Sic. J. Fac. Sci. Menoufia Univ. Vol. VIII (1994)

ENERGY TRANSFER DYE LASER RHODAMINE 6G - RHODAMINE B, RHODAMINE 6G - CRESYL VIOLET, AND COUMARINE - FLUORESINE.

By

Z. El-Gohary
Physics Department, Faculty of Science, El Menufia University,
Sheben El-Koom, Egypt.

ABSTRACT

Energy transfer dye laser ETDL in the visible region was performed in Rhodamine 6 G - Rhodamine B, Rhodamine 6 G - Cresyl Violet and Coumarine - Fluoresine dye mixtures in ethanol of various concentrations with different ratios pumped by a 300 KV N_2*-laser of 337.1 nm. Excitation of a dye laser through energy transfer process of these three pairs is very efficient for the improvement of the dye laser efficiency and the extension of their tuning band.*

I. INTRODUCTION

Excitation of laser through energy transfer (ETDL) processes is very effective in improving laser performance. Using this technique, not only the optimum condition for lasing can be reached at lower pump powers than those needed for conventional dye laser[1], but also some dyes that cannot lase separately when pumped with N_2-laser can be made to lase in the mixture[2]. Moreover, extension of the wavelength tunability range gained through (ETDL) processes allows wide application in laser physics, spectroscopy, photochemistry and photobiology.

In ETDL systems, energy is transferred from an absorbing dye (donor) that absorbs at the pump wavelengths and emits near the absorption wavelength peak of the acceptor to be consequently pumped. As being donors, Rhodamine 6 G (Rh.6G) and Coumarine1 have been studied by several authors[2-9]. The excitation transfer in Rh.6G and Cresyl Violet (C.V.) dye mixture was investigated by Lin and Dienes[2]. They found a Stern-Volmer quenching relation for the donor system and concluded that resonant transfer is the dominant energy transfer in this lase dye mixture. On the other hand, Jie and Honglang[3,4] suggested a combined effect of both resonant and radiative energy transfer processes with an estimated value of $(1.58 \pm 0.40)\text{x}10^{11}$ $LM^{-1}S^{-1}$ for the rate constant of resonant transfer. Coumarine dyes have been reported to be used as efficient donors, in spite of their T-T absorption effect, using short pulse pumping[5,6]. Muto and Ito[6] observed gain enhancement in N_2 laser pumped Coumarine1-Uranine mixture relative to a solution containing Uranine alone. An estimated value for the critical energy transfer radius R_0 was found to be $57A^0$ suggesting long range dipole-dipole interaction to predominate in this ETDL system.

The aim of the present work is to investigate the characteristics of the three dyes mixtures namely, Rh 6G - Rh B, Rh 6G - CV and Coumarine - Fluoresine.

II. EXPERIMENTAL

In the present work all dyes are used without purification to make three different mixtures, Rh 6G - Rh B, Rh 6G - CV and Coumarine - Fluoresine, Ethanol is used as the common solvent. A N_2-laser at about 300 KW peak output power from a homemade[10] N_2-laser is used. A conventional quartz spectro-fluorometer cell containing the dye mixtures is pumped by an N_2-laser. The dye laser output is monitored with a Jobin-Yvon H10 monochromator and detected with R 446 Hamamatsu photomultiplier tube which is connected with storage oscilloscope TEK 466 to measure the relative lasing intensities.

III. RESULTS AND DISCUSSIONS

The variations of the laser emission relative intensity and the wavelength tuning range are studied as a function of the concentration of the dye mixtures for different donor/acceptor ratios.

The N_2-laser radiation of 337.1 nm is focused on to the dye cell to excite the dye for obtaining the superradiance output. The concentration effects of the donor on the lasing wavelength λ_{max} for different D/A ratios (1-7) of the dye mixture are shown in fig. (1a, b, c). This figure is discussed for the three different mixtures as in the following:

a) For the dye mixture Rh. 6G. - Rh. B., the lasing wavelength λ_{max} of the Rh. B. as a function of Rh. 6G. concentration in fig. (1a) shows that, at fixed D/A ratio the λ_{max} increases rapidly as Rh. 6G.

concentration is increased from $2x10^{-3}$ M/L to $4x10^{-3}$ M/L, after that the λ_{max} increases remarkably. This effect is shown for all ratios (D/A 1-7). The λ_{max} becomes about 618 nm in case of D/A=1, and in case of D/A 3.5 and 7, becomes 601 nm, 598.5 nm, respectively, as compared with that Rh. 6G. at 588 nm.

b) For the dye mixture Rh. 6G. - C.V., the λ_{max} of the C.V. as a function of Rh. 6G. concentration is shown in fig. (1b). At the ratio D/A=1 the λ_{max} is gradually increased winth increasing Rh. 6G. concentration from $3x10^{-3}$ M/L to $8x10^{-3}$ M/L, and λ_{max} becomes 637 nm. But at D/A (3, 5, and 7), the effect is small and λ_{max} becomes 625 nm, 622 nm, and 620 nm respectively.

c) For the third mixture Coum. - Fluo., the dependence of λ_{max} on the Coum. concentration is shown in fig. (1c). In the Coum. concentration range from $3x10^{-3}$ M/L to $5x10^{-3}$ M/L, the same effect as in (b) is occured, and the λ_{max} becomes about 547 nm, 540 nm, 534 nm, and 532 nm in case of D/A ratios 1, 3, 5, and 7, respectively.

Then the maximum laser wavelength of different mixtures in the ETDL system, which are achieved at certain ratio D/A and at certain donor concentration are summarized in table (1).

The dependence of the λ_{max} on the concentration of the acceptor for different donor concentration are calculated and are shown in fig. (2a, b, and c) for the three different mixtures. The distribution of the λ_{max} with the acceptor concentration (Rh. B., C.V., and Fluo.) is the same at different donor concentration, and it could be seen that at certain donor concentration as the acceptor concentration increases, the λ_{max} is red shifted, and also as the donor concentration increases, the λ_{max} shifts towards shorter wavelength. The tuning band is varied with donor concentration, and a wide tuning band extension are realized and are shown in table (1).

Then in these mixtures and from these results, it can be shown that, for fixed D/A ratio the maximum lasing wavelength λ_{max} of the acceptor (Rh. B., C.V., and Fluo.) increases as the donor concentration increase, and also as donor concentration increase by varying the D/A ratios, the λ_{max} shifts towards shorter wavelength.

Then the higher D/A the lower λ_{max} obtained for a given donor concentration. These results prove that the gain enhancement of the acceptor due to the energy transfer occured efficiently.

The energy transfer dye system can operate at low acceptor concentration, at which the excitation energy absorbed by the donors are transfered to the acceptor as useful pump power making theexcitation transfer quite efficient. This effect expand the spectral region of the operation.

Hence continuous tuning is possible over both lasing bands of the donor and the acceptor.

In conclusion it can be summurized that Rh. 6G. - Rh. B., Rh. 6G - C.V. and Coum. - Fluo. mixtures can be used to widen the tuning range of the dye laser, and are found to be useful as an energy transfer dye laser system.

ACKNOWLEDGMENT.

The author is indebted to Prof. Dr. M. M. Sabry, Faculty of Science, Menoufia University, for his assistance in rendering my facilities in the experimental work, and for helpful discussions.

REFERENCES

1- S. Speiser and R. Katraro, J. Optics Commun., vol. 27, No.2 (1978) 287.

2- C. Lin and A. Dienes, J. Appl. Phys., 44(1973) 5050

3- L. Jie and F. Honglang, J. Chinese Physics-Lasers, vol. 15, No.3 (1988) 166.

4- L. Jie and F. Honglang, J. Chinese Physics-Lasers, vol. 15, No.11 (1988) 831.

5- S. Muto and C. Ito, Jpn. J. Appl. Phys. vol. 20, No.8 (1981) 1258.

6- M. M. Sabry, Delta J. Sci., vol 13, No.3 (1989) 1258.

7- R. Y. Lu, Z. X. Yu, R. R. Alfano and J. I. Gersten Phys. Rev. A, vol 26, No.6 (1982) 3610.

8- M.M.F. Sabry and F.M. Mekawey, Jpn. J. Appl. Phys. vol. 29, No 1 (1990) 101.

9- S.A. El-Daly, M.E. El-Zeiny, S.M. El-Hazmy, Z. El-Gohary and Guy Duportail. Proc. Indian Acad. Sci. (Chem. Sci.) 105, 6, 651 (1993).

10- M.M. Sabry, A. Hassan and M. Ewaida, J. Phys. E. Sci. Instrum. 17, 103 (1984).

Caption for Fig. 1

The donor concentration as a function of λ_{max} for different D/A ratios 1, 3, 5 and 7 for the dye mixtures.

a) Rhodamine 6G - Rhodamine B
b) Rhodamine 6G - Cresyl Violet
c) Coumarine - Fluoresine

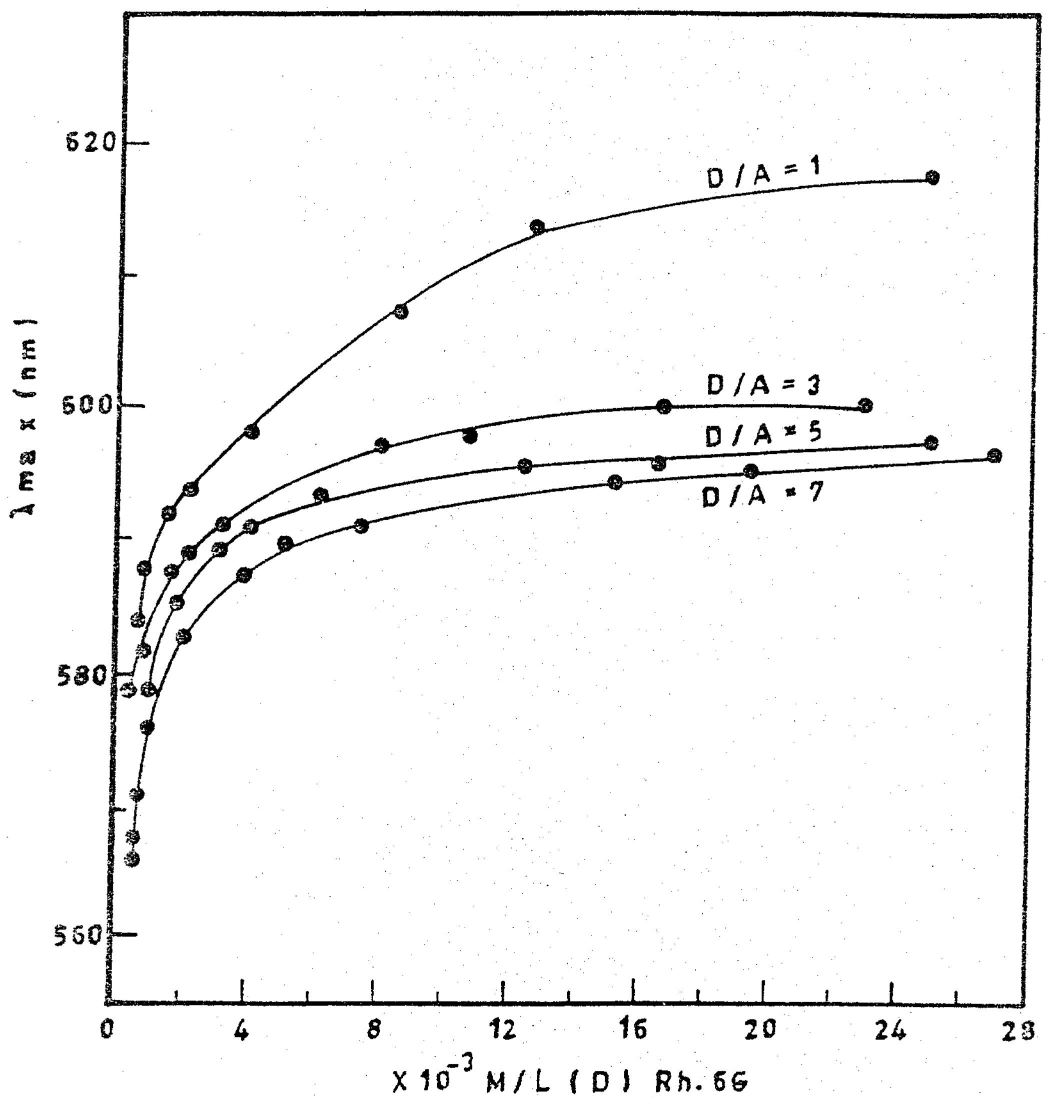
Caption fFig. 2

The effect of the acceptor concentration on the λ_{max} for different donor concentration for the dye mixtures.

a) Rhodamine 6G - Rhodamine B
b) Rhodamine 6G - Cresyl Violet
c) Coumarine - Fluoresine

Table (1)

	Dye mixture	λ_{max} (nm)	D/A	D-concentration M/L	Tuning band nm
a	Rh 6G - Rh B	618	1	16×10^{-3}	575-618
b	Rh 6G - CV	637	1	8×10^{-3}	580-637
c	Coum. - Fluo.	543	3	14×10^{-3}	453-543



620
600
580
560
λ max (nm)
0
4
8
12
16
20
24
28
X 10^{-3} M/L (D) Rh.6G
D / A = 1
D / A = 3
D / A = 5
D / A = 7

Fig. 1.a.

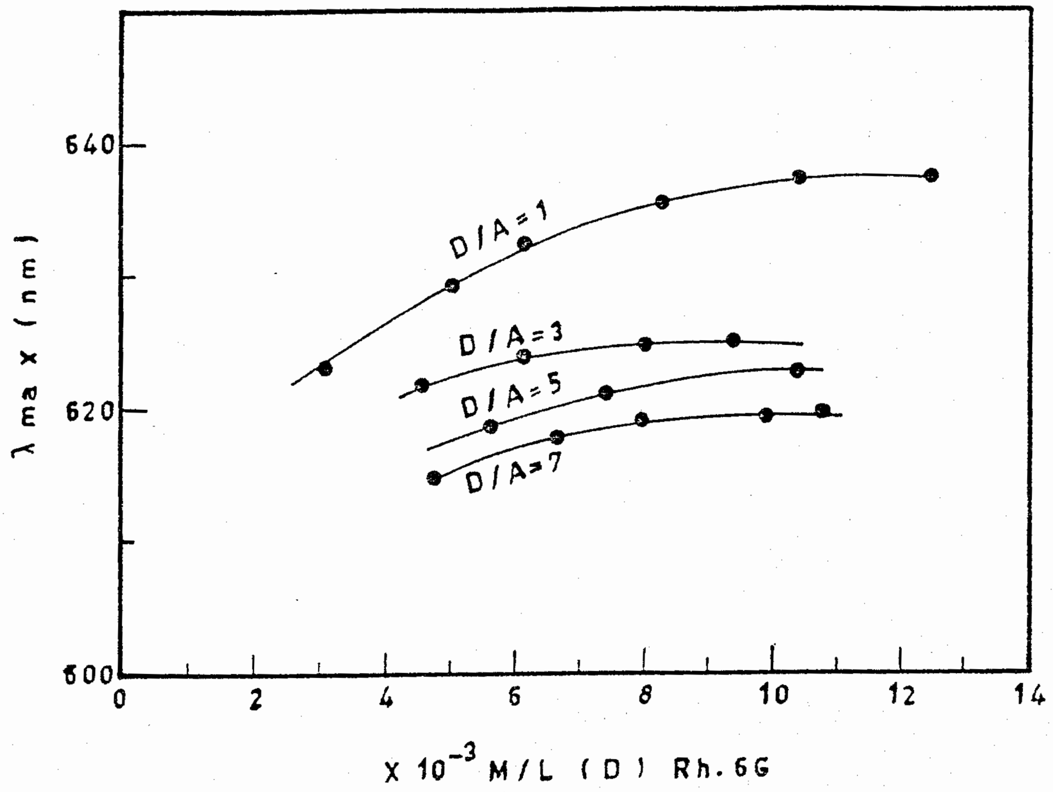


Fig. 1. b.

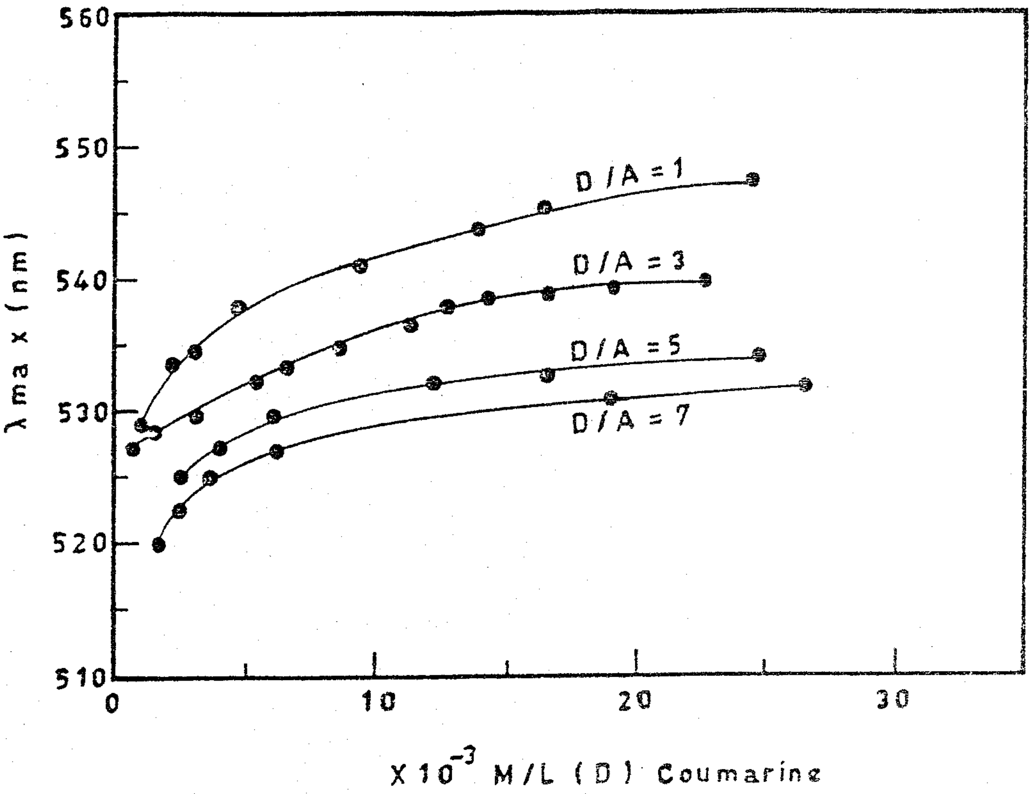

560
550
540
530
520
510
λ ma x (nm)
0
10
20
30
X 10^{-3} M/L (D) Coumarine
D/A = 1
D/A = 3
D/A = 5
D/A = 7

Fig. 1.c.

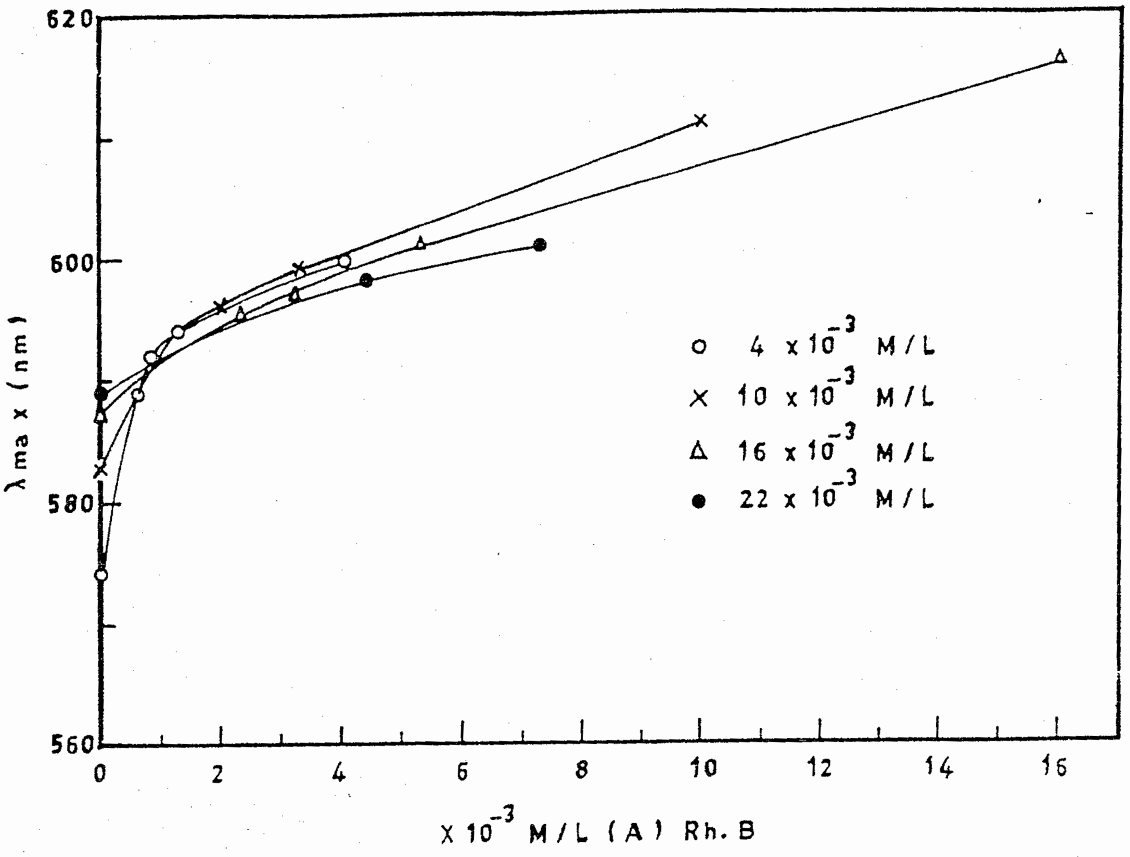
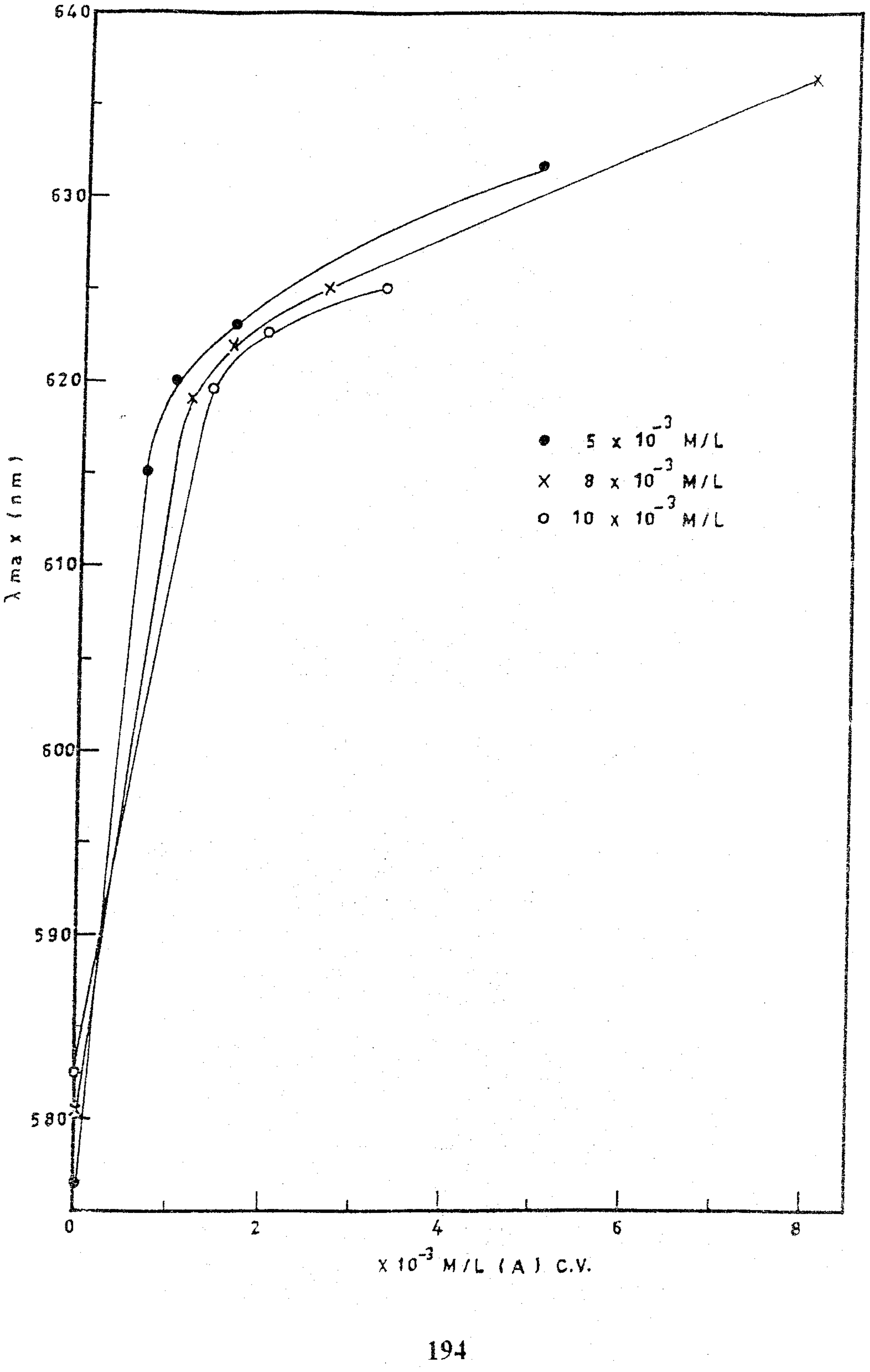

620
600
580
560
λmax (nm)
0
2
4
6
8
10
12
14
16
X 10^{-3} M/L (A) Rh. B
○ 4 x 10^{-3} M/L
× 10 x 10^{-3} M/L
Δ 16 x 10^{-3} M/L
● 22 x 10^{-3} M/L

Fig. 2. a.


640
630
620
610
600
590
580
λ max (nm)
0
2
4
6
8
x 10^-3 M/L (A) C.V.
● 5 x 10^-3 M/L
× 8 x 10^-3 M/L
o 10 x 10^-3 M/L

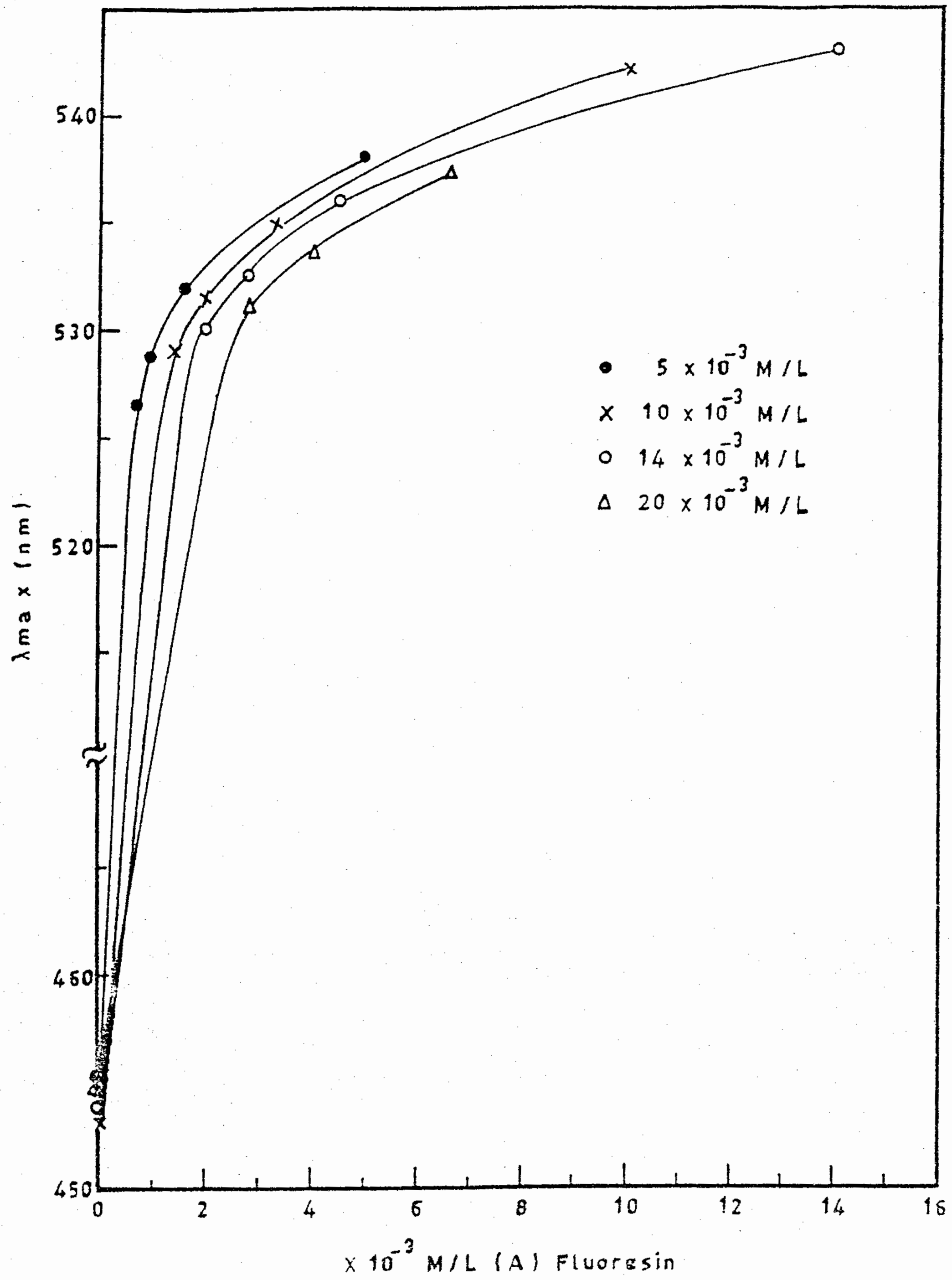

λmax (nm)
540
530
520
460
450
0
2
4
6
8
10
12
14
16
x 10⁻³ M/L (A) Fluoresin
● 5 x 10⁻³ M/L
X 10 x 10⁻³ M/L
O 14 x 10⁻³ M/L
Δ 20 x 10⁻³ M/L

Fig. 2.c.