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PHOTOCHEMICAL STUDY ON THE PHOTOCHEMOTHERAPY.I . SOLVENT EFFECT ON FLUORESCENCE SPECTRUM OF 8-METHOXYPSORALEN

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The absorption and fluorescence spectra of 8-methoxypsoralen were investigated in various kinds of solvents.
It was found that the emission maximum wavelength and the intensity of fluorescence from π-π^* excited 8-methoxypsoralen markedly depend on solvent polarity.
A possible energy diagram of 8-methoxypsoralen was discussed.

In the photochemotherapy for such skin diseases as vitiligo[1] and psoriasis,[2-5] 8-methoxypsoralen(8-MOP) has been used as an effective photosensitizer. The photochemotherapy for psoriasis by the use of 8-MOP and a black light or the sunlight has been widely used from 1970. Many investigations have been reported on the action spectrum[6-9], the electronic structure[10-12] and photochemical reaction mechanism[13-17] of 8-MOP, however, important observations such as the big difference among the efficiencies of psoralen derivatives have not yet been explained.

In order to clarify the correlation between electronic states and the photochemical reaction mechanism of psoralen derivatives including 8-MOP, we have investigated the absorption and fluorescence spectra of 8-MOP in various solvents. It was found that the fluorescence intensity and emission maximum wavelength of 8-MOP markedly changed with the polarity of solvents.

8-MOP was obtained from Taisho Pharmacy Co.Ltd., and Tokyo Kasei Co. The purity of both samples was guaranteed by the high speed liquid chromatography (JASCO FLC-A700, JEOL). The absorption spectrum was recorded on a Hitachi spectro-

photometer type EPS-3T. The fluorescence and phosphorescence spectra were measured with a Hitachi fluorescence spectrophotometer, type MPF-2A.

It has been often reported by many investigators that 8-MOP has no absorption peak corresponding to the maximum of action spectrum in the 320 to 380nm region. In order to ascertain their results, the absorption spectrum of 8-MOP was examined in various kinds of solvents; e.g., water, ethanol, methanol, chloroform, dioxane, n-hexane, and cyclo-hexane. Figure 1 shows the absorption spectra of aqueous, ethanol, and n-hexane solutions of 8-MOP. No absorption peak in the above mentioned wavelength region was observed in the aqueous solution, while the absorption band (λ_{max}= 340nm) was distinctly observed in the case of n-hexane solution.

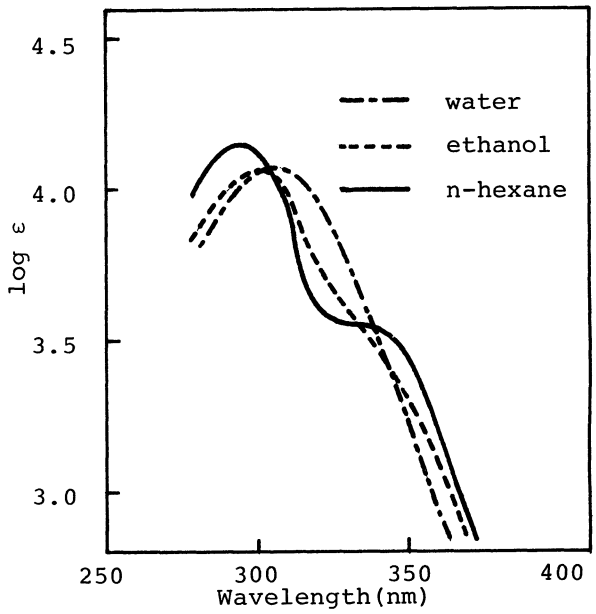

Fig.1. Absorption spectra of 8-MOP in water, ethanol, and n-hexane at 298K.

Mantulin and Song[12] observed the absorption peak of 8-MOP at about 345nm in ethanol solution at 77K and assingned this absorption band to the π-π* transition. They also obtained fluorescence quantum yield(Φ_F= 0.013) of 8-MOP in ethanol at 77K. For the explanation of their result, they suggested that the energy levels of $S_1(\pi-\pi^*)$ and $T(n-\pi^*)$ are located very closely to each other. If their suggestion is the actual case, it is expected that the fluorescence intensity will drastically change depending on the kind of solvent, since the solvent effects on the π-π* and n-π* excited states may be quite different.

The fluorescence spectrum of 8-MOP was observed in various solvents. The fluorescence emission and excitation spectra of 8-MOP are shown in Fig.2. It was found that the emission maximum and fluorescence intensity markedly depended on the polarity of solvent. As shown in Fig.3 the emission maximum shifted to the shorter wavelength and fluorescence quantum yield by the excitation at 300nm extremely decreased with the decrease of solvent polarity.

The phosphorescence spectrum almost coincident with Mantulin and Song's observation[12] in ethanol at 77K was observed in each solvents at 77K. The above results will be explained by the energy level diagram as shown in Fig. 4.

Here, the T(n-π*) level neighbouring $S_1(\pi-\pi^*)$ is assumed as suggested by Mantulin and Song. With increase of solvent polarity $S_1(\pi-\pi^*)$ shows red shift and, on the other hand, T(n-π*) transition may show blue shift. It seems possible that the inversion of the relative location of the energy levels, $S_1(\pi-\pi^*)$ and T(n-π*), will occur at a certain value of solvent polarity. In a polar solvent the fluorescence was observed because the energy of T(n-π*) is higher than that of $S_1(\pi-\pi^*)$.

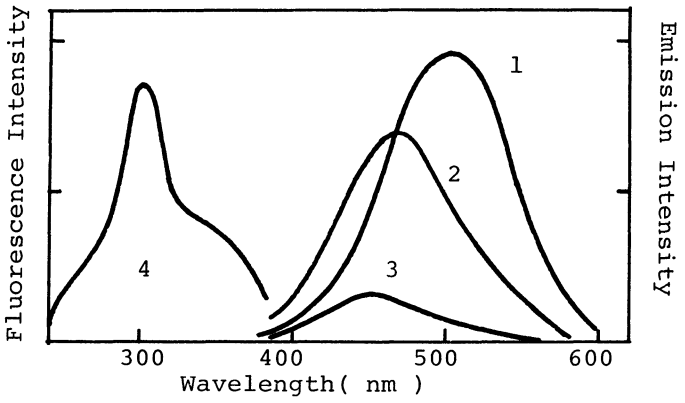

Fig.2. Emission and excitation spectra of 8-MOP solutions at 298K.[8-MOP: 1×10^{-5} mol/l]
Emission spectra at the excitation wavelength of 300nm in water(1), ethanol(2), and chloroform(3).
Excitation spectrum for the emission at 465nm in ethanol(4).

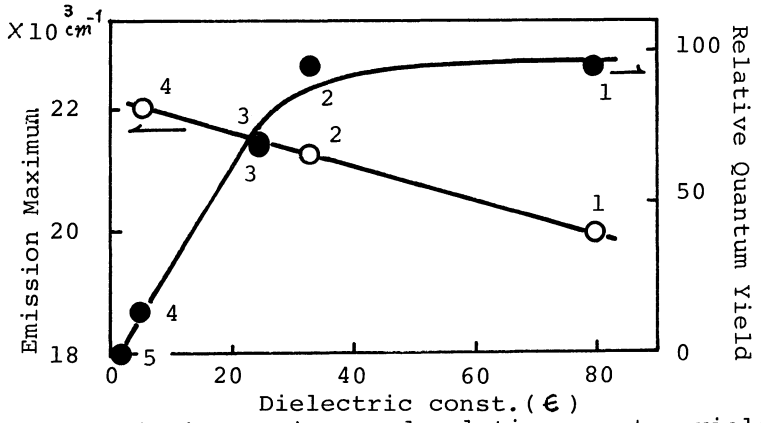

Fig.3. Emission maximum and relative quantum yield of fluorescence in various kinds of solvents at 298K. 1. water 2. methanol 3. ethanol 4. chloroform 5. dioxane.

However, in a nonpolar solvent these two energy levels will reverse each other, the transition probability of $S_1(\pi-\pi^*)\rightarrow T(n-\pi^*)$ much increases and then the fluorescence will not be observed. The phosphorescence data obtained in rigid matrices at 77K can be discussed in the same manner as the fluorescence data in fluid media at room temperature. There must be an S(n-π*) state around the $S_1(\pi-\pi^*)$ level, if the diagram in Fig.4 is correct, but we could not find an n-π* absorption band in the present experiment. It is suggested that the T(n-π*) state may play an important role in the course of the photochemotherapy although the photoreactive excited state was suggested to be the T(π-π*) state.[12)]

It is considered that 8-MOP in the use of photochemotherapy may exist in aqueous or semi-wet state. Therefore, the above results suggest that it is very important to determine the fluorescence quantum yield and the yield of triplet state in such system for clarifying the photochemical mechanism of photochemotherapy and surveying

more effective sensitizer for photochemotheraphy.

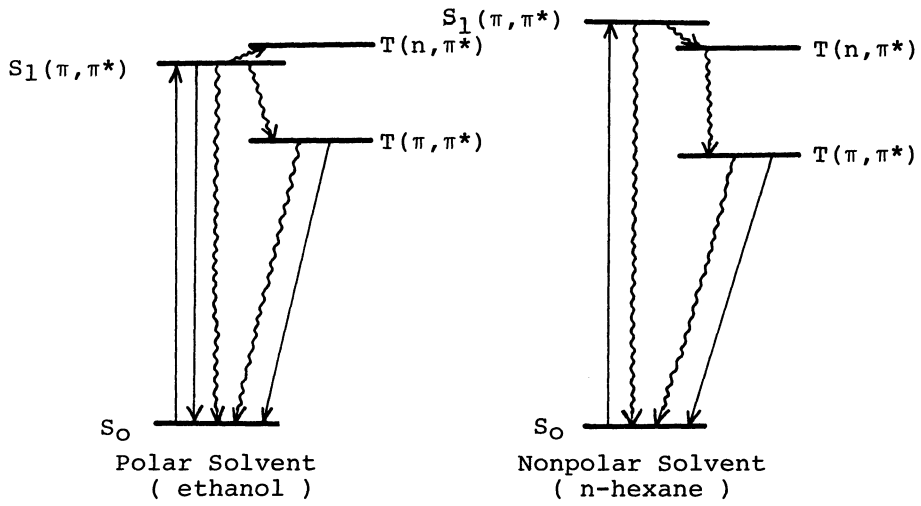

Fig.4. A possible energy diagram of 8-MOP.

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References

1. J.E.Fulton Jr., J.Leyden, and C.Papa, Arch.Derm., 100, 224(1969).
2. G.Weber, Brit. J. Derm., 90, 317(1974).
3. H.Tronnier und H.Heidbüchel, Z. Hautkr., 51, 405(1976).
4. N.Mizuno, M.Ohno, and S.Uematsu, Japan J. Derm.(Nihon Hihu Kagaku Zassi) 85, 577, 595(1775).
5. A.Ozawa, I.Matsuo, K.Niizuma, M.Ohokido, and M.Nakano, Nishi Nihon Hihuka, 38, 311(1976).
6. M.A.Pathak, J. Invest. Derm., 37, 397(1961).
7. R.Kooij, A.T.Neser, and E.P.Scott, Brit. J. Derm., 75, 245(1963).
8. E.Yeargers and L.Augenstein, J. Invest. Derm., 44, 181(1965).
9. W.Donald, M.Joseph, M.D.Glicksman, G.Robert, M.D.Freeman, and M.A.C.Robin, J. Invest. Derm., 51, 435(1968).
10. E.Yeargers and L.Augenstein, Nature, 212, 251(1966).
11. T.A.Moore, A.B.Montgomery, and A.L.Kwiram, Photochem. Photobiol., 24,83(1976).
12. W.W.Mantulin and P.S.Song, J. Am. Chem. Soc., 95, 5122(1973).
13. M.A.Pathak, J. Invest. Derm., 37, 397(1961).
14. L.Musajo, G.Rodighiero, and F.Dall'Acqua, Experientia, 21, 24(1965).
15. L.Musajo and G.Rodighiero, Photochem. Photobiol., 11, 27(1970).
16. J.F.Walter, J.J.Voorhees, W.H.Kelsey, E.A.Duell, and A.Arboor, Arch Derm., 107, 861(1973).
17. W.Poppe and L.I.Grossweiner, Photochem. photobiol., 22, 217(1975).

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