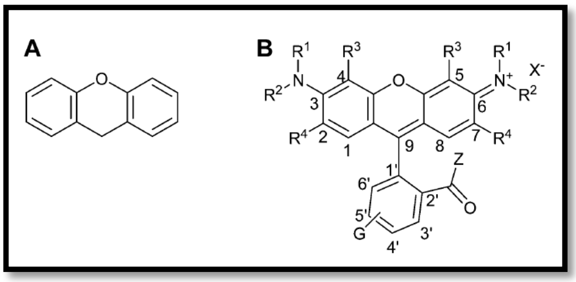


Fig (1): Molecular structures of Xanthene (A) and Rhodamine dyes (B) [5].

The Rhodamine 6G dye emits laser light of a broad range of frequencies, including the orange-light frequency of 590 nm, where its pumping with a blue-green light, usually from an argon or krypton ion laser, and also it has highly efficient, where that up to 20% of the input energy is converted to laser light output [4]. Rhodamine 6G dye has high quantum efficiency, where the quantum efficiency is one of the most important optical properties of fluorescent materials and it is the essential parameter in determining the lasing characteristics of the active laser medium [5].

Rhodamines dye has various applications in many scientific branches, where used as laser dyes, fluorescence standards (for quantum yield and polarization), pigments and as fluorescent probes to characterize the surface of polymer nanoparticles, fluidity of lipid membranes as well as in the detection of polymer-bioconjugates, studies of adsorption of oligonucleotides on latexes, studies of structure and dynamics of molecules, single-molecule imaging and imaging in living cells [6,7].

The Quantum efficiency is the ratio of the number of emitted photons to the number of absorbed photons (or The fluorescence quantum yield is the fraction of excited molecules that return to the ground state S_0 with emission of fluorescence photons) [8,9].

$$q_{FM} = \frac{Number\ of\ emitted\ photons}{Number\ of\ obsorption\ photons} \quad (1)$$

And also the radiation lifetime can be calculated using relation as follows [9]:

$$\frac{1}{\tau_{FM}} = 2.88 * 10^{-9} n_0{}^2 \bar{v}^2 \int \in (\bar{v}) d\,\bar{v} \quad (2)$$

Where, n is refractive index of a medium, ύ is wave number at the maximum absorption, and $\int \in (\bar{v}) d\,\bar{v}$ is the area under the absorption spectrum curve as a function of the wave number.

In this work we used R6G dye were dissolved in acetone solvent for different concentration ($5x10^{-6}$, $1x10^{-5}$, $5x10^{-5}$, $1x10^{-4}$, and $5x10^{-4}$) mol/l, and study spectral properties of them.

EXPERIMENTAL PART:

In this work R6G dye, Molecular formula ($C_{28}H_{31}N_2O_3Cl$), molar mass (479.02 g/mole), supplied by HiMedia Laboratories Pvt company. Ltd. India and it's structure shown in figure (2):

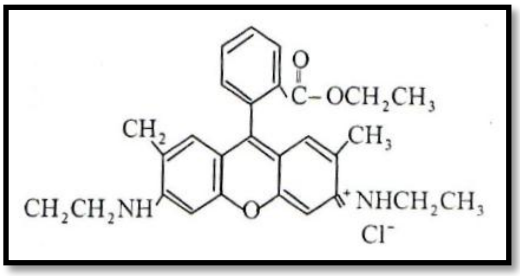


Fig (2): The structure of Rhodamine 6G.

Acetone (systematically named propanone) have formula (CH_3COCH_3), refractive index about (1.361) at temperature 17 C^0, purity (99 %), molecular weight (58.08 $g.mol^{-1}$).

The Spectrophotometer T60 supplied from the English company (Insrtrumrnts) was used to measure the absorption spectra of liquid samples, This device operates within the range of the visible and ultraviolet region where contains lamp of execution, and the emission spectrum taken by using (Spectrofluorometer-model SL174, Elico). Refractive index is taken by using a refractometer (Bellingham and Stanley Ltd, Tunbridgewells, AR4, England).

RESULTS AND DISCUSSION:

The absorption and fluorescence spectra of R6G dye with concentrations (**$5*10^{-6}$** , **$1*10^{-5}$**, **$5*10^{-5}$**, **$1*10^{-4}$**, and **$5*10^{-4}$**) mol/l, are shown in the figure (3), where the absorption spectrum shifted to short wavelength (blue shift) and the fluorescence spectrum shifted to longer wavelength (red shift) with increasing the concentration. Table (1) shows the absorption, fluorescence peaks, stock shift, the wide curve at half intensity, and Table (2) shows the quantum efficiency of the dye, lifetime of radiation and fluorescence. It is observed, increase the peak of absorption spectrum with increased the concentration, and these agreements with Beer – Lambert Law, The peaks of fluorescence spectrum shifted to a long wavelength with increase the concentration, because of energy loss in the excited state due to vibrational relaxation [10]. The quantum efficiency decreased as the dye concentrations were increased because of the increase the probability of non-radiative transition (Inter System Crossing (I.S.C) and Internal Conversion (I.C) [7].

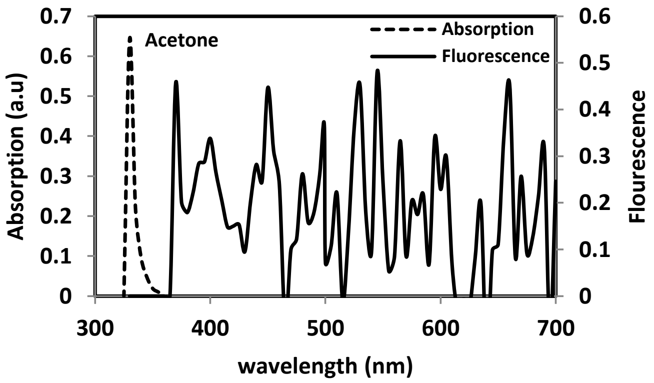
The results above are in agreement with Refs [11,12,13].

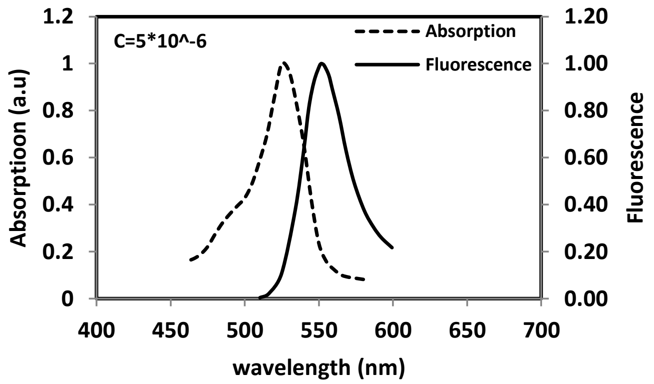
Table 1: The stock shift between the absorption and fluorescence spectra, curv wide at half intensity.

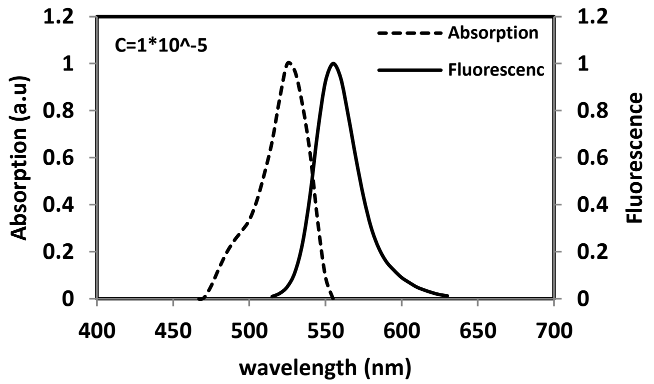
C (Mole/l)	Absorption λ_{max} (nm)	Fluorescence λmax (nm)	Stock Shift (nm)
$5*10^{-6}$	525	551	26
$1*10^{-5}$	525	555	30
$5*10^{-5}$	525	555	30
$1*10^{-4}$	525	560	35
$5*10^{-4}$	495	570	75

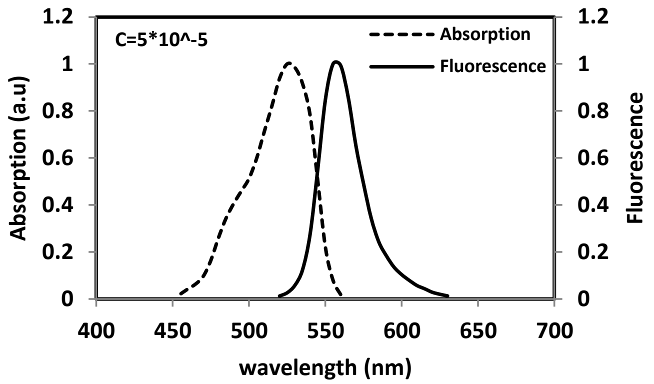
Table 2: The quantum efficiency of fluorescence, the radiative and fluorescence lifetime for R6G.

C (Mole/l)	Quantum Efficiency %	τ_{Fm} (nsec)	τ_{F} (nsec)
$5*10^{-6}$	98. 53	1.41	1.39
$1*10^{-5}$	97.55	3.71	3.62
$5*10^{-5}$	71.70	13.84	9.93
$1*10^{-4}$	51.24	21.2	10.87
$5*10^{-4}$	33.27	58.41	19.43


Acetone
Absorption
Fluorescence
Absorption (a.u)
Flourescence
wavelength (nm)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
300
400
500
600
700


C=5*10^-6
Absorption
Fluorescence
Absorptioon (a.u)
Fluorescence
wavelength (nm)
1.2
1
0.8
0.6
0.4
0.2
0
1.20
1.00
0.80
0.60
0.40
0.20
0.00
400
450
500
550
600
650
700


C=1*10^-5
Absorption
Fluorescenc
Absorption (a.u)
Fluorescence
wavelength (nm)
1.2
1
0.8
0.6
0.4
0.2
0
400
450
500
550
600
650
700


C=5*10^-5
Absorption
Fluorescence
Absorption (a.u)
Fluorescence
wavelength (nm)
1.2
1
0.8
0.6
0.4
0.2
0
400
450
500
550
600
650
700

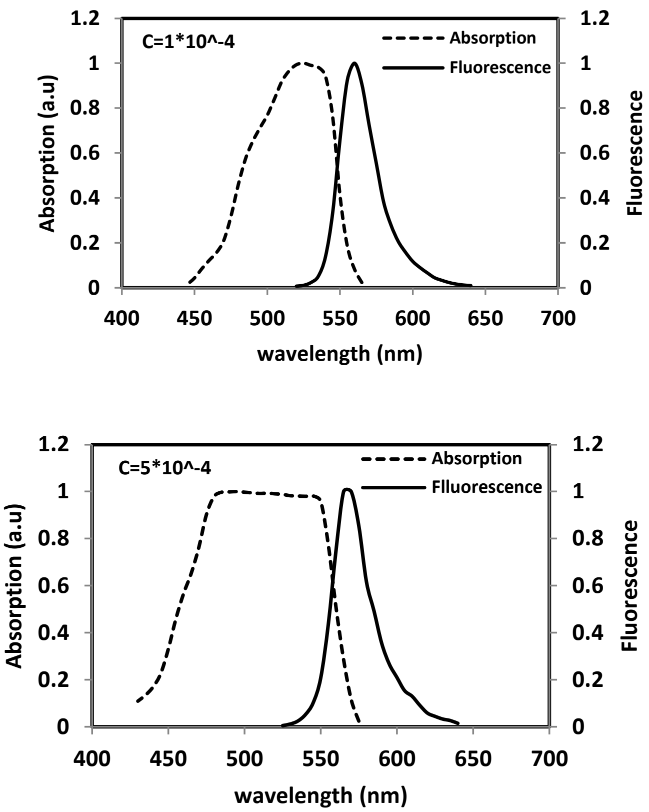


Fig (3): The fluorescence and absorption spectra for R6G dye dissolved in aceton.

Conclusions

The study of the Rhodamine 6G dye solutions in the acetone solvent with increase concentration could conclude: Shifted the fluorescence spectrum of Rhodamine 6G dye solution in the acetone solvent toward the longer wavelength (red shift). Increase both the fluorescence lifetime and radiative lifetime of the dye solution, and also, the fluorescence lifetime is small as compared to a radiative lifetime of the dye solution. Decrease the overlap between the absorption spectrum and the fluorescence of due to increase of stokes shift, with increases concentration of the dye solution and this case reduce self-absorption process. The width of curve absorption, increased with increase concentration the dye solution, but decrease width of fluorescence curve due to increase with increase concentration of the dye solution. The quantum efficiency of the dye solution decreases when the dye concentration increases, where, at the concentration ($5*10^{-6}$) mol/l, the quantum efficiency equal (98.53 %) while at ($5*10^{-4}$) mol/l, equal (33.27%). So, this dye can be used to improve solar cell conversion efficiency.

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